Application of an ‘information system on the water system’ in the city of Birmingham, UK.

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Abstract

Integrated water management often faces a not enough coordinated institutional framework, in which various organizations specifically tackle issues related to their own interest. This sectorial water resources management approach leads potentially to a waste of efficiency, but more certainly to a poor consultation between the different stakeholders. Whithin this institutional framework, actions undertaken aren't coordinated enough and don't always integrate the various stakeholders interests, which can be sometimes divergent.

In this perspective, a data-centralization software providing a holistic view of the water system would be an interesting tool, in order to take into account the entire problematic.

The information system on the water system (ISWS) applied to the city of Birmingham (UK) is a tool which allows visualizing the different components of the water system. It includes stakeholders, infrastructures, ecosystem, legislation, publications, databases and planned urban developments. Moreover, this tool allows consulting information such as text information, interactions, numeric values, websites directly available for consultation or document files.

Using the base diagram of the software, thematic views can be shaped. Those views gather information related to a specific issue and give an overview centralizing its different aspects. The ISWS tool is designed to provide support along the decision-making process and to promote the integration of all the water-related domains.

Résumé

La gestion intégrée des eaux se heurte souvent à une structure institutionnelle insuffisamment coordonnée, dans laquelle diverses organisations s'occupent spécifiquement des problématiques relatives à leurs intérêts. Cette approche de gestion sectorielle de la ressource en eau conduit potentiellement à une perte d'efficacité, mais plus certainement à une faible consultation entre les différents acteurs du domaine de l'eau. Dans ce cadre institutionnel, les démarches de gestion de l'eau ne sont pas suffisamment coordonnées et n'intègrent pas forcément les intérêts, parfois divergents, de tous les acteurs impliqués.

Dans cette perspective, un logiciel de centralisation des données, permettant de fournir une vue holistique du système de l'eau serait un outil intéressant afin de prendre en compte l'ensemble d'une problématique et de concilier les intérêts de chacun.

Le système d'information du système de l'eau (ISWS) appliqué à la ville de Birmingham (UK) est un outil qui permet de visualiser les différents éléments constituant le système de l'eau. Ceci inclut les acteurs, les infrastructures, les écosystèmes, la législation, les publications existantes, les bases de données et outils informatiques ainsi que les développements urbains projetés. Cet outil permet en outre la consultation d'informations, sous la forme de textes courts, d'interactions, de valeurs numériques, de sites web directement accessibles ou de documents attachés.

Sur la base de la vue principale dans le logiciel, des vues thématiques peuvent être construites. Ces vues rassemblent les informations relatives à une problématique donnée et fournissent une vue d'ensemble rassemblant ses différents aspects. L'outil proposé fournit un support durant le processus de décision et promeut l'intégration des différents domaines de gestion de l'eau.

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Abbreviations

AMP : Asset Management Plan.
CAMS : Catchment Abstraction Management Strategy.
CFMP : Catchment Flood Management Plan.
CWIS : Combined Water Information System.
DEFRA : Department for Environment, Food and Rural Affairs.
DSS : Decision Support System.
EA : Environment Agency.
ELL : Economic Level of Leakage.
EPFL : Ecole Polytechnique Fédérale de Lausanne.
GIS : Geographical Information System.
GWMU : GroundWater Management Unit.
ISWS : Information System on the Water System.
IUWM : Integrated Urban Water Management.
IWRM : Integrated Water Resources Management.
OFWAT : Office for Water Services.
SUDS : Sustainable Urban Drainage Systems.
UK : United Kingdom.
WFD : Water Framework Directive.
WMSM : Water Management System Model.
WFA : Water Flow Analysis.

1 Introduction

1.1 Explanation of the project

This MSc project focuses on the water system of Birmingham, UK. The main objectives are to implement an **information system on the water system (ISWS**), including stakeholders, water-related elements and infrastructures, ecosystems, developments and studies and to bind it up with a database gathering a wide range of data and information about the water system. The idea is to display in the ISWS software a view, as complete as possible, of the water system so as to allow the understanding of links and influences between elements through a rough assessment. The ISWS allows a wide data-centralization and provides to the user a systemic view of the water management framework. A better integrated and holistic view of the water system and thus an improvement on decision-making processes and strategic options selection are expected.

The project subscribes to the view of a research study carried out at the EPFL, Switzerland, by two Research assistants, PhD students, Colin Schenk and Bastien Roquier, and their supervisor, Dr Marc Soutter. The programme used, the ISWS, has been developed by Colin Schenk. He created also the **water management system model** (WMSM, see annex 9.18), which is a graphical map and description of the different water-related components and their interactions. It has been used as a basis for the ISWS implementation.

The concept of an information system on the system is explained through the following definition [Schenk et al., 2007]:

"An information system on the system (ISS) is defined as an application system able to display a system organisation and its related data. Involved elements are either components (nodes) or interactions (connexions). Components may be of physical (infrastructures, environment, natural and anthropogenic resources, etc.) or cultural nature (policies, laws, etc.); interactions provide a qualitative (textual) or quantitative information about the functional relationship between two components. Groups of components are also components and are appropriate support to the application of synthetic information. Therefore, ISS might be a complementary alternative to GIS, especially to show synthetic information, interactions, and non-geographic data."

The creation of an ISWS is thus explained by a lack in current tools. The mental map of the water system partly existing in involved people's mind is expected to be transcribed through a systemic view displayed in the ISWS and available for all. The result is a tool providing support for consulting and managing the information within the decision-making process.

1.2 Objectives and steps of the project

The objectives of the project are to carry out a holistic analysis of the water management in the local and national contexts, and to provide a first draft of the ISWS software for the city of Birmingham.

To carry out the objectives quoted above, several main steps have been set. They contain in depth the following points:

i. Overall analysis of the water management and WMSM validation

- Understand the water management in the local and national context.
- Identify and get in touch with the key people, in charge of the various fields involved in the model.
- Confront the model (components and interrelations) to their analysis of the local situation.
- Possibly adapt, and validate the model.

ii. Application of the ISWS: deploy and feed the database and configure the application

- Set the limits of the system.
- Collect the detailed data on the components, their interrelations and identify causal networks.
- Feed the application with this data.
- Validate the various parts of the application with key people.

iii. Critical analysis of the process and the results

- Assessment of the thematic views' relevance.
- Acceptation by local stakeholders.
- Potential utility of the application onwards.

The acceptation of the ISWS by local stakeholders still has to be undertaken. The thematic views have to be introduced to them in order to receive a feedback and an appraisal of the ISWS potential.

1.3 Context of the project

1.3.1 Switch

The research carried out at the EPFL is part of the Switch project[1]. It is a five years action research programme, co-funded by the European Commission and bringing together 13 cities around the world. Switch aims to tackle the future water-related challenges that cities will have to face such as global change pressures, by achieving a sustainable water management.

Birmingham is one of the involved cities. A Switch Learning Alliance, gathering several stakeholders (see annex 22) is meeting three to four times per year to share background, promote consultation and build some new consistent strategies for the future.

Within this project, a decision support system (DSS) for the integrated water resources management (IWRM) and planning will be created. It will include different components tackling the main water issues. The information system on the water system (ISWS) is part of this process.

Another MSc student, Philippe Brandenberg, is following the same approach as the one introduced in this paper for another Switch city: Belo Horizonte, Brazil.

1.3.2 Integrated Water Resources Management (IWRM)[2]

Water supply and sewerage are essential public services. Water is vital for our health and well-being, for agriculture and industries, but also for the ecosystems. Water demand and population growth, pollution issues and climate change are threatening the sustainability of our water supply.

The key-concept behind this project is the IWRM. It is a widely accepted concept, but its application is difficult due to the lack of application frameworks. The concept is mostly not completely achieved, mainly due to the complexity of the whole system, the management framework and the lack of communication and cooperation between stakeholders.

IWRM is an up and coming field in which people and governments are more and more aware. It aims to tackle the different water issues by combining resources exploitation with people and goods protection. The economic but also ecological optimization of the different water uses is expected. A widely accepted definition of the concept is captured by the Global Water Partnership [GWP, 2000]: *"IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"*.

[1] SWITCH, www.switchurbanwater.eu, last time consulted: May 2008.
[2] [UNESCO, 2006]

The traditional sectorial water management doesn't always lead to integrated strategies, taking into account the different objectives of all the water-domains involved. The issues are seldom tackled within a holistic approach and the brought solutions are strongly limited into a specific view. It is the result of a not enough concerted decision-making process and it leads to a sub-optimal use of the available means. The participatory approach to achieve is effectively captured in the second principle set out at the 1992 International Conference on Water and the Environment in Dublin[3] : *"Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels"*.

In the Birmingham context, a participatory process already exists for water issues, but the objectives targeted are not completely achieved, mainly because of governance and framework issues.

IWRM should be applied at catchment level and takes into account both human and natural activities. This way of managing water takes into account regional and also local issues. It provides an ecosystemic approach and lead to solutions subscribing into a sustainable prospect. It allows also identifying water management priorities by considering cumulative impacts on the aquatic ecosystem.

Tomorrow's population will be predominantly urban. That's why the IWRM has to be strongly tackled in the city scale. The major pressures on water that Birmingham will have to face in the future are generally in line with all similar western European cities with a similar evolution[4]. Population growth, flood hazard, water quality and groundwater issues will require an efficient management optimizing the resource's use, which is precisely the objective of the IWRM [5].

As the catchment is the basic hydrological unit of analysis and management, IWRM should be applied at catchment level. At implementation step, the integrated urban water management (IUWM) allows tackling specific problematic context of urban areas and is then a practical means to achieve IWRM rather than a goal in itself.

In IUWM, considerations have to be given to the interaction and impacts of water-related urban processes. It gathers different domains such as human health, environmental conservation, water quality, sustainability of supply, flood risk, etc.

Such an inter-sectorial management requires stakeholders' full involvement and cooperation. In this perspective, a data-centralizing tool can allow to give a holistic view of the water system to people involved in specific water-related domains. Such a holistic view of the water system isn't yet provided by any software. The currently available tools are intended for their specific domain only.

The tool developed during the MSc project is expected to be useful in order to achieve a better IUWM by displaying the whole water system and the flows and influences within it.

[3] Global Development Research Center, www.gdrc.org/uem/water/dublin-statement.html, last time consulted: June 2008.
[4] Switch, www.switchurbanwater.eu, last time consulted: June 2008.
[5] Global Development Research Center, www.gdrc.org, last time consulted: June 2008.

2 The ISWS

2.1 Structure

The ISWS (or City Water System) is composed by an Oracle database and by a software interface created by Colin Schenk. It allows displaying a wide and holistic view of all the involved elements (organizations, legislation, ecosystem, groundwater, surface water, water supply and treatment infrastructures, drainage networks, etc. See annex 9.18 and 9.19) and to visualize the relations, fluxes and influences between them.

The components are set under a hierarchical structure in the base diagram of the ISWS. The user can then navigate in the information system and find easily the required component, its role and interactions within the water system and furthermore the attached information. It is possible to focus on a specific component and select the attached interactions and information by using the View tab onto the menu bar.

Each component in the ISWS is identified with a unique ID number. A parent-key sets the potential belonging within a group. Information (text information, numeric values and documents) are provided and linked with the appropriate nodes, through secondary tables relating for instance a numeric value with a node.

Attached icons for each node give a pictorial view of the water system and aim to facilitate a fast understanding of the views displayed.

Thematic views for specific issues come next by selecting all the required components and by setting them in an understandable view. The base diagram is taken as a basis to build those thematic views. The hierarchical structure has to be partially disaggregated and reorganized in order to make the thematic view more understandable.

2.2 Interface

The ISWS interface displays the data held in the Oracle database. It is a user-friendly interface which allows to navigate within the information (base diagram or thematic view) and to find the required data by selecting a specific node. Changes can be made through the interface or directly through the database.

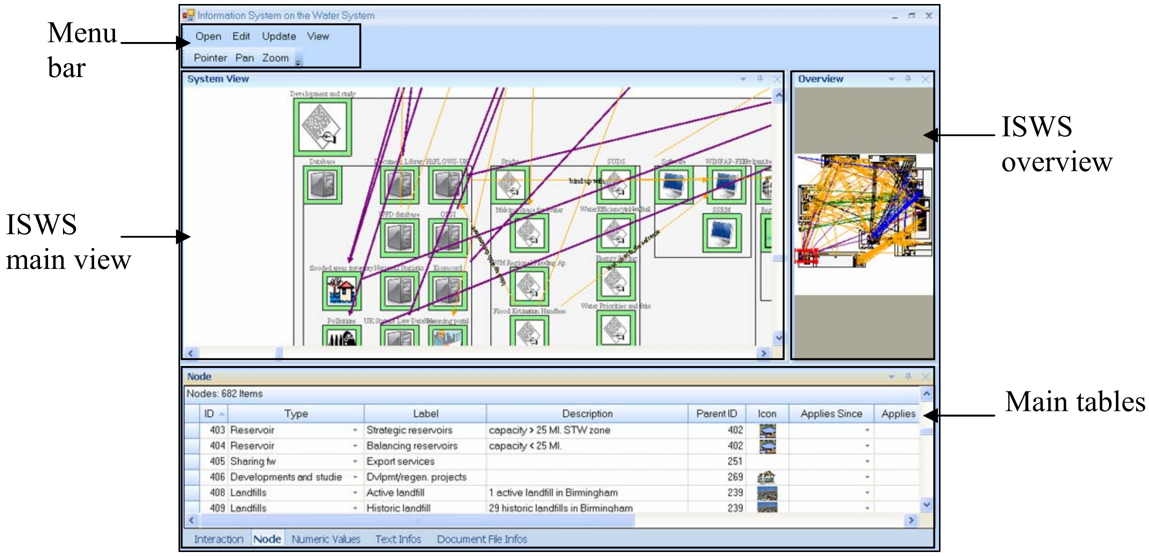


Figure 1. View of the ISWS interface.

The complexity of the water system displayed within the base diagram restricts its operational use. The base diagram can be used for data and information consultation, but can't render a specific issue at a glance. However, thematic views can be created for whatever water-related issue (see chapter 5.3) and gather the interesting nodes, interactions and information.

2.2.1 Menu bar

The ISWS menu bar is constituted by the following tabs:

- **Open.**

Diagram:	Open the ISWS base diagram.
Document File:	Open the selected document.
Website:	Open the selected website.

- **Edit.**

Add Node:	Add a node in the base diagram.
Add Interaction:	Add an interaction in the base diagram.
Modify Node Icon:	Modify selected node's icon.
Upload Document:	Upload a document in the ISWS.
Change Node's Group:	Change parent node of the selected node.
Modify Interaction Colour:	
Default Interaction Colour:	

- **Update.**

Nodes:	Update information related on nodes.
Interaction:	Update information related on interactions.
Numeric Info:	Update information related on numeric values.
Text Info:	Update information related on text information.
Document Files:	Update information related on documents.

- **View.**

Show Selected Only:	Display the selected node and the information related on it only.

- **Themes.**

New Thematic View:	Create a new thematic view based on the base diagram.
Add Element into View:	Allows adding an element from the base diagram to a thematic view.
Save:	Save the thematic view in a .iss file.
Load:	Load a thematic view.
Create Info Bubble:	Create an information bubble (still not available).
Create Flux Arrow:	Create a flux with width related to a numeric value.
Fluxes Groups Properties:	Set the properties of the fluxes.
Export as Image:	Allows exporting a view as an image (.png image).

2.2.2 Tables

The ISWS contains the following main tables:

- **Nodes.**
  The nodes represent the real objects or entities of the water system. It includes laws and policies, people and organizations, resources, ecosystem, water-related elements, developments and studies.

- **Interactions.**
  The interactions stand for the relations between the nodes. It can be an influence, a flux, equivalence or a condition. The different types of fluxes are: cash flow, data flux, water flux, sludge flux, energy flux.

- **Text information.**
  This type of element is useful to provide any kind of text information on a node or an interaction. The text information is bound up with nodes and/or interactions. The different types of text information are: website, e-mail, address, scenario, information, vision, strategy, problem, assessment, opinion, comment.

- **Numeric values.**
  The numeric values are in different forms and units and provide numeric information on nodes or interactions. It can be a reference value, a measure, an expert judgement or a statistic value.

- **Document files information.**
  The document files are bound up with nodes or interactions in order to provide further information on the linked element. They are available for consultation by using the tab Open Document.

2.3 ISWS expectations

2.3.1 Why use an ISWS?

The ISWS provides a new tool to tackle water management issues. An innovative and more efficient IUWM by taking into account the whole water system through its pictorial visualization is expected. The ability to display non-geographic elements as organizations, laws and policies, etc., is one of the main reasons why the ISWS can be useful in order to achieve an IUWM. A better vision of the whole water system will enable a much more relevant synoptic understanding of the system for decision makers.

Different services, organizations or companies tackle the different water domains. Each of them created a specific approach by considering their specific issues and objectives. It leads to a fragmented and inconsistent way to deal with complex issues such as water shortages or water quality. There is a need for a centralized consultation on those issues around a common basis.

The main way of representing information with geographical location is to use geographical information systems (GIS). However, the GIS fails to show functional interactions between displayed components of the water system. Moreover, a lot of components, such as stakeholders, policies or cash flows cannot be displayed within such a tool, simply because they have no geographical location.

It is obvious that filling these gaps would lead to some very interesting new functionalities such as, for instance, the availability for consultation of population forecast related to an area, the Hands-Off flow related to a river, (minimal flow under which the upstream abstractions would be limited), or information on the services and other benefits that a wetland offers (such as sport fishing, protection against floods or natural attenuation).

The knowledge tool provided would allow involved people to navigate in the information system and to select the required information, but also to produce a thematic view of a given issue by selecting the relevant nodes, linkages and information. This view can be used as a basis and a help for further thought and strategic options' selection.

People involved in new developments planning and regeneration projects can use the ISWS as a database gathering population growth forecast, new developments planned, building regulations, planning policies and other useful information.

The ISWS is a knowledge and planning tool, but also a data-centralizing tool. The integration of the ISWS in the consultation process would offer new possibilities concerning data-sharing and communication between stakeholders.

The ISWS has already those functionalities and is a powerful tool. However, it still needs further developments to be completely operational and to be able to tackle any water-related issue.

Finally, the main benefits currently or potentially provided by the ISWS are:

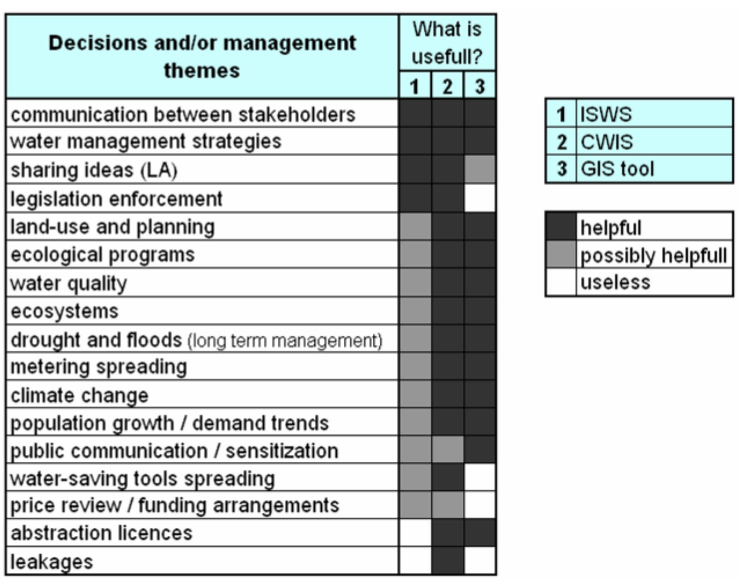
- Holistic view / systemic display of the water system.

- Possibility of tracking the linkages and influences between elements.
- Institutional mapping / governance efficiency appraisal.
- Data centralization / water system inventory.
- Support for participative decision-making process.
- Communication between water stakeholders.
- Legislation integration and enforcement (ex. WFD enforcement).
- Information system for public communication and sensitization.

2.3.2 What can ISWS be used for?

More detailed information might be required to refine specific issues under focus to carry out dedicated thematic views. It is important to know for what kind of issues the ISWS would be interesting, in order to feed the information system with relevant data.

The ISWS stays in a high level. It will not be able to help people on issues like network infrastructures design or abstraction licensing. Nevertheless, the gathering of data can allow a better understanding on key issues. The table below provides a series of themes and shows what is/would be useful for each theme. It is not a rooted list since it has been defined in accordance with the different feedbacks received until now and our given point of view.



Decisions and/or management themes	What is usefull? 1	2	3
communication between stakeholders	helpful	helpful	helpful
water management strategies	helpful	helpful	helpful
sharing ideas (LA)	helpful	helpful	possibly helpfull
legislation enforcement	helpful	helpful	useless
land-use and planning	possibly helpfull	helpful	helpful
ecological programs	possibly helpfull	helpful	helpful
water quality	possibly helpfull	helpful	helpful
ecosystems	possibly helpfull	helpful	helpful
drought and floods (long term management)	possibly helpfull	helpful	helpful
metering spreading	possibly helpfull	helpful	helpful
climate change	possibly helpfull	helpful	helpful
population growth / demand trends	possibly helpfull	helpful	helpful
public communication / sensitization	possibly helpfull	possibly helpfull	helpful
water-saving tools spreading	possibly helpfull	helpful	useless
price review / funding arrangements	possibly helpfull	possibly helpfull	useless
abstraction licences	useless	helpful	helpful
leakages	useless	helpful	useless

1	ISWS
2	CWIS
3	GIS tool

Legend: helpful / possibly helpfull / useless

Figure 2. ISWS, CWIS and GIS use possibilities.

Potential uses for the ISWS are many, but have to be assessed. It can be useful in a lot of cases, particularly by displaying a holistic view of the system, binding up elements to show implications of potential changes. The simple gathering of data coming from all the water-related domains can provide a wide view for people who usually work on their specific domain. The public communication tool is also relevant in the purpose of spreading information and good habits.

One interesting thing is that the model, in a second step (CWIS, see chapter 2.4), could be a useful tool for any level of decision-making given above.

2.3.3 Who would use the ISWS?

The ISWS provides a knowledge tool. It can be useful to have a holistic view of the system, with fluxes and influences, in order to display all the consequences of an action on a particular element of the system. It is an information system providing a view of the whole system. A major contribution is that the model allows binding up all the water stakeholders. This feature is very important in order to apprehend the whole decision-making process and to integrate the relevant legislation, which is very complex in the British context (see chapter 3). Such an IWRM tool can be useful for a lot of people and for a lot of cases. Different possibilities are to consider:

Organisation or company	Benefits examples
▪ every Learning Alliances partaker	holistic view of the system with fluxes and influences
▪ Water UK	sustainable ways research
▪ Environmental Agency	ecosystem values' and needs' integration in the system
▪ Severn Trent Water Ltd.	stakeholders and legislation deeper integration
▪ Planners	holistic view of the system. Wide range of data available
▪ WFD-UKTAG	WFD enforcement

Table 1. Various benefits examples for stakeholders.

These different organizations or companies will be described in chapter 3.

A lot of people work on the water system, in their specific domain. But only a few of them have a good understanding and vision of the whole system, because of its complexity. The ISWS is able to centralize a wide range of information and data.

By gathering and linking all the specific domains, the ISWS can provide this vision to the people involved and thus allow them to carry out better integrated solutions and strategies for the future. However, it is not an engineering and design tool. The ISWS is intended for planning and for water-related decision-making processes.

As the ISWS gathers all the different domains of water management, it would be useful for communication between all the stakeholders. This is the key-point for an efficient IWRM. The potential use of the model as a communication/sensitization tool for water consumers is also non-negligible.

After some discussions with Philip Sharp (Arup) and Rae MacKay (University of Birmingham), the conclusion reached was that, in the Birmingham context, the first people who could be interested in the ISWS are the planners. Main developments planned within the city have then been included in the ISWS and linked to their respective Wards. The Upper River Rea thematic view shall give a more defined idea of what kind of product the ISWS is able to provide in a development area. The main issue in this case is flood mitigation. The

development area (former MG Rover work) has to be designed by taking into account storm water retention.

2.4 Outlook for the combined water information system (CWIS)

The tool currently developed at the EPFL will combine three modules to constitute the CWIS general interface. The three modules are:

- **Geographic Information System (GIS)**: constituted by geographical layers where the ISWS components which have geographic location are displayed.
- **ISWS**: geographic and non-geographic components are displayed, bound up together and referenced by several types of information.
- **Indicator viewer**: data viewer which is able to display charts with the attached numeric values in the ISWS.

A general interface, the CWIS, results from the combining of the three modules. As the tool is still under development, an expected view of the interface has been created [C. Schenk, 2008]:

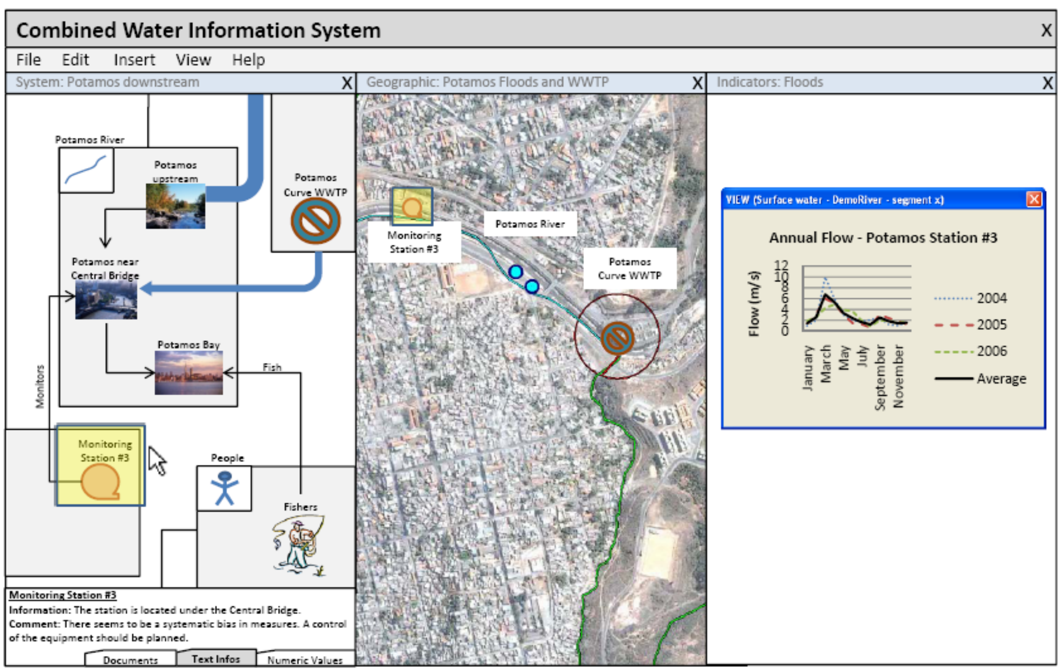


Figure 3. Combined Water Information System's user interface.

By combining the three modules, the CWIS enables the user to navigate within the information through those three completing modules.

The present report focuses on the second module, which is the ISWS, and its application.

3 Context

3.1 Introduction

It is fundamental to have a good understanding of the whole water system before to implement an information system, in order to shape the water framework as close as possible from the reality. The WMSM and its influences have to be validated. Time has therefore been devoted to describe the system, the stakeholders involved and the influences joining them. It aims to provide an overall analysis and a diagnosis of the water management in Birmingham.

Policy and practice are constantly in a state of change. It is thus necessary to consider the current framework to make any institutional change proposal. Transcribing the current situation into the ISWS software aims to provide an institutional mapping through a new vision, differing from written appraisals and reports.

This chapter focuses on the various domains involved in water management as well as their interactions.

3.2 At a national scale: The water management in the United Kingdom context

3.2.1 Introduction[6]

Household water demand is now more than half of the public water supply use. It has been increasing since the 1950s. This is due to population growth and changes in water use habits. In contrast, industrial water demand has been declining, reflecting in part the changing nature of the UK industry. Total water consumption (industry, commercial and household consumption) is currently about 264 l/pers/day for the Severn Trent Water zone [Ofwat, 2007c] (355 l/pers/day in Switzerland [SSIGE, 2008]). The average household consumption in England is currently about 150 l/pers/day (162 l/pers/day in Switzerland).

Water management had to face important problems these last years in the UK: serious drought in 2004 and 2006, summer floods in 2007. Those extreme events gave the incentive for more pro-active actions for flood risk and water shortages, and generally a more efficient water use and management. They also call people's attention on future challenges, such as climate change.

The Future Water Government's water strategy and the Making Space for Water programme are the government response to those challenging issues.

[6] [Defra, 2008b]

3.2.2 The water management framework

The water services have been privatized in the UK in 1989. The more fundamental reason was the Thatcher government's neo-liberal economic policies, which led to a reduction of the role of the state. The expected benefits of the privatisation were mainly concerning efficiency, money availability and competition. These claims were not confirmed by evidence from comparative studies focusing on the actual performance of public and private sector water companies [PSIRU, 2001]. The competition is not effective, since there is no choice of water supplier for household customers, and several problems appeared with increasing water prices and water companies' lack of transparency.

The UK water industry currently counts 12 water and sewerage service providers and 13 water suppliers. In England and Wales these services are provided by private companies which own infrastructures (in Wales as a not-for-profit company). It is different in Scotland and Northern Ireland where the infrastructures are publicly owned but main water services are provided by private companies. This chapter focuses on the situation in England and Wales and quotes the figures for the water company involved in the city of Birmingham: Severn Trent Water Ltd.

3.2.2.1 Charging for water

The current charging system for water is based on houses rateable values from the 1970s. Household without meter are charged for water in accordance with the rateable value of their house (The charging system is set up differently by each private company but follows this rule.). It is not an incentive for water efficiency, for indeed unmetered customers water bills have no relation with water use. Less than one third of customers have a water meter in the UK (29.3% within the Severn Trent area). They pay fairly for what they use, and it introduces a financial incentive to save water. On average, households reduce their water consumption by 6.5% after a meter is fitted (Severn Trent Water zone, calculation). The figure of 10% reduction is given in Future Water, the Government's water strategy. Severn Trent Water advocates the installation of water meters in domestic premises and fits them free of charge. All homes built since 1989 are fitted with water meters and the business customers (>10 Ml/year) have to have a meter.

The charging system is very complex. For the Severn Trent Water zone, customers' bill depend on the charging zones (8 charging zones, including the Birmingham charging zone, which contains also the city's surroundings), the type of property (detached, semi-detached, other), the size of the meter (standing charge) and the consumption (for metered customers) and the rateable value of the property (for unmetered customers) [Severn Trent Water, 2007e]. Vulnerable customers have fixed charges, set by Severn Trent Water, and can pay their charges with the help of the Independent Trust Fund. As a guide, the average household bill for the Severn Trent zone is £141 for water and £138 for sewerage (including surface water drainage) for 2007/2008. One cubic meter of water is worth more than £2 for household customers (supply and sewerage) [Ofwat, 2007c].

The entire charging system is not implemented into the ISWS, because of its complexity. It is not an objective; a simple charging leaflet is able to provide that information in a much more

efficient manner. The Severn Trent Water Summary of charges is available for consultation within the ISWS.

3.2.2.2 Companies' regulation and price setting

The privatisation process created three public regulators: Ofwat, to set the price regime that companies have to follow; the Environment Agency (EA, formerly called the National Rivers Authority) for monitoring river and environmental pollution; and the Drinking Water Inspectorate (DWI) monitoring water quality. The companies are thus subject to legal obligations such as to include specific projects in their plans to improve people's well-being.

Ofwat is the economic regulator for water and sewerage services in England and Wales. It has to ensure that water companies carry out their function properly and have access to sufficient finance to do so. It monitors private companies' performances, sets water efficiency targets, leakage targets and water prices in collaboration with water companies themselves. Their conclusions are overseen by ministers. Ofwat priorities are summarized on the track of sustainable development by considering social, economical and environmental pillars: protecting consumers, promoting value and safeguarding the future.

The EA has the duty to control air, land and water quality and provides abstraction licences (see chapter 3.2.2.3) in order to control the uptake of water from the environment and so to keep it valuable.

The DWI, working on tap water quality, has an important role on setting price. This public organization is responsible to keep companies aware of their regulatory duties and responsibilities to meet drinking water quality standards. It publishes an annual report on water quality and controls water companies' data.

The Consumer Council for Water has also an important influence on price setting. It stands for consumers and takes into account their opinion and satisfaction on water services.

Water price is set each five years on the Ofwat Asset Management Plan (AMP). The current AMP is AMP4 and sets price limits for each year in the 2005/2010 period. The price limits restrict the annual average increase in customers' bill. Severn Trent Water has to insure that their price increase doesn't exceed inflation plus "K".

RPI represents general retail price inflation (as measured by the Retail Price Index, RPI, which is the most familiar general purpose domestic measure of inflation in the UK), and K adjusts the price in accordance with performance standards, efficiency and level of service.

K factors are different for each company, depending on their economic situation. During the current period, K factors are all positive for Severn Trent Water, it means that the bill increase is higher than inflation. Overall values of K factors for Severn Trent Water are presented in the table below:

	Units	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010
K factors	**%**	11.8	4.8	2	1.7	2.3

Table 2. K factors for the 2005-2010 period (STW Ltd., Monitoring Plan 2005-2010).

When companies deliver water services at lower than forecast costs ("outperforming" efficiency target), they can retain the savings. The efficiency is thereby stimulated.

Water companies have to produce every five years a Water Resources Management Plan (WRMP) and a Monitoring Plan, every three years a Drought Plan (see chapter 3.3.5), and an annual financial report.

The WRMP provides an overview on the next 5 years, 2005-2010 for the WRMP currently in effect (WRP04), and a forecast on 25 years, to 2030. It outlines the water company's strategy for water supply and sewerage. It contains also data on water supply and leakage for all the Severn Trent zones.

The 5-years company business monitoring plan (currently Monitoring Plan for 2005-2010) includes the proposed price limits for the next five years and details on investment plans and targets. Moreover, it sets out what the average price increases will be in each year and the reasons behind the increases. The next final company business plans and price proposals are expected for April 2009. After debates with all the stakeholders, Ofwat will set final price limit on November 2009 for the 2010-2015 period. This setting price limit process is visible in annex 9.9.

The ethic of public supply and the expertise and access to capital of private companies are expected to be achieved by this framework, continuously developed since water supply and sewerage privatization in 1989. The companies' monopolistic service of water supply is managed by the government (mainly the Ofwat) in order to guarantee a cheap service for the customers, to enforce the law (customers' rights, environmental legislations, etc.) and to stimulate innovation and efficiency.

However, the Ofwat should promote some competition among suppliers in the future. Consumers should be able to choose their water supplier. In the Daily Telegraph from 2008 Friday May 16, Regina Finn, Ofwat's chief executive, said : *"The current scope for competition in the water and sewerage sectors is severely limited by legislation, is confined to a small number of business customers and has not developed successfully. We propose that more of the market is opened progressively, starting with all business customers. In time, households could be able to choose their water supplier – when the market is ready and safeguards are in place."*

It should lead in the future to water bills' cut, innovation and would help to deal with problems including climate change and the growth of populations in areas of water scarcity.

3.2.2.3 Abstraction licensing

The main way to achieve sustainable water management is the EA's system of abstraction licensing. The system was created in the 1960s and has recently been updated through the enforcement of the Water Act 2003.

People who want to take more than 20 m^3/day from a source of supply (river, stream lake, well, etc.) must have an abstraction licence, provided by the EA. This licence is provided if the abstraction respects these points [Environment Agency, 2008b]:

- The potential impact on environment and other users have to be acceptable (sustainability).
- The quantities and the purpose of the abstraction are reasonable (continued justification).
- The water has to be used efficiently.

Another part of the EA's job is to promote an integrated water management, among other things through the Water Framework Directive (WFD) enforcement. The Catchment Abstraction Management Strategy (CAMS) subscribes to this view. The country is divided into catchment basins and the abstractions are managed into this scale (see also chapter 3.3.3.5). It provides a consistent approach to local water resources management and helps to balance the needs of water users and the environment. Birmingham is mainly located within the Tame, Anker and Mease CAMS area.

The EA provided for free the document and CD for this CAMS. A lot of data concerning abstractions are available, but everything hasn't been implemented in the database, since this issue is not expected to be undertaken by the ISWS (see Figure 2).

3.2.2.4 Other stakeholders

The Birmingham Learning Alliance gathers the main water stakeholders. However, there are also several secondary stakeholders involved in water management, who are no part of the Learning Alliance:

- The Chartered Institution of Water and Environmental Management (CIWEM, sustainable management) is an independent professional body, gathering scientists, engineers and other professionals in order to stimulate research on the science and practice of water, environmental management and resource protection for the public benefit.

- Water UK is the industry association that represents all water and wastewater services suppliers at national and European level.

- Waterwise is an independent not-for-profit NGO focused on decreasing water consumption in the UK by 2010.

- The Department for the Environment, Food and Rural Affairs (Defra) is the government department responsible for water supply and licensing policies.

- Natural England (biodiversity, landscape and wildlife) is a governmental agency. It provides data and GIS layers for protected areas.

- Internal Drainage Boards manage all water courses in an Internal Drainage Board area, which is usually an area of high flood risk.

The exhaustive list of the stakeholders and the scheme of influences between stakeholders are given in annex 9.22 and in annex 9.17 respectively.

3.2.3 Water policies and legislation

The water legislation is very complex in England and refers to the European legislation. Here, only the few most relevant texts are given.

- The **Water Act 2003** is the base of the water legislation in the UK. It includes the abstractions licensing framework, specifies the role of each stakeholder, the content of drought plans and Water Resources Management Plans. It includes also some information on efficiency, discharge contents, sewers and drains.

- The **Water Industry Act 1991 / 1999** and the **Water Resources Act 1991** set general duties and functions for the main stakeholders. It provides legislation framework for some specific issues such as droughts and floods.

- The **Water Framework Directive** (2000/60/EC) is a piece of UE legislation which gives a water management framework. The River Basin District is the basic unit of management. The objectives of the Directive are set in Article 4. For instance, all surface water and groundwater bodies have to achieve a good status by 2015. The Directive is the trigger of many projects on water management in the UK, mostly undertaken by the EA. The model is able to display all the domains required to put into effect the Directive.

- The Government's new water strategy for England is widely described on **Future Water**. This new report [Defra, 2008] sets a clear and complete vision and objectives on water efficiencies and demand. For instance, a new goal of 130 litres per person and per day by 2030, or possibly even 120 litres per person and per day depending on new technological developments and innovation, is expected (England average : almost 150 now). Efficiency constraints for new buildings will be introduced on Building Regulations, through a performance standard set at 125 l/pers/day. A new technical guidance will be available from October 2008 and the new performance standard will come into force in April 2009. It will impose the metering in water-stressed areas by 2030. The report stays however at an aspiration level. It's not specified how to reach these objectives.

An exhaustive list of the relevant national and European legislation is given in annex 9.7.

3.3 At a regional scale: Global analysis in the city of Birmingham

3.3.1 The West Midlands Region

The West Midlands Region has a wide range of landscape, including the hills of Herefordshire and the Malvern, agricultural plains of Shropshire Plain and Vale of Evesham and urban areas like Birmingham conurbation.

Parts of the West Midlands are among the driest areas in the UK, with not more than 650 mm/year precipitation for some areas. The annual average for the region, and for Birmingham, is 750 mm/year.

145 l/pers/day are used every day in the West Midlands for household purposes [West Midlands Regional Observatory, 2001]. That is less than the UK average.

The region counts three water companies, Severn Trent Water, South Staffordshire Water, and Dŵr Cymru Welsh Water's Operations. They are delivering water services to the population, almost nine million consumers. Severn Trent Water is supplying the city of Birmingham (see Figure 4).

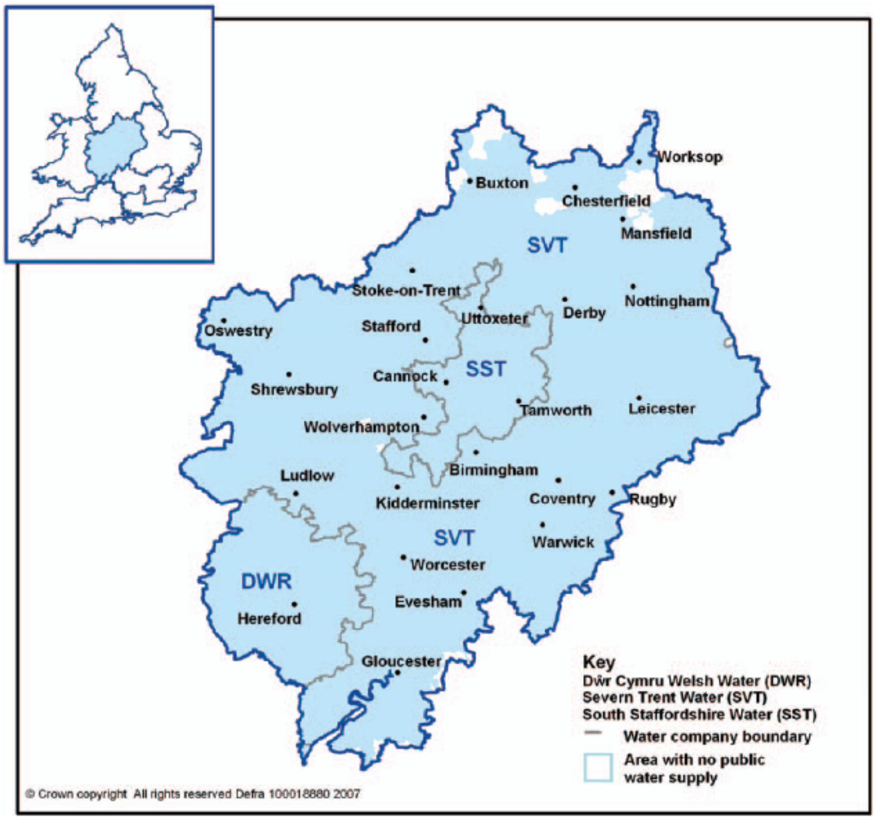


Figure 4. West Midlands Region water companies [DWI, 2007]. With the authorization of the DWI.

The region faces new housing development projections, which will constitute a challenge to regional policies. The West Midlands conurbation (Birmingham and surroundings) is expected to grow the next few decades. It will lead to a strain on regional infrastructure, including water supply and sewerage infrastructure.

The EA has the duty to develop national and regional water resource strategies that protect the environment while encouraging sustainable development. A twin-track approach should be followed to meet future demands. It consists in combining further water resource developments and improvements with sensible management of demands through efficient use.

The major source of water in the West Midlands Region (65%) is surface water abstracted from rivers. There are a lot of reservoirs which stock water. The Elan Valley reservoirs in

Wales supply the city of Birmingham since the beginning of the twentieth century (see Chapter 3.3.3.2).

3.3.2 Severn Trent Water Ltd.

Severn Trent Water is the world's fourth largest privately-owned water company, employing over 5000 people and, dealing with both water supply and sewage treatment. The company supplies fresh water and treats sewage for approximately 8 million people in the West Midlands and also certain parts of Wales. It takes its name from the two main rivers of the region, the Severn and the Trent. Severn Trent Water has many duties, such as publishing several reports and data. It is watched over by the three public regulators. The obligations of the company are provided in the Ofwat's Guaranteed Standards Scheme.

The Severn Trent Water network is sub-divided into Control Groups, which are the operational zones with specific characteristics (water quality, pressure, etc.). The strategic system of the Severn Trent Water company, with main reservoirs, sewage treatment works and strategic grid, is given in annex 9.1.

There is normally no import/export of water between the different Control Groups, because of a different water quality. The Severn Trent network is managed at this large scale, but also at another scale which is the Water Resource Zone. Birmingham and its surroundings accounts for the Birmingham Water Resource Zone. That's why some data are implemented at this scale within the ISWS. The Company Water Resource Zones are given in the below figure:

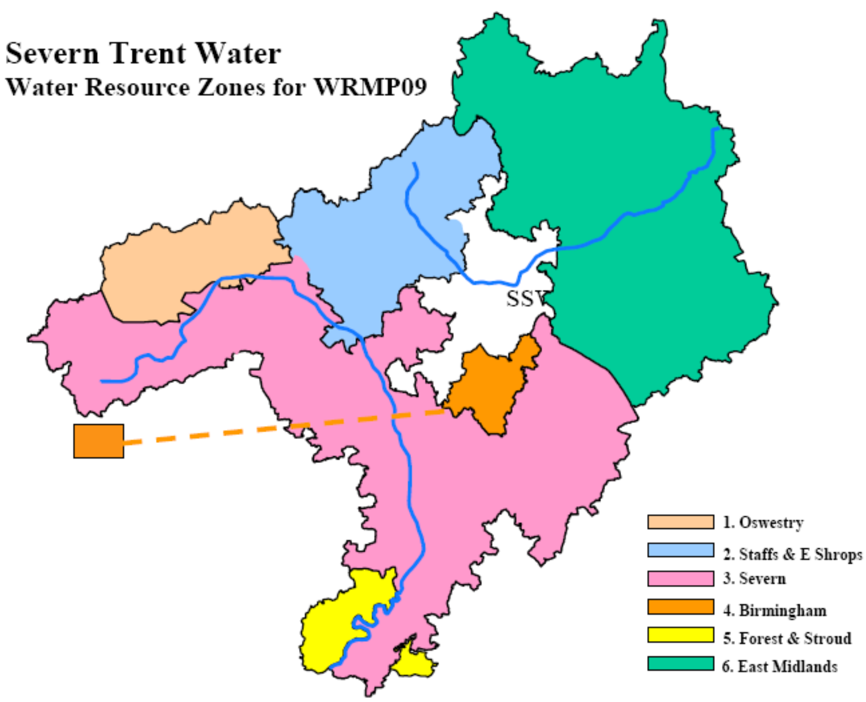


Figure 5. Severn Trent Water Water Resource Zones [Severn Trent Water, 2008b].

Water exchanges are obviously possible between Birmingham and its surroundings. The city is not a closed system. However, the input data for the Birmingham Water Resource Zone is calculated with an input-output balance.

Severn Trent Water uses geographical models for the water supply and sewerage infrastructures. They are for now not really interested in the ISWS functionalities (talk with Matthew Foster, Commercial Development Manager for Severn Trent Water); they are working with their own tool, which is specifically designed for their needs, and much more accurate concerning water flows. They aren't the target users of the ISWS anyway.

3.3.3 The city of Birmingham

3.3.3.1 Demography and geographic situation

Birmingham, the West Midlands region's main city, is the second city in England, after London, with a population of about one million inhabitants (1'014'000 in 2008[7]). It makes a whole, with Walsall, Solihull, Wolverhampton, Dudley and Sandwell the West Midlands conurbation (about 5 million inhabitants). The city has a long industrial history dating back to the beginning of the industrial revolution in 1800. During the twentieth century, industries, dominated by metal product manufactures, have declined and have been partially replaced by services such as banking and insurances. This heritage has an important impact on the current situation. Landfills and polluted sites are many and can cause groundwater pollution. Former industrial zones are thought to be regenerated with new developments. New buildings and facilities design have to take into account good efficiency standards and SUDS, in order to promote water-saving and flood-risk mitigation.

The city is almost completely (main rivers and discharges, GWMUs) located on the River Humber Basin (Tame, Anker and Mease CAMS). However, a small part is on the River Severn Basin, in the Severn Corridor CAMS.

3.3.3.2 Birmingham water supply

The main water consumers in Birmingham are the households, industries and commerce. Agriculture water demand is almost non-existent and then negligible within the administrative city of Birmingham. The average household consumption is, during the 2006/2007 year, about 144 l/pers/day [Severn Trent Water, 2008b].

In the end of the nineteenth century, the city of Birmingham was under pressure from the fast development of its industry and population. The amount of water used has hugely increased and there were major epidemics of water-borne diseases including typhoid, cholera and diarrhoea. The authorities decided then to catch water from the Elan and Claerwen Valleys in Wales. The catchment area (180 km^2) has an average annual rainfall of 1830 mm. A few dams have been built in several steps from that time[8].

The city of Birmingham is still currently almost entirely supplied, among other regions, with Welsh water from the Elan Valley reservoirs. An aqueduct carries raw water along 73 miles

[7] Office for National Statistics.
[8] Powys Digital History Project, history.powys.org.uk/history/rhayader/elanmenu.html, last time consulted : June 2008.

(115 km) from the storage reservoirs on the upstream zone of the River Wye in Wales to Frankley treatment works in Birmingham. The water is stored in Bartley and Frankley terminal reservoirs close to Frankley treatment works, in the South-West of the city, where drinking water is produced, mainly from raw Welsh water. Frankley treatment works' average input is about 330 Ml/day and its capacity about 400 Ml/day[9].

The different treatments in the two parallel streams in Frankley are: coagulation, flocculation, flotation, transiting through sand filters and chlorine addition.

The below figure is a simplified water flow chart of the city of Birmingham. It has been created with a free software designed for material flow analysis (MFA) called STAN[10], by gathering data from several sources (Severn Trent Water and the EA mainly. See annex 9.25). The city is not a closed system and is a part of the whole Severn Trent Water network. Water exchanges occur with surrounding cities. It is nevertheless very useful to visualize main water flows in Birmingham.

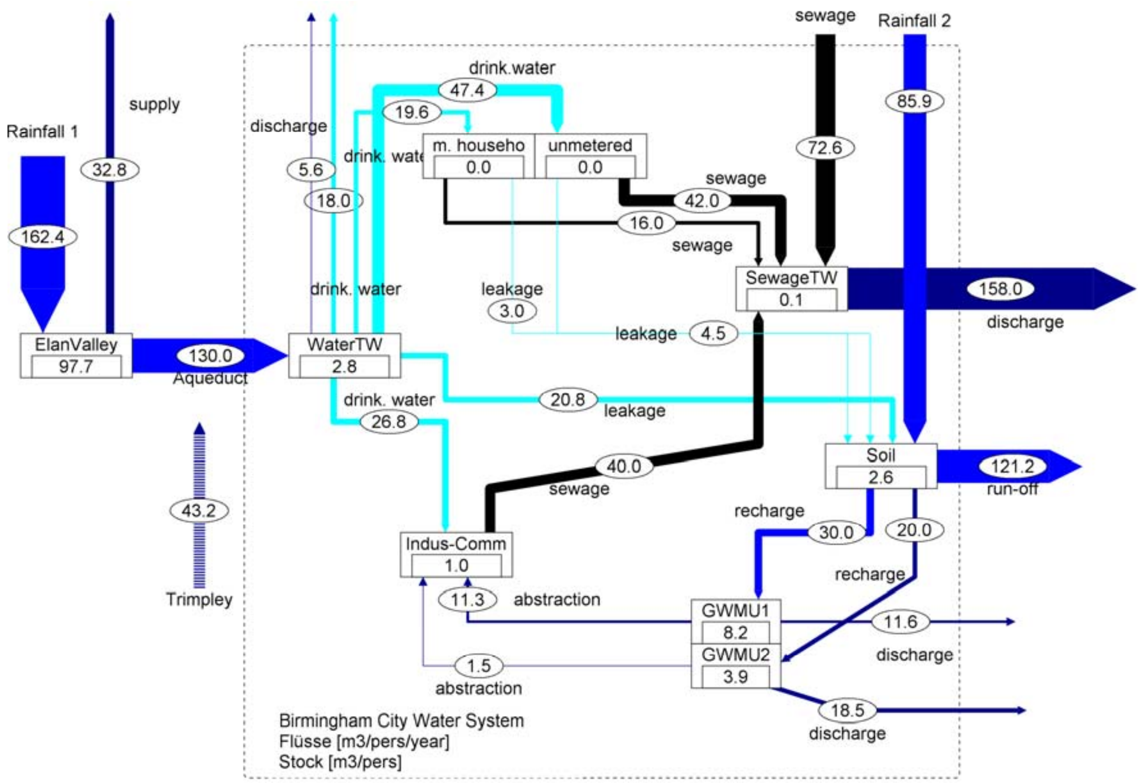


Figure 6. Water flow chart for the City of Birmingham with STAN.

This flow chart has been set with the unit m^3/pers/year, in order to potentially compare the figures with other similar studies. However, the unit Ml/day is more fitted to work on specific local issues (see chapter 5.1).

[9] Talk with Pr. John Bridgeman, University of Birmingham, formerly working for Severn Trent Water.
[10] Vienna University of Technology, Department of waste and resources management, www.iwa.tuwien.ac.at/iwa226_english/stan.html, last time consulted: June 2008.

A lack of water is expected in the Birmingham Water Resource Zone by 2018/2019 [Severn Trent Water, 2008b], although a granular activated carbon (GAC) treatment is planned at Frankley treatment works, which will allow to treat additional surface water. In the future, with changes on water demand, the main solution for further water supply is to increase the flow in the Elan Aqueduct by abstracting water from the River Severn at Trimpley (120 Ml/day). But this abstraction can be limited in case of drought downstream and Severn Trent requires permission from South Staffordshire Water, another private water company (supply only).

Water coming from the Coventry region has not the same physical characteristics. Mixing the two types of water isn't advised and could lead up to changes on the water taste.

A marginal amount of water is abstracted from the groundwater for industrial purposes. It is not more than 9 Ml/day for the Birmingham Groundwater Scheme.

3.3.3.3 Birmingham sewage treatment[11]

The huge Minworth sewage treatment works, owned by Severn Trent Water, is treating sewage from Birmingham and other cities around like Walsall and Wolverhampton, for about 1.7 million people. It includes domestic and industrial discharges. Moreover, sewage sludge coming from other smaller works is tankered and treated with primary and secondary sludge digesters. Biogas from the sludge treatment process is used to produce electricity. 22 MWh/day are produced in Minworth sewage treatment works from this renewable resource. A part of this electricity is used to run the works and the excess is sold to the national grid.

Treated water discharge is regulated by the EA and flows to the River Tame. The consented dry weather flow is 450 Ml/day (to be compared with an average sewage input of 500 Ml/day). The River Tame crosses over the city and is a very polluted river, with a very poor diversity, mainly because of treated water discharges, polluted runoff water and polluted groundwater inflows (see chapter 3.3.3.6).

In Minworth, 6 storm tanks have the capacity of 68 Ml of water and are used to store sewage either during storm events or during dry weather, because of the consented dry weather flow.

The main pieces of legislation for sewage are the Water Act 2003 and the Urban Waste Water Treatment Directive (91/271/EEC).

3.3.3.4 Canal network

The city is the heart of the national waterways network. Canals are currently used for leisure and amenity and almost not used anymore for transport of goods. It has also a great touristic value. The canal network within the city is historically very important and has to be conserved and maintained. British Waterways and the EA are responsible for its management.

In Birmingham, in the middle of the 18th century, there were 174 miles of canals in the area. The industrial development has been the trigger for their construction. Now only 114 miles remain as navigable water, most of the rest has completely disappeared[12].

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[11] [Severn Trent Water, 2005a]

The Edgbaston Reservoir supplies water for the canals.

The canal network of the city, resulting from Birmingham industrial history, is one of the main assets for tourism and amenity within the city. Its tourism promotion has to be improved.

3.3.3.5 Groundwater management and CAMS

The aquifer of Birmingham is constituted by Triassic red sandstone underlain by carboniferous coal measures, which is the effective base of the aquifer. The region is covered by a mantle of quaternary glacial deposits, between 0 and 40 m thick and comprising mainly clay and gravels. Flows within the aquifer are very complex, partially due to the fault of Birmingham and varying abstractions [Ford & Tellam, 1993].

The EA specified different protection zones for groundwater[13]. These zones are:

- **Zone 1** (Inner protection zone): travel to the borehole within 50 days.
- **Zone 2** (Outer protection zone): travel to the borehole within 400 days.
- **Zone 3** (Total catchment): The total catchment is the total area needed to support removal of water from the borehole, and to support any discharge from the borehole.
- **Zone of special interest**: industrial sites and other polluters could affect the groundwater source even though they are outside the normal catchment area.

Groundwater protection maps are available on EA's website.

The groundwater resource is divided into several Groundwater Management Units (GWMU) and the abstraction licensing process is managed through the EA's CAMS program. The abstractions are linked with several minimal flows, HoF (Hands-off Flow: minimal flow below which the upstream abstractions are limited). The main HoF downstream is 1380 Ml/d on the Drakelow gauging station on the River Trent. Below this figure, the upstream abstractors are required to reduce or stop their abstraction.

The Birmingham GWMU has an amount of water available (without compromising the water required for the environment) estimated to 58 Ml/day. Groundwater levels throughout the Birmingham GWMU have been rising for 40 years, on some locations by 25 m (5 m in the mean), resulting from the decline of heavy industry and then of the reduced industrial abstractions (see annex 9.10 for groundwater level between 1971 and 2007 at Dares Brewery).

Estimates of total abstractions, within an area which is nearly the same as the Birmingham GWMU area, provide the figure of more than 70 Ml/day in the 1940s and less than 20 Ml/day currently. This situation raises several problems [CIRIA, 1993]:

- Although sandstone's physical properties are not significantly affected by a rising aquifer, drift materials and deposits present a different case: the bearing capacity of saturated glacial silty clayey sands and gravel, compared with unsaturated, could be

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[12] Birmingham City Council, www.birmingham.gov.uk/GenerateContent?CONTENT_ITEM_ID=710&CONTENT_ITEM_TYPE=0&MENU_ID=1671&EXPAND=1650, last time consulted: June 2008.

[13] EA, www.environment-agency.gov.uk/maps/info/groundwater, last time consulted: June 2008.

reduced by as much as 50%. Then, a lowering of the aquifer can cause settlement. This could be a real problem, particularly for old buildings with narrow groundwork.
- The rising aquifer in contaminated sites can lead to the contamination of water, which can affect aquatic ecosystem, public health, and also groundwork's concrete by chemical attack.
- It is also a problem for pipelines, mains, tunnels and other sub-surfaces structures.
- Historically, abstractions have kept groundwater level below the beds of the rivers. Now the situation has changed and potentially contaminated water can migrate into the rivers. The main contaminants groups are dissolved organic compounds and the lighter-fraction oils and tars.

Some control over the effect of a rising aquifer can be achieved by different options:

- Pumping. That requires a regional control of groundwater levels. It is estimated that a total pumped abstraction of 35 to 40 Ml/day would achieve general levels of the 1970s. The estimated current abstraction amount for the area is less than 20 Ml/day.
- Land drainage. Local gravity drainage systems may be a relevant possibility, particularly in areas where the groundwater level is much higher than the bed level of the adjacent rivers. This method needs a contamination survey to avoid drainage of contaminants by choosing another option in very contaminated areas.
- Rising surface levels. It is an option that could be practicable for new development areas. The estimated cost to raise levels by 1 meter with clean imported fill, fully layered and compacted is between £75'000 and £85'000 per hectare.

The Birmingham Groundwater Scheme is currently undertaken by Severn Trent Water and aims to produce fresh water to support river flows during drought periods and thus to secure surface water abstractions. It will maybe partially solve the problem.

3.3.3.6 Groundwater pollution[14]

The industries and the urban development have led to a widely contaminated soil and then groundwater. Heavy metals and organic contaminants like chlorinated solvents have been identified in the groundwater. This groundwater is used for abstractions but also flows to rivers. The Tame, for instance, is known to receive 20% of the inflow from groundwater [Ellis, 2003]. The groundwater income is very important during dry weather flow periods.

Since the 1950s, the industry has declined, and let place to services, banking and insurances. But the pollution has remained. Chlorinated solvents TCE and PCE predominate in the Birmingham aquifer. Historic and current landfills have been implemented within the ISWS, but a lot of industrial sites are polluted. This issue has thus to be tackled on a large scale. Several studies and PhD Thesis have been, and are still currently undertaken, at the University of Birmingham in order to assess the groundwater pollution within the Birmingham aquifer and to estimate the natural attenuation from the hyporheic zone (beneath and lateral to a stream bed, where there is a mixing of shallow groundwater and surface water).

The European legislation sets groundwater quality objectives for 2015 through the Groundwater Directive (2006/118/EC) and the WFD (2000/60/EC).

[14] [Shepherd, 2002]

3.3.4 Planning policies and building regulations

3.3.4.1 National and regional scales

The Planning Policy Statements (25 themes) are the main piece of national planning legislation. They provide a legislation framework for nature conservation, flood risk, regional and local development, pollution control, etc. The Building Regulations and the Code for Sustainable Homes set some standards for water consumption and will be soon updated by the legislator, as explained in Future Water.

The Regional Spatial Strategy for West Midlands comes next and gives a regional appraisal of the planning policies with the main related issues.

Most of the time, when there is new urban development, highways and private properties drain into the public sewer. The initial costs of constructing sewerage are met by the developer. The ongoing costs of drainage are met by the sewerage undertaker (Severn Trent Water for Birmingham), and are recovered through customers' charges. The highway connection is owned by the highway authority and the property connection is owned by the property owner. The highway authority is the Highway Agency (funding from central government) for main roads and the local authority (funding from local tax) for other roads. The highway authority pays no charges for public sewerage services, other than connection charges. There is no incentive to route drained water away from public sewers, in order to mitigate sewer flooding risk. However, when there is an Internal Drainage Board, rates are charged [Defra, 2007c].

For water supply, the water company owns the water mains and public pipes; the property owner owns the private pipe (connection for the property). Leakage occurs for ¼ in private pipes and is, in this case, under the responsibility of the property owner. However, Severn Trent Water offers a subsidised or free supply pipe repair to customers, under certain circumstances. The current policy is the Bursts on Private Property Scheme [Severn Trent Water, 2008c]. Despite a free supply pipe repair, the leakages in private pipes are not efficiently sought.

3.3.4.2 City scale

On the city scale, the Birmingham City Council, through its Planning Service, has the duty to manage land-use and planning and focuses particularly upon regeneration projects. The Birmingham Local Development Framework [Birmingham City Council, 2006] is the legal base for the city and contains several documents, plans and general guidelines such as the Unitary Development Plan and annual Monitoring Reports.

3.3.4.3 Local scale

On a local scale, the Area Action Plans gives a general vision of the current local issues, projects undertaken and future developments, for a given area. After consultation, the preferred options concerning developments and land use are chosen and proceeded. The Longbridge Area Action Plan has been implemented in the ISWS in the frame of the Upper River Rea thematic view (see chapter 5.3.1).

3.3.4.4 Environment protection

Protection policies against further urban development are important to safeguard ecological areas. The main piece of legislation for environment protection is the Environment Act 1995. Some Planning Policy Statements provide also legislation framework for biodiversity and Green Belt conservation. National Nature Reserves (NNR) and Sites of Special Scientific Interest (SSSI) are nationally designated, whilst Local Nature Reserves (LNR) and Sites of Importance for Nature Conservation (SINC) are recognised locally. Birmingham counts 5 LNR and 2 SSSI (Sutton Park, which is also a NNR, and Edgbaston Pool).

The Regional Spatial Strategy for West Midlands and Birmingham Unitary Development Plan (2005) acknowledge the importance and the value of the Green Belt, which includes grass lands and other areas of countryside which extend into the City, often along river valleys. Green Belt areas can only be altered in exceptional circumstances.

Severn Trent Water publishes a Biodiversity Action Plan. It appraises the general impact of the company's activities, such as groundwater abstractions and water treatment by taking into account protected areas and current legislation.

3.3.5 Extreme situations

The UK lies in a maritime climatic zone, with a very variable weather. With climate change, rainfall events are going to become more and more extreme.

3.3.5.1 Drought emergency[15, 16]

The city of Birmingham constitutes one of the nine Drought Zones of the Severn Trent Water company. There are different strategies for each of them, in order to supply enough water for customers. The main piece of legislation involved in this issue is the Water Resource Act 1991, under sections 73 to 81. Severn Trent Water, but also the EA, have a Drought Plan.

Elan Valley Reservoirs level of storage is the main trigger in case of drought. Drought management options are applied by taking into account different levels of storage. A storage alert line, a drought warning trigger and a licence rule curve are defined and given in the Severn Trent Water's Drought Plan 2006, in order to trigger different actions.

A lot of measures can be applied to improve the efficiency of use, to narrow down the demand or to increase the supply. It includes water efficiency campaigns, leakage reduction, increasing metering, new abstractions, etc. In case of drought, more constraining measures can be put in place. The first level of restrictions is a hosepipe and sprinkler ban for domestic customers. The amount of water saved with this ban is not really important but it is a strong signal to the customers that there is a water shortage and it promotes water-saving.

The Drought Permit allows special actions, such as new abstractions or the reduction of the compulsory release in rivers, introduced in case of drought only; it is granted by the EA. The Drought Order allows restricting use of water in any way necessary and is granted by the

[15] [Severn Trent Water, 2006a]
[16] [Environment Agency, 2007a]

secretary of state. The target of Severn Trent Water is to have not more than 3 Drought Orders or Permits in 100 years.

The Elan Valley Reservoirs provide significant regulatory releases to the River Wye. It is then also possible to limit these releases, through Drought Permits. But this action has to be corroborated by Dwr Cymru, which is the Welsh water company.

The winter storage of water will be more and more important in the future, in order to prevent water shortage in the West Midlands, because of the expected changes in precipitation and also because of the population growth.

The annexes 9.14, 9.15 and 9.16 show the different triggers, actions undertaken and the drought management options for the whole Severn Trent Water zone and also specifically for the Birmingham Drought Zone.

3.3.5.2 Floods emergency

Flooding is one of the main water-related issues for Birmingham. Important floods (river and sewer flooding) with high costs are frequent.

The EA provides flood warnings online 24 hours a day. The current floods and warning status are available for the selected area. The information is updated every 15 minutes.

The main pieces of legislation involved in this issue are the Water Resource Act 1991 and the Planning Policy Statement/Guidance 25, defining flood zones. Moreover, Catchment Flood Management Plans (CFMP) are published for each main catchment by the EA, following the Defra and EA's policy guidance. The Trent CFMP provides a lot of information (historic flooding, geology, land use, framework, issues, etc.) and flood maps for the region of Birmingham; it is available in the ISWS.

The Flood Estimation Handbook [Centre for Ecology and Hydrology, 1995] is the basis for most current flood estimation in the UK. It gives guidance on rainfall and river flood frequency estimations. The HiFlows-UK website[17] provides flood peak data for the main rivers.

The management framework is complex and several stakeholders are responsible for land drainage (landowner, water company, highway authorities, Internal Drainage Boards) and also for river management (EA, local authority, riparian owners). This complexity inhibits partially the efficiency required for such a big issue. The ISWS is able to display this fragmented framework and can be used as an institutional mapping for future framework/responsibilities amendments.

After the 2007 summer floods, the Government launched the Making Space for Water programme [Defra, 2008a]. It will probably be in the future the trigger of changes concerning floods and rivers management. The Upper River Rea thematic view focuses on this issue (see chapter 5.3.1).

[17] Environment Agency, www.environment-agency.gov.uk/hiflowsuk, last time consulted: June 2008.

The responsibility depends on the type of flooding. The usual responsibilities, under conditions, are given in the table below.

Type of flooding	Responsibility
Public sewer flooding	Severn Trent Water
Private sewer flooding	Homeowner
Highway flooding	Highways Authority
River flooding	Environmental Agency
Groundwater seepage	Homeowner
Land drainage	Environmental Agency

Table 3. Flood responsibilities.

The ISWS allows displaying this kind of information in a readable way. A more complete description is given in annex 24, with flood contacts and links. This information is available within the ISWS.

3.3.6 Future challenges

There are different pressures on the water resource, coming from economic and demographic growth, agricultural needs and potential impacts of climate change. A twin-track approach is needed to face future challenges, combining further water resources development and improvement of the water supply through efficient use (population sensitization, leakage decrease, widespread metering, development of winter storage, etc.).

3.3.6.1 Precipitations and climate change

Some parts of the West Midlands region, such as Coventry or Worcester are amongst the driest in the UK, with annual rainfall average of 650 mm (see annex 9.3). The average annual rainfall in Birmingham is about 773 mm (1920-2006)[18] and in the whole West Midlands Region about 750 mm. A part of this rainfall is taken up by crops, trees and other plants for their growth (green water) and some evaporates. The rest is called the effective rainfall, which is about 2000 l/pers/day in West Midlands [West Midlands Regional Observatory, 2001]. It is a really little amount of available water per person and it is not completely available for human needs, because we have to guarantee sufficient level in the rivers and aquifer to keep the quality of the valuable aquatic ecology. The amount of rainfall is spread non-uniformly through the year (see annex 9.4), with much of it occurring during the winter and less during the summer. This non-uniformity will increase in the future, in accordance with UK Climate Impacts Programme data (see annex 9.8). It is therefore important to promote water storage during fall and winter months in order to use it during spring and summer months. The reservoirs will become more and more fundamental in the West Midlands Region for water resources management.

3.3.6.2 Population growth

The sustainability of the water supply for Birmingham is unsecured, mainly because of population growth. There is also another factor which increases household water demand: the number of households is increasing due to the change in family structure. A lack of water is

[18] Rainfall gauging station data. University of Birmingham (1920-2006).

expected in the Birmingham Water Resource Zone by 2018/2019 [Severn Trent Water, 2008b]. However, several options are conceivable for the water company in order to avoid frequent water shortages in the future. Population growth projections are shown in the Figure below:

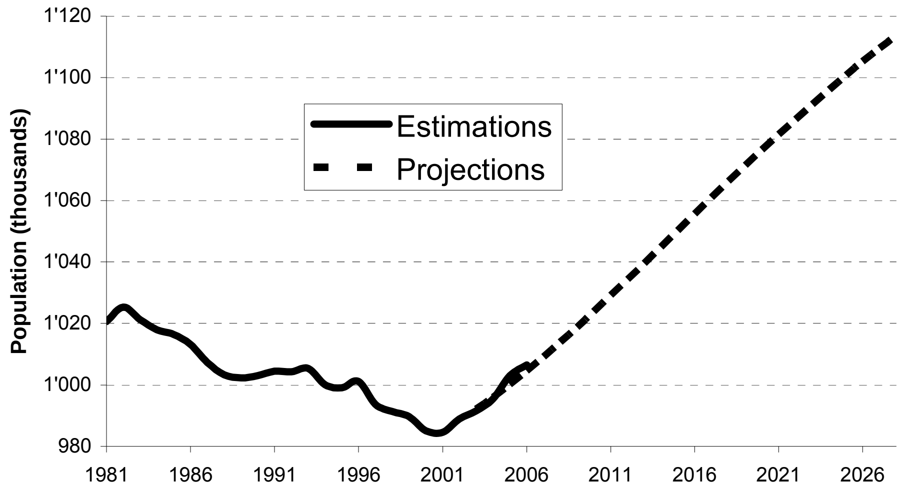

Figure 7. Birmingham population estimates [Birmingham City Council, 2006] and projections[19].

As the population is increasing quickly, water management strategies have to consider long-term options in order to be efficient.

3.3.7 Water-saving and sensitization

Water-saving and sensitization allow partially balancing water demand increase. With a so quickly growing demand, the research of new supply sources probably won't be sufficient.

Public sensitization is a long-term challenge. Waterwise is not able to take on the task alone. The City Council has to be involved by promoting sensitization at school, at home, in the industry and in the agriculture. High water price is a kind of sensitization, but efficiency devices' spreading and consumption targets for new buildings have to prevail, for social reasons.

Water-saving and efficiency have to be a priority for Severn Trent Water, through Save-a-flush displacement cistern device, rain saver kit and other devices' distribution, and obviously also with leakage reduction.

Leakage is currently high (27% for Severn Trent zone [Severn Trent Water, 2008b]). Ofwat's price setting considers financial costs of leakage reduction but doesn't give enough financial incentive to improve the situation. Leakage issue is managed through the Economic Level of Leakage (ELL) policy.

The ELL is currently (2008/2009) estimated to 77.6 Ml/day for the Birmingham Water Resource Zone (21 Ml/day in private pipes only) and 500 Ml/day for the entire Severn Trent

[19] UK Statistics Authority, www.statistics.gov.uk, last time consulted: June 2008.

Water zone. Severn Trent Water analysis indicates that further reductions in leakage through increased detection and repairs are not economic. There is a burst increase with old pipes. Severn Trent Water's AMP5 (2010-2015) mains renewal programme will be targeted on pipes with a high risk of future bursts, rather than on high leakage areas. It is expected to achieve leakage targets more efficiently. However, the company will carry on active leakage control. Mains replacement is managed by the Severn Trent Water engineers through the Stella software [Severn Trent Water, 2006b and 2008b].

With expected water supply costs increase in the next years, because of climate change, further leakage reduction will probably be encouraged through ELL decrease.

The current water-saving framework is given in annex 9.12.

3.3.8 Virtual water

Today's water management has to take into account virtual water, or embedded water, to be really integrated and efficient. Virtual water does mean all the water used to produce agricultural and industrial goods. This amount of water is much more important than household consumption. Food consumption is the most important part of our water consumption (see annex 9.2). For instance, a glass of milk (0.2 l) needs 200 to 650 l of water to be produced depends on the source of the information and the country where it is produced [Chapagain & Hoekstra, 2004a].

The UK is a net importer of water, through goods import, mainly from North and South America. Data from Waterwise, a NGO focusing about water efficiency show that an average person in the UK consumes not less than 3'411 l/day = 1'245 m^3/year by taking into account goods import [Waterwise, 2007b].

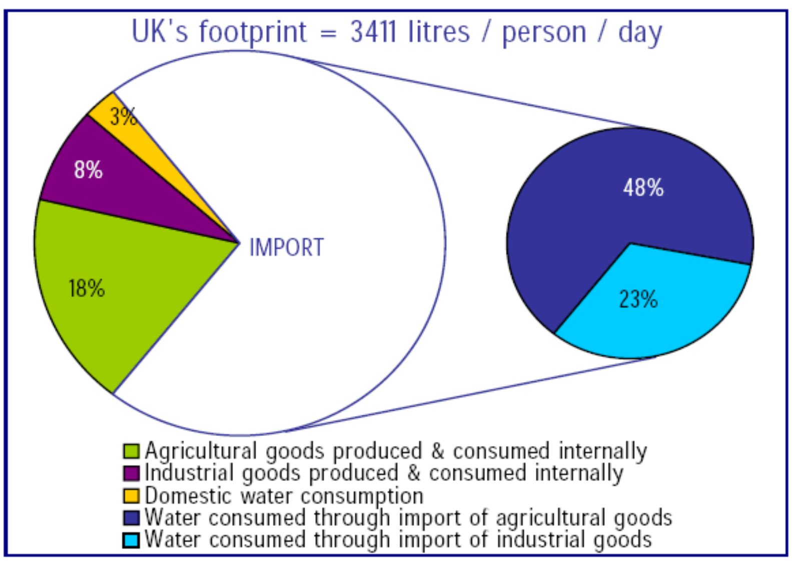

Figure 8. UK's footprint [Waterwise, 2007b].

This figure is called the water footprint. The majority of the water involved in this footprint (71%) is used in foreign countries to produce foods and goods consumed in the UK.

Moreover, the report The food we waste [Wrap, 2008] shows that about one third of the food bought in the UK ends up being thrown away. It means that roughly 1 m^3 of water per person is wasted every day. Water-saving is not only possible on the tap.

It is not a sustainable way to increase import of virtual water in the purpose of saving Welsh or English water. The target has to be the decrease of the global water footprint, in order to ensure water supply in the future.

It is therefore important to keep these data in mind and to include the virtual water in global water management strategies. For instance, water-stressed areas could import more water through foods and goods. Highly water-consuming crops don't have to be developed in such areas.

What is lacking on the figure above is the amount of water consumed internally in order to produce foods and goods for export. Highly water-consuming products should be replaced by others, if it's possible.

In conclusion, virtual water consumption has to be thought in a global level, because of the huge amount of international water exchanges through foods and goods.

4 Application of an ISWS in Birmingham

4.1 Limits of the system

Setting the limits of a so complex system is not very easy. The data collection scale depends on the focused water-domain. The main stakeholders are dealing with their specific issues which are related to different scales The ISWS has been finally built on a few different scales:

- Administrative city of Birmingham for developments, local policies, ecosystem and population.
- Severn Trent Water’s zone and, within it, Birmingham Water Resource Zone, for water supply, consumption and leakage (population also available for these zones).
- Tames, Anker and Mease CAMS area for abstractions, discharges, rivers and groundwater management.

This way of collecting data is justified by the different management levels which are dealing with specific issues. Data for those specific issues are often available (and have to be provided) only within the related scale.

4.2 WMSM validation

The WMSM is an exhaustive view of the water system into a lambda city. It gives the main water-related components’ groups and a few general interactions. Some adaptations have been required among those main components. Some nodes were not relevant for the given context and thus have been dropped; some nodes were missing and thus have been added. However, the general framework is consistent and can be applied to whatever city throughout the world, with minimal adaptations.

Nevertheless, the interactions strongly depend on the local context and framework and thus have to be applied differently for each city. But a common basis remains between cities from the same country, because of a similar management framework, and would make easier the transfer of the ISWS tool from a city to another one, within the same country.

The WMSM validation consists in discussions with key people, process understanding and in transcribing the given framework into a readable system-oriented view. Such a representation displays involved objects according to their role within the system.

The final validation process will occur by providing thematic views to involved stakeholders for consultation. This step will be carried out after the complete development of the ISWS.

4.3 Implementation approach

4.3.1 WMSM as a basis

The implementation of the ISWS of Birmingham has been based on the WMSM influences/fluxes chart (see annex 9.18) created by the Research assistant, PhD student Colin Schenk.

This relational model gives a basis upon which the implementation process can be built on. In the ISWS, a hierarchical structure, as used for the WMSM, is imposed by the huge amount of nodes and interactions in the base diagram. This consistent and organized structure allows finding easily the required nodes, even in the base diagram. A systemic view, taking into account the location of the components or the water cycle, would be neither relevant nor easily readable. Geographic locations will be available with the GIS, which has still to be linked with the ISWS.

All the components of the WMSM are not required in the Birmingham context. The complexity level required in the information system strongly depends on the users' needs. It is then important to understand the water management framework, to identify the main issues and the potential users before to implement the WMSM within the ISWS.

People in charge of the implementation of the water system into the ISWS software have to keep a degree of freedom from the WMSM structure and have to take into account local specificities to provide a representation as close as possible to the water management framework in operation within the given context. In this current case, some specific groups of components have been thereby simplified or modified.

4.3.2 Implementation methodology

After having understood the water resources management framework, identified the main stakeholders and the main issues, the water system can be implemented into the ISWS.

There is no universal and predefined drill to follow in order to carry out the implementation process. The chosen approach for Birmingham is however given below and follows a logical path.

It is an iterative process which has to be reassessed at each step in order to reach the given objectives and to focus on the relevant issues. That's why consultation with key people is important even during the implementation process.

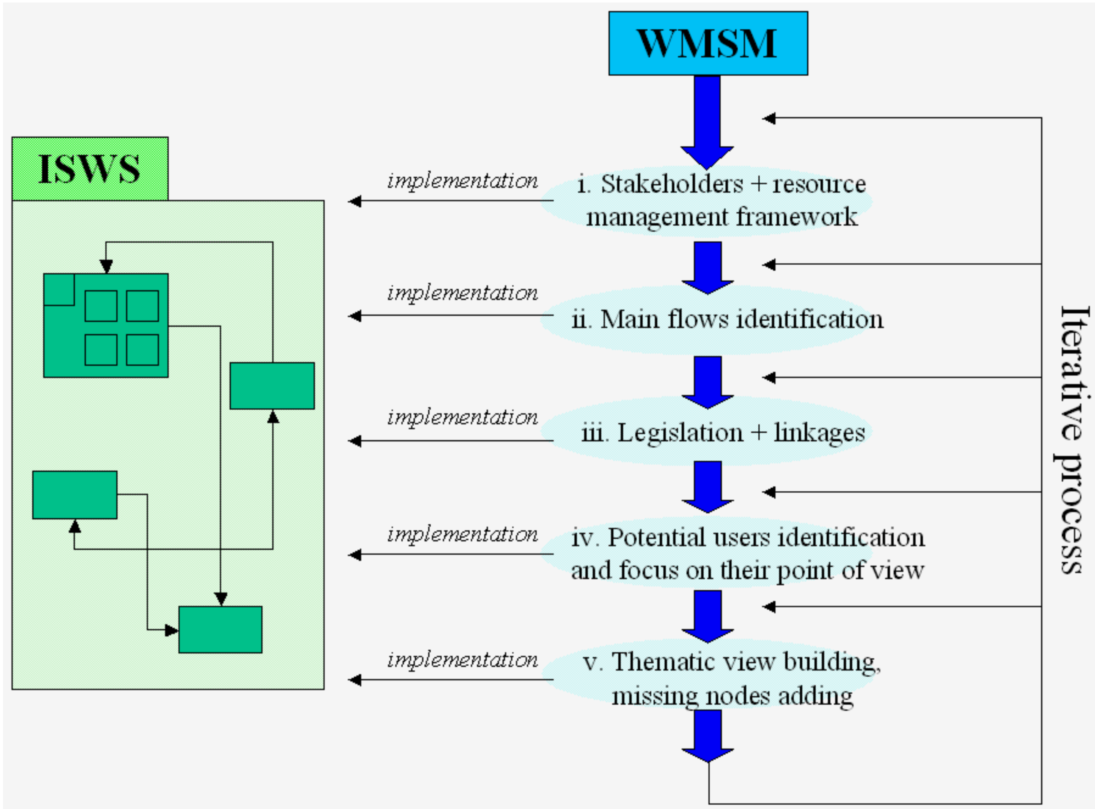

Figure 9. Implementation approach.

Four months are not enough to tackle all the water-related domains profoundly and to provide an accurate information system rendering all the relevant components. Therefore, some specific issues have been studied more deeply (step v.) in order to produce interesting thematic views.

The main steps of the implementation are explained below, as listed in Figure 9. The final result is provided by the ISWS software.

i. Stakeholders + resource management framework.

Stakeholders' identification and resource management framework understanding is the first and compulsory step for the water system analysis. It has been done by studying bibliography and speaking with key people. Because of the non-availability of the ISWS software at the beginning of the project, this general framework has been built in broad outline with Visio and then transcribed within the ISWS.

The Visio outline of this first step is available in annex 9.17. The governance thematic view (see chapter 5.3.3) is deeply related to this step, but contains also the legislation framework.

ii. Main flows' identification.

This step has been carried out with a balanced water flow analysis (see chapter 5.1).

It was an almost compulsory step before implementing water flows in the ISWS. However, Severn Trent Water has its own complex model for water supply and sewerage and doesn't need such a rough view. It is not expected to provide a design tool with these data, but it can be useful for other purposes, such as planning purposes by providing consumption's trends, forecast and targets.

A thematic view has also been built on this theme. It is shown in annex 20.

iii. Legislation + linkages.

The legislation in the UK context is very complex. Moreover, the European legislation has to be taken into account, among other things because of the weight of the WFD in current issues. The relevant legislation has been found through stakeholders' publications and also through the EA's website. The legislation sets different objectives and targets, such as consumption targets, which have also to be implemented (numeric values, text information, documents). Within the ISWS, the legislation is available for consultation either through the web (UK Legislation[20], and EU legislation[21]) or through a pdf document.

The implementation of the water-related legislation allows clarifying the linkages between water management strategies, stakeholders' role and the relevant legislation. It gives a tool for legislation enforcement.

iv. Potential users' identification and focus on their concerns.

It is obvious to say that the ISWS has to be shaped according to potential users' needs. Planners have been identified as potential users. Consequently, this step consists in implementing future developments, population growth projections and planning policies.

v. Thematic views building, addition of missing nodes.

Once the major part of the water system has been implemented, the thematic views, which tackle the key issues, can be built on (see chapter 5.3). The thematic views have to be refined. They are indeed related to very specific components which have maybe not yet been taken into account. For instance, the Upper River Rea thematic view needs to display local action stakeholders such as the local Environment and Flood Action Group or local issues such as clay soil (low infiltration) and sewers low capacity.

Along the implementation process, numeric values, text information and documents have been integrated into the ISWS. Finally, the ISWS for Birmingham comprises about 700 nodes, 450 interactions, 650 numeric values, 150 text information and 130 document files. All these components are listed in annex 9.26.

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[20] UK Statute Law Database, www.statutelaw.gov.uk, last time consulted: June 2008.
[21] EUR-Lex, eur-lex.europa.eu, last time consulted: June 2008.

4.4 Collecting data

In order to collect data and information, a lot of reports and publications have been useful. People involved in the different water-domains (water supply, environment, land-use and planning, price setting, etc.) have been consulted. The main sources of data are:

- Severn Trent Water. The water company has the duty to publish reports such as the water resource management plan.

- The EA. Some data are available on the web. The EA provided the Tame, Anker and Mease CAMS document + CD for free. However, some specific data such as treated water discharge standards for Minworth sewage treatment works are not free of charge. As the ISWS is expected to be provided free of charge, it has been decided to do without those data.

- The Ofwat. The public regulator publishes data on water companies.

- Birmingham City Council. The local authority provides information on local policies, statistics and new developments.

- Contact with involved people, such as professors at the University of Birmingham or Switch Learning Alliance's partakers.

- The Office for National Statistics, which provides data on population, food and water consumption.

The numeric values and their source are given in annex 9.21.

4.5 ISWS limits

The different water-related domains are thought by many as unlikely to be gathered and managed together. In a report [EAWAG, 2003], the EAWAG estimates that different approaches and tools have to be undertaken for the different water-related domains, that it's too complex to be undertaken through an only way. However, the ISWS aims to provide a holistic view of the water system, but doesn't replace specific tools.

Some water-related domains need specific software to deal with specific data. For instance, the abstraction licensing process needs accurate data on groundwater levels, recharge and discharge. The ISWS is not relevant to tackle this kind of process, but it is not its expected role. The objectives and possibilities of the ISWS still have to be refined. That's possible by confronting thematic views with key people. Unfortunately, this step has not been undertaken during the MSc project, lapse of time. Since the ISWS is still under development, the results of the ISWS, especially the thematic views, will have to be reassessed periodically.

The ISWS is not directly useable and has to undergo some changes to lead toward an operational tool. The relevant part of the water system within the ISWS has to be extracted to

create thematic views. It is not an automatic step and requires some work to display the issue in a readable way. For instance, tracking the interactions is not very easy. Linked nodes could be automatically brought closer to clarify the relation. The selected node has to be highlighted and an option could allow tracking the interactions by navigating to the further node. Information bubbles creation (problem, text information, etc) is still not developed.

This step requires further development in order to improve the final product.

There is for the time no possibility to simulate scenarios with the ISWS. This option could be useful in order to compare different strategies. For instance, population and water demand growths could be simulated. However, the usefulness of such an option still has to be demonstrated. The ISWS might not allow for enough accuracy.

The visualization of water stocks is not available with the ISWS. It would be interesting in order to display the stocks of reservoirs, aquifer, storm tanks, etc. However, numeric values can be associated to nodes and can be consulted.

Combining the three modules (ISWS, GIS and indicator viewer) will be a significant step in order to create an effective DSS.

Finally, the potential use of the ISWS is strongly related to the institutional framework. Indeed, sectorial water management wouldn't allow using a tool which is promoting the integration of the various water-related domains. Without consultation between stakeholders and a central management team, the usefulness of the ISWS is limited.

4.6 Problems encountered

- Different scales exist for the different water domains (Environmental Agency, administrative city, water supply through Severn Trent Water, etc.). The region is differently divided into charging zones, Water Resource Zones, water infrastructures zones, catchments, administrative areas, etc. It is not easy to implement it without GIS layers in a readable way within the ISWS.

- The software was not available in the beginning of the MSc project. The design of the Information System has been developed during the MSc project and the thematic views were not available until the last week of the project's period. It has been difficult to shape these views without the required development. There is still work to produce consistent thematic views for Birmingham.

- Some data are not available because of confidentiality issue for Severn Trent Water. Some EA's data are not free of charge and haven't been bought.

- The Severn Trent Water Resource Management Plan 09 (draft version) [Severn Trent Water, 2008b] has been published in the end of the Master project.

- Complexity and extent of the whole water system and management. Defining the required accuracy the data have to reach is not easy before to define clearly the use of the tool.

- The Oracle database is an English version. Compatibility with a French version Excel has been sometimes very complicated in terms of data import.

5 Results

5.1 Water flow analysis (WFA)

The water flow analysis for the city of Birmingham has been achieved by gathering data from various sources (see annex 9.25). It is a simplified view of the water flows within the city. It provides an appraisal of the main water flows by giving the relative orders of magnitudes. The unit m^3/person/year (see Figure 6) would allow comparing the result with another similar study. However, the unit Ml/hour is relevant to tackle a specific case. Moreover, depending on the focused issue, the system can be differently displayed. Only the water supply and removal infrastructures are displayed in the figure below:

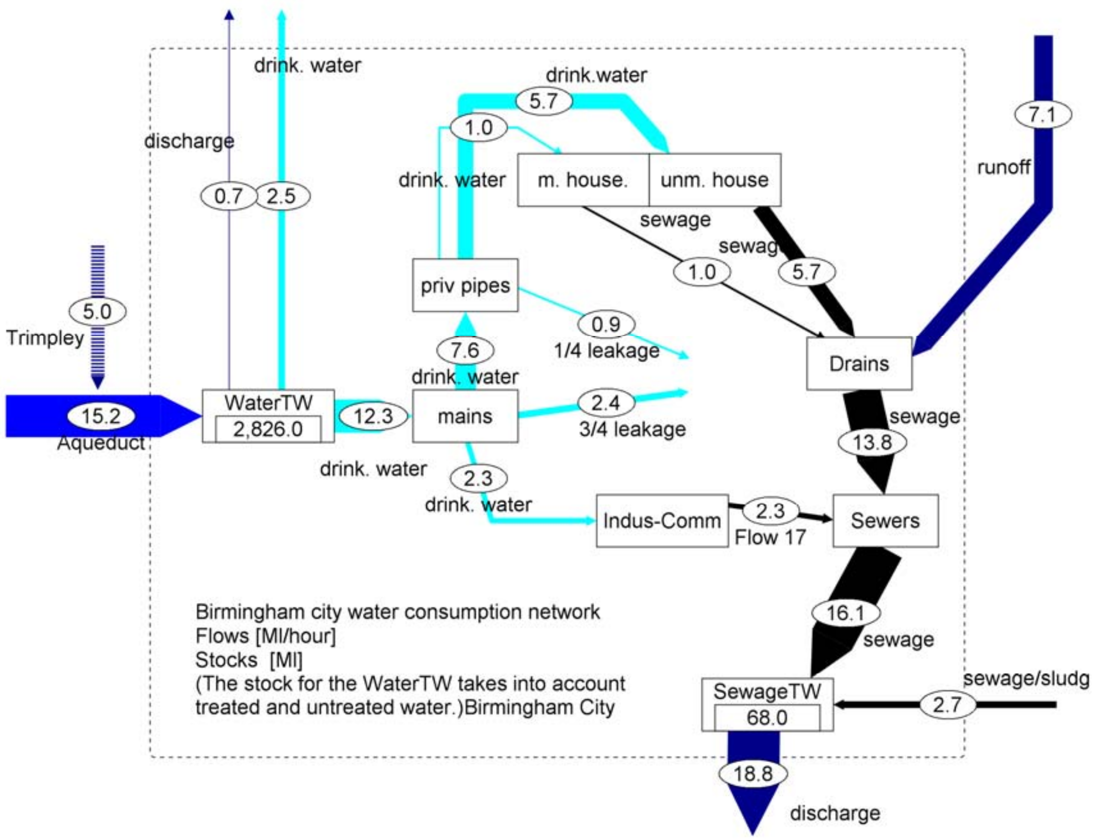

Figure 10. Birmingham water supply and sewerage network. Water flow chart.

Such a water flow chart allows some estimates. For instance, in the case of a cut in the main aqueduct, the Frankley water treatment works would be able to supply the city during one week, assuming that the Frankley and Bartley reservoirs are full at the time of the cut. On the other hand, Minworth sewage treatment works has the capacity to store not more than three and a half hour of sewage, assuming that the storage tanks are empty at the start.

The runoff has been calculated with the average annual precipitation and by assuming a runoff coefficient of 30%. The same situation during a rainfall event is provided in annex 9.13.

One quarter of the leakage occurs on private pipes, the last meters before the tap. The water flow chart is an interesting tool to figure out this issue by comparing leakage with other flows, and, generally, to grasp the water system by providing main water flows' visualization.

5.2 Main identified issues

5.2.1 Water-related issues

- Flood hazard. See chapter 3.3.5.2.
- Rivers bad ecological state. Watercourse renaturation has to be tackled by combining flood-risk mitigation. The Making Space for Water programme is a good opportunity to improve watercourses' ecological state.
- Rising aquifer / groundwater pollution. See chapters 3.3.3.5 and 3.3.3.6.
- Invasive species. The Edgbaston Pool (is a SSSI, Site of Special Scientific Interest) is located close to the Winterbourne Botanic Garden. The Head Gardener of the Botanic Garden, Lee Hale, is aware of the issue concerning species invading surroundings areas such as the Edgbaston Pool. Generally, the main invasive species in the region are the Japanese Knotweed (Fallopia japonica), the Himalayan Balsam (Impatiens sp.) and the Mares tail (Equisetum arvense). The EA is responsible to manage this specific issue.

5.2.2 Framework issues

- In general, a too complex organisational structure and legislation, which inhibits efficiency and coordination:
  "The legislation needs to be tightened to enable surface water management to be carried out through statutory duties with fewer organisations and stakeholders involved. Maximising real benefits by reducing surface water quantity, and perhaps more importantly by improving quality, are being lost every day as a result of the current complex organisational structure and legislation." [Defra, 2008a].
  Several organizations are involved in river management, but there is not enough funding for flood risk mitigation. There is not enough legislative/institutional incentive.

  This issue is the subject of the governance thematic view (see chapter 5.3.3). Some reports have been published on this issue [Green, 2007]. The ISWS can be useful in order to provide an institutional mapping in a different way.

- Lack of communication between stakeholders. An organization such as the Learning Alliance has to proceed in order to allow more dialogue, cooperation and consultation in the future. This responsibility could be tackled by the Water Group which will normally be created [Defra, 2008a].

- Lack of data sharing concerning soil pollution (confidentiality issue with consultants' reports not published).

- Lack of transparency with Severn Trent Water / confidentiality issue. Ofwat proposes 2.9% of 2006-07 turnover (£34.7 million) fine on Severn Trent Water for deliberately misreporting some key customer service information[22]. Moreover, the water company doesn't publish all the data.

- Not enough strength of will from the Ofwat for metering spreading. Severn Trent Water proposed [Severn Trent Water, 2006b] to achieve around 70% household meter connection by 2030. That metering policy would have required additional funding in price limits by Ofwat, but Ofwat considers that this policy is not required to achieve target headroom. Therefore, Severn Trent will not apply this policy during the current AMP period.

5.3 Thematic views

It is expected to use the ISWS for specific issues by selecting the relevant nodes, interactions and information. It leads to the creation of thematic views, which are the functional versions of the ISWS. The thematic views after-specified derive from the main identified issues in the particular situation in Birmingham.

The tackled issues are very specific and therefore several nodes such as local action groups or secondary ecosystems needed to be added.

The base diagram of the ISWS is used as a basis. Groups have to be disaggregated in order to build an interesting thematic view. The linked nodes can be brought closer, in order to clarify the relations. Shaping the thematic views requires time. It is a design work which allows shaping a view freely according to the issue but also to the targeted people's concerns.

Time was missing at the end of the project to have a feedback from key people on the below thematic views.

5.3.1 Flood mitigation and drainage: Upper River Rea case study

The Making Space for Water Programme is a cross government programme taking forward the development of a new strategy for flood and coastal erosion risk management in England. The Upper River Rea area is one of the several pilot sites where the strategy is applied.

In this area, new developments are planned and have to be designed so as to prevent more runoff. SUDS have thus to be integrated in the development area. The thematic view makes the main SUDS papers and interesting web links available for consultation. Moreover, River Rea water quality data are provided. Pollution occurs because of the low capacity of the sewer system.

[22] Severn Trent Water, www.stwater.co.uk/server.php?show=ConWebDoc.3403, last time consulted: June 2008.

The thematic view aims to tackle this specific case study by providing a tool for proactive flood-risk mitigation. River, pluvial and sewer flooding occur in the area and are the main issue. However, the thematic view aims to integrate other information such as water quality, legislation. It is shown in annex 9.20.

5.3.2 Rising groundwater levels

A recent article in the Birmingham Post (17 April 2008) focuses on the rising groundwater issue. Groundwater levels have been rising the last three decades and can potentially cause flooding in buildings' underground levels. It addresses the issue of pollutants mobilisation and has also engineering implications (see chapter 3.3.3.5).

This issue is also bound up with the abstraction licensing. An option for Severn Trent Water is to pump and treat groundwater from the aquifer underlying the city to supply the drinking water network. Studies are currently undertaken by the West Midlands Regional Assembly and Severn Trent Water. Moreover, a project planned for the 2008 summer at the University of Birmingham, led by Dr. Mike Rivett, will focus on water table levels rising in Birmingham.

Abstractions will have to be increased in the next years to make balance groundwater levels' rising.

5.3.3 Improving governance and funding arrangements

Governance issues are problematic for Birmingham and inhibit an efficient use of the available means. Coordinated actions involving all the stakeholders would lead to a better efficiency. [Defra, 2008a].

The thematic view displays the water management institutional framework with main stakeholders' roles, the legislation involved and the main information sources (databases) and studies. Legislation, code of practice, funding arrangement and studies on SUDS are also available. There is no incentive for SUDS, although it is one of the very main ways to mitigate flood-risk in urban areas. However, funding arrangements can be set under section 106 of the Town and Country Planning Act 1990 (Agreements regulating development or use of land). There is a Defra report focusing on this issue [Defra, 2007c]. It appears that there is indeed no substantive (financial or legal) incentive for a sewerage undertaker (the private water company), but also for local authorities, to adopt SUDS; flood defence is a permissive activity, not an obligation. That is the main reason inhibiting the spreading of SUDS components. All this information can be efficiently displayed by the ISWS.

Colin Green [Green, 2007] focuses also on this issue. Publications are not the only way to tackle institutional arrangements and mapping for the governance of urban water management. It can be displayed in the ISWS in a readable manner. The user navigates within the information and has not to consult the entire system; only the relevant nodes and information can be consulted. The governance thematic view is shown below:

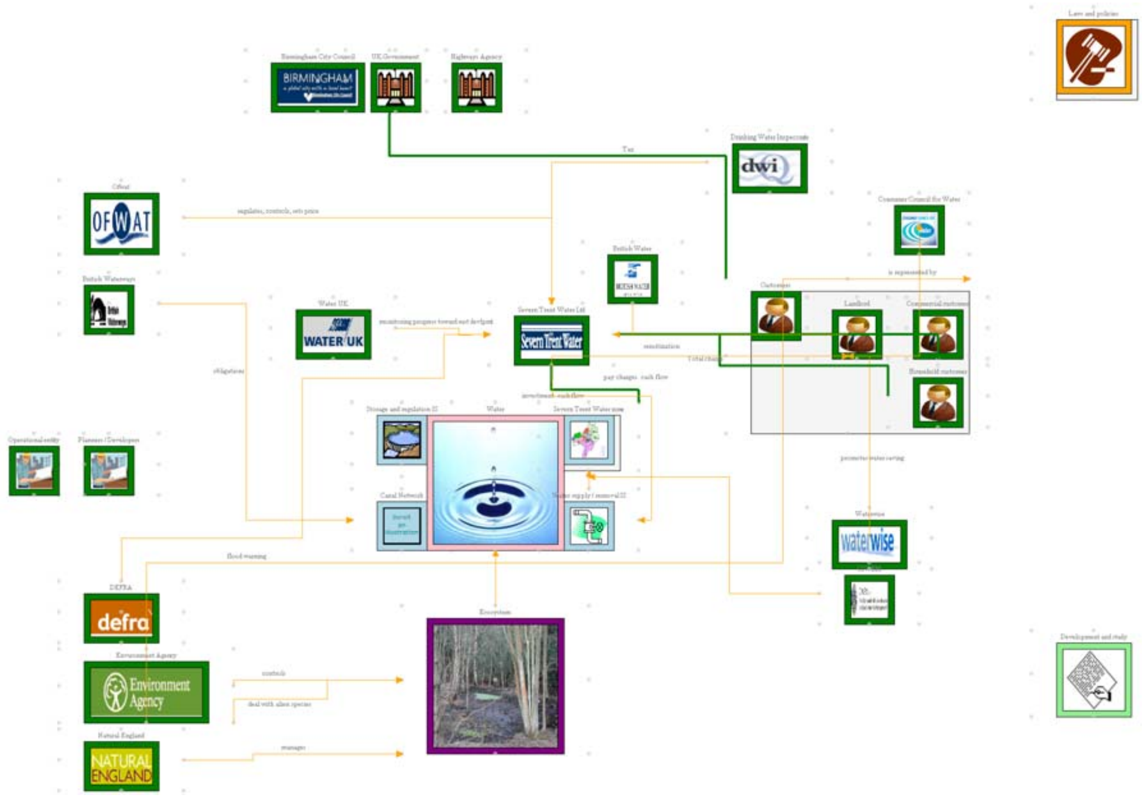

Figure 11. Governance thematic view. Laws and studies minimized.

5.4 Acceptance and use of the ISWS in Birmingham?

As proposed in chapter 2.3, the ISWS can be useful in order to improve the water management in Birmingham. But this hasn't yet been demonstrated. Find a potential user is difficult, mainly because of the institutional framework. It is also difficult to kindle people's interest with this new water management tool before having concrete results and consistent thematic views. The tool still has to be developed before to really know who would be interested to use it.

In case of an acceptance of the ISWS in Birmingham, there would be a need to manage the information system. The changing legislation and management framework would require to update the ISWS regularly, to refine it and to build other thematic views. Some work could be undertaken by MSc students. However, as the tool is designed to be used with a computer and not only as a paper support, future users would need to install the Oracle database (currently 1.5 GB) and the ISWS software (currently 12 MB). A long-term application of the ISWS would require somebody responsible, within each main organization, for the creation of thematic views and data-sharing.

In fact, the update of the ISWS would also require data-sharing and consultation between stakeholders. The current framework presents a lack of cooperation and consultation. There is no permanent centralized management board dealing with the different water-related domains' integration. Such a centralizing operational entity is missing. The Switch Learning Alliance could play this role in the future if it is carried on. The Defra pilot report on the

Upper River Rea [Defra, 2008a] talks about the creation of a Water Group which could be a centralizing entity.

A talk with Pr. Rae McKay and the author of the Defra report, Liam Foster (Hyder Consulting) focused on the acceptance of the ISWS in Birmingham. Liam Foster is involved in planning; he is interested in the ISWS's concept but admits that the current institutional framework doesn't lend itself to the use of the ISWS.

It has been decided to apply the ISWS to the Upper River Rea issue (see chapter 5.3.1). This case is a good example since the Making Space for Water programme is currently undertaken. The corresponding thematic view has to be validated by Liam Foster and other people involved in the Making Space for Water programme.

6 Conclusion

This MSc project aims to analyse the water management in the city of Birmingham, UK, and to provide a first draft of an information system on the water system (ISWS). This tool gathers stakeholders, water-related elements and infrastructures, ecosystems, developments, studies, laws and policies. The holistic view of the water system allows a wide data-centralization, so as to provide support along the decision-making process and to promote the integration of all the water-related domains.

The Birmingham water management system has been analysed; stakeholders, legislation, ecosystem, infrastructures and main issues have been identified and implemented into the ISWS. Meeting with key people and consultation of publications and reports led to a broad understanding of the water management. Thematic views, which gather a part of the water system implemented in the base diagram of the ISWS, have been shaped, in order to tackle specific issues. The thematic views available in annex 20 are: governance, Upper River Rea, groundwater and water flows thematic views.

Finally, the ISWS for Birmingham comprises about 700 nodes, 450 interactions, 650 numeric values, 150 text information and 130 document files. Any kind of water-related issue can be quickly embodied and shaped by using the base diagram of the ISWS.

By gathering a wide range of data on the main components of the water system and by providing a first draft of the information system for the city of Birmingham, the objectives of the MSc project have been achieved. However, an appraisal of the thematic views' usefulness still has to be undertaken by confronting them to key people involved in different organizations. It includes the local authorities, the Switch Learning Alliance, the Environment Agency, the planners and the private water company, Severn Trent Water.

7 Outlook

The Upper River Rea thematic view will have to be validated and presented to people involved in the Making Space for Water programme. The ISWS, with other thematic views, can be also presented to the Birmingham Learning Alliance, the EA, the Defra or the local authorities. The interest of the various stakeholders would be efficiently evaluated by presenting the ISWS and its thematic views during a Learning Alliance meeting, which gathers the main organizations involved in water management.

The main objective of the MSc project is the implementation of an ISWS for the city of Birmingham. The next step will be to bind up the ISWS with a GIS and an indicator viewer. It will lead to a water management tool, able to provide support along the decision-making process. The indicator viewer will allow consulting data-series, which are already implemented in the ISWS. The GIS will be bound up with the ISWS, in order to provide geographic information for components implemented in the ISWS. Combining the three modules will lead to the creation of the Combined Water Information System (CWIS), a tool for discussion and decision support in water management.

It was planned to apply some semi-quantitative values to the interactions. That would be useful to roughly assess cascading consequences of a given change in the water system, such as an improvement on a sewage treatment works. However, this functionality hasn't been yet developed.

The complex funding and charging arrangements for drainage system could be efficiently undertaken by a thematic view. All the interactions (responsibilities and charges) and nodes haven't been yet implemented. The current institutional framework isn't favourable to SUDS incorporation into drainage system (see [Defra, 2007c]).

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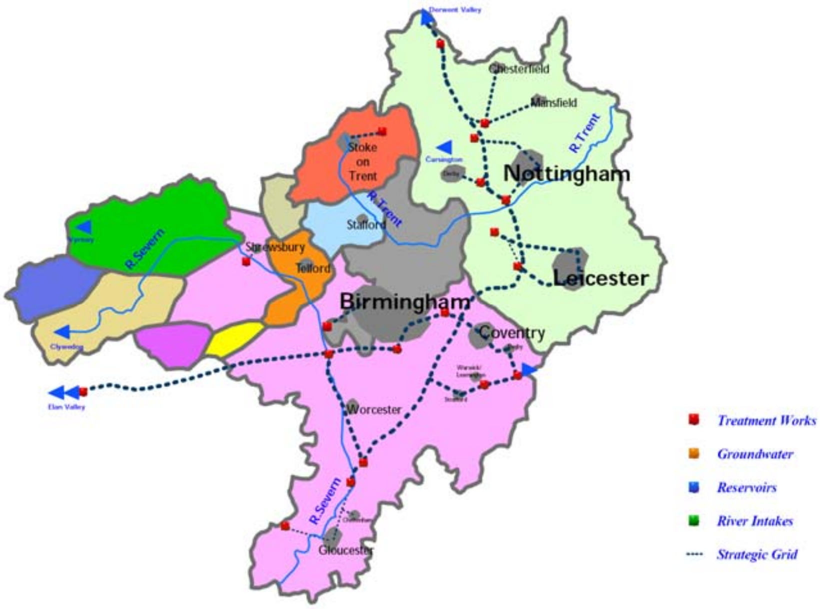
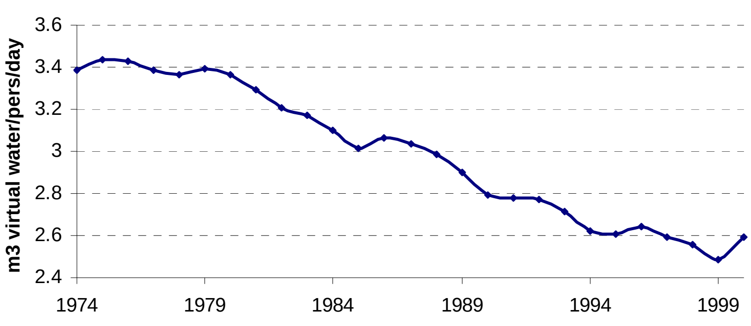
9. Annexes

9.1 Strategic system and Control Groups of Severn Trent Water in the West Midlands region



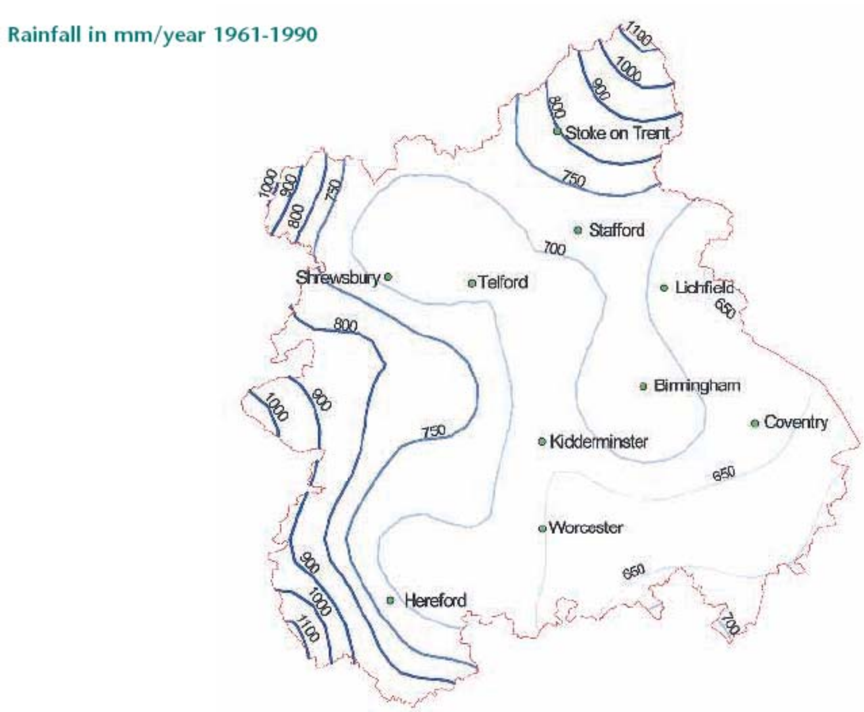
Source: [Severn Trent Water, 2007c]

9.2 Virtual water consumption through food only for an average person in the UK (Office for National Statistics and Waterwise datas).



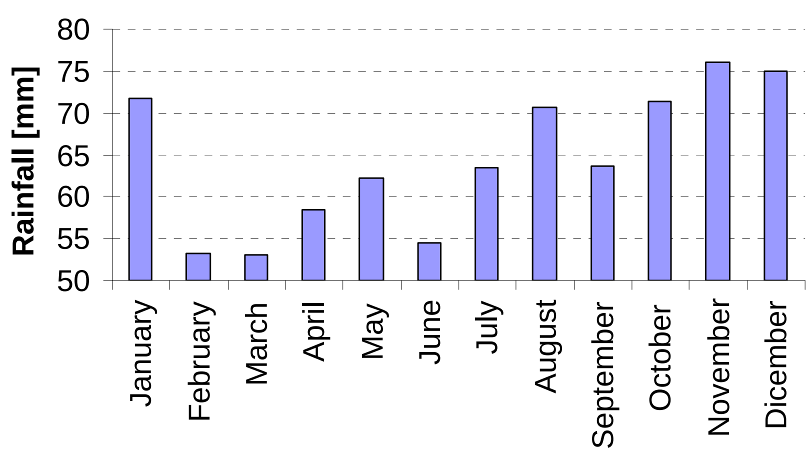
The total decrease is mainly due to milk and meat consumption decrease.

9.3 Average annual rainfall in the West Midlands Region



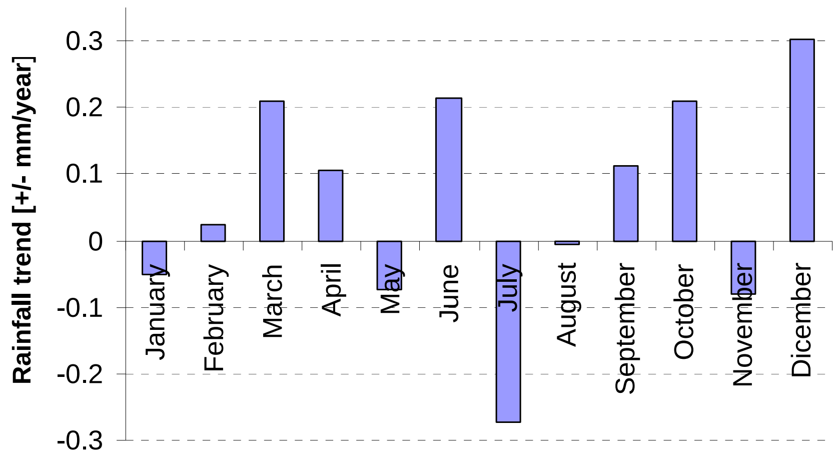
Source: [West Midlands Regional Observatory, 2001]

9.4 Average monthly rainfall during the 1920-2006 period. University rainfall gauge.



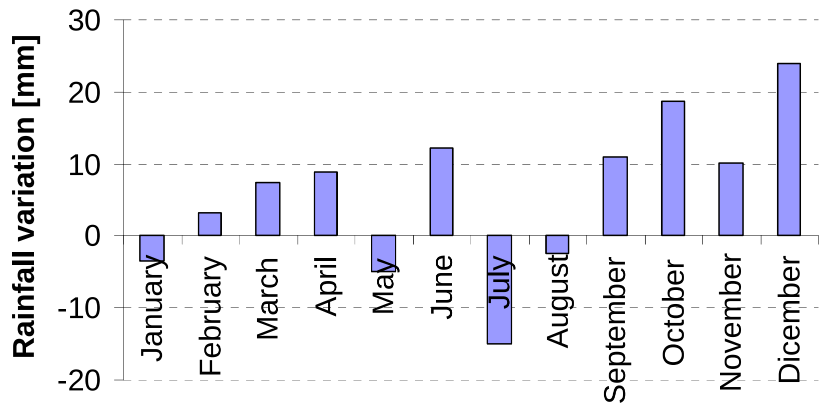
The main part of the annual precipitation occurs during winter months. It explains why the reservoirs are very important for the sustainability of the water supply.

9.5 Rainfall trend during the 1920-2006 period. Changes in ±mm/year for each month. University rainfall gauge.



The chart has been produced with the slope of the trends for each month.

9.6 Variation of monthly rainfall between the 15 years-long periods (1920-1934) and (1992-2006). Rain gauge of the University of Birmingham.



The annual average rainfall is increasing. Between the periods (1920-1934) and (1992-2006), the increase of annual rainfall is almost 70 mm (rain gauge of the University of Birmingham).

9.7 National and European legislation

National Legislation

Water Act 2003 (Water Industry Act 1991 and 1999)
www.opsi.gov.uk/acts/acts2003/20030037.htm
Water Resources Act 1991
http://www.opsi.gov.uk/acts/acts1991/Ukpga_19910057_en_1.htm
Water Industry Act 1991
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Water Supply (Water Fittings) Regulations 1999
www.opsi.gov.uk/si/si1999/19991148.htm
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http://www.opsi.gov.uk/RevisedStatutes/Acts/ukpga/1981/cukpga_19810069_en_1
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http://www.planningportal.gov.uk/uploads/br/BR_PDF_ADH_2002.pdf
Code for Sustainable Homes

http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf
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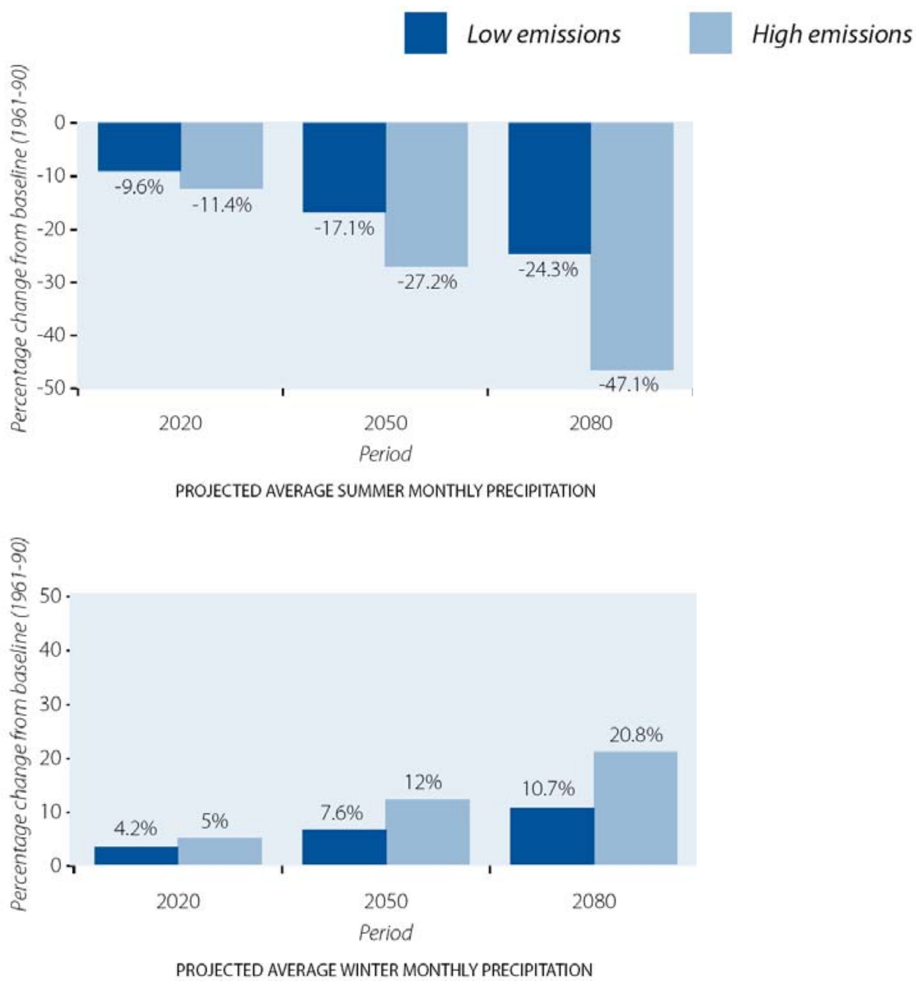
http://www.opsi.gov.uk/RevisedStatutes/Acts/ukpga/1949/cukpga_19490097_en_1
Town and Country Planning Act 1990
http://www.opsi.gov.uk/acts/acts1990/ukpga_19900008_en_1
Salmon and Freshwater Fisheries Act 1975
http://www.opsi.gov.uk/acts/acts1975/pdf/ukpga_19750051_en.pdf
The Fish Health Regulations 1997
http://www.opsi.gov.uk/si/si1997/19971881.htm
Groundwater Regulations 1998
http://www.opsi.gov.uk/si/si1998/19982746.htm

European Legislation

Water Framework Directive 2000/60/EC
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF
Drinking Water Directive (98/83/EC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF
Groundwater Directive (2006/118/EC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF
Bathing Water Directive (2006/7/EC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:064:0037:0051:EN:PDF
Urban Waste Water Treatment Directive (91/271/EEC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0271:EN:HTML
Nitrates Directive (91/676/EEC)
http://ec.europa.eu/environment/water/water-nitrates/directiv.html
Environmental Impact Assessment Directive (85/337/EEC)
http://ec.europa.eu/environment/eia/full-legal-text/85337.htm
Assessment of the effects of certain plans and programmes on the environment (2001/42/EC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:197:0030:0037:EN:PDF
Sewage Sludge Directive(86/278/EEC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31986L0278:EN:HTML
Freshwater Fish Directive (78/659/EEC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1978L0659:20030605:EN:PDF
Surface Water for the abstraction of drinking water Directive (75/440/EEC)
http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1975/L/01975L0440-19911223-en.pdf
Surface water sampling/analysis Directive (79/869/EEC)
http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1979/L/01979L0869-20030605-en.pdf
Habitats Directive (92/43/EEC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:HTML
Dangerous Substances Directives
http://ec.europa.eu/environment/water/water-dangersub/pdf/76_464.pdf
Lanfill Directive (1999/31/EC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0031:EN:HTML
Integrated Pollution Prevention Control Directive (96/61/EC)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0061:EN:HTML

9.8 UKCIP projected climate change scenarios for West Midlands Region



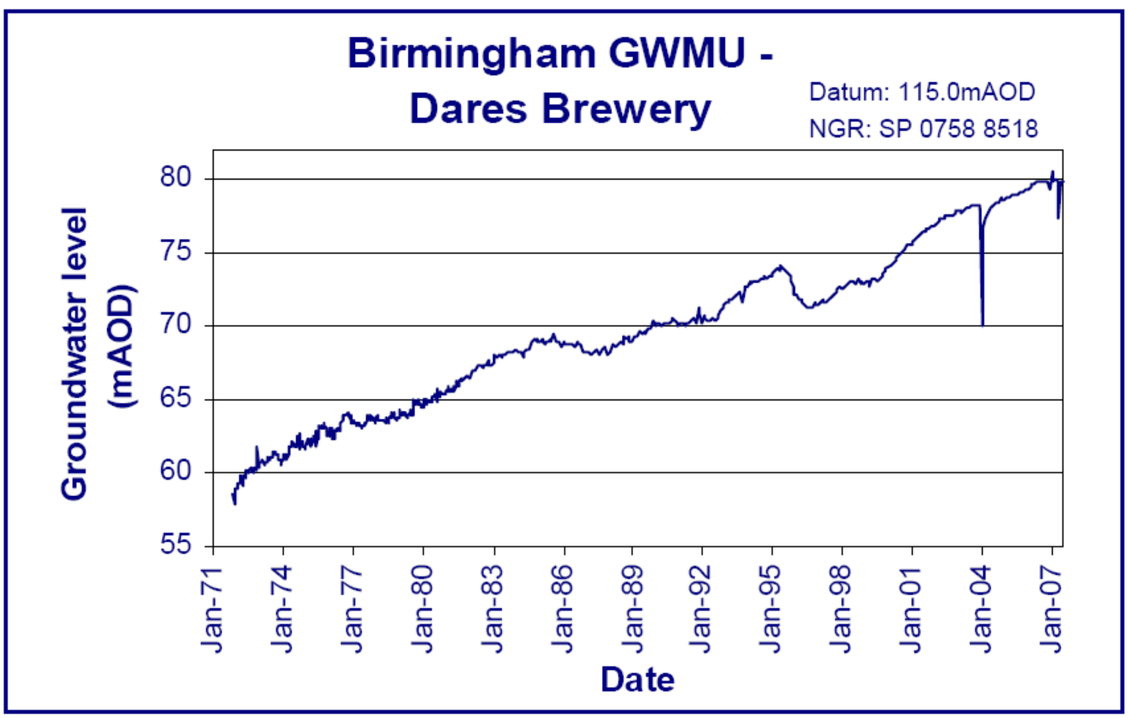
Source: [West Midlands Regional Observatory, 2007]

9.9 Setting price limits 2010-2015. Schedule

Setting price limits for 2010 - 2015	
October 2007 - January 2008	Ofwat consults on its approach to the 2009 price review
August 2008	Companies publish draft business investment plans and price proposals
September 2008 - January 2009	Joint research by companies, regulators and stakeholders into consumers' views on draft plans
April 2009	Companies publish final business plans and price proposals
July 2009	Ofwat publishes draft price limits for consultation
November 2009	Ofwat publishes final price limits
April 2010	2010-11 prices take effect

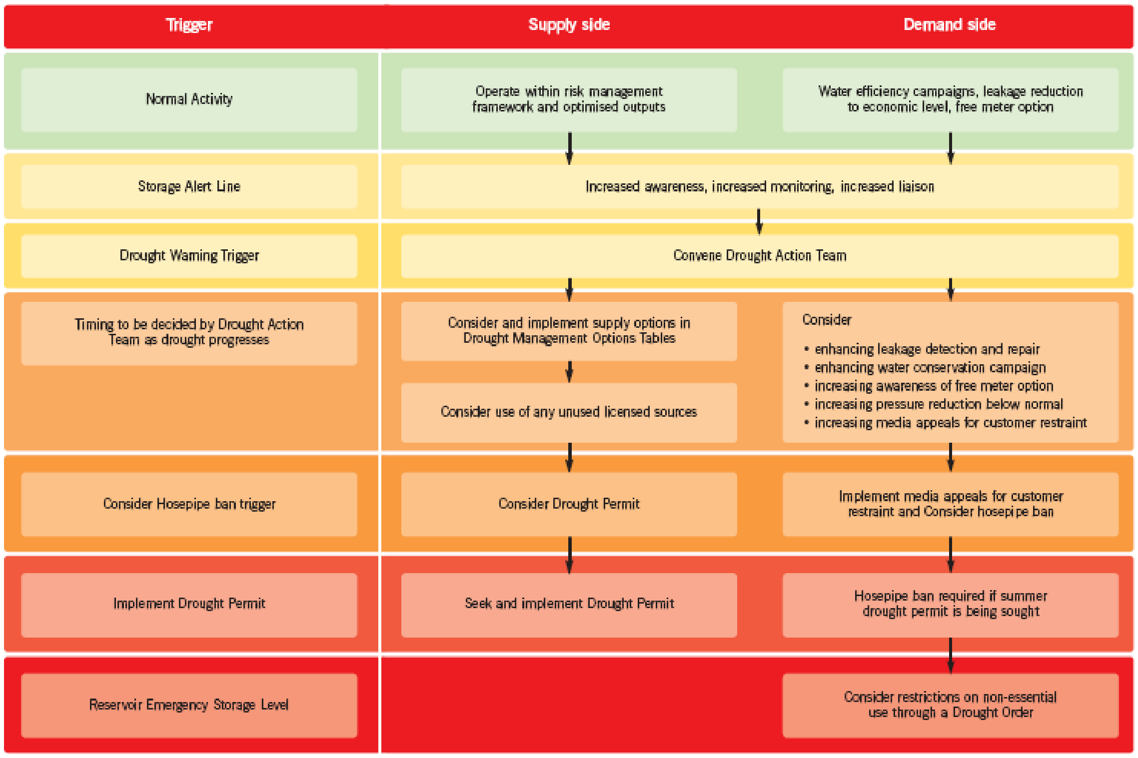
Source: [West Midlands Regional Observatory, 2007]

9.10 Raising groundwater



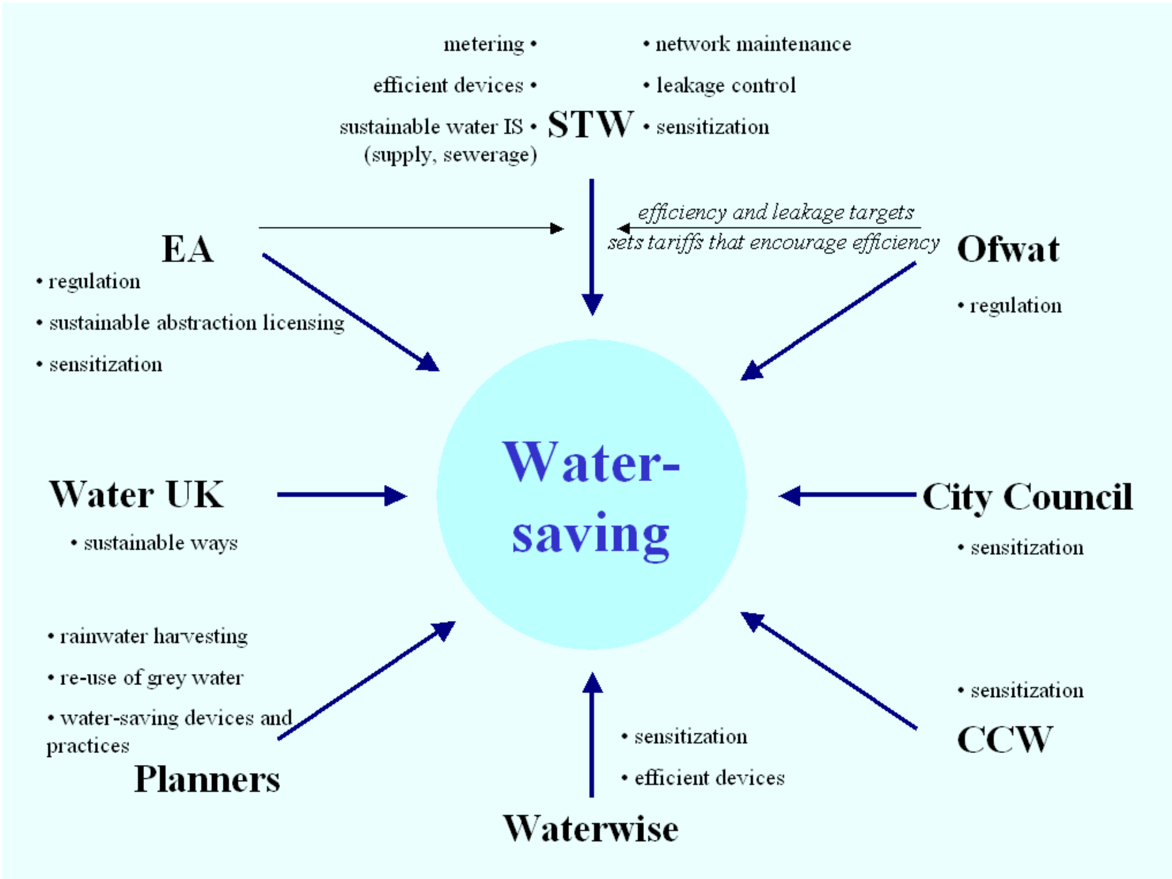
Source: [Environment Agency, 2008b]

9.11 Drought Triggers. Supply and demand sides actions

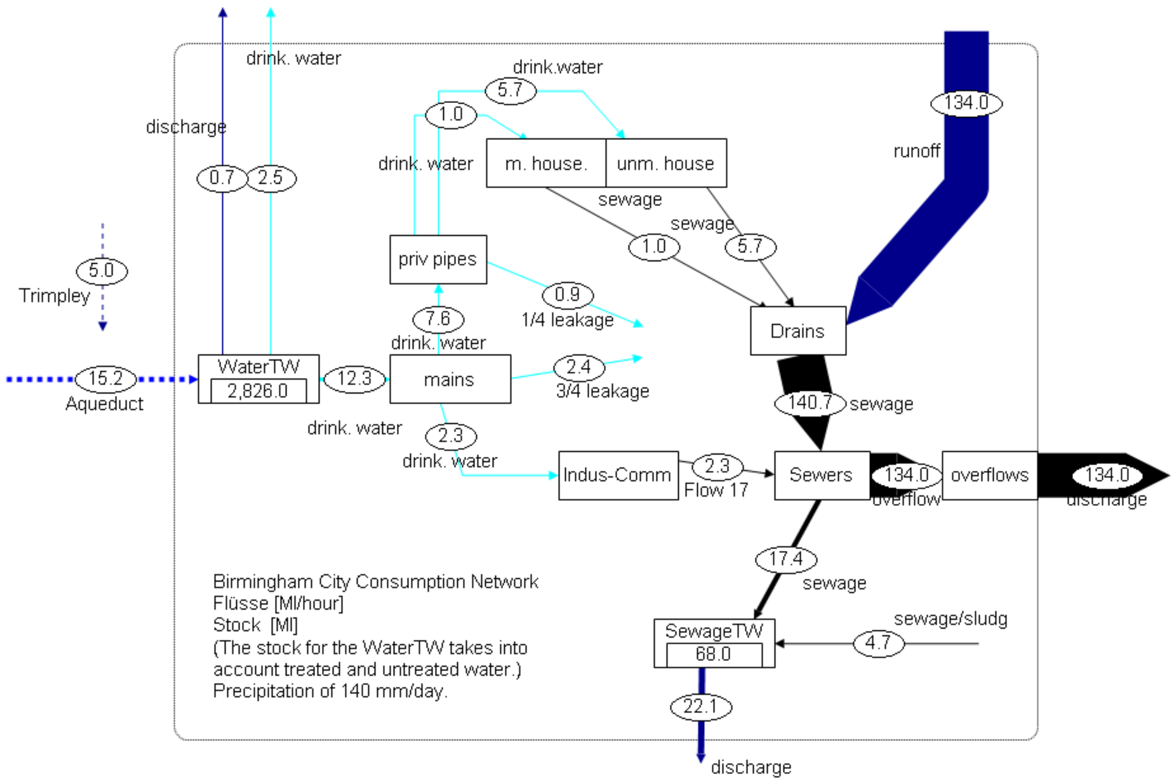


Source : [Severn Trent Water, 2006a]

9.12 Water-saving and efficiency framework



9.13 Birmingham City consumption network. STAN flow chart. Rainfall event



This chart has been shaped with the program STAN. The rainfall intensity has been set arbitrarily to about 6 mm/hour.

9.14 Drought management options. Company-wide Demand Side Options.

Table B.2 Drought Management Options – Company-wide Demand Side Options
These actions will be deployed in every Drought Zone as triggers are crossed

Option Name	Trigger	Demand saving	Implementation timetable	Permissions required	Risks	Risk to environment	Environmental impact	Studies undertaken	Monitoring requirements	Mitigation actions	Other impacts
Water efficiency campaign	Normal operation		Ongoing	None	None	None	None	Research started into scale of demand savings	Consumption monitoring to support research	None	None
Leakage reduction to economic level	Normal operation		Ongoing	None	None	None	None	None	None	None	None
Free meter option	Normal operation		Ongoing	None	None	None	None	None	None	None	None
Raise awareness in Company and EA	Storage alert line		Ongoing	None	None	None	None	None	None	None	None
Convene Drought Action Team and liaise with EA	Drought Warning Trigger			None	None	None	None	None	None	None	None
Staged pressure reduction below normal level	Drought Action Team	0 – 2%	7 days	None	Possible DG2 Complaints	None	None	None	None	None	None
Enhanced leakage detection and repair	Drought Action Team	0 – 2%	14 days	None	None	None	None	None	None	None	None
Enhanced water conservation campaigns	Drought Action Team	0 – 2%	7 days	None	None	None	None	None	None	None	None
High profile promotion of meter option	Drought Action Team	0 – 0.5%	7 days	None	None	None	None	None	None	None	None
Media appeals for customer restraint	Drought Action Team	0 – 2%	7 days	None	None	None	None	None	None	None	None
Consider hosepipe ban	Trigger Line	0 – 5%	7 days	7 day Public Notice	Reduced level of service	None	None	None	None	None	None
Consider non-essential use ban	Drought Action Team	Possibly 15%	28 days	Drought Order granted by Secretary of State	Impact on customer livelihood	None	None	None	None	None	None
Return to normal	Drought cessation line			None	None	None	None	None	None	None	None

Source : [Severn Trent Water, 2006a]

9.15 Drought management options. Demand Side Options for the Birmingham Drought Zone.

Table B.8 Birmingham Zone – Drought Management Options – Demand Side

Option Name	Trigger	Demand saving	Implementation timetable	Permissions required	Risks	Risk to environment	Environmental impact	Studies undertaken	Monitoring requirements	Mitigation actions	Other impacts
Minimise exports from Birmingham	Normal operation	Up to 20 Ml/d	Ongoing	None	None provided water available elsewhere	None	None	None	None	None	None

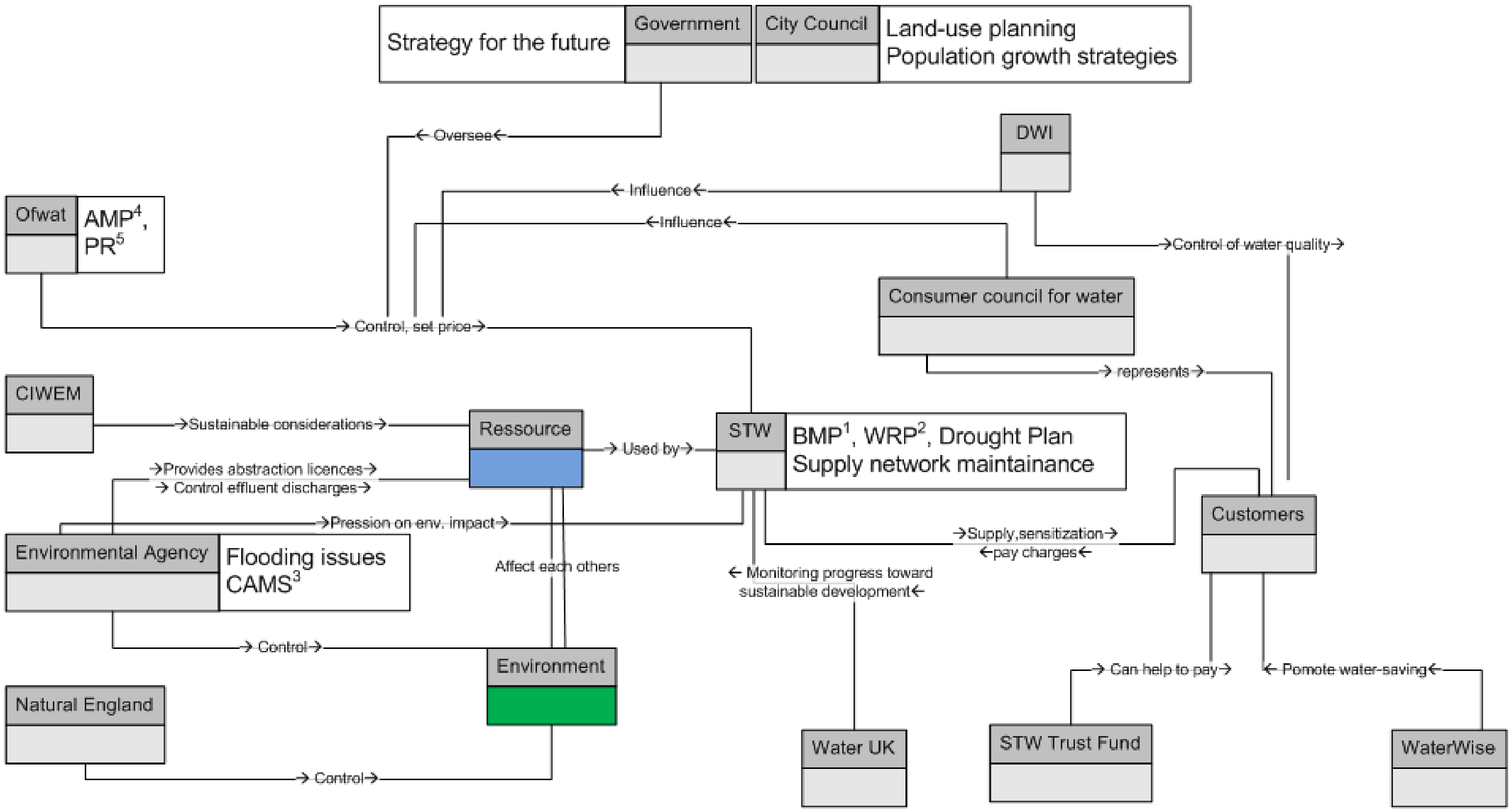
Source : [Severn Trent Water, 2006a]

9.16 Drought management options. Supply Side Options for the Birmingham Drought Zone.

Table B.9 Birmingham Drought Zone – Drought Management Options – Supply Side

Option Name	Trigger	Demand saving	Implementation timetable	Permissions required	Risks	Risk to environment	Environmental impact	Studies undertaken	Monitoring requirements	Mitigation actions	Other impacts
Operate system within normal operating parameters	Normal operation		Ongoing	None	None	None	None	None	None	None	None
Raise awareness in Company and with EA and liaise with Welsh Water over situation	Clywedog or Elan Res Storage Alert line		Ongoing	None	None	None	None	None	None	None	None
Convene Drought Action Team and liaise with the EA	Clywedog or Elan Res Drought Warning Trigger		1 day	None	None	None	None	None	None	None	None
Liaise with SSW over projected use of River Severn	Trimpley Control Curve		1 day	None	None	None	None	None	Normal	None	None
Consider use of Trimpley to support Frankley to maintain storage in Elan Valley Optimise use of Trimpley and Hampton Loade (SSW)	Trimpley Control Curve	Up to 120 Ml/d on Elan Valley system	1 day	Agreement with SSW	Abstraction licence limits. Quality of River Severn water	See Env Impact report	See Env Impact report	See Env Impact report	See Env Impact report	See Env Impact report	See Env Impact report
Consider import to Birmingham from Whitacre	Clywedog or Elan Res Drought Warning Trigger	Extra 20 Ml/d into Birmingham supply	1 day	None	High risk of major discolouration in supply to NE Birmingham	None	None	Birm'ham Security of Supply Scheme	Water quality in supply	Extensive mains flushing beforehand	
Review schedule of maintenance at major works	Drought Action Team		7 days	None	Plant failure if change is protracted	Low	None	None	None	None	None
Consider Norton and Beechtree Lane Emergency Boreholes Supply to Aqueduct	Drought Action Team	Up to 36 Ml/d extra to Aqueduct	7 days	None	Limited amount available on 5 year rolling licence	None	None	None	As stipulated in abstraction licence	None	None
Seek Drought Permits as required	Drought Permit Trigger	Increased abstraction to support to Frankley WTW from Severn	28 days	DP granted by EA	As Env Impact Assessment	s Env Impact Assessmnt	As Env Impact Assessmnt	As Env Impact Assessmnt	As Env Impact Assessmnt	As Env Impact Assessmnt	None
Return to normal operations	Drought Cessation Trigger		7 days	None	None	None	None	None	None	None	None

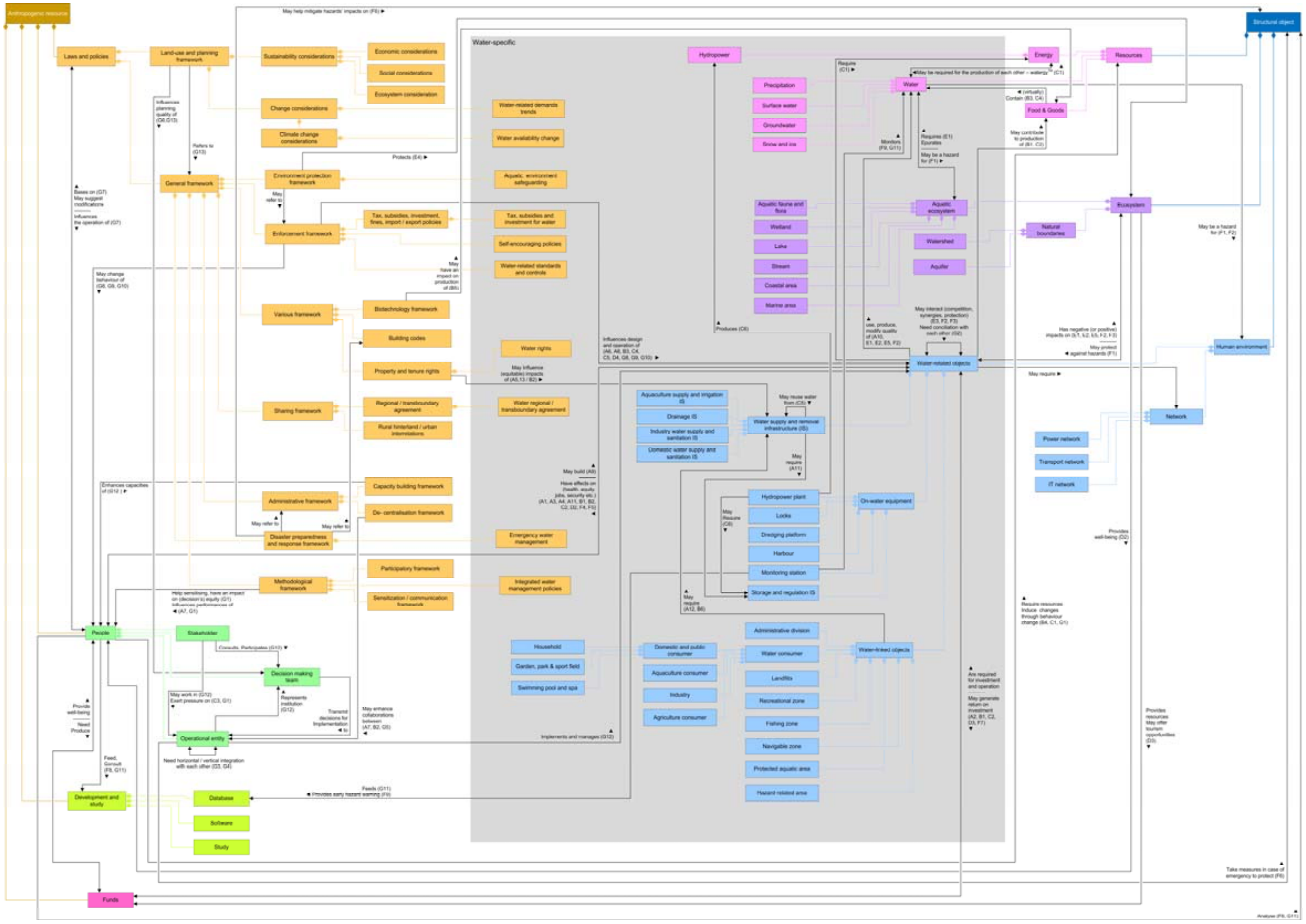
9.17 Main water stakeholders. City of Birmingham.



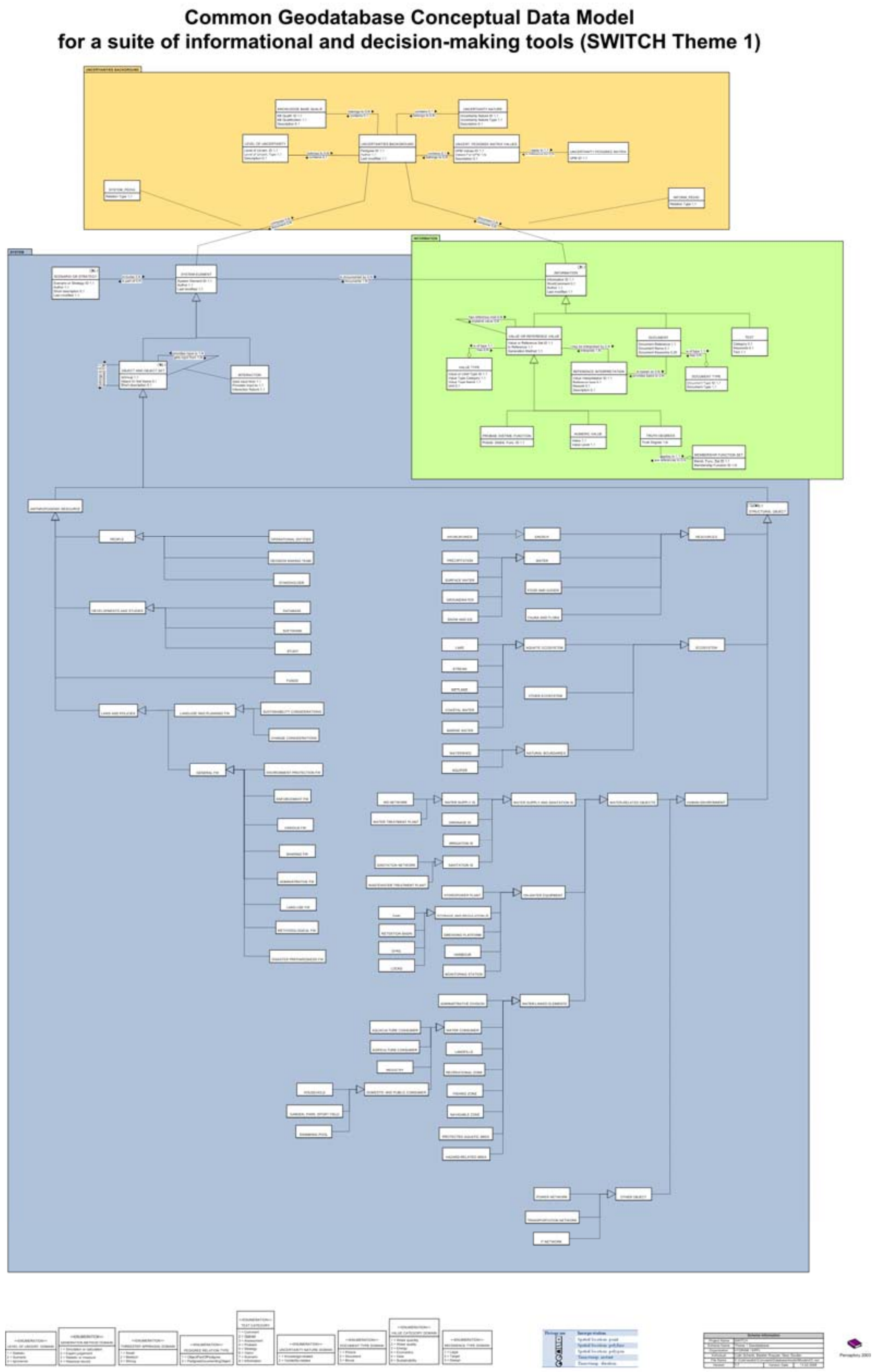
1. Business Management Plan
2. Water Resources Plan
3. Catchment Abstraction Management Strategy
4. Asset Management Plan
5. Price Review

This scheme has to be compared with the governance thematic view. It shows the displaying possibilities of the ISWS.

9.18 Water Management System Model



9.19 Hierarchical model



Colin Schenk, 2008.

9.20 Thematic views

A3 format.

9.21 Numeric values

Excel file

9.22 Stakeholders

Excel file

9.23 Legislation

Excel file

9.24 Flood contacts, responsibilities and links

Excel file

9.25 Water Flow Analysis

Excel file

9.26 Components of the system

Excel file

9.20 Thematic views