DECISION-SUPPORT SYSTEM
FOR
DOMESTIC WATER DEMAND FORECASTING AND MANAGEMENT

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ABSTRACT

A generic but flexible decision-support system for domestic water demand forecasting and management (DFMS) has been developed as part of a highly-integrated decision-support system for river-basin management. Its purpose is to provide water-resources planners with the facilities for estimating future water demand for any demand region and time period, having regard to the possibility of introducing demand-management measures. The system has the capability of predicting domestic-water demand by various methods according to the data availability, computing conservation effectiveness due to the implementation of various demand-management measures, forecasting the number of customers for different consumption units (person, household, water connection) and facilitating the development of demand-scenarios for eveluating various options. The system is designed in such a way that makes it easy to use for both novice and experienced users since it is driven by a menu system which relies on a mouse rather than the keyboard. Moreover, the communication between user and the system is by means of a user-friendly interface which makes extensive use of hypertext and colour graphics in presenting the results.

Briefly, DFMS comprises the following components:

- a GIS that stores, displays and analyses all geo-coded information such as satellite imagery, urban areas, cities and towns, etc.;

- a database which provides access to non-spatial data such as demand-area location and characteristics including top-level descriptors such as population, total demand, per-capita consumption, etc.;

- an expert system which uses the rule-based inference for data entry and predicting values (quantitative or qualitative) of variables from the knowledge-base;

- four methods of demand forecasting ranging from superficial to detailed, namely time extrapolation, econometric variables, end-uses variables and households classification;

- a multi-objective decision component which helps the user to determine the most appropriate forecasting method and conservation measures;

- a set of mathematical models to provide the analytical capability for quantifying descriptors, producing multiple outputs etc.;

- a user-interface with access to the various functional components of the system and the various help/explain files;

- a set of pre- and post-processors which support editing of the inputs data and the visualisation or analysis of model output, in addition to handling scenarios for each of the models or variables;

- a set of help files which are used to provide the user with the necessary assistance if for any reason, a more detailed explanation is required, based on a hypertext;

In order to demonstrate the system capability, DFMS has been applied to the Swindon demand area of Thames Water Utilities Ltd.

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LIST OF ABBREVIATIONS

Symbol	*Description*
ACA	*Advanced computer applications group at the International Institute for Applied Systems Analysis, Austria*
ACORN	*A classification of residential neighbourhoods database*
AI	*Artificial intelligence*
AQUATOOL	*Decision-support system for water-resources management*
ARC/INFO	*GIS commercial software*
ARIMA	*Auto-regressive integrated moving average time-series model*
BREEAM	*Building Research Establishment*
CONFIG	*Configuration file*
CP	*Conventional programming*
CROPWAT	*Crop water-requirement model*
DBMS	*Data base management system*
DFMS	*Decision system for demand forecasting and management*
DP	*Data processing*
DSS	*Decision-support system*
ERDAS	*GIS commercial software*
ES	*Expert system*
GIS	*Geographic information system*
GRASS	*GIS commercial software*
IDD	*Identification number*
IRP	*Integrated resource planning*
IWR-MAIN	*Integrated water-resources main system*
MIS	*Management information system*
SQL	*Structured query language for development of database management systems*

Symbol	*Description*
TERRA	*Decision-support system for water-resources management*
TWUL	*Thames Water Utility Limited*
WaterWare	*Decision- support system for water resources planning*
WRM	*Water-resources model*

INTRODUCTION

1.1 - Planning perspectives

Water-resources planning can be defined as the orderly consideration of water management schemes from the original statement of purpose, through the evaluation of alternatives, to final decision on a course of action *(Linsley and Franzini, 1979).* It involves identification of future water-use requirements, supply sources and the possibilities for bringing these into balance, in terms of criteria that reflect economic, social, environmental, institutional and political feasibility. The planning process itself is an exercise which should be undertaken in conjunction with all other water-related activities. Furthermore, rather than being a one-off, set-piece exercise, it is a process which should be repeated periodically to ensure the assumptions made are still valid. If this approach is adopted, it is more likely to be compatible with the general objectives of water-resources planning, defined by the *United Nations (1987)* as the rational selection of water polices, programmes and projects that will help to achieve the social and economic goals of the nation. To that end, the planning process seeks to achieve a balance between the general goals, as expressed in national and water-sector plans, and the aims defined by the needs of implementing agencies or user categories. Therefore, it is important that the planning agency in general and water utility in particular take into account all the competing interests when defining the over-all goals and evaluating options, subjects to given time and budgetary constraints.

1.1.1 - Integrated planning

Integrated resources planning (IRP), which is increasingly being used by the water industry, represents a change of philosophy in decision-making. A conceptual planning approach, IRP was developed during the mid-1980s by the electricity and natural gas utilities. Unlike the traditional forms of planning which were largely undertaken in isolation, IRP involves extensive public participation *(PMCL,* *1994)*. Therefore, a planning exercise can be viewed as a general decision-making process for choosing the 'best' course of action, based on competing goals and estimated future impacts. Although IRP still encompasses the notion of least-cost, both monetary and environmental, it also includes an open and participatory decision-making process which integrates many institutions, policies, and plans that affect water resources. As a result, the plan which emerges is likely to be more broadly acceptable with in-built flexibility which allows the possibility of future modification according to changes in political, economical, technical and environmental circumstances.

In the particular case of water resources, the concept of IRP has been expanded to include all aspects of river-basin management such as water supply, land drainage, effluent disposal, hydro-power generation etc. in a unified manner rather than considering each separately. While resource utilisation remains small, interactions between these different interests are largely absorbed by the natural buffering within the physical system. However, as demands increase, it soon becomes necessary to co-ordinate activities. Eventually, there comes time when, to realise the full potential, the only sensible way of proceeding is to consider the whole basin as one complex integrated system *(Jamieson and Fedra, 1996)*. This concept of integrated river-basin management has been recognised by practitioners since the early 1970s. More recently, it was endorsed by the United Nations in the so-called Dublin Statement *(United Nations, 1992)*.

1.1.2 - Demand forecasting

Closely allied to planning is forecasting which is the methodology of looking to the future whereas planning is the strategy of coping with it *(Viessman and Welty, 1985)*. For water-resources planning, demand forecasting can be considered at two distinct levels:

1 - at a strategic-planning level, long-term forecasts are required for future demands so that resources can be developed in good time to meet the projected needs;

2 - for operational planning, short-term forecasts are required for the scheduling and allocation of resources to the various demand centres.

Reliable and accurate forecast cannot be achieved without including many variables that affect the consumption of water, including any measures taken to influence customer's habits. However, the more the number of variables included in water-demand forecasting, the more complicated are the methods required. Fortunately, in recent years, there have been a marked improvement in the techniques available for demand forecasting as a result of the increased use of computerised systems.

1.1.3 - Decision-support systems

Although the principle of integrated-river basin management has been aspired to in many countries, more often than not problems are considered in a piecemeal fashion. In part, this was due to the lack of analytical tools with the capability of dealing with multi-facet problems. Hitherto, the mathematical models available have been restricted to just one facet of river-basin management such as resources assessment, river-water quality or environmental assessment whereas in reality, problems tend to be a combination of many different aspects. Even then, these techniques have tended to be restricted to predicting what might happen given various planning assumptions, leaving the manager to interpret the output and decide what to do. Therefore, the idea of developing a generic decision-support system (DSS) for water-resources planning and management is becoming increasingly attractive to many planning agencies. Besides the obvious advantages of assisting management in making rational choices, the benefits of using DSS include:

- making mathematical modelling more accessible to users;

- enabling rational use of the analytical facilities without the necessity of an in-depth knowledge of modelling techniques;

- enhancing user-experience by reference to domain knowledge from elsewhere;

- providing an integrated framework in which models can interact with each other, rather than having a series of separate models which are frequently incompatible;

- maintaining upgrade paths for the incorporation of new or improved knowledge;

- facilitating public accountability in the way decisions are reached;

- etc.

1.2 - Purpose of research study

Bearing in mind that the available demand forecasting systems at present still rely on the traditional engineering approach, they lack flexibility in dealing with data requirements, are not generic, and do not use advanced computing facilities such as expert systems, Geographic Information Systems (GIS), etc. This research study aims to:

- to develop a generic and flexible decision-support system for forecasting domestic water demand including demand management as part of a highly-integrated decision-support system for river-basin management;

- to incorporate some of the advanced computing facilities including GIS, and an expert system, coupled with a set of prediction models for forecasting domestic demand using various methods within a single computer program.

- to exploit the capabilities of an expert system including data entry, results deduction and trace back, models interaction etc.

- to demonstrate the system functionality and capability using the data of one of the demand zones (Swindon zone) supplied by Thames Water Utility.

In general, the proposed system has the following characteristics:

- the potential for future inclusion in a highly-integrated system for water-resources planning;

- incorporates a variety of different forecasting approaches ranging from superficial to detailed, since the availability of data varies from country to country;

- combines both the classical computing techniques represented by prediction models with the emerging computing technologies such as database management, GIS, expert systems, graphic user-interface and hypertext facilities in one coherent program;

- includes an expert system to assist with evaluating the various options, drawing conclusions and recommending on appropriate actions, enabling planners to make informed choices from the broad array of alternatives;

- assists in developing various scenarios for future demands and conducting an extensive analysis of existing and projected demands at the end-use level;

- incorporates a multi-objective decision component to assist with the selection of the most appropriate forecasting methodology and conservation measures based on various criteria which reflect planner's needs;

- easy to use for both the novice and experienced manager since it is a driven by menu system which relies on a mouse rather than the keyboard;

- user-friendly since the communication between user and the system is by means of a user-interface which makes extensive use of hypertext (if for any reason and at any stage of analysis a more detailed explanation is required, the user is able to access hypertext files which act as an on-line user-guide).

1.2.1 - Scope of research study

This research study is divided into the following chapters:

Chapter two contains a literature review of the basic methodologies used in forecasting water demand and the role of demand management, particularly for domestic water use. Moreover, it provides the definitions of terms such as water demand, water uses, water requirements, demand forecast, demand management and other related terms. In addition, an explanation is given of water demand levels, categories and variables as an important introduction to the understanding of forecasting methodologies. With regard to forecasting methods, the various methodologies which have been used in the past are described and a comparison made between them based on an evaluation of each methodology and the circumstances in which it can be used. The chapter also describes the uncertainty and how that can be minimised in forecasting water demand. The various data types which are necessary in forecasting water demand and the different conservation measures, including their potential in reducing water consumption, are included as well. Finally, the case is made for an improved (computerised) system for demand forecasting.

Chapter three is dedicated to a review of decision-support systems in general and expert systems in particular. Additionally, it describes the traditional engineering approaches as well as the emerging systems and shows how a combination of both is more robust in solving many problems related to water-resources planning including demand forecasting.

Chapter four concentrates on the structure of the decision-support system which has been developed for water-demand forecasting and management (DFMS), as part of the WaterWare system for river-basin planning. This includes: (a) a description of WaterWare; (b) WaterWare's structure and various modules; (c) specifications of software and hardware; (d) DFMS's structure and various components (database, expert system, mathematical models, GIS, hypertext files and user interface).

Chapter five describes in detail both the forecasting procedures for domestic water demand, including prediction models and demand management, before indicating how the expert system is used in this process. Moreover, it shows the various types and formats of data required by the system.

Chapter six demonstrates the application of DFMS in the Swindon area of Wiltshire, using various forecasting methods and conservation measures. Furthermore, it highlights some of the system capability through real examples such as creating demand scenarios based on re-deduction trials, tracing knowledge through the browser facility, helping the user with the hypertext files. Moreover, it describes the system verification and evaluation including the possibility of updating the knowledge-base and data limitations.

Finally, chapter seven summarises the main outcome of this study and suggests some new ideas for complementary work to further what has been accomplished to date.

DEMAND FORECASTING AND MANAGEMENT BACKGROUND

2.1 - Introduction

Water-demand forecasts are required for a wide variety of planning studies, frequently by different water-service companies and other water-planning agencies. During the past 30 years, considerable effort has been spent on the improvement of water-demand forecasting methodologies. The main attention has been focused on disaggregation of demand into different sectors, improving forecasting methods, reducing forecasting uncertainty, integration of demand-management effects and realising the benefits of computer technology.

Notwithstanding the move towards disaggregated forecasting, the most commonly employed technique for demand forecasting at the present time relies on an aggregate description of water use in which the forecast depends on a single coefficient (usually amount of water per capita) whose value may or may not be permitted to change during the forecast period. Aggregate forecasts are insensitive to changing sectoral patterns in developing communities, as in the case of differential growth rates for multi-unit and single-unit housing. Moreover, specific water-conservation measures, which selectively alter water use within each sector, are impossible to consider in absence of sectoral disaggregation, since most variables known to affect water use are omitted (such as price, income, family size, weather conditions, levels of commercial and industrial activity, etc.). Furthermore, aggregate forecasts are insensitive to any change in past relationships that may have existed between these variables.

The literature is full of applications on demand forecasting and demand management, but little is available on integrated systems for demand forecasting and management which covers both aspects. In this chapter, the focus will be on the theoretical background of water-demand forecasting methodologies, integration of demand management and how these methodologies can be improved in the future. However, before discussing any new improvements in this respect, it is necessary to define demand forecasting, demand management, and other related terms.

2.2 - Definition of demand-related terms

This section deals with the definition of three basic terms: 'water demand', 'water-demand management', and 'water-demand forecasting'. The term 'water demand', is usually taken to mean the amount of water required for various uses, such as domestic, industrial, agricultural, etc., at a certain time in a specified area, whereas the phrase 'water-demand management' refers to the various methods by which water demand may be limited. The later is primarily aimed at persuading or compelling customers to lower overall consumption by restricting particular uses and requiring water companies to improve control thereby reducing leakage from water-supply system. Water-demand forecasting is the methodology used to predict future water needs.

Hank and Boland, (1971) defined demand as a general concept used by economists to denote the willingness of consumers or users to purchase goods, services, or inputs to production processes, since that willingness varies with the price of items purchased and other factors. The term 'requirement' is something that does not obey the willingness variability with prices since no matter what the price, the same quantity is purchased. However, in the water industry, the terms 'demand' and 'requirements' are frequently regarded as interchangeable *(Hank and Boland, 1971).*

The concept of water-demand management concept was first introduced by the US Congress' senate committee on national water resources *(USSC, 1960).* With the emphasis on water-demand management rather than on supply, it is possible to improve the position of communities by better use of the available resources.

There are several means by which the demand-management goal can be achieved, such as (1) use of conservation technology (including water-saving devices, pressure control in the distribution system, recycling, etc.), (2) pricing policy (flat-rate, rising-block, falling-block, seasonal-rate, peak-rate tariffs, etc.), (3) raising public awareness of water-conservation measures through educational programmes, media campaigns, etc., (4) introduction of water-use regulations and restrictions, etc.

Grima, (1972) defined water-demand forecasting as a matter of educated guess-work based on a study of local conditions and past experience. *Boland, (1985)* has a different definition since "a forecast is statement about the future". The most general term for such statements is "prediction," but not all predictions are forecasts. A forecast is usually taken to be a conditional prediction or a statement about what is expected to happen if various assumptions turn out to be valid. Projection is a type of forecast that relies on a set of assumptions which include continuation of at least some past trends and/or relationships. Some forecasts based on assumptions which consist entirely of continuation of past trends are usually termed "extrapolations".

Bolands adds that forecasting, though subjective, has substantial objective content: it is an art based on science. This can be demonstrated by dividing the process of forecasting into two stages: explanation and prediction. Explanation occurs when forecasters study past experience (facts) in order to understand, for example historic water-use patterns, behaviours and the factors that caused those patterns. The knowledge obtained by studying the past can be used to determine appropriate assumptions and relationships for the future, assuming that what happened in the past may continue in the future.

Jones et al., (1984) defined water-use forecasts as a conditional prediction of the required amount of water at some future time. In practice, most forecasts are projections (relying at least to some degree, on continuation of past trends) and some are extrapolation (based wholly on past trends). However, 'forecasts', 'projection', 'prediction', and 'extrapolation' are commonly used within the water industry to mean the same thing.

Dziegielewski and Boland, (1981) summarised more than 80 references on water-demand forecasting, most of which were in the United States. These studies covered the experience of different states or cities in demand forecasting for different water-use sectors (municipal, industrial, and agricultural) based on actual data collected from different locations and analysed by different methodologies.

2.3 - Water demand sectors

As mentioned previously, much of the research effort has been spent on the improvement of demand forecasting through the disaggregation of water demand into various sectors prior to summing the various components. The main purpose behind this component-based approach is to allow each individual water-use sector to be described in terms of its own explanatory variables which vary from one sector to another (i.e. homogenous categories rather than mixed ones). Thus industrial water-demand can be described in terms of industrial output whilst domestic water-demand is a function of population. Similarly, agricultural water-demand is primarily a function of crop produce.

This component-based approach of forecasting provides a detailed understanding of each sector's water requirements which enables measures for controlling demand to be introduced. The level of disaggregation is usually designed to accommodate the evaluation of various measures to improve efficiency by targeting specific end-uses. Increasing the degree of disaggregation normally has the effect of improving the accuracy and reliability of the forecasts, providing the relationships can be established and the data are available.

The literature contains different categorisations for the various water sectors. *Towrt, (1976)* proposed the following water-use classification;

- water for domestic purposes, including households uses, car washing, gardening as well as wasteful use and leakage.

- water for commercial / industrial / agricultural uses, such as shops, offices, industries, institutional, irrigation and horticultural use.

- unaccounted-for water, such as illegal connections, leakage from the distribution system, overflow and meter errors.

Lauria and Chaing, (1975) proposed another water-uses classification based on purposes of use. Such purposes include irrigation, cooling, commercial uses, domestic uses, street washing and fire fighting. However, the classification of water uses varies from country to country, the most commonly-used classification being:

- Municipal water uses,
- Industrial water uses,
- Agricultural water uses.

2.3.1 - Municipal water uses

Municipal water is that provided by the public water-supply system. Municipal water is considered to be the most important use since it meets the daily needs of the population which require the highest quality and therefore, the most investment. Municipal water can be disaggregated into smaller sub-classes according to purpose of uses. The most common ones are: domestic, commercial, and unaccounted-for water.

Domestic uses which are sometimes referred to as residential uses comprise those amounts of water consumed by household activities, either indoor such as toilet-flushing, dishwashing, laundering, bathing, etc., or outdoor such as lawn watering, car washing, etc.

Commercial uses which are some times referred to as public uses comprise the water needs of businesses, both public and private, such as hotels, shops, banks, schools, hospitals, government offices, etc. It is also common to include light industry and workshops which do not require process water.

Unaccounted-for water in simple terms can be defined as the difference between amounts of water put into supply and amounts billed. It includes losses due to leakage from supply system, illegal connections and meter errors.

2.3.2 - Industrial-water uses

Industrial water is mainly that required for major industries which consume large amounts of water basically in the manufacturing process, such as cooling, steam production, washing, conveying and waste removal. In addition to manufacturing processes, industrial water also includes other on-site requirements such as employees hygiene, air conditioning, etc. Some obvious examples of such industries include iron and steel, mining, cement manufacturing, electricity generation, etc.

2.3.3 - Agricultural-water uses

Agricultural water uses comprise the requirements for crop irrigation and livestock rearing. Irrigation is generally requires the most water in catering for crop needs, soil leaching and conveyance losses which in some countries, can account for up to 80 percent of the total water demand.

2.4 - Domestic water demand

Having regard to the importance of domestic water demand, the following sections concentrate solely on domestic water in terms of demand determinants, forecasting methods, forecasting accuracy, data requirements and demand management.

2.4 .1- Water-demand determinants

Domestic-water demand can be characterised by various explanatory variables. An explanatory variable is one which has been observed to account in whole or part, for past variations in water use. These can be used to assist in explaining variations in future water use. The most frequently used explanatory variables can be grouped under the following headings: spatial, temporal, socio-economic, institutional, technological and climatic.

2.4.2 - Spatial variables

Obviously, domestic demand has to be referenced to a spatial unit. Spatial units can be part of either an administrative or hydrologic classification. Administrative levels normally have the following tiers, namely country, region, city, zone neighbourhood, property, household and person as shown in Figure (2.1). The hydrologic classification differs inasmuch that the river basin is substituted for region but otherwise is similar to the administrative.

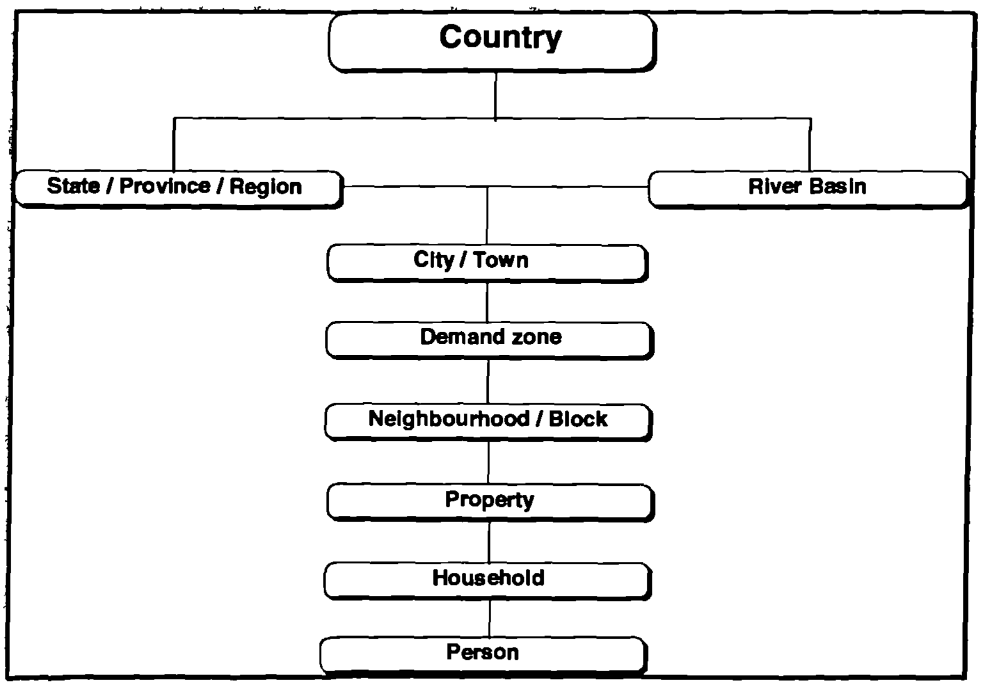

Figure (2.1) - Domestic demand spatial levels

As far as spatial variables are concerned, the most important at any level belong to the demographic aspects, basically households and population. Accordingly, domestic water demand is usually linked to one of the two smallest reference units (household or person). In this way, demographic change concerning population or households has an immediate impact on domestic demand. Sometimes households or population, depending on which is used, is called the driver variable of domestic water.

2.4.3 - Temporal variables

Another important determinant of domestic demand is the time period. Domestic demand can encompass different time periods, which can be either short-term, or long-term.

Short term is usually taken to mean a period of less than one year. The most commonly-used short-term periods are season (summer or winter), month, week, day and hour. Accordingly, domestic demand becomes more specific when referenced to one of these periods, since the types of variables differ according to the time period. For example, average summer demand includes variables which do not exist in winter demand: Similarly the variables which affect maximum daily demand are different from those affecting peak hourly demand, etc.

Long term is defined as durations in excess of a year. Typically, planning horizons ranges from 20 to 30 years ahead with time-increments of 5 years. The purpose of having intermediate values is to determine how demand is increasing within the planning period in order to ensure adequate resources are available when needed. However, even annual values are usually expressed in terms of average daily demand.

2.4.4 - Socio-economic variables

Social and economical characteristics play an important role in determining domestic water demand. For example, water-use behaviour is a reflection of social classes and the extent of water-use awareness. Moreover, personal income and water price are other key factors in this area. In general, social factors include education level, profession, family size, family composition, etc., whereas economical factors comprise standard of living, family income, appliance ownership, etc.

2.4.5 - Institutional variables

Institutional or administrative variables mainly relate to the policies adopted by the government or water companies in respect to water supply and demand. Examples of institutional variables include method of charging (metered or unmetered), tariff structure, water-conservation measures imposed, water-use regulations, etc.

2.4.6 - Technological variables

Technological variables basically affect household plumbing fixtures and appliances, including conservation devices such as low-flush toilets, low-flow shower-heads, water-efficient dishwashers and washing machines, etc. In general, the combination of stricter water-use regulations and the growing awareness of the need to conserve should encourage manufacturers to produce more water-efficient household appliances, adopting new technology where appropriate.

2.4.7 - Climatic variables

Climatic conditions will to some extent affect indoor use such as frequency of showering for instance. However, the main impact will be on the outdoor water-use relating to the garden, particularly lawn watering. Moreover, the higher temperature associated with climatic change may lead to an increase in the number of outdoor swimming pools.

2.5 - Water demand forecasting

Forecasts of future water requirements are linked to the values of these water-use determinants. The latter may be projected by a number of methods, depending on data and other available information. *Gardiner and Herrington, (1986)* defined forecasting methods as the procedures and conventions were used to analyse past water use (explanation) and to apply the resulting knowledge to the future. In other words, water-demand forecasting methods translate projected values of one or more of these explanatory variables such as population, income, water price, etc. into estimates of future water requirements. Available forecasting methods make various assumptions regarding the number and type of the explanatory variables, the nature of the relationship with water use and the way in which that relationship may change over time.

A number of the forecasting methods developed are based on an analytical or mathematical view of the problem. Some of these algorithms have been shown to be effective in modelling the regular cyclic variations observed in typical water demand time-series data. However, if this cyclic pattern is disrupted by an abnormal demand event or any change in prevailing conditions, a purely mathematical approach will fail to model this deviation accurately. Others have proposed a short-term demand-forecasting method that uses a purely heuristic approach *(Rahman and Bhagnagar, 1988).* Subsequently, some researchers have attempted to integrate both mathematical and heuristic approaches for short-term water-demand forecasts *(Hartley and Powell, 1991).*

Generally, existing forecasting methods rely for the most part, on the notion of aggregate water use, which express domestic water demand as the product of the population and the per-capita consumption (usually in litres per day). This relationship is projected into the future, using expected future population and extrapolated values of the per-capita consumption. Since water usage is aggregated, these forecasts are insensitive to differing community structures or water-use patterns. Accordingly, the results of an aggregate forecast are not particularly useful for many planning tasks (such as the consideration of water-conservation measures which selectively alter water use) as most variables known to affect water use are omitted, including price, income, appliance ownership, etc.

Moreover, these forecasts are insensitive to any changes in past relationships that may exist amongst these variables. In particular, the sensitivity of future water use to alternative assumptions regarding future economic and demographic change cannot be determined.

Inclusion of additional explanatory variables creates the need to forecast future values of those variables, increasing data requirements in areas where data may not be readily available. In selecting the most appropriate forecasting technique for a particular application, it is necessary to not only consider the planning needs but also balance the benefits arising from adopting a more sophisticated technique against the cost of data acquisition and analysis.

In order to understand forecasting methods properly, it is necessary to investigate some other related issues such as methods classification and evaluation criteria.

2.5.1 - Methods classification

The principles and techniques of forecasting water demand are described in general terms in several works such as *Encel et al. (1976), Ascher (1978), Granger (1980), Levenbach and Cleary (1981), Boland and Baumann (1981), Boland et al. (1981), Dziegielewski and Boland (1981), Gardiner and Herrington (1986)* and others. Before describing the procedures relating to forecasting methods, it is necessary to categorise and evaluate them first. Accordingly, forecasting methods can be classified in the following way:

- Judgemental methods;
- Time-extrapolation methods;
- Disaggregate end-uses;
- Single-coefficient method;
- Multiple-coefficient method;
- Probabilistic method;
- Other methods.

2.5.2 - Methods evaluation

As far as methods-evaluation criteria are concerned, the *US Army Corps of Engineers (1981)* published a report entitled "An Assessment of Municipal and Industrial Water Use Forecasting Approaches". Others like *Boland (1985), Crews (1983)* have also assessed some of the forecasting methods. Based on these studies, forecasting methods can be evaluated using the following criteria:

- time horizon;
- data requirements;
- forecast accuracy;
- disaggregation ability;
- consideration of explanatory variables;
- suitability for reconnaissance studies;
- ability to provide detailed information;
- ease of application;
- ability to include and evaluate conservation measures.

Table (2.1) on page 34 summarises evaluation of the most commonly-used forecasting methods in terms of the previously mentioned criteria.

2.6 - Demand-forecasting methods

Having described data types and formats, forecasting-methods classification, and forecasting-methods evaluation criteria for the most commonly-used methodologies, this section concentrates on forecasting methods description and procedures. Moreover, it provides the definition of each of these methods and describes how domestic demands can be determined, including the relevant equations. It briefly ends with an evaluation of each method.

2.6.1 - Judgemental forecasting

The judgmental forecast is a subjective prediction which depends on personal or group knowledge. Personal forecast is called simple judgement, whilst group forecast is called collective or structured judgement. The Delphi technique is an example of structured judgement in which various individuals give their opinions before modifying them in the light of discussion, thereby arriving at a consensus value. The Delphi technique has been used to address problems in economics, environmental control, water-resources planning, regulatory decision-making, and policy setting *(Harold et al. 1975)*.

Judgemental forecasts are generally used in cases where there is little or no information which can be applied in any of the other above-mentioned methods. This kind of forecast is subjective and the expected error in forecasts is high.

2.6.2 - Extrapolative forecasting

The time-extrapolation method is still commonly used in the water industry. Time extrapolation depends on the assumption that past trends of water uses will continue in the same way, for the future. This method has been described, evaluated and criticised by *Hittman (1969), Parker and Penning-Rowsell (1980), Jones et al. (1984) and McDonald and Kay (1988)*. Based on this assumption, no other data or information are considered apart from historical records (for at least three years) of water use with time. Extrapolation may be accomplished by graphical or mathematical means and the change over time may be assumed to follow a linear, logarithmic, exponential, or other function.

The most popular mathematical equation for predicting demand by time extrapolation is simple linear regression. In general, regression analysis identifies a relationship between one specific dependent or response variable (water use), and one or more other related variables, called independent variables or covariates (time). This relationship is represented by a mathematical model referred to as a regression function. The regression function involves a set of unknown parameters which give the best fit for a given set of data. The parameters are known as the regressors (regression constant and coefficients).

The reasons for using a regression model are firstly, to obtain a description of the relationship between the variables as an indicator of possible causality and secondly, to predict the value of the dependent variable from a set of values of the independent variables. The linear-regression equation has the following general form:

$$q = a + bx + e \qquad (2.1)$$

Where:

q = *predicted water use per spatial unit and time period;*

a = *regression constant;*

b = *regression coefficient;*

x = *forecasting year;*

e = *error.*

The graphical form of this equation is shown in Figure (2.2).

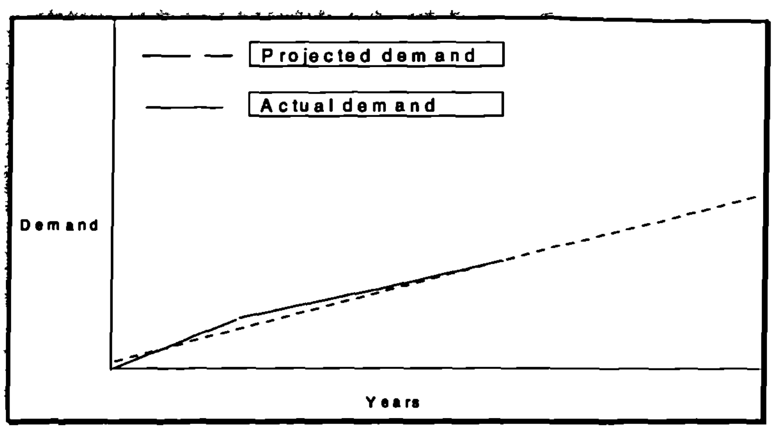

Figure (2.2) - Dummy trend for extrapolated-water demand

The time-extrapolation method is more appropriate for short-term forecasts (less than 10 years ahead). When using it for long-term forecasts, the best way to minimise errors is by building scenarios around projected trend (lower and upper projections) about which, more will be said later.

2.6.3 - Single-coefficient forecasting

Single-coefficient methods depend on referencing water demand to a single unit called the driver variable. Usually, these units reflect the physically smallest consumption element. Basically, domestic water can be referenced to a person, household or water connection. Accordingly, water demand for any area and time period, is expressed as the product of average consumption unit rate and number of units for the corresponding service area and time period. This can be formulated by the following equation:

$$q = u * c \qquad (2.2)$$

Where:

q = *water demand for a given area and time period;*

u = *water amount required per-consumption unit (per-capita, per-household, per-water connection);*

c = *number of consumption units (population, households, connections).*

As indicated in the above equation, water demand is estimated from the projection of water-use amount per user and number of users in the future. Each variable is projected independently from the other.

The per-capita coefficient remains the most popular in water industry. It represents the average amount of water required by one person. The simplest way of determining its past or present value is as follows:

$$p_c = h_c / o_r \tag{2.3}$$

Where:

p_c = *per- capita in litres per day;*

h_c = *measured household consumption in litres per day;*

o_r = *occupancy rate in persons per households.*

Future per-capita values may be assumed to be fixed over time or may itself be the subject of a projection. Its value and where applicable, rate of change, may be determined from past water-use patterns in the study area, or from data for other areas (national or international) if none of these exist. Despite that, the per-capita approach is simple and requires little data which are easily obtained. However, it has shortcomings which include:

- limiting the number of explanatory variables to one (population), other factors affecting the water use being omitted;

- the aggregate nature of this method result in forecasts which are insensitive to most trends and changes known to affect water use;

- it provides minimal information for those wishing to plan future facilities or management strategies.

The per-connection/household coefficient represents the average amount of water required or consumed by each water connection/household. Its value can be determined by direct measurements from installed meters. Future values are usually extrapolated from past records. Single-coefficient forecasting methods including per capita, per-connection and per-household have been reported by *Dziegielewski and Boland (1981), Boland and Baumann (1981), Jones et al. (1984), Langowski (1984), Boland (1985)* and others.

The advantages of using households or water connections rather than per-capita is that the former are a more natural and therefore more representative unit for all water-consumption activities, both indoor and outdoor. Moreover, it is directly measurable which leads to the prospect of better estimation, particularly in metered water-supply areas.

2.6.4 - Multiple-coefficient forecasting

The multiple-coefficient methods comprise a set of statistically-estimated mathematical equations derived by multiple-regression analysis, which explain how changes in a set of independent variables will affect the dependent variable. The aim is to supply as complete a set of explanatory variables as possible, which minimise the unexplained variance in the dependent variable. The dependent variable is usually household consumption, whilst the independent variables are the factors which affect consumption. The most commonly variables are:

- household income;
- occupancy-rate per household;
- household distribution (adults and children);
- household type (with garden, or without garden);
- ownership of water-using appliances (percentage and technology);
- prices of water and sewerage services;
- structure of pricing system (flat-rate, rising-block, falling-block, seasonal, etc.);
- climatic conditions (rainfall and temperature);

The general mathematical form of such models is as follows:

$$q = \Phi(b, i, h, t, r, p, \ldots x) \qquad (2.4)$$

Where:

q = *predicted average household water use;*

b = *household type;*

i = *household income;*

h = *household occupancy rate;*

t = *maximum daily temperature;*

r = *total rainfall;*

p = *unit price of water;*

x = *any other variable.*

The solution of this equation is achieved by means of multiple regression either linear or non-linear, both forms being listed below:

Multiple linear regression:

$$q = \sum_{i}^{n} a_i x_i \qquad (2.5)$$

Multiple non-linear regression:

$$q = \sum_{i}^{n} a_i x_i^m \qquad (2.6)$$

Where:

$a_{i\text{-}n}$ = *regression coefficients;*

$x_{i\text{-}n}$ = *independent variables;*

i,n = *> 0, depending on number of independent variables;*

m = *function power, m >1.*

The effect of explanatory variables on domestic water demand can be derived from other related statistical studies or estimated from the correlation between water use as the dependent variable and other factors as independent variables. Explanatory variables are assumed to be valid for the given area and time period and can be projected separately. If possible, the regression relationship should be modified to reflect any future changes of the independent variable, otherwise the present relationship is assumed to continue into the future.

In the literature, some researchers have distinguished between two kinds of multiple-coefficient models (requirement and econometric models), depending upon the variables selected. Requirement models include variables observed to be significantly correlated with water use, but not necessarily those suggested by a priori economic reasoning . In other words, models which do not include economic factors, such as water price, income, etc. are refered to as requirement models (since they imply that water use is an absolute requirement, unaffected by economic choice). Econometric models differ from requirement models in as much that they include variables which are related to economic aspects of water uses such as water price and household income, as well as other variables. Both the requirement and econometric models have been described by *How and Linaweaver (1967), Hittman (1969), Herrington (1973), Batcheler (1975); Domokos et al. (1976), Clouser and Miller (1980), Boland and Baumann (1981), Boland (1985)* and many others.

Generally, multiple-coefficient methods, both requirement and econometric models, produce better forecasts of water demand than single-coefficient methods and therefore, they are appropriate for both short-term and long-term planning. In both cases, water demand is determined by multiplying the predicted household consumption obtained by the regression model and the number of households for the specified area and time period.

2.6.5 - End-uses forecasting

The end-uses or component method relies on a detailed disaggregation of household water-use to smaller water-use activities (end-uses), such as dishwashing, toilet flushing, etc. Furthermore, end-use activities themselves can be further disaggregated into smaller components such as volume per use, frequency of use and use-coverage. These components can be predicted as a function of influencing variables such as price, income, household size, housing density and weather as shown in Figure (2.3).

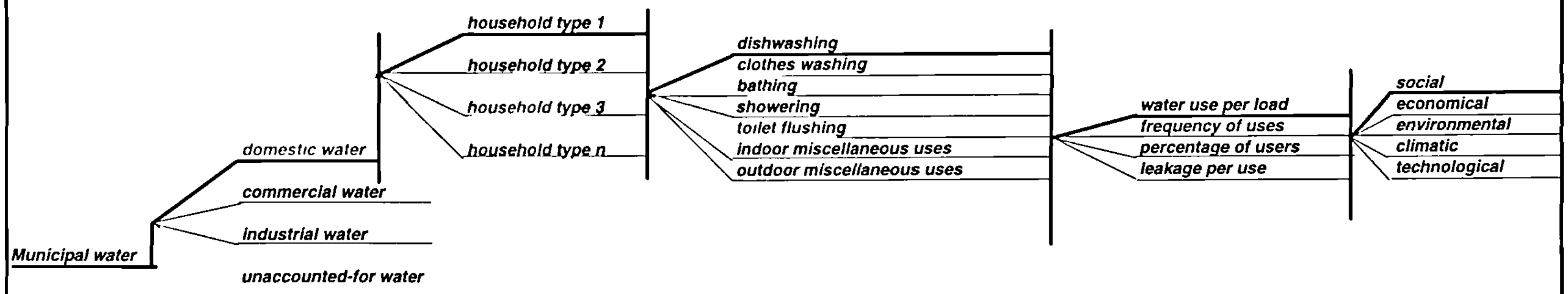

Figure (2.3) - End-uses disaggergation levels and components

The mathematical expression for this method is as follows:

$$q = \sum_{i}^{n} e_i \qquad (2.7)$$

Where:

q = *household water use in litres per day;*

e_i = *water use for each end-use (dishwashing, showering, toilet flushing, etc.);*

i = *1,2,3...., n (number of included end-uses).*

The general mathematical form for predicting water consumption by each end-use according to *Dziegielewski et al. (1991)* is as follows:

$$q_i = ((m_1 s_1 + m_2 s_2 + m_3 s_3)(u) + (kf))a \qquad (2.8)$$

Where:

q_i = *quantity of water used by a given end-use, in litres per unit;*

$m_{1\text{-}3}$ = *volume per use (e.g., litres per flush);*

u = *frequency of end use (e.g., number of flushes per day);*

$s_{1\text{-}3}$ = *coverage percentage of m_1, m_2, m_3;*

k = *rate of leakage per end-use in litres;*

f = *coverage percentage of end-use leakage;*

a = *coverage percentage of end-use per spatial unit.*

1-3 = *class of volume and corresponding percentage*

i = *end-use category (e.g., dishwashing, toilet flushing, etc.,).*

As implied in the above equation, volume per use or flow rate of each end-use can be divided into, say, three classes to account for different technologies. For example, toilet flushing could be divided into three main classes: non-conserving, conserving, and ultra-conserving volumes, corresponding to high, moderate and low classes. Multiplication of each class by its coverage percentage produces average volume per use for a given area and time period. The average end-use volume can be corrected by including an average leakage rate per end-use. Multiplication of the average corrected volume per end-use and frequency of use per day and coverage percentage of end use in a given area, produces the average quantity of end-use per day. Aggregation of all end uses leads to household consumption. Figure (2.4) shows the structural end use relationships presented in the previous example.

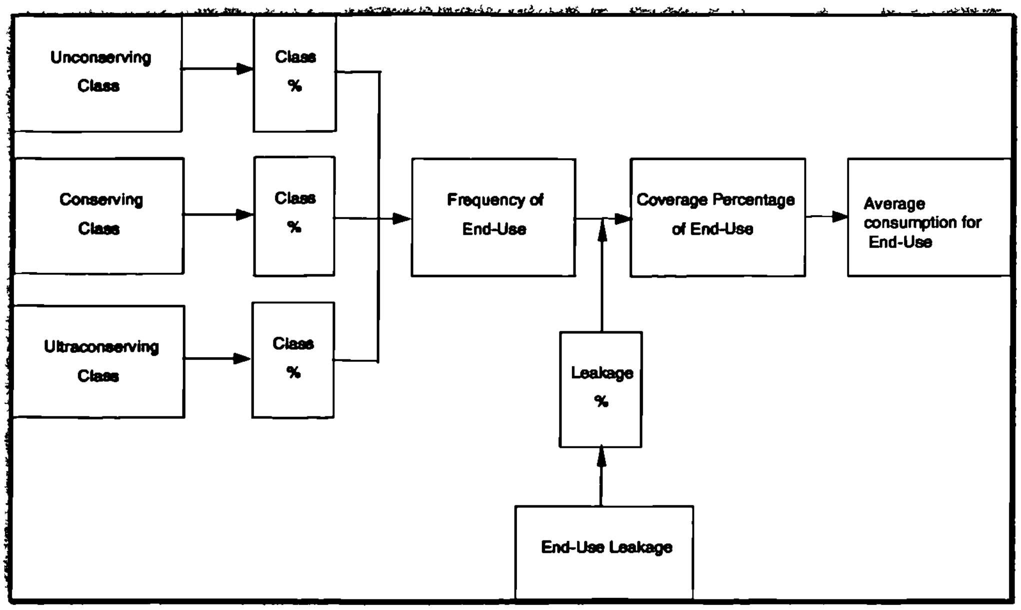

Figure (2.4)- Structural relationships for end-use components

While this approach is intuitive, logical and appealing for long-term forecasting, some researchers do not recommend using it for short-term forecasting since patterns in end-use water consumption do not change quickly. However, the component method is being used more extensively than, say, multivariate regression models in recent years since the latter do not provide a framework to investigate possible changes of water use, as for example an increase in the frequency of bathing. The end-uses approach has been used for forecasting domestic water demand in many reports and publications by *Mayers (1971), Thackray et al. (1978), Power et al. (1981), National Water Council (1982), Dziegielewski et al. (1993), PMCL (1994)* and others. Again, domestic demand is determined by multiplying the predicted household consumption and the number of households within a given service area for a specific time period.

2.6.6 - Probability forecasting

The aim of the multivariate demand models is to explain as much of the variance in observed water-use data as possible but typically, up to 50 percent remains. It is assumed that the remaining variance is random and not explainable in terms of the other variables. Therefore, a stochastic forecasting model could be used to provide a probability distribution around the central projection by means of upper/lower bands of confidence intervals. While the need for probabilistic forecasts has been often stated, there have been few attempts to construct and use stochastic models and mor often than not, these attempts have been less than successful in accomplishing their objectives.

The contingency-tree method is a good example of probabilistic forecasting of water demand. Normally, the contingency-tree approach requires that a base forecast be prepared, using one of the methods mentioned previously. Thereafter, possible sources of uncertainty regarding future water-use levels are identified and subjective probabilities assigned for each postulated outcome. The base forecast is then modified to reflect the effects of all possible combinations of the uncertain factors, one combination at a time, and the joint probability of each is related to the forecast water-use expected to result from that combination. This method was proposed by *Whitford (1972)* and has been used for forecasts of industrial water use by *Collins and Plummer (1972)* and for all sectors by *Boland et al. (1985).* Whilst probabilistic methods provide a means for considering uncertainty in water-demand forecasting, they need a base forecast and estimated probabilities, making them more suitable for short-term demand forecasting.

2.6.7 - Other forecasting techniques

Whereas the previous section has dealt with the more commonly-used methods for forecasting domestic demand, this section will outline other techniques which have been proposed at various times. They include memory-based technique, time-series models and number of unconventional techniques such as neural network.

(i) Memory -based learning technique

A memory-based learning approach has recently been developed and applied to forecasting domestic demand by *Tamada et al. (1994).* The underlying principles of this approach are firstly, storing past water-use examples in memory which can be achieved by any GIS or database software and secondly, searching for "nearest" available and similar conditions to a given input within the memory. The procedures involves defining a metric distance on the database (past examples), retrieving the nearest data for a similar condition, then using the weighted sum of such data as an output and representative result.

In this technique, definition of the distance, adding of new examples and managing the structure of the database are crucial. Distance is defined by the nearest reference point in the database to the neighbourhood in question, for which information exist. If there exist examples within the "neighbourhood" of the input data, then the forecast is given based on available data. Accordingly, forecasting is only performed if there are adequate examples available, otherwise regression is used to predict water use. As a consequence, this method is restricted to short-term forecasts where large amounts of data are available.

(ii) Time-series models.

Time-series models are usually restricted to forecasting water demand on hourly or daily basis. One of the best known models of this type is the so-called ARIMA model (Auto Regressive Integrated Moving Average) which is a particular form of the original Box-Jenkins approach *(Box and Jenkins 1976).*

The literature provides extensive coverage of time-series models relating to short-term water-demand forecasting such as (i) an adaptive forecasting model of hourly municipal water consumption *(Homwongs et al. 1994)*, (ii) an evaluation model of weekly and monthly time-series forecasts of municipal water use *(Franklin and Maidment 1986)*, (iii) a time-series analysis model of hourly domestic water demand *(Cronauer and Gidley 1985)* and many others.

(iii) Unconventional techniques

Since there are causal factors which play an important role in determining domestic demand and the relationship between these factors and demand is still not well defined, attempts have been made to modify and enhance the time-series models which were mentioned previously, by applying some of the intelligent computing techniques such as expert systems, fuzzy logic and neural networks. For example, *Rahman and Bhagnagar (1991)* proposed a demand-forecasting method that uses a purely heuristic approach to improve the accuracy of short-term demand forecasts. In this approach, a mathematical algorithm (ARIMA model) provides the base forecast which is augmented by a knowledge-base containing information pertaining to any abnormal events thought likely to affect demand over the prediction period.

Another example of where an adaptive model for domestic demand has been developed using neural networks, is the work by *Canu et al. (1990)*. This model was developed to deal with the non-stationary of the consumption variations (especially between summer and winter) which can be approximated using an ARIMA model. Thereafter, neural networks are used to add a multi-layered perception to model water consumption in order to forecast its value. This technique was found effective since it gives a good representation of the phenomenon in addition to being able to adapt itself to time-evolutive data.

Table (2.1) - Evaluation of forecasting methods

Forecasting method / *Evaluation criteria*	*Time extrapolation*	*Single coefficient Per-capita*	*Single coefficient per-household*	*Single coefficient per-connection*	*Multiple coefficient*	*Disaggregate end-uses*
time horizon	*short term*	*medium term*	*medium term*	*medium term*	*long term*	*long term*
Data requirements	*low*	*low to moderate*	*low to moderate*	*low to moderate*	*moderate to high*	*high*
Difficulty of obtaining data	*low*	*low*	*low to moderate*	*low to moderate*	*moderate to high*	*high*
Consumption reference-units	*municipality households connections*	*population*	*households*	*water connections*	*households*	*households*
Inclusion of conservation measures	*not possible*	*not possible*	*not possible*	*not possible*	*possible*	*possible*
Forecast accuracy	*low*	*moderate*	*moderate*	*moderate*	*high*	*high*
Consideration of explanatory variables	*very low*	*very low*	*very low*	*very low*	*moderate to high*	*high*
Consideration of economical aspects	*not possible*	*not possible*	*not possible*	*not possible*	*possible*	*possible*
Implementation (ease of application)	*simple*	*simple*	*simple*	*simple*	*complex*	*too complex*
Suitability for reconnaissance studies	*suitable*	*suitable*	*suitable*	*suitable*	*not suitable*	*not suitable*
Ability to provide detailed planning data	*low*	*low*	*low*	*low*	*moderate*	*high*
Disaggregation possibility	*not possible*	*not possible*	*possible*	*possible*	*possible*	*possible*

2.7 - Forecasting uncertainty

Water-demand forecasting is subject to considerable uncertainty as a result of interaction between many variables, (social, economic, climatic, demographic, political, etc.) and their fluctuating nature over time. Researchers have identified three basic situations facing decision-makers namely, complete certainty, risk, uncertainty. Complete certainty is defined as an event where the decision-maker knows all possible options available and their exact outcome. Risk is defined as a situation where the decision-maker knows all the options available but each option has a number of possible outcomes to which probabilities can be assigned. Objective risk means the probabilities are estimated logically whilst subjective risk relies on people's belief about the likelihood of events. Uncertainty prevails in those circumstances where the decision-makers know all possible outcomes but have no way of assigning probabilities.

It is the responsibility of the decision-maker or analyst to identify, clarify, and quantify areas of uncertainty whenever possible. The degree of uncertainty depends amongst other things on number of variables included in the analysis and the accuracy of the data used. Uncertainty is minimised by increasing the quantity and quality of information used which can be accomplished by expanding the database, eliminating or minimising errors, in addition to specifying the effects of each variable so that changes in water demand that are attributable to changes in the variables over time, can be accurately included in the forecast.

Since most forecasting procedures depend on variables such as population growth, family income, personal behaviour, etc. which are difficult if not impossible to predict for the longer-term, *Ascher (1978)* recommended that a range of possible outcomes should be used in forecasting future demand. In this approach, each forecast scenario corresponding to one possible set of assumptions is used to create a series of projections rather than one single projection. This allows the sensitivity of future water use to the full range of assumptions to be tested and reveals something about the level of uncertainty inherent in the forecast. Figure (2.5) shows a dummy scenarios of how the future water demand looks like.

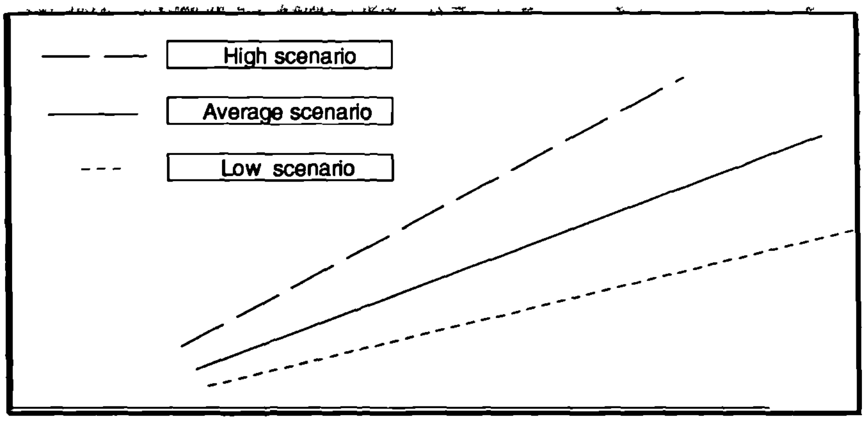

Figure (2.5). Dummy scenarios for future water demand

In general, a scenario can be defined as a hypothetical series of events constructed for the purpose of focusing attention on causal processes and points which decisions might be made *(Kahan 1967)*. The use of scenarios helps analysts to understand issues by providing an analytical framework in which having quantified their assumptions, the extent of uncertainty is revealed at various times throughout the planning period. Moreover, by testing the sensitivity of any one assumption, they can provide a measure of robustness when predicting the effects of factors which are difficult to quantify.

Generally, it is difficult to evaluate more than a few planning scenarios and most studies involve only three or four carefully selected ones. Sometimes, one of the scenarios is refered to as the baseline-scenario and two others are used to define the upper and lower limits on what could materialised in the future, as shown in Figure (2.5). Hence, the range defined by these extremes is a guide to the amount of uncertainty that might have to be accommodated in the planning process. Some specialists in this field do not recommend labelling any scenario as most probable or more likely, since this kind of labelling gives the impression that these are the only ones deserving attention. In reality, all scenarios should be considered with some degree of uncertainty since all are based on a series of assumptions, some more probable than others. Forecast scenarios can be included in most methods of demand forecasting by making a series of pessimistic and optimistic assumptions about future water use which respectively, define the upper and lower bounds of extrapolation.,

Another possibility of minimising uncertainty in demand forecasting is to focus on a relatively short-term period. By concentrating on what might happen to water use in, say, the next 5 years rather than the more usual 20 or 30 years, forecast accuracy can be expected to increase since the assumptions will be more realistic. However, medium-term forecasting is clearly not compatible with water-resources planning investments which may take decades to implement. Medium-term forecasting favours an incremental approach to water water-resources planning but although adaptable to short-term changes, does not reap the economies of scale that arise from building one large project which may be the better option for the longer term *(Qunn 1980).*

2.8 - Demand management

Demand management is becoming an important aspect of forecasting future water requirements due to the rapid increase in the demand for water. Moreover, traditional management emphasis on expanding water supply is costly and has caused problems such as ground subsidence, use-allocation conflicts and environmental disruption *(Baumann 1978), (Pearse et al. 1985).* Managing the demand for water has been promoted as an alternative to water supply which can reduce investment requirements or can make water-development funds cover a larger area. Other benefits relating to demand management include, lowering the peak volume requirements for both water supply and waste-water treatment which may lead to significant energy savings. Last but not least, environmental considerations increasingly make the case for greater use of demand management in water supply. However, it is important to appreciate that demand management is not necessarily an alternative to development of new sources but can help defer construction of additional capacity *(Tate 1984), (Mitchell 1984), (Grima 1985).*

In the literature, the terms "demand management" and "water conservation" are usually taken to have the same meaning. For example, demand management has been defined as the management of the total quantity of water abstracted from a source of supply, using measures to control water consumption. An alternative definition is the task of selecting specific actions from among a range of available options for meeting target demands *(AWWA 1980), (Moomaw and Warner 1981).* On the other hand water conservation was defined by *Baumann et al. (1980)* as "the socially beneficial reduction of water use or water loss". In this context socially beneficial implies trade-offs between the benefits and costs of water management actions. Accordingly, the main aims of demand management or water conservation are to encourage customers to make more efficient use of water.

Based on the previous definitions, the methods by which demand management or water conservation can be achieved are called conservation measures or actions. These actions can be carried out either by water suppliers (water companies), or by customers themselves. Measures applied by water companies target all types of water sectors which share the same water-supply system whilst the measures applied by the customers themselves are more specific to a particular sector. For example, reducing water leakage from the distribution system is not related to one specific sector and is the responsibility of the water company. On the other hand, household leakage is related to domestic water and it is the duty of customer rather than company. Since the main interest in this research is domestic water rather than other sectors, the focus will be on conservation measures which are related to this particular sector.

2.9 - Conservation measures

The literature contains various categorisations of conservation measures for domestic water use. Some researchers categorised conservation measures according to each measure's related field. These categories include economic measures such as water pricing, structural measures such as water metering, operational measures such as pressure reduction and socio-political measures such as education programmes *(Kreutzwiser and Feagan 1989).*

Other researchers categorised conservation measures into long-term and short-term, depending on duration. Long-term measures are those focusing on a permanent shift in the use of efficient devices whilst short-term measures are restricted to those which temporarily alter the behaviour of customers. Based on this categorisation, conserving devices are long-term measure whilst water use-restrictions such as banning the use of hosepipes for car washing or garden watering, etc., are considered as short-term measures *(PMCL 1994).*

A third group divided conservation measures into water efficiency and water restrictions action's according to their impact on customers. Water efficiency measures include actions which reduce water use and at the same time do not affect the standard of living of customers. With these measures, customers perceive no difference before and after their implementation as they become part of everyday life, an obvious example being a conserving device. On the other hand, water-restriction measures include actions which reduce water use but at the same time, interfere with a customer's standard of living. As a consequence of this, customers perceive curtailment of water supply which leads to a change in their daily life. Examples of this type include a ban on using hosepipes, rota-cuts in supply, use of stand-pipes, etc.

However, the most commonly-used measures which have significant potential in reducing domestic demand or at least slowing the rate of increase in water demand, can be grouped as follows:

- Water metering
- Water pricing
- Water-saving devices
- Household leakage-control
- Education programmes
- Water-use restrictions
- Water Bye-laws

Implementation of joint measures tend to be mutually reinforcing and more effective in reducing water consumption than a singular measure. However, some combinations may have little or no less effect even if they are applied jointly. Furthermore, certain measures may overlap at least to some extent with others. For example, water pricing is more effective if applied on metered households than unmetered ones, whilst metering itself can help in reducing household leakage. Moreover, water-pricing policies (defining appropriate tariffs) can provide incentives for customers to adopt water-efficient practices and technologies. These interaction effects will be discussed in detail in chapter 5.

Generally speaking, each conservation measure usually includes one or more of the following:

- incentives (financial or non-financial)
- legislation
- education and publicity
- innovation

For example, household leakage-control has a financial incentive to metered customers whilst water-use regulations involve legislation and require publicity. The same thing can be said about conserving devices where recent innovations in washing machines and dishwashers technology for example, have resulted in substantially improved water and energy efficiencies, providing financial incentives to customers. Table (2.2) which can be found on page 49, summarises conservation measures and their potential for reducing water demand.

2.9.1 - Water metering

Metering is recognised as an important measure for reducing water use since it is the necessary first step in moving towards effective pricing arrangements *(Gysi 1981)*. Some examples on the potential of metering in reducing household consumption from trials in USA and UK are given below;

In the USA, a 30 percent difference was reported between metered and unmetered cities in California *(Minton et al. 1979)*; a 13 to 20 percent decrease in domestic water-use was achieved after metering *(Loudon 1984)*; a 35 percent reduction in domestic water at Boulder, Colorado was reported by *Flack (1980)*. In the UK, the National Metering Trials which ran for three years and finished in March 1992 provided a preliminary indication of the demand reductions which can be achieved under varying pricing policies for different types of homes and levels of affluence. The largest trial area was 50,000 homes on the Isle of Wight, where the reduction in water demand during the first two years of metering was 5.2 percent. However, the reduction of water put into supply was 11.1 percent, the difference being attributed to lower leakage rates and other factors *(Water Services Association 1993)*. Elsewhere, other UK water companies, using different tariff structures in different areas, indicated metering had a potential of reducing household consumption by at least 5 percent.

However, whilst domestic metering is one of the most efficient measures in reducing household consumption in the long-run, especially if accompanied by an appropriate tariff, it has some disadvantages. The main disadvantage is cost since metering requires a large investment for installation, maintaining meters, taking readings regularly etc., which make it less attractive to water companies.

2.9.2 - Water-pricing policy

Water conservation for metered customers can be promoted by changes in the price structure or rates. In recent years, pricing has been used to not only cover capital and operational costs but also promote conservation and sustainability in the use of water resources. Previous research shows that household consumption responds to price, with various ranges of elasticity being quoted. Accordingly, most researchers agree that the pricing of water is one of the most effective means of reducing metered-water consumption *(Hank and Davis 1973), (Tate 1984), (Grima 1985).* However, other researchers have stated that pricing of water has no significance on saving until the family's expenditure on water exceeds 25 to 30 percent of its net income *(United Nations 1987).* Notwithstanding, the effectiveness of any pricing policy in reducing demand depends on the type of tariff structure imposed which include:

- flat-rate tariff
- rising-block tariff
- falling-block tariff
- peak-rate tariff
- seasonal tariff
- sewer-surcharge tariff.

The flat-rate tariff means that customers will be charged for the consumed amount based on a fixed price for each unit ,say, a cubic metre, implying that the user would be charged the same unit price regardless of the amount consumed. This particular tariff structure is considered to be the least effective, providing little or no incentive to conserve water *(Baumann 1978).* This was reflected in the UK National Metering Trials where a change in demand of between - 5.2 to + 2.3 percent was reported for the flat-rate tariff *(Water Services Association 1993).*

A rising-block tariff is a schedule in which an increasing unit rate is charged within each specified consumption range, known as block. This tariff structure is thought to hold the most potential for reducing water demand since it would affect all customers throughout the year, having its greatest impact on the large-volume users *(Gysi and Louks 1971), (Grima 1973).* Although rarely used, a few studies have generated empirical results to support the theoretical potential of this rate structure. *McGarry and Brusnighan (1979)* found caused a reduction of 13.8 percent in domestic demand, with a reduction of about 15.1 percent being reported in the UK by *Water Services Association (1993)*

A falling-block tariff is similar to rising block but with decreasing unit rate within each specified consumption range. Where water-resources are more than adequate, a falling-block tariff has sometimes been used to reflect the economies of scale that are associated with the production and distribution of water. Intuitively, one would expect a falling-block tariff would increase rather than decrease demand, but there is little evidence either way, to support this hypothesis. However, a reduction in water demand of 11.1 percent was achieved in some areas in the UK by this tariff structure *(Water Services Association 1993).*

The daily peak-hour rate is usually imposed to reduce consumption in certain hours in the day. This tariff structure may take the form of rising rate or flat rate which are charged for a base amount of water, established according to each customer's average daily consumption. Although, daily peak-hour is cited as an effective conservation measure, it has rarely been implemented *(Millerd 1984).* However, despite there being little research on this form of tariff, the belief is that it can reduce water demand by 5 to 15 percent *(Griffith 1984), (Millerd 1984), (AWWA 1984), (Hank and Fortin 1985), (Water Services Association 1993).*

Seasonal tariff is similar to peak tariff but it is imposed during certain months of the year (summer months). It is considered as another option to control demand by imposing higher prices for water in summer than in winter. Having a price elasticity between 0.5 to 0.9 as it has reported by *Grima (1973)* and *Ellis (1978)* and a reduction potential between 7.2 to 18.9 percent according to *Water Services*

Association (1993), it is thought to be an effective way in reducing the high demands during the summer months

Sewer-surcharge tariff is usually imposed to reduce waste water and as a consequence of this, consumption also decreases. This type of tariff also may take different rate structures which may cause a reduction in domestic water of up to 10 percent *(Moomaw and Warner 1981), (Griffith 1984), (Elliot 1973), (Loudon 1984).*

2.9.3 - Water-saving devices

Water-saving devices offer significant potential for water conservation. *Barclay (1984)* suggested that a 30 to 40 percent reduction is possible by such devices, but others such as *Palmini and Shelton (1982)* found the figure to be nearer 10 or 20 percent for domestic water uses. Elsewhere, *Howe and Vaughan (1978)* reported a 32 percent savings as a result of using conservation devices. Whatever the actual figures, researchers agree that the use of water-saving devices is one of the most effective measures available if applied comprehensively. Generally speaking, the term 'conserving devices' is taken to cover all water-using fixtures and appliances in the household (dishwashers, washing machines, showers, toilets, taps, etc.). However, the most important fixtures based on amount of water consumed are toilets, followed by showers and taps.

(i) Toilets

Conventional toilets in some countries can consume up to 15 or 20 litres per flush. Although the frequency of toilet flushing varies from one household to another, the overall consumption can account for between 20 and 35 percent of indoor use. There are two broad options for reducing the flushing volume firstly, by replacing the larger-flush toilets with smaller ones and secondly, by the installation of conserving devices. Replacing a conventional toilet with a low-flush or ultra-flush toilet can reduce the volume of water used by up to 78 percent in the case of some models. In the recent years, toilets technology has reduced the flushing-volume down to less than 4 litres per flush. With regard to the conserving devices currently available, they can be grouped into three main types. Firstly, there are damming devices including, toilet dams or partitions to section-off a portion of the toilet tank which have the potential of reducing the flushing volume by up to 35 percent. The second category is displacement devices such as plastic bottles or bags which displace water in the toilet tank and as a result, can reduce the flushing volume by between 10 and 25 percent. Finally, there are various devices which are used to modify the flushing-mechanism to provide a dual-flush mode which is claimed to have the potential of reducing the flushing volume of conventional toilets by up to 55 percent. In the case of the dual-flush toilets, the reduction in the flushing volume does not equal to 55 percent saving in the quantity of water used for toilet flushing since that is also dependent upon the frequency each mode is used *(How 1970), (California Water Resources Department (1978), (Sharp and Grear 1978), (Rocky Mountains Institute 1991).*

(ii) Showers

Although shower consumption depends on type and showering time, on average shower-water use accounts for about 20 percent of household consumption. A typical showering time is thought to be about 5 minutes. The amount of water used in 5 minutes for different shower types is as follows:

- shower connected to bath taps consumes 15-25 litres;
- instant-electric shower consumes 25-35 litres;
- mixed-valve shower consumes 30-40 litres;
- power-shower consumes 45-60 litres.

Reducing shower consumption can be achieved by limiting the flow rate, replacing the high-flow shower-heads with low or ultra-flow heads. In this way, there is a possibility of reducing flow rate between 30 and 50 percent *(Sharp and Fletcher 1977), (Rocky Mountains Institute 1991).*

(iii) Taps

Water used from bathroom and kitchen taps, including outside hosepipe and sprinkler use, can account for the highest portion of domestic demand in some households, accounting for more than 40 percent of household consumption. Conventional bathroom and kitchen taps use approximately 5 to 10 litres per minute. As with showers, reducing tap consumption can be achieved by limiting the flow rate. This can be accomplished by installation of flow controllers which can limit flow rates to 5 litres per minute for certain purposes. As a result, the flow controllers currently available have the potential of reducing flow rates by 15 to 50 percent *(Sharp and Fletcher 1977), (Consumers Report 1989), (Rocky Mountain Institute 1991).*

(iv) Dishwashers and washing machines

Domestic appliances such as dishwashers and washing machines can contribute additional savings in household consumption as and when new models which use less water become more widely available to customers. For example, the amount of water used by a dishwasher depends on the make and model of the machine. Similarly, the older-style washing machines use between 90 and 150 litres per load (95 litres on average) to wash 5 kg of clothes whereas the most efficient machines currently available use between 50 and 70 litres *(Consumers Report 1985), (Rocky Mountain Institute 1991). (Which Magazine 1992-1995).*

(v) Waste-water recycling

The feasibility of small-scale reuse of water in the home has also been investigated. Recycling of bath, shower and wash-basin waste water for use in toilet flushing has the potential of reducing individual household demand by 20 to 30 percent but is financially very unattractive at the present time and expected to remain so for many years to come. Recycling of domestic waste-water for water gardening is a complex resource issue where indirect effluent re-use is practised and therefore, not widely encouraged under normal circumstances.

2.9.4 - Household leakage-control

Generally speaking, household leakage includes that from fittings, pipes, fixtures, appliances and dripping taps. Although there can be considerable variations depending upon the state of plumbing, age and other factors, it can account for approximately 10 to 30 percent of the total household consumption. Whilst the domestic supply pipe linking the home to the distribution network is probably the worst offender, toilet leakage and tap dripping also contribute a significant amount. Therefore, perhaps the best way of reducing household leakage efficiently is to introduce other measures such as metering, pricing or pressure reduction *(Richards et al. 1984).*

2.9.5 - Education programmes

The main objective of public education programmes is to raise the public awareness to a level at which they are convinced that conserving water is worthwhile. Public education programmes typically consist of direct-mail promotions, news-media campaigns, school projects etc. Direct-mail promotions refers to the inclusion of water-conservation literature or "bill stuffers" with customers invoices for the service provided. News-media campaigns comprise the provision of material to newspapers and the use of radio and television to disseminate information on water conservation. Other options include teaching material for schools, wall-posters, films and lectures to civic groups. In order that these measures are effective, they have to be applied continually over long periods. However, although education programmes target both indoor and outdoor uses, the belief is more attention has to be given to outdoor uses. For example a sustained education and publicity campaign should promote ;

- water butts
- mulching
- good soil preparation
- infrequent deep watering
- sparing use of lawn watering

- watering in the late evening
- selection of suitable plants
- use of trigger nozzles for car washing.

Overall, the various studies which have examined the water savings associated with education programmes suggest a reduction of 5 to 10 percent in water use is possible *(Bishop et al. 1982), (AWWA 1981), (AWWA 1984).*

2.9.6 - Water-use restrictions

Water-use restrictions include both mandatory and voluntary restraints. Mandatory restrictions comprise rota-cuts, pressure reductions, hosepipes and sprinkler bans, etc., whereas voluntary restraints are normally the results of appeals for reductions in water use. Most of these measures can only be applied for relatively short periods and are therefore more suitable for drought situations. Various studies suggested that a reduction of between 10 to 30 percent is possible with mandatory restrictions *(Hanks and Fortin 1985), (AWWA 1980), (Grima 1985).* On the other hand voluntary restrictions on water use normally have less impact, with less than 10 percent reductions being reported from various studies *(Bishop et al. 1982), (Bruvold 1979).*

2.9.7 - Water Bye-laws

The last group of conservation measures comprises water-use regulations in general and plumbing codes in particular. Water bye-laws vary from country to country and even within the same country. Generally speaking, they target both indoor and outdoor use but require long periods to be effective. For example, plumbing codes mainly affect new buildings which represent a small percentage of the total. According to the various studies that have been conducted, water-use regulations have a potential of reducing water demand by up to 20 percent *(Hanks and Fortin 1985), (AWWA 1980), (Grima 1985).*

Table (2.2) - Conservation measures and potential reduction in water consumption

conservation measure	*Potential reduction factor %*	*references*
1 - water pricing policy	*from -19 to +2.3*	*Hank and Davis 1973; Tate 1984; Grima 1985; Richards et al. 1984; Water Service Association 1993; How and Linaweaver 1967; Howe 1970*
1.1 - flat-rate tariff	*from -5.2 to + 2.3*	*Bauman 1978; Water Service Association 1993.*
1.2 - rising-block tariff	*from - 5 to -15*	*Gysi and Loucks 1971; Grima 1973; McGarry and Brusunighan 1979; Water Service Association 1993.*
1.3 - falling-block tariff	*about -11*	*Water Service Association 1993.*
1.4 - peak-hour tariff	*from -5.8 to -15*	*Millerd 1984; Uri 1980; Grifith 1984; Ellis 1978; Water Service Association 1993.*
1.5 - seasonal tariff	*from -7.2 to -18.9*	*Grima 1973; Ellis 1978; Leitch and Gill 1983; National Metering Trial 1994.*
1.6 - maximum-day tariff	*from 0 to -2*	*Baumann et al. 1980, 1981.*
1.7 - sewer-surcharge tariff	*from -1 to -5*	*Moomaw and Warner 1981; Griffith 1984; Ellioot 1973; Loudon 1984.*
2 - water metering	*from -5 to -30*	*Carver and Boland 1980; Flack 1980,19 81; Loudon 1984; Gysi 1981; Minton et al. 1979; Richard et al. 1984; Brown and Caldwell 1984; Water Service Association 1993.*
3 - water saving devices	*from -10 to -25*	*Sharp and Grear 1978; Barclay 1984; Palmini and Shelton 1982; Stone 1978; Maclaren 1985; Rocky Mountains Institute 1991.*
3.1 - toilet conserving devices	*to - 55**	*California Department of Water Resources 1978; Rocky Mountains Institute 1991.*
3.1.1 - displacement types	*to - 26**	*California Department of Water Resources 1978.*
3.1.2 - assorted types	*to - 54**	*California Department of Water Resources 1978.*
3.1.3 - damming types	*to - 36**	*California Department of Water Resources 1978.*
3.2 - showers conserving devices	*to - 65**	*Sharp and Fletcher 1977; Shindeler 1980; Consumers Report 1989; Rocky Mountains Institute 1991.*
3.3 - taps conserving devices	*to - 65**	*Sharp and Fletcher 1977; Shindeler 1980; Rocky Mountains Institute 1991.*
4 - public education programmes	*from -5 to - 10*	*Bishop et al. 1982; AWWA 1981, 1984; Richards et al. 1984.*
5 - Household leakage control	*from 0 to - 30*	*Richards et al. 1984.*
6 - water use restrictions	*from -5 to -28*	*Hanke and Fortine 1985; AWWA 1980; Grima 1985; Bishop et al. 1982; Bruvold 1979; Moomaw and Warner 1981.*
6.1 - water rationing	*from 0 to -25*	*Richards et al. 1984.*
6.2 - pressure reduction	*from -2 to -10*	*Stone 1978; Brown and Caldwell 1984.*
6.3 - sprinkler or hosepipe restriction	*from 0 to -22*	*Richards et al. 1984.*
7. Water Bye-laws	*from 0 to -28*	*Brown and Caldwell 1984.*
7.1 - plumbing codes	*from 0 to -28*	*Brown and Caldwell 1984.*

** These values represent potential reduction in volumes rather than household consumption*

2.10 - Measures evaluation criteria

Since there are various conservation measures, selecting the most appropriate one requires some kind of evaluation procedure. Moreover, such evaluations may help in selecting those measures which can control water demand with the minimal inconvenience to customers. Evaluation criteria may include various aspects such as economic, technical, social and environmental considerations etc. *(Organisation for Economic Co-operation and Development 1987b).*

2.10.1 - Technical evaluation

The technical evaluation aims to give the decision-makers an estimate of the reduction in water demand resulting from various measures. This can be achieved by estimating the ratio between water consumption before and after measure(s) have been implemented for similar applications. Accordingly, conservation measures can be ranked based on their efficiency in reducing water consumption, implying that the measures with the higher reduction potentials are more appropriate.

2.10.2 - Economic evaluation

Since the cost of implementing conservation measures vary considerably, the technical evaluation alone is normally not enough. Therefore, concept of "economically-efficient measures" is required in addition to technical evaluation. Here, economic efficiency refers to the relative cost of implementation, both capital and operating. Financial analysis forms part of the economic evaluation. From a financial point of view, a particular measure would be feasible if the rate of return is greater than the costs incurred, whereas an economic evaluation would require benefit-cost ratio to be greater than one. In general, economic evaluation is very important, especially when investments are large, as in the case of water metering. Therefore, it is necessary to balance both the benefits and costs before taking a decision in this regard.

2.10.3 - Social evaluation

Social evaluation focuses on the implications for customers resulting from different demand-management strategies, which to some extent determines the public acceptability. For example, it might tend to discourage some options such as higher water prices despite political or institutional acceptability of such measures. Similarly, water restrictions also have negative social impacts on family's welfare and general health. On the other hand, water metering may receive reluctant acceptance from the general public if it perceived to be a fairer way of allocating the charges for services provided.

2.10.4 - Other criteria

In addition to the previous assessments, there are several other criteria which can be considered in the evaluation of conservation measures. These include the durability of conservation measures and the ease of implementation. Durable measures reflect the lasting effects in reducing water demand, as in the case of ,say, water metering. By way of contrast, education programmes are less durable and, therefore, have to be applied regularly in order to maintain their impact which would otherwise decrease with time. With regard to ease of implementation, different measures may require different amounts of effort. For example, imposing the first level of water-use restrictions can be accomplished in a matter of weeks whereas water metering may take years to complete.

2.11 - Domestic water demand data

Data required to forecast water demand vary from one method to another in terms of data type, format, sources and collection effort. Similarly, data for demand management depends on the type of conservation measures applied. In general, the required data for both demand forecasting and demand management fall in one of the following categories:

- discrete data;
- cross-sectional data;

- time-series data.

Discrete data consists of single observations which might take one value or range of values for certain location and time period. The cross-sectional data comprise simultaneous observations of water use and explanatory variables at a number of locations within the service area during a single time period, whereas time-series data consist of observations of water use or explanatory variables at the same location(s) in the service area over a number of time periods.

The data required for water-demand forecasting, depending on the type, can be obtained from government departments, census bureau, regional agencies, planning authorities, water companies and such like. The difficulty of obtaining data depends to a large extent on the level of disaggregation chosen: the finer the level of disaggregation (in terms of the size of the service area and the extent of sectoral detail), usually the more difficult they are to obtain. For example, obtaining population data as much easier than data for household end uses.

The effort required to secure data varies widely from one forecasting application to another depending on the variables. In some cases, data-collection effort may consist of a telephone call, an exchange of correspondence, an office visit, personal interviews, questionnaires, or review and analysis of previous studies. In other cases, data collection may require strenuous and time-consuming efforts, such as field measurements, manual analysis of water billing records, field surveys of users, data interpolation and extrapolation etc., not to mention continual referral from agency to agency in search of data.

2.12 - Water-demand systems

The final element for improving demand forecasting which was mentioned earlier in this chapter concerns the research effort required to create a computerised system for demand forecasting, demand management or some combination of both. Progress to date has been limited and the literature shows that at the present time, there are very few computerised systems relating to water-demand forecasting and demand management which are available for use. Some of these are stand-alone whilst others form part of a water-resources planning system. One of the most popular stand-alone software packages is the IWR-MAIN system *(US Army Corps of Engineers 1981).* IWR program is a computer model for water demand forecasting which also incorporates water-conservation measures, as well as other factors.

The IWR-MAIN system covers four water-use sectors: domestic, commercial, industrial and unaccounted-for water. Domestic-water demand is estimated from a combination of indoor and outdoor uses. Indoor uses are computed by an econometric model, which consider the price of water where appropriate, whilst outdoor uses are computed by a separate model which includes amongst other variables, the area of irrigation land and price of water. Commercial demands are calculated by different coefficients which have been derived from the previous studies. For example, coefficient for barber-shops consumption is an average consumption per number of chairs or stations, etc. Industrial demand is estimated by the water-use per-employee in which employment figures for each firm are used as water-use parameter. Unaccounted-for water is computed based on per-capita for the total population.

The IWR program was developed using a conventional programming language and is available as a PC version. It is not entirely generic since it was developed for use by the water industry in the United States and contains several econometric models which depend on certain assumptions/local parameters which cannot be used for other countries. Additionally, the amount of data required to run the system make it difficult to use in practice.

2.13 - Need for improved systems

Notwithstanding the efforts which have been made to improve results, demand forecasting systems still rely on the traditional engineering approach and lack the use of advanced computing facilities such as expert systems, Geographic Information Systems (GIS), etc. The need for more flexible computerised forecasting systems has also become more apparent. These systems would comprise a variety of forecasting methods, combined with the necessary data-management facilities within a single computer program. The user should be able to select the appropriate forecasting method for each use-category, consistent with the planning needs and data availability. The forecasting system should be flexible in respect to data requirements and capable of functioning with data sets ranging from minimal to comprehensive. Where specific data are not available, the system should be able to generate estimated values which are consistent with other accessible data or fairly that, substitute default values from libraries of national or regional data sets. In this way, faced with a variety of planning needs and data availability, it should be easy to find a combination of techniques and assumptions which best fit each situation and circumstances.

In this research programme, an attempt is made to develop a demand-forecasting system which combines the advantages of the most-used methods with the latest computing techniques such as GIS, expert systems, database management, models and hypertext facilities, in one comprehensive package as part of a river-basin management system. However, before describing the system development and procedures, it necessary to provide background information on decision-support systems in general and some of the advanced computing techniques such as expert systems in particular which comprise the main contents of the next chapter.

DECISION-SUPPORT SYSTEMS BACKGROUND

3.1 - Introduction

As mentioned in the previous chapter, the development of integrated, computerised water demand forecasting systems is still in the early stages. In this research study, a further step is added to the previous efforts through the development of a decision-support system for demand forecasting and management which has benefited from previous efforts. Chapters 4 and 5 describe in detail the structure and procedures of the proposed system, but before that, it is necessary to review decision-support systems in general and their application within water industry in particular.

Generally speaking, technical decisions in whatever field require many factors to be considered such as financial, manpower, locational, environmental and other related issues. Inclusion of such factors makes the decision process more complicated and time consuming. The role of a decision-support system (DSS) is to simplify the decision process by providing the necessary analytical assistance to the decision-maker where required.

Since DSSs are linked to computer development, their evolution is based on advances in computer technology in both hardware and software terms. This chapter focuses on DSSs from different standpoints, including how DSSs evolved, their characteristics and structure. Bearing in mind their importance to the research study, particular emphasis has been given to knowledge-based and expert systems.

3.2 - The systems approach

The word "system" is used in describing a large number of phenomena. *Alexander (1974)* arrived at the following definition of a system: "*A system is a group of elements, either physical or non-physical in nature, that exhibit a set of* *interrelationships among themselves and interact together toward one or more goals, objectives, or ends."*

Typically, the system approach to problem-solving would comprise a number of phases including data collection and analysis, conceptual structuring, model formulation and problem evaluation. Each of these phases are described in detail in the coming sections.

3.2.1 - Data collection and analysis

Data collection and analysis is the first phase of problem-solving. Moreover, it is an important aspect for the initial assessment of a physical system. The three main related aspects can be stated as follows: (a) what is the optimal schedule, both temporal and spatial for data acquisition? (b) how reliable are the data? (c) what information can be extracted from those data? The first aspect is associated with sampling in general and depends to some extent on the system characteristics. Secondly, data reliability, requires an a priori understanding of the controlling processes, assessment of the measurements and applicability of the data-collection techniques. Hence, a gross estimate of the nature and the range of magnitude of the measured quantities should be available if possible. In this way, both bias and errors can be identified by comparison with existing historical data, statistical analysis or even logical reasoning. The third aspect deals with the recognition of data patterns and trends which can lead to a better understanding of the behaviour of physical system and provide an insight of its structure. Periodicity, long-term trends, abrupt changes and stochastic variations are all very important in characterising the system.

3.2.2 - Conceptual structuring

After collection and analysis of data, conceptual structuring of the process involved is possible using physical concepts, management plans, legal constraints and socio-economic considerations. All of these aspects should be described in a way that explains the behaviour of the observed data in a qualitative but integrated manner. During conceptual structuring, the methodology used relates natural laws, shared understandings, common acceptable assumptions, simplifications and any other source of information in the form of beliefs, past experiences or facts that can be substantiated. This will provide a basis for any mathematical model that may be developed to evaluate the system's performance. A successful conceptual structure requires a thorough understanding of the components of the system, their individual characteristics, interrelationships, and importance within the overall system.

3.2.3 - Model formulation

In model formulation phase, the system components are represented by quantitative expressions. These expressions can simulate the behaviour of an individual component and/or of the system as a whole. Mathematical models can range from simple relationships to complex multi-variable sets of equations. In most cases, analytical solutions are not feasible and therefore, numerical techniques are usually employed. The main drawback of traditional mathematical models is that they require a strong user-background in mathematics and computing techniques. Moreover, they tend to operate in a pre-defined pattern without being able to demonstrate even elementary common sense or intelligence.

3.2.4 - Problem evaluation

The last phase of the system approach is the application and use of mathematical models. Various types of mathematical models can be used as a tool for problem evaluation, impact assessment, event forecasting, sensitivity analysis, robustness appraisals and solution identification. Based on the results, management strategies and operational decisions can be developed.

3.3 - Need for improved systems

Mathematical models frequently suffer from the problem that although the models themselves might provide a reasonable representation of reality, they are difficult to apply in practical situations. Many models need large amounts of input data, some of which may be difficult to collect. Others require so much domain knowledge that the model they can only be used by experts. This is particularly the case in water-resources planning which requires not only vast amounts of hydrometric data as inputs to the large simulation models but also a detailed understanding of related disciplines such as socio-economics, hydrology, ecology, biology etc.

Specialist knowledge is also required when dominance factors for some forms of multi-objective, multi-criteria evaluation models have to be determined. The same is true on the output side where interpretations of the results frequently requires considerable experience which sometimes resides with the model-builder himself. Even if the relevant data can be acquired and even if the specialist is available to set up the model and interpret the results, many practical problems remain. In the same way, if a model needs a lot of input data and if this requires considerable amount of work, possibly by a specialist, application of such a model becomes a cumbersome and expensive procedure. These logistical problems become worse when the same model needs to be run many times to solve a specific problem.

Moreover, the problems can become even more complicated when more than one model is included in the analysis. In this case, model testing implies input preparation and output explanation which require many runs in order to find where the results start to change or where the critical points occur. By taking away as much of the tedious work as possible, models can be made easier to use. However, that requires the model-builder to pay more attention to the development and improvement of the model itself, including an efficient user-interface.

3.4 - Emerging technologies

Improved modelling techniques are inextricably linked to the development of computer technology, both hardware and software. During the past decade or so, progress in this area has seen the introduction of Geographic Information Systems (GIS), relational databases, interactive user-interfaces, color-graphics and that such like. This in turn has facilitated emerging technologies such as fuzzy logic, soft computing, expert systems and other forms of artificial intelligence. The emphasis now seen to be slanted towards improving the quality of decision-making rather than just providing an analytical capability. To that end these emerging technologies are beginning to pervade all aspects of business life, including the water industry. Freed from the tedium of data manipulation, managers themselves are beginning to use computers in an intelligent way for decision-making. Their interest is in making rational use of the facilities provided without necessarily having an in-depth knowledge of modelling techniques.

3.5 - DSS overview

Decision-support systems (DSS) are a relatively-new discipline that has emerged from the development of earlier management information systems (MIS) which are data oriented and for the most part, simply a means of retrieving data from large databases grounded on selected queries. This new discipline focuses on the design and development of DSS, where at the present time, there is a solid conceptual footing and increasing number of applications that demonstrate their importance and efficiency in aiding management.

In recent years, the computer has progressed from data processing, through the user's office into knowledge processing. The main factor involving computers is the treatment of information as the sixth resource alongside people, machines, money, materials and management. Notwithstanding, the close links between data processing (DP), management information systems (MIS) and the decision-support systems (DSS), a widely-accepted definition of DSS is not available. However, some of the interim definitions are presented here;

Bonczek et al. (1981) defined DSS as a computer-based system consisting of the following interacting components;

- a language system or a mechanism to provide communication between the user and other components of DSS;

- a knowledge system database to store domain knowledge either as data or procedures, for use within the DSS;

- a problem-processing system providing the link between the other two components, containing problem manipulatry capabilities required for decision making.

Turban (1990) defined decision-making as *" a process of choosing among alternative courses of action for the purpose of attaining a goal or goals".* The decision-making process as outlined by *Turban* involves the following steps;

- defining the problem;

- classifying the problem into a standard category;

- constructing a model that describes the real-life problem;

- finding potential solutions to the modelled problem and evaluating them;

- recommending a solution to the problem.

Louks and daCosta (1991) gave the following general definition of DSS: "*Decision support system is a computer-based tools having interactive, graphical and modelling characteristics to address specific problems and assist individuals in their study and search for a solution to their management problem".*

However, several authors such as *Bosman (1983), Mittra (1986), Sprague (1986), Davis and Grant (1987) and many others* have defined DSS and pointed out why DSS were developed but an obvious difference in opinion emerges regarding the range of possible applications. A somewhat narrow view with regards to the objective of DSS would be to improve the performance of knowledge workers in organisations or to help improve the effectiveness and productivity of managers and professionals *(Bosman (1983), Sprague (1986)* and others*)*. According to this view, DSS seems to be limited to applications in an organisational context. Other authors such as *Mittra (1986), Fedra et al. (1986), Jamieson and Fedra (1996)* and others show a much wider perspective for the use and application of DSS. They concentrate on the more general character of the tasks for which DSS are developed. Perhaps the most important aspect for which DSS are developed is related to the assistance provided in solving ill-structured decision problems (not well defined).

Summarising, one could say that DSSs are computer-based systems aimed at investigating the possibilities of realising a pre-defined goal or objective, given a set of pre-defined constraints, each of which refers to aspects of the real world that are subject to decision-making by user *(Reitsma 1990)*. It stands to reason that as the complexity of problems increases, more powerful tools are needed: DSS enables the user to consider many factors at the same time, thereby making it possible derive the optimal economic solution whilst at the same time, assuring the decision is sensible, environmentally.

3.6 - DSS characteristics

According to *Turban, (1990)* a DSS is expected to have the following major characteristics:

- a DSS provides information to support decision-makers in the solution of problems of an unstructured or semi-structured nature by combining human judgement with computerised information;

- a DSS can also be applied where sequential or several interdependent decisions are made. Thus, it can be made to support an environment where many different decisions have to be made sequentially with one decision affecting the outcome of another;

- all phases of the decision-making process: intelligence, design, choice, and implementation are supported by the DSS;

- the DSS should be flexible and adaptable to changing situations within the environment the DSS was developed for. Users should be able to effect modifications to the system be adding deleting, combining or changing elements to suit current conditions.

Another important characteristic relates to users of DSS as the user can be the decision-maker or any other stakeholder. The type of user affects the user needs which should be defined before proceeding with the system design and the selection of analytical methods *(Andriole 1989)*. DSS also require that the models used are understandable to the user: whilst the details of a complex model need not be entirely appreciated by the user, the concept and rationale for the model must be fully understood. Other considerations that have to be balanced against the cost of providing are effectiveness, accuracy, timeliness and quality of decision-making.

3.7 - DSS general structure

Decision-support systems either use data, information or knowledge, with the more sophisticated systems using knowledge rather than data or information. *Turban (1992)* shows that data, information and knowledge can be classified by their degree of interact and quantity, with knowledge being the most abstract and existing in least quantity. Data occupies the other end of the spectrum with information somewhere in between.

In general, a DSS structure has three basic components: input mechanism, processing mechanism and output mechanism. These components are usually formulated or supported by at least some of the following computational elements which are also shown in Figure (3.1):

- Database;
- Geographic Information System (GIS);
- Mathematical models;
- Artificial-intelligence tools;
- Graphical user-interface.

Although a DSS is a tool to solve difficult problems, some researchers consider the user as one of the components of the DSS since both, the user and the DSS work towards achieving the same goal. However, these two have incompatible natures and therefore, should be evaluated in different categories.

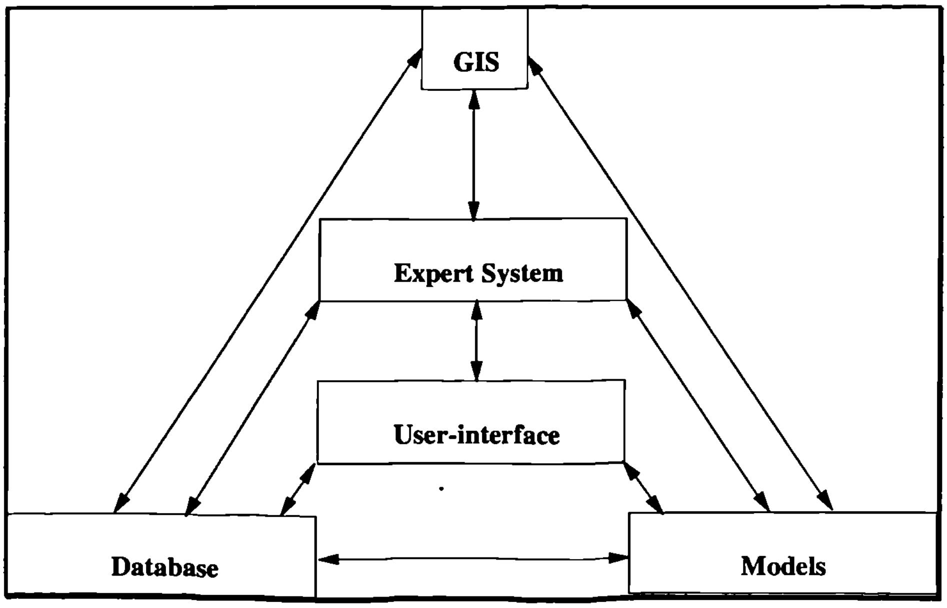

Figure (3.1) - Schematic of DSS components

3.7.1 - Database

The database comprises a software management system for storing and retrieving all non-spatial but nevertheless geo-referenced data which are normally used in modelling and analysis. Moreover databases are used for holding relevant data or information relating to object details and time-series. However, the databases alone are not suitable for data processing or decision-making. According to the data type, there are many different forms of databases available such as ORACLE, FOX-PRO, etc. which are suitable for different hardware platforms.

3.7.2 - Geographic information system (GIS)

The original perspective on GIS was to emulate the graphics perspective of traditional disciplines which rely heavily on maps for their spatial components. Thematic information, often associated with the spatial component, is usually displayed on map graphics and associated with tabular data contained within a relational database package. In this way, GIS can be defined as a set of computer-based tools to capture, manipulate, process, and display spatial or geo-coded data, such as satellite imagery maps, topography, other areal data (geology, soil type, vegetation cover etc.). There are many GIS packages available for various hardware platforms, amongst the well known are GRASS, ARC/INFO and ERDAS.

3.7.3 - Mathematical models

Models are used to provide the analytical capability and can take many forms. Some are used for explanatory or predictive purposes of which, statistical models and simulation models are perhaps the most common. A simulation model is essentially, an evaluation tool without any decision-making capability. This has to be provided manually on a trial-and-error basis or more recently, by the inclusion of numeric optimisation procedures such as linear and dynamic programming, genetic algorithm, etc. Other types of models incorporate multi-objective decision components for the same purpose. Similarly, statistical models are used as a predictive tool which can help the decision-makers in formulating future policy for a certain sector. The literature is full of many examples of both types and others, for a wide range of applications, including water resources.

3.7.4 - Artificial-intelligence tools

Recent progress in the field of artificial intelligence (AI) is significantly increasing the capacity of DSSs to enhance human creativeness and analytical thinking. The literature contains many definitions of AI, one of the popular definitions being by *Rich and Knight (1991)* who defined artificial intelligence as *"the study of how to make computers do things which, at the moment, people do better"*.

AI now provides many successful design and programming tools: these include algorithms for machine learning, robotics, fuzzy logic, expert systems, knowledge-based programming techniques, etc. From a practical standpoint, the goal of AI is to make computers more useful. This can be achieved by producing computer programs that assist people in decision-making, intelligent information-search, or simply making computers easier to use with natural language interfaces. A second goal of AI, but an equally important one, is to improve understanding of human intelligence. Accordingly, building an intelligent computer system requires us to understand how humans capture, organise, and use knowledge for problem solving. The literature contains many applications in different fields including water resources, using one or more AI programming tools.

3.7.5 - Graphical user-interfaces

The user-interface is one of the most important components of a DSS which enables the user to communicate with the system. The more sophisticated versions are interactive, providing considerably more than a means of accessing the different features of the system. For example, some make extensive use of color graphics in presenting the results in a more manipulated way. Others provide access to hypertext which can be used as on-line user-guide in the event of assistance being required. Either way, the aim is to provide easy-to-use facilities which are both flexible and robust, thereby encouraging maximum exploitation of the system's capability. User-interfaces depend on the type of hardware as well as the software itself and can take different shapes or designs, depending on the particular problem. For example, some systems includes one main menu to control the user-machine interface whilst others include different menus.

3.8. - Expert systems

The evolution of expert systems (ES) as with other systems, can be traced to advances in computer science and engineering, especially in the field of AI. *Durkin (1994)* described expert systems as encoding a human expert's knowledge for a computer in such a fashion that this expert program can be run and knowledge applied where needed. The expert program is built from explicit pieces of knowledge extracted from the human specialist. It is modular and can be easily changed when new approaches to the problem-solving become available or when the needs of the problem-solver change. An expert program can explain itself, by describing why some line of questioning is relevant as well as presenting proof for how it arrived at some conclusion. The program is also heuristic in that it seldom relies on exhaustive research methods but rather considers data and knowledge of the application in much the same way as the human expert, with confidence, rules of thumb and encoded experience of problem application.

Others described expert systems as computer programs designed to model a multifold problem and solving it using human expert's experience. In essence, they are a new methodology which have a prominent future in solving many complex multi-variable problems by using the accumulated knowledge of human experts. This process consists of structuring the problem, analysing it and taking a series of sequential and conditional reasoning steps to reach some conclusions. Depending on the nature of the problem, an expert might proceed to the conclusion by passing through a series of steps never before encountered *(McKinney et al. 1993)*.

Hayes-Roth et al. (1983) defined ES as computer programs that embody the knowledge, experience and expertise of one or more experts in the same domain and then apply this knowledge to make inferences about the domain. There are other definitions or functional descriptions of expert systems which cover a broad spectrum, ranging from fairly modest to rather optimistic parallels with human, or even super-human, performance, but all share the same concept. These definitions and descriptions can be found in publications by *Davis and Lenat (1982), Fedra (1991), Merry (1985), Ortlano and Perman (1987), Forsyth (1984)* and many others.

Although expert systems are offshoots of research in artificial intelligence, at this stage they in no way replicate true human reasoning. It is probably better to say that expert systems emulate the actions and decisions of the human expert using some representation of the expert's knowledge and reasoning process *(Collins 1990)*. In simple terms, an expert system is a computer program designed to model and solve problems based on human expertise. Alternatively, an expert system is designed to simulate the advice and knowledge that an expert or experts provide relating to the problem. The knowledge itself is necessary for understanding, formulating and solving problems. Since the main source of knowledge is experts, a knowledge-base is a collection of knowledge in a certain field. It includes two basic facts: problem situation and special heuristic rules which can be used in the problem-solving *(Turban 1990)*.

3.8.1 - ES Characteristics

Expert systems enable dissemination of the decision making skills to others, any time, without having to contact the expert: it's like having an expert available 24 hours a day. This frees the expert for other work and increases work efficiency.

Generally speaking, the main functions of an expert system can be summarised according to *Fedra et al. (1993)* as follows:

- to supply factual information, based on existing data, statistics and scientific evidence;

- to assist in designing alternatives and to asses the likely consequences of such new plans or policy options;

- to assist in a systematic, multi-criteria evaluation and comparison of alternatives generated and studied.

The individual component's of the system can be based on different concepts, levels of aggregation and methods of analysis such as numerical simulation, mathematical programming, symbolic simulation, qualitative reasoning and rule-based inference, all of which could be integrated into one coherent system.

3.8.2 - ES and CP differences

Expert systems are different from conventional programming (CP) techniques. As mentioned before, ES depend on building a knowledge base for a domain problem, where knowledge itself can be represented in various forms and formats. Being close to natural language in their structure, ES are familiar to programmers who use one of the classical procedural languages such as FORTRAN or C. The solution is determined from data-sensitive unordered rules in much the same way as a human expert would. By way of comparison, conventional programs (models) are limited to processing data and unable to reason about the information provided to them. The basis of conventional programming is a step-by-step procedure with a well-defined beginning and end points that will provide an answer to a specific problem in a finite number of steps *(Collins et al. 1990).*

It is clear from the differences between ES and CP that each has its own concept and area of use. Due to complexity of many problems where neither ES nor CP alone can solve the problem, recently a combination of both has become a reality. This affords the prospect of a model that "knows" about the limits of its applicability, what kind of input data it needs, how to estimate its parameters from available information, how to format its input, how to undertake production runs and how to interpret its output. In this way, mathematical modelling would become more accessible to users since it is less depending on computing skills.

3.8.3 - ES main elements

Building an expert system for a particular application, requires the following essential elements:

- a knowledge-acquisition facility which makes it possible for the developer to capture the knowledge and preserve it in an expert system code;

- a knowledge base which contains the specific knowledge consisting of simple facts, rules that describe relations, characteristics and heuristics in addition to ideas for solving problems in the specific domain;

- an inference-engine which implements knowledge-base searching and reasoning, aids in solving problems and answers the questions posed by the user;

- a user-interface which facilitate input from the user and on request, explains the system's inference procedure;

- validation and testing of included knowledge.

1 - Knowledge acquisition

Knowledge acquisition is one of the crucial and probably the most time-consuming step. It can be defined as a process of extracting knowledge from the source of expertise and transferring it to a program (expert system). It involves problem identification, conceptualisation, formulation and implementation as shown in Figure (3.2). The source of expertise is generally a human expert but could also be empirical data, text books, case studies, or other sources. It requires what is called a "knowledge engineer" to extract the necessary knowledge from the expert in a pre-defined way.

Knowledge identification involves determining of (i) participants and their role, (ii) the problem, its definition and characteristics, (iii) the resources for knowledge, computing facilities and time and (iv) goals or objectives for the proposed expert system. The knowledge conceptualisation comprises constructing diagrams of concepts and relationships to make a conceptual base for the ES. It also involves processing the problem solution, its constraints and justification for proposed solutions. The knowledge formulation includes mapping the concepts and sub-problems, into final representation based on various selected tools. Lastly, knowledge implementation consists of mapping the finalised knowledge onto a useful representational framework, implying that the knowledge at this stage is to be well organised, consistent, compatible and ready for representation.

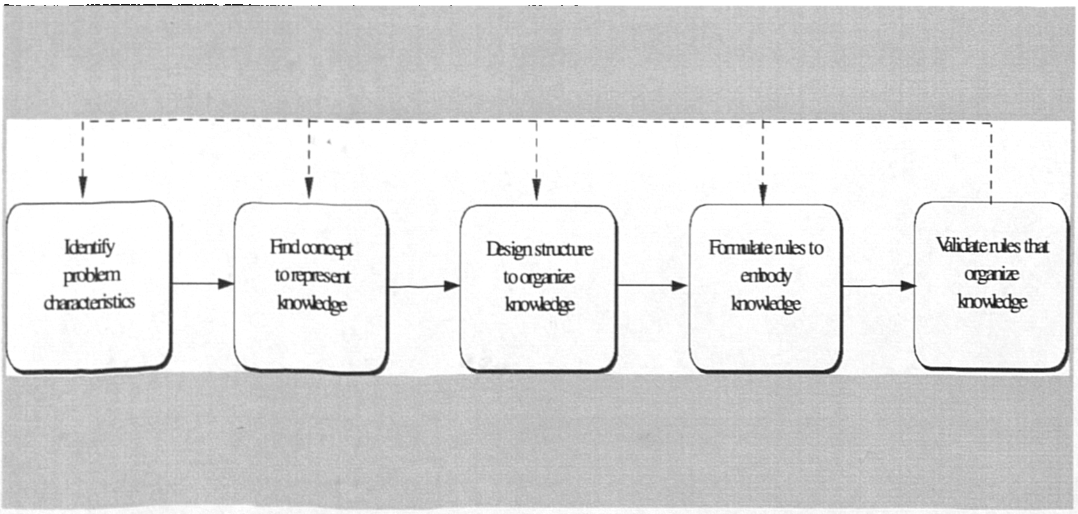

Figure (3.2) - Stages of knowledge acquisition

2 - Knowledge representation

Knowledge representation, is the second element in building an expert system. Once the knowledge is ready, it can be represented in various forms and formats, following different paradigms. The more commonly used forms include rules, attribute value lists, frames or schematics and semantic networks. Probably the most widely used format and also the most understandable form of knowledge representation are rules, which are sometimes referred to as production rules. The most popular form of these rules is (IF ... THEN... ELSE).

3 - Inference-engine

The third essential element for building an expert system is the inference engine. In simple terms, it can be defined as the part of the program that arrives at conclusions or new facts given the primary knowledge base and information which are supplied by the user. There are two basic inference strategies: forward and backward chaining. Forward chaining implies reasoning from data to hypothesis, whilst backward chaining attempts to find the data to prove or disprove a hypothesis *(Forsyth 1984).* Since both strategies have advantages as well as disadvantages, many systems use a mixture of both, as for example in the rule-value approach *(Naylor 1983).*

4 - User-interface facility

Another essential element is the user-interface facility which controls the communication between system and user. It represents the interactive-processing mode, incorporating a user-machine interface that provides answers to identified problems when such information is needed. In many systems, the user-interface also controls the connection to other components in the system such as database, GIS, and external models.

5 - Knowledge testing

The last element in constructing a successful expert system is the testing of the included knowledge. This involves checking that the system correctly implements the original specifications to substantiate that the system performs with an acceptable accuracy by comparing the system outputs with expected ones. However, in addition to deducting the errors and amending them, testing the system includes assurance of producing the correct knowledge for the particular enquiry.

3.9 - DSS and ES applications relating to water resources

Having described the basic characteristics and structure of both decision-support systems in general and expert systems in particular, attention is turned to their applications relating to water resources. As with any other resources, the efficient management of water requires a systematic approach, including data acquisition and processing, use of mathematical models for assessment and forecasting purposes, evaluation of options or alternative courses of action, selection of the most appropriate strategy and implementation of action plans to achieve whatever goals are set. The disciplines involved in the process comprise hydrology, socio-economics, meteorology, environmental science, hydraulic engineering, systems and control engineering to name but a few. Each has its own domain knowledge which is specific to that discipline. Quantitative information is not always available and in many situations, it is necessary to rely on qualitative descriptions, empirical rules and past experience. Where data are available, manual processing is not normally viable and manipulation by conventional programming is not a simple task *(Frenzel 1987)*.

The recent advancement in GIS, database technology, artificial intelligence and other related techniques, offers the prospect of improved efficiency and effectiveness in the management of water resources. These capabilities can be enhanced even further by the inclusion of modelling techniques which act as an analytical kernel, within the DSS. Moreover, data processing and retrieval, pattern recognition, user-friendly interfaces, integrated graphics and support systems have all become more easy to use than ever before *(Waterman 1986)*. As a result there are an increasing number of applications relating to the use of DSS within the water sector. Space considerations dictate that these can not be described in detail and therefore, mentioning the references of the more notable contributions will have to suffice. These include: *McMahon et al. (1984), Fedra and Loucks (1985), Loucks et al. (1985); Fayegh and Russell (1986), Lemon (1986), Barnwell et al. (1986), Fedra et al. (1987), Palmer and Holmes (1988), Dendrou et al. (1988) Crum and Mulvihille (1989), Greathouse et al. (1989), Osterkamp et al. (1989), Rossman (1989), Donker and Jirka (1990), Belyaeva (1993), Richards et al. (1993), Liong et al. (1991), Jamieson and Fedra (1996).*

Notwithstanding these systems cover a wide range of subjects, until recently practical applications have generally been confined to a particular aspect of river-basin management rather than the wide range of considerations normally associated with integrated river-basin management. The concept of integrated river-basin management implies a need for a broader approach than what has hitherto been available, thereby allowing the impact of one aspect on another to be evaluated before taking decision on what is best overall. Recent examples of this approach include AQUATOOL, a generalised decision-support system for water resources management *(Andreu and Capilla 1993)* and the TERRA system for operational river-basin management *(Reitsma et al. 1994)*.

Most of the previously mentioned systems do not have a comprehensive module for computing water demand and effectiveness of demand management. Instead, they consider water demand as an external input which has to be estimated outside the system and to be entered by user. This particular research study focuses specifically on the use of knowledge-based system coupled with other computational techniques such as mathematical models for prediction of future requirements including the effectiveness of demand management, in a module which forms part of a DSS for river-basin planning. The next chapters describe in detail, the DSS structure, functionality, facilities used and the computational procedures involved.

DEMAND-SYSTEM DEVELOPMENT, STRUCTURE AND CAPABILITY

4.1 - Demand-system main objectives

The aim in this research study was to develop a generic, flexible, user-friendly and comprehensive decision-support system (DSS) for predicting domestic water demand, inclusive of demand management. Moreover, it has the potential of future incorporation within a highly-integrated system for water-resources planning. The research was based on a combination of both classical computing techniques represented by the prediction models and the emerging computing technologies such as database, GIS, expert system, user-interface and hypertext facilities.

Since this DSS is intended to be a generic system and the availability of data varies from one country to another and even between different regions within the same country, the system incorporates various forecasting methods ranging from superficial to detailed which can be used for any area and time period. Similarly, it embodies different conservation measures to account for demand management, including the interaction between the proposed and previous conservation actions. Moreover, since the system incorporates rule-based inference and qualitative reasoning, it enables the user to produce several scenarios based on different selected variables. If for any reason and at any stage of analysis a more detailed explanation is required, the user is able to access hypertext files which act as an on-line user-guide.

4.2 - Historical development of the system

As mentioned earlier, the proposed DSS is intended to form part of a highly-integrated and comprehensive water-resource management system for an entire river-basin (WaterWare) which was originally developed within the framework of the EUREKA EU 487 project *(Jamieson and Fedra 1996).* WaterWare is designed to support the water industry and government agencies in the planning and management of water resources at a river-basin scale. The idea of developing a comprehensive management system for river-basin planning was conceived in 1990 and initiated in January 1992. Participants in the project include: University of Bologna, Italy; University College Cork, Republic of Ireland; University of Newcastle upon Tyne, UK; International Institute for Applied Systems Analysis, Austria; and Thames Water International, UK.

The role assigned to the three academic partners involved adapting existing models and formulating new ones for inclusion within the system, whereas that of the International Institute of Applied Systems Analysis was to develop the architectural framework and create a software environment for model integration. Thames Water International assumed the responsibility for providing the domain knowledge and applying the prototype system. The present base system does not have all the functionality originally envisaged but has sufficient to be applicable to the normal range of problems encountered in river-basin planning. Further functionality is being added, including a demand-forecasting module, and that is likely to continue for foreseeable future.

4.3 - WaterWare concept and design

The main objective was to develop a comprehensive DSS for river-basin planning and management which was capable of addressing a wide range of related planning issues. Due to complexity of such issues, the approach adopted was to create a flexible, modular package which allows the selection of appropriate elements for a particular application, thereby avoiding the need to implement the whole package. The inherent flexibility in the system allows the users to undertake the analysis themselves rather than rely on some third party such as external consultants. This is achieved through the provision of expert advice and intelligent interrogation facilities. The artificial intelligence involved is provided by a mixture of optimisation techniques and expert systems which can evaluate, draw conclusions and recommend appropriate actions. Moreover, embedded expert systems are made available to assist in the use of analytical facilities provided. In this way, the manager can make rational use of the system without an in-depth knowledge of modelling techniques.

Accordingly, the software system has been designed based on a set of standards, conventions and formats, shared tools, and a common language for problem representation. This provides the greatest possible flexibility for future updates and continuing development of the system. Within this framework, various applications can be undertaken using appropriate components of the system which are configured for the particular river basin. Differences from one river basin to another are reflected in the components selected and the data set they require but all share the same common software system.

Communication with the system is by means of a user-friendly interface which makes extensive use of hypertext to guide the user and color graphics in presenting the results. If the user is familiar with the system, he can call the appropriate model directly: if not, he will eventually be able to find help files which will provide assistance in model selection. Either way, the actual operation of the system has been designed for easy use. A keyboard is not normally required since all the facilities are accessed by touching the appropriate icon representing the particular component.

The basic architecture of the system, including the interaction between various components is illustrated in Figure (4.1). This comprises the following components:

- a main program that co-ordinates the individual tasks and provides access to every module through a menu of options: in the simplest case, this is just one screen with an appropriate menu that triggers individual applications or components: in a more complex situation, this could involve a decision-support or expert system module that co-ordinates the individual applications or components, most notably models, in a problem-specific manner;

- a GIS that stores, displays and analyses all geo-coded information such as satellite imagery, maps etc.: in the simplest case, this could be based on public domain software such as GRASS or a propriety package as for example, Arc/Info: alternatively, it could comprise a dedicated GIS specifically developed for a particular application which only supports an efficient sub-set of options;

- a generic database management system (DBMS) that provides access to non-spatial but nevertheless geo-referenced data such as object details, time-series data etc.: again, this could be a commercial DBMS such as SQL databases or a dedicated file-handling system for a particular application;

- at least one and in most cases, several simulation, optimisation, expert-system models with access to data from GIS, DBMS and other functional modules to provide the analytical capability: for example, these could include demand forecasting and management, environmental-impact assessment, water-resources planning etc.

- a set of pre- and post-processors which support editing of the input data and the visualisation or analysis of model output, in addition to handling scenarios for each of the models;

-a user-interface with access to the various functional components of the system and the various help/explain files;

- a set of utility functions which assist in data preparation and management tasks.

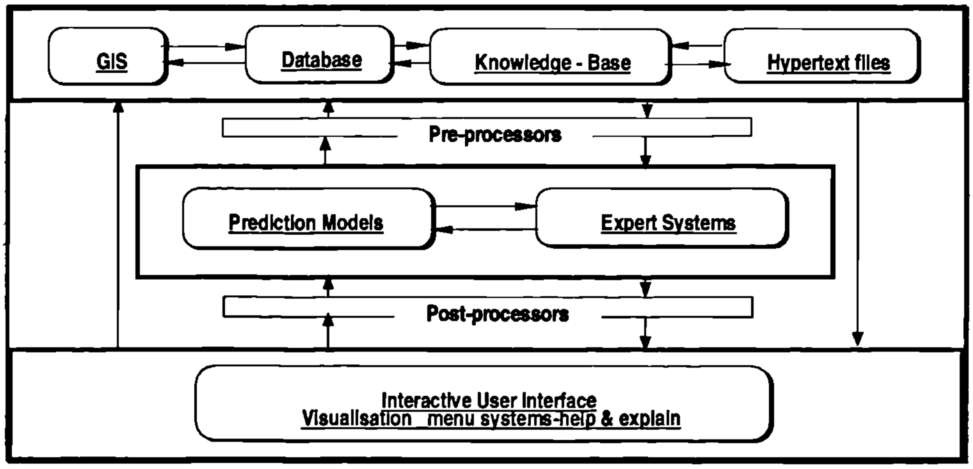

Figure (4.1) WaterWare system architecture

4.3.1 - Hardware and software standards

WaterWare has been designed with a variety of general-purpose UNIX workstations in mind. The average size and complexity of a realistic river-basin application with its simulation models and highly integrated data sets dictated this choice at the time the system was developed. The preferred platform is the SUNSparc station (2, 5, 10, 20) with a minimum of 32 MB RAM and 1 GB disk space, 8-bit color-graphics and a 120 x 1024 screen resolution (GX plus, TGX plus). The current version occupies close to 500 MB of disk space.

With respect to software standards, the operating system and windows environment are UNIX (Solaris 2.x) and X Windows/X lib (R11.5/6) respectively. Several window managers, including uwm, twm, and SUN Open Windows can be used to run the application. Although WaterWare is coded in C/C^{++}, making extensive use of ACA Toolkit to ensure common style, look and feel, it is also capable of integrating models written in FORTRAN 77. Compatibility with Arc/Info, GRASS and ERDAS is achieved through a set of filters which convert external formats into the specific GIS data structure used. Other formats such as DXF can be imported by first converting to, say Arc/Info.

4.3.2 - WaterWare Components

Currently, WaterWare (Thames version) consists of GIS and DBMS coupled to an increasing number of analytical components including water-resources planning, groundwater pollution control, reservoir-site selection, irrigation requirements, etc. The individual functions and modules of WaterWare system are accessible through the various levels of icon menus, commencing at the top level on the start-up screen. New components can be added and existing ones expanded to include additional models and modules. Provided the new components comply with the generic interface definition, there are no limits on the capability to replace existing or to add new elements.

The various components in the system deal with different sets of river-basin objects which are geo-referenced that is to say, they are known by location (map display and selection through GIS component). The various river-basin objects are grouped by classes in the database, as for example, climatic stations, flow gauges, water-quality stations, irrigation districts, industries, treatment plants etc. Each object is represented by a node in the network whose connectivity is described by its linkage to other nodes. In this way, the physical layout of the river basin can be configured, providing a node-arc structure to which the various models can be attached.

4.3.3 - Water demand in WaterWare

The current version of WaterWare provides the users with the possibility to store water demands for different purposes according to their spatial units. This is achieved by considering these units as independent classes in the database as for example, irrigation districts, industries, urban areas. In this way, the user can find and change these values as required. This is necessary prior to, say, running the water-resources model (WRM) which allocates the available resources to meet the projected demands, thereby ascertaining the system reliability.

In all cases, estimates of water demand for the various sectors are prepared outside the system and entered as input data. The only exception in this respect is irrigation requirements which can be computed by an agro-economic model referred to as CROPWAT *(Doorenbos and Pruitt 1977)* which is the only predictive model presently included within the demand-forecasting component. This still leaves the need for a similar capability to estimate future demand for other sectors in general and domestic in particular since the later represents a significant portion of the water demand in most countries. The possibility of developing additional modules for commercial and industrial water demand remains unresolved and dependent upon future funding becoming available.

4.4 - Decision-support system for domestic water demand (DFMS)

Since the main objective of the DFMS is to help water planners or decision makers (both experienced or inexperienced) in forecasting domestic water demand, the first step in designing the system was to look to user's requirements. The following requirements were found as the most important:

- capability of dealing with different types of data since the planning needs of users and data vary from country to country and even within the same country;

- flexibility since there will be future developments in computing the various variables. For example, the system has to accept adding new components or deleting existing ones or linking external models without the need to restructure or recompile the whole system;

- potential of integration within a more advanced water management system;

- informative, easy to use and user-friendly since the experience and computing capabilities of users vary. For example, the system has to provide the users with the necessary information and help when required and with minimal effort.

Based on these requirements, the proposed DFMS will have the following characteristics:

- eventually form part of a highly-integrated system for water resources planning (WaterWare);

- incorporates several prediction models for forecasting domestic water demand depending on data availability, taking into account the effectiveness of various conservation measures, coupled with some of the emerging technologies such as GIS, database management, expert system, user-interface and hypertext facilities in one coherent program;

- intensive use of an expert system to assist with the prediction of demand variables, evaluation of the various options, drawing conclusions and recommending appropriate actions;

- easy to use for both the experienced and inexperienced users since it is driven by menu system which relies on a mouse rather than a keyboard;

- informative and user-friendly since the communication between user and system is by means of a graphic user-interface which makes extensive use of hypertext files.

4.4.1 - DFMS architecture and design

Since the DFMS forms part of WaterWare, it has benefited from the various computing facilities of the main system such as GIS, database, expert system shell, user-interface and hypertext. Therefore, the DFMS is structured in a way which is compatible with other modules in WaterWare; for example, it starts from the GIS side where geo-refernced information are located then accesses the database where the non-spatial data are stored, then the expert system where data can be entered to the system or results can be deduced from the knowledge-base.

Moreover, expert system provides the user with possibility to link an external models and hypertext files.

Since the DFMS references water demand to the demand zone (demand zone is a discrete area of supply which is largely defined by the perimeter of the water distribution network), a new class named 'demand zone' has been added to form one of the numerous classes of river-basin objects such as climatic stations, wells, water quality etc. of the database module of WaterWare. This has been effected simply by adding the demand-zone class in the *CONFIG* file relating to the *data/objects* directory (the contents of the *CONFIG* file are shown in Appendix I). The demand-zone class includes all the names of the various demand areas of the river basin which in this case, has been taken to be the Thames in southern England. Each demand zone has its own display screen which contains important information relevant to the needs of the responsible manager. Part of this information is a list of descriptors (a descriptor being the basic element of an expert system) which represents the natural link between the database and expert system as shown in Figure (4.2).

Since site-specific data are required, information is solicited from the user which is subsequently combined with spatial and time-series data from the GIS and database respectively. This takes the form of a question-and-answer session. If the user does not have the specific information requested, an embedded expert system using domain knowledge gleaned from the literature will attempt to estimate missing information. As with any expert system, if the answer is not understood, it is possible to browse the knowledge-base in order to obtain a logical explanation as to why the system has deduced that particular answer. Moreover, if for any reason further information or explanations are required at any stage, it is possible to invoke the necessary support from hypertext files specially created for this purpose

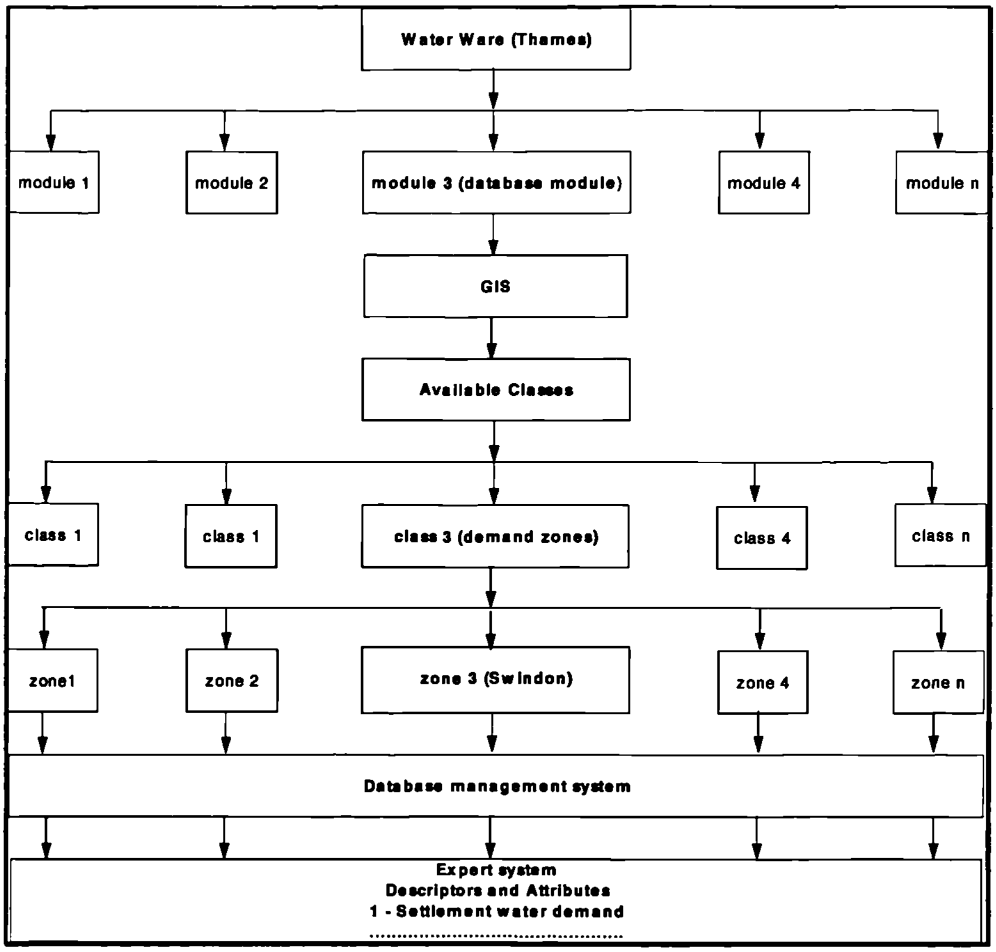

Figure (4.2) - DFMS hierarchical link with WaterWare system

4.5 - Geographic Information System (GIS)

The GIS is an essential feature of the WaterWare system, since almost all modules have an explicit spatial dimension. It is linked to and accessible from, most components of the system. As a major component in its own right, the GIS provides functionality in storing, displaying and analysing all forms of geo-coded information. Amongst other things, this includes base maps, satellite imagery, windows for active and passive layers, arbitrary zooming, help facilities etc. The location (x,y,z) of the any site in the river basin can be obtained by dragging a cross-hair cursor over the map displayed on the screen and pressing the left mouse button at the appropriate spot. GIS layers include the major characteristics of a river basin such as catchment areas, basin boundaries, roads, cities, urban areas, rural areas, satellite images etc. All GIS overlays are held in Sun raster formats and located in the *data/rasters* directory.

4.6 - Database management system

Information relating to the demand zones is contained within the database. This information is coded in a special format under a specific header-file carrying the name of the demand zone. The DBMS is responsible for activating a screen-display function that enables editing of the various attributes before loading the save functions which are used to make any changes in this information permanent.

The header files for the various demand zones are located within the *data/objects/settlements* directory, an example of which, together with the contents of one of these files is shown in Appendix I. Although the features of header file vary from one application to another, the demand-zone file normally includes the following main elements:

- a list of target descriptors which usually represent the most important information the decision makers are looking for such as regional water demand, population, growth rate etc.;

- lists of numbers and text strings which contain header information that specifies the type, name and units for its elements (such as locational data, elevation etc.), as well as (optional) reference to a hypertext file with additional meta-data;

- images which can have different formats (either Sun rasters or X Window Dumps), with a corresponding hypertext reference that includes the title and related meta-data.

4.7 - Embedded expert system (ES)

Besides assisting with the estimation of missing information, the ES undertakes a variety of other tasks. For example, its basic elements (descriptors, and inference strategy) are used as a development tool in a similar way to any other programming languages in organising the forecasting process, performing arithmetic computations and communicating with external programs. Additionally, the ES facilitates interaction between the user and the system through its communication menu which is used for both data entry and deduction. In this way, the ES is more helpful than classical programming techniques which lack many of these advantages. Moreover, the ES does not require any compilation procedures once any additions or changes are included, which is not the case with other languages.

ES descriptors are used to reference each variable or component in the demand-system whilst rules describe the necessary pre-conditions of the descriptor, including various possible answers (values or text) which the descriptor can take. The rules (tables) are also used to link the different components which are necessary to predict a descriptor's value by means of simple numerical formulae. Bearing in mind that descriptors are limited to only one value at any time, there is no direct way of dealing with multiple inputs and outputs. Therefore, the only possibility for achieving this end is through linking an external model to a descriptor. These models also can be used to include more sophisticated mathematical formulae which can not be performed by the rules themselves.

4.7.1 - Descriptors

Descriptors use a straight forward syntax, including an object-oriented design for the basic element in the inference procedure. They are linked through natural rules that allow the derivation of a given descriptor from other descriptors through standard first-order logical or arithmetic operations. There are two types of descriptors: (1) target descriptors which are included in the demand zone header-file and displayed jointly with other attributes of the demand zone on a special screen, (2) complementary descriptors which represent any further information or procedures required to deduce the answers of the target descriptor. The second type of descriptors is not included in the header file and as a consequence of this, tdesscriptors values are not saved and displayed on the main screen. However, the deduced answers of these descriptors becomes default values once the user confirms them and they will remain so as long as the system is operating. The complementary descriptors are listed in a plain text file named *Descriptors* at *data/KB* directory, the full list of which, together with its contents, is shown in Appendix II.

Descriptor definition includes basic characteristics such as name, type, units of measurement and a list or range of legal values the descriptor can take. Depending on the descriptor, these values can be symbolic, numeric, or both (hybrid). Descriptors also know about methods they can use to establish their values in a given context (for example, the current values of other descriptors). These methods include questions to ask of the user, database or GIS references, rules, tables, references to complex numerical functions and simulation or numerical models that can be used to obtain an appropriate value.

In the interactive dialogue, the user can choose between different methods. Priorities of methods (i.e. which one should be tried first) are also defined in the descriptor definitions and can be dynamically modified through rules. Finally, descriptors can have an alternative set of (partial) definitions which are under rule control, to be used depending on the context. This helps in avoiding redundant descriptors by using the same descriptor with a different alternative range of answers. Generally speaking, the generic syntax of descriptors may include different elements according to the application involved. Some of these are mandatory (have to be included in any descriptor) and others are optional (depending on the application involved and source of information). A dummy example of a descriptor structure containing the most common parts is shown in Figure (4.3a).

```
DESCRIPTOR
name
T S
U (unit)
V (values) low [ 0, 200 ] / moderate [ 200, 400] / high [ 400, 600 ] /
R (rule) 50010 /
ALTERNATIVE
Alternative(aaaaa)
V low [ 0, 300 ] / moderate [ 300, 500] /high [ 500, 700 ] /
ENDALTERNATIVE
Q(question) yyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyy?
ENDESCRIPTOR
```

Figure (4.3a) - General syntax of a dummy descriptor with an alternative option

Each descriptor has to start with the word DESCRIPTOR and it has to end with the word ENDDESCRIPTOR. Between the start and end terms there should be a descriptor name, descriptor type, unit, values and a question: other parts such as tables, rules, model, alternative and layout are optional, their inclusion depending on the descriptor function and source of answer. Whilst underscores are filtered out for display purposes, they are, however, required to simplify the file input procedures.

The descriptor type is an essential part of the descriptor definition since it controls the basis on which the descriptor will interact with both the user and other descriptors. If the descriptor only has symbolic information, this leaves the descriptor without context. In other words, when setting a descriptor value to small, medium or large, the user must have the context of the problem in his mind so he can decide what is big, what is small and compared to what. The hybrid type of descriptors have both numerical and symbolic values (a numerical value range assigned to a symbol). The inference engine uses the numerical value assigned to the descriptor, but when a symbol is assigned to a hybrid descriptor the median of the corresponding value range is used. If a symbol needs to be derived from a number, the corresponding interval/symbol is determined: if the number needs to be derived from the symbol, the mean value of the range corresponding to the symbol is used. The choice of the value range is the most essential step in the construction of the hybrid knowledge base. The alternative option to avoid redundant descriptors (two descriptors with same context but with different numerical ranges for the symbols) can be performed by using meta-rules to adapt the numerical range based on the same context. All meta rules are fired before the inference engine tries to determine the value of the descriptor under consideration. In this way, the system "knows" the context in which the descriptor is used, so that it can use the appropriate value range. An example of settlement-water demand descriptor is shown in Figure (4.3b).

```
DESCRIPTOR
settlement_water_demand
T S
mcm/day
V very low [ 0, 0.1 ]  /  low [ 0.1, 0.2]  / moderate [ 0.2, 0.3 ]  /
V high [ 0.3, 0.4 ]  /  very high [0.4, 0.5 ]
V low [ 0, 300 ]  / moderate [ 300, 500]  /high [ 500, 700 ] /
Q what is the expected water demand for this area in millions of litres
Q per day ?
R 500115 / 500116 / 500120 / 500122 /
ENDESCRIPTOR
```

Figure (4.3b) - Descriptor of settlement water demand

4.7.2 - Rules

The rules represent the explanation required by a descriptor to obtain its value from other descriptors. Rules can include basic first-order logic operators or simple arithmetic. Moreover, they can be used in conjunction with both numerical or hybrid descriptors. Tables are another form of rules which represent a shorthand notation for a set of rules. Rules and tables are similar to descriptors in that they are saved in a plain text file named *Rules/Tables* and located in the same directory *data/KB,* the full list of rules and tables with their contents being shown in Appendix II. Rules consists of two basic parts: (1) premise (the list of conditions which are to be tested); (2) conclusion (the actions to be performed, if all conditions of the premise have been fulfilled). Both premise and conclusion are linked together by a logical operator; sometimes, the premise itself contains an arithmetic equation. Rule structure varies from simple to complex depending on the context. However, the rules in the simplest syntax would contain the parts shown in Figure (4.4).

```
RULE 500200
IF        [bbbbb     ==    ccccc
OR         bbbbb     ==    ddddd ]
AND       [aaaaa     ==    ggggg + fffff
OR         aaaaa     ==    hhhhh ]
THEN xxxxx           =     zzzzz
ENDRULE
```

Figure (4.4) - A standard dummy rule with three condition statements, one of which has arithmetic expression

Any rule has to start with the word RULE followed by reference number (IDD) and to end with the word ENDRULE. Between the start and the end terms, there should be at least one condition and one action statement. In this way, the rules can have as many conditions as required but only one action related to these conditions. Once all these actions have been fired, then the rule assigns a result (action) to the related descriptor. The various conditions of any rule should be linked by a logical operator (AND/OR), before assigning a value to descriptor (action). Within the same condition statement there may be a string or a mathematical expression with simple operators which link more than one descriptor together. However, if more complex mathematical expressions are required, the only possibility is to include an external model with the descriptor. In the particular case when the descriptor includes an alternative option, it is necessary to associate a set of meta-rules with the descriptor. The common syntax of such rules is shown in Figure (4.5).

```
RULE 50010
IF          bbbbb      ==     ccccc
THEN xxxxx Becomes Alternative(aaaaa)
ENDRULE
```

Figure (4.5) - Meta-rule with one condition statement

4.7.3 - Inference engine

The ES inference strategy depends on the structure of the problem which usually starts with a target descriptor representing the final objective or the end result to be deduced. The rule-based inference chain contains a target descriptor which may contain a sets of rules or tables or an external model. In the same way, each of the complementary descriptors may contain rules or tables or a model. Therefore, the inference procedure starts from the top with the target descriptor and works its way to the bottom until it arrives at a descriptor or set of descriptors which has no further links: then it returns back step-by-step until it arrives at the target descriptor again as shown in Figure (4.6).

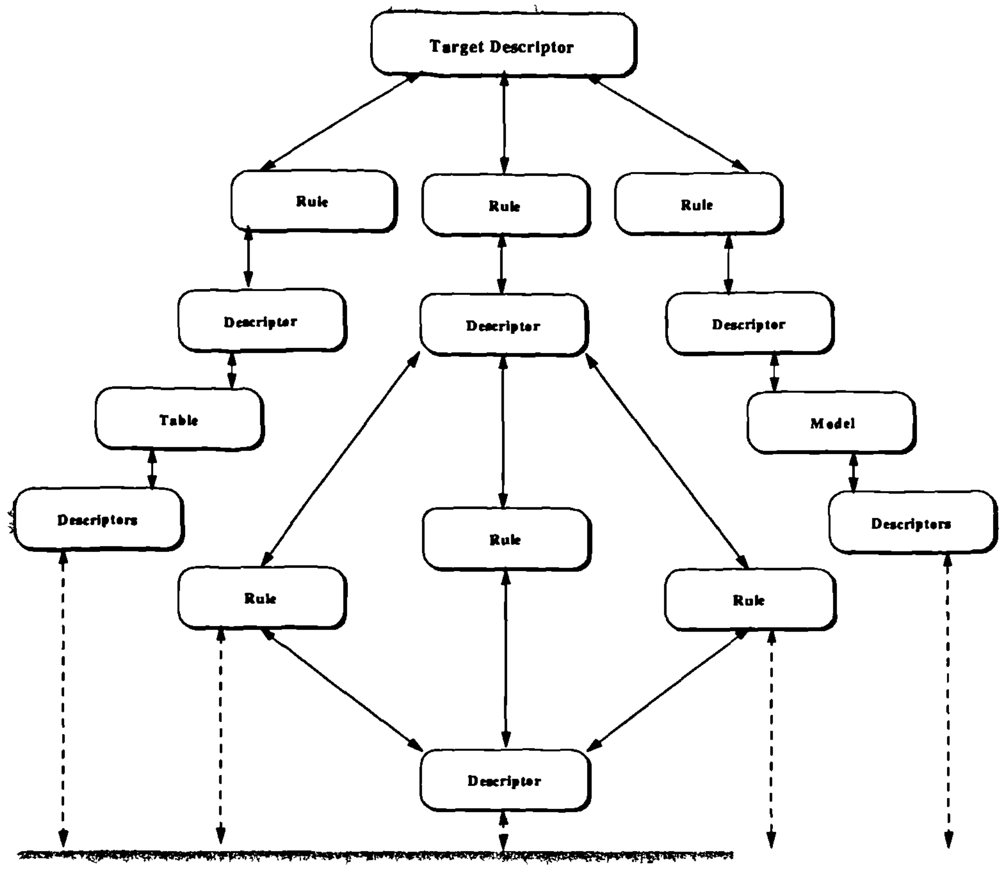

Figure (4.6) - Expert system inference tree

Accordingly, whenever a descriptor is needed (i.e. referred to in a rule), its definition is instantiated, that is to say, it assumes specific properties such as a list of possible values, an admissible range of values or a default value, in place of the generic description definition. Therefore, the instantiated descriptors are organised in an object-oriented, hierarchical network as individual entities with associated rules which form the basis of the reference process as shown in Figure (4.7).

These rules are applied within the present context, defined by the descriptor values currently pertaining and can be one of three types viz.:

- estimation rules, which deduce the value for a descriptor, either from other sub-problems, which are represented as descriptors or alternatively, formats which are entered by the user;

- consistency and plausibility rules, which maintain the consistency and plausibility of the descriptor values by selectively restricting the list of possible values for descriptors to be instantiated, based on the current context;

- learning rules, which maintain the consistency of the value ranges of the generic descriptor definitions, based on a history of all contexts which have been generated in previous runs of the expert system.

The inference procedures depend on the listing of rule numbers (IDDs). It starts with the estimation rules: if no rules are specified, a simple editing tool is available to set the required parameter values directly. If a set of rules (at least one) is specified, the editing tool also offers the option of Rule-Based Deduction. This triggers the deduction system, which will automatically determine a value for the target descriptor in the current context. If the system cannot obtain a required data item (the value of another descriptor) required for the inference, this may include a step-by-step interactive dialogue with the user, who is then asked to supply the missing information.

The user can also choose to display (trace) individual rules as they are processed and for that matter, skip rules that he does not wish to use. An inference result can be traced back, step-by-step, in an explain-function triggered by the WHY option to assist in the assessment. This is in addition to the possibility of using the knowledge-base browser which can display all the rules and descriptors, their current values and definitions, for a given first-order descriptor.

Once all the rules which set descriptor values (for a given top-level descriptor) have been tested and possibly applied, all the incrementing rules, if they exist are evaluated. Incrementing rules, use INCREASES and DECREASES operators and can modify descriptor values which have already been set by another rule. The result of their evaluation is therefore, a shift up or down, in the final value of the given descriptor, by one or more units. More than one incrementing rule can apply and their individual modifying effects are accumulated. The corrected values are then used at the context level of inference.

When the descriptor answer has been deduced, the consistency and plausibility rules are activated in order to check if the new descriptor value places any restrictions on the possible values of not yet instantiated descriptors and mark their values as "not plausible". In the current implementation, this is restricted to setting descriptor values not required in the current inference chain to specific values automatically as a consequence of the user input. Once the rules are fired one or more times, they become learning rules.

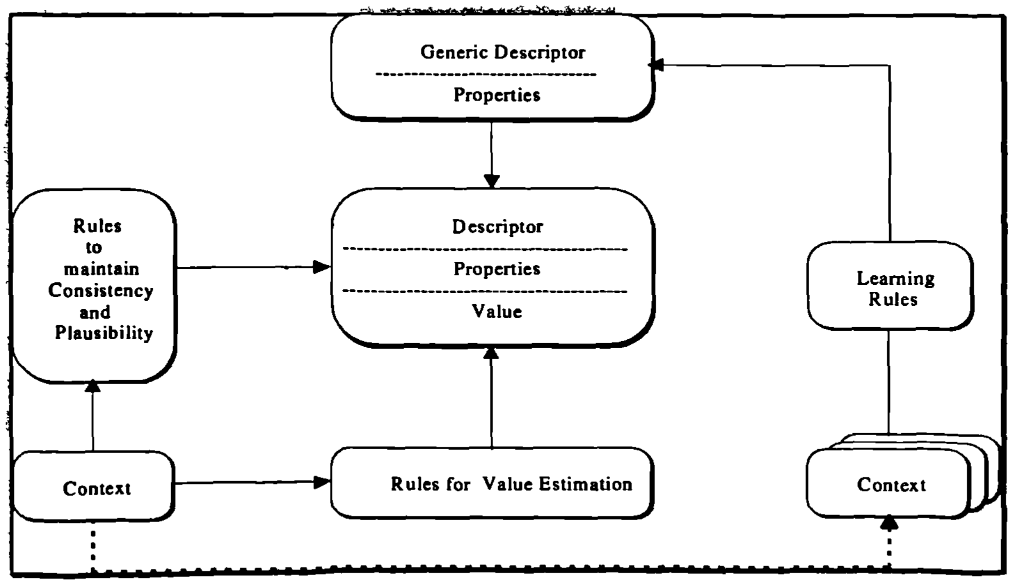

Figure (4.7) Inference strategy for a descriptor

4.8 - Mathematical models

Several prediction models for forecasting domestic water demand are coupled to the expert system since the rules cannot handle complex arithmetic. Moreover, it is possible to display multiple outputs by means of these models whereas this is not the case with the expert system which only supports one single result. The combination of an external model with the expert system has to allow for a smooth transfer of the data between them which requires a third program. Basically, this program comprises four interrelated routines: *interfreceive, interfsend, interface and model itself.* The external programs which are linked to various descriptors are located within the *models.sun5* directory which are described in detail in the next chapter. The main duties of the external program can be summarised as follows :

- accepting a connection from the expert system;
- receiving the model input descriptors ;
- checking the validity of the received descriptor values;
- converting the input descriptors from expert system to model data format;
- transferring input data from the interface program to the model;
- starting the model, waiting for the model to exit, and collecting model outputs;
- checking the results of the model outputs according to any included criteria;
- converting model output to descriptor values in the expert system;
- sending the model results to the expert system;
- displaying model outputs on the screen.

Obviously, the extra option of invoking an external model in the inference process needs to be incorporated in the descriptor definition as shown in Figure (4.8). This definition has to start with the word MODEL and to end by the word ENDMODEL. In between, the following elements also have to be included:

- model name;

- model type (T), which can be "local wait" or "local not wait" or "remote wait" or "remote not wait". Model type is dependent upon the computer system used. For example, a model which can run on the same machine should include a "local wait" mode, or if the model is running on another machine communicating with the system through a network then a "remote wait" mode has to be included. Similarly, other types can be used for different purposes.

- model input descriptors (I): this element includes all the model input parameters regardless of their order. However, the inference engine will check whether all input descriptors have a value before invoking the model run.

- model output descriptors: these may include one or more descriptors which represent the main outcome of the model. All the outputs should have descriptors since the inference engine knows which descriptors are expected from the model.

```
DESCRIPTOR (name 'xxxxx')
T S
U (unit)
V (values) low [ 0, 200 ] / moderate [ 200, 400] / high [ 400, 600 ] /
MODEL(model name 'aaaaa')
T local_wait
I model input 1 / input 2 / input 3 / etc. /
O model output 1/ ouptut 2 / output 3 / etc. /
ENDMODEL
Q(question) yyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyy?
ENDESCRIPTOR
```

Figure (4.8) - Syntax of a dummy descriptor combined with an external model

4.9 - User interface

The main function of this facility is to allow the user in a simple, flexible and friendly way, to communicate with system. The DFMS interface is part of WaterWare user-interface whose functions are based on the Xlib (a public-domain library which represents an integral part of the X Windows system). Figure (4.9) shows a schematic of the integration between the X-Windows system and WaterWare modules.

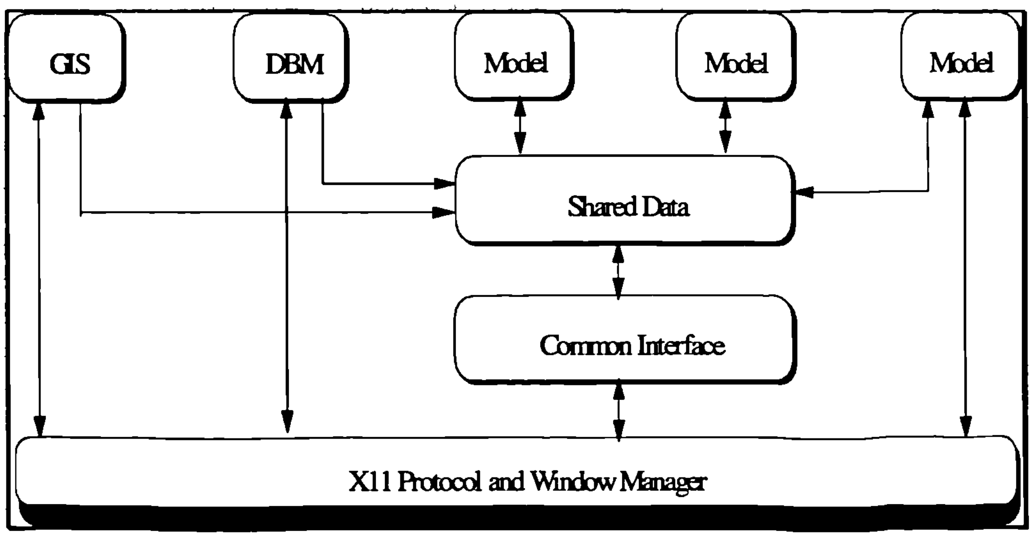

Figure (4.9) - Integration and common interface through X Windows

All modules share a number of similar features which when taken together, provide a common style for the user-interface. Each module has it own full-screen start-up page which conforms to a standard layout, including a header bar with a set of icons and the name of the module. At the bottom of the screen, there is a message bar containing status information and prompts for the user. Additionally, every screen contains at least two icons, namely an information icon, giving access to the hypertext and an exit icon which returns the user to the previous level of the application or to the UNIX system shell from the top level.

Furthermore, a default set of options is defined for every module in order to control the initial results or status, as in the case of a default scenario for a model or deduction process.

The options which the user can invoke are either icons, items in a selector (such as a descriptors list or names, GIS layers, etc.), specific header parts or symbols on a map. Moreover, the options (icons, windows, selector lines) provide optical feed-back by highlighting a colour change when the mouse pointer is positioned in or over them, to indicate that they represent selectable options. For example, numbers that can be selected for editing are blue; hot keys in the hypertext are also blue etc. In many cases, the message bar at the bottom of the screen provides additional guidance to the user by identifying options. Options are always selected with the mouse, by positioning the pointer and clicking the left button.

With regard to screen design, the left part of the screen is used for status information and further options, leaving the right part to be used for graphical displays such as maps and diagrams. Icon menus are usually located in the lower part of the screen whilst both information and exit icons can be found in the header bar of the window. Pop-up windows are usually identified by a shadow-style frame that sets them off from the underlying set of windows.

4.9.1 - ES-communication menu

The ES communication menu is designed to serve rule-based inference by means of a step-by-step, question-and-answer session. Therefore, it can be activated by selecting any of the target descriptors from the demand-region display-screen, say, settlement (urban) water demand. As far as menu design is concerned, it can be divided into three main parts: firstly, the question window, where the descriptor question appear;. secondly, the answer window, which contains two smaller windows one for numeric entries and the other for symbolic answers (high, moderate, low, etc.) from either keyboard or by mouse; thirdly, the communication and deduction buttons which include the following:

1- Rule-Based Deduction button: this button becomes active only if the descriptor definition contains at least one rule or table, otherwise it is inactive. The button is used for step-by-step deduction of the descriptor result, either from direct rules, or tables, or arithmetic equation. If an answer for any descriptor has been deduced already, selecting this button again leads to re-deduction mode, where another trial can be undertaken. The re-deduction mode has its own window which contain a set of buttons including confirm, re-deduce, browse etc. Before the system re-deduces any answer it displays the previous one in default format (with a blue colour) to remind the user, that it has been deduced before.

2- Run-Model button: this button will be active only if the descriptor contains a link to an external model. Its functionality is similar to Rule-based deduction button, the only difference is that the results will be the outcome of an external program and will be displayed in a special window (model-output window) rather than the expert-system window.

3- Model Parameters: this button is complementary to previous one, providing the means by which the user can update and change model-input values. Selecting this button leads to the model-inputs window, where all input values are displayed. Any change in model inputs will be reflected on the Run Model button by changing its colour to green indicating that there is some change in the model parameters which have not been considered in the previous run and therefore, the model has to be run again.

4- Abort button: this button provides the exit from the ES window, selecting it will take the user to demand-zone display screen.

5- Confirm button: this button is to save values deduced or entered by user and to move forward to the next step in deduction process.

6- Rule-Trace Off/On button: this button is complementary to Rule-Based deduction process by which it is possible to change deduction mode from Off to On. Off-mode means no rules will be displayed during deduction whilst On-mode allows the user to see the various rules and follow them one by one in the deduction process which can be helpful in understanding the deduction procedures and for that matter skip rules that user does not wish to use.

7- Check Hypothesis/Why buttons: these two buttons are used for knowledge browsing, to trace back the deduced results in terms of descriptors and rules structure in the knowledge base. It displays the text of rules and descriptors which are used in the deduction. The user will be able to see descriptor definitions including data ranges, rules and hypertext files. Moreover, it displays a summary of all required descriptors and indicate whether they have answers or not.

8- Hypertext button: this button enables the user to display hypertext files for that descriptor. The hypertext button is located at the top right corner of expert-system menu.

4.10 - Hypertext files

Hypertext files provide an on-line user manual for guidance. More specifically, it contains further information and explanation of the terms and descriptors used in the system's knowledge base, if for any reason help is requested. Hypertext files are accessible from any level of the system, with special icons (information icon) located on all screens (start-up screen, object display screen, ES screen etc.). Selecting any of these icons by the mouse pointer will call up the corresponding explanatory-text page which in turn, contains numerous other keywords leading to further related information.

Hypertext files are written in a special format which are dedicated to this file type of ACA hypertext format. Through this format it is possible to link key words in the hypertext file to another help-files which contain further explanation and details. Moreover, there is a facility to link pictures or icons in the same way, in addition to the possibility of using different colours and fonts in writing these explanations which can be useful for highlighting important aspects. Hypertext files are located within the *data/explain* directory which are distributed depending on the screen functionality. For example, the demand-zone screen has a hypertext file within the *data/explain/settlement/* directory.

DOMESTIC DEMAND VARIABLES AND COMPUTATIONAL PROCEDURES

5.1 - Introduction

This chapter focuses on the various computational procedures for forecasting domestic water demand and demand management as they appear in the knowledge-base. Moreover, it illustrates the various types of information which are necessary to predict domestic demand. The method adopted in describing these variables and procedures has been taken from the structure of the system itself: in other words, the target components are described first, then sub-components and so on to the smallest element. However, prior to that a brief description is given on how the domestic-demand component appears in the knowledge-base.

According to the DFMS structure, the various attributes of any demand zone are referenced in the knowledge-base by target descriptors such as settlement-water demand, population, per-capita consumption, population-growth rate, etc. Since settlement-water uses includes domestic uses, commercial uses and unaccounted-for water, its descriptor is connected to a set of rules which distinguish between these uses. Moreover, these rules allow for selecting either an individual water-use or an aggregate set of uses. The domestic-demand descriptor is the only one which has full procedures for forecasting water demand and demand management, whilst the descriptors of commercial uses and unaccounted-for water only accept exogenous values for the time being.

5.2 - Domestic-demand model

Domestic demand depends on different variables such as demographic, socio-economic, climatic, etc. These variables are organised in what is called "domestic-demand tree" as shown in Figure (5.1). All the variables in the demand tree are referenced in the knowledge-base by descriptors. Some of these descriptors

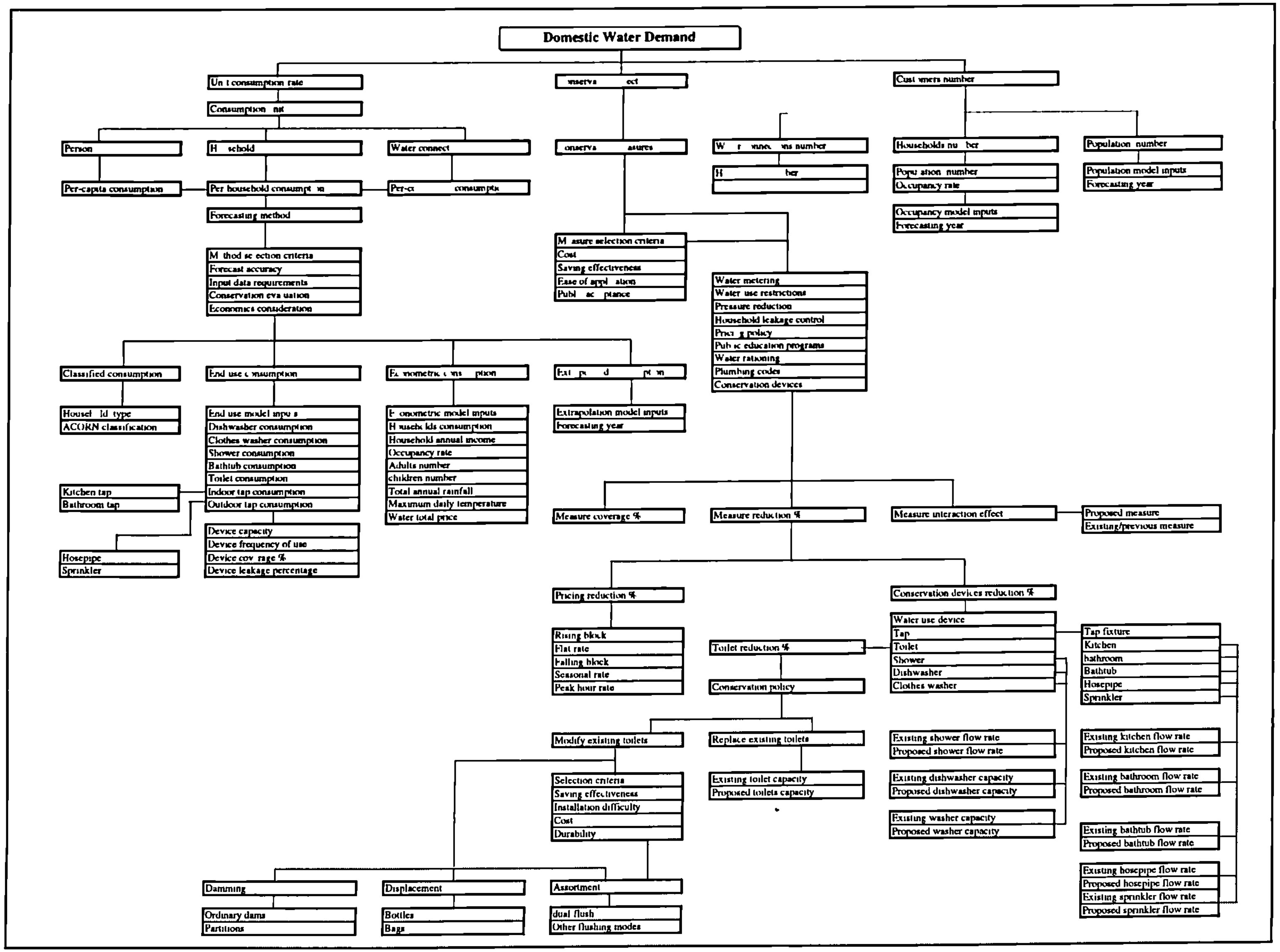

Figure (5.1) - Schematic of Domestic-Water Demand Components

contain rules whilst others contain external models. Both the rules and external models relate the different variables to each other, thereby producing one coherent system.

The main functions of domestic-demand model are firstly, to predict domestic demand from top-level variables of the demand tree (unit consumption-rate, conservation effectiveness and number of customers) and secondly, to allow for independent predictions of these variables whenever requested, without the need to run domestic-demand model itself. The latter function is part of the technicality of linking mathematical models with the expert system which was described in the previous chapter. With respect to the first function, domestic demand is predicted by a mathematical model which relates unit consumption-rate, conservation effectiveness and number of customers using the following formula:

$$D_m = C_r(1-(C_e/100)C_n \qquad (5.1)$$

Where:

D_m = *domestic demand for a given zone and time period in litres per day;*

C_r = *consumption rate per customer in litres per day;*

C_e = *conservation effectiveness as percentage;*

C_n = *number of customers.*

Both unit consumption-rate and number of customers are generic variables which can take different forms based on the type of consumption unit (person, household or water connection). In this way, unit consumption-rate will become equivalent to household consumption, if the household is chosen to reference domestic demand. Similarly, number of customers will become equivalent to number of households. The same applies for both per capita and per water-connection consumption since selecting them will link unit consumption-rate with the capita-consumption and connection-consumption respectively. Similarly, number of customers is also connected to population and water connections as a result of selecting these units.

Therefore, the descriptor of unit consumption-rate is associated with a set of rules to distinguish between these various consumption units.

Since the household unit is measurable for both water consumption and conservation-effectiveness, it is considered as the pivotal unit, by which it is possible to predict per-capita consumption and per-connection consumption. Moreover, household consumption itself can be forecast by more than one approach which is not the case with the per-capita unit. Therefore, per-capita consumption is predicted by dividing household consumption by household-occupancy rate and for the purpose of this exercise, per-connection consumption is assumed equivalent to household consumption. Since conservation-effectiveness is calculated as a percentage of household consumption which in turn determines the other unit consumption-rates, there is no problem in applying it to either the per-capita or per-water connection consumption. The household consumption itself can be computed by the following forecasting methods:

- time extrapolation;
- econometric variables;
- end-use variables;
- classified households

These span a wide range of the technologies available, taking account of data availability and the different requirements for accuracy.

In order to link the forecasting methods with household consumption, the household-consumption descriptor has to be connected with a set of rules which identify the specific forecasting method. Accordingly, the descriptor of household consumption becomes equivalent to one of the following descriptors: extrapolated consumption, econometric consumption, end-use consumption or classified consumption, as soon as the corresponding forecasting method has been selected.

5.3 - Extrapolated consumption

The extrapolated consumption represents the average amount of water which is expected to be consumed by each household at some specified future date, based on the past trend of household consumption. The mathematical function for extrapolating household consumption depends mainly on establishing a simple linear regression relationship between an dependent variable (household consumption) and independent variable (time) in the following form:

$$y_i = a + bx_i + e_i \tag{5.2}$$

Where:

y_i = *household consumption in litres per day;*

a = *regression constant;*

b = *regression coefficient;*

x_i = *forecasting year;*

e_i = *error;*

i = *1,.....n (n>2)*

In order to perform the extrapolation in the knowledge-base, an external model is connected to the extrapolated-consumption descriptor. The main duty of this model is to form the previous extrapolation equation, once both the regression constant and coefficient are computed, then to predict the consumption for the specified forecasting year. The regression constant *(a)* and regression coefficient *(b)* in the extrapolation model are calculated by a special FORTRAN program named "*svt.f*". This in turn calls a special library function (NAG routine) named G02CAF *(FORTRAN Library Routine Document NAG, (1994)),* which performs a simple linear regression using the historical data on household consumption with time as shown in Figure (5.2). The NAG routine calculates the regression constant and coefficient based on minimising the errors *(e_i)* as shown in the following formula:

$$\textit{Minimise } \left(\sum_{i=1}^{n} e_i^2 \right) \tag{5.3}$$

The historical data are listed in a data file named *"sv.dat"* which contains n pairs of observations in the following form $(x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots\ldots\ldots\ldots (x_n, y_n)$, where the y_i correspond to household consumption and x_i, the corresponding years. An example of the contents of this file is shown in Appendix III.

5.3.1 - Model adequacy

Beside the regression constant a and the regression coefficient b, the NAG routine calculates many other parameters, such as *mean value of x and y, standard deviation of x and y, standard error of regression constant and coefficient, t-value for regression coefficient, Pearson product-moment correlation between the independent variable x and dependent variable y, mean square of deviations about the regression (MSD) etc.* Some of these parameters can be used for testing the adequacy of the regression model in extrapolating household consumption. The most common parameters include:

- the 95% confidence interval of the extrapolated consumption;
- the estimated standard error in the extrapolated consumption;
- the determination coefficient of regression model.

95 % confidence interval, it is a measure of the overall adequacy of the regression line in general and the uncertainty of the predicted values in particular. It indicates that there is a 95 % chance of existence that the predicted value will be between its limits. Therefore, the interval width becomes smaller as the predicted values lie closer to the original trend. This interval changes with time, so as the extrapolation period becomes longer, the interval itself becomes wider as the results deviate more from the trend. The following relation is used to estimate 95% confidence ranges:

$$y \pm t_{\alpha/2,n-2}\sqrt{MSD(1+1/n+(x_i-x_m)^2/S_{xx})}$$

(5.4)

Where:

y = *predicted value (extrapolated consumption);*

$t_{\alpha/2,n-2}$ = *t-statistic at n-2 degree of freedom (equal to 2.18 in this particular case);*

MSD = *mean square of deviations about the regression;*

n = *number of observations;*

x_i = *independent variable (years);*

x_m = *mean of independent variable (years);*

S_{xx} = *sum of squares of independent variables which can be obtained based on the following relation:*

$$S_{xx} = \sum_{i=1}^{n}(x_i - x_m)^2 \quad (5.5)$$

The standard error is a measure of the variation in the regressor y, the amount of error becoming smaller when the observations are close to regression line. In an arithmetic terms, the standard error can be predicted from the square root of mean square of deviations about the regression line as shown in the following formula:

$$\sigma = \sqrt{MSD} \quad (5.6)$$

Where:

σ = *estimated error or standard error of regression;*

MSD = *mean square of deviations about the regression.*

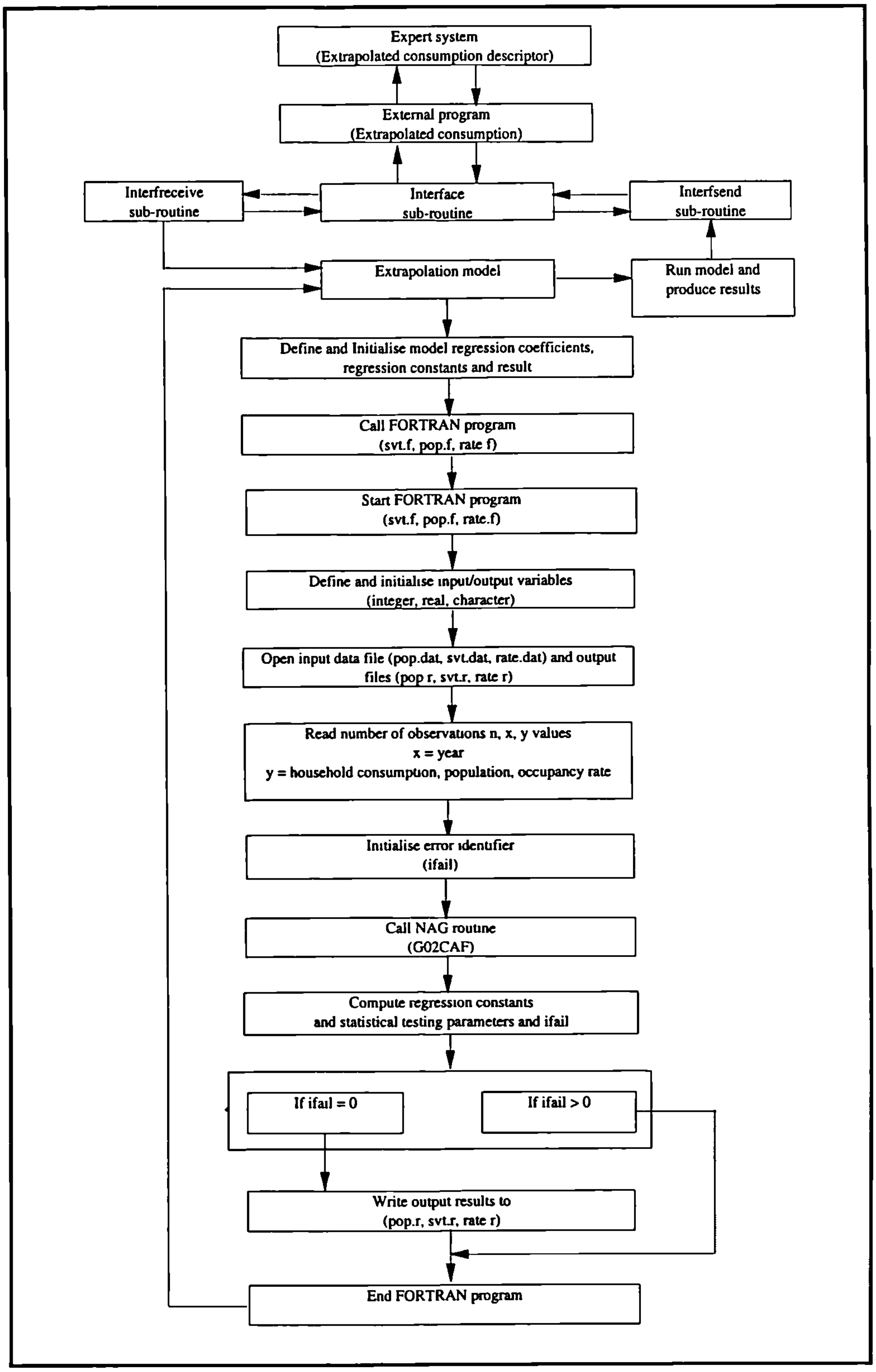

Figure (5.2) - A flow-chart of extrapolation model

The determination coefficient (R^2) is based on the proportion of variation between predicted and actual observations. The values of R^2 range between 0 and 100, with the values closer to 100 indicating a more adequate model. By way of illustration, if R^2 equals 90 this means that 90 percent of the variability in the data is accounted for by the regression model. The following formula is used for computing *(R^2):*

$$R^2 = r^2 \qquad (5.7)$$

Where:

R^2 = *determination coefficient;*

r = *Pearson product-moment correlation between the independent variable x and dependent variable y.*

The determination coefficient *(R^2)* should be used with caution, since it is always possible increase its value by adding further terms to the model which does not necessarily mean the revised model is superior to the old one. Unless the *(MSD)* in the revised model is reduced by an amount equal to the original mean square of the errors, the new model will have a large *(MSD)*. Thus the new model will actually be worse than the old one. The magnitude of *(R^2)* also depends on the range of variability in the regressor variable *(x)*. Generally, its value will increase as the spread of the x_i increases and decrease as the spread of x_i decreases provided the assumed model form is correct.

5.4 - Econometric consumption

The econometric consumption is computed by means of multiple regression, where the amount of water consumed by a household is correlated to a set of explanatory variables which usually include economic, social, behavioural and climatic considerations. The name of this approach is related to the econometric variables rather than other variables since it has been found that the econometric variables such as household income and water price have a greater impact on the household consumption, to the extent they can be considered as the dominant factors. However, there are a number of other variables which may affect household consumption. Based on a variety of studies in different areas, it has been found that the following variables are the most effective in explaining the variance viz.: household income, household occupancy rate, household composition (number of adults in relation to children), water price and climatic conditions (rainfall and temperature). In order to predict household consumption by this means, an external model has been connected to the econometric-consumption descriptor as shown in Figure (5.3). The main functions of this model include the following:

- identifying the most important variables using the stepwise technique and ranking them accordingly in descending order;

- building the multiple-regression model;

- forecasting household consumption from different explanatory variables;

- computing statistical parameters for testing the adequacy of econometric model in predicting household consumption.

5.4.1 - Variables identification and ranking

The first role of the econometric model deals with the identification and ranking of the most important variables according to their effect on household consumption. Normally, testing the correlation between independent variables and dependent variables in any regression model is a crucial step which has to precede building the model itself. In most situations, there are several possible independent variables, not all of which may be needed in the model. In order to select a suitable set of independent variables which have the most effect on the dependent variable, several approaches can be used including: the determination-coefficient approach, the C_p statistics approach and stepwise approach, etc., none of which however, can be relied on to identify the most appropriate selection of variables.

Therefore, the best way of predicting such variables is to try several models before selecting those variables which are identified most frequently.

For simplicity reasons, only the forward stepwise technique has been incorporated in the system. This technique is probably the most widely used in the selection of variables. The underlying principle of this technique is based on the following: variables should be added to the model, one at a time, until there are no remaining candidate variables that produce a significant increase in the regression sum of squares. That is to say, variables are added in a singular fashion so long as $F > F_c$. Therefore, an external program carries out the following procedures for ranking the explanatory variables which is also shown in Figure (5.3):

(i) A FORTRAN program named "*mv.f*" is called which reads the input data (household consumption with various explanatory variables) from an input data file named "*mv.dat*". This program calls a special NAG routine named G02EEF which, in turn, carries out the following steps:

-find and select the best fitting independent variable, i.e. the independent variable which gives the smallest residual sum of squares;

- if the *F test* for this variable is greater than a chosen critical value F_c , then include the variable in the list: a suggested value of F_c is 2.0 is commonly used in the exploratory modelling;

- find the independent variable that leads to the greatest reduction in the residual sum of squares when added to the current list;

- if the *F test* for this variable is greater than, F_c , then include the variable in the list and go to the previous step, otherwise stop.

(ii) Once the G02EEF routine produces the variables and their corresponding rank order, they are transferred from the FORTRAN program to the econometric model, prior to being stored and displayed in the same sequence (the most important first and so on). The variables which have very low correlation or did not satisfied the previous conditions will not be displayed in the model outputs.

For the purpose of giving the planner the necessary flexibility in controlling the variables in the proposed model, a special parameter named *isx* is included in the data file. This variable is an integer array, indicating which independent variables are to be considered in the model. Therefore, the *isx* can take one of the following values: 0 or 1 or 2. A zero value indicates that the variable contained in the *j*th column of *x* is not included in the model. A value of 1 indicates that the variables contained in the *j*th column of *x* is considered for inclusion in the regression model and a value of 2 indicates that the variable in the *j*th column of *x* is automatically included in the regression model. In the econometric model *isx* is given a value of 1 to consider all included variables in the regression.

5.4.2 - Model building and application

The second role of the econometric model is to determine a regression function from the various explanatory variables identified. For this purpose, two NAG library routines are used namely, G02BKF and G02CHF. The first routine (G02BKF) is used to compute the means, standard deviation, sum of squares, cross-products about zero and correlation coefficients based on the explanatory variables' data and corresponding household consumption which are listed in an input data file named "*mv.dat*". This file contains n observations in the form of $[x_{ij}]$ array where x_{ij} is the *i*th observation on the *j*th variable for $i = 1,2,.....n$ $(n \geq 2)$, $j = 1,2,.....m$ $(m \geq 2)$: an example of the contents relating to this data file is shown in Appendix III. The second routine (G02CHF) performs a multiple linear regression in the following form:

$$y = b_1x_1 + b_2x_2 + \ldots\ldots + b_ix_i + e_i \qquad (5.12)$$

Where:

y = *dependent variable (household consumption in litres per day);*

x_i = *independent variables* $i = 1,\ldots, n$;

b_i = *regression coefficients* $i = 1,\ldots, n$;

e_i = *error* $i = 1,\ldots, n$;

n > 1

This routine calculates the regression coefficients, b_1, b_2, ..., b_n and various other statistical parameters by minimising errors based on following equation:

$$\textbf{\textit{Minimise}}\ (\sum_{i=1}^{n} e_i^2) \qquad (5.13)$$

The input information to this routine are obtained from outputs of the previous routine (G02BKF) which include the following:

- the number of observations per variable, n, on which the regression is based;
- the total number of variables, dependent and independent in the regression, (i+1);
- the number of independent variables in the regression, i;
- the (i+1) by (i+1) matrix of sum of squares and cross-products about zero of all variables in the regression, the terms involving the dependent variable y, which appears in the (i+1)th row and column;
- the (i+1) by (i+1) matrix of correlation-like coefficients for all the variables in the regression, the correlation which involves the dependent variable y, appearing in the (i+1)th row and column.

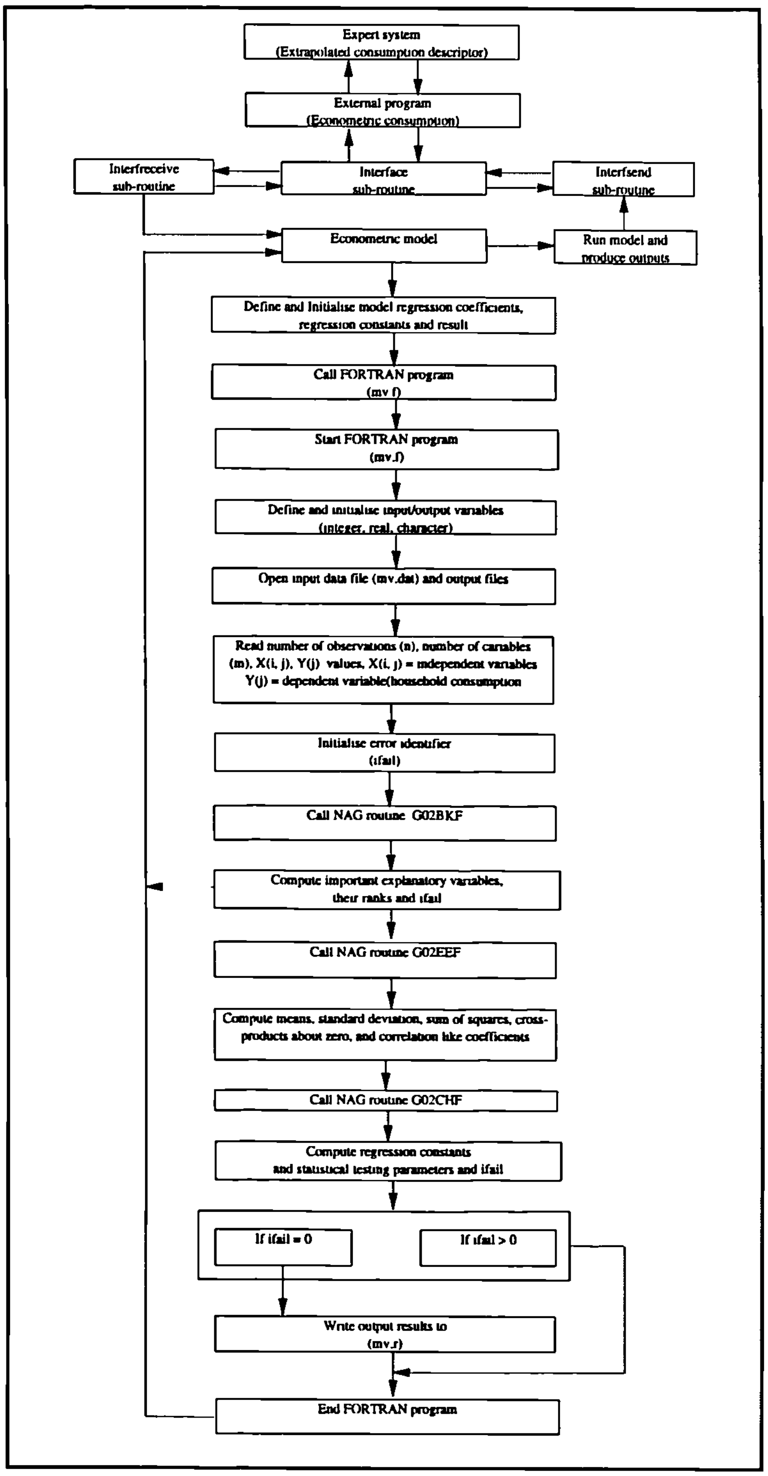

Figure (5.3) - A flow-chart of econometric model

5.4.3 - Model adequacy

The NAG routine (G02CHF) computes other statistical parameters in addition to the regression coefficients and constants. These parameters are used for testing the model adequacy in predicting household consumption from the explanatory variables. The most common parameters are:

- the standard error (*s*);
- the *F*-value for the analysis of variance (*F*);
- the determination coefficient (R^2);
- the corrected determination coefficient (R^2);

Based on these parameters, the best-fitting regression model is the one with the smallest error and highest determination coefficient and *F* value.

5.5 - End-uses consumption

Forecasting household consumption from end-uses is more precise than aggregate uses, since the number of variables which control each end-use is less and can be estimated, which is not the case when dealing with the aggregate water uses. For example, the estimation of water consumption by a dishwasher is more accurate than the estimation of household consumption. The end-uses consumption can be defined as the expected amount of water consumed by a household based on the summation of the individual elements that comprise household consumption. Bearing in mind there are several end-uses that can share the same source (water-use device) in the household, it is difficult to disaggregate consumption relating to that device into end-uses. For example, water from a kitchen tap (device) can be used for drinking, cooking and cleaning (end-uses). Therefore, it is more appropriate to disaggregate household consumption into various water-use devices rather than end-uses. In this way, household consumption can be predicted from the following components which are the most common in the majority of households:

- dishwasher consumption;
- washer consumption;
- shower consumption;
- bathtub consumption;
- toilet consumption,
- kitchen-tap consumption;
- bathroom-tap consumption;
- hosepipe consumption;
- sprinkler consumption.

In order to include this approach in the knowledge-base, an external model has been linked to the descriptor of end-uses consumption. The purpose of this model is to compute water consumption from different combinations of water-use devices as shown in Figure (5.4). Moreover, it calculates some planning information which may be useful including:

- percentage of indoor consumption with respect to household consumption;
- percentage of outdoor consumption with respect to household consumption;
- percentage of consumption by the various devices with respect to household consumption.

In general, the end-uses model is based on the following mathematical formula:

$$y = \sum_{i}^{n} dc_i \qquad (5.14)$$

Where:

y = *household consumption in litres per day;*

dc_i = *device consumption in litre per day;*

i = *number of included devices.*

The device consumption itself depends on other variables such as the device capacity, frequency of use, device-use coverage percentage and device-leakage percentage. Therefore, the following formula is used to predict device consumption:

$$dc_i = c_i * f_i * p_i * (1 + l_i) \qquad (5.15)$$

Where:

dc_i = *device consumption in litres per day;*

c_i = *device capacity in litres per load*

($c_i = c_1 * pc_1 + c_2 * pc_2 + ..etc.$);

f_i = *device frequency of use per day;*

p_i = *device-use coverage percentage;*

pc_i = *device capacity coverage percentage;*

l_i = *device-leakage percentage;*

i = *device number, i = or > 1.*

Device capacity represents the amount of water required per load of use (dishwashing, clothes-washing, flushing, etc.). It is measured by litres per load and therefore, depends on the level of technology deployed in its manufacture. For example, there are various types of dishwashers, some of which require large amount of water per load whilst other types are more efficient and require less water for the same dishwashing load. However, the device capacity of some other devices especially showers and taps, depends on other factors such as flow rate and time of use. Therefore, in these instances, the following relationship is included for predicting device capacity:

$$c_i = r_i * t_i \qquad (5.16)$$

Where:

c_i = *device capacity in litres per load;*

r_i = *device flow rate in litres per minute*

$(r_i = r_1 * rc_1 + c_2 * rc_2 + .. etc.)$;

rc_i = *device flow-rate coverage percentage;*

t_i = *device- usage time in minutes per day;*

i = *device number,* i = *or* >1.

Device frequency of use comprises the number of times or number of device loads per unit time (most likely a day). It would appear that this variable reflects the economical, social and behavioural factors of households members rather than the devices themselves which may include the occupancy rate, family income, number of wage-earnest in the family, education level, etc.

Device-coverage percentage indicates that of level of ownership or penetration of a certain water-use device in a given area which is largely a reflection of the household income. For simplicity purposes, it is assumed that the coverage percentage of any device is the same for both the capacity and the frequency of use of that device. For example, if the coverage percentage of dishwasher users in a certain zone is 50 percent, this implies that 50 percent of households have dishwashers with the same specified capacity, which are used with the same frequency.

Finally, device leakage is defined as the amount of water wasted and can take different forms such as taps dripping or losses due to bad fittings, pipe connections, etc. This is expressed as percentage of the total amount consumed by any of these devices.

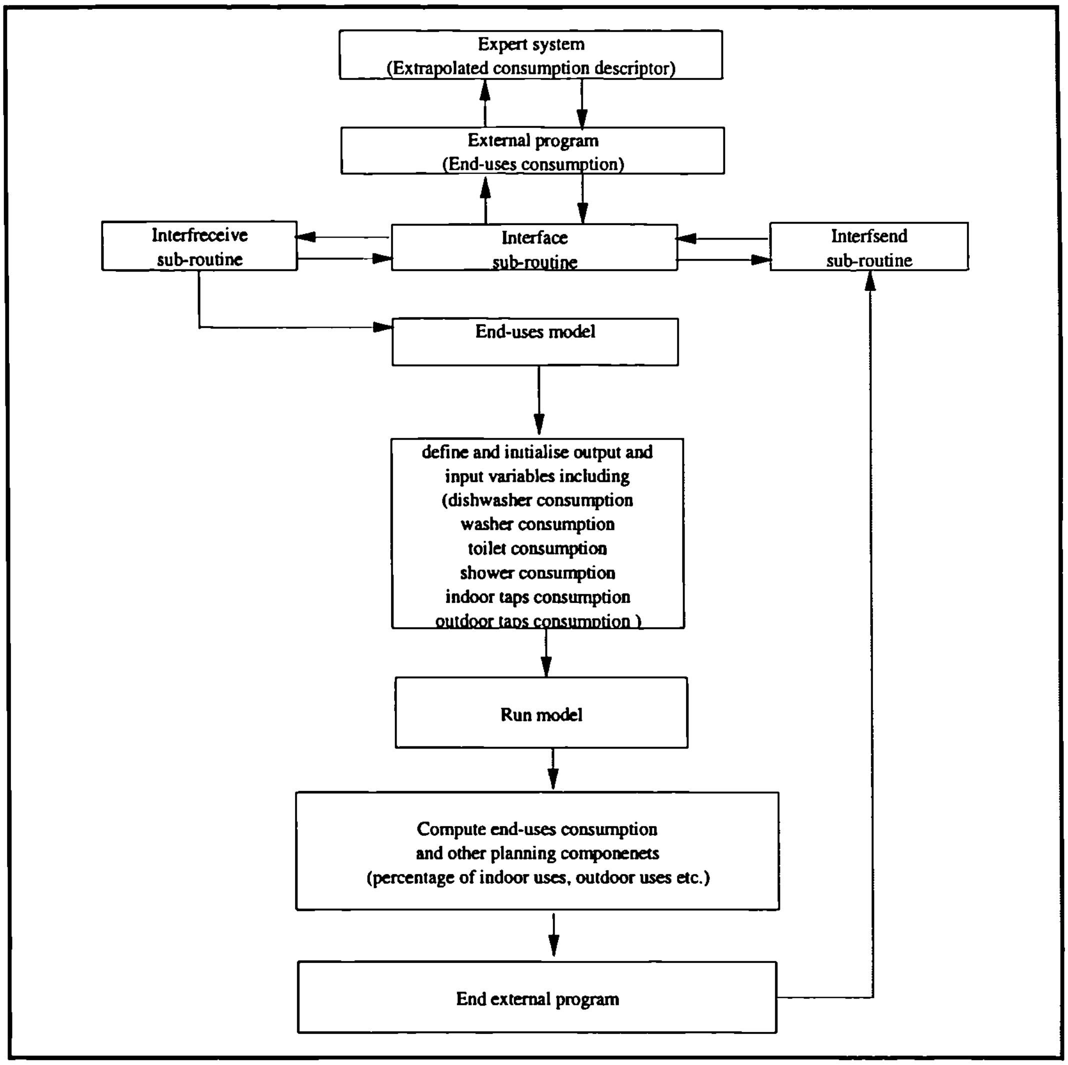

Figure (5.4) - A flow-chart of end-uses model

5.6 - Classified consumption

The remaining approach used for predicting household consumption depends on a socio-economic classification of customers. This approach is useful where there are little or no data available which restricts the use of the other methods described. Moreover, there are occasions when a rough and ready estimate is required for preliminary planning purposes, in which case, this approach may suffice.

In general, the households in any demand zone can be categorised according to their socio-economic and demographic factors which can be related to their water-consuming habits. Accordingly, the average household consumption of a demand zone, for any time period, can be taken as equivalent to that pertaining to one or more of these classes, assuming that the selected class/classes are the most dominant ones.

Since household classification is specific and depends on local conditions, this approach cannot be generic and is therefore, restricted to a particular country. For the UK, the DFMS categorise households based on the *ACORN* (A Classification of Residential Neighbourhoods) classification system. The *ACORN* classification system combines location with demographic characteristics to create a socio-economic database which can be used for various types of planning studies, including water supply *(CACI, 1993)*.

Based on this system, households are grouped into seventeen major categories as shown in Table (5.1), each class having its own average consumption per day. In this way, the descriptor of classified-consumption is associated with a set of pre-defined rules which contain household classes, their corresponding consumption rates and coverage. Once, the dominant household class or classes and their coverage in the demand area have been defined, the system is capable of producing the average consumption rate of households for that area. The shortcomings of this approach is that at the present time, there is no mechanism

Table (5.1) - ACORN categories and consumption rates for year 95/96

class description	*consumption class*	*per capita consumption liters per day*
Wealthy Achievers, Suburban Areas	*class A*	*177*
Affluent Greys, Rural Communities	*class B*	*167*
Prosperous Pensioners, Retirement Areas	*class C*	*157*
Affluent Executives, Family Areas	*class D*	*129*
Well-Off Executives, Inner City areas	*class E*	*149*
Affluent Urbanites	*class F*	*151*
Prosperous Professionals, Metropolitan Areas	*class G*	*157*
Better-Off executives, Inner City Areas	*class H*	*197*
Comfortable Middle Agers, Mature Home Owning Areas	*class I*	*136*
Skilled Workers, Home Owning Areas	*class J*	*164*
New Home Owners, Mature Communities	*class K*	*168*
White Collar Workers, Better-Off multi-Ethnic Areas	*class L*	*160*
Older People, Less Prosperous Areas	*class M*	*138*
Council Estate Residents, Better Off Homes	*class N*	*127*
Council Estate Residents, High Unemployment	*class O*	*213*
Council Estate Residents, Greatest Hardship	*class Q*	*97*
People in Multi Ethnic, Low Income Areas	*class P*	*128*

for projecting household-consumption rates into the future. Therefore, either the current values have to be assumed or some other method used. Whatever way is preferred, the system has the facility to amend the household-consumption rates for future years.

5.7- Selection of forecasting method

Since there are various methods of forecasting household consumption, it may be quite difficult for someone who is inexperienced to select the most appropriate forecasting approach. Therefore, a multi-criteria decision-making technique is included to help planners in identifying the most appropriate method according to their needs and the availability of data. By this means, the user can either select the methodology of his/her choice or rely on the system to help with the selection process.

5.7.1 - Multiple-objective decision theory

Decision analysis with multiple objectives requires the determination of multi-attribute utility function which can be can be extremely complex, depending on the size of the problem and the degree of dependence among the various objectives. Therefore, a relatively simple and direct method is provided for evaluating a diverse set of objectives based on what is called 'weighted-objective decision analysis' *(Ang and Tang, 1984)* in which the resolution of several objectives versus a number of feasible alternatives is considered. The information required for weighted-objective decision-analysis can be summarised as shown in Table (5.2).

To implement this approach, a set of alternative weights has to be assigned to the various objectives. This might involves a two-step ranking procedure according to users interests. Firstly, the objectives are listed in decreasing order of importance which is refered to as ordinal ranking. In this step, a preference statement is also solicited from the decision-maker with respect to combinations of objectives. For example if o_1, o_2 , o_3 , o_4 represent four objectives in order of decreasing importance, then in addition to the preference statement $o_1 > o_2 > o_3 > o_4$, the decision-maker may also be asked if he believes o_1 to be greater than a combination of o_2 ,o_3 and o_4. Subsequently, a cardinal ranking of each of the objectives is established. The relative importance of each objective with respect to other objectives is reflected by assigning numerical weights to each objective starting with the most important which is assigned an arbitrary weight of , say, 1.

Next, the numerical weights are assigned to each of the other objectives according to a set of initial statements established in the ordinal ranking. For example, if w_1, w_2, w_3, w_4 represent, respectively, the set of relative weights assigned to *objectives* o_1, o_2, o_3, o_4, then a consistency check would require $w_1 > w_2 + w_3 + w_4$ *if* $o_1 > o_2 + o_3 + o_4$. This assumes implicitly that the overall weight of a combination of objectives is equal to the sum of the weights of the individual objectives, assuming the objectives are measurable. However, in the event that inconsistency in the preference statement is found, the user has to revise his preference statement or his assignment of relative weights or both, until inconsistencies are eliminated.

Secondly, there is a need to include a listing of feasible alternatives and assign qualitative values P_{ij} which reflects each option's effectiveness in achieving the objectives or criteria. Some of these values may be computed based on actual measurements, whereas others may have to be estimated subjectively based on decision-maker's own experience and judgement.

Finally, the overall relative utility of each alternative is computed as

$$u_i = \sum p_{ij} w_j \qquad (5.17)$$

Where:

u_i = *overall relative utility of all options;*

p_{ij} = *qualitative value of achieving objective j through option i;*

w_j = *relative weight of importance to objective j.*

The optimal alternative is the one that has the maximum overall relative utility. It should be noted that the absolute numerical value of u_i is not important as the relative value of u_i is sufficient for the selection of the optimal alternative.

Table (5.2) Weighted-objective decision-analysis parameters

Relative Weights	w_1	w_2	w_n	
Objectives	o_1	o_2	o_n	*Overall relative utility*
Options/Alternatives				
a_1	p_{11}	p_{12}	p_{1n}	$u_1 = \Sigma p_{1j}\, w_j$
a_2	p_{21}	p_{22}	p_{2n}	$u_2 = \Sigma p_{2j}\, w_j$
a_3	p_{31}	p_{32}	p_{3n}	$u_3 = \Sigma p_{3j}\, w_j$
a_m	p_{m1}	p_{m2}	p_{mn}	$u_m = \Sigma p_{mj}\, w_j$

a_i = *ith alternative*, $i = 1$ *to* m

o_j = *jth objective*, $j = 1, n$

w_j = *relative weight of importance to objective* o_j, $j = 1$ *to* n.

p_{ij} = *qualitative value of achieving objective* o_j *through alternative* a_i

u_i = *overall relative utility of alternative* a_i

5.7.2 - Application of decision theory

The method adopted in implementing this approach in the knowledge-base relies on the maximum relative utility being the optimal alternative. Therefore, a set of pre-defined rules which contain Equation (5.17) have been linked to the forecasting-method descriptor. Moreover, a set of dummy descriptors *(L1, L2, L3, L4)* have been established to perform the optimisation process. Simply by comparing the values of each of the dummy descriptors with the others, the one with the maximum value is considered to be the optimal answer.

As far as the selection criteria are concerned, the following have been chosen to reflect the most important aspects of the various forecasting methods:

- forecast accuracy;
- input data requirements;
- conservation evaluation;
- consideration of economics
- ease of application

The selection process is structured to take the form of user preferences, starting with the most important criterion and ending with the least. Each criterion takes a relative weight of between 0 and 1, according to its significance. Therefore, the order of these criteria is crucial since the first criterion will has the highest weight, then the second and so on. However, the ranking of various weights depends on the problem context and user interests as shown in the previous section, in this particular exercise, the weights themselves are distributed in a way to make sure that the first preference is the most effective then the second then the third etc., at the same time the summation of these weights is equivalent to one as shown by the following conditions:

$(w_1 > w_2); (w_2 > w_3); (w_3 > w_4); (w_4 > w_5);$

and

$\Sigma\, w_1 + w_2 + w_3 + w_4 + w_5 = 1$

where: $w_{1 \text{ to } 5}$ are the relative weights which have been assigned to various objectives (criteria). For example, based on these two conditions, the first important criterion could be given a weight of 0.33, the second 0.27, the third 0.2, the fourth 0.13 and the fifth is 0.07.

The second type of parameters is the qualitative values. These indicate the likelihood of achieving the objectives through one of the forecasting methods *(p_{ij})* and are assumed to be based on a relative comparison between the various methods for each criterion which are ranked accordingly, in ascending order. Each rank is given a value between 0 and 1. Both, 0 and 1 are excluded since they are assumed to represent the worst and ideal conditions respectively. Therefore, for the purpose of this exercise, the upper value is assumed to have a value of 0.9 whilst the lower value is assumed to be 0.1. For the two intermediate values, the difference between upper and lower values is divided into equal portions, each portion being associated with the corresponding rank, as shown in Table (5.3).

Table (5.3) - Qualitative values of achieving the various criteria for forecasting methods

criteria / *methods*	*forecast accuracy*	*input data requirements*	*conservation evaluation*	*economics consideration*	*ease of application*
classified households	0.1	0.9	0.1	0.37	0.9
time extra-polation	0.37	0.63	0.37	0.1	0.63
econometric variables	0.63	0.37	0.63	0.9	0.37
end-use variables	0.9	0.1	0.9	0.63	0.1

5.8 - Conservation effectiveness

The second consideration in domestic-demand model is conservation effectiveness which reflects the demand-management side of the system. In general, it can be defined as the potential reduction (percentage) in consumption which can be achieved by implementing conservation measures either individually or collectively, now or in the future. These include the following which have been incorporated in the system:

- metering;
- pricing policy;
- conservation devices;
- household-leakage control;
- education programmes;
- water-use restrictions
- water rationing
- pressure reduction
- plumbing codes

These measures have already been described in detail as part of chapter 2 and their potential effectiveness in reducing water demand is given in Table (2.2).

5.8.1 - Selection of conservation measure

The multi-objective decision theory which has been used in selecting the forecasting method is also used for predicting the most appropriate conservation measure. For this purpose, the following selection criteria are used:

- time horizon;
- measure cost;
- saving effectiveness;
- public acceptance;
- ease of application.

Initially, consideration is given to the time horizon, with the conservation measures being divided into long-term and short-term. Therefore, with respect to the other criteria, it is obvious that the measures which are cheap and effective in reducing water consumption, in addition to being easy to implement and have a high level of public acceptances, are the preferred options and consequently, given the highest weights.

With regard to assigning the set of weights and qualitative values of achieving various criteria, the same procedures as before are used. For the relative importance of the criteria, the same weights of 0.36, 0.29, 0.21 and 0.14 are used. Table (5.4) gives the qualitative values which reflect the effectiveness of each conservation measure in achieving the various criteria. These figures are based on value-judgement and can be altered by the user if appropriate.

Table (5.4) - Qualitative values of achieving various criteria for conservation measure

criteria / *measures*	*cost*	*effectiveness*	*public acceptance*	*ease of application*
water metering	*0.1*	*0.8*	*0.8*	*0.1*
water rationing	*0.8*	*0.4*	*0.1*	*0.9*
pressure reduction	*0.9*	*0.1*	*0.6*	*0.7*
leakage control	*0.3*	*0.5*	*0.7*	*0.3*
conservation devices	*0.2*	*0.9*	*0.5*	*0.2*
education programs	*0.4*	*0.2*	*0.9*	*0.4*
plumbing codes	*0.7*	*0.7*	*0.2*	*0.5*
pricing policy	*0.6*	*0.3*	*0.4*	*0.8*
water-use restrictions	*0.5*	*0.6*	*0.3*	*0.6*

5.8.2 - Estimation of conservation effectiveness

The effectiveness of conservation measures can be affected by other factors. For example, the presence of any measures previously introduced, may significantly affect or even cancel the expected reduction in water consumption due to the proposed measure. Another factor is the level of coverage which if less than 100 percent, will reduce the expected savings. Therefore, conservation effectiveness is estimated based on the following relation:

$$C_e = \sum_{j}^{n} rf_j * if_j * cf_j \qquad (5.18)$$

Where:

C_e = *conservation effectiveness;*

rf_j = *potential reduction relating to a particular conservation measure;*

if_j = *interaction effect with existing and other proposed measures;*

cf_j = *measure coverage percentage;*

j = *measure number, 1,...n, n = or > 1.*

As with other components of the domestic-demand model, conservation effectiveness has its own descriptor named "conservation effectiveness" which is linked to a set of rules that distinguishes between the various conservation measures and calculates the effectiveness of any measure or group of measures in accordance with Equation (5.18).

(i) Reduction factor

This variable represents the potential reduction of between 0 and 100 percent in the household consumption as a result of implementing a particular conservation measure. Each conservation measure has a descriptor which represent this factor. However, some descriptors such as the pricing policy and conservation devices are dependent on other variables. For example, in order to predict the potential reduction in household consumption due to the pricing policy, it is necessary to define the tariff structure as being flat-rate, rising-block, falling-block, seasonal or peak-hour. Similarly, to predict potential reduction resulting from the introduction of a certain conservation device, the user has first to define the water-use device itself. Therefore, the following devices are included in the system: shower, toilet, dishwasher, clothes-washer and taps. Moreover, the taps themselves also require further explanation on the type of fixture to which the tap is connected such as kitchen sink, bathroom, bathtub, hosepipe and sprinkler. For most of these devices, the reduction factor is based on the following relationship:

$$rf_i = (ec_i - pc_i) / ec_i \tag{5.19}$$

Where:

rf_i = *reduction factor for ith device (i=1, 5);*

ec_i = *existing capacity or flow rate;*

pc_i = *proposed capacity or flow rate;*

i = *device number, i = or >1.*

The only exception is the toilet since the reduction descriptor for the toilet distinguishes between two types of conservation policies, either replacing existing toilets with new conserving ones or modifying the existing toilets to conserve water. The first option is similar to the previous devices and therefore, Equation (5.19) can be used to predict the reduction factor. However, the second option depends on the type of modification which includes:

- damming devices such as toilet dams, partition walls, etc.;
- displacement devices such as bricks, bottles and bags;
- other assorted devices such as dual flushing.

Since the potential of reducing water consumption by any household device (tap, shower, toilet, etc.) is referenced to the device consumption itself rather than household as a whole, a correction factor is necessary to transfer the potential reduction from a device level to an aggregate level (household). Therefore, a special correction factor is included for this purpose.

(ii) Coverage factor

The coverage of any conservation measure within a given demand zone and time period is an important consideration in estimating the effectiveness since 100 percent penetration is seldom achieved. Its value may be expected to increase over time as more users comply with a given measure or decrease as the water-saving devices wear out.

(iii) Interaction factor

As mentioned earlier in this section, the introduction of a new measure may interact with any other existing measure(s). Similarly, if there are several measures to be applied, they may interact with each other in addition to interaction with the existing measures. Therefore, it is necessary to include a correction factor which accounts for the interaction between various conservation measures. This can be accomplished according to *Richards et al. (1984)* by using the following formula:

$$c_{123} = i_{p1} * c_1 + (i_{p2} * i_{12} * c_2) + (i_{p3} * i_{13} * i_{23} * c_3) \quad (5.20)$$

Where:

c_{123} = *the combined effectiveness of measure 1,2, and 3;*

c_1 = *the effectiveness of measure 1 when implemented alone;*

c_2 = *the effectiveness of measure 2 when implemented alone;*

c_3 = *the effectiveness of measure 3 when implemented alone;*

i_{12} = *the interaction factor of measure 2 added to measure 1;*

i_{13} = *the interaction factor of measure 3 added to measure 1;*

i_{23} = *the interaction factor of measure 3 added to measure 2;*

i_{p1} = *the overall interaction of measure 1 added to existing measures;*

i_{p2} = *the overall interaction of measure 2 added to existing measures;*

i_{p1} = *the overall interaction of measure 3 added to existing measures;*

The same thing can be repeated for measures 4,5,...,etc. *Richards et al. (1984)*, estimated some of the values for interaction factors relating to various conservation measures are shown in Tables (5.5). These factors are used to correct the effectiveness of any proposed measure with the existing or another proposed measure(s). Existing measures are listed vertically whilst proposed measures are listed horizontally, carrying the same numbers of existing measures. In the case of several proposed measures these titles becomes the previous and additional measure respectively.

Table (5.5) - Interaction factors

additional measure / previous measure	1	2	3	4	5	6	7	8	9
1 - Education programmes	*0.00*	*1.00*	*1.00*	*1.00*	*0.20*	*0.9*	*1.00*	*0.90*	*1.00*
2 - metering	*1.00*	*0.00*	*1.00*	*1.00*	*0.00*	*1.00*	*1.00*	*1.00*	*1.00*
3- pressure reduction	*1.00*	*1.00*	*0.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
4 - pricing policy	*1.00*	*0.00*	*1.00*	*0.00*	*1.00*	*0.90*	*1.00*	*0.90*	*1.00*
5 - rationing	*0.60*	*1.00*	*1.00*	*1.00*	*0.00*	*0.60*	*1.00*	*1.00*	*1.00*
6 - sprinkling restrictions	*0.90*	*1.00*	*1.00*	*1.00*	*0.60*	*0.00*	*1.00*	*0.00*	*0.00*
7 - leakage control	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*0.00*	*1.00*	*1.00*
8 - saving devices	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.00*	*1.00*	*0.00*	*1.00*
9 - plumbing codes	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*0.00*	*1.00*	*1.00*	*0.00*

Another vital aspect in determining the interaction effect is the order of the various conservation measures whether existing or proposed. For this reason several sets of rules and tables are used to predict the interactions based on all possible combinations between existing and proposed measures (or between proposed measures themselves).

As a result, the user has to define these measures in order of implementation and the system will identify the effect between each measure and others by searching for the rules (tables) which include these combinations, before predicting the interaction factors. Having finished the prediction process, the system will automatically sum up these effects and use the result in correcting the reduction percentage.

5.9 - Number of customers

The final top-level component in domestic-demand model is the number of customers. The customer type is determined from the reference unit of water consumption (household, person or water connection). Usually, the number of customers being the individual persons, households or water connections, can be obtained from census data or water-billing records. However, if water-billing records are used, a degree of caution is required in some countries owing to the high level of illegal connections (the so-called non-revenue water). Either way, estimates are required for not only the existing number of customers but also the future, normally at 5-year intervals up until the end of planning horizon. If such forecasts are not readily available, they can be predicted within the DFMS, provided the historic data are available.

Since, the census data are more likely to be available and projecting them into the future is probably more reliable than other types, population is considered to be pivotal unit by which it is possible to predict the numbers of other customer types, especially households. Since population numbers can be predicted using the time-extrapolation approach, a similar model to the one used for the extrapolation of household consumption, is associated with the population descriptor. The extrapolation model is based on historical records of population with time which are listed in a special data file named "*pop.dat*", the contents of which are shown in Appendix III.

The number of households can be computed from population data and the occupancy rate per household. Since the occupancy rate can also be projected into the future in a way similar to population, another extrapolation model is linked to its descriptor to allow prediction of its value from past records. Therefore, the historical records of occupancy rate with time are listed in a data file named "*rate*", the file contents again being shown in Appendix III.

With respect to number of connections, it is generally assumed that they are equal to the number of households. Usually, this includes the existing households which are connected to the water supply system, any existing households which for whatever reason remain unconnected, some provision for illegal connections where appropriate and future proposals for housing development. However, there are difficulties in using the number of connections as the basis for predicting domestic demand as some apartment blocks have a single connection.

5.10 - DFMS data types and formats

The DFMS incorporates two types of data namely, general and specific. General data are generic in the sense that they are widely applicable, having been acquired from the literature, magazines, reports, brochures etc., an example of which might be the amount of water required by a dishwasher or the flow rate of a power shower etc. The main purpose of these data is to provide the user with some practical guidance on the range of possible answers for any considered variable. This type includes either numeric data ranges or textual statements which represent the scope of possible answers for variables (descriptors) of demand forecasting and management. Accordingly, data of this type can be used for any demand zone; the only limitation in this respect is that, the data itself has to be updated with time. For example, current dishwasher capacity ranges from 20 to 60 litres per load; this might change in ten years time to a smaller range.

The second data type is specific data which are related to the local conditions of the demand zone under consideration and include population numbers, household income, metering coverage etc., which can be obtained from water companies, census departments etc. This type has two forms, the first being data ranges which represent the scope of possible answers for descriptors whilst the second includes a specific value would be used as a default answer, in the event that the user has no relevant information that can be used either directly or within the expert system. Usually, this type may include time series data for prediction models such as population, occupancy rate and extrapolated consumption models or cross-sectional data such as the data which are necessary for an econometric consumption model. In both cases the data has to be prepared in a special format and in an input data file (plain text data file) where it can be updated or changed if necessary. This type of data is relevant to a specific demand zone therefore, it can only be used for predicting domestic demand for the selected demand zone. Moreover, both time-series data and cross-sectional data has to be representative and reflects the changes over long time periods. In other way, as the number of observations increases and represents the various economical and social classes as the the predicted results becomes more reliable.

The numeric data ranges for both types (general and specific) are determined as follows, the lower and upper limits having already been defined for each descriptor. Assuming these ranges follow a normal distribution, the difference between these limits is divided into five equal intervals, each of which is associated with a qualitative answer such as, very low, low, moderate, high, and very high. In this way, the answer for any descriptor is restricted by the limits of these data ranges. On the one hand, this restriction is considered to be some kind of protection measure against the entry of unrealistic data for different variables. On the other hand, it provides an appreciation of data by categorising values of any variable into several qualitative answers. Moreover, these answers are useful in building different scenarios based on different inputs. If the qualitative answers are used rather than numeric ones, the median value of relevant data range is used as the descriptor result. Table (5.6) includes both types of data for various descriptors in the system.

As a result of this structure, the number of possible answers becomes dependent on the number of the variables which are necessary to provide an answer. The following mathematical relation can be used to predict the number of possible answers based on the number of variables included:

$$n = k^m \tag{5.21}$$

Where:

n = *number of possible answers;*

m = *number of variables (descriptors) included;*

k = *number of values within a range.*

For example, if a descriptor result depends on one variable assuming k equal 5, there are five possible answers to that descriptor (very low, low, moderate, high, very high): if the number of variables (m) equals two for the same k, there are 25 possible outcomes and so on. This situation leads to a difficulty in classifying the descriptor output for a specific qualitative answer. Therefore, regardless of how many variables might be included in deriving a descriptor result, the values are artificially constrained to conform with the original five categories as indicated in Figure (5.5).

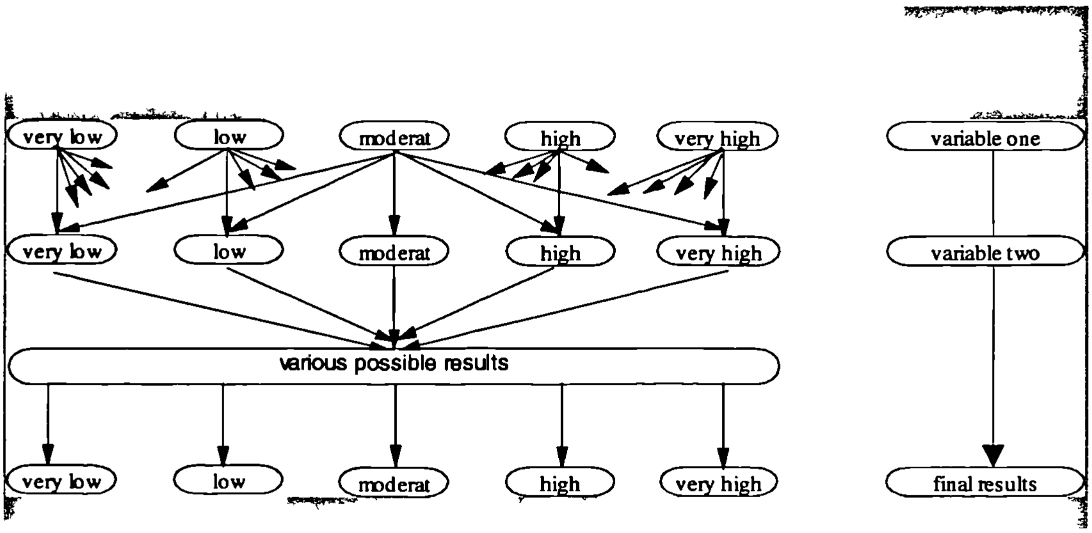

Figure (5.5) - Descriptor-results scenarios

Table (5.6) - Data ranges of domestic-demand variables

variable name / data range	lower value	upper value	very low		low		moderate		high		very high	
dishwasher												
dishwasher capacity in litres per load	0.00	50.00	0.00	10.00	10.00	20.00	20.00	30.00	30.00	40.00	40.00	50.00
frequency of loads per day	0.00	1.50	0.00	0.30	0.30	0.60	0.60	0.90	0.90	1.20	1.20	1.50
dishwasher consumption in l/d	0.00	75.00	0.00	3.00	3.00	12.00	12.00	27.00	27.00	48.00	48.00	75.00
clothes washer												
washer capacity in litres per load	0.00	175.00	0.00	35.00	35.00	70.00	70.00	105.00	105.00	140.00	140.00	175.00
frequency of loads per day	0.00	1.50	0.00	0.30	0.30	0.60	0.60	0.90	0.90	1.20	1.20	1.50
washer consumption in l/d	0.00	262.50	0.00	10.50	10.50	42.00	42.00	94.50	94.50	168.00	168.00	262.50
shower												
flow rate in litres per min	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
showering time in min	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
frequency of showers per day	0.00	2.00	0.00	0.40	0.40	0.80	0.80	1.20	1.20	1.60	1.60	2.00
shower consumption l/d	0.00	450.00	0.00	3.60	3.60	28.80	28.80	97.20	97.20	230.40	230.40	450.00
bath												
bath capacity in litres	0.00	175.00	0.00	35.00	35.00	70.00	70.00	105.00	105.00	140.00	140.00	175.00
frequency of baths per day	0.00	2.00	0.00	0.40	0.40	0.80	0.80	1.20	1.20	1.60	1.60	2.00
bath consumption in l/d	0.00	350.00	0.00	14.00	14.00	56.00	56.00	126.00	126.00	224.00	224.00	350.00

variable name / data range	*lower value*	*upper value*	*very low*		*low*		*moderate*		*high*		*very high*	
toilet												
toilet capacity in litters per flush	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
frequency of flushing per day	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
toilet consumption in l/d	0.00	225.00	0.00	9.00	9.00	36.00	36.00	81.00	81.00	144.00	144.00	225.00
kitchen tap												
tap flow rate in l/min	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
tap opening time in min/day	0.00	30.00	0.00	6.00	6.00	12.00	12.00	18.00	18.00	24.00	24.00	30.00
kitchen taps consumption l/d	0.00	450.00	0.00	18.00	18.00	72.00	72.00	162.00	162.00	288.00	288.00	450.00
bathroom tap												
tap flow rate in l/min	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
tap opening time in min/day	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
bathroom taps consumption l/d	0.00	225.00	0.00	9.00	9.00	36.00	36.00	81.00	81.00	144.00	144.00	225.00
hosepipe consumption												
hosepipe flow rate in l/min	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
hosepipe opening time in min/day	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
hosepipe consumption l/d	0.00	225.00	0.00	9.00	9.00	36.00	36.00	81.00	81.00	144.00	144.00	225.00
sprinkler consumption												
sprinkler flow rate in l/min	0.00	15.00	0.00	3.00	3.00	6.00	6.00	9.00	9.00	12.00	12.00	15.00
sprinkler opening time in min/day	0.00	30.00	0.00	6.00	6.00	12.00	12.00	18.00	18.00	24.00	24.00	30.00
sprinkler consumption l/d	0.00	450.00	0.00	18.00	18.00	72.00	72.00	162.00	162.00	288.00	288.00	450.00

household consumption in litres per day	0.00	750.00	0.00	150.00	150.00	300.00	300.00	450.00	450.00	600.00	600.00	750.00
per-capita consumption in litres per day	0.00	300.00	0.00	60.00	60.00	120.00	120.00	180.00	180.00	240.00	240.00	300.00
Domestic demand in million of litres per day	0.00	3750.00	0.00	75.00	75.00	150.00	150.00	225.00	225.00	300.00	300.00	375.00
settlement demand in millions of c.m per day	0.00	0.50	0.00	0.10	0.10	0.20	0.20	0.30	0.30	0.40	0.40	0.50
population number in millions	0.00	10.00	0.00	2.00	2.00	4.00	4.00	6.00	6.00	8.00	8.00	10.00
households number in millions	0.00	5.00	0.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00
connections number in millions	0.00	5.00	0.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00
occupancy rate (persons per household)	0.00	5.00	0.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00
household annual income in £	0.00	50000.00	0.00	10000.00	10000.00	20000.00	20000.00	30000.00	30000.00	40000.00	40000.00	50000.00
household adults number	0.00	2.00	0.00	0.40	0.40	0.80	0.80	1.20	1.20	1.60	1.60	2.00
household children number	0.00	3.00	0.00	0.60	0.60	1.20	1.20	2.80	2.80	2.40	2.40	3.00
average annual rainfall	0.00	1000.00	0.00	200.00	200.00	400.00	400.00	600.00	600.00	800.00	800.00	1000.00
max. daily temperature	0.00	35.00	0.00	7.00	7.00	14.00	14.00	21.00	21.00	28.00	28.00	35.00
water price in £/c.m	0.00	1.00	0.00	0.20	0.20	0.40	0.40	0.60	0.60	0.80	0.80	1.00
conservation effectiveness	0.00	100.00	0.00	20.00	20.00	40.00	40.00	60.00	60.00	80.00	80.00	100.00

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DFMS DOMENSTRATION AND EVALUATION

6.1 - Introduction

Having described the system development, design structure and computational methods in the previous two chapters, this chapter demonstrates the various procedures for forecasting domestic water demand, including demand, management using the data for the Swindon demand zone of Thames Water Utility. The chapter is divided into five main sections: the first describes the WaterWare pilot-study area in general and Thames river-basin in particular including current water resources and demand; the second describes the demand regions and zones of Thames Water Utility including the Swindon demand zone; the third demonstrates the DFMS procedures in forecasting domestic water demand using the data for the Swindon area; the fourth describes how some of the DFMS special facilities can be used to help the user in the development of different demand scenarios and provide him with the necessary explanations if they are required; the final section describes the system verification and evaluation including system limitations.

6.2 - WaterWare pilot applications

As mentioned previously, WaterWater is a generic decision-support system which can be applied to different river basins. At present, there are two pilot applications, the first being the Thames basin in southern England, the other being the Lerma basin in Mexico. The Thames basin was selected to be a prototype application of the WaterWare, mainly because of its complexity. Notwithstanding the modest size of the basin, the Thames system is perhaps one of the most intensively used in the world. Therefore, if the prototype version of WaterWare could be applied successfully to the Thames basin, there should little difficulty in applying it to other basins. A further reason for selecting the Thames basin was the need for data which were readily available from Thames Water Utilities Ltd (TWUL).

6.3 - Thames basin general description

The Thames basin covers an area of approximately 13000 Km ^{2}. It is considered to one of the most extensively-managed catchments in the world, supporting a population in the order of 12 million including that of London. On average, about 3.7 x 10^6 m^3 per day are abstracted for public water supply. The public water-supply requirements alone represents about 55 percent of the natural runoff from the freshwater portion of the catchment in an average year and correspondingly more in a dry year. On average about 12 percent of resources for public supply are derived from indirect effluent re-use and during a dry summer, this figure can rise to 70 percent locally.

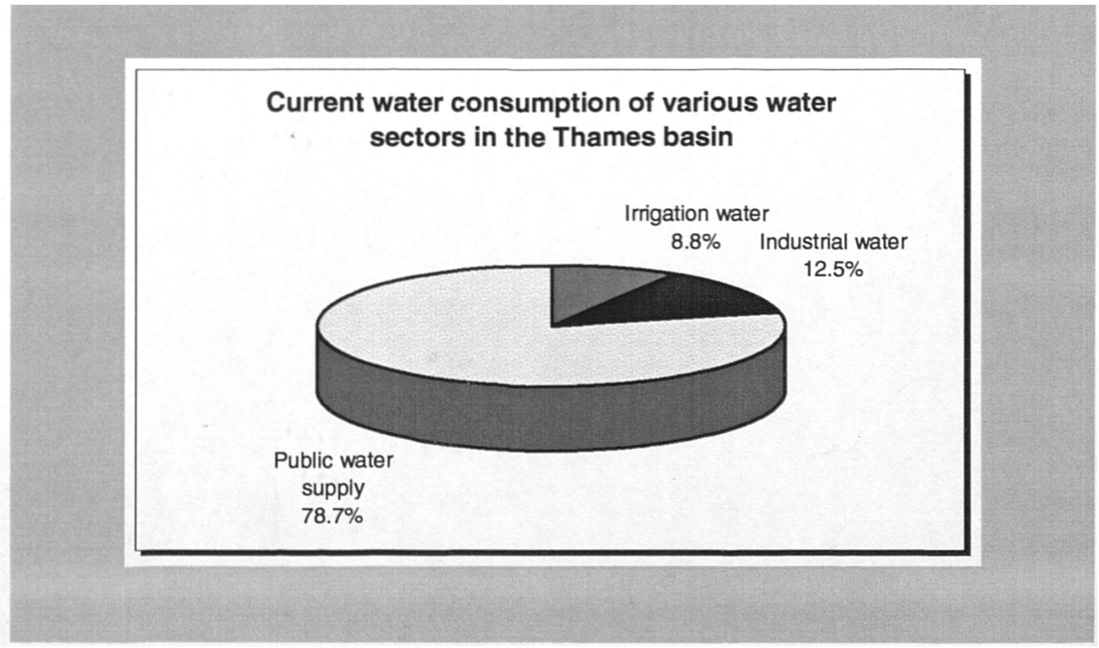
6.3.1 - Water resources

Thames basin can be considered as self-sufficient in terms of water resources, with no imports from or exports to adjacent basins at present. The main source of supply is the River Thames itself. Overall, about 58 percent of all water-supply needs are met from surface-water abstractions, including indirect effluent re-use. As there are no natural reservoir sites within the basin, all reservoirs are fully-bunded pumped-storage, of which there are some 24, mainly in the lower reaches of Thames. These reservoirs provide a useful storage capacity of approximately 220 x 10^6 m^3, which represents little more than 3 months supply. Extensive use, particularly in the rural areas, is made of largely unconfined aquifers which underlie most of the basin. In terms of water quality, the fresh-water portion of Thames has always been reasonably good since it is the primary source of supply for London. Nevertheless, there was a gradual deterioration from about 1974 onwards when water services were still in the public sector. Since privatisation of the water industry in 1989, this trend has been reversed. Now the main problems related to water quality are caused by pollution incidents rather than background conditions *(TWUL, 1994).*

6.3.2 - Water demand

One of the most serious problems in the Thames basin is to meet the continuing increase in water demand without adversely affecting the environment. Although industrial demand has declined since the early 1960s, increases in commercial and particularly domestic uses have more than offset this reduction. Overall, the demand for water, according to TWUL, is expected to increase by about 0.7 percent per annum compound over the next 20 years, largely as a result of improved living standards rather than population increase. Therefore, for the basin as a whole, the projected water-resources deficit would be in order of 0.44×10^6 m^3 per day by the year 2016 if no further resources were developed. This however, is an understatement of the additional resource requirements, as surpluses in one part of the basin can not necessarily be traded for deficits in another. Nor does it take into account the predicted impact of global warming, voluntary reductions in groundwater abstraction or possible loss of existing temporary licences.

Whilst irrigation consumes about 8.8 percent of the basin's water resources and industry uses a further 12.5 percent (including industrial cooling water), public water supply accounts for the remaining 78.7 percent of the total abstracted as shown below.



Most premises are supplied by the statutory water companies although a small percentage about (0.9 percent) is abstracted directly for private (such as ground water wells or from river). Public water supply can be divided into the following categories:

- unmetered domestic demand;
- metered domestic demand;
- metered industrial/commercial demand;
- unmetered industrial/commercial demand;
- total losses

For the purpose of both water supplying and forecasting it demand, the Thames basin is divided into a large number of demand zones as shown in Figure (6.1). A demand zone as it was defined in chapter 4 is a discrete area of supply which is if adequate resources are provided for that area as a whole, it can be assumed that the demand for water is met. Frequently, demand zones are grouped into regions which are supplied from the same sources. A demand region could comprise:

- an entire company's distribution area;
- a combination of zones within one or more companies;
- an individual zone within a company's area.

As the largest of the six water companies within the Thames basin, TWUL has the responsibility for the following demand regions:

- Lower Thames which consists of primarily the London area;

- Middle Thames which includes Slough, Wycombe, Aylesbury, Guildford, Reading, South Oxfordshire and Kennet Valley areas;

- Upper Thames which is based on the Oxford, Banbury and Swindon areas.

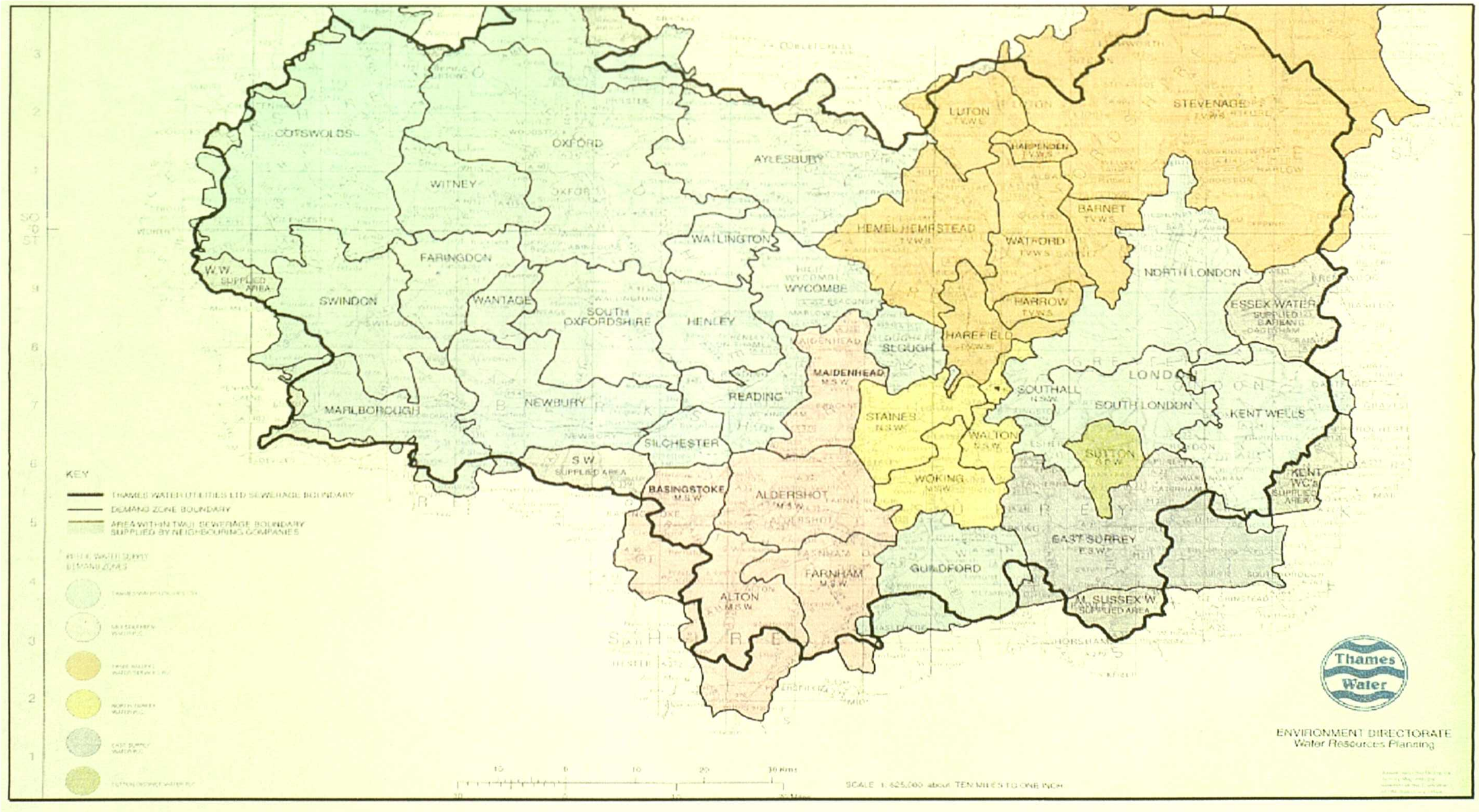


Figure (6.1) - Demand zones of Thames Water Utility

The Swindon demand zone is part of Upper Thames demand region, comprising Wiltshire, parts of Gloucestershire and West Oxfordshire. Since this area has a high growth rate in terms of population, it is expected to have a serious water deficit within the next twenty years if water demand continues to grow in as the recent past. Therefore, it has been selected as a case study to demonstrate DFMS's capabilities and computational procedures for forecasting domestic water demand including demand management. Table (6.1) summarises the base year (1995/1996) information (population, occupancy rate, households, water consumption etc.) for the Thames basin as a whole and the Swindon area in particular.

6.4 - DFMS activation procedures

Since the DFMS is linked to the database component in WaterWare, the top level start-up screen of both systems is the same as shown in Figure (6.2). Therefore, in order to start DFMS, the user has first to select the database icon on the main screen.

Figure (6.2) - WaterWare start-up screen

The selection of database icon displays the object-database screen in which the DFMS start-up window is located. The object display screen contains a basic map

Table (6.1) - Base-year (95/96) data for Thames basin and Swindon area

	population number	occupancy rate persons / household	households number	per-capita consumption litres / day	per-household consumption litres / day	total consumption millions of litres / day
Thames Basin						
total/average	7358390	2.32	3171720	154	357	1133
Swindon Area						
total/average	344410	2.52	13657	154	388	53

of the Thames basin, a window for the available object classes and a list of icons for GIS connection, screen exist, help information and map zooming. Object-classes include various basin features such as water-quality stations, reservoirs, demand zones, climatic stations etc., as shown in Figure (6.3).

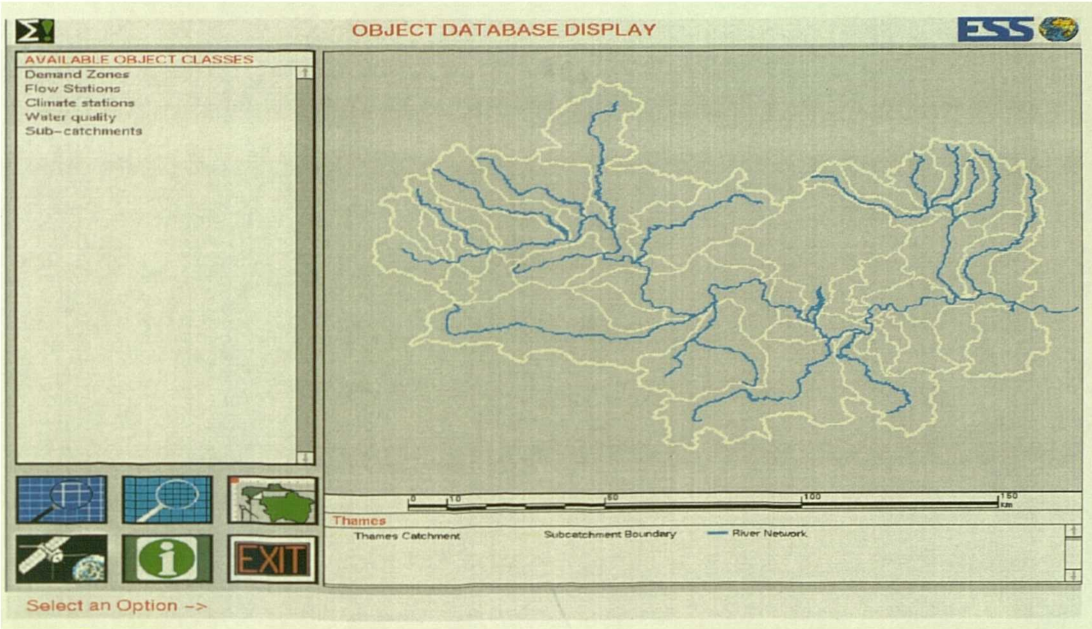


Figure (6.3) - Objects database display screen

At this stage, the user can switch to GIS to display the required geographical information such as basin boundaries, sub-catchments, urban areas, rural areas, cities, towns etc. Furthermore, the GIS can be used to display different satellite images, elevation details in two or three dimensions etc. These overlays can be combined to provide a composite image which can be enlarged with the zooming facilities provided. Once the overlay is selected, it will be displayed in the active window. For example, large urban areas, river network, catchment boundaries and Thames catchment are active overlays, as shown in Figure (6.4). Conversely, once any of these overlays becomes inactive, it will disappear from active window.

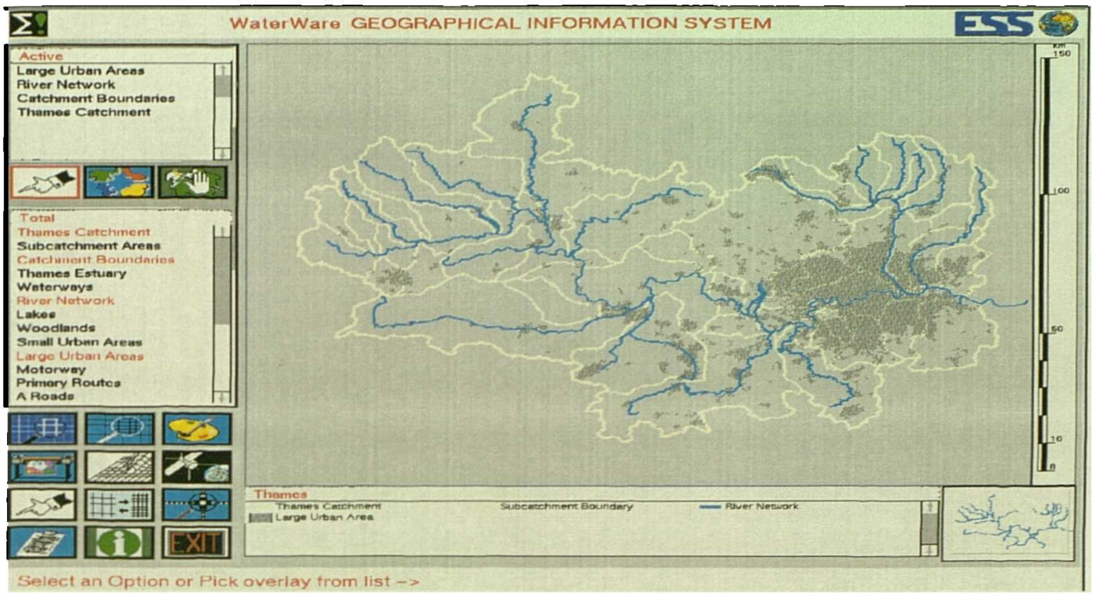


Figure (6.4) - GIS display screen and control icons

The selection of the "demand zones" object will display a sub-window contains a full list of demand zones in Thames basin as shown in Figure (6.5).

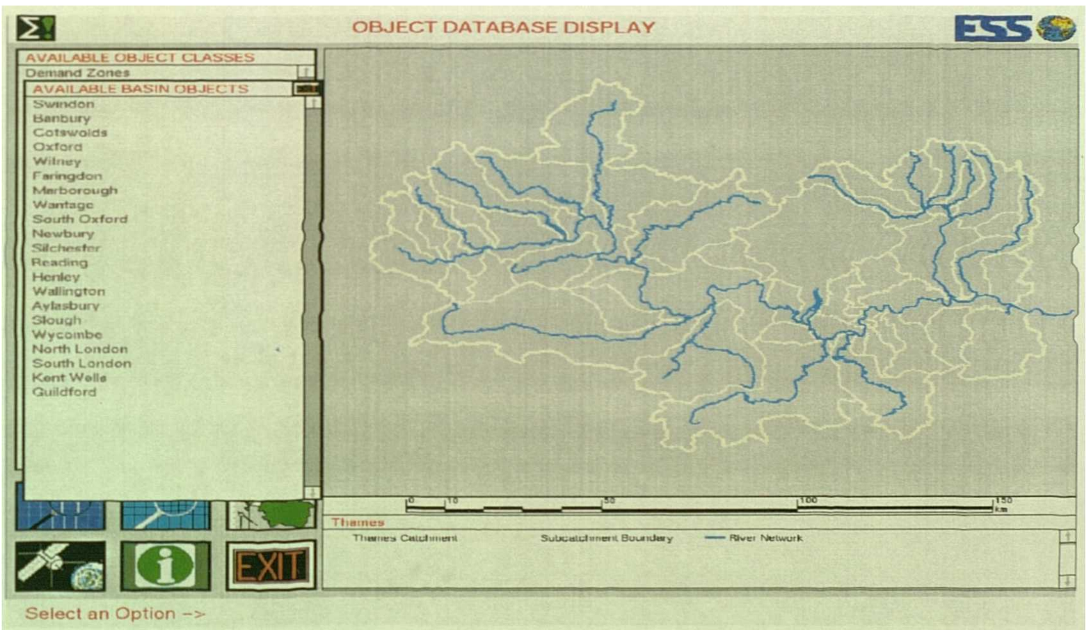


Figure (6.5) - List of demand zones in Thames basin

Selecting any of these zones will activate the corresponding attributes screen. For example, if the Swindon zone is chosen, then the Swindon attributes screen will be displayed. The attributes screen for any demand zone contains a summary of most important information relating to the zone. More specifically, the information can be grouped into: (i) descriptive information such as name of demand zone, name of the river basin, catchment name, longitude, latitude and elevation; (ii) planning information such as population, domestic-water demand, industrial demand, re-use water etc.; (iii) help information including text material and pictures either on the front screen or as hypertext files; (iv) data links either to display data files or results in different forms as shown in Figure (6.6).

Since the planning information is in the form of a target descriptors within the knowledge-base, it is possible to activate an expert system to predict a value for any of these descriptors. Accordingly, if the value is unknown, the next step is to click on one of the target descriptors for answer deduction. Once the answer has been deduced, it will be saved permanently in the header file of the zone unless otherwise changed.

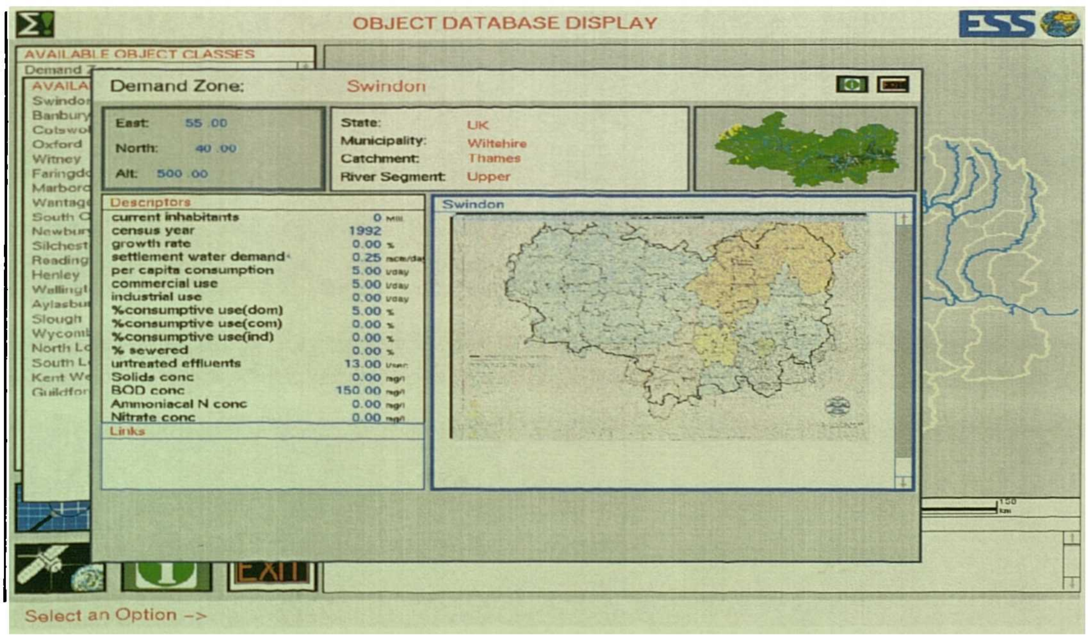


Figure (6.6) - Attributes screen of Swindon zone

6.5 - DFMS deduction procedures

As mentioned previously, the DFMS is based on an expert system and therefore, all the necessary variables for forecasting domestic water demand and demand management are in the form of descriptors in the knowledge-base. These descriptors are linked to each other either through rules or an external model. In this way, the target result (target descriptor) cannot be achieved unless all the related descriptors have values from either the user or the knowledge-base. The deduction process for any descriptor (either target descriptor or any complementary descriptor at any level) is a step-by-step procedure which includes questions and answers, creating a dialogue between the user and the system. The questions are raised by the system whilst the answers may come from the user or the system in the case where the user does not know the answer. Both questions and answers (communication procedures) are controlled by the expert-system menu.

The expert-system menu includes buttons for answers deduction such as Rule-based and Run-model in addition to knowledge browser, answer confirmation, exit and help. The normal way is to use the Rule-based deduction option for predicting a value for any descriptor. However in some cases where an external model is linked to the descriptor, the Run-model option will be used instead of Rule-based deduction.

Either way, once the value is deduced, it has to be confirmed before the system moves to next descriptor. The confirmed values will be stored in the system and kept there as default answers for new trials. When a default value is used, it will be displayed in a different colour (the colour of deduction menu will change from red to blue). Default values can be confirmed as presented, changed or deduced again.

The same procedures have been applied in the coming sections in deducing the necessary variables for forecasting domestic water demand in the Swindon zone.

This includes a graphical presentation of various deduction menus for these variables as well as an explanation of the input data, deduction procedures and deduced values. The order of variable-deduction is in accordance with their hierarchical organisation in the knowledge-base. Since many of the variables in this hierarchy are similar, only one example is given to demonstrate the deduction procedures, thereby avoiding repetition.

6.6 - Settlement water demand

Settlement water demand is the target descriptor which links domestic water demand with the knowledge-base. The selection of this descriptor activates its own menu as shown in Figure (6.7). By definition, settlement water includes domestic, commercial and unaccounted-for water, and consequently, the deduction of settlement water demand requires information on one or more of these water uses.

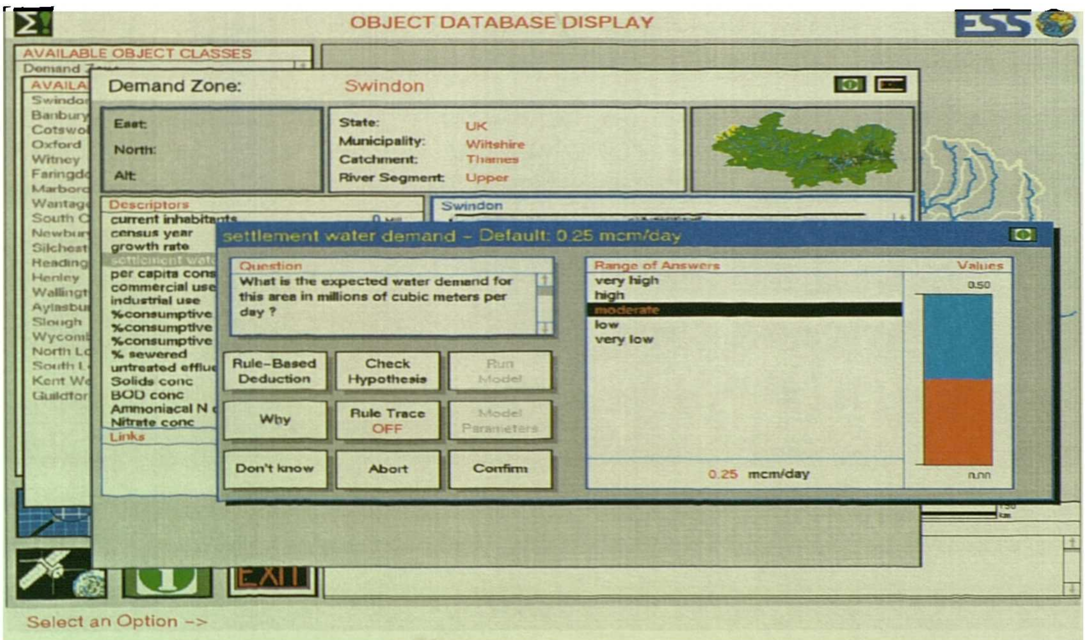


Figure (6.7) - Settlement-water demand deduction menu

Therefore, the water sector has to be identified first, simply by selecting one of the listed water sectors as shown in Figure (6.8). Since only domestic water has full procedures for demand forecasting and management, there is no rule-based deduction options for either commercial water demand or unaccounted-for water. Therefore, the water demand for these sectors has to be prepared outside the system at this stage of development.

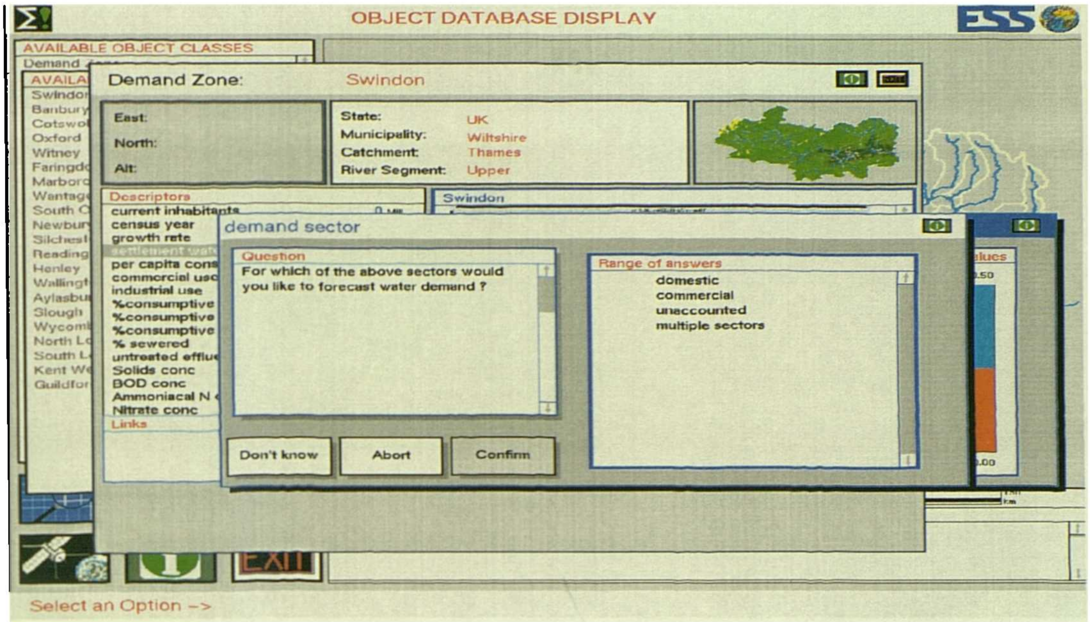


Figure (6.8) - Demand sectors list of answers

6.7 - Domestic water demand

As a result of selecting domestic water sector, the deduction menu for domestic demand will be displayed as shown in Figure (6.9). Since the domestic demand descriptor contains an external model, the Rule-Based deduction option is inactive as shown in the deduction menu. Therefore, the only possibility for predicting domestic demand value is by *the Run-Model option.*

The domestic demand model requires information on the following inputs: unit consumption-rate, conservation effectiveness and number of customers. In order to run the model, there should be a value for each of these inputs either from the user or to be deduced from the system if the user does not know a value. The latter option is assumed in order to demonstrate the computational procedures for the three inputs of the domestic demand model. For the purpose of this exercise, the year 1995/1996 was selected as the base year of analysis since most of the required data are available for that year whilst the year 2015/2016 was selected as the forecast year for data projections. Most of the furnished data in the system either for year 1995/1996 or year 2015/2016 are obtained from TWUL. If there is no data available on the future values (2015/2016) of domestic demand variables, the current values are assumed valid and where there is no data available at all, either at present or in the future the data are assumed based on available information from other demand zones or even other water companies or from the literature. In some occasions the assumed data are based on direct interpolation with the available data of other demand zones or extrapolated from past records.

However, the reliability of input data for various variables varies from one variable to another; the values of these inputs can be easily changed or updated since the expert system communication window allows a user to enter his own value or to use the default one which is already in the system.

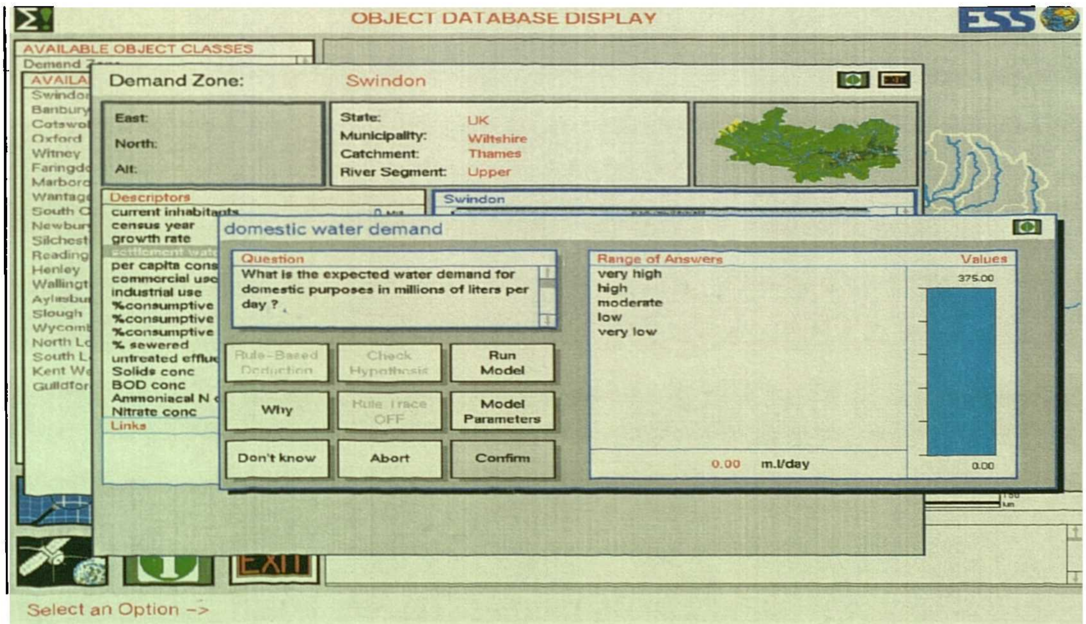


Figure (6.9) - Domestic-water demand deduction menu

Notwithstanding, it is possible to deduce each of these parameters without running the model itself by selecting the Model-Parameter button from the deduction menu. The selection of this option will display the various inputs and their values (either qualitative or quantitative) as shown in Figure (6.10). If there is no value associated with any particular parameter, the word "unknown" will appear instead of the answer. Once any of the model parameters has been changed, then the colour of "Run-Model" button will change automatically to green to indicate that some of the parameters have been modified and consequently the model has to be run again. When all the inputs have values, the model will run, produce the outputs and display it on a special window as shown in Figure (6.11).

Model outputs may include in addition to domestic demand, other information based on the users interests such as the reliability of forecast demand value. This can be in a form of a criteria which is based on the historical records of water demand in each demand zone.

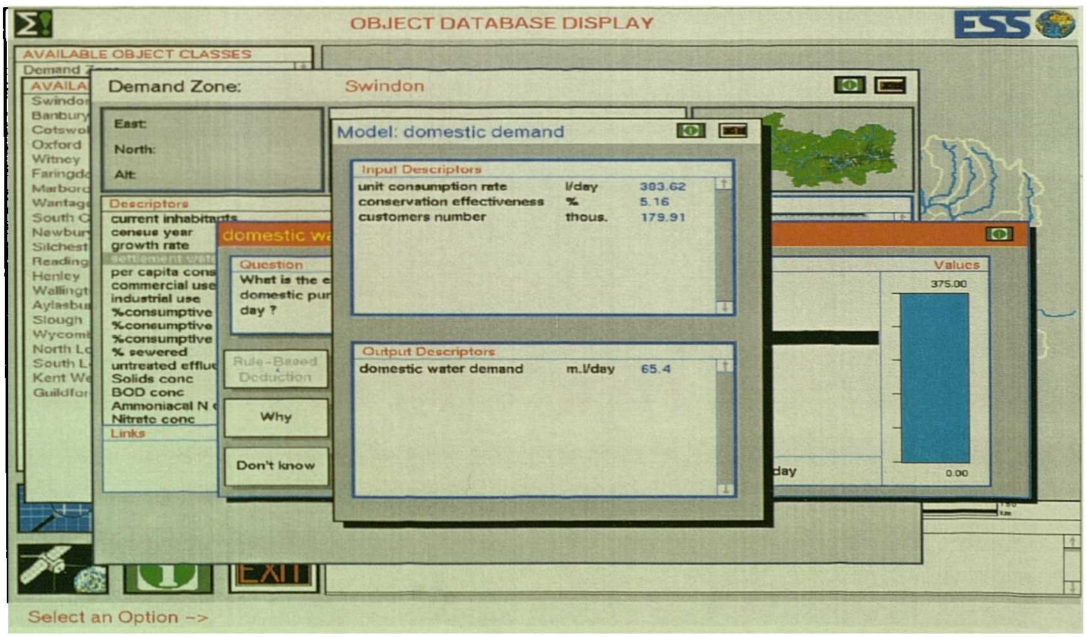


Figure (6.10) - Domestic-demand model, list of inputs

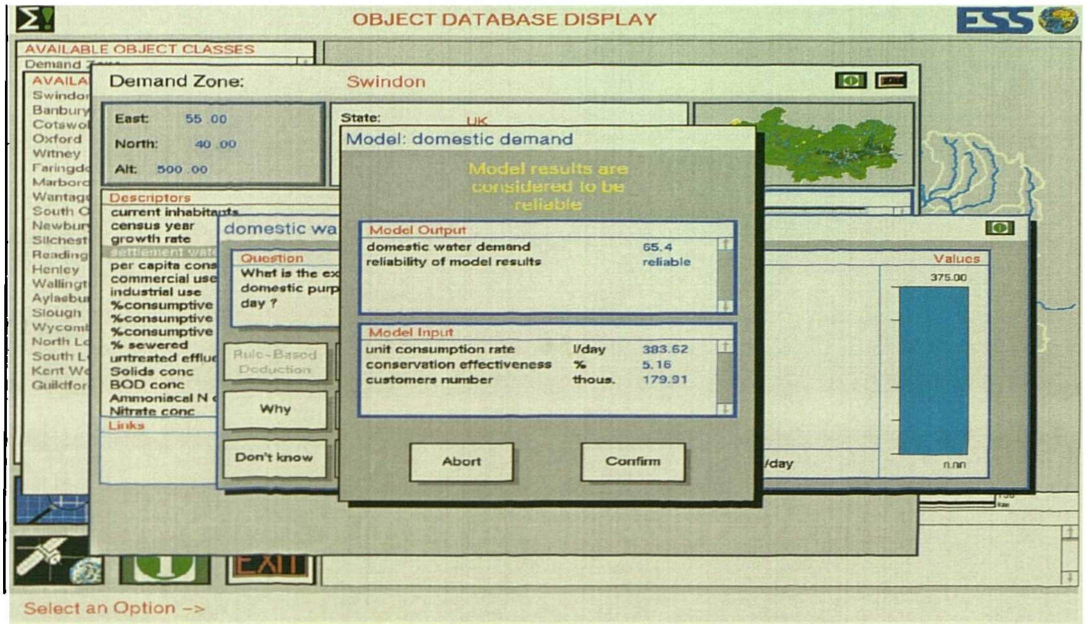


Figure (6.11) - Domestic-demand model, list of outputs

6.8 - Unit consumption rate

The deduction of unit consumption rate requires information on both the consumption unit and forecasting method. The system offers three possible options for consumption units: person, household and water connection as shown in Figure (6.12). Selection of the consumption unit depends on the data availability. However, for the purpose of this exercise, it is assumed that water consumption is referenced by household unit. As a result of this selection, the system will replace unit consumption-rate with household consumption and number of customer's with number of households. Therefore, the next step is to forecast household consumption and number of households as the determinants of unit consumption-rate and number of customers.

In order to deduce household consumption for any time period, the user has to identify the forecasting method in the first stage. The system provides the possibility of selecting the forecasting method which the user thinks is the most suitable for those conditions, or alternatively the most appropriate method based on different selection criteria. Figures (6.13,14) show the list of forecasting methods and selection criteria as they appear in the answers window. Since the intention is to demonstrate the system's capabilities, household consumption has been predicted by all four methods.

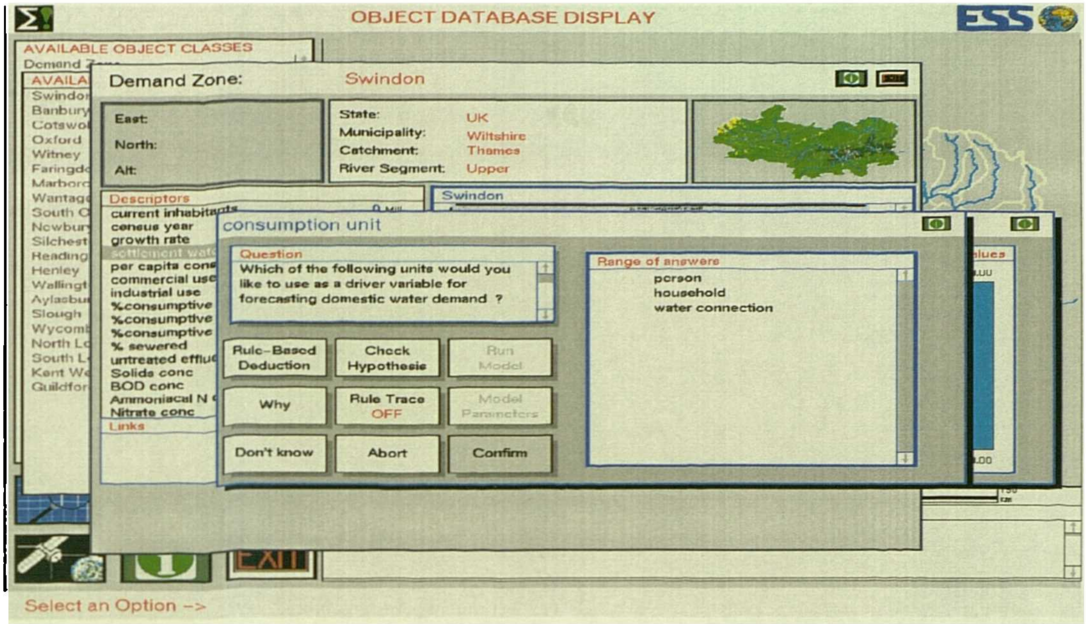


Figure (6.12) - Water-consumption reference units, list of options

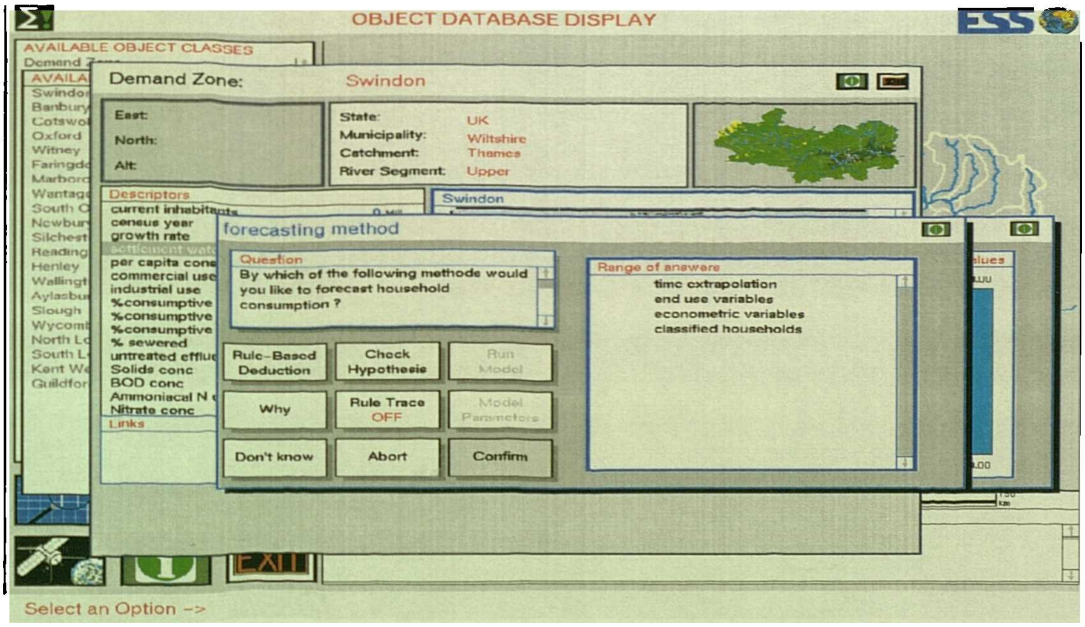


Figure (6.13) - Forecasting methods

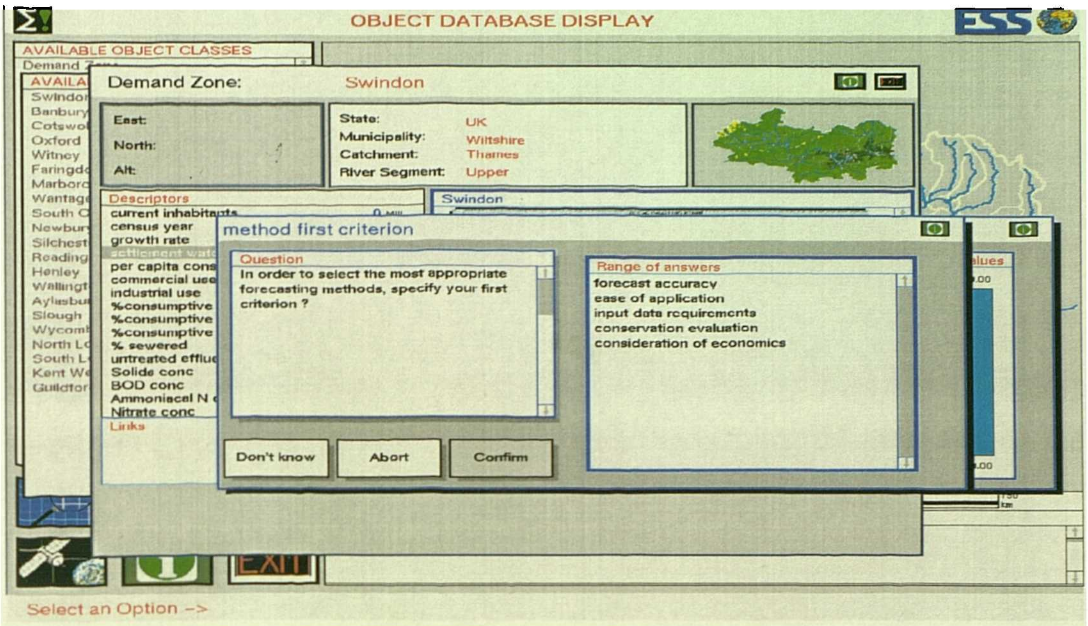


Figure (6.14) - Methods-selection criteria

6.8.1 - Extrapolated consumption rate

Household consumption can be projected into the future by using the extrapolation model. This is accomplished simply by identifying the required forecast year which represents the only input parameter of this model from the list of answers as shown in Figure (6.15).

Once the forecast year has been identified, the model will run and display the outputs on the screen as shown in Figure (6.16). In addition to the projected consumption, the outputs of extrapolation model include three statistical parameters which indicate the model adequacy in predicting household consumption.

Since, there are no historic data available for household consumption in Swindon area, or for that matter, any similar areas in Thames basin, the projected consumption by the extrapolation model represents the per-capita figure for Thames basin (demand zones which are supplied by TWUL) rather than per-household. However, household consumption can be computed by the multiplication of predicted per-capita consumption and projected occupancy rate for households in the Swindon zone.

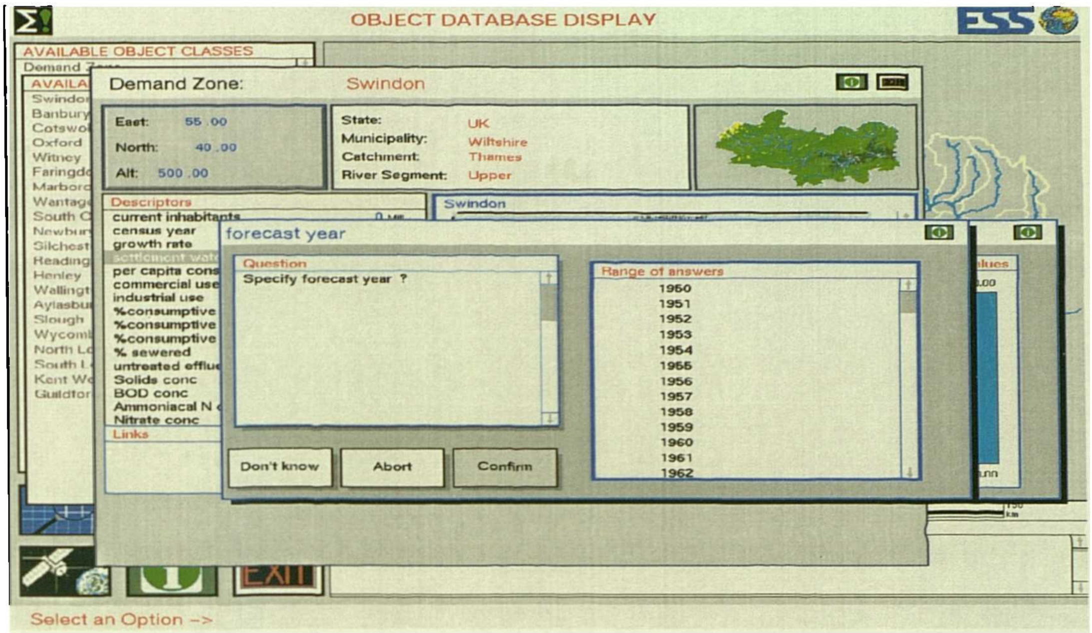


Figure (6.15) - Forecast years, list of options

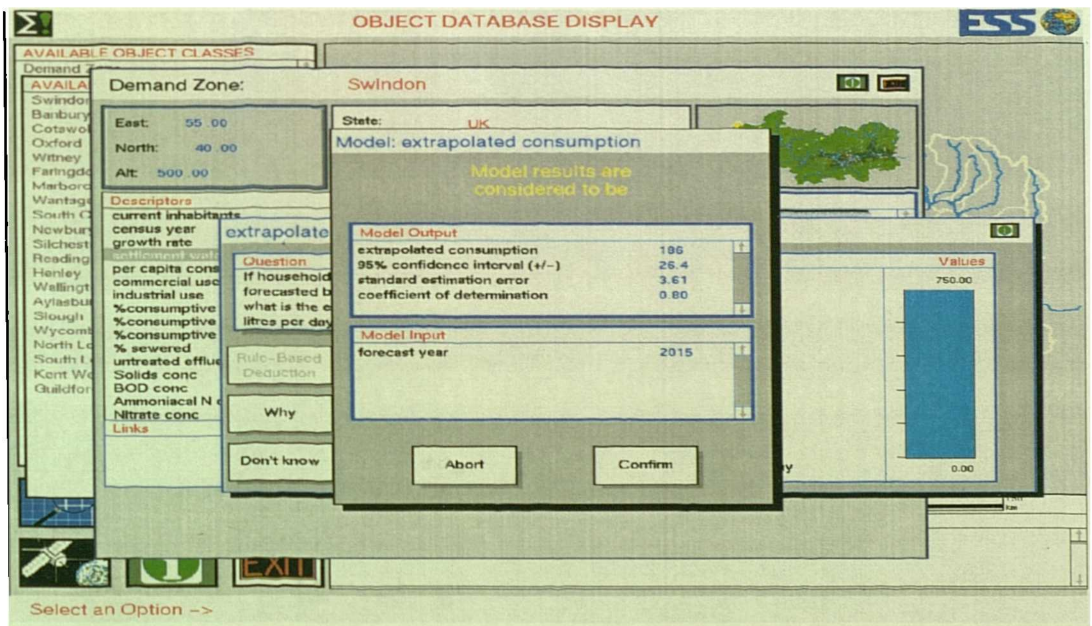


Figure (6.16) - Outputs of extrapolation model

A summary of the historic data for both Thames basin and Swindon zone, including the population and the number of households together with the predicted values of per-capita and household consumption rates for years 1995/1996 and 2015/2016 are given in Table (6.2a and 6.2b) respectively: the corresponding statistical parameters are given in Table (6.3).

It is clear from these results that, the per-capita consumption for the Swindon demand zone is expected to continue increasing (from 154 to 186) as a result of improved standards of living whilst the occupancy rate for Swindon area is expected to decrease to around 2.04 persons per household by year 2015. With regards to model adequacy, the computed statistical parameters (95 percent-confidence interval, standard error and determination coefficient for per-capita, occupancy rate and population projections) indicate acceptable projections. For example, determination coefficient for the extrapolated variables is more than 80 percent.

Table (6.2a) - Predicted per-capita and household consumption rates for Thames basin

year	population	occupancy rate persons / household	number of households	per-capita consumption litres/day	household consumption litres/day
1983	7080460	2.63	2692190	137	359
1988	7270370	2.53	2873664	142	360
1993	7355720	2.45	3002335	143	351
1995	7358390	2.32	3171720	154	357
2000	7500000	2.24	3348214	162	363
2005	7620000	2.12	3594340	170	360
2010	7730000	2.01	3845771	178	358
2015	7850000	1.89	4153439	186	352

Table (6.2b) - Predicted per-capita and household consumption rates for Swindon area*

year	population	occupancy rate persons / household	number of households	per-capita consumption** litres/day	household consumption litres/day
1983	331401	2.87	115471	137	392
1988	340290	2.76	123293	142	392
1993	344285	2.67	128946	143	383
1995	344410	2.52	136671	154	387
2000	351000	2.43	144444	162	394
2005	356000	2.30	154783	170	391
2010	362000	2.17	166820	178	386
2015	367000	2.04	179902	186	379

** Historic data of population and occupancy rate were estimated based on an interpolation with Thames data.

* It is assumed that, per-capita consumption data for Thames basin are valid for Swindon.

Table (6.3) - Statistical parameters of projected data for Swindon area

statistical parameter	Years			
	2000	2005	2010	2015
projected per-capita				
95%-confidence interval	11.3	13.3	15.6	18
error	3.61	3.61	3.61	3.61
determination cofficient	0.8	0.8	0.8	0.8
projected occupancy rate				
95%-confidence interval	0.22	0.27	0.34	0.41
error	0.05	0.05	0.05	0.05
determination cofficient	0.92	0.92	0.92	0.92
projected population				
95%-confidence interval	9.03	11.4	14	16.8
error	2.07	2.07	2.07	2.07
determination cofficient	0.92	0.92	0.92	0.92

6.8.2. - Econometric consumption rate

The procedures for using the econometric model or changing its parameters are the same as in the previous model. However, the econometric-model inputs include household income, number of adults, number of children, water price, annual rainfall and average maximum daily temperature. For demonstration purposes, a set of dummy observations for these variables have been used in this model since there are no available data for Swindon or any other zone in the Thames basin. Despite the model itself being based on dummy data, the knowledge-base includes answers for some of the input parameters based on data provided by TWUL such as annual rainfall, average maximum daily temperature and water price. In this way, it is possible to predict an answer for any parameter independently if requested.

In addition to the econometric consumption rate, model outputs include the ranking of model inputs (independent variables) according to their correlation with household consumption and other parameters for testing model adequacy as shown in Figure (6.17a and 6.17b).

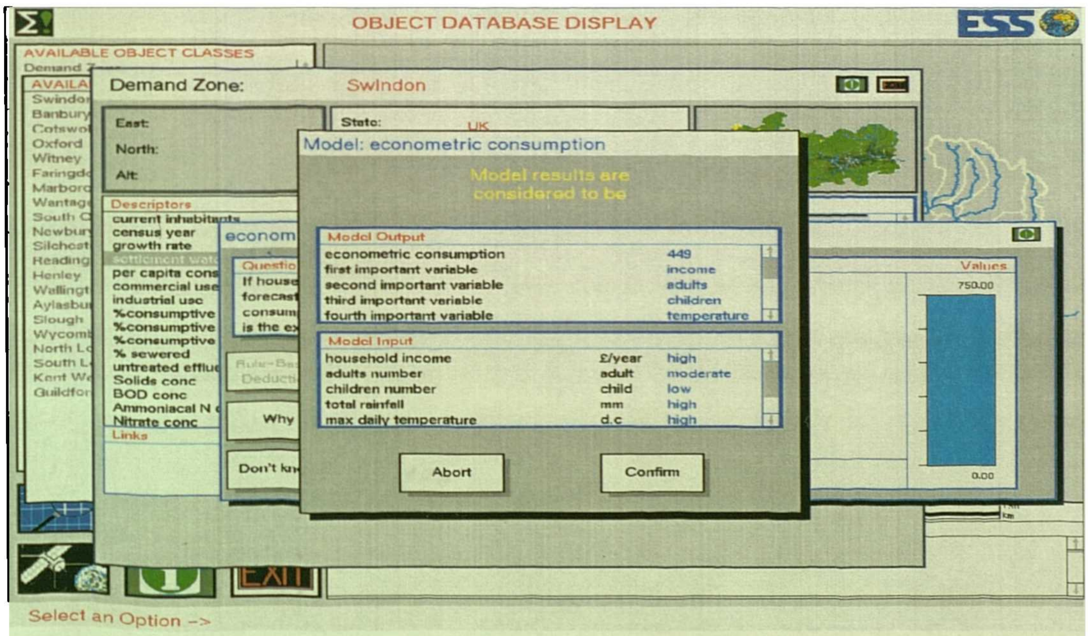


Figure (6.17a) - Outputs of econometric model

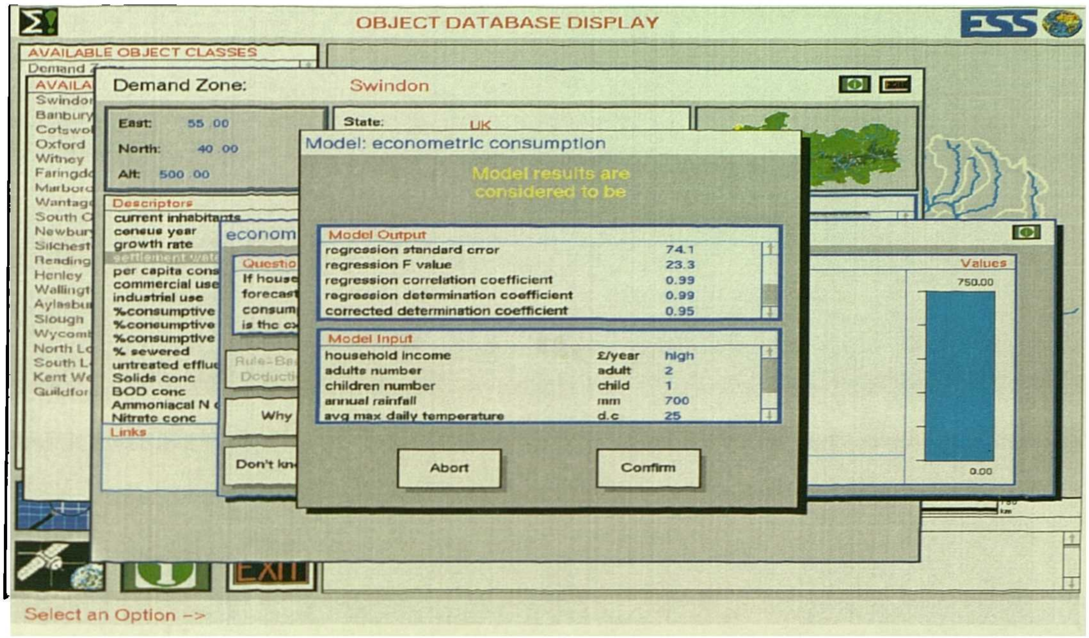


Figure (6.17b) - Outputs of econometric model (continued)

6.8.3 - End-uses consumption rate

The end-uses model inputs include dishwasher consumption, clothes-washer consumption, shower consumption, bathtub consumption, toilet consumption, indoor taps consumption (kitchen and bathroom tap consumption) and outdoor taps consumption (hosepipe and sprinkler consumption). The deduction of each of these inputs requires information for the following variables: device capacity, frequency of use, coverage percentage and leakage percentage. Since not all of the required information is available, some assumptions had to be made. For example, it was assumed that, leakage percentage for all devices was zero. Similarly, the flow rate of the various taps was assumed to be between 5 and litres per minute and the usage time taken to be between 5 to 10 minutes per day on average.

The deduction process for deriving the consumption rates of the various devices are similar and therefore, toilet consumption has been selected to demonstrate these procedures for toilet-flushing capacity, frequency of use and coverage percentage. These are shown in Figures (6.18, 19, 20, 21) respectively and the predicted consumption rate for toilets is given in Figure (6.22). The only exception is in deducing the consumption rates of both taps and showers which require information on the flow rate, usage time in minutes in addition to frequency of use, coverage percentages and leakage percentage. The deduction process starts with the estimation of the toilet capacity which requires identification of the dominant type of toilets in the demand zone. The assumed answer was 'all types', which includes both conventional and efficient toilets. As a result of this answer there should be an estimate of the coverage distribution of these types in order to estimate the average weighted capacity (since the replacement rate of conventional toilets to efficient ones is expected to be in an order of 3 percent a year, it was assumed that the coverage percentages of both types by the year 2015 are 40 percent and 60 percent respectively *(TWUL 1994))*. Therefore the predicted capacity was about 8.1 litres per flush. Next, the user has to defined the frequency of toilet flushing per day (deduced value is about 13 flushes per day, assuming the frequency of use for both the base and forecast years are the same). Finally, the coverage percentage of toilets was assumed to be 100 percent. Once all these variables have been estimated, the predicted consumption rate of is deduced to be about 105.3 litres per day.

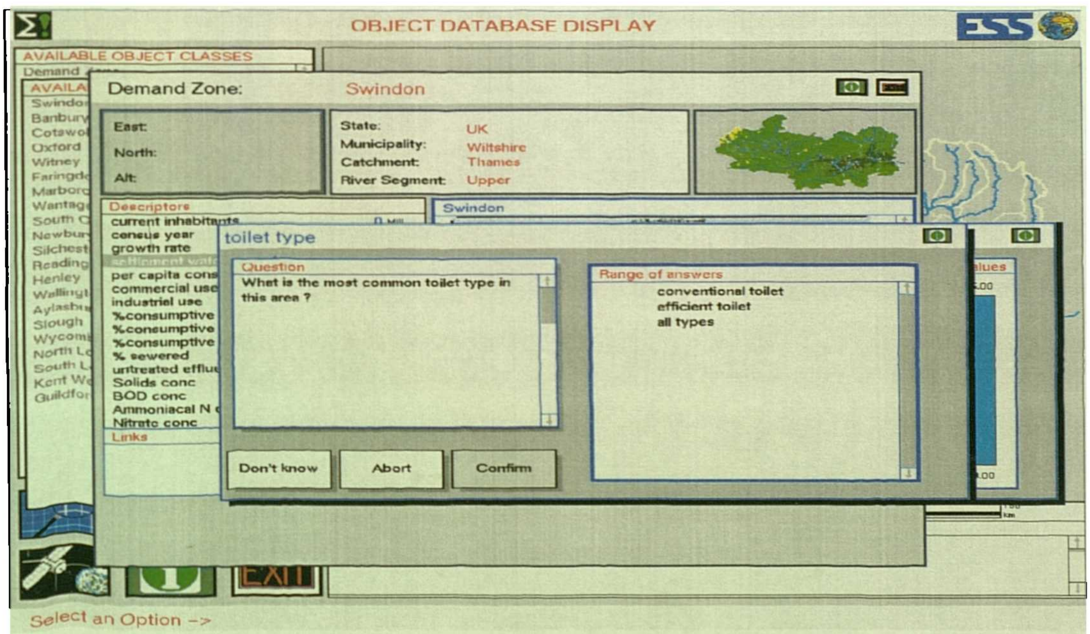


Figure (6.18) - Toilet types, list of options

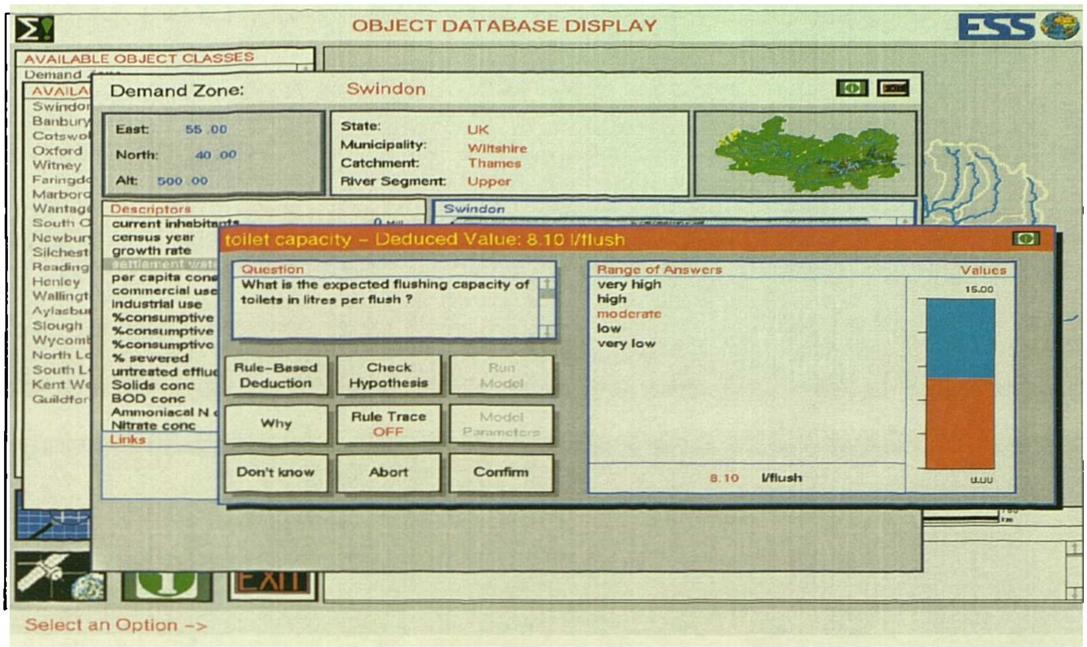


Figure (6.19) - Toilet flushing capacity, deduced answer

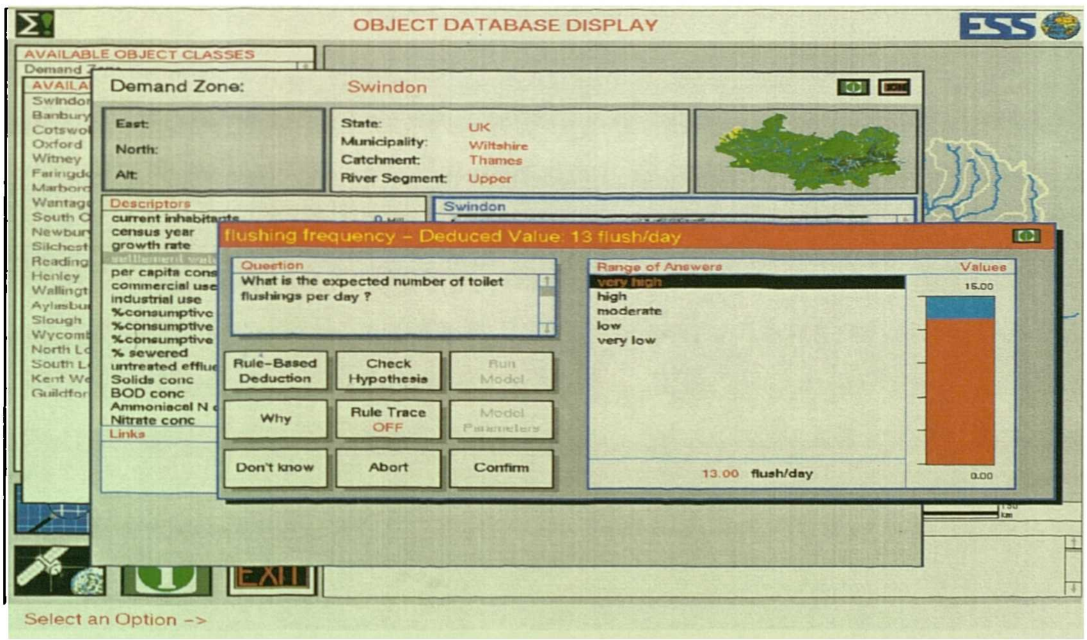


Figure (6.20) - Toilet flushing frequency of use, deduced answer

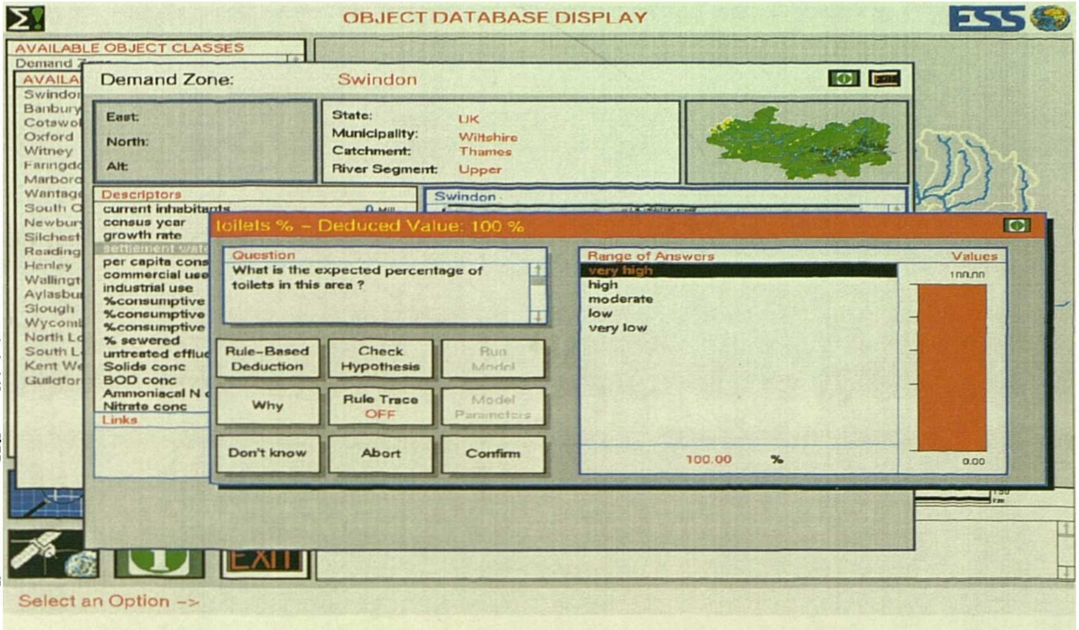


Figure (6.21) - Toilet-coverage percentage, deduced answer

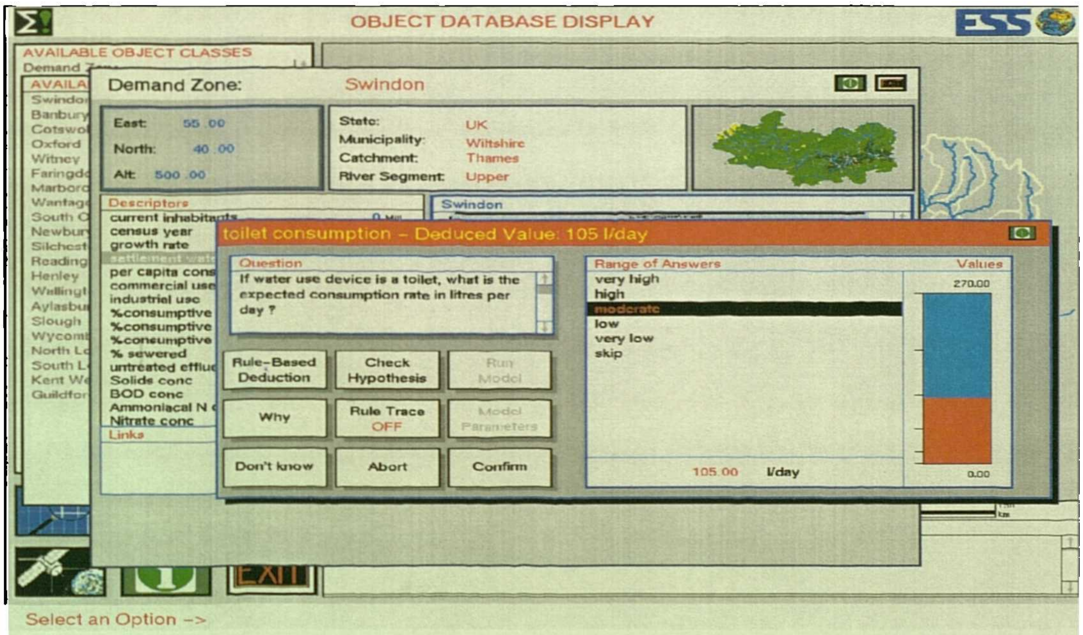


Figure (6.22) - Toilet-consumption rate, deduced answer.

The same procedures can be used for deducing the consumption rates of other devices. Once the consumption estimates for all the various devices have been completed, the model will produce the outputs as shown in Figure (6.23). In addition to the end-uses consumption rate, the model outputs include planning information such as percentages of indoor and outdoor water use, as well as consumption of the various devices relative to end-uses consumption rate. If the user is interested in estimating the consumption rate for one specific device, it is not necessary to run the end-uses model: instead, the user can select the particular device from the list of model inputs and deduce its value separately.

A summary which contains consumption of various devices, household consumption, relative percentages of devices-consumption rates to household consumption and per-capita consumption for Swindon area and for both the base and forecast years are listed in Tables (6.4 and 6.5) respectively.

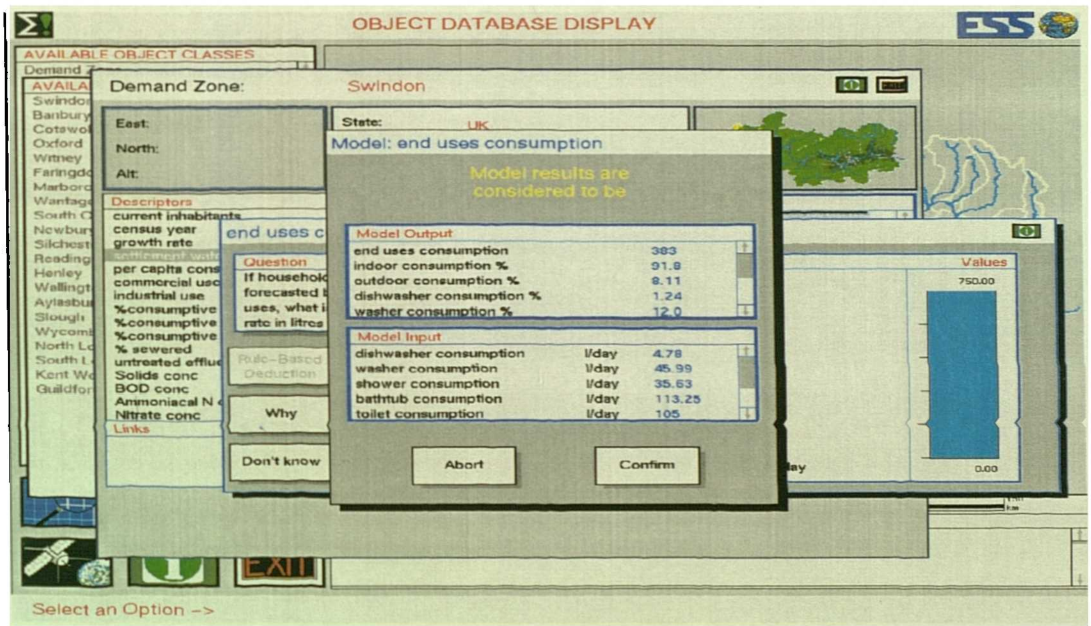


Figure (6.23) - Outputs of end-uses model

Table (6.4) - Household consumption based on end-uses for Thames basin and Swindon area for base year (1995/1996)*

water use device	flow rate litres/minute	time of usage minutes / day	capacity liters	capacity/flow %	frequency times/day	leakage %	coverage %	device consumption liters/day	device consumption % relative to household
conventional dishwasher	....	....	40.00	95.00	0.79	....	16.70	5.28	1.36
efficient dishwasher	....	....	20.00	5.00	0.79	....	0.90	0.14	0.04
average dishwasher	....	....	39.00	100.00	0.79	....	17.60	5.42	1.40
conventional washer	....	....	95.00	95.00	0.75	....	79.00	56.29	14.52
efficient washer	....	....	70.00	5.00	0.75	....	4.00	2.10	0.54
average washer	....	....	93.75	100.00	0.75	....	83.00	58.36	15.05
conventional shower	5.00	5.00	....	84.00	1.07	....	61.00	16.32	4.21
power shower	10.00	5.00	....	16.00	1.07	....	12.00	6.42	1.66
average shower	5.80	5.00	....	100.00	1.07	....	73.00	22.65	5.84
bathtub	....	....	108.00		1.07	....	98.00	113.25	29.21
conventional toilet	....	....	9.00	100.00	13.00	....	100.00	117.00	30.18
efficient toilet	....	....	7.50	0.00	13.00	....	0.00	0.00	0.00
average toilet	......	....	9.00	100.00	13.00	....	100.00	117.00	30.18
bathroom tap	3.00	5.00	....	....	....	....	100.00	15.00	3.87
kitchen tap	5.00	8.00	....	....	....	....	100.00	40.00	10.32
indoor taps consumption**								55.00	14.19
hosepipe	3.00	5.00	....	....	....	....	46.00	6.90	1.78
sprinkler	7.00	10.00	....	....	....	....	13.00	9.10	2.35
outdoor taps consumption**								16.00	4.13
household consumption								387.68	100.00

* These data are based on TWUL reports.

** Components of both indoor and outdoor taps are based on subjective assumptions.

Table (6.5) - Household consumption based on end-uses for Thames basin and Swindon area for the forecast year 2015/2016*

water use device	flow rate litres/minute	time of usage minutes / day	capacity litres	capacity/flow %	frequency of use times/day	leakage %	coverage %	device consumption litres/day	device consumption % relative to household
conventional dishwasher	....	....	40.00	12.00	0.79	....	3.24	1.02	0.27
efficient dishwasher	....	....	20.00	88.00	0.79	....	23.76	3.75	0.98
average dishwasher	....	....	22.40	100.00	0.79	....	27.00	4.78	1.25
conventional washer	....	....	95.00	12.00	0.75	....	10.08	7.18	1.87
efficient washer	....	....	70.00	88.00	0.75	....	73.92	38.81	10.12
average washer	....	....	73.00	100.00	0.75	....	84.00	45.99	11.99
conventional shower	5.00	5.00	....	52.00	1.07	....	46.80	12.52	3.26
power shower	10.00	5.00	....	48.00	1.07	....	43.20	23.11	6.02
average shower	7.40	5.00	....	100.00	1.07	....	90.00	35.63	9.29
bathtub	....	....	108.00	....	1.07	....	98.00	113.25	29.52
conventional toilet	....	....	9.00	40.00	13.00	....	40.00	46.80	12.20
efficient toilet**	....	....	7.50	60.00	13.00	....	60.00	58.50	15.25
average toilet	....	....	8.10	100.00	13.00	....	100.00	105.30	27.45
bathroom tap	3.00	5.00	....	....	....	....	100.00	15.00	3.91
kitchen tap	5.00	6.50	....	....	....	....	100.00	32.50	8.47
indoor taps consumption***								47.50	12.38
hosepipe	3.00	7.00	....	....	....	....	77.00	16.17	4.22
sprinkler	5.00	10.00	....	....	....	....	30.00	15.00	3.91
outdoor taps consumption***								31.17	8.13
household consumption								383.62	100.00

*These data are based on TWUL reports.

** Toilets replacement rate is assumed to be about 3% per year.

*** Components of both indoor and outdoor taps are based on subjective assumptions.

6.8.4 - Classified-consumption rate

This approach is based on the ACORN classification system for households in the UK. The system allows the user to select one class or multiple classes to represent the households in the demand zone as shown in Figure (6.24). For the former, usually the dominant class would be selected to represent the demand zone. In the case of the second option (multiple classes), the user has to define both the type and coverage for each of these classes before the system estimates the average consumption rate.

Since Swindon area has more than one class, the selected option was "multiple classes". As a result of selecting this option, the system will inquire about the type of neighbourhood and coverage for each class before producing a value for the household consumption rate. Based on the TWUL data for consumption rates and coverage of the various classes for the demand zones of Thames basin, the deduced household consumption rate was about 378 litres per day for the base year 1995/1996.

In order to estimate the consumption rate for the forecast year, both classes consumption- rate and their coverage have first to be projected into the future. For this purpose it is assumed that the coverage of various classes will remain the same as at present whilst the consumption rate by each class will increase by 22 percent based on the projected per-capita of the extrapolation method. Therefore, the expected classified-consumption rate for Swindon area by year 2015/2016 could be about 374 litres per day as shown in Figure (6.25). The main reason for the slight reduction in predicted household consumption for year 2015 is related to the decrease in the occupancy rate which expected to be about 2.04 persons per households in comparison with 2.52 persons per household at present. Table (6.6) summarises various households classes and average consumption by each class for both base and forecast years.

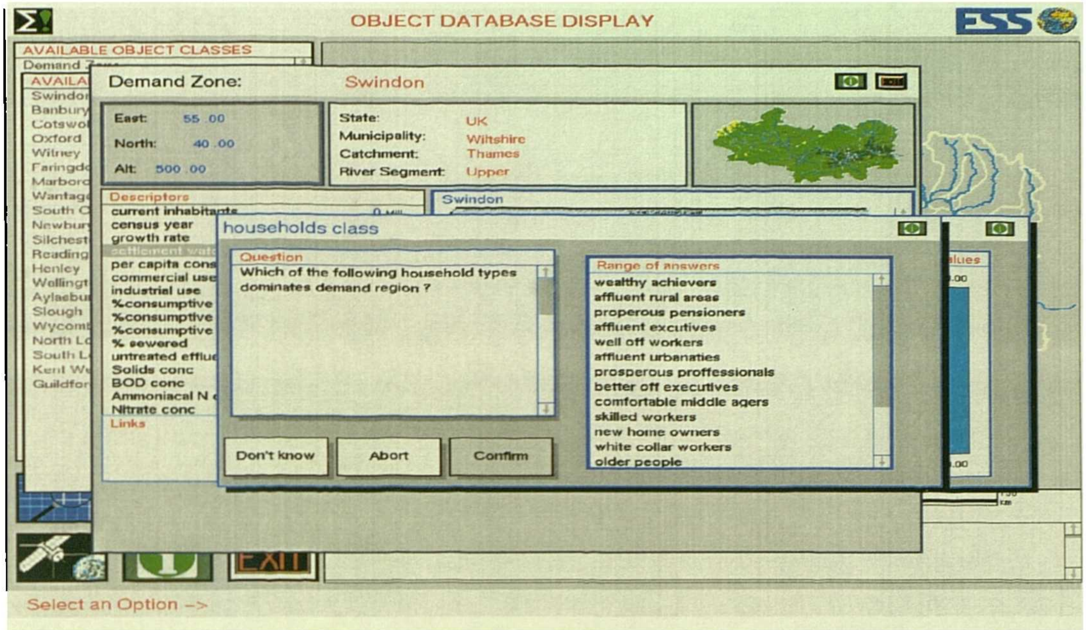


Figure (6.24) - Household classes, list of options

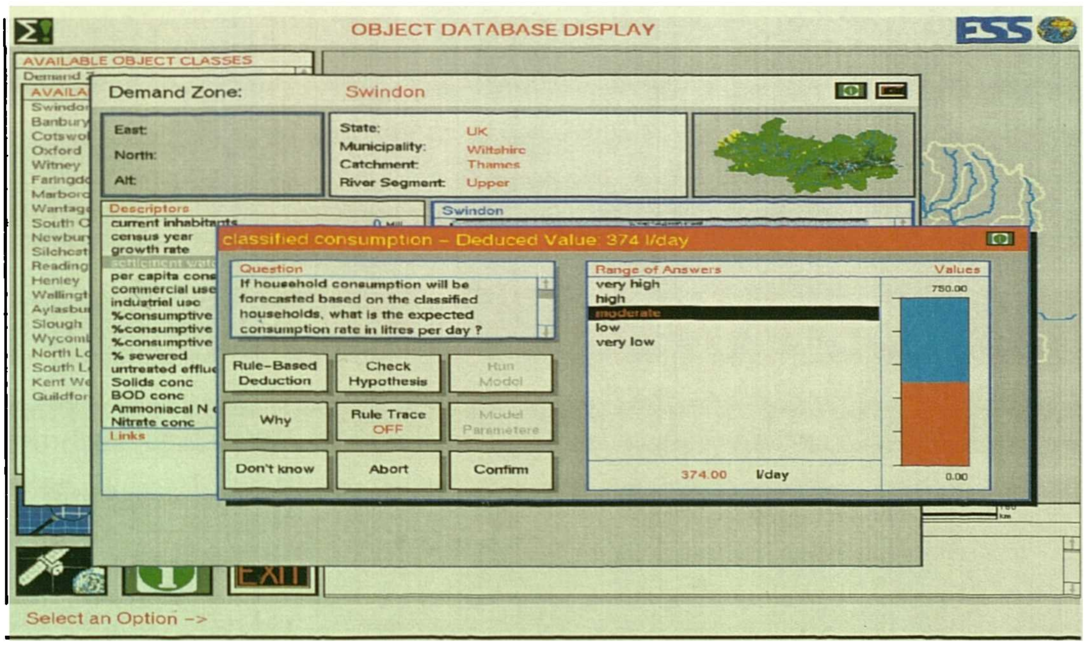


Figure (6.25) - Classified-consumption rate, deduced value

Table (6.6) - ACORN consumption rates for Thames basin and Swindon area for base and forecast years.

class description	consumption class	class coverage %*	per-capita consumption in litres/day for year 95/96 *	per-capita consumption in litres/day for year 2015/2016***
Wealthy Achievers, Suburban Areas	class A	19.40	177	215
Affluent Greys, Rural Communities	class B	4.90	167	203
Prosperous Pensioners, Retirament Areas	class C	2.80	157	191
Affluent Executives, Family Areas	class D	13.10	129	158
Well-Off Executives, Inner City areas	class E	10.80	149	182
Affluent Urbanites	class F	1.80	151	185
Prosperous Professionals, Metropolitan Areas	class G	0.40	157	191
Better-Off executives, Inner City Areas	class H	0.30	197	240
Comfortable Middle Agers, Mature Home Owning Areas	class I	15.80	136	166
Skilled Workers, Home Owning Areas	class J	8.70	164	200
New Home Owners, Mature Communities	class K	5.50	168	204
White Collar Workers, Better-Off multi Ethnic Areas	class L	2.30	160	195
Older People, Less Prosperous Areas	class M	2.60	138	169
Council Estate Residents, Better Off Homes	class N	10.00	127	155
Council Estate Residents, Greatest Hardship	class Q	1.00	97	118
People in Multi Ethnic, Low Income Areas	class P	0.6	128	156
				184
average per-capita consumption rate in litres per day			150	184
occupancy rate for Thames basin (persons per household)			2.32	1.89
occupancy rate for Swindon area (persons per household)			2.52	2.04
household consumption for Thames basin (litres/day)			348	348
household consumption for Swindon area (litres/day)			378	374

* Classes coverage percentage and per-capita consumption per class are based on TWUL data.
** It is assumed that on the forecast year the coverage of various classes will stay the same whilst per-capita consumption will increase by 22%.

6.9 - Conservation effectiveness

Thames Water Utility (TWUL) has proposed several measures to control the water demand in general and domestic water-use in particular. These measures are assumed to be valid for all areas supplied by TWUL including the Swindon zone. The proposed conservation measures include: households metering, pricing policy, encouragement to adopt conservation devices, raising public awareness through a special education programmes, imposing restrictions on some uses and reducing the leakage mainly from water supply system. Leakage from distribution network is not considered further here since it is beyond the scope of this study.

The system provides the user with the possibility to choosing an individual conservation measure or multiple measures (combination of two or more measures) or alternatively, to deduce the most appropriate measure based on different selection criteria as shown in Figures (6.26 and 6.27). Conservation measures should be selected in the following order so that the combined effectiveness of any two or more measures can be estimated: metering and pricing policy first, followed by conservation devices, education programmes etc.

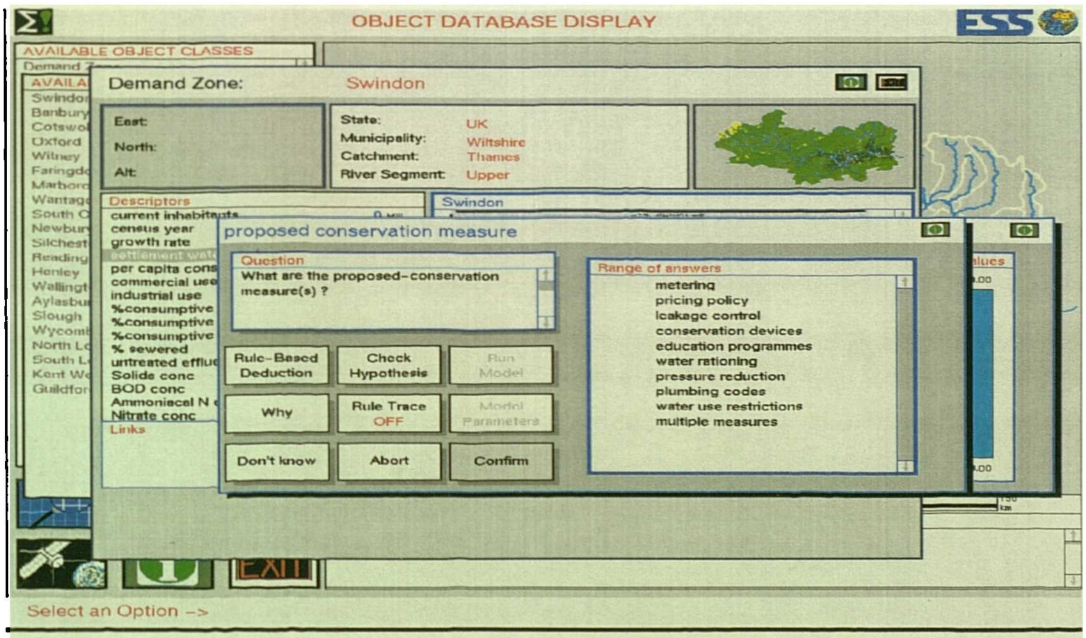


Figure (6.26) - Conservation measures, options

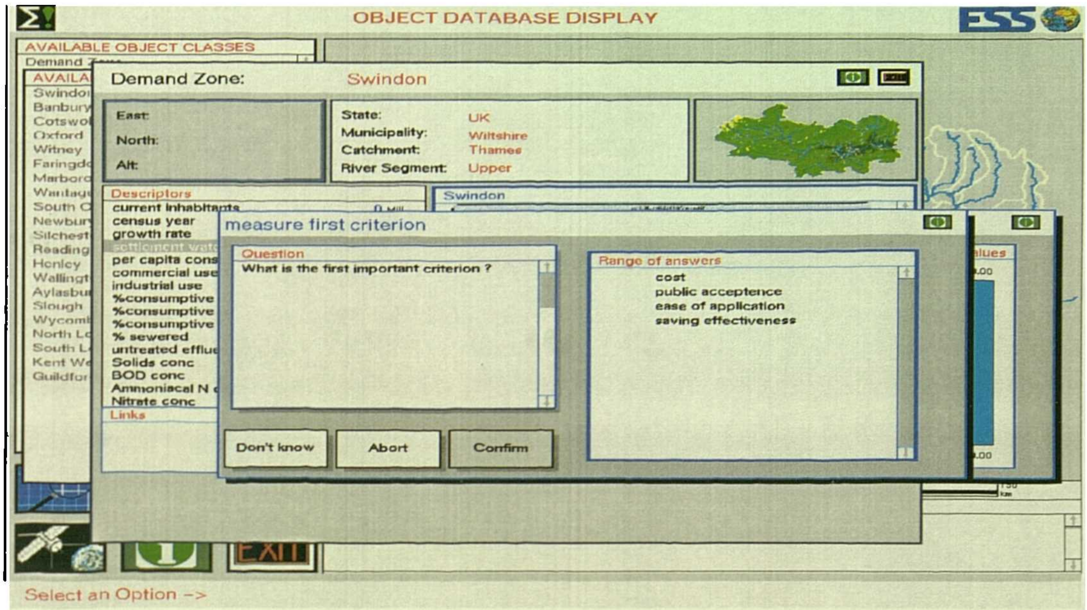


Figure (6.27) - Conservation measures selection criteria, list of options

Once, a proposed measure has been selected or deduced, the system enquires about what conservation measures are already in place, if any. If there are previous measures, the system needs to take account of them in order to estimate the combined effectiveness. For the purpose of this exercise, it was assumed that there are no previous measures which means that the interaction effect is only due to the proposed measures themselves. When the proposed and previous measures are completed the interaction effect between various measures will be computed and used to correct the potential reduction percentages by the various measures. Next, the system will inquire about both the potential reduction and coverage percentages of each of the proposed measured. When the values of these variables are deduced, the system will compute the overall conservation effectiveness. If there are multiple measures, the same previous procedures will be repeated for all the conservation measures before the prediction of conservation effectiveness.

In this particular instance, the overall predicted conservation effectiveness due to metering and pricing, conservation devices (replacing conventional toilets, dishwashers and clothes washers by efficient devices) and education programmes was about 9.87 percent, implying that if all the proposed measures were implemented, the expected household consumption would be reduced by 9.87 percent as shown in Figure (6.28). If the household consumption was computed by the end-uses approach specifically, the conservation-devices measure has to be excluded from the proposed conservation measures since efficient devices were assumed to replace the conventional ones in predicting household consumption. Therefore, in this particular case, the expected conservation effectiveness would reduce household consumption using end-uses approach , by around 5.16 percent.

The coming section describes in detail how each of the conservation measures has been deduced, using the TWUL data. In the case of unavailable data, some assumptions were made, specifically for the coverage percentages of the measures. Moreover, the potential reduction percentage of various conservation measures are assumed as average values for the data ranges which have been estimated from the combined experiences of the UK water companies. Table (6.7) summarises the conservation-measures and the effectiveness of each measure as deduced by the system, assuming that their effects are valid until the end of the forecast period (2015).

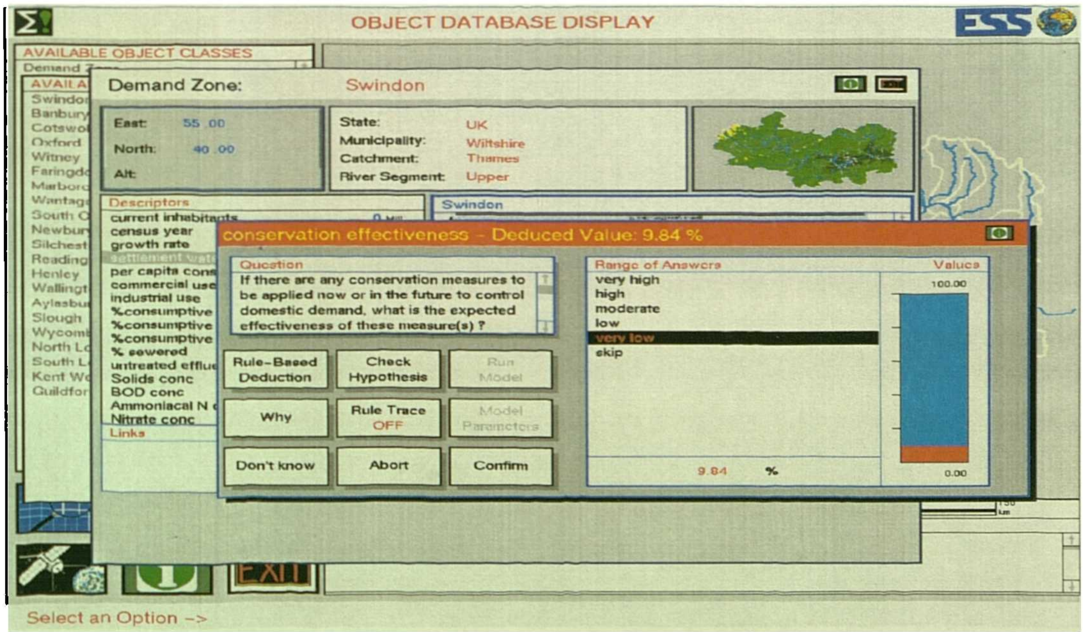


Figure (6.28) - Conservation effectiveness, deduced value

Table (6.7) - Proposed conservation measures and corresponding effectiveness for the year (2015/2016)*

conservation measures	existing capacity in litres or flow rate in litres/minute	proposed capacity in litres or flow rate in litres/minute	potential reduction %	base year coverage %	forecast year coverage %	device consumption relative % to household consumption	interaction*** factor	measure effectiveness %
metering with flat-rate tariff	....	....	1.45	3.00	80.00	....	1.00	1.16
conserving toilets	9.00	7.50	16.67	0.00	60.00	27.50	0.90	2.48
conserving dishwashers	40.00	20.00	50.00	0.90	23.80	1.25	0.90	0.13
conserving clothes washers	95.00	70.00	26.32	4.00	73.90	12.00	0.90	2.10
education programmes	....	....	5.00	....	100.00	....	0.80	4.00
conservation effectiveness								9.87

* These data are based on TWUL policy for future demand control.

** metering and pricing reduction percentage is based on the results of the National Metering Trial in the UK *(Water Services Association 1994)*.

*** Interaction factor between pricing and saving devices is 0.9 whilst interaction factor between education programmes and saving devices is 0.8 *(Richards et al. 1984)*.

6.9.1 - Metering and pricing

The charging system for domestic demand in Swindon area is dominated by unmeasured households, (i.e. charges are made on the basis of rateable value of the property) which account for some 97 percent of total. The present metering strategy proposes that between March 1996 and March 1999, a further 17 percent of households would be metered, particularly detached houses with gardens *(TWUL 1994)*. Moreover, there is already a water byelaw requiring all new and converted properties to be metered. Therefore, the coverage of metered households is expected to increase from 3 percent at present to over 20 percent by year 1999 and if the same rate is continued in the future, the coverage will increase to 80 percent by the year 2015.

Although metering is likely to reduce household consumption, its effectiveness as a demand management tool lies in the possibility of applying tariffs which provide strong incentives to reduce some elements of water consumption. Several tariffs were trialed in different areas in the UK for two years and according to *Water Services Association 1994*, the following reductions were achieved:

Tariff (price rate structure)	Demand change in percent
flat-rate tariff	from -5.2 to + 2.3
peak-hour rate tariff	from -5.8 to -14.8
seasonal-rate tariff	from -7.2 to -18.9
falling-block rate tariff	about -11.1
rising-block rate tariff	about - 15.1

For the purpose of this exercise, it is assumed that metered households will continue to pay their bills according to flat-rate tariff-structure over the coming 20 years. Accordingly, metering and pricing conservation measure is expected to reduce household consumption by 1.45 percent on average. The various tariff rates have been incorporated in the system and the effectiveness of each can be easily deduced by selecting the appropriate tariff type from the list of options as shown in Figure (6.29). Since the metering and pricing option is assumed to be applied first, there is no interaction effect and the value of the interaction factor is one. As a result, the expected reduction in household consumption due to metering and pricing is about 1.16 percent assuming 80 percent coverage .

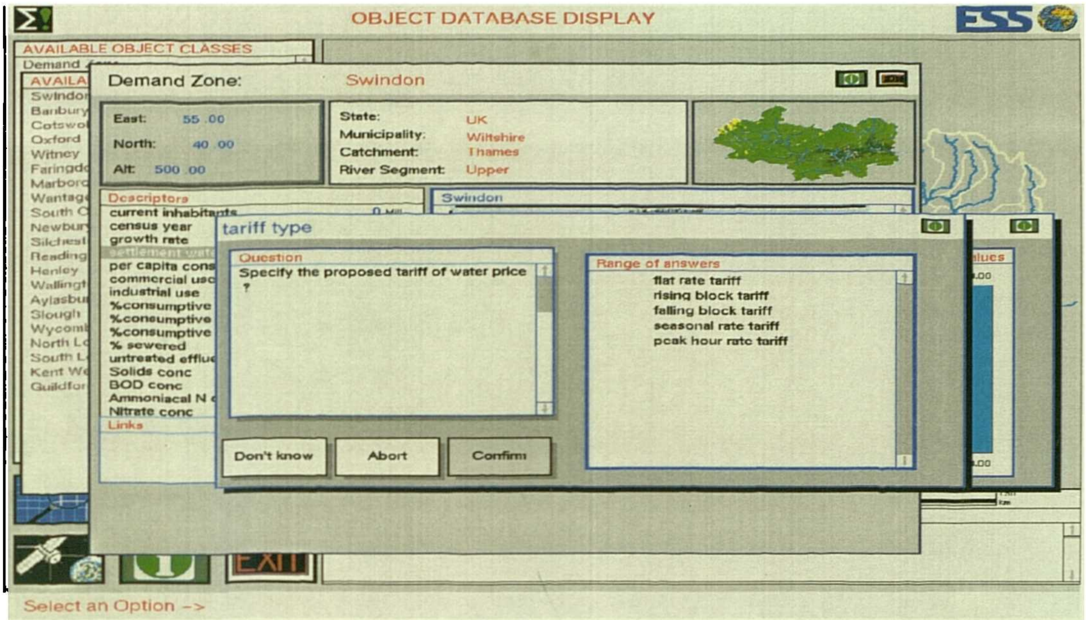


Figure (6.29) - Tariff rates, list of options

6.9.2 - Conservation-devices

The effectiveness of conservation devices depends on the type of device, existing capacity, future capacity, device-consumption relative to household consumption and coverage. Since this measure is assumed to follow the metering and pricing option, there is an interaction effect with the previous measure, which in this case equals 0.9 *(Richards et al. 1984).*

The obvious candidates deserving attention are toilets, dishwashers, washing machines, showers, taps etc. As previously, the user is given the choice of either selecting an individual device or several devices as shown in Figure (6.30). As a result of selecting a certain water-use device, the system enquires about the existing and proposed capacity of that device in order to estimate the expected reduction as a percentage of device consumption. The next enquiry relates to the coverage of replacing existing devices with more efficient ones within the demand zone. Once these variables are input or deduced, the system will produce the conservation effectiveness due to that device. If the campaign targeted more than one device, the same previous procedures would be repeated for all devices and the overall effectiveness estimated.

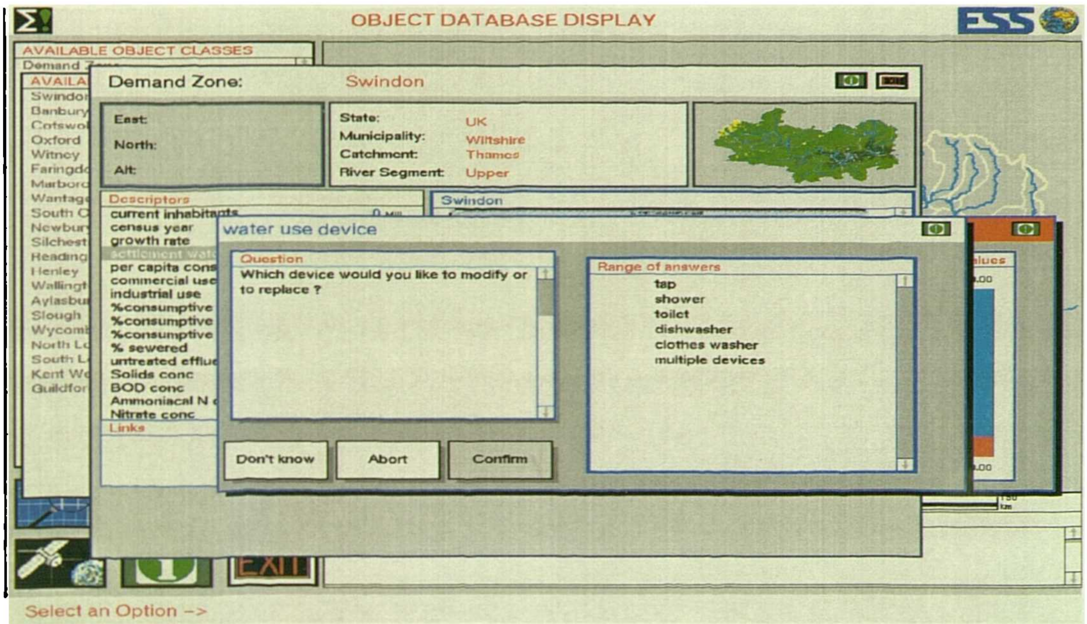


Figure (6.30) - Water-use devices, list of options

(i) - Dishwashers and washing machines

Technological improvements in machine design have substantially improved the efficiency of water consumption by these machines substantially. Modern washing machines use about 70 litres for 5 kg load compared with 95 -110 litres for older-style machines. Similarly, dishwashers currently use about 20 litres to wash 12 place settings compared with 40-50 litres only a few years ago *(TWUL 1994)*. However, it is also likely that the number of households using dishwashers and washing machines will increase over the planning period, off-setting the efficiency gained due to improved technology.

Through the EC SAVE programme on energy efficiency, a voluntary labelling scheme for washing machines was introduced in late 1992/ early 1993. The label is required to provide comparative information on energy and water consumption. In due course, it is possible that the labelling scheme could become mandatory with a pass/fail level for efficiency. Support even for voluntary labelling schemes and publicity about efficient machines could persuade a large percentage of households to replace their machines by more efficient models when the time comes. As a result of this policy, it is estimated that 23.8 percent of households will use efficient dishwashers and 73.9 percent will use efficient washing machines by the year 2015. Moreover, the consumption of dishwasher is assumed to represent about 1.25 percent of household consumption whilst consumption of washing machines is assumed to represent about 12 percent of household consumption *(TWUL 1994)*. Therefore, the expected reductions in household consumption due to efficient dishwashers and washing machines are about 0.15 percent and 2.33 percent respectively.

(ii) - Toilets

From 1 January 1993, TWUL bye-laws require all new and replacement toilets to have cisterns which use no more than 7.5 litres per flush instead of 9.0 litres. This leads to a reduction in toilet flushing of about 16.67 percent. However, in this particular case there are two options: either to replace existing toilets with efficient ones or to modify existing toilets to become more efficient as shown in Figure (6.31). In the case of the first option (replace exiting toilets), the system enquires about both the capacity of the existing and the proposed toilets before computing the expected reduction. The second option requires information on the type of conservation tool which to be installed in the toilets to reduce the flushing volume. For this purpose, the system incorporates three types of conservation tools: damming tools (such as ordinary dams or partition walls), displacement tools (such as bags, including the so-called "Hippo") and assortment tools (such as dual-flushing mechanism) as shown in Figure (6.32). If the user has no information on the most appropriate conservation tool, the system can provide him with the necessary support based on a set of selection criteria as shown in Figure (6.33).

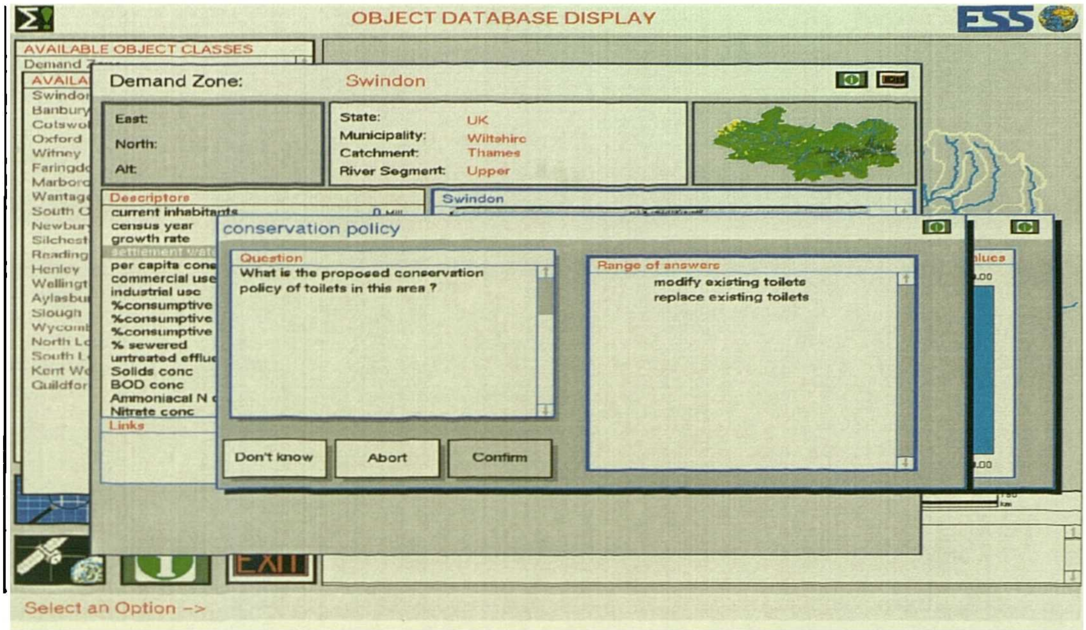


Figure (6.31) - Toilets-conservation policy, list of options

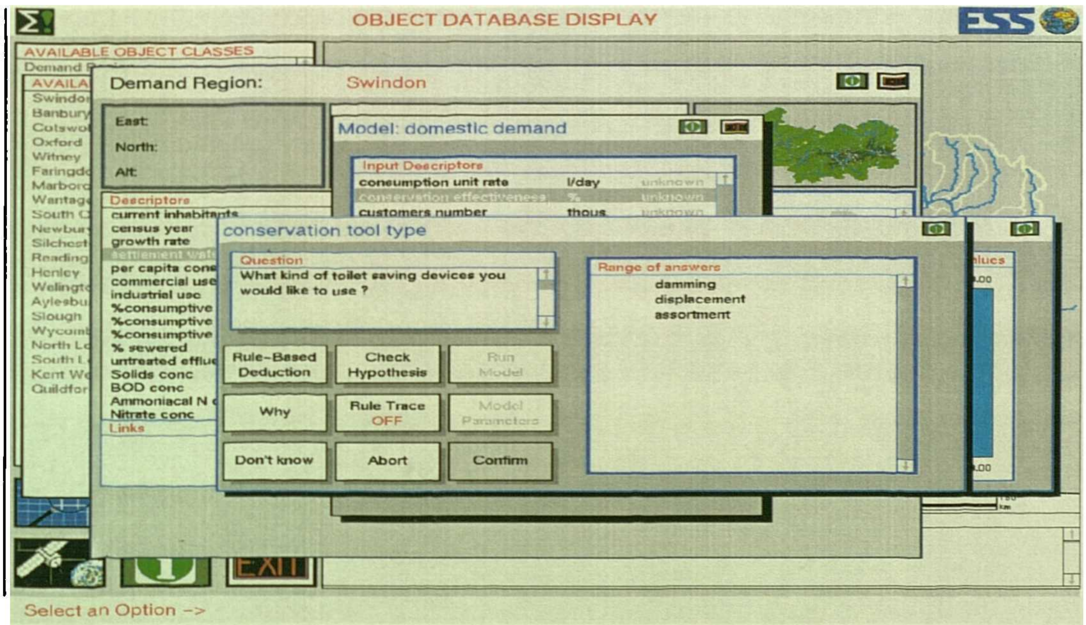


Figure (6.32) - Toilet-conservation tools, list of options

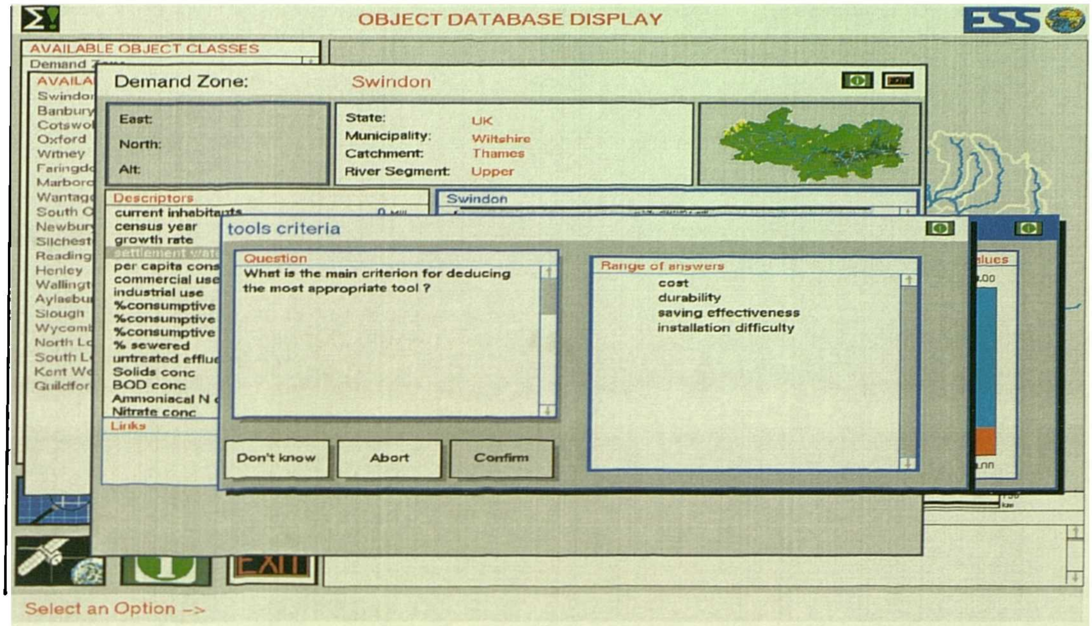


Figure (6.33) - Criteria for selecting conservation tools

For demonstration purposes, it is assumed that the second option is adopted for the Swindon zone. Although the replacement rate of toilets is not known with any certainty in the Thames basin, it is thought to be about 3 percent per year *(TWUL 1994)*. Assuming that the same replacement rate (3 percent per year) will continue to the end of the planning period (2015), the coverage of efficient toilets in this zone would be approximately 60 percent.

Once the existing and proposed flushing volumes and coverage of the replaced toilets are defined, the system enquires about toilet consumption relative to household consumption which is assumed to be around 27.5 percent by the year 2015 *(TWUL 1994)*. Figures (6.34, 6.35 and 6.36) show the deduced values of reduction, coverage and relative percentages. When all these variables have been estimated the system will produce the conservation effectiveness relating to toilet consumption. On this basis, the expected reduction in household consumption due to efficient toilets is about 2.75 percent. However, this value has to be multiplied by a factor of 0.9 to account for the interaction effect between this measure and the previous measures *(Richards et al. 1984)*.

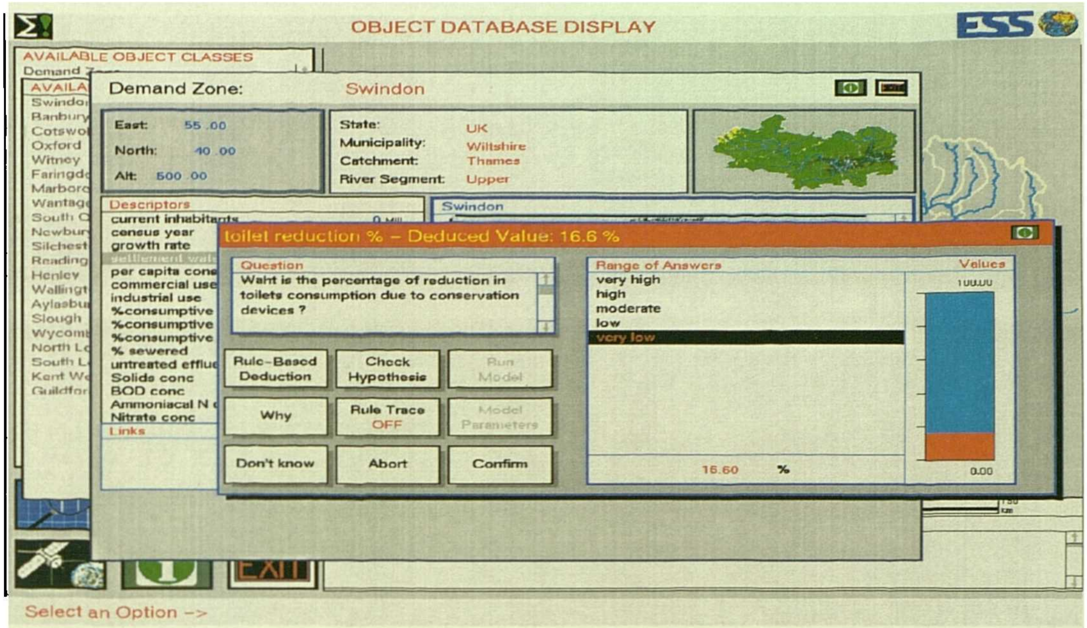


Figure (6.34) - Toilet-reduction percentage, deduced value

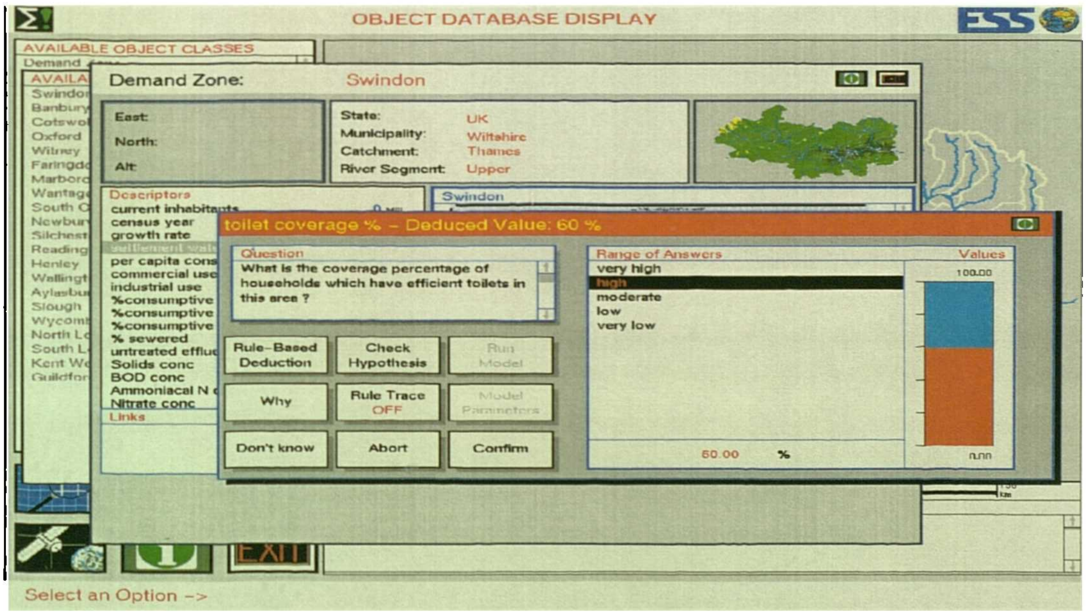


Figure (6.35) - Toilet-coverage percentage, deduced value

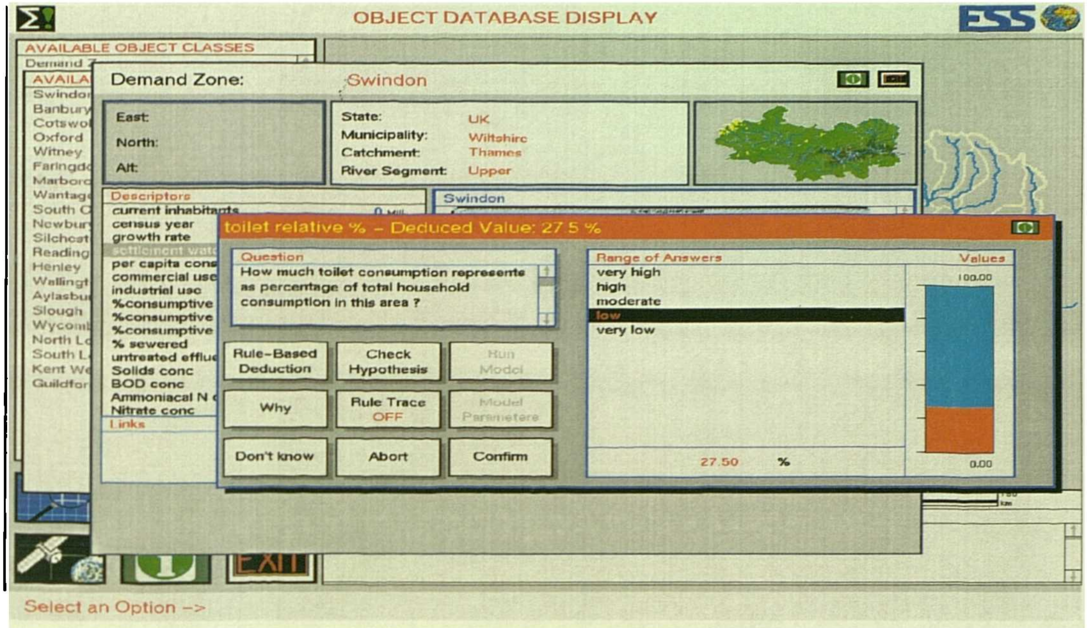


Figure (6.36) - Toilet consumption relative to household consumption, deduced value

(iii) - Taps and showers

Showerheads and taps have also been targeted by TWUL in an effort to conserv water. A reduction in water consumption can be achieved by replacing high flow-rate showers such as power showers with lower flow-rate showers using less than 10 litres per minute. Similarly, tap flow-rate can be reduced by using the flow-restrictors. With regard to taps, the system displays different types of fixtures based on the tap location such as kitchen sink, bathroom, bathtub, hosepipe and sprinkler as shown in Figure (6.37).

The reduction in the consumption of showers and taps depends on the proposed flow rates in comparison with the existing ones. Therefore, by defining the values of these two variables, the system will produce the expected reduction. For the purpose of this exercise, the effectiveness of showers and taps in reducing household consumption is not included since there is no information available about various parameters.

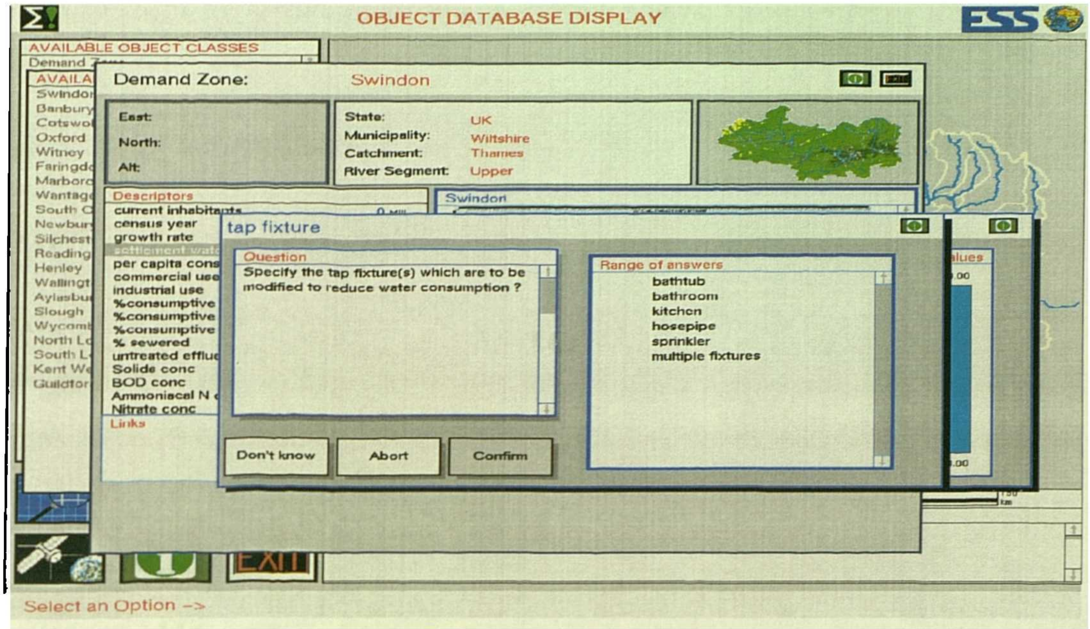


Figure (6.37) - Taps-fixtures, list of options

6.9.3 - Education programmes

It is likely that the previous measures would be more effective if backed by public-awareness campaigns, covering both indoor and outdoor uses. Indoor uses would be affected by changes in water-using habits within the home such as the frequency of use and amount of use, whilst outdoor uses would be affected mainly through any reduction in garden watering or car washing.

Education and awareness campaigns have a variety of means for disseminating information such as hand-out material for schools, leaflets, posters, seminars, meeting, media coverage etc. which might be expected to reduce consumption by a further 5 percent (assumed value) on average if properly conducted and continually reinforced. Whilst these campaigns would cover the whole area, there is no guarantee they would be 100 percent effective. Moreover, since this measure is assumed to follow on from others, the expected reduction will be reduced by a factor of 0.8 to account for the interaction between this measure and the previous ones *(Richards et al. 1984)*. Therefore, the expected reduction in household consumption due to education programmes is about 4 percent.

6.10 - Number of customers

Since the household has been selected to reference water consumption, the number of customers equals the number of households and the system provides the user with the possibility of forecasting future numbers of households, based on population and occupancy rate. Both population and occupancy rate can be predicted by an extrapolation models and therefore, the procedures for deducing their values are the same as previously.

According to TWUL, Swindon's population is expected to grow by 0.8 percent per annum over the next 20 years. However, the historic records of population are included in the system and can be used to project the population for the Swindon zone up until 2015. Similarly, the occupancy-rate has been extrapolated to the same years by the occupancy-rate model. The outputs of both population and occupancy-rate models are shown in Figures (6.38 and 6.39) respectively. Once the population and occupancy-rate has been predicted, the system will deduce the number of households for as shown in Figure (6.40). Accordingly, the number of households in Swindon area is expected to be about 179,907 by year 2015.

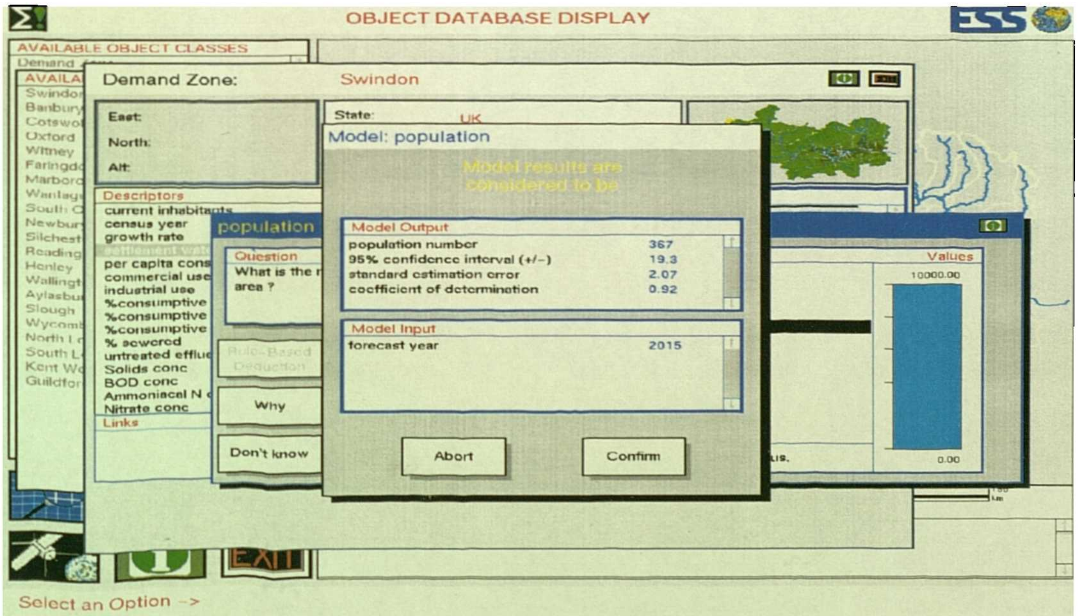


Figure (6.38) - Outputs of population model

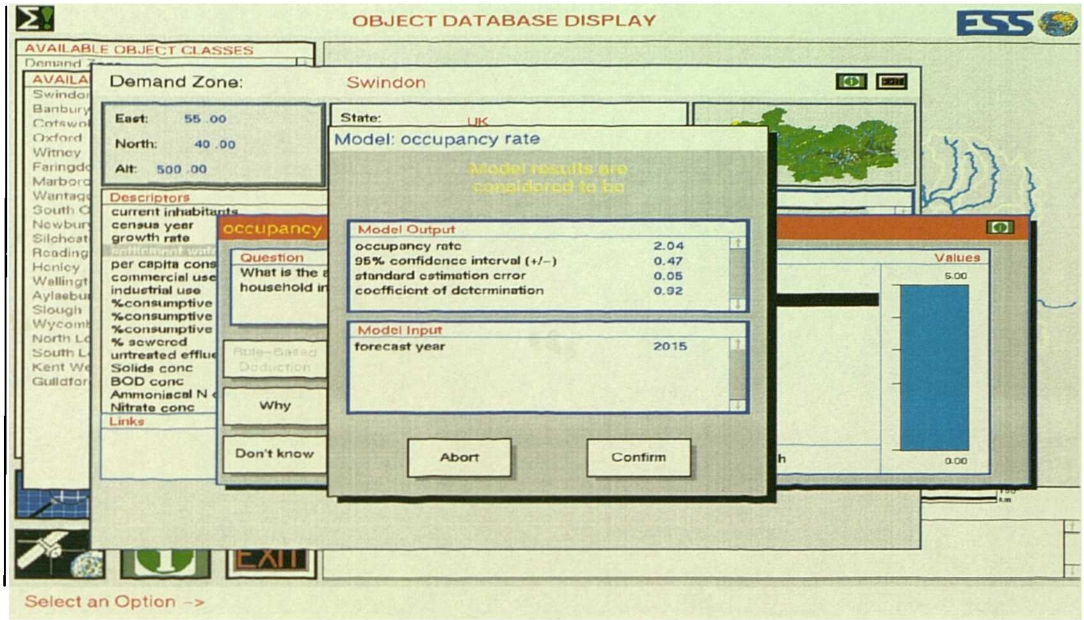


Figure (6.39) - Outputs of occupancy rate model

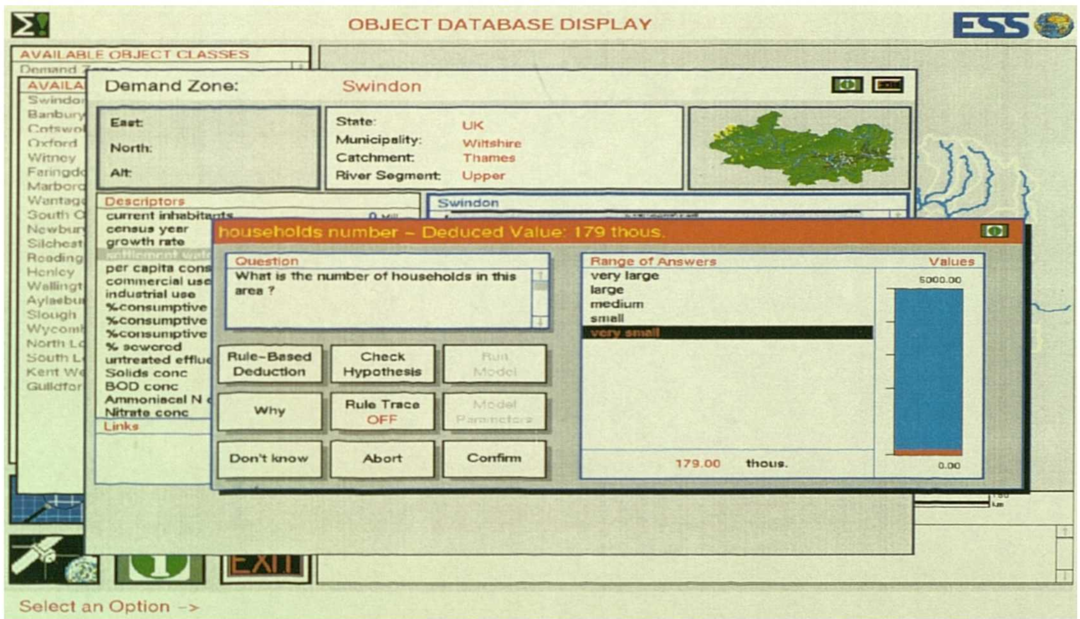


Figure (6.40) - Number of households, deduced value

A summary of the historic records which have been used in these models including the predicted number of households and associated statistical parameters are listed in Tables (6.2b and 6.3) which can be found on pages 158 and 159.

6.11 - DFMS scenarios support

Since forecasting domestic water demands is subject to various assumptions, it is usual to test the sensitivity of these assumptions by including more than one forecast scenario. The DFMS can help the user develop these scenarios in several ways, such as the classification of quantitative answers into qualitative symbols (very low, low, moderate, high and very high). Therefore, if the deduced answer for one of the variables was low, then the user can try other possibilities such as very low or moderate to produce another demand scenario. Additionally, producing demand scenarios requires changing the values of various elements in the logic structure, for which the system provides the user with the possibility of using the re-deduction option. This enables the user to change the deduced value by entering his own values. The re-deduction can be easily performed by selecting the Rule-based deduction button again. This will display the re-deduction menu which contains buttons for confirming default values, re-deducing the value again and browsing the knowledge-base as shown in Figure (6.41).

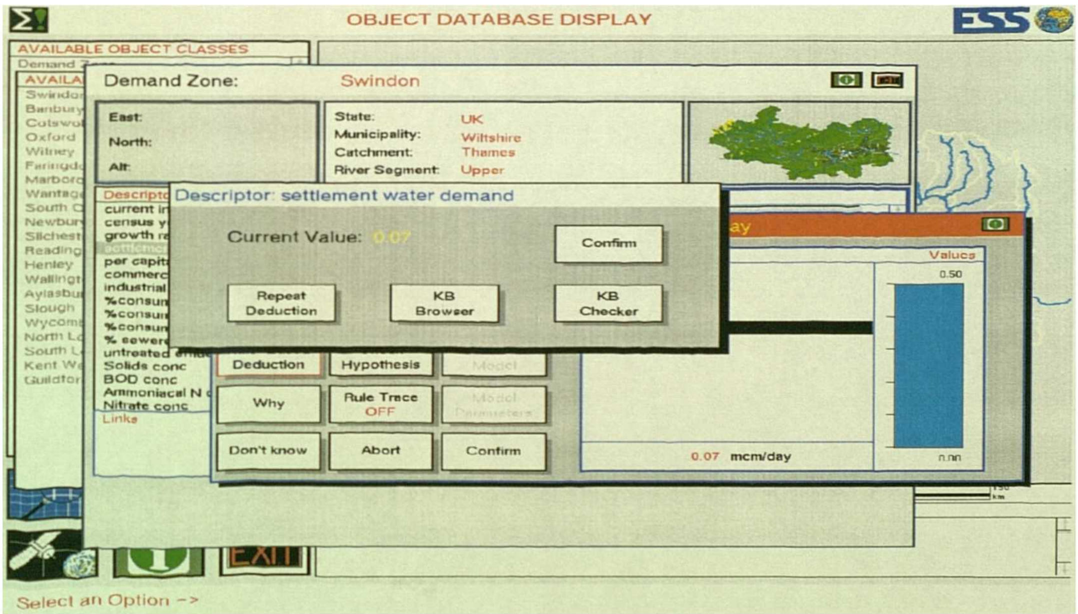


Figure (6.41) - Descriptor re-deduction menu

Similarly, the parameters of any external model can be re-deduced by the selection of Model-parameters option which displays these inputs in order. Selection of re-deduction values for these inputs is effected by pressing the continue option as shown in Figure (6.42). This automatically replaces the previous default value and once the re-deduced value has been confirmed, it becomes the new default answer for that descriptor.

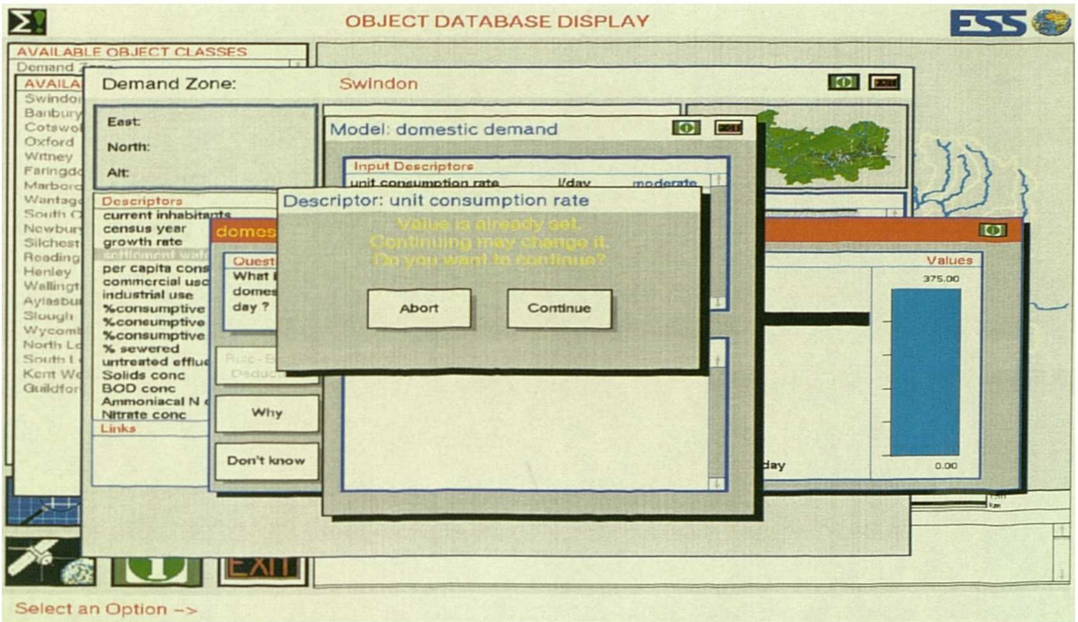


Figure (6.42) - Model-parameters re-deduction menu

Since the system provides the user with the possibility of forecasting household consumption by four different methods, depending on data availability, it is possible to have up to four different forecasts even before sensitivity analysis is considered. These values could be used to form a range for household consumption values in the future, especially if there is a significant difference between the forecasted results. Accordingly, it is possible to have three scenarios for household consumption (lower, average and upper). However, in this specific example, the deduced values of household consumption by various methods for the year 2015 are very close to each other (379, 384 and 374 litres per day). Therefore, assuming average household consumption is 382 litres per day, the number of households in Swindon area is 179,900 by the year 2015 (an increase of 166,250 over the present number) and the conservation effectiveness is 9.87 percent, one possible forecast of domestic demand for the Swindon zone would be about 61.97 megalitres per day by the year 2015. Table (6.8) summarises the forecast household consumption by the various methods for both base and forecast years, having regard to conservation effectiveness and number of households for the Swindon zone.

Alternatively, it is possible to restrict the predictions to one specific forecasting methodology such end-uses and test the sensitivity of the results to ,say, the effectiveness of conservation measures. Similarly, other scenarios can be formed based on the conservation effectiveness, population and occupancy rate. However, this can quickly develop into an unmanageable number of scenarios. For example, if consideration is given to three possibilities for each of the three main variables (unit consumption rate, conservation effectiveness and number of customers), this results in some 9 possible scenarios. In order to reduce the number of scenarios to a more manageable size, the values have been artificially constrained at each stage to five categories namely very low, low, moderate, high and very high. Even then, it is preferable to restrict the number of realisations to three (low, moderate and high).

For demonstration purposes, the 95-percent confidence intervals of the extrapolated per-capita, population and occupancy rate in Table (6.3) have been used to form an upper and lower bands of the predicted household consumption and number of households for the years 2000 to 2015 for the Swindon zone. Assuming conservation measures reduce household consumption by 9.87 percent for these years as estimated previously, it is possible to develop three scenarios for domestic demand as shown in Figures (6.43) and (6.44). In the First figure, conservation effectiveness is excluded in the scenarios whilst in the second Figure, it was included.

Table (6.8) - Summary of domestic demand results for Swindon area by year 2015/2016

forecasting method	household consumption litres/day	conservation effectiveness* %	number of households	domestic demand in megalitres per day
time extrapolation	379	9.87	179907	61.45
end-uses	384	5.16	179907	65.45
classified households	375	9.87	179907	60.81

* Conservation effectiveness with end-uses has a lower value since the methodology already allows for conservation devices.

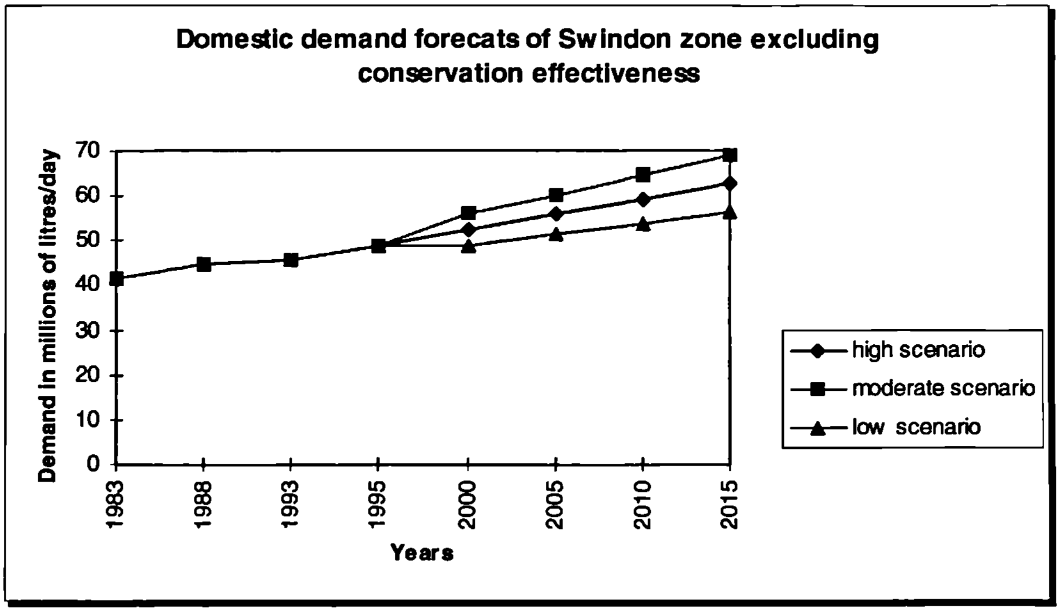


Figure (6.43) - Domestic demand scenarios excluding conservation effectiveness

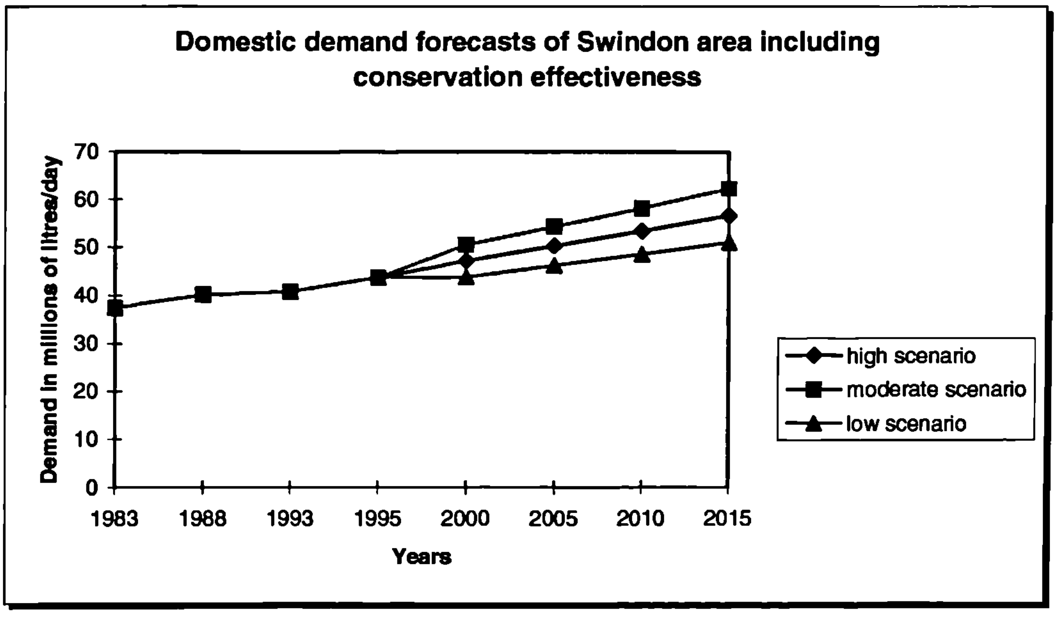


Figure (6.44) - Domestic-demand scenarios including conservation effectiveness

6.12 - DFMS information support

Although the system is easy to use as a result of adopting a step-by-step procedure, there is still a need for further explanation regarding some of the variables. For example, there is little information on the computational procedures of external models which can be gleaned during the deduction process. Similarly, most of the variable names have been shortened to make coding of the knowledge-base possible and these variables need to be defined properly to ensure they are comprehensible to user. For this and many other reasons, hypertext files are linked to the descriptors, providing the user with the necessary help when required.

The activation of the help files is by means of a dedicated hypertext icon "i" which can be accessed at various levels of system activation or deduction. In addition to descriptive material, the hypertext files themselves contain links to other descriptors or images. Once the user clicks on the one of these links, a sub-window will display more information on the link itself. Similarly, a sub-link can be coupled to other links, etc., as shown in Figure (6.45). However, the links in the DFMS follow the same hierarchy of demand variables as in the logic structure.

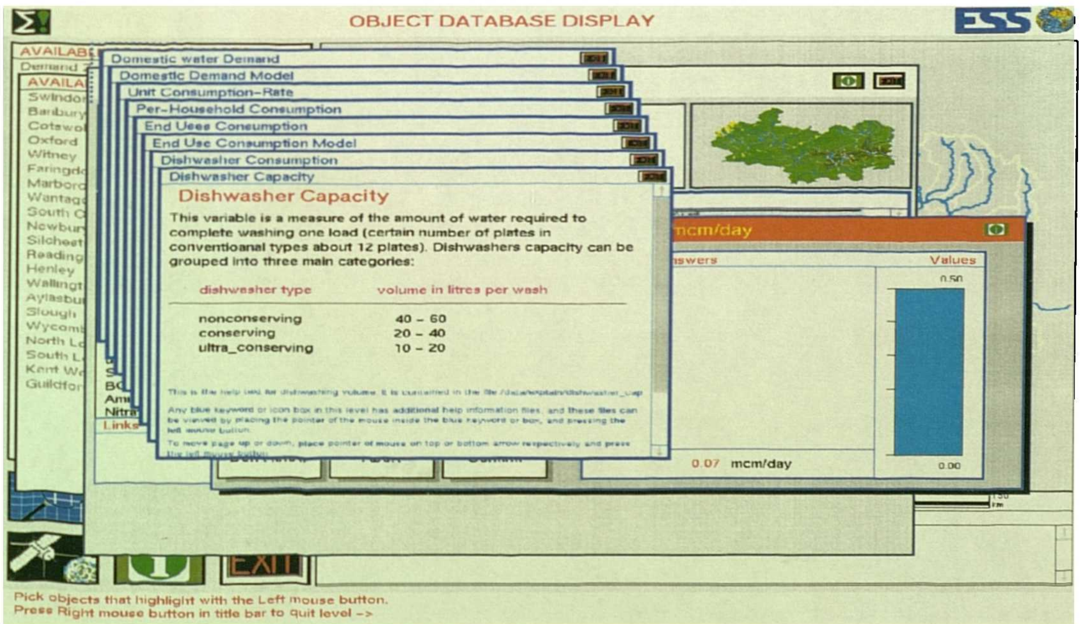


Figure (6.45) - Sample of a displayed hypertext files

6.13 - DFMS verification and evaluation

Since the main aim of this study is to develop a decision-support system for forecasting domestic water demand rather than forecasting domestic demand for a certain area, the focus in this chapter was on using the data of the Swindon demand zone of Thames Water Utility to demonstrate the various capabilities of the system. In order to make sure that the system produces correct answers (numeric or text), the system has been verified using two main criteria:

(i) models testing; this implies checking that the computations which are carried out by different models or arithmetic equations are correct. In this respect, the system has been tested by doing the same exercise twice one by using the system itself and second by manual calculations (or using EXCEL spread sheet) and it has been found that the outputs of both trials are exactly the same. Similarly, the prediction models (regression models) coefficients and results were tested using a commercial software (EXCEL) and also they are found compatible with the coefficients and results of the models which are used by the system.

Moreover, the regression models in the system are dynamic since there is no need to update the model coefficients. In other words, the models in the system automatically create new coefficients, once the original (historical) data are changed or updated. Furthermore, these models produce several statistical checks for testing model adequacy. For example, the extrapolation model of per-capita consumption for Swindon shows a predicted per-capita consumption of 186 litres/day by year 2015 with a 95-percent confidence interval of +/- 18.0 litres per day and determination coefficient of 80 percent, providing proof of the model's adequacy.

(ii) knowledge-testing; this involves checking that the system correctly produces the right answers through expert system deduction. This can easily be done by using the knowledge-browser which has the ability to derive the sequence of logical arguments which has led to that particular conclusion. This facility is included within the knowledge-base which can be used for tracing back the different steps in deducing the value for any descriptor at any level. This is achieved by clicking on the "Why" button from expert system menu which will display a main window with the descriptor name. The browser window contains the list of rules (rule number and context) which are linked to that descriptor, including any arithmetic to predict the descriptor value. In the bottom part of this menu, there is a small window containing the list of descriptors which are used in the listed rules, as shown in Figure (6.46). Whenever any of these descriptors is accessed, the system will display a message describing the source of information. If it depends on other descriptors, the system will display another sub-window which contains these descriptors and so on.

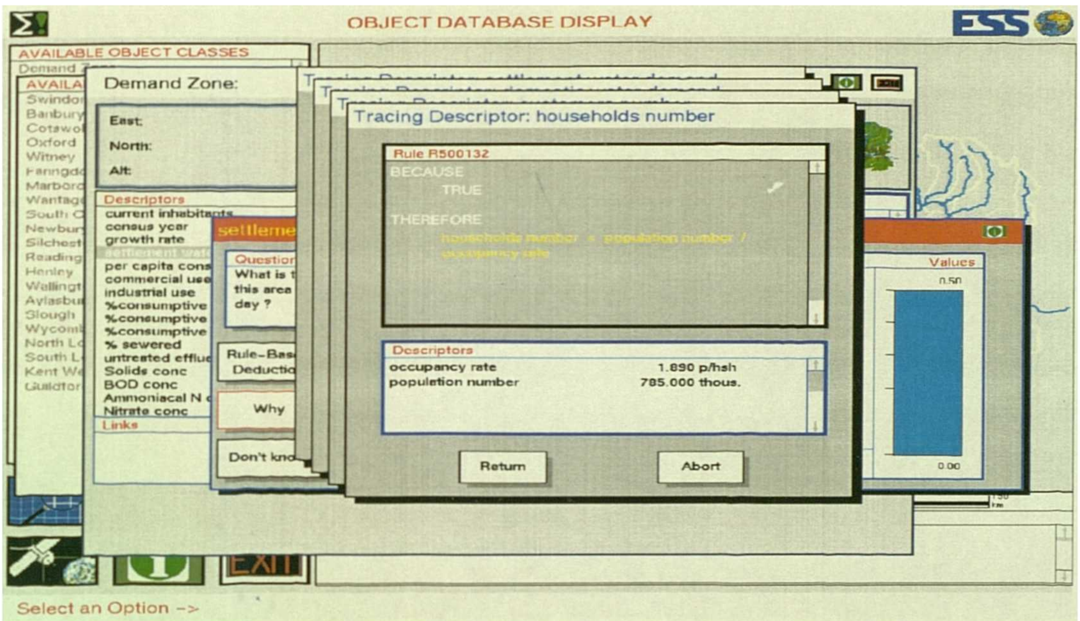


Figure (6.46) - Knowledge-base browser window

If the descriptor contains an external model rather than rules, the model parameters will be displayed. Similarly, clicking on any of these parameters will lead to others rules, then descriptors, until it reaches the user-entry level. Moreover, in addition to rules and model parameters, the user can view the descriptor contents, including descriptor name, data ranges, deduced values, etc., as shown in Figure (6.47 and 6.48).

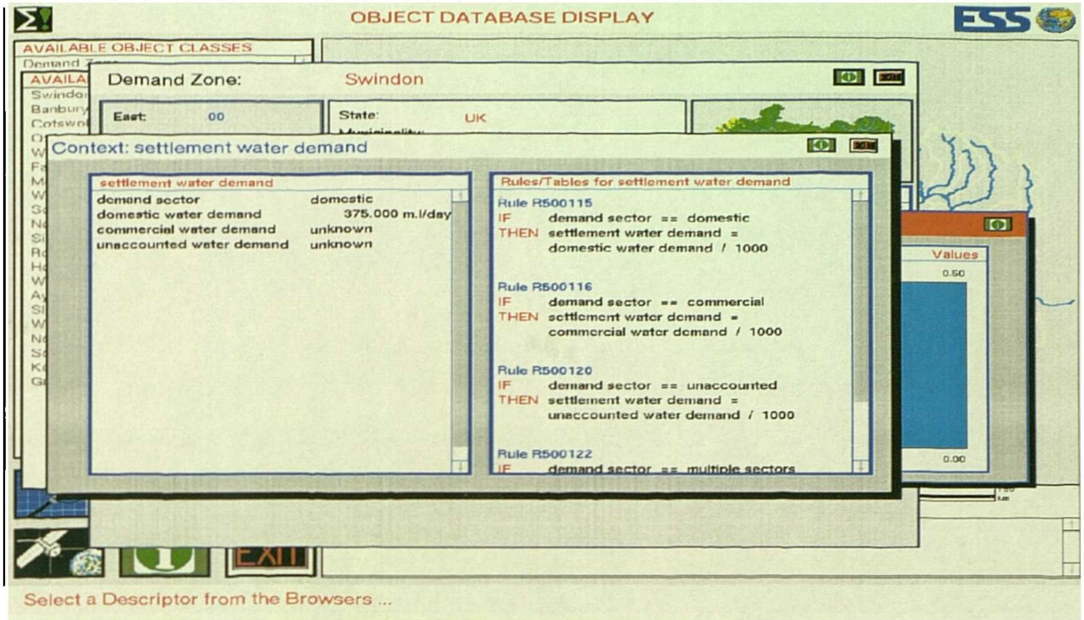


Figure (6.47) - Knowledge-browser menu, list of descriptors and rules

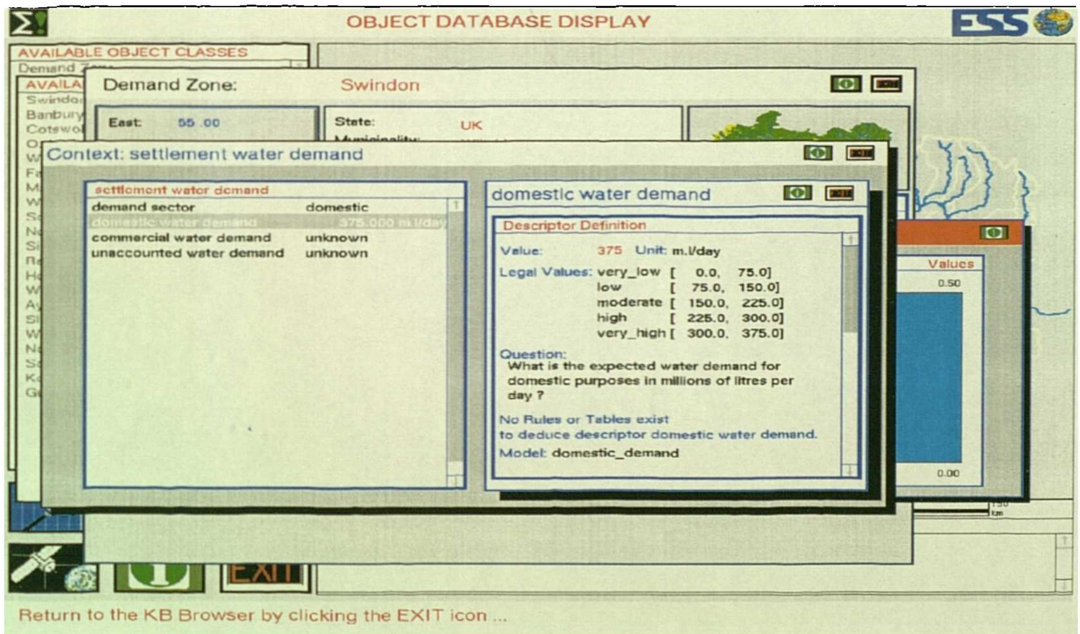


Figure (6.48) - Knowledge-browser menu, descriptor contents

Based on these two criteria the system is found to be satisfactory in forecasting domestic water demand, estimating conservation effectiveness and predicting the number of customers. However, as with any other system there will be some shortcoming or restrictions. For example, the user has to be careful in selecting the qualitative symbols since the median of each class is considered in the arithmetic calculations. Moreover, the data ranges of various variables might require updates in the future due to economic, technological or social factors. The DFMS is capable of updating data ranges of the different descriptors (variables) without the need to re-compile the source code of the main programme. For example, once the range of answers for a certain descriptor is updated in the knowledge-base, the system will identify the new changes and use them automatically. Furthermore, the system can be easily extended to include new descriptors, rules and models to cope with any developments in the future.

SUMMARY, CONCLUSIONS AND FUTURE WORK

7.1 - Summary

Before presenting the conclusions of this study, a summary of the main characteristics of domestic demand forecasting system (DFMS) is provided as follows:

- the system forms part of a highly-integrated system for water-resources planning (WaterWare) and has the potential of future integration with it.

- includes an expert system which uses a straight forward syntax, combining an object-oriented design for the descriptors which represent the basic elements of the inference procedures. Descriptors are linked to rules or external models in order to predict descriptor values quantitatively or qualitatively. The expert system communication menu is used for descriptor-value inputs and outputs. This menu has several buttons to control the dialogue between user and system, allowing the inputs and outputs in either numeric or symbolic form. As with any expert system, if the answer is not understood, one can always press the 'why' button to obtain a logical explanation as to why the system is making that particular recommendation by tracing the various rules and the source of information. In the same way, the expert system helps the user to re-deduce any predicted answers either for descriptors or model parameters. Moreover, the data ranges for the various descriptors of the expert system can be easily updated without re-compilation.

- combines both the GIS and database which are other sources of information in the DFMS to provide user with spatial and time-series data respectively. Whilst the GIS is used to display geo-coded information such as rural areas, urban areas, cities, etc., the database contains the values of target descriptors for the expert system. Moreover, the database provides links to include time-series data for target descriptors and other display functions such as pie charts, etc.

- incorporates four different forecasting methods ranging from superficial to detailed since the availability of the data varies from one country to other. Obviously, the more information that can be provided on population growth and distribution, disposable income, weather factors, etc., the more realistic are the forecasts but even with small amounts of data, the system can still be used but obviously, with increased uncertainty. Three of the forecasting methods take the form of predictive models (time extrapolation, econometric variables and end-uses variables) whilst the fourth is based on the ACORN classification for residential households in the UK. The reference unit for water consumption can be per-capita, per-household or per-connection.

- incorporates predictive models which make use of simple arithmetic, single regression or multiple regression. Whilst, the end-uses model is based on the aggregation of water quantities required by the different household uses, both indoor and outdoor, the time extrapolation and econometric variables models use regression techniques to establish a statistical relationship between water demand and variables such as, time, climate, household income, etc. Moreover, the multiple regression model ranks the included variables according to their effect on water consumption which can help in identifying the factors which have a major influence on domestic water demand. The regression models are dynamic rather than static in the sense that the model coefficients are estimated from the available data and, if these data are changed, the model coefficients will be updated automatically, making the models suitable for application in any area and time period, now or in the future.

- allows for independent estimation of the conservation effectiveness due to any proposed conservation measure and any future number of customers. Basically, it incorporates the most commonly used measures such as water metering, pricing policy, conservation devices, education programmes etc. However, some of these measures require further explanation. For example, the pricing policy includes several tariff structures such as flat-rate, rising-block, falling-block, peak-hour and seasonal tariff. Similarly, conservation devices includes various water-use devices such as toilets, showers, taps, dishwashers and washing machines. Moreover, taps comprise several water-use fixtures such as kitchen sink, wash basin, bath, hosepipe and sprinkler. In the same way, the flushing capacity of toilets depend on the size or the type of conservation device installed such as damming tools (ordinary dams or partition walls etc.), displacement tools (plastic bottle or bag) and other assorted tools (dual-flush mode). The system also accounts for any interaction effects between the various proposed or previously installed measures and corrects the expected reduction in water consumption accordingly. With respect to the future number of customers, the system incorporates two models one, for population and the second for occupancy rate by which the user will be able to forecast the number of customers for different consumption units (person, household and water connection).

- includes a multi-objective decision component to assist the user with the selection of the most appropriate forecasting method and which conservation measures to use. This is based on a multi-attribute utility function which evaluates the joint utility values of various measures of effectiveness in fulfilling the different objectives. In this way, several selection criteria are associated with a set of subjective weights according to the importance of the criteria to the user. The selection criteria take the form of user preferences such as the first important criterion, then the second etc., which makes the selection procedures very simple and easy to use especially for inexperienced users.

- allows for the development of different demand scenarios. This is based on an expert system which allows for the re-deduction of the included variables.

Additionally, the combination of qualitative and quantitative results are helpful in building different scenarios since the data ranges of each qualitative symbol are displayed on the screen which allows the user to select the appropriate answer. The data ranges themselves can be considered as a safety measure which protects the user from entering unrealistic values.

- informative since it includes hypertext files which are used to provide the user with the necessary assistance if, for any reason, a more detailed explanation is required. Touching the information icon will access the hypertext files which act as an on-line user-guide to help users re-orientate themselves. All included descriptors in the expert system are linked to hypertext files which in turn are connected to each other through linking key words. This enables the user to move from one help file to another, seeking further explanation on any variable at different levels.

- easy to use even for the novice, since it is driven by a menu system which relies on a mouse rather than the keyboard, with all the facilities being accessed by touching the icon representing that particular component. Moreover, the communication between user and the system is by means of a user-friendly interface which makes extensive use of hypertext to guide the user or to explain unclear information. Furthermore, care has been taken in presenting the results so that there is no confusion. For example, the default answers are in blue whilst the newly-predicted answers are in red. Similarly, when any of the model inputs has been changed, the Run-Model button becomes green, indicating that the model needs to be run again.

7.2 - Conclusions

The following conclusions can be drawn from this research study:

A decision-support system has been developed for forecasting domestic-water demand (DFMS) and demonstrated using the Swindon zone of Thames Water Utilities. This forms part of a highly-integrated decision-support system for river-basin planning. Emphasis has been placed on the importance of the DFMS being generic, flexible, comprehensive and easy to use, with all the complexity being hidden from the user. Although flexibility demands greater user awareness, this is compensated by user-support facilities in the form of an embedded expert system to help quantify input variables and hypertext which acts as an on-line user guide.

The DFMS comprises a database, GIS, expert system, predictive models, a multi-objective decision component, hypertext files and a user-interface component. The system is initiated from the GIS by asking the user to select the demand zone. Thereafter, the main component is an expert system which uses rule-based inference and qualitative reasoning in the form of question-and-answer sessions, to determine future domestic demand forecasts. The option of using both qualitative and quantitative methods in the same application, allows the system to be responsive to the user's requirements and constraints, having regard to the information available. The combination of four different methods of forecasting, integrated with GIS, database and hypertext, enables the efficient exploitation of whatever information or data are available for a given demand area.

The system has been tested and verified then demonstrated using the data of the Swindon demand zone of Thames Water Utility. The predicted domestic demand for this zone by year 2015/2016 ranges between 60.82 to 65.5 megalitres per day. This is based on a predicted household consumption ranges between 375 to 384 litres per day, conservation effectiveness in the range between 5.2 to 9.9 percent and number of households about 179,907.

7.3 - Possible future work

The scope of possible work in the future can be divided into two broad categories namely, maximising the use of the existing capability and opportunities for expansion into other areas of water-demand forecasting. With regard to the former, the DFMS model for domestic demand forecasting has been developed as a free standing package to a level where it can be demonstrated. Notwithstanding that the DFMS uses parts of WaterWare's GIS, database and expert system shell, no attempt has been made to integrate it into the WaterWare decision-support system. Whilst DFMS can be called from the WaterWare system, at the present time it relies on its own external files and knowledge base. Full integration requires the integration of these data files and descriptors into WaterWare's geo-referenced database and knowledge base which is not a trivial task. Moreover, further layers would have to be added to the GIS to cover population census data and possibly the ACORN socio-economic database. Therefore, more work would be required in linking the improved functionality to the GIS, database and knowledge-base, in order that other components such as the Water Resources Planning Model can benefit from this enhanced capability.

To achieve this end will take time and money, neither of which are currently available. Therefore, before the domestic demand forecasting model can be fully integrated, it is necessary to find a fee-paying client with a need for the additional functionality. As part of the agreement, the client would be provided with a free-standing version of DFMS, with the promise that by the end of the contract period, it would be fully integrated within WaterWare. At the same time, the opportunity would be taken to extend the functionality of DFMS to include short-term considerations such as seasonal, monthly, daily and hourly peak values which may be of interest to those designing distribution networks.

Turning to opportunities for expansion into other areas of water demand forecasting, it will of course be appreciated that DFMS is limited to domestic demand, leaving commercial demand, industrial demand, agricultural demand and water leakage to be addressed at some future date. To some extent, agricultural demands have already been catered for through the incorporation of the Food and Agriculture Organisation's CROPWAT agro-economic model for irrigation demands *(Doorenbos and Pruitt, 1977)* within Waterware. Nevertheless, a similar capability is required for industrial and commercial interests which, when combined with the existing models and leakage control targets, will provide estimates of the overall demand for water within a given river basin. No doubt present shortcomings will be addressed in the future through involvement of users according to their interests but in the meantime, the domestic demand forecasting model resulting from this study, forms an important step towards that goal.

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Appendix I

I.1 - Configuration file

```
CLASS
Demand_Region SE
E Swindon    SE001 .              /data/objects/settlements/Swindon.dat
E Banbury    SE002 .              /data/objects/settlements/Banbury.dat
E Cotswolds SE003 .               /data/objects/settlements/Cotswolds.dat
E Oxford     SE004 .              /data/objects/settlements/Oxford.dat
E Witney     SE005 .              /data/objects/settlements/witney.dat
E Faringdon SE006 .               /data/objects/settlements/Faringdon.dat
E Marborough SE007                /data/objects/settlements/Marborough.dat
E Wantage    SE008 .              /data/objects/settlements/Wantage.dat
E South_Oxford SE009 .            /data/objects/settlements/South_Oxford.dat
E Newbury SE010 .                 /data/objects/settlements/Newbury.dat
E Silchester SE011 .              /data/objects/settlements/Silchester.dat
E Reading SE012 .                 /data/objects/settlements/Reading.dat
E Henley SE013 .                  /data/objects/settlements/henley.dat
E Walington SE014                 /data/objects/settlements/Walington.dat
E Aylesbury SE015 .               /data/objects/settlements/Aylesbury.dat
E Slough SE016 .                  /data/objects/settlements/Slough.dat
E Wycombe SE017 .                 /data/objects/settlements/Wycombe.dat
E North_London SE018 .            /data/objects/settlements/North_London.dat
E South_London SE019 .            /data/objects/settlements/South_London.dat
E Kent Weels SE020 .              /data/objects/settlements/Kent_Weels.dat
E Guildford SE021 .               /data/objects/settlements/Guildford.dat
ENDCLASS
```

I.2 - Header data file of demand zone

```
NA Swindon
ID SE001
LO      55 0000
LA      40 0000
EL      500 0000
AU n4522800 Sun May 11 14:24:14 1997
HY /data/explain/settlements/Swindon.dat
PI /data/explain/settlements/map1.pic
DE 0                    current_inhabitants
DE 1992                 census_year
DE 0000                 growth_rate
DE 0 25                 settlement_water_demand
DE 5 00                 per capita_consumption
DE 5 00                 commercial_use
DE 0000                 industrial_use
DE 5 00                 consumptive_use dom
DE 0000                 consumptive_use_com
DE 0000                 consumptive_use_ind
DE 0000                 sewered
DE 13 0                 untreated_effluents
DE 0000                 Solids_conc
DE 150                  BOD_conc
DE 0000                 Ammoniacal_N_conc
DE 0000                 Nitrate_conc
DE 0000                 Phosphorus_conc
DE 0000                 Fecal_coliform_count
DE 0000                 Metals_conc

TABLE
georeference
E string_name
E string_value
E overlay
E attribute
D State UK overlay 000
D Municipality W 000
D Catchment Thames overlay 000
D River Segment Thames overlay 000
END_TABLE
```

Appendix II

II.1 - List of Descriptors

```
DESCRIPTOR
settlement_water_demand
T S
U mcm/day
V very_low          [ 0,  0.1 ] /
V low               [ 0.1, 0.2 ] /
V moderate          [ 0.2, 0.3 ] /
V high              [ 0.3, 0.4 ] /
V very_high         [ 0.4, 0.5 ] /
Q What is the expected water demand for this area in millions of
Q cubic meters per day ?
R 500115 / 500116 / 500120 / 500122 /
ENDDESCRIPTOR

DESCRIPTOR
demand_sector
T S
V domestic/
V commercial/
V unaccounted/
V multiple_sectors /
Q For which of the above sectors would you like to forecast water
demand ?
ENDDESCRIPTOR

DESCRIPTOR
commercial_water_demand
T S
U m l/day
V very_low          [ 0, 1000 ] /
V low               [ 1000, 2000 ] /
V moderate          [ 2000, 3000 ] /
V high              [ 3000, 4000 ] /
V very_high         [ 4000, 5000 ] /
Q What is the expected commercial water demand in millions of litres
per day
Q for this region ?
ENDDESCRIPTOR

DESCRIPTOR
unaccounted_water demand
T S
U m.l/day
V very_low          [ 0, 1000 ] /
V low               [ 1000, 2000 ] /
V moderate          [ 2000, 3000 ] /
V high              [ 3000, 4000 ] /
V very_high         [ 4000, 5000 ] /
Q What is the expected unaccounted water demand in millions of
litres per day
Q for this region ?
ENDDESCRIPTOR

DESCRIPTOR
domestic_water_demand
T S
U m.l/day
V very_low          [ 0, 75 ] /
V low               [ 75, 150 ] /
V moderate          [ 150, 225 ] /
V high              [ 225, 300 ] /
V very_high         [ 300, 375 ] /
MODEL
domestic_demand
T local_wait
I unit_consumption_rate /
I conservation_effectiveness /
I customers_number /
O domestic_water_demand /
ENDMODEL
Q What is the expected water demand for domestic purposes in
millions
Q of litres per day ?
ENDDESCRIPTOR

DESCRIPTOR
forecasting_method
T S
V time extrapolation/
V end_use_variables/
V econometric variables/
V classified_households/
Q By which of the following methods would you like to forecast
Q household consumption ?
R 501601 / 501603 / 501604 / 501605 / 501606 /
R 501540 / 501545 / 501550 / 501555 /
ENDDESCRIPTOR

DESCRIPTOR
method_first_criterion
T S
V forecast_accuracy/
V ease_of_application/
V input_data_requirements/
V conservation_evaluation/
V consideration_of_economics/
Q In order to select the most appropriate forecasting methods, specify
Q your first criterion ?
ENDDESCRIPTOR

DESCRIPTOR
method_second_criterion
T S
V none/
V forecast_accuracy/
V ease_of_application/
V input_data_requirements/
V conservation_evaluation/
V consideration_of_economics/
Q In order to select the most appropriate forecasting methods, specify
Q your second criterion ?
ENDDESCRIPTOR

DESCRIPTOR
method_third_criterion
T S
V forecast_accuracy/
V ease_of_application/
V input_data_requirements/
V conservation_evaluation/
V consideration_of_economics/
Q In order to select the most appropriate forecasting methods, specify
Q your third criterion ?
ENDDESCRIPTOR

DESCRIPTOR
method_forth_criterion
T S
V forecast_accuracy/
V ease_of_application/
V input_data_requirements/
V conservation_evaluation/
V consideration_of_economics/
Q In order to select the most appropriate forecasting methods, specify
Q your forth criterion ?
ENDDESCRIPTOR

DESCRIPTOR
method_fifth_criterion
T S
V forecast_accuracy/
V ease_of_application/
V input_data_requirements/
V conservation_evaluation/
V consideration_of_economics/
Q In order to select the most appropriate forecasting methods, specify
Q your fifth criterion ?
ENDDESCRIPTOR

DESCRIPTOR
L1
T S
V [ 0, 1 ] /
R 501560 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
L2
T S
V [ 0, 1 ] /
R 501562 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
L3
T S
V [ 0, 1 ] /
R 501564 /
Q specify criteria result ?
ENDDESCRIPTOR
```

```
DESCRIPTOR
L4
T S
V [ 0, 1 ] /
R 501565 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
w1
T S
V [ 0, 1 ] /
R 501570 / 501571 / 501572 / 501573 / 501574 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
w2
T S
V [ 0, 1 ] /
R 501575 / 501577 / 501579 / 501581 / 501583 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
w3
T S
V [ 0, 1 ] /
R 501585 / 501586 / 501587 / 501588 / 501589 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
w4
T S
V [ 0, 1 ] /
R 501590 / 501591 / 501592 / 501593 / 501594 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
w5
T S
V [ 0, 1 ] /
R 501595 / 501596 / 501597 / 501598 / 501599 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
consumption_unit
T S
V person /
V household /
V water_connection /
Q Which of the following units would you like to use as a driver variable for
Q forecasting domestic water demand ?
R 500130 /
ENDDESCRIPTOR

DESCRIPTOR
unit_consumption_rate
T S
U l/day
V very_low          [ 0, 150 ] /
V low               [ 150, 300 ] /
V moderate          [ 300, 450 ] /
V high              [ 450, 600 ] /
V very_high         [ 600, 750 ] /
Q What is the expected consumption unit rate in this area in
Q litres per day ?
R 400100 / 400105 / 400110 /
ENDDESCRIPTOR

DESCRIPTOR
per_household_consumption
T S
U l/day
V very_low          [ 0, 150 ] /
V low               [ 150, 300 ] /
V moderate          [ 300, 450 ] /
V high              [ 450, 600 ] /
V very_high         [ 600, 750 ] /
Q What is the expected consumption rate per household in litres per day ?
R 400030 / 400032 / 400034 / 400036 /
ENDDESCRIPTOR

DESCRIPTOR
per_capita_consumption
T S
U l/day
V very_low          [ 0, 50 ] /
V low               [ 50, 100 ] /
V moderate          [ 100, 150 ] /
V high              [ 150, 200 ] /
V very_high         [ 200, 250 ] /
Q What is the expected consumption rate per person in litres per day ?
R 400200 /
ENDDESCRIPTOR

DESCRIPTOR
per_connection_consumption
T S
U l/day
V very_low          [ 0, 150 ] /
V low               [ 150, 300 ] /
V moderate          [ 300, 450 ] /
V high              [ 450, 600 ] /
V very_high         [ 600, 750 ] /
Q What is the expected consumption rate per one coonection in litres per day ?
R 400205 /
ENDDESCRIPTOR

DESCRIPTOR
classified_consumption
T S
U l/day
V very_low          [ 0, 150 ] /
V low               [ 150, 300 ] /
V moderate          [ 300, 450 ] /
V high              [ 450, 600 ] /
V very_high         [ 600, 750 ] /
Q If household consumption will beforecasted based on the classified
Q households, what is the expected consumption rate in litres per day ?
R 500550 / 500551 / 500552 / 500553 / 500554 / 500555 / 500556 /
R 500557 / 500558 / 500559 / 500560 / 500561 / 500562 / 500563 /
R 500564 / 500565 / 500566 / 500567 /
ENDDESCRIPTOR

DESCRIPTOR
households_class
T S
V wealthy_achievers /
V affluent_rural_areas /
V properous_pensioners /
V affluent_excutives /
V well_off_workers /
V affluent_urbanaties /
V prosperous_proffessionals /
V better_off_executives /
V comfortable_middle_agers /
V skilled_workers /
V new_home_owners /
V white_collar_workers /
V older_people /
V council_better_off /
V council_high_unmployment /
V council_greatest_hardship /
V multi_ethnic_low_income /
V multiple_classes /
Q Which of the following household types dominates demand region ?
ENDDESCRIPTOR

DESCRIPTOR
wealthy_achievers_%
T S
U %
V skip              [ 0, 0 ] /
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506000 /
ENDDESCRIPTOR

DESCRIPTOR
affluent_rural_%
T S
U %
V skip              [ 0, 0 ] /
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506019 /
ENDDESCRIPTOR

DESCRIPTOR
properous_pensioners_%
T S
U %
```

```
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506001 /
ENDDESCRIPTOR

DESCRIPTOR
affluent_excutives_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506002 /
ENDDESCRIPTOR

DESCRIPTOR
well_off_workers_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506003 /
ENDDESCRIPTOR

DESCRIPTOR
affluent_urbanates_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506004 /
ENDDESCRIPTOR

DESCRIPTOR
prosperous_proffessionals_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506005 /
ENDDESCRIPTOR


DESCRIPTOR
better_off_executives_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506006 /
ENDDESCRIPTOR

DESCRIPTOR
comfortable_middle_agers_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506007 /
ENDDESCRIPTOR

DESCRIPTOR
skilled_workers_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506008 /
ENDDESCRIPTOR

DESCRIPTOR
new_home_owners_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506009 /
ENDDESCRIPTOR

DESCRIPTOR
white_collar_workers_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506010 /
ENDDESCRIPTOR

DESCRIPTOR
older_people_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506011 /
ENDDESCRIPTOR

DESCRIPTOR
council_better_off_%
T S
U %
V skip                  [ 0, 0  ] /
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506012 /
ENDDESCRIPTOR

DESCRIPTOR
council_high_unmployment_%
T S
U %
V skip                  [ 0, 0   ] /
V very_low              [ 0, 20  ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected coverage percentage of this class in this area ?
R 506013 /
ENDDESCRIPTOR

DESCRIPTOR
multi_ethnic_low_income_%
T S
```

```
U %
V skip                  [0, 0    ] /
V very_low              [0, 20   ] /
V low                   [20, 40  ] /
V moderate              [40, 60  ] /
V high                  [60, 80  ] /
V very_high             [80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506015 /
ENDDESCRIPTOR

DESCRIPTOR
council_greatest_hardship_%
T S
U %
V skip                  [0, 0    ] /
V very_low              [0, 20   ] /
V low                   [20, 40  ] /
V moderate              [40, 60  ] /
V high                  [60, 80  ] /
V very_high             [80, 100 ] /
Q What is the expected coverage percentage of this class in this area
?
R 506014 /
ENDDESCRIPTOR


DESCRIPTOR
wealthy_achievers_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506020 /
ENDDESCRIPTOR

DESCRIPTOR
affluent_rural_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506045 /
ENDDESCRIPTOR

DESCRIPTOR
properous_pensioners_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506021 /
ENDDESCRIPTOR

DESCRIPTOR
affluent_excutives_consumption
T S
U %
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506022 /
ENDDESCRIPTOR

DESCRIPTOR
well_off_workers_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506023 /
ENDDESCRIPTOR
```

```
DESCRIPTOR
affluent_urbanaties_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506024 /
ENDDESCRIPTOR

DESCRIPTOR
prosperous_proffessionals_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506025 /
ENDDESCRIPTOR


DESCRIPTOR
better_off_executives_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506026 /
ENDDESCRIPTOR

DESCRIPTOR
comfortable_middle_agers_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506027 /
ENDDESCRIPTOR

DESCRIPTOR
skilled_workers_consumption
T S
U l/day
V very_low              [ 0, 150 ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506028 /
ENDDESCRIPTOR

DESCRIPTOR
new_home_owners_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506029 /
ENDDESCRIPTOR

DESCRIPTOR
white_collar_workers_consumption
T S
U l/day
V very_low              [ 0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506030 /
ENDDESCRIPTOR

DESCRIPTOR
older_people_consumption
```

```
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506031 /
ENDDESCRIPTOR

DESCRIPTOR
council_better_off_consumption
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506032 /
ENDDESCRIPTOR

DESCRIPTOR
council_high_unemployment_consumption
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506033 /
ENDDESCRIPTOR

DESCRIPTOR
multi_ethnic low income consumption
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506035 /
ENDDESCRIPTOR

DESCRIPTOR
council_greatest_hardship_consumption
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
Q What is the expected consumption rate of this class in this area ?
R 506034 /
ENDDESCRIPTOR


DESCRIPTOR
extrapolated_consumption
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very_high             [ 600, 750 ] /
MODEL
extrapolated_consumption
T local_wait
I forecast_year/
O extrapolated_consumption/
ENDMODEL
Q If household consumption will beforecasted based on time
extrapolation,
Q what is the expected consumption rate in litres per day ?
ENDDESCRIPTOR

DESCRIPTOR
end_uses_consumption
T S
U l/day
V very_low              [  0, 150  ] /
V low                   [ 150, 300 ] /
V moderate              [ 300, 450 ] /
V high                  [ 450, 600 ] /
V very high             [ 600, 750 ] /
MODEL
end_uses_consumption
T local_wait
I dishwasher_consumption /
I washer_consumption /
I shower_consumption /
I bathtub_consumption /
I toilet_consumption /
I indoor_taps_consumption /
I outdoor_taps_consumption /
O end_uses_consumption /
ENDMODEL
Q If household consumption will beforecasted based on household-end uses,
Q what is the expected consumption rate in litres per day ?
ENDDESCRIPTOR

DESCRIPTOR
dishwasher_consumption
T S
U l/day
V skip        [ 0, 0   ] /
V very_low    [ 0, 6   ] /
V low         [ 6, 18  ] /
V moderate    [ 18, 36 ] /
V high        [ 36, 60 ] /
V very_high   [ 60, 90 ] /
Q If water use device is a dishwasher, what is the expected consumption
Q rate in litres per day ?
R 500300 /
ENDDESCRIPTOR

DESCRIPTOR
dishwasher_capacity
T S
U l/load
V very_low              [ 0, 10 ] /
V low                   [ 10, 20 ] /
V moderate              [ 20, 30 ] /
V high                  [ 30, 40 ] /
V very_high             [ 40, 50 ] /
Q What is the expected capacity of dishwashers in litres per load ?
R 500305 / 500306 / 500307 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_dishwasher_capacity
T S
U l/load
V very_low   [ 0, 10 ] /
V low                   [ 10, 20 ] /
V moderate              [ 20, 30 ] /
V high                  [ 30, 40 ] /
V very_high             [ 40, 50 ] /
Q What is the expected capacity of conventional dishwashers in this area ?
R 500308 /
ENDDESCRIPTOR

DESCRIPTOR
efficient_dishwasher_capacity
T S
U l/load
V very_low              [ 0, 10 ] /
V low                   [ 10, 20 ] /
V moderate              [ 20, 30 ] /
V high                  [ 30, 40 ] /
V very_high             [ 40, 50 ] /
Q What is the expected capacity of efficient dishwashers in this area ?
R 500309 /
ENDDESCRIPTOR

DESCRIPTOR
dishwasher_type
T S
V conventional /
V efficient /
V all_types /
Q What is the most common type of dishwashers in this area ?
ENDDESCRIPTOR


DESCRIPTOR
existing_dishwasher_capacity
T S
U l/load
V very_low              [ 0, 10 ] /
V low                   [ 10, 20 ] /
V moderate              [ 20, 30 ] /
V high                  [ 30, 40 ] /
V very_high             [ 40, 50 ] /
Q What is the average capacity of existing dishwashers in litres per load ?
R 501984 /
ENDDESCRIPTOR

DESCRIPTOR
```

proposed_dishwasher_capacity
T S
U l/load
V very_low [0, 10] /
V low [10, 20] /
V moderate [20, 30] /
V high [30, 40] /
V very_high [40, 50] /
Q What is the expected capacity of proposed dishwashers in litres per load ?
R 501985 /
ENDDESCRIPTOR

DESCRIPTOR
dishwashing_frequency
T S
U load/day
V very_low [0.0, 0.3] /
V low [0.3, 0.6] /
V moderate 0.6, 0.9] /
V high [0.9, 1.2] /
V very_high [1.2, 1.5] /
Q What is the expected number of dishwashing loads per week in this area ?
R 500310 /
ENDDESCRIPTOR

DESCRIPTOR
dishwashers_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of dishwashers in this area ?
R 500319 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_dishwashers_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the percentage of conventional dishwashers ?
R 500317 /
ENDDESCRIPTOR

DESCRIPTOR
efficient_dishwashers_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the percentage of efficient dishwashers in this ?
R 500318 /
ENDDESCRIPTOR

DESCRIPTOR
dishwasher_leakage_%
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the expected leakage in dishwashers consumption ?
R 500316 /
ENDDESCRIPTOR

DESCRIPTOR
washer_consumption
T S
U l/day
V skip [0, 0] /
V very_low [0, 22.5] /
V low [22.5, 60.0] /
V moderate [60, 112.5] /
V high [112.5, 180] /
V very_high [180, 262.5] /
Q If water use device is a washing machine, what is the expected
Q consumption rate in litres per day ?
R 500320 /
ENDDESCRIPTOR

DESCRIPTOR
washer_capacity
T S
U l/load
V very_low [0, 35] /
V low [35, 70] /
V moderate [70, 105] /
V high [105, 140] /
V very_high [140, 175] /
Q What is the expected capacity of washing machines in litres per load ?
R 500325 / 500326 / 500327 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_washer_capacity
T S
U l/load
V very_low [0, 35] /
V low [35, 70] /
V moderate [70, 105] /
V high [105, 140] /
V very_high [140, 175] /
Q What is the expected capacity of conventional washing machines in this area ?
R 500328 /
ENDDESCRIPTOR

DESCRIPTOR
efficient_washer_capacity
T S
U l/load
V very_low [0, 35] /
V low [35, 70] /
V moderate [70, 105] /
V high [105, 140] /
V very_high [140, 175] /
Q What is the expected capacity of efficient washing machines in this area ?
R 500329 /
ENDDESCRIPTOR

DESCRIPTOR
washer_type
T S
V conventional_washer /
V efficient_washer /
V all_types /
Q What is the most common type of washing machines in this area ?
ENDDESCRIPTOR

DESCRIPTOR
existing_washer_capacity
T S
U l/load
V very_low [0, 35] /
V low [35, 70] /
V moderate [70, 105] /
V high [105, 140] /
V very_high [140, 175] /
Q What is the average capacity of existing washing machines in litres
Q per load ?
R 501986 /
ENDDESCRIPTOR

DESCRIPTOR
proposed_washer_capacity
T S
U l/load
V very_low [0, 35] /
V low [35, 70] /
V moderate [70, 105] /
V high [105, 140] /
V very_high [140, 175] /
Q What is the expected capacity of proposed washing machines in litres
Q per load ?
R 501987 /
ENDDESCRIPTOR

DESCRIPTOR
washing_frequency
T S
U load/day
V very_low [0.0, 0.3] /
V low [0.3, 0.6] /
V moderate [0.6, 0.9] /
V high [0.9, 1.2] /
V very_high [1.2, 1.5] /
Q What is the expected number of washing loads per day ?
R 500330 /
ENDDESCRIPTOR

DESCRIPTOR
washers_%
T S

```
U %
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100  /
Q what is the coverage percentage of clothes washers in this area ?
R 500339 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_washers_%
T S
U %
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q what is the percentage of conventional washers ?
R 500337 /
ENDDESCRIPTOR

DESCRIPTOR
efficient_washers_%
T S
U %
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q what is the percentage of efficient washers ?
R 500338 /
ENDDESCRIPTOR

DESCRIPTOR
washer_leakage_%
T S
U %
V skip                  [ 0, 0 ] /
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected leakage in washing machine consumption ?
R 500336 /
ENDDESCRIPTOR

DESCRIPTOR
bathtub_consumption
T S
U l/day
V skip                  [ 0, 0 ] /
V very_low              [ 0, 30 ] /
V low                   [ 30, 80 ] /
V moderate              [ 80, 150 ] /
V high                  [ 150, 240 ] /
V very_high             [ 240, 350 ] /
Q If water use device is a bathtub, what is the expected consumption
rate
Q in litres per day ?
R 500350 /
ENDDESCRIPTOR

DESCRIPTOR
bathtub_capacity
T S
U l/bath
V very_low              [ 0, 35 ] /
V low                   [ 35, 70 ] /
V moderate              [ 70, 105 ] /
V high                  [ 105, 140 ] /
V very_high             [ 140, 175 ] /
Q What is the expected water volume per bath in litres per bath ?
R 500357 /
ENDDESCRIPTOR

DESCRIPTOR
bathing_frequency
T S
U bath/day
V very_low              [ 0, 0.4 ] /
V low                   [ 0.4, 0.8 ] /
V moderate              [ 0.8, 1.2 ] /
V high                  [ 1.2, 1.6 ] /
V very_high             [ 1.6, 2.0 ] /
Q What is the expected number of baths per day in this area ?
R 500358 /
ENDDESCRIPTOR

DESCRIPTOR
bathtubs_%
T S
U %
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q what is the coverage percentage of bathing activity ?
R 500359 /
ENDDESCRIPTOR

DESCRIPTOR
bathtub_leakage_%
T S
U %
V skip                  [ 0, 0 ] /
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the average leakage percentage of bathtub taps consumption ?
R 500360 /
ENDDESCRIPTOR

DESCRIPTOR
shower_consumption
T S
U l/day
V skip                  [ 0, 0 ] /
V very_low              [ 0, 19.6 ] /
V low                   [ 19.6, 64.8 ] /
V moderate              [ 64.8, 145.2 ] /
V high                  [ 145.2, 270.4 ] /
V very_high             [ 270.4, 450.0 ] /
Q If water use device is a shower, what is the expected consumption amount
Q in litres per day ?
R 500400 /
ENDDESCRIPTOR

DESCRIPTOR
shower_flow_rate
T S
U l/min.
V very_low              [ 0, 3 ] /
V low                   [ 3, 6 ] /
V moderate              [ 6, 9 ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of showers in litres per minute ?
R 500405 / 500406 / 500407 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_shower_flow_rate
T S
U l/min.
V very_low              [ 0, 3 ] /
V low                   [ 3, 6 ] /
V moderate              [ 6, 9 ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of conventional showers in this area ?
R 500408 /
ENDDESCRIPTOR

DESCRIPTOR
power_shower_flow_rate
T S
U l/min.
V very_low              [ 0, 3 ] /
V low                   [ 3, 6 ] /
V moderate              [ 6, 9 ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of power showers in this area ?
R 500409 /
ENDDESCRIPTOR

DESCRIPTOR
shower_type
T S
V conventional_shower /
V power_shower /
V all_types /
Q What is the most common type of showers in this area ?
ENDDESCRIPTOR

DESCRIPTOR
existing_shower_flow
T S
U l/min.
V very_low              [ 0, 3 ] /
V low                   [ 3, 6 ] /
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V moderate              [ 6, 9 ]/
V high                  [ 9, 12]/
V very_high             [12, 15]/
Q What is the average flow rate of existing showers in litres per
minute ?
ENDDESCRIPTOR

DESCRIPTOR
proposed_shower_flow
T S
U l/min.
V very_low              [ 0, 3 ]/
V low                   [ 3, 6 ]/
V moderate              [ 6, 9 ]/
V high                  [ 9, 12]/
V very_high             [12, 15]/
Q What is the expected flow rate of proposed showers in litres per
minute ?
ENDDESCRIPTOR

DESCRIPTOR
showering_time
T S
U min.
V very_low              [ 0, 3 ]/
V low                   [ 3, 6 ]/
V moderate              [ 6, 9 ]/
V high                  [ 9, 12]/
V very_high             [12, 15]/
Q What is the expected showering time in minutes per shower ?
R 500415 /
ENDDESCRIPTOR

DESCRIPTOR
showering_frequency
T S
U sh/day
V very_low              [0 , 0.4 ]/
V low                   [0.4, 0.8 ]/
V moderate              [0.8, 1.2 ]/
V high                  [1.2, 1.6 ]/
V very_high             [1.6, 2.0 ]/
Q What is the expected number of showers per day ?
R 500420 /
ENDDESCRIPTOR

DESCRIPTOR
showers_%
T S
U %
V very_low              [ 0, 20 ]/
V low                   [20, 40 ]/
V moderate              [40, 60 ]/
V high                  [60, 80 ]/
V very_high             [80, 100 ]/
Q what is the coverage percentage of showers in this area ?
R 500427 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_showers_%
T S
U %
V very_low              [ 0, 20 ]/
V low                   [20, 40 ]/
V moderate              [40, 60 ]/
V high                  [60, 80 ]/
V very_high             [80, 100 ]/
Q what is the percentage of conventional showers ?
R 500425 /
ENDDESCRIPTOR

DESCRIPTOR
power_showers_%
T S
U %
V very_low              [ 0, 20 ]/
V low                   [20, 40 ]/
V moderate              [40, 60 ]/
V high                  [60, 80 ]/
V very_high             [80, 100 ]/
Q what is the percentage of power showers ?
R 500426 /
ENDDESCRIPTOR

DESCRIPTOR
shower_leakage_%
T S
U %
V very_low              [ 0, 20 ]/
V low                   [20, 40 ]/
V moderate              [40, 60 ]/
V high                  [60, 80 ]/
V very_high             [80, 100 ]/
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```
Q What is the expected leakage in showers consumption ?
R 500430 /
ENDDESCRIPTOR

DESCRIPTOR
toilet_consumption
T S
U l/day
V skip                  [  0,   0 ]/
V very_low              [  0,  18 ]/
V low                   [ 18,  54 ]/
V moderate              [ 54, 108 ]/
V high                  [ 108, 180 ]/
V very_high             [ 180, 270 ]/
Q If water use device is a toilet, what is the expected consumption rate
Q in litres per day ?
R 500460 /
ENDDESCRIPTOR

DESCRIPTOR
toilet_capacity
T S
U l/flush
V very_low              [ 0,3 ]/
V low                   [ 3,6 ]/
V moderate              [ 6,9 ]/
V high                  [ 9,12]/
V very_high             [12,15]/
Q What is the expected flushing capacity of toilets in litres per flush ?
R 500461 / 500462 / 500463 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_toilet_capacity
T S
U l/flush
V very_low              [ 0,3 ]/
V low                   [ 3,6 ]/
V moderate              [ 6,9 ]/
V high                  [ 9,12]/
V very_high             [12,15]/
Q What is the expected flushing capacity of conventional toilets in this area ?
R 500464 /
ENDDESCRIPTOR

DESCRIPTOR
efficient_toilet_capacity
T S
U l/flush
V very_low              [ 0,3 ]/
V low                   [ 3,6 ]/
V moderate              [ 6,9 ]/
V high                  [ 9,12]/
V very_high             [12,15]/
Q What is the expected flushing capacity of efficient toilets in this area ?
R 500465 /
ENDDESCRIPTOR


DESCRIPTOR
toilet_type
T S
V conventional_toilet /
V efficient_toilet /
V all_types /
Q What is the most common toilet type in this area ?
ENDDESCRIPTOR


DESCRIPTOR
existing_toilet_capacity
T S
U l/flush
V very_low              [ 0,3 ]/
V low                   [ 3,6 ]/
V moderate              [ 6,9 ]/
V high                  [ 9,12]/
V very_high             [12,15]/
Q What is the average flushing capacity of existing toilets in litres
Q per flush ?
R 501980 /
ENDDESCRIPTOR

DESCRIPTOR
proposed_toilet_capacity
T S
U l/flush
V very_low              [ 0,3 ]/
V low                   [ 3,6 ]/
V moderate              [ 6,9 ]/
V high                  [ 9,12]/
V very_high             [12,15]/
Q What is the expected flushing capacity of proposed toilets in litres
Q per flush ?
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```
R 501981 /
ENDDESCRIPTOR

DESCRIPTOR
flushing_frequency
T S
U flush/day
V very_low          [ 0, 3  ] /
V low               [ 3, 6  ] /
V moderate          [ 6, 9  ] /
V high              [ 9, 12 ] /
V very_high         [ 12, 15 ] /
Q What is the expected number of toilet flushings per day ?
R 500466 /
ENDDESCRIPTOR

DESCRIPTOR
toilets_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q what is the expected percentage of toilets in this area ?
R 500470 /
ENDDESCRIPTOR

DESCRIPTOR
conventional_toilets_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q what is the percentage of conventional toilets ?
R 500468 /
ENDDESCRIPTOR

DESCRIPTOR
efficient_toilets_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q what is the percentage of efficient toilets ?
R 500469 /
ENDDESCRIPTOR

DESCRIPTOR
toilet_leakage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the expected leakage in toilets consumption ?
R 500467 /
ENDDESCRIPTOR

DESCRIPTOR
indoor_taps_consumption
T S
U l/day
V skip              [ 0, 0 ] /
V very_low          [ 0, 135 ] /
V low               [ 135, 270 ] /
V moderate          [ 270, 405 ] /
V high              [ 405, 580 ] /
V very_high         [ 580, 675 ] /
Q If water use device is an indoor taps, what is the expected
consumption
Q rate in litres per day ?
R 500500 /
ENDDESCRIPTOR

DESCRIPTOR
kitchen_consumption
T S
U l/day
V skip              [ 0, 0 ] /
V very_low          [ 0, 90 ] /
V low               [ 90, 180 ] /
V moderate          [ 180, 270 ] /
V high              [ 270, 360 ] /
V very_high         [ 360, 450 ] /
Q If indoor tap is a kitchen tap, what is the average consumption
Q rate in litres per day ?
R 500502 /
ENDDESCRIPTOR

DESCRIPTOR
kitchen_flow_rate
T S
U l/min
V very_low          [ 0, 3  ] /
V low               [ 3, 6  ] /
V moderate          [ 6, 9  ] /
V high              [ 9, 12 ] /
V very_high         [ 12, 15 ] /
Q What is the expected flow rate of kitchen taps in litres per minute ?
R 500503 /
ENDDESCRIPTOR

DESCRIPTOR
existing_kitchen_flow
T S
U l/min
V very_low          [ 0, 3  ] /
V low               [ 3, 6  ] /
V moderate          [ 6, 9  ] /
V high              [ 9, 12 ] /
V very_high         [ 12, 15 ] /
Q What is the average flow rate of existing taps in litres per minute ?
ENDDESCRIPTOR

DESCRIPTOR
proposed_kitchen_flow
T S
U l/min
V very_low          [ 0, 3  ] /
V low               [ 3, 6  ] /
V moderate          [ 6, 9  ] /
V high              [ 9, 12 ] /
V very_high         [ 12, 15 ] /
Q What is the expected flow rate of proposed taps in litres per minute ?
ENDDESCRIPTOR

DESCRIPTOR
kitchen_opening_time
T S
V very_low          [ 0, 6 ] /
V low               [ 6, 12 ] /
V moderate          [ 12, 18 ] /
V high              [ 18, 24 ] /
V very_high         [ 24, 30 ] /
Q What is the average opening time of kitchen taps in minutes per day ?
R 500504 /
ENDDESCRIPTOR

DESCRIPTOR
kitchen_taps_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the expected percentage of kitchen taps in this area ?
R 500505 /
ENDDESCRIPTOR

DESCRIPTOR
kitchen_leakage_%
T S
U %
V skip              [ 0, 0 ] /
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the expected leakage in kitchen taps consumption ?
R 500506 /
ENDDESCRIPTOR

DESCRIPTOR
bathroom_consumption
T S
U l/day
V skip              [ 0, 0 ] /
V very_low          [ 0, 21 ] /
V low               [ 21, 54 ] /
V moderate          [ 54, 99 ] /
V high              [ 99, 156 ] /
V very_high         [ 156, 225 ] /
Q If indoor tap is a bathroom tap, what is the expected consumption
Q rate in litres per day ?
R 500510 /
```

```
ENDDESCRIPTOR

DESCRIPTOR
bathroom_flow_rate
T S
U l/min
V very_low              [ 0, 3  ] /
V low                   [ 3, 6  ] /
V moderate              [ 6, 9  ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of bathroom taps in litres per
minute ?
R 500511 /
ENDDESCRIPTOR

DESCRIPTOR
bathroom_opening_time
T S
U min.
V very_low              [ 0, 3 ] /
V low                   [ 3, 6 ] /
V moderate              [ 6, 9 ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected opening time of bathroom taps in minutes per
day ?
R 500512 /
ENDDESCRIPTOR

DESCRIPTOR
existing_bathroom_flow
T S
U l/min
V very_low              [ 0, 3  ] /
V low                   [ 3, 6  ] /
V moderate              [ 6, 9  ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the average flow rate of existing taps in litres per minute ?
ENDDESCRIPTOR

DESCRIPTOR
proposed_bathroom_flow
T S
U l/min
V very_low              [ 0, 3  ] /
V low                   [ 3, 6  ] /
V moderate              [ 6, 9  ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of proposed taps in litres per
minute ?
ENDDESCRIPTOR

DESCRIPTOR
bathroom_taps_%
T S
U %
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected percentage of bathroom taps in this area ?
R 500513 /
ENDDESCRIPTOR

DESCRIPTOR
bathroom_leakage_%
T S
U %
V skip                  [ 0, 0 ] /
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the expected leakage in bathroom consumption ?
R 500514 /
ENDDESCRIPTOR

DESCRIPTOR
existing_bathtub_flow
T S
U l/min
V very_low              [ 0, 3  ] /
V low                   [ 3, 6  ] /
V moderate              [ 6, 9  ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the average flow rate of existing bathtub taps in
Q litres per minute ?
ENDDESCRIPTOR
```

```
DESCRIPTOR
proposed_bathtub_flow
T S
U l/min
V very_low              [ 0, 3  ] /
V low                   [ 3, 6  ] /
V moderate              [ 6, 9  ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of proposed bathtub taps in
Q litres per minute ?
ENDDESCRIPTOR

DESCRIPTOR
outdoor_taps_consumption
T S
U l/day
V skip                  [ 0, 0 ] /
V very_low              [ 0, 135 ] /
V low                   [ 135, 270 ] /
V moderate              [ 270, 405 ] /
V high                  [ 405, 580 ] /
V very_high             [ 580, 675 ] /
Q If water use device is an outdoor taps, what is the expected consumption
Q rate in litres per day ?
R 500520 /
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_consumption
T S
U l/day
V skip                  [ 0, 0 ] /
V very_low              [ 0, 21 ] /
V low                   [ 21, 54 ] /
V moderate              [ 54, 99 ] /
V high                  [ 99, 156 ] /
V very_high             [ 156, 225 ] /
Q If outdoor tap is connected to a hosepipe, what is the expected
Q consumption rate in litres per day ?
R 500521 /
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_flow_rate
T S
U l/min
V very_low              [ 0, 3  ] /
V low                   [ 3, 6  ] /
V moderate              [ 6, 9  ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected flow rate of hosepipes in litres per minute ?
R 500522 /
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_opening_time
T S
U min.
V very_low              [ 0, 3 ] /
V low                   [ 3, 6 ] /
V moderate              [ 6, 9 ] /
V high                  [ 9, 12 ] /
V very_high             [ 12, 15 ] /
Q What is the expected opening time ofhosepipes in minutes per day ?
R 500523 /
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_taps_%
T S
U %
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q what is the average percentage of hosepipe users in this area ?
R 500524 /
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_leakage_%
T S
U %
V skip                  [ 0, 0 ] /
V very_low              [ 0, 20 ] /
V low                   [ 20, 40 ] /
V moderate              [ 40, 60 ] /
V high                  [ 60, 80 ] /
V very_high             [ 80, 100 ] /
Q What is the leakage in hosepipes consumption ?
```

```
R 500525 /
ENDDESCRIPTOR

DESCRIPTOR
existing_hosepipe_flow
T S
U l/min
V very_low              [0, 3  ]/
V low                   [3, 6  ]/
V moderate              [6, 9  ]/
V high                  [9, 12 ]/
V very_high             [12, 15 ]/
Q What is the average flow rate of existinghosepipe in litres per
minute ?
ENDDESCRIPTOR

DESCRIPTOR
proposed_hosepipe_flow
T S
U l/min
V very_low              [0, 3  ]/
V low                   [3, 6  ]/
V moderate              [6, 9  ]/
V high                  [9, 12 ]/
V very_high             [12, 15 ]/
Q What is the expected flow rate of proposed hosepipe in litres per
minute ?
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_consumption
T S
U l/day
V skip                  [ 0, 0 ]/
V very_low              [ 0, 90 ]/
V low                   [90, 180 ]/
V moderate              [180, 270 ]/
V high                  [270, 360 ]/
V very_high             [360, 450 ]/
Q If outdoor tap is connected to a sprinkler, what is the expected
Q consumption rate in litres per day ?
R 500530 /
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_flow_rate
T S
U l/min
V very_low              [0, 3  ]/
V low                   [3, 6  ]/
V moderate              [6, 9  ]/
V high                  [9, 12 ]/
V very_high             [12, 15 ]/
Q What is the expected flow rate of sprinklers in litres per minute ?
R 500531 /
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_opening_time
T S
U min.
V very_low              [0, 6 ]/
V low                   [6, 12 ]/
V moderate              [12, 18 ]/
V high                  [18, 24 ]/
V very_high             [24, 30 ]/
Q What is the expected opening time of sprinklers in minutes ?
R 500532
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_taps_%
T S
U %
V very_low              [ 0, 20 ]/
V low                   [ 20, 40 ]/
V moderate              [ 40, 60 ]/
V high                  [ 60, 80 ]/
V very_high             [ 80, 100 ]/
Q what is the expected percentage of sprinkler users in this area ?
R 500533 /
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_leakage_%
T S
U %
V skip                  [ 0, 0 ]/
V very_low              [ 0, 20 ]/
V low                   [ 20, 40 ]/
V moderate              [ 40, 60 ]/
V high                  [ 60, 80 ]/
V very_high             [ 80, 100 ]/
Q What is the expected leakage in sprinklers consumption ?
```

```
R 500534 /
ENDDESCRIPTOR

DESCRIPTOR
existing_sprinkler_flow
T S
U l/min
V very_low              [0, 3  ]/
V low                   [3, 6  ]/
V moderate              [6, 9  ]/
V high                  [9, 12 ]/
V very_high             [12, 15 ]/
Q What is the average flow rate of existing sprinkler in litres per minute ?
ENDDESCRIPTOR

DESCRIPTOR
proposed_sprinkler_flow
T S
U l/min
V very_low              [0, 3  ]/
V low                   [3, 6  ]/
V moderate              [6, 9  ]/
V high                  [9, 12 ]/
V very_high             [12, 15 ]/
Q What is the expected flow rate of proposed sprinkler in litres per minute ?
ENDDESCRIPTOR

DESCRIPTOR
econometric_consumption
T S
U l/day
V very_low              [  0, 150 ]/
V low                   [ 150, 300 ]/
V moderate              [ 300, 450 ]/
V high                  [ 450, 600 ]/
V very_high             [ 600, 750 ]/
MODEL
econometric_consumption
T local_wait
I household_income /
I adults_number /
I children_number /
I annual_rainfall /
I avg_max_daily_temperature /
I water_price /
O econometric_consumption /
O consumption_probability /
ENDMODEL
Q If household consumption will beforecasted based on consumption-
expalnatory
Q variables, what is the expected household consumption rate in litres
Q per day ?
ENDDESCRIPTOR

DESCRIPTOR
household_income
T S
U £/year
V very_low              [ 0,  10000 ]/
V low                   [ 10000, 20000 ]/
V moderate              [ 20000, 30000 ]/
V high                  [ 30000, 40000 ]/
V very_high             [ 40000, 50000 ]/
Q What is the expected  average annual household income ?
R 500570 / 500571 / 500572 / 500573 / 500574 / 500575 / 500576 /
R 500577 / 500578 / 500579 /
ENDDESCRIPTOR

DESCRIPTOR
social_class
T S
V unstated/
V unskilled/
V semi_skilled/
V skilled_manual/
V skilled_non_manual/
V govt_training_scheme/
V proffessional/
V armed_forces/
V managerial/
V mixed /
Q specify the economically active household residents (adults) by
Q social class which dominates this area ?
R 500580 /
ENDDESCRIPTOR

DESCRIPTOR
adults_number
T S
U adult
V very_low              [ 0, 0.4 ]/
V low                   [ 0.4, 0.8 ]/
V moderate              [ 0.8, 1.2 ]/
V high                  [ 1.2, 1.6 ]/
```

```
V very_high              [ 1.6, 2.0 ] /
Q What is the expected average number of adults per household ?
R 500581 /
ENDDESCRIPTOR

DESCRIPTOR
children_number
T S
U child
V very_low               [ 0, 0.6 ] /
V low                    [ 0.6, 1.2 ] /
V moderate               [ 1.2, 1.8 ] /
V high                   [ 1.8, 2.4 ] /
V very_high              [ 2.4, 3.0 ] /
Q What is the expected average number of children per household ?
R 500582 /
ENDDESCRIPTOR

DESCRIPTOR
annual_rainfall
T S
U mm
V very_low               [ 0  200 ] /
V low                    [ 200, 400 ] /
V moderate               [ 400, 600 ] /
V high                   [ 600, 800 ] /
V very_high              [ 800, 1000 ] /
Q What is the expected annual rainfall in this area ?
R 500583 /
ENDDESCRIPTOR

DESCRIPTOR
avg_max_daily_temperature
T S
U d.c
V very_low               [ 0, 6 ] /
V low                    [ 6, 12 ] /
V moderate               [ 12, 18 ] /
V high                   [ 18, 24 ] /
V very_high              [ 24, 30 ] /
Q What is the expected average max dailytemprature ?
R 500584 /
ENDDESCRIPTOR

DESCRIPTOR
water_price
T S
U £/c.m
V very_low               [ 0, 0.2 ] /
V low                    [ 0.2, 0.4 ] /
V moderate               [ 0.4, 0.6 ] /
V high                   [ 0.6, 0.8 ] /
V very_high              [ 0.8, 1.0 ] /
Q What is the expected real water price per cubic meter ?
R 500585 /
ENDDESCRIPTOR

DESCRIPTOR
customers_number
T S
U thous.
V very_small             [ 0, 2000 ] /
V small                  [ 2000, 4000 ] /
V medium                 [ 4000, 6000 ] /
V large                  [ 6000, 8000 ] /
V very_large             [ 8000, 10000 ] /
Q What is the number of water customers in this area ?
R 400115 / 400120 / 400125 /
ENDDESCRIPTOR

DESCRIPTOR
households_number
T S
U thous.
V very_small             [ 0, 1000 ] /
V small                  [ 1000, 2000 ] /
V medium                 [ 2000, 3000 ] /
V large                  [ 3000, 4000 ] /
V very_large             [ 4000, 5000 ] /
Q What is the number of households in this area ?
R 500132 /
ENDDESCRIPTOR

DESCRIPTOR
connections number
T S
U thous.
V very_small             [ 0, 1000 ] /
V small                  [ 1000, 2000 ] /
V medium                 [ 2000, 3000 ] /
V large                  [ 3000, 4000 ] /
V very_large             [ 4000, 5000 ] /
Q What is the number of domestic water connections in this area ?
R 500133 /
```

```
ENDDESCRIPTOR

DESCRIPTOR
population_number
T S
U thous.
V very_small             [ 0, 2000 ] /
V small                  [ 2000, 4000 ] /
V medium                 [ 4000, 6000 ] /
V large                  [ 6000, 8000 ] /
V very_large             [ 8000, 10000 ] /
MODEL
population
T local_wait
I forecast_year /
O population_number /
ENDMODEL
Q What is the number of population in this area ?
ENDDESCRIPTOR

DESCRIPTOR
forecast_year
T S
VS 1950/ 2050 / 1
Q Specify forecast year ?
ENDDESCRIPTOR

DESCRIPTOR
occupancy_rate
T S
U p/hsh
V very_low               [ 0.0, 1.0 ] /
V low                    [ 1.0, 2.0 ] /
V moderate               [ 2.0, 3.0 ] /
V high                   [ 3.0, 4.0 ] /
V very_high              [ .0, 5.0 ] /
MODEL
occupancy_rate
T local_wait
I forecast_year
O occupancy_rate
ENDMODEL
Q What is the average occupancy rate per household in this area ?
ENDDESCRIPTOR

DESCRIPTOR
conservation_effectiveness
T S
U %
V skip                   [ 0, 0 ] /
V very_low               [ 0, 20 ] /
V low                    [ 20, 40 ] /
V moderate               [ 40, 60 ] /
V high                   [ 60, 80 ] /
V very_high              [ 80, 100 ] /
Q If there are any conservation measures to be applied now or in the future
Q to control domestic demand, what is the expected effectiveness of these
Q measure(s) ?
R 501850 / 501852 / 501854 / 501856 / 501858 / 501860 / 501862 /
R 501864 / 501866 / 501868 / 501869 / 501870 / 501871 / 501872 /
R 501873 / 501876 / 501877 / 501878 / 501880 / 501882 / 501884 /
R 501886 / 501888 / 501890 / 501892 / 501894 / 501896 / 501682 /
R 501684 / 501686 / 501688 / 501690 / 501700 / 501702 / 501704 /
R 501706 / 501708 / 501710 /
ENDDESCRIPTOR

DESCRIPTOR
first_measure_effectiveness
T S
U %
V skip                   [ 0, 0 ] /
V very_low               [ 0, 20 ] /
V low                    [ 20, 40 ] /
V moderate               [ 40, 60 ] /
V high                   [ 60, 80 ] /
V very_high              [ 80, 100 ] /
Q What is the effectiveness of this measure onhousehld consumption ?
R 500610 / 500674 / 500694 / 500712 / 500730 / 500748 / 500766 / 500784 /
R 500802 / 503700 / 503702 / 503704 / 503706 / 503708 / 503710 /
R 504002 / 504004 / 504005 /
ENDDESCRIPTOR

DESCRIPTOR
second_measure_effectiveness
T S
U %
V skip                   [ 0, 0 ] /
V very_low               [ 0, 20 ] /
V low                    [ 20, 40 ] /
V moderate               [ 40, 60 ] /
V high                   [ 60, 80 ] /
V very_high              [ 80, 100 ] /
Q What is the effectiveness of this measure on household consumption ?
R 500600 / 500612 / 500676 / 500696 / 500714 / 500732 / 500750 / 500768 /
```

R 500786 / 500804 / 503712 / 503714 / 503716 / 503718 / 503720 / 503722 /
R 504006 / 504008 / 504010 / 504012 / 504013 /
ENDDESCRIPTOR

DESCRIPTOR
third_measure_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this measure on household consumption ?
R 500602 / 500614 / 500678 / 500698 / 500716 / 500734 / 500752 / 500770 /
R 500788 / 500806 / 503724 / 503722 / 503726 / 503728 /
R 503730 / 503732 / 503734 / 504014 / 504016 / 504018 / 504020 / 504021 /
ENDDESCRIPTOR

DESCRIPTOR
forth_measure_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this measure on household consumption ?
R 500604 / 500616 / 500680 / 500700 / 500718 / 500736 / 500754 /
R 500790 / 500808 / 503736 / 503738 / 503740 /
R 503742 / 503744 / 503746 / 504022 / 504024 / 504026 / 504028 / 504029 /
ENDDESCRIPTOR

DESCRIPTOR
fifth_measure_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this measure on household consumption ?
R 500606 / 500618 / 500682 / 500702 / 500720 / 500738 /
R 500756 / 500774 / 500792 / 500810 /
R 503748 / 503750 / 503752 / 503754 / 503756 / 503758 / 504030 / 504032 /
R 504034 / 504036 / 504037 /
ENDDESCRIPTOR

DESCRIPTOR
first_device_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501810 / 501815 / 501825 / 501830 /
R 502900 / 502902 / 502904 / 502906 / 502908 / 502909 /
ENDDESCRIPTOR

DESCRIPTOR
second_device_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501800 / 501811 / 501816 / 501826 / 501831 /
R 502910 / 502912 / 502914 / 502916 / 502918 / 502919 /
ENDDESCRIPTOR

DESCRIPTOR
third_device_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501801 / 501812 / 501817 / 501827 / 501832 /
R 502920 / 502922 / 502924 / 502926 / 502928 / 502929 /
ENDDESCRIPTOR

DESCRIPTOR
forth_device_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501802 / 501813 / 501818 / 501828 / 501833 /
R 502930 / 502932 / 502934 / 502936 / 502938 / 502939 /
ENDDESCRIPTOR

DESCRIPTOR
fifth_device_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501803 / 501814 / 501819 / 501829 / 501834 /
R 502940 / 502942 / 502944 / 502946 / 502948 / 502949 /
ENDDESCRIPTOR

DESCRIPTOR
first_tap_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501722 / 501731 / 501740 / 501750 / 501760 /
ENDDESCRIPTOR

DESCRIPTOR
second_tap_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501780 / 501724 / 501732 / 501742 / 501752 / 501762 /
ENDDESCRIPTOR

DESCRIPTOR
third_tap_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the effectiveness of this device on household consumption ?
R 501781 / 501726 / 501734 / 501744 / 501754 / 501764 /
ENDDESCRIPTOR

DESCRIPTOR
forth_tap_effectiveness
T S
U %
V skip [0, 0] /
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /

```
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q What is the effectiveness of this device on household consumption
?
R 501782 / 501728 / 501736 / 501746 / 501756 / 501766 /
ENDDESCRIPTOR

DESCRIPTOR
fifth_tap_effectiveness
T S
U %
V skip                    [ 0, 0 ] /
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q What is the effectiveness of this device on household consumption
?
R 501783 / 501730 / 501738 / 501748 / 501758 /
R 501768 /
ENDDESCRIPTOR

DESCRIPTOR
toilet_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q waht is the percentage of reduction in toilets consumption due to
Q conservation devices ?
R 501954 / 501955 / 501956 / 501957 / 501958 / 501962 / 501960 /
ENDDESCRIPTOR

DESCRIPTOR
shower_reduction %
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q waht is the percentage of reduction in showers consumption due to
Q conservation devices ?
R 501924 / 501922 /
ENDDESCRIPTOR

DESCRIPTOR
bathtub_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in bathtub-tap consumption
due to
Q conservation devices ?
R 501944 / 501934 /
ENDDESCRIPTOR

DESCRIPTOR
bathroom_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in bathroom-tap consumption
due to
Q conservation devices ?
R 501946 / 501936 /
ENDDESCRIPTOR

DESCRIPTOR
kitchen_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in kitchen-tap consumption
due to
Q conservation devices ?
R 501948 / 501938 /
```

```
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in hosepipe consumption due to
Q conservation devices ?
R 501950 / 501940 /
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in sprinkler consumption due to
Q conservation devices ?
R 501952 / 501942 /
ENDDESCRIPTOR

DESCRIPTOR
dishwasher_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in dishwasher consumption due to
Q use of efficient dishwashers ?
R 501928 / 501926 /
ENDDESCRIPTOR

DESCRIPTOR
washer_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q what is the percentage of reduction in washer consumption
Q due to use of efficient washers ?
R 501932 / 501930 /
ENDDESCRIPTOR

DESCRIPTOR
education_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q What is the percentage of reduction in household consumption due to
Q education programmes ?
R 501911 /
ENDDESCRIPTOR

DESCRIPTOR
pricing_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
V very_high               [ 80, 100 ] /
Q What is the percentage of reduction in household consumption due to metering
Q combined with a certain pricing policy ?
R 501912 / 501914 / 501916 / 501918 / 501920 /
ENDDESCRIPTOR

DESCRIPTOR
metering_reduction_%
T S
U %
V very_low                [ 0, 20 ] /
V low                     [ 20, 40 ] /
V moderate                [ 40, 60 ] /
V high                    [ 60, 80 ] /
```

V very_high [80, 100] /
Q What is the percentage of reduction in household consumption due to
Q metering policy ?
R 501905 /
ENDDESCRIPTOR

DESCRIPTOR
rationing_reduction_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q Waht is the percentage of reduction in household consumption due to
Q rationing policy ?
R 501898 /
ENDDESCRIPTOR

DESCRIPTOR
pressure_reduction_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q Waht is the percentage of reduction in household consumption due to
Q pressure reduction in the water supply system ?
R 501902 /
ENDDESCRIPTOR

DESCRIPTOR
plumbing_reduction_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q Waht is the percentage of reduction in household consumption due to
Q plumbing codes regulations ?
R 501900 /
ENDDESCRIPTOR

DESCRIPTOR
restrictions_reduction_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q Waht is the percentage reduction in household consumption due to
Q water-use restrictions ?
R 501904 /
ENDDESCRIPTOR

DESCRIPTOR
leakage_reduction_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q Waht is the percentage of reduction in household consumption due to
Q households leakage control ?
R 501910 /
ENDDESCRIPTOR

DESCRIPTOR
leakage_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of household leakage repair in this area ?
ENDDESCRIPTOR

DESCRIPTOR
pressure_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of households which are affected by pressure
Q reduction in this area ?
ENDDESCRIPTOR

DESCRIPTOR
metering_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of metered households in this area ?
R 501357 /
ENDDESCRIPTOR

DESCRIPTOR
education_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of households which are affected by
Q education programmes in this area ?
R 501355 /
ENDDESCRIPTOR

DESCRIPTOR
pricing_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of households which are affected
Q by the pricing policy in this area ?
R 501356 /
ENDDESCRIPTOR

DESCRIPTOR
rationing_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of households which are affected by
Q rationing plan in this area ?
ENDDESCRIPTOR

DESCRIPTOR
plumbing_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of households which are fulfilled the
Q plumbing regulations in this area ?
ENDDESCRIPTOR

DESCRIPTOR
restrictions_coverage_%
T S
U %
V very_low [0, 20] /
V low [20, 40] /
V moderate [40, 60] /
V high [60, 80] /
V very_high [80, 100] /
Q What is the coverage percentage of households which are affected by water
Q use restrictions in this area ?
ENDDESCRIPTOR

DESCRIPTOR

```
toilet_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have
efficient toilets
Q in this area ?
R 501358 /
ENDDESCRIPTOR

DESCRIPTOR
shower_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have
efficient
Q showerheads in this area ?
ENDDESCRIPTOR

DESCRIPTOR
bathtub_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have
efficient bathtubs
Q in this area ?
ENDDESCRIPTOR

DESCRIPTOR
bathroom_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have
efficient bathroom
Q taps in this area ?
ENDDESCRIPTOR

DESCRIPTOR
kitchen_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have
efficient kitchen
Q taps in this area ?
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have
efficient hosepipes
Q in this area ?
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_coverage %
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have efficient
Q sprinklers in this area ?
ENDDESCRIPTOR

DESCRIPTOR
dishwasher_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have efficient
Q dishwashers in this area ?
R 501365 /
ENDDESCRIPTOR

DESCRIPTOR
washer_coverage_%
T S
U %
V very_low          [ 0, 20 ] /
V low               [ 20, 40 ] /
V moderate          [ 40, 60 ] /
V high              [ 60, 80 ] /
V very_high         [ 80, 100 ] /
Q What is the coverage percentage of households which have efficientwahing
Q machines
Q in this area ?
R 501366 /
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_p
T S
V very_high         [ 0, 0.2 ] /
V high              [ 0.2, 0.4 ] /
V moderate          [ 0.4, 0.6 ] /
V low               [ 0.6, 0.8 ] /
V very_low          [ 0.8, 1.0 ] /
V none              [ 1.0, 1.0 ] /
R 501842 / 501844 /
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_ps
T S
V very_high         [ 0, 0.2 ] /
V high              [ 0.2, 0.4 ] /
V moderate          [ 0.4, 0.6 ] /
V low               [ 0.6, 0.8 ] /
V very_low          [ 0.8, 1.0 ] /
V none              [ 1.0, 1.0 ] /
TB 40
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp1
T S
V very_high         [ 0, 0.2 ] /
V high              [ 0.2, 0.4 ] /
V moderate          [ 0.4, 0.6 ] /
V low               [ 0.6, 0.8 ] /
V very_low          [ 0.8, 1.0 ] /
V none              [ 1.0, 1.0 ] /
R 501280 /
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp2
T S
V very_high         [ 0, 0.2 ] /
V high              [ 0.2, 0.4 ] /
V moderate          [ 0.4, 0.6 ] /
V low               [ 0.6, 0.8 ] /
V very_low          [ 0.8, 1.0 ] /
V none              [ 1.0, 1.0 ] /
R 501282 /
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp3
```

```
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501284 /
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp4
T S
V very_high          [ 0, 0.2 ]
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501286 /
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor sp5
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501288 /
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp11
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0 6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 52
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp12
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0 8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 54
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp13
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 56
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor sp21
T S
V very high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 58
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp22
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 60
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp23
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 62
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp31
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 64
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp32
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 66
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp33
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 68
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp41
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 70
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```
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp42
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 72
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_sp43
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 74
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp51
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 76
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp52
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 78
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_sp53
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
TB 80
Q Is there any interaction between this measure and any other
previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_pm
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none    [           1.0, 1.0 ] /
R 501846 /
Q Is there any interaction between this measure and any other
previous
Q measures ?
```

```
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_p1
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501325 /
TB 42
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_p2
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501330 /
TB 44
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_p3
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501332 /
TB 46
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_p4
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501334 /
TB 48
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_p5
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501336 /
TB 50
Q Is there any interaction between this measure and any other previous
Q measures ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_2
T S
V very_high          [ 0, 0.2 ] /
V high               [ 0.2, 0.4 ] /
V moderate           [ 0.4, 0.6 ] /
V low                [ 0.6, 0.8 ] /
V very_low           [ 0.8, 1.0 ] /
V none               [ 1.0, 1.0 ] /
R 501836 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_12
```

```
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501300 /
TB 10 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_3
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501837 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_13
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501301 /
TB 12 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_23
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501310 /
TB 20 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_4
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501838 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_14
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
Q What is the average interaction factor of this measure ?
R 501302 /
TB 13 /
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_24
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
Q What is the average interaction factor of this measure ?
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```
R 501311 /
TB 21 /
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_34
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
Q What is the average interaction factor of this measure ?
R 501317 /
TB 27 /
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_5
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501839 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_15
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501303 /
TB 14 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_25
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501313 /
TB 22 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR

DESCRIPTOR
interaction_factor_35
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501318 /
TB 28 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR


DESCRIPTOR
interaction_factor_45
T S
V very_high            [ 0, 0.2 ] /
V high                 [ 0.2, 0.4 ] /
V moderate             [ 0.4, 0.6 ] /
V low                  [ 0.6, 0.8 ] /
V very_low             [ 0.8, 1.0 ] /
V none                 [ 1.0, 1.0 ] /
R 501321 /
TB 33 /
Q What is the average interaction factor of this measure ?
ENDDESCRIPTOR

DESCRIPTOR
bathtub_relative_%
T S
U %
V very_low             [ 0, 20 ] /
```

```
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much bathtub-tap consumption represents as percentage of
Q total household consumption in this area ?
ENDDESCRIPTOR

DESCRIPTOR
bathroom_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much bathroom-tap consumption represents as percentage of
Q total household consumption in this area ?
ENDDESCRIPTOR

DESCRIPTOR
kitchen_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much kitchen-tap consumption represents as percentage of
Q household consumption in this area ?
ENDDESCRIPTOR

DESCRIPTOR
hosepipe_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much hosepipe-tap consumption represents as percentage of
Q total household consumption in this area ?
ENDDESCRIPTOR

DESCRIPTOR
sprinkler_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much sprinkler-tap consumption represents as percentage of
total
Q household consumption ?
ENDDESCRIPTOR

DESCRIPTOR
shower_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much shower consumption represents as percentage of total
Q total household consumption in this area ?
ENDDESCRIPTOR

DESCRIPTOR
toilet_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much toilet consumption represents as percentage of
Q total household consumption in this area ?
R 501312 /
ENDDESCRIPTOR

DESCRIPTOR
dishwasher relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
```

```
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much dishwasher consumption represents as  percentage of
Q total household consumption in this area ?
R 501314 /
ENDDESCRIPTOR

DESCRIPTOR
washer_relative_%
T S
U %
V very_low           [ 0, 20 ] /
V low                [ 20, 40 ] /
V moderate           [ 40, 60 ] /
V high               [ 60, 80 ] /
V very_high          [ 80, 100 ] /
Q How much clothes-washer consumption represents as percentage of
Q total household consumption in this area ?
R 501316 /
ENDDESCRIPTOR

DESCRIPTOR
measure_first_criterion
T S
V cost/
V public_acceptence/
V ease_of_application/
V saving_effectiveness/
Q What is the first important criterion ?
ENDDESCRIPTOR

DESCRIPTOR
measure_second_criterion
T S
V none/
V public_acceptence/
V ease_of_application/
V saving_effectiveness/
Q What is the second important criterion ?
ENDDESCRIPTOR

DESCRIPTOR
measure_third_criterion
T S
V public_acceptence/
V ease_of_application/
V saving_effectiveness/
Q What is the third important criterion ?
ENDDESCRIPTOR

DESCRIPTOR
measure_forth_criterion
T S
V public_acceptence/
V ease_of_application/
V saving_effectiveness/
Q What is the forth important criterion ?
ENDDESCRIPTOR

DESCRIPTOR
measure_type
T S
V long_term/
V short_term/
Q Based on time requirement how do you classify the proposed conservation
Q measure ?
ENDDESCRIPTOR

DESCRIPTOR
c1
T S
V [ 0, 1 ] /
R 502720 / 502721 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c2
T S
V [ 0, 1 ] /
R 502722 / 502723 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c3
T S
V [ 0, 1 ] /
R 502724 /  502725 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
```

```
c4
T S
V [ 0, 1 ] /
R 502726 / 502727 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c5
T S
V [ 0, 1 ] /
R 502728 / 502729 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c6
T S
V [ 0, 1 ] /
R 502730 / 502731 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c7
T S
V [ 0, 1 ] /
R 502732 / 502734 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c8
T S
V [ 0, 1 ] /
R 502718 / 502719 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
c9
T S
V [ 0, 1 ] /
R 502716 / 502717 /
Q specify criteria result ?
ENDDESCRIPTOR

DESCRIPTOR
wc1
T S
V [ 0, 1 ] /
R 502740 / 502742 / 502744 / 502746 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
wc2
T S
V [ 0, 1 ] /
R 502750 / 502752 / 502754 / 502756 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
wc3
T S
V [ 0, 1 ] /
R 502760 / 502762 / 502764 / 502766 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
wc4
T S
V [ 0, 1 ] /
R 502770 / 502772 / 502774 / 502776 /
Q specify criteria weight ?
ENDDESCRIPTOR

DESCRIPTOR
proposed_conservation_measure
T S
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
V multiple measures /
Q What are the proposed-conservation measure(s) ?
R 502780 / 502782 / 502784 / 502786 / 502788 / 502790 / 502792 / 502794 /
R 502700 / 502702 / 502704 / 502706 / 502708 / 502710 / 502712 / 502714 /
R 502715 /
ENDDESCRIPTOR

DESCRIPTOR
first_proposed_measure
T S
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
Q What is the first proposed measure ?
ENDDESCRIPTOR

DESCRIPTOR
second_proposed_measure
T S
V none/
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
Q What is the second proposed measure ?
ENDDESCRIPTOR

DESCRIPTOR
third_proposed_measure
T S
V none/
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
Q What is the third proposed measure ?
ENDDESCRIPTOR


DESCRIPTOR
forth_proposed_measure
T S
V none/
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
Q What is the forth proposed measure ?
ENDDESCRIPTOR


DESCRIPTOR
fifth_proposed_measure
T S
V none/
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
Q What is the fifth proposed measure ?
ENDDESCRIPTOR

DESCRIPTOR
previous_conservation_measure
T S
V none/
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
```

V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
V multiple_measures /
Q What are the previous conservation measure(s) ?
ENDDESCRIPTOR

DESCRIPTOR
first_previous_measure
T S
V none /
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water_use_restrictions /
Q What is the first previous measure ?
ENDDESCRIPTOR

DESCRIPTOR
second_previous_measure
T S
V none /
V metering /
V pricing_policy /
V leakage control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water use_restrictions /
Q What is the second previous measure ?
ENDDESCRIPTOR

DESCRIPTOR
third_previous_measure
T S
V none /
V metering /
V pricing_policy /
V leakage_control /
V conservation_devices /
V education_programmes /
V water_rationing /
V pressure_reduction /
V plumbing_codes /
V water use_restrictions /
Q What is the third previous measure ?
ENDDESCRIPTOR

DESCRIPTOR
tariff_type
T S
V flat_rate tariff /
V rising_block_tariff /
V falling_block tariff /
V seasonal_rate_tariff /
V peak_hour_rate_tariff /
Q specify the proposed tariff of water price ?
ENDDESCRIPTOR

DESCRIPTOR
water_use_device
T S
V tap/
V shower/
V toilet/
V dishwasher /
V clothes_washer /
V multiple devices/
Q Which device would you like to modify or to replace ?
ENDDESCRIPTOR

DESCRIPTOR
tap_fixture
T S
V bathtub /
V bathroom /
V kitchen /
V hosepipe /
V sprinkler /
V multiple fixtures /
Q Specify the tap fixture(s) which are to be modified to reduce water
Q consumption ?
ENDDESCRIPTOR

DESCRIPTOR
first_tap_fixture
T S
V bathtub /
V bathroom /
V kitchen /
V hosepipe /
V sprinkler /
Q What is the first tap-fixture to be modified ?
ENDDESCRIPTOR

DESCRIPTOR
second_tap_fixture
T S
V none /
V bathtub /
V bathroom /
V kitchen /
V hosepipe /
V sprinkler /
Q What is the second tap-fixture to be modified ?
ENDDESCRIPTOR

DESCRIPTOR
third_tap_fixture
T S
V none /
V bathtub /
V bathroom /
V kitchen /
V hosepipe /
V sprinkler /
Q What is the third tap-fixture to be modified ?
ENDDESCRIPTOR

DESCRIPTOR
forth_tap_fixture
T S
V none /
V bathtub /
V bathroom /
V kitchen /
V hosepipe /
V sprinkler /
Q What is the forth tap-fixture to be modified ?
ENDDESCRIPTOR

DESCRIPTOR
fifth_tap_fixture
T S
V none /
V bathtub /
V bathroom /
V kitchen /
V hosepipe /
V sprinkler /
Q What is the fifth tap-fixture to be modified ?
ENDDESCRIPTOR

DESCRIPTOR
first_water_use_device
T S
V tap/
V shower/
V toilet/
V dishwasher /
V clothes_washer /
Q Which device would you like to modify or to replace first ?
ENDDESCRIPTOR

DESCRIPTOR
second_water_use_device
T S
V none/
V tap/
V shower/
V toilet/
V dishwasher /
V clothes_washer /
Q Which device would you like to modify or to replace second ?
ENDDESCRIPTOR

DESCRIPTOR
third_water_use_device
T S
V none/
V tap/
V shower/
V toilet/
V dishwasher /
V clothes_washer /
Q Which device would you like to modify or to replace third ?
ENDDESCRIPTOR

```
DESCRIPTOR
forth_water_use_device
T S
V none/
V tap/
V shower/
V toilet/
V dishwasher /
V clothes_washer /
Q Which device would you like to modify or to replace forth ?
ENDDESCRIPTOR

DESCRIPTOR
fifth_water_use_device
T S
V none/
V tap/
V shower/
V toilet/
V dishwasher /
V clothes_washer /
Q Which device would you like to modify or to replace fifth ?
ENDDESCRIPTOR

DESCRIPTOR
conservation_policy
T S
V modify existing_toilets/
V replace_existing_toilets/
Q What is the proposed conservation policy of toilets in this area ?
ENDDESCRIPTOR

DESCRIPTOR
conservation_tool
T S
V damming_type /
V displacement_type /
V assortment_type /
Q What kind of toilet saving devices would you like to use ?
R 501964 / 501966 / 501968 / 501970 /
ENDDESCRIPTOR

DESCRIPTOR
damming_tool
T S
V ordinary dams /
V partitions /
Q which of the above tools would you like to use for reducing
flushing volume ?
R 501972 /
ENDDESCRIPTOR

DESCRIPTOR
displacement_tool
T S
V plastic_bottle /
V plastic bag /
Q Which of the above tools would you like to use for reducing
flushing volume?
R 501974 /
ENDDESCRIPTOR

DESCRIPTOR
assortment_tool
T S
V two_flushing_modes /
V other_flushing_modes /
Q Which of the above tools would you like to use for reducing
flushing volume ?
R 501976 /
ENDDESCRIPTOR

DESCRIPTOR
tools_criteria
T S
V cost /
V durability /
V saving_effectiveness /
V installation_difficulty /
Q What is the main criterion for deducing the most appropriate tool ?
ENDDESCRIPTOR

DESCRIPTOR
time_period
T S
V short_term /
V long_term /
Q Would the proposed measure be applied for long-term or short-
term
Q period ?
ENDDESCRIPTOR
```

II.2 - List of rules

```
RULE 500115
IF        demand_sector == domestic
THEN      settlement_water_demand  =
          domestic_water_demand / 1000
ENDRULE

RULE 500116
IF        demand_sector == commercial
THEN      settlement_water_demand  =
          commercial_water_demand / 1000
ENDRULE

RULE 500120
IF        demand_sector == unaccounted
THEN      settlement_water_demand  =
          unaccounted_water_demand / 1000
ENDRULE

RULE 500122
IF        demand_sector == multiple_sectors
THEN      settlement_water_demand  =
          domestic_water_demand +

          commercial_water_demand +

          naccounted_water_demand
ENDRULE

RULE 500130
IF        TRUE
THEN      consumption_unit = household
ENDRULE

RULE 500132
IF        TRUE
THEN      households_number = population_number /
occupancy_rate
ENDRULE

RULE 500133
IF        TRUE
THEN      connections_number        =
          households_number
ENDRULE

RULE 400030
IF        forecasting_method == time_extrapolation
THEN      per_household consumption =
          extrapolated_consumption
ENDRULE

RULE 400032
IF        forecasting_method        ==
          econometric variables
THEN      per_household_consumption =
          econometric_consumption
ENDRULE

RULE 400034
IF        forecasting_method == end_use_variables
THEN      per_household_consumption =
          end_uses_consumption
ENDRULE


RULE 400036
IF        forecasting_method == classified_households
THEN      per household_consumption =
          classified_consumption
ENDRULE

RULE 501540
IF        [ L1                      >        L2
AND       L1                        >        L3
AND       L1                        >        L4 ]
THEN      forecasting_method        =
          classified_consumption
ENDRULE

RULE 501545
IF        [ L2                      >        L1
AND       L2                        >        L3
AND       L2                        >        L4 ]
THEN      forecasting_method        =
          econometric_variables
ENDRULE

RULE 501550
IF        [ L3                      >        L1
AND       L3                        >        L4
AND       L3                        >        L2 ]
THEN      forecasting_method =      end_use_variables
ENDRULE

RULE 501555
IF        [ L4                      >        L1
AND       L4                        >        L3
AND       L4                        >        L2 ]
THEN      forecasting_method =      time_extrapolation
ENDRULE

RULE 501560
IF        TRUE
THEN      L1 =        [ w1 * 0.1  ] +
                      [ w2 * 0.9  ] +
                      [ w3 * 0.1  ] +
                      [ w4 * 0.37 ] +
                      [ w5 * 0.9  ]
ENDRULE

RULE 501562
IF        TRUE
THEN      L2 =        [ w1 * 0.63 ] +
                      [ w2 * 0.37 ] +
                      [ w3 * 0.63 ] +
                      [ w4 * 0.9  ] +
                      [ w5 * 0.37 ]
ENDRULE

RULE 501564
IF        TRUE
THEN      L3 =        [ w1 * 0.9  ] +
                      [ w2 * 0.1  ] +
                      [ w3 * 0.9  ] +
                      [ w4 * 0.63] +
                      [ w5 * 0.1  ]
ENDRULE

RULE 501565
IF        TRUE
THEN      L4 =        [ w1 * 0.63 ] +
                      [ w2 * 0.37 ] +
                      [ w3 * 0.63 ] +
                      [ w4 * 0.9  ] +
                      [ w5 * 0.37 ]
ENDRULE

RULE 501570
IF        method_first_criterion == forecast_accuracy
THEN      w1         =            0.33
ENDRULE

RULE 501571
IF        method_second_criterion     == forecast_accuracy
THEN      w1         =            0.27
ENDRULE

RULE 501572
IF        method_third_criterion      == forecast_accuracy
THEN      w1         =            0.2
ENDRUL

RULE 501573
IF        method_forth_criterion      == forecast_accuracy
THEN      w1         =            0.13
ENDRULE

RULE 501574
IF        method_fifth_criterion      == forecast_accuracy
THEN      w1         =            0.07
ENDRULE

RULE 501575
IF        method_first_criterion      ==
          input_data_requirements
THEN      w2         =            0.33
ENDRULE


RULE 501577
IF        method_second_criterion     ==
          input_data_requirements
THEN      w2         =            0.27
ENDRULE


RULE 501579
```

```
IF      method_third_criterion      ==
        input_data_requirements
THEN    w2          =       0.2
ENDRULE

RULE 501581
IF      method_forth_criterion      ==
        input_data_requirements
THEN    w2          =       0.13
ENDRULE

RULE 501583
IF      method_fifth_criterion      ==
        input_data_requirements
THEN    w2          =       0.07
ENDRULE

RULE 501585
IF      method first_criterion      ==
        conservation_evaluation
THEN    w3          =       0.33
ENDRULE

RULE 501586
IF      method_second criterion     ==
        conservation_evaluation
THEN    w3          =       0.27
ENDRUL

RULE 501587
IF      method third_criterion      ==
        conservation_evaluation
THEN    w3          =       0.2
ENDRULE

RULE 501588
IF      method_forth_criterion      ==
        conservation_evaluation
THEN    w3          =       0.13
ENDRULE

RULE 501589
IF      method_fifth_criterion      ==
        conservation_evaluation
THEN    w3          =       0.07
ENDRULE

RULE 501590
IF      method first_criterion      ==
        consideration_of_economics
THEN    w4          =       0.33
ENDRULE

RULE 501591
IF      method_second_criterion     ==
        consideration_of_economics
THEN    w4          =       0.27
ENDRULE

RULE 501592
IF      method_third_criterion      ==
        consideration_of_economics
THEN    w4          =       0.2
ENDRULE

RULE 501593
IF      method forth criterion      ==
        consideration_of_economics
THEN    w4          =       0.13
ENDRULE

RULE 501594
IF      method fifth_criterion      ==
        consideration_of_economics
THEN    w4          =       0.07
ENDRULE

RULE 501595
IF      method_first_criterion      ==
        ease_of application
THEN    w5          =       0.33
ENDRULE

RULE 501596
IF      method_second criterion     ==
        ease_of_application
THEN    w5          =       0.27
ENDRULE

RULE 501597
IF      method_third_criterion      ==
        ease_of_application
THEN    w5          =       0.2
ENDRULE

RULE 501598
IF      method_forth_criterion      ==      ease_of_application
THEN    w5          =       0.13
ENDRULE

RULE 501599
IF      method_fifth_criterion      ==      ease_of_application
THEN    w5          =       0.07
ENDRULE

RULE 501601
IF      method_first_criterion      =
        input_data_requirements
AND     method_second_criterion     == none
THEN    forecasting_method          = classified_households
ENDRULE

RULE 501603
IF      method_first_criterion      ==
        conservation_evaluation
AND     method_second_criterion     == none
THEN    forecasting_method = end_use_variables
ENDRULE

RULE 501604
IF      method_first_criterion      ==
        consideration_of_economics
AND     method_second_criterion     == none
THEN    forecasting_method          = econometric_variables
ENDRULE

RULE 501605
IF      method_first_criterion      == ease_of_application
AND     method_second_criterion     == none
THEN    forecasting_method          = classified_households
ENDRULE

RULE 501606
IF      method_first_criterion      == forecast_accuracy
AND     method_second_criterion     == none
THEN    forecasting_method          = end_use_variables
ENDRULE

RULE 400100
IF      consumption_unit            == person
THEN    unit_consumption_rate       =
        per_capita_consumption
ENDRULE

RULE 400105
IF      consumption_unit            == household
THEN    unit_consumption_rate       =
        per_household_consumption
ENDRULE

RULE 400110
IF      consumption_unit            == water_connection
THEN    unit_consumption_rate       =
        per_connection_consumption
ENDRULE

RULE 400115
IF      consumption_unit            == person
THEN    customers_number            = population_number
ENDRULE

RULE 400120
IF      consumption_unit            == household
THEN    customers_number            = households_number
ENDRULE

RULE 400125
IF      consumption_unit            == water_connection
THEN    customers_number            =       connections_number
ENDRULE

RULE 400200
IF      TRUE
THEN    per_capita_consumption      =
per_household_consumption /
occupancy_rate
ENDRULE

RULE 400205
IF      TRUE
THEN    per_connection_consumption =
        per_household_consumption
ENDRULE

RULE 500300
IF      TRUE
```

```
THEN        dishwasher_consumption       =
[ dishwasher_capacity              ] *
[[dishwashing_frequency            ] *
[ dishwashers % / 100              ] *
[ 1 + [ dishwasher_leakage_% / 100 ] ]
ENDRULE

RULE 500305
IF          dishwasher_type                 ==
            conventional
THEN        dishwasher_capacity          =
            conventional_dishwasher_capacity
ENDRULE

RULE 500306
IF          dishwasher_type          == efficient
THEN        dishwasher_capacity      =
            efficient_dishwasher_capacity
ENDRULE

RULE 500307
IF          dishwasher_type          == all_types
THEN        dishwasher_capacity      =
[ conventional_dishwasher_capacity *
conventional_dishwashers_% / 100 ] +
[ efficient_dishwasher_capacity  *
 efficient_dishwashers_% / 100     ]
ENDRULE

RULE 500308
IF          TRUE
THEN        conventional_dishwasher_capacity= 40
ENDRULE

RULE 500309
IF          TRUE
THEN        efficient_dishwasher_capacity= 20
ENDRULE

RULE 500310
IF          TRUE
THEN        dishwashing_frequency       = 0.79
ENDRULE

RULE 500316
IF          TRUE
THEN        dishwasher_leakage_%       = 0
ENDRULE

RULE 500317
IF          TRUE
THEN        conventional_dishwashers_% = 12
ENDRULE

RULE 500318
IF          TRUE
THEN        efficient_dishwashers_%     = 88
ENDRULE

RULE 500319
IF          TRUE
THEN        dishwashers_%               =  27
ENDRULE

RULE 500320
IF          TRUE
THEN        washer_consumption         =
[ washer_capacity          ] *
[ washing_frequency        ] *
[ washers % / 100          ] *
1 + [ washer_leakage_% / 100 ] ]
ENDRULE

RULE 500325
IF          washer_type == conventional_washer
THEN        washer_capacity =onventional_washer_capacity
ENDRULE

RULE 500326
IF          washer type == efficient_washer
THEN        washer_capacity = efficient_washer_capacity
ENDRULE

RULE 500327
IF          washer type   == all_types
THEN        washer_capacity =
[ conventional_washer_capacity *
conventional_washers_% / 100 ] +
[ efficient_washer_capacity *
 efficient washers_% / 100      ]
ENDRULE

RULE 500328
IF          TRUE
THEN   conventional_washer_capacity = 95
ENDRULE

RULE 500329
IF          TRUE
THEN   efficient_washer_capacity          = 70
ENDRULE

RULE 500330
IF          TRUE
THEN        washing_frequency =       0.75
ENDRULE

RULE 500336
IF          TRUE
THEN        washer_leakage_%          = 0
ENDRULE

RULE 500337
IF          TRUE
THEN        conventional_washers_%     = 12
ENDRULE

RULE 500338
IF          TRUE
THEN        efficient_washers_% = 88
ENDRULE

RULE 500339
IF          TRUE
THEN        washers_% = 84
ENDRULE

RULE 500350
IF          TRUE
THEN        bathtub_consumption          =
[ bathtub_capacity          ] *
[ bathing_frequency         ] *
[ bathtubs_% / 100          ] *
[ 1 + [ bathtub_leakage_% / 100 ] ]
ENDRULE

RULE 500357
IF          TRUE
THEN        bathtub_capacity            =  108
ENDRULE

RULE 500358
IF          TRUE
THEN        bathing_frequency            = 1.07
ENDRULE

RULE 500359
IF          TRUE
THEN        bathtubs_%                  = 98
ENDRULE

RULE 500360
IF          TRUE
THEN        bathtub_leakage_%            =  0
ENDRULE

RULE 500400
IF          TRUE
THEN        shower_consumption          =
[ shower_flow_rate          ] *
[ showering_time            ] *
[ showering_frequency       ] *
[ showers_% / 100           ] *
[ 1 + [ shower_leakage_% / 100 ] ]
ENDRULE

RULE 500405
IF          shower_type == conventional_shower
THEN        shower_flow_rate = conventional_shower_flow_rate
ENDRULE

RULE 500406
IF          shower_type == power_shower
THEN        shower_flow_rate = power_shower_flow_rate
ENDRULE

RULE 500407
IF          shower_type ==              all_types
THEN        shower_flow_rate  =
[ conventional_shower_flow_rate *
conventional_showers_% / 100  ] +
[ power_shower_flow_rate        *
power_showers_% / 100           ]
ENDRULE

RULE 500408
IF          TRUE
THEN        conventional_shower_flow_rate=            5
```

```
ENDRULE

RULE 500409
IF          TRUE
THEN        power_shower_flow_rate     = 10
ENDRULE

RULE 500415
IF          TRUE
THEN        showering_time             =        5
ENDRULE

RULE 500420
IF          TRUE
THEN        showering_frequency        = 1.07
ENDRULE

RULE 500425
IF          TRUE
THEN        conventional_showers_%     = 52
ENDRULE

RULE 500426
IF          TRUE
THEN        power_showers_%            =48
ENDRULE

RULE 500427
IF          TRUE
THEN        showers_%    = 90
ENDRULE

RULE 500430
IF          TRUE
THEN        shower_leakage_% =        0
ENDRULE

RULE 500460
IF          TRUE
THEN        toilet_consumption =
[ toilet_capacity          ] *
[ flushing_frequency       ] *
[ toilets % / 100          ] *
[ 1 + [ toilet_leakage_% / 100 ] ]
ENDRULE

RULE 500461
IF          toilet_type == conventional_toilet
THEN        toilet_capacity = conventional_toilet_capacity
ENDRULE

RULE 500462
IF          toilet_type == efficient_toilet
THEN        toilet_capacity = efficient_toilet_capacity
ENDRULE

RULE 500463
IF          toilet_type == all_types
THEN        toilet_capacity =
[ conventional_toilet_capacity *
conventional_toilets % / 100 ] +
[ efficient_toilet_capacity     *
efficient_toilets_% / 100       ]
ENDRULE

RULE 500464
IF          TRUE
THEN        conventional_toilet_capacity = 9
ENDRULE

RULE 500465
IF          TRUE
THEN        efficient_toilet_capacity      =7.5
ENDRULE

RULE 500466
IF          TRUE
THEN        flushing_frequency = 13
ENDRULE

RULE 500467
IF          TRUE
THEN        toilet_leakage_% =  0.0
ENDRULE

RULE 500468
IF          TRUE
THEN        conventional_toilets_% =  40
ENDRULE

RULE 500469
IF          TRUE
THEN        efficient_toilets_%  = 60
ENDRULE
```

```
RULE 500470
IF          TRUE
THEN        toilets_% =    100
ENDRULE

RULE 500500
IF          TRUE
THEN        indoor_taps_consumption =
kitchen_consumption +
athroom_consumption
ENDRULE

RULE 500502
IF          TRUE
THEN        kitchen_consumption =
[ kitchen_flow_rate        ] *
[ kitchen_opening_time     ] *
[ kitchen_taps_% / 100     ] *
[ 1 + [ kitchen_leakage_% / 100 ] ]
ENDRULE

RULE 500503
IF          TRUE
THEN        kitchen_flow_rate =         5
ENDRULE

RULE 500504
IF          TRUE
THEN        kitchen_opening_time =      6.5
ENDRULE

RULE 500505
IF          TRUE
THEN        kitchen_taps_% =            100
ENDRULE

RULE 500506
IF          TRUE
THEN        kitchen_leakage_% =         0
ENDRUL

RULE 500510
IF          TRUE
THEN        bathroom_consumption        =
[ bathroom_flow_rate        ] *
[ bathroom_opening_time     ] *
[ bathroom_taps_% / 100     ] *
[ 1 + [ bathroom_leakage_% / 100 ] ]
ENDRULE

RULE 500511
IF          TRUE
THEN        bathroom_flow_rate =        3
ENDRULE

RULE 500512
IF          TRUE
THEN        bathroom_opening_time       = 5
ENDRULE

RULE 500513
IF          TRUE
THEN        bathroom_taps_% =           100
ENDRULE

RULE 500514
IF          TRUE
THEN        bathroom_leakage_% =        0
ENDRULE

RULE 500520
IF          TRUE
THEN        outdoor_taps_consumption =
hosepipe_consumption +
sprinkler_consumption
ENDRULE

RULE 500521
IF          TRUE
THEN        hosepipe_consumption        =
[ hosepipe_flow_rate        ] *
[ hosepipe_opening_time     ] *
[ hosepipe_taps_% / 100     ] *
[ 1 + [ hosepipe_leakage_% / 100 ] ]
ENDRULE

RULE 500522
IF          TRUE
THEN        hosepipe_flow_rate=         3
ENDRULE

RULE 500523
IF          TRUE
```

```
THEN     hosepipe_opening_time     = 7
ENDRULE

RULE 500524
IF       TRUE
THEN     hosepipe_taps_%     = 77
ENDRULE

RULE 500525
IF       TRUE
THEN     hosepipe_leakage_%     = 0
ENDRULE

RULE 500530
IF       TRUE
THEN     sprinkler_consumption     =
[ sprinkler flow_rate     ] *
[ sprinkler_opening_time  ] *
[ sprinkler_taps_% / 100  ] *
[ 1 + [ sprinkler_leakage_% / 100 ] ]
ENDRULE

RULE 500531
IF       TRUE
THEN     sprinkler_flow_rate = 5
ENDRULE

RULE 500532
IF       TRUE
THEN     sprinkler_opening_time     = 10
ENDRULE

RULE 500533
IF       TRUE
THEN     sprinkler_taps_% = 30
ENDRULE

RULE 500534
IF       TRUE
THEN     sprinkler_leakage_% = 0
ENDRULE

RULE 500550
IF       households_class = wealthy_achievers
THEN     classified_consumption = 438.6
ENDRULE

RULE 500551
IF       households_class == affluent_rural_areas
THEN     classified_consumption = 414.12
ENDRULE

RULE 500552
IF       households_class == properous_pensioners
THEN     classified_consumption = 389.64
ENDRULE

RULE 500553
IF       households_class == affluent_excutives
THEN     classified_consumption = 322.32
ENDRULE

RULE 500554
IF       households_class == well_off_workers
THEN     classified_consumption = 371.28
ENDRULE

RULE 500555
IF       households_class == affluent_urbanaties
THEN     classified_consumption = 377.4
ENDRULE

RULE 500556
IF       households_class == prosperous_proffessionals
THEN     classified_consumption = 389.64
ENDRULE

RULE 500557
IF       households_class == better_off_executives
THEN     classified_consumption = 489.6
ENDRULE

RULE 500558
IF       households_class == comfortable_middle_agers
THEN     classified_consumption = 338.64
ENDRULE

RULE 500559
IF       households class == skilled workers
THEN     classified_consumption = 408
ENDRULE

RULE 500560
IF       households_class == new_home_owners
```

```
THEN     classified_consumption = 416.16
ENDRULE

RULE 500561
IF       households_class == white_collar_workers
THEN     classified_consumption = 397.80
ENDRULE

RULE 500562
IF       households_class == older_people
THEN     classified_consumption = 344.76
ENDRULE

RULE 500563
IF       households_class == council_better_off
THEN     classified_consumption = 316.2
ENDRULE

RULE 500564
IF       households_class == council_high_unmployment
THEN     classified_consumption = 240.72
ENDRULE

RULE 500565
IF       households_class == council_greatest_hardship
THEN     classified_consumption = 240.72
ENDRULE

RULE 500566
IF       households_class == multi_ethnic_low_income
THEN     classified_consumption = 318.24
ENDRULE

RULE 500567
IF       households_class == multiple_classes
THEN     classified_consumption     =
[ wealthy_achievers_consumption *wealthy_achievers_% / 100 ] +
[ affluent_rural_consumption *affluent_rural_% / 100 ] +
[ properous_pensioners_consumption * properous_pensioners_% / 100 ] +
[ affluent_excutives_consumption *affluent_excutives_% / 100 ] +
[ well_off_workers_consumption *well_off_workers_% / 100 ] +
[ affluent_urbanaties_consumption *affluent_urbanaties_% / 100 ] +
[ prosperous_proffessionals_consumption *prosperous_proffessionals_% / 100 ] +
[ better_off_executives_consumption *better_off_executives_% / 100 ] +
[ comfortable_middle_agers_consumption *comfortable_middle_agers_% / 100 ] +
[ skilled_workers_consumption *skilled_workers_% / 100 ] +
[ new_home_owners_consumption *new_home_owners_% / 100 ] +
[ white_collar_workers_consumption *white_collar_workers_% / 100 ] +
[ older_people_consumption *older_people_% / 100 ] +
[ council_better_off_consumption *council_better_off_% / 100 ] +
[ council_greatest_hardship_consumption *council_greatest_hardship_% / 100 ] +
[ multi_ethnic_low_income_consumption *multi_ethnic_low_income_% / 100 ]
ENDRULE

RULE 506000
IF       TRUE
THEN     wealthy_achievers_% = 19.4
ENDRULE

RULE 506019
IF       TRUE
THEN     affluent_rural_%     = 4.9
ENDRULE

RULE 506001
IF       TRUE
THEN     properous_pensioners_%     = 2.8
ENDRULE

RULE 506002
IF       TRUE
THEN     affluent_excutives_% = 13.1
ENDRULE

RULE 506003
IF       TRUE
THEN     well_off_workers_% =     10.8
ENDRULE

RULE 506004
IF       TRUE
THEN     affluent_urbanaties_% =     1.8
ENDRUL

RULE 506005
IF       TRUE
THEN     prosperous_proffessionals_% = 0.4
ENDRULE

RULE 506006
IF       TRUE
THEN     better_off_executives_%     = 0.3
ENDRULE
```

```
RULE 506007
IF          TRUE
THEN        comfortable_middle_agers_% = 15.8
ENDRULE

RULE 506008
IF          TRUE
THEN        skilled_workers_%  = 8.7
ENDRULE

RULE 506009
IF          TRUE
THEN        new_home_owners_%  = 5.5
ENDRULE

RULE 506010
IF          TRUE
THEN        white_collar_workers_% = 2.3
ENDRULE

RULE 506011
IF          TRUE
THEN        older_people_% = 2.6
ENDRULE

RULE 506012
IF          TRUE
THEN        council_better_off_%  = 10
ENDRULE

RULE 506013
IF          TRUE
THEN        council_high_unmployment_% = 0.4
ENDRULE

RULE 506014
IF          TRUE
THEN        council_greatest_hardship_% = 1.0
ENDRULE

RULE 506015
IF          TRUE
THEN        multi_ethnic_low_income_% = 0.6
ENDRULE

RULE 506020
IF          TRUE
THEN        wealthy_achievers_consumption = 438.6
ENDRULE

RULE 506045
IF          TRUE
THEN        affluent_rural_consumption = 414.12
ENDRULE

RULE 506021
IF          TRUE
THEN        properous_pensioners_consumption = 389.64
ENDRULE

RULE 506022
IF          TRUE
THEN        affluent_excutives_consumption = 322.32
ENDRULE

RULE 506023
IF          TRUE
THEN        well_off_workers_consumption = 371.28
ENDRULE

RULE 506024
IF          TRUE
THEN        affluent_urbanaties_consumption = 377.4
ENDRULE

RULE 506025
IF          TRUE
THEN        prosperous_proffessionals_consumption  = 389.64
ENDRULE

RULE 506026
IF          TRUE
THEN        better_off_executives_consumption  = 489.6
ENDRULE

RULE 506027
IF          TRUE
THEN        comfortable_middle_agers_consumption = 338.64
ENDRULE

RULE 506028
IF          TRUE
THEN        skilled_workers_consumption = 408
ENDRULE

RULE 506029
IF          TRUE
THEN        new_home_owners_consumption  = 416.16
ENDRULE

RULE 506030
IF          TRUE
THEN        white_collar_workers_consumption  = 397.8
ENDRULE

RULE 506031
IF          TRUE
THEN        older_people_consumption    = 344.76
ENDRULE

RULE 506032
IF          TRUE
THEN        council_better_off_consumption = 316.2
ENDRULE

RULE 506033
IF          TRUE
THEN        council_high_unmployment_consumption  = 240.72
ENDRULE

RULE 506034
IF          TRUE
THEN        council_greatest_hardship_consumption  = 240.72
ENDRULE

RULE 506035
IF          TRUE
THEN        multi_ethnic_low_income_consumption = 318.24
ENDRULE

RULE 500570
IF          social_class == proffessional
THEN        household_income = very_high
ENDRULE

RULE 500571
IF          social_class == managerial
THEN        household_income = very_high
ENDRULE

RULE 500572
IF          social_class == skilled_non_manual
THEN        household_income = high
ENDRULE

RULE 500573
IF          social_class == skilled_manual
THEN        household_income = moderate
ENDRULE

RULE 500574
IF          social_class == semi_skilled
THEN        household_income = low
ENDRULE

RULE 500575
IF          social_class == unskilled
THEN        household_income = low
ENDRULE

RULE 500576
IF          social_class == govt_training_scheme
THEN        household_income = moderate
ENDRULE

RULE 500577
IF          social_class == armed_forces
THEN        household_income = moderate
ENDRULE

RULE 500578
IF          social_class == unstated
THEN        household_income = moderate
ENDRULE

RULE 500579
IF          social_class == multiple_classes
THEN        household_income = moderate
ENDRULE

RULE 500580
IF          TRUE
THEN        social_class =  skilled_non_manual
ENDRULE

RULE 500581
IF          TRUE
THEN        adults_number = 2
```

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ENDRULE

RULE 500582
IF          TRUE
THEN        children_number = 1
ENDRULE

RULE 500583
IF          TRUE
THEN        annual_rainfall = 700
ENDRULE

RULE 500584
IF          TRUE
THEN        avg_max_daily_temperature = 25
ENDRULE

RULE 500585
IF          TRUE
THEN        water_price = 0.5
ENDRULE

RULE 500600
IF          proposed_conservation_measure ==
multiple_measures
AND         second_proposed_measure == none
THEN        second_measure_effectiveness= 0
ENDRULE

RULE 500602
IF          proposed_conservation_measure = multiple_measures
AND         [ second_proposed_measure == none
OR          third_proposed_measure == none ]
THEN        third_measure_effectiveness = 0
ENDRULE

RULE 500604
IF          proposed_conservation_measure == multiple_measures
AND         [ second_proposed_measure == none
OR          third_proposed_measure == none
OR          forth_proposed_measure == none ]
THEN        forth_measure_effectiveness = 0
ENDRULE

RULE 500606
IF          proposed_conservation_measure == multiple_measures
AND         [ second_proposed_measure == none
OR          third_proposed_measure == none
OR          forth_proposed_measure == none
OR          fifth_proposed_measure == none ]
THEN        fifth_measure_effectiveness = 0
ENDRULE

RULE 500610
IF          interaction_factor_sp1 == 0
THEN        first_measure_effectiveness = 0
ENDRULE

RULE 500612
IF          interaction_factor sp2 == 0
THEN        second_measure_effectiveness = 0
ENDRULE

RULE 500614
IF          interaction_factor_sp3 == 0
THEN        third_measure_effectiveness = 0
ENDRULE

RULE 500616
IF          interaction factor_sp4 == 0
THEN        forth_measure_effectiveness = 0
ENDRULE

RULE 500618
IF          interaction_factor sp5 == 0
THEN        fifth_measure_effectiveness = 0
ENDRULE

RULE 500674
IF          first_proposed_measure == metering
THEN        first_measure_effectiveness =
            interaction_factor_sp1 *
            [ metering_reduction_% / 100 ] *
            [ metering_coverage_% / 100 ] * 100
ENDRULE

RULE 500676
IF          second_proposed_measure == metering
THEN        second_measure_effectiveness =
            interaction_factor sp2 *
            [ metering_reduction_% / 100 ] *
            [ metering_coverage_% / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 500678
IF          third_proposed_measure == metering
THEN        third_measure_effectiveness =
            interaction_factor_sp3 *
            [ metering_reduction_% / 100 ] *
            [ metering_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 500680
IF          forth_proposed_measure == metering
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ metering_reduction_% / 100 ] *
            [ metering_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 500682
IF          fifth_proposed_measure== metering
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ metering_reduction_% / 100 ] *
            [ metering_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 500694
IF          first_proposed_measure == leakage_control
THEN        first_measure_effectiveness =            interaction_factor_sp1
*
            [ leakage_reduction_% / 100 ] *
            [ leakage_coverage_% / 100 ] *
            100
ENDRULE

RULE 500696
IF          second_proposed_measure == eakage_control
THEN        second_measure_effectiveness              =
            interaction_factor_sp2 *
            [ leakage_reduction_% / 100 ] *
            [ leakage_coverage_% / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 500698
IF          third_proposed_measure == leakage_control
THEN        third_measure_effectiveness =            interaction_factor_sp3
*
            [ leakage_reduction_% / 100 ] *
            [ leakage_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 500700
IF          forth_proposed_measure == leakage_control
THEN        forth_measure_effectiveness =            interaction_factor_sp4
*
            [ leakage_reduction_% / 100 ] *
            [ leakage_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 500702
IF          fifth_proposed_measure == leakage_control
THEN        fifth_measure_effectiveness =            interaction_factor_sp5
*
            leakage_reduction_% / 100 ] *
            [ leakage_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 500712
IF          first_proposed_measure == pricing_policy
THEN        first_measure_effectiveness =            interaction_factor_sp1
*
            [ pricing_reduction_% / 100 ] *
            [ pricing_coverage_% / 100 ] *
            100
ENDRULE

RULE 500714
IF          second_proposed_measure == pricing_policy
THEN        second_measure_effectiveness =           interaction_factor_sp2
*
            [ pricing_reduction_% / 100 ] *
            [ pricing_coverage_% / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 500716
IF          third_proposed_measure == pricing_policy
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```
THEN      third_measure_effectiveness =
          interaction_factor_sp3 *
          [ pricing_reduction_% / 100 ] *
          [ pricing_coverage_% / 100 ] *
          100 * interaction_factor_3
ENDRULE

RULE 500718
IF        forth_proposed_measure == pricing_policy
THEN      forth_measure_effectiveness =
          interaction_factor_sp4 *
          [ pricing_reduction_% / 100 ] *
          [ pricing_coverage_% / 100 ] *
          100 * interaction_factor_4
ENDRULE

RULE 500720
IF        fifth_proposed_measure == pricing_policy
THEN      fifth_measure_effectiveness =
          interaction_factor sp5 *
          [ pricing_reduction_% / 100 ] *
          [ pricing_coverage % / 100 ] *
          100 * interaction_factor_5
ENDRULE

RULE 500730
IF        first_proposed_measure ==
          education_programmes
THEN      first_measure_effectiveness =
          interaction_factor_sp1 *
          [ education_reduction_% / 100 ] *
          [ education_coverage % / 100 ] *
          100
ENDRULE

RULE 500732
IF        second_proposed_measure ==
          education_programmes
THEN      second_measure_effectiveness =
          interaction_factor_sp2 *
          [ education_reduction % / 100 ] *
          [ education coverage_% / 100 ] *
          100 * interaction_factor_2
ENDRULE

RULE 500734
IF        third_proposed_measure == education_programmes
THEN      third_measure_effectiveness =
          interaction_factor_sp3 *
          [ education_reduction_% / 100 ] *
          education_coverage_% / 100 ] *
          100 * interaction_factor_3
ENDRULE

RULE 500736
IF        forth_proposed_measure == education_programmes
THEN      forth_measure_effectiveness =
          interaction_factor_sp4 *
          [ education_reduction_% / 100 ] *
          [ education_coverage % / 100 ] *
          100 * interaction_factor_4
ENDRULE

RULE 500738
IF        fifth_proposed_measure == education_programmes
THEN      fifth_measure effectiveness =
          interaction_factor sp5 *
          [ education_reduction_% / 100 ] *
          education_coverage_% / 100 ] *
          100 * interaction_factor_5
ENDRULE

RULE 500748
IF        first_proposed_measure == water_rationing
THEN      first_measure effectiveness =
          interaction_factor sp1 *
          [ rationing_reduction_% / 100 ] *
          [ rationing_coverage_% / 100 ] *
          100
ENDRULE

RULE 500750
IF        second_proposed_measure == water_rationing
THEN      second_measure_effectiveness =
          interaction_factor sp2 *
          [ rationing_reduction_% / 100 ] *
          [ rationing_coverage_% / 100 ] *
          100 * interaction_factor 2
ENDRULE

RULE 500752
IF        third_proposed_measure == water_rationing
THEN      third measure_effectiveness =
          interaction factor sp3 *
          [ rationing_reduction_% / 100 ] *
          [ rationing_coverage_% / 100 ] *
          100 * interaction_factor_3
ENDRULE

RULE 500754
IF        forth_proposed_measure == water_rationing
THEN      forth_measure_effectiveness =
          interaction_factor_sp4 *
          [ rationing_reduction_% / 100 ]
          [ rationing_coverage_% / 100 ] *
          100 * interaction_factor_4
ENDRULE

RULE 500756
IF        fifth_proposed_measure == water_rationing
THEN      fifth_measure_effectiveness =
          interaction_factor_sp5 *
          [ rationing_reduction_% / 100 ] *
          [ rationing_coverage_% / 100 ] *
          100 * interaction_factor_5
ENDRULE

RULE 500766
IF        first_proposed_measure == pressure_reduction
THEN      first_measure_effectiveness =
          interaction_factor_sp1 *
          [ pressure_reduction_% / 100 ] *
          pressure_coverage_% / 100 ] * 100
ENDRULE

RULE 500768
IF        second_proposed_measure == pressure_reduction
THEN      second_measure_effectiveness =
          interaction_factor_sp2 *
          [ pressure_reduction_% / 100 ] *
          [ pressure_coverage_% / 100 ] *
          100 * interaction_factor_2
ENDRULE

RULE 500770
IF        third_proposed_measure == pressure_reduction
THEN      third_measure_effectiveness =
          interaction_factor_sp3 *
          [ pressure_reduction_% / 100 ] *
          [ pressure_coverage_% / 100 ] *
          100 * interaction_factor_3
ENDRULE

RULE 500772
IF        forth_proposed_measure == pressure_reduction
THEN      forth_measure_effectiveness =
          interaction_factor_sp4 *
          [ pressure_reduction_% / 100 ] *
          [ pressure_coverage_% / 100 ] *
          100 * interaction_factor_4
ENDRULE

RULE 500774
IF        fifth_proposed_measure == pressure_reduction
THEN      fifth_measure_effectiveness =
          interaction_factor_sp5 *
          [ pressure_reduction_% / 100 ] *
          [ pressure_coverage_% / 100 ] *
          100 * interaction_factor_5
ENDRULE

RULE 500784
IF        first_proposed_measure == plumbing_codes
THEN      first_measure_effectiveness =
          interaction_factor_sp1 *
          [ plumbing_reduction_% / 100 ] *
          [ plumbing_coverage_% / 100 ] *
          100
ENDRULE

RULE 500786
IF        second_proposed_measure == plumbing_codes
THEN      second_measure_effectiveness =
          interaction_factor_sp2 *
          [ plumbing_reduction_% / 100 ] *
          [ plumbing_coverage_% / 100 ] *
          100 * interaction_factor_2
ENDRULE

RULE 500788
IF        third_proposed_measure == plumbing_codes
THEN      third_measure_effectiveness =
          interaction_factor_sp3 *
          [ plumbing_reduction_% / 100 ] *
          [ plumbing_coverage_% / 100 ] *
          100 * interaction_factor_3
ENDRULE
```

```
RULE 500790
IF          forth_proposed_measure ==  plumbing_codes
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ plumbing_reduction_% / 100 ] *
            [ plumbing_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 500792
IF          fifth_proposed_measure ==  plumbing_codes
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ plumbing_reduction_% / 100 ] *
            [ plumbing_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 500802
IF          first_proposed_measure == water_use_restrictions
THEN        first_measure_effectiveness = i
            nteraction_factor_sp1 *
            [ restrictions_reduction_% / 100 ] *
            [ restrictions_coverage_% / 100 ] *
            100
ENDRULE


RULE 500804
IF          second_proposed_measure == water_use_restrictions
THEN        second_measure_effectiveness=
            interaction_factor_sp2 *
            [ restrictions_reduction_% / 100 ] *
            [ restrictions_coverage_% / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 500806
IF          third_proposed_measure ==  water_use_restrictions
THEN        third_measure effectiveness =
            interaction_factor_sp3 *
            [ restrictions_reduction_% / 100 ] *
            [ restrictions coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 500808
IF          forth_proposed_measure ==  water_use_restrictions
THEN        forth_measure_effectiveness =
            interaction_factor sp4 *
            [ restrictions_reduction_% / 100 ] *
            [ restrictions coverage % / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 500810
IF          fifth_proposed_measure ==  water_use_restrictions
THEN        fifth_measure_effectiveness =
            interaction_factor sp5 *
            [ restrictions_reduction_% / 100 ] *
            [ restrictions_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 501682
IF          proposed_conservation_measure ==
conservation_devices
AND         water_use_device == tap
AND         tap fixture == bathtub
AND         bathtub_reduction_% == 0
THEN        conservation_effectiveness   = 0
ENDRULE

RULE 501684
IF          proposed_conservation_measure ==
conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          bathroom
AND         bathroom_reduction_% ==     0
THEN        conservation_effectiveness  = 0
ENDRULE

RULE 501686
IF          proposed_conservation_measure ==
            conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          kitchen
AND         kitchen_reduction_% ==      0
THEN        conservation_effectiveness  = 0
ENDRULE


RULE 501688
```

```
IF          proposed_conservation_measure == conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          hosepipe
AND         hosepipe_reduction_%        ==          0
THEN        conservation_effectiveness  =           0
ENDRULE

RULE 501690
IF          proposed_conservation_measure == conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture                 ==          sprinkler
AND         sprinkler_reduction_%       ==          0
THEN        conservation_effectiveness  =           0
ENDRULE

RULE 501700
IF          proposed_conservation_measure == conservation_devices
AND         water_use_device==          tap
AND         tap_fixture                 ==          bathtub
THEN        conservation_effectiveness  =
            interaction_factor_p *
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 501702
IF          proposed_conservation_measure ==          conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          bathroom
THEN        conservation_effectiveness   =            interaction_factor_p *
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 501704
IF          proposed_conservation_measure ==          conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          kitchen
THEN        conservation_effectiveness   =            interaction_factor_p *

            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 501706
IF          proposed_conservation_measure ==          conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          hosepipe
THEN        conservation_effectiveness   =            interaction_factor_p *

            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 501708
IF          proposed_conservation_measure ==          conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          sprinkler
THEN        conservation_effectiveness   =            interaction_factor_p *

            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] * 100
ENDRULE

RULE 501710
IF          proposed_conservation_measure ==          conservation_devices
AND         water_use_device == ap
AND         tap_fixture     == multiple_fixtures
THEN        conservation_effectiveness   =            interaction_factor_p *
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third_tap_effectiveness +
            forth_tap_effectiveness +
            fifth_tap_effectiveness ]
ENDRULE

RULE 501722
IF          first_tap_fixture == bathtub
THEN        first_tap_effectiveness =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE
```

```
RULE 501724
IF          second_tap_fixture == bathtub
THEN        second_tap_effectiveness =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 501726
IF          third_tap_fixture == bathtub
THEN        third_tap_effectiveness =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 501728
IF          forth_tap_fixture == bathtub
THEN        forth_tap_effectiveness =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 501730
IF          fifth_tap_fixture == bathtub
THEN        fifth tap_effectiveness =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 501731
IF          first_tap fixture == bathroom
THEN        first_tap_effectiveness =
            [ bathroom_reduction % / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 501732
IF          second_tap_fixture == bathroom
THEN        second_tap_effectiveness =
            [ bathroom_reduction % / 100 ] *
            [ bathroom_relative % / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 501734
IF          third tap fixtur == bathroom
THEN        third tap effectiveness =
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 501736
IF          forth_tap_fixture == bathroom
THEN        forth_tap_effectiveness =
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative % / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 501738
IF          fifth tap fixture == bathroom
THEN        fifth_tap_effectiveness =
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 501740
IF          first_tap_fixture == kitchen
THEN        first_tap effectiveness =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 501742
IF          second_tap_fixture == kitchen
THEN        second_tap_effectiveness =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 501744
IF          third_tap_fixtur == kitchen
THEN        third_tap_effectiveness =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 501746
IF          forth_tap_fixtur == kitchen
THEN        forth_tap_effectiveness =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 501748
IF          fifth_tap_fixture == kitchen
THEN        fifth_tap_effectiveness =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 501750
IF          first_tap_fixture == hosepipe
THEN        first_tap_effectiveness =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 501752
IF          second_tap_fixtur == hosepipe
THEN        second_tap_effectiveness =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 501754
IF          third_tap_fixture == hosepipe
THEN        third_tap_effectiveness =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 501756
IF          forth_tap_fixture == hosepipe
THEN        forth_tap_effectiveness =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 501758
IF          fifth_tap_fixture == hosepipe
THEN        fifth_tap_effectiveness =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 501760
IF          first_tap_fixture == sprinkler
THEN        first_tap_effectiveness =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100
ENDRULE

RULE 501762
IF          second_tap_fixture == sprinkler
THEN        second_tap_effectiveness =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100
ENDRULE
```

```
RULE 501764
IF          third_tap_fixture ==          sprinkler
THEN        third_tap_effectiveness   =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_%  / 100 ] *
            [ sprinkler_coverage_%  / 100 ] *
            100
ENDRULE

RULE 501766
IF          forth_tap_fixture == sprinkler
THEN        forth_tap_effectiveness   =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_%  / 100 ] *
            [ sprinkler_coverage_%  / 100 ] *
            100
ENDRULE

RULE 501768
IF          fifth_tap_fixture == sprinkler
THEN        fifth_tap effectiveness   =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_%  / 100 ] *
            [ sprinkler_coverage_%  / 100 ] *
            100
ENDRULE

RULE 501780
IF          second_tap_fixture ==         none
THEN        second_tap_effectiveness      = 0
ENDRULE

RULE 501781
IF          second_tap fixture ==         none
OR    third_tap fixture       ==          none
THEN        third_tap_effectiveness =     0
ENDRULE

RULE 501782
IF          second_tap_fixture ==         none
OR    third_tap fixture == none
OR    forth_tap fixture == none
THEN        forth_tap_effectiveness =     0
ENDRULE

RULE 501783
IF          second_tap fixture ==         none
OR    third_tap_fixture == none
OR    forth_tap_fixture == none
OR    fifth_tap_fixture == none
THEN        fifth_tap_effectiveness =     0
ENDRULE

RULE 501800
IF          water use device ==           multiple_devices
AND         second_water_use_device == none
THEN        second_device_effectiveness =               0
ENDRULE

RULE 501801
IF          water_use_device==            multiple_devices
AND         [ second_water_use_device  ==               none
OR          third_water_use_device     ==               none ]
THEN        third_device_effectiveness    =             0
ENDRULE

RULE 501802
IF          water_use_device==            multiple_devices
AND         [ second_water_use_device  ==               none
OR          third_water_use_device     ==               none
OR          forth_water_use_device     ==               none ]
THEN        forth_device_effectiveness    =             0
ENDRULE


RULE 501803
IF          water_use_device==            multiple_devices
AND         [ second_water use_device  ==               none
OR          third_water_use_device     ==               none
OR          forth_water_use_device     ==               none
OR          fifth_water_use_device     ==               none ]
THEN        fifth_device_effectiveness    =             0
ENDRULE

RULE 501810
IF          first_water_use device        == toilet
THEN        first_device_effectiveness    =
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100  ] *
            [ toilet_coverage_% / 100  ] *
            100
ENDRULE
```

```
RULE 501811
IF          second_water_use_device == toilet
THEN        second_device_effectiveness =
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100  ] *
            [ toilet_coverage_% / 100  ] *
            100
ENDRULE

RULE 501812
IF          third_water_use_device ==    toilet
THEN        third_device_effectiveness      =
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100  ] *
            [ toilet_coverage_% / 100  ] * 100
ENDRULE

RULE 501813
IF          forth_water_use_device ==    toilet
THEN        forth_device_effectiveness      =
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100  ] *
            [ toilet_coverage_% / 100  ] *
            100
ENDRULE

RULE 501814
IF          fifth_water_use_device ==    toilet
THEN        fifth_device_effectiveness      =
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100  ] *
            [ toilet_coverage_% / 100  ] *
            100

ENDRULE

RULE 501815
IF          first_water_use_device ==    shower
THEN        first_device_effectiveness      =
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100  ] *
            [ shower_coverage_% / 100  ] * 100
ENDRULE

RULE 501816
IF          second_water_use_device       == shower
THEN        second_device_effectiveness =
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100  ] *
            [ shower_coverage_% / 100  ] *
            100
ENDRULE

RULE 501817
IF          third_water_use_device ==    shower
THEN        third_device_effectiveness      =
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100  ] *
            [ shower_coverage_% / 100  ] *
            100
ENDRULE

RULE 501818
IF          forth_water_use_device ==    shower
THEN        forth_device_effectiveness      =
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100  ] *
            [ shower_coverage_% / 100  ] *
            100
ENDRULE

RULE 501819
IF          fifth_water_use_device ==    shower
THEN        fifth_device_effectiveness      =
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100  ] *
            [ shower_coverage_% / 100  ] *
            100
ENDRULE

RULE 501825
IF          first_water_use_device ==    dishwasher
THEN        first_device_effectiveness      =
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_%  / 100 ] *
            [ dishwasher_coverage_% / 100  ] *
            100
ENDRULE

RULE 501826
IF          second_water_use_device == dishwasher
THEN        second_device_effectiveness =
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_%  / 100 ] *
```

```
                [ dishwasher_coverage_% / 100 ] *
                100
ENDRULE

RULE 501827
IF              third_water_use_device ==   dishwasher
THEN            third_device_effectiveness   =
                [ dishwasher_reduction_% / 100 ] *
                [ dishwasher_relative_%  / 100 ] *
                [ dishwasher_coverage_% / 100 ] *
                100
ENDRULE

RULE 501828
IF              forth_water_use_device ==   dishwasher
THEN            forth_device_effectiveness   =
                [ dishwasher_reduction_% / 100 ] *
                [ dishwasher relative_%  / 100 ] *
                [ dishwasher_coverage_% / 100 ] *
                100
ENDRULE

RULE 501829
IF              fifth water_use_device ==   dishwasher
THEN            fifth device_effectiveness   =
                [ dishwasher reduction_% / 100 ] *
                [ dishwasher_relative_%  / 100 ] *
                [ dishwasher_coverage_% / 100 ] *
                100
ENDRULE

RULE 501830
IF              first_water_use device       == clothes_washer
THEN            first_device_effectiveness   =
                [ washer_reduction_% / 100 ] *
                [ washer_relative_%  / 100 ] *
                [ washer_coverage_% / 100 ] *
                100
ENDRULE

RULE 501831
IF              second_water_use_device == clothes_washer
THEN            second_device_effectiveness =
                [ washer_reduction_% / 100 ] *
                [ washer_relative_%  / 100 ] *
                [ washer_coverage_% / 100 ] *
                100
ENDRULE

RULE 501832
IF              third_water_use_device ==   clothes_washer
THEN            third_device_effectiveness   =
                [ washer_reduction_% / 100 ] *
                [ washer_relative_%  / 100 ] *
                [ washer_coverage_% / 100 ] *
                100
ENDRULE

RULE 501833
IF              forth_water use_device ==   clothes_washer
THEN            forth_device_effectiveness   =
                [ washer_reduction_% / 100 ] *
                [ washer_relative_%  / 100 ] *
                [ washer_coverage_% / 100 ] *
                100
ENDRULE

RULE 501834
IF              fifth_water_use_device ==   clothes_washer
THEN            fifth device effectiveness   =
                [ washer_reduction_% / 100 ] *
                [ washer_relative_%  / 100 ] *
                [ washer_coverage_% / 100 ] *
                100
ENDRULE

RULE 502900
IF              first_water_use_device ==   tap
AND             tap_fixture      ==         bathtub
THEN            first_device_effectiveness   =
                [ bathtub_reduction_% / 100 ] *
                [ bathtub_relative_%  / 100 ] *
                [ bathtub_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502902
IF              first_water_use_device ==   tap
AND             tap fixture == bathroom
THEN            first_device_effectiveness   =
                [ bathroom_reduction_% / 100 ] *
                [ bathroom_relative_%  / 100 ] *
                [ bathroom_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502904
IF              first_water_use_device ==   tap
AND             tap_fixture == kitchen
THEN            first_device_effectiveness   =
                [ kitchen_reduction_% / 100 ] *
                [ kitchen_relative_%  / 100 ] *
                [ kitchen_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502906
IF              first_water_use_device == tap
AND             tap_fixture      ==hosepipe
THEN            first_device_effectiveness   =
                [ hosepipe_reduction_% / 100 ] *
                [ hosepipe_relative_%  / 100 ] *
                [ hosepipe_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502908
IF              first_water_use_device ==   tap
AND             tap_fixture      ==         sprinkler
THEN            first_device_effectiveness   =
                [ sprinkler_reduction_% / 100 ] *
                [ sprinkler_relative_%  / 100 ] *
                [ sprinkler_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502909
IF              first_water_use_device ==   tap
AND             tap_fixture      ==         multiple_fixtures
THEN            first_device_effectiveness   =
                [ first_tap_effectiveness +
                second_tap_effectiveness +
                third_tap_effectiveness +
                forth_tap_effectiveness +
                fifth_tap_effectiveness ]
ENDRULE

RULE 502910
IF              second_water_use_device     == tap
AND             tap_fixture                 == bathtub
THEN            second_device_effectiveness =
                [ bathtub_reduction_% / 100 ] *
                [ bathtub_relative_%  / 100 ] *
                [ bathtub_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502912
IF              second_water_use_device     ==t tap
AND             tap_fixture      ==         bathroom
THEN            second_device_effectiveness =
                [ bathroom_reduction_% / 100 ] *
                [ bathroom_relative_%  / 100 ] *
                [ bathroom_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502914
IF              second_water_use_device     == tap
AND             tap_fixture      ==         kitchen
THEN            second_device_effectiveness =
                [ kitchen_reduction_% / 100 ] *
                [ kitchen_relative_%  / 100 ] *
                [ kitchen_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502916
IF              second_water_use_device     == tap
AND             tap_fixture      ==         hosepipe
THEN            second_device_effectiveness =
                [ hosepipe_reduction_% / 100 ] *
                [ hosepipe_relative_%  / 100 ] *
                [ hosepipe_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502918
IF              second_water_use_device     == tap
AND             tap_fixture      == sprinkler
THEN            second_device_effectiveness =
                [ sprinkler_reduction_% / 100 ] *
                [ sprinkler_relative_%  / 100 ] *
                [ sprinkler_coverage_%  / 100 ] *
                100
ENDRULE

RULE 502919
```

```
IF          second_water_use_device     == tap
AND         tap_fixture     ==          multiple_fixtures
THEN        second_device_effectiveness =
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third_tap_effectiveness +
            forth_tap_effectiveness +
            fifth_tap_effectiveness ]
ENDRULE

RULE 502920
IF          third_water_use_device ==   tap
AND         tap_fixture     ==          bathtub
THEN        third device_effectiveness    =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 502922
IF          third_water_use_device ==   tap
AND         tap_fixture == bathroom
THEN        third_device_effectiveness    =
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 502924
IF          third_water_use_device ==   tap
AND         tap_fixture == kitchen
THEN        third device_effectiveness    =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 502926
IF          third water use device ==   tap
AND         tap fixture == hosepipe
THEN        third device_effectiveness    =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative % / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 502928
IF          third water_use device ==   tap
AND         tap_fixture     ==          sprinkler
THEN        third_device_effectiveness    =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100
ENDRULE

RULE 502929
IF          third_water_use_device      == tap
AND         tap fixture     ==          multiple_fixtures
THEN        third_device_effectiveness    =
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third_tap effectiveness +
            forth_tap_effectiveness +
            fifth tap_effectiveness ]
ENDRULE

RULE 502930
IF          forth_water_use device ==   tap
AND         tap fixture == bathtub
THEN        forth_device_effectiveness    =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 502932
IF          forth_water_use_device      == tap
AND         tap_fixture                 == bathroom
THEN        forth_device_effectiveness    =
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 502934
IF          forth_water_use_device ==   tap
AND         tap fixture == kitchen
THEN        forth_device_effectiveness    =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 502936
IF          forth_water_use_device ==   tap
AND         tap_fixture == hosepipe
THEN        forth_device_effectiveness    =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 502938
IF          forth_water_use_device ==   tap
AND         tap_fixture == sprinkler
THEN        forth_device_effectiveness    =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100
ENDRULE

RULE 502939
IF          forth_water_use_device == tap
AND         tap_fixture     == multiple_fixtures
THEN        forth_device_effectiveness    =
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third_tap_effectiveness +
            forth_tap_effectiveness +
            fifth_tap_effectiveness ]
ENDRULE

RULE 502940
IF          fifth_water_use_device ==tap
AND         tap_fixture     ==          bathtub
THEN        fifth_device_effectiveness    =
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100
ENDRULE

RULE 502942
IF          fifth_water_use_device == tap
AND         tap_fixture     ==          bathroom
THEN        fifth_device_effectiveness    =
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100
ENDRULE

RULE 502944
IF          fifth_water_use_device == tap
AND         tap_fixture     == kitchen
THEN        fifth_device_effectiveness    =
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100
ENDRULE

RULE 502946
IF          fifth_water_use_device ==   tap
AND         tap_fixture     ==          hosepipe
THEN        fifth_device_effectiveness    =
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100
ENDRULE

RULE 502948
IF          fifth_water_use_device == tap
AND         tap_fixture     ==          sprinkler
THEN        fifth_device_effectiveness    =
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100
ENDRULE

RULE 502949
IF          fifth_water_use_device ==   tap
AND         tap_fixture     ==          multiple_fixtures
THEN        fifth_device_effectiveness    =
            [ first_tap_effectiveness +
            second_tap_effectiveness +
```

```
        third_tap_effectiveness +
        forth_tap_effectiveness +
        fifth_tap_effectiveness ]
ENDRULE

RULE 503700
IF      first_proposed_measure ==  conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         bathtub
THEN    first_measure_effectiveness =
        interaction_factor_sp1 *
        [ bathtub_reduction_% / 100 ] *
        [ bathtub_relative_% / 100 ] *
        [ bathtub_coverage_% / 100 ] *
        100
ENDRULE

RULE 503702
IF      first_proposed_measure ==  conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         bathroom
THEN    first_measure_effectiveness =
        interaction_factor_sp1 *
        [ bathroom_reduction_% / 100 ] *
        [ bathroom_relative_% / 100 ] *
        [ bathroom_coverage_% / 100 ] *
        100
ENDRULE

RULE 503704
IF      first_proposed_measure ==  conservation_devices
AND     water use_device ==        tap
AND     tap_fixture     ==         kitchen
THEN    first_measure_effectiveness =
        interaction_factor sp1 *
        [ kitchen_reduction_% / 100 ] *
        [ kitchen_relative_% / 100 ] *
        [ kitchen_coverage_% / 100 ] *
        100
ENDRULE

RULE 503706
IF      first_proposed_measure     ==
        conservation_devices
AND     water use device ==        tap
AND     tap_fixture     ==         hosepipe
THEN    first_measure effectiveness =
        interaction_factor_sp1 *
        [ hosepipe_reduction_% / 100 ] *
        [ hosepipe_relative % / 100 ] *
        [ hosepipe_coverage_% / 100 ] *
        100
ENDRULE

RULE 503708
IF      first_proposed_measure ==  conservation_devices
AND     water_use device ==        tap
AND     tap_fixture == sprinkler
THEN    first_measure effectiveness =
        interaction_factor_sp1 *
        [ sprinkler_reduction_% / 100 ] *
        [ sprinkler_relative % / 100 ] *
        [ sprinkler_coverage_% / 100 ] *
        100
ENDRULE

RULE 503710
IF      first_proposed_measure ==  conservation_devices
AND     water use_device ==        tap
AND     tap_fixture     ==         multiple_fixture
THEN    first_measure_effectiveness =
        interaction factor_sp1 *
        [ first_tap_effectiveness +
        second_tap effectiveness +
        third_tap_effectiveness +
        forth_tap_effectiveness +
        fifth_tap_effectiveness ]
ENDRULE

RULE 503712
IF      second_proposed_measure    ==
        conservation_devices
AND     water use_device == tap
AND     tap_fixture     ==         bathtub
THEN    second_measure_effectiveness =
        interaction_factor_sp2 *
        [ bathtub_reduction_% / 100 ] *
        [ bathtub_relative_% / 100 ] *
        [ bathtub_coverage_% / 100 ] *
        100 * interaction_factor_2
ENDRULE

RULE 503714
IF      second_proposed_measure    ==      conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         bathroom
THEN    second_measure_effectiveness =     interaction_factor_sp2
*
        [ bathroom_reduction_% / 100 ] *
        [ bathroom_relative_% / 100 ] *
        [ bathroom_coverage_% / 100 ] *
        100 * interaction_factor_2
ENDRULE

RULE 503716
IF      second_proposed_measure    ==      conservation_devices
AND     water_use_device==         tap
AND     tap_fixture     ==         kitchen
THEN    second_measure_effectiveness =     interaction_factor_sp2
*
        [ kitchen_reduction_% / 100 ] *
        [ kitchen_relative_% / 100 ] *
        [ kitchen_coverage_% / 100 ] *
        100 * interaction_factor_2
ENDRULE

RULE 503718
IF      second_proposed_measure ==         conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture == hosepipe
THEN    second_measure_effectiveness =     interaction_factor_sp2
*
        [ hosepipe_reduction_% / 100 ] *
        [ hosepipe_relative_% / 100 ] *
        [ hosepipe_coverage_% / 100 ] *
        100 * interaction_factor_2
ENDRULE

RULE 503720
IF      second_proposed_measure ==         conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture == sprinkler
THEN    second_measure_effectiveness =
        interaction_factor_sp2 *
        [ sprinkler_reduction_% / 100 ] *
        [ sprinkler_relative_% / 100 ] *
        [ sprinkler_coverage_% / 100 ] *
        100 * interaction_factor_2
ENDRULE

RULE 503722
IF      second_proposed_measure    ==      conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         multiple_fixture
THEN    second_measure_effectiveness =
        interaction_factor_sp2 *
        [ first_tap_effectiveness +
        second_tap_effectiveness +
        third_tap_effectiveness +
        forth_tap_effectiveness +
        fifth_tap_effectiveness ]
        * interaction_factor_2
ENDRULE

RULE 503724
IF      third_proposed_measure ==  conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         bathtub
THEN    third_measure_effectiveness =      interaction_factor_sp3
*
        [ bathtub_reduction_% / 100 ] *
        [ bathtub_relative_% / 100 ] *
        [ bathtub_coverage_% / 100 ] *
        100 * interaction_factor_3
ENDRULE

RULE 503726
IF      third_proposed_measure ==  conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         bathroom
THEN    third_measure_effectiveness =      interaction_factor_sp3
*
        [ bathroom_reduction_% / 100 ] *
        [ bathroom_relative_% / 100 ] *
        [ bathroom_coverage_% / 100 ] *
        100 * interaction_factor_3
ENDRULE

RULE 503728
IF      third_proposed_measure ==  conservation_devices
AND     water_use_device ==        tap
AND     tap_fixture     ==         kitchen
THEN    third_measure_effectiveness =      interaction_factor_sp3
*
        [ kitchen_reduction_% / 100 ] *
        kitchen_relative_% / 100 ] *
        [ kitchen_coverage_% / 100 ] *
```

```
            100 * interaction_factor_3
ENDRULE

RULE 503730
IF          third_proposed_measure      ==
            conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture == hosepipe
THEN        third_measure_effectiveness =
            interaction_factor_sp3 *
            [ hosepipe_reduction_% / 100 ] *
            hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 503732
IF          third_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap fixture     ==          sprinkler
THEN        third_measure_effectiveness =
            interaction_factor_sp3 *
            [ sprinkler_reduction_% / 100 ] *
            sprinkler_relative % / 100 ] *
            [ sprinkler coverage % / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 503734
IF          third_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap fixture     ==          multiple_fixture
THEN        third_measure_effectiveness =
            interaction_factor sp3 *
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third tap effectiveness +
            forth_tap_effectiveness +
            fifth tap effectiveness ]
            * interaction_factor_3
ENDRULE

RULE 503736
IF          forth_proposed_measure ==   conservation_devices
AND         water use_device ==         tap
AND         tap fixture     ==          bathtub
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ bathtub_reduction % / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 503738
IF          forth_proposed_measure ==   conservation_devices
AND         water use_device ==         tap
AND         tap fixture     ==          bathroom
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage % / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 503740
IF          forth_proposed_measure ==   conservation_devices
AND         water use device == tap
AND         tap fixture     ==          kitchen
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 503742
IF          forth_proposed_measure ==   conservation_devices
AND         water use_device ==         tap
AND         tap fixture == hosepipe
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative % / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 503744
IF          forth_proposed_measure ==   conservation_devices
AND         water use_device ==         tap
AND         tap fixture == sprinkler
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 503746
IF          forth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     == multiple_fixture
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third_tap_effectiveness +
            forth_tap_effectiveness +
            fifth_tap_effectiveness ]
            * interaction_factor_4
ENDRULE

RULE 503748
IF          fifth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture     ==          bathtub
THEN        fifth_measure_effectiveness =                interaction_factor_sp5
*
            [ bathtub_reduction_% / 100 ] *
            [ bathtub_relative_% / 100 ] *
            [ bathtub_coverage_% / 100 ] *
            100 * interaction_factor_5

ENDRULE

RULE 503750
IF          fifth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture == bathroom
THEN        fifth_measure_effectiveness =                interaction_factor_sp5
*
            [ bathroom_reduction_% / 100 ] *
            [ bathroom_relative_% / 100 ] *
            [ bathroom_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 503752
IF          fifth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture == kitchen
THEN        fifth_measure_effectiveness =                interaction_factor_sp5
*
            [ kitchen_reduction_% / 100 ] *
            [ kitchen_relative_% / 100 ] *
            [ kitchen_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 503754
IF          fifth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture == hosepipe
THEN        fifth_measure_effectiveness =                interaction_factor_sp5
*
            [ hosepipe_reduction_% / 100 ] *
            [ hosepipe_relative_% / 100 ] *
            [ hosepipe_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 503756
IF          fifth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture == sprinkler
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ sprinkler_reduction_% / 100 ] *
            [ sprinkler_relative_% / 100 ] *
            [ sprinkler_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 503758
IF          fifth_proposed_measure ==   conservation_devices
AND         water_use_device ==         tap
AND         tap_fixture == multiple_fixtures
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ first_tap_effectiveness +
            second_tap_effectiveness +
            third_tap_effectiveness +
            forth_tap_effectiveness +
            fifth_tap_effectiveness ]
```

```
            * interaction_factor_5
ENDRULE

RULE 504002
IF          first_proposed_measure ==  conservation_devices
AND         water_use_device ==        shower
THEN        first_measure_effectiveness  =
            interaction_factor_sp1 *
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100 ] *
            [ shower_coverage_% / 100 ] *
            100
ENDRUL

RULE 504002
IF          first_proposed_measure ==  conservation_devices
AND         water_use_device ==        dishwasher
THEN        first_measure_effectiveness  =
            interaction_factor_sp1 *
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_% / 100 ] *
            [ dishwasher_coverage_% / 100 ] *
            100
ENDRULE

RULE 504004
IF          first_proposed_measure =   conservation_devices
AND         water_use_device =         clothes_washer
THEN        first_measure_effectiveness  =
            interaction_factor_sp1 *
            [ washer_reduction_% / 100 ] *
            [ washer_relative_% / 100 ] *
            [ washer_coverage_% / 100 ] *
            100
ENDRULE

RULE 504005
IF          first_proposed_measure =   conservation_devices
AND         water_use_device =         multiple_devices
THEN        first_measure_effectiveness  =
interaction_factor sp1 *
            [ first_device_effectiveness +
            second_device_effectiveness +
            third_device_effectiveness +
            forth_device effectiveness +
            fifth_device_effectiveness ]
ENDRULE

RULE 504006
IF          second_proposed_measure   =
            conservation_devices
AND         water_use_device ==        toilet
THEN        second_measure_effectiveness =
            interaction_factor sp2 *
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative % / 100 ] *
            [ toilet_coverage % / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 504008
IF          second_proposed_measure ==
            conservation_devices
AND         water_use device ==        shower
THEN        second_measure_effectiveness =
            interaction_factor sp2 *
            [ shower_reduction_% / 100 ] *
            [ shower_relative % / 100 ] *
            [ shower_coverage_% / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 504010
IF          second_proposed_measure ==
            conservation_devices
AND         water_use_device ==        dishwasher
THEN        second_measure_effectiveness=
            interaction factor_sp2 *
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_% / 100 ] *
            [ dishwasher_coverage_% / 100 ] *
            100 * interaction_factor_2
ENDRULE

RULE 504012
IF          second_proposed_measure   ==
            conservation_devices
AND         water use device ==        clothes_washer
THEN        second_measure_effectiveness =
            interaction_factor_sp2 *
            washer_reduction_% / 100 ] *
            [ washer_relative_% / 100 ] *
            [ washer_coverage_% / 100 ] *
            100 * interaction_factor 2
ENDRULE

RULE 504013
IF          second_proposed_measure   ==          conservation_devices
AND         water_use_device ==        multiple_devices
THEN        second_measure_effectiveness =    interaction_factor_sp2 *
            [ first_device_effectiveness +
            second_device_effectiveness +
            third_device_effectiveness +
            forth_device_effectiveness +
            fifth_device_effectiveness ]
            * interaction_factor_2
ENDRULE

RULE 504014
IF          third_proposed_measure ==  conservation_devices
AND         water_use_device ==        toilet
THEN        third_measure_effectiveness =             interaction_factor_sp3
*
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100 ] *
            [ toilet_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 504016
IF          third_proposed_measure ==  conservation_devices
AND         water_use_device ==        shower
THEN        third_measure_effectiveness =             interaction_factor_sp3
*
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100 ] *
            [ shower_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 504018
IF          third_proposed_measure ==  conservation_devices
AND         water_use_device ==        dishwasher
THEN        third_measure_effectiveness =
            interaction_factor_sp3 *
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_% / 100 ] *
            [ dishwasher_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 504020
IF          third_proposed_measure ==  conservation_devices
AND         water_use_device ==        clothes_washer
THEN        third_measure_effectiveness =             interaction_factor_sp3
*
            [ washer_reduction_% / 100 ] *
            [ washer_relative_% / 100 ] *
            [ washer_coverage_% / 100 ] *
            100 * interaction_factor_3
ENDRULE

RULE 504021
IF          third_proposed_measure ==  conservation_devices
AND         water_use_device ==        multiple_devices
THEN        third_measure_effectiveness =
            interaction_factor_sp3 *
            [ first_device_effectiveness +
            second_device_effectiveness +
            third_device_effectiveness +
            forth_device_effectiveness +
            fifth_device_effectiveness ]
            * interaction_factor_3
ENDRULE

RULE 504022
IF          forth_proposed_measure ==  conservation_devices
AND         water_use_device ==        toilet
THEN        forth_measure_effectiveness =             interaction_factor_sp4
*
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100 ] *
            [ toilet_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 504024
IF          forth_proposed_measure ==  conservation_devices
AND         water_use_device ==        shower
THEN        forth_measure_effectiveness =             interaction_factor_sp4
*
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100 ] *
            [ shower_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 504026
```

```
IF          forth_proposed_measure ==  conservation_devices
AND         water_use_device ==        dishwasher
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_% / 100 ] *
            [ dishwasher_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 504028
IF          forth_proposed_measure ==  conservation_devices
            water_use_device ==        clothes_washer
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ washer_reduction_% / 100 ] *
            [ washer_relative_% / 100 ] *
            [ washer_coverage_% / 100 ] *
            100 * interaction_factor_4
ENDRULE

RULE 504029
IF          forth_proposed_measure ==  conservation_devices
AND         water_use_device ==        multiple_devices
THEN        forth_measure_effectiveness =
            interaction_factor_sp4 *
            [ first_device_effectiveness +
            second_device_effectiveness +
            third_device_effectiveness +
            forth_device_effectiveness +
            fifth device_effectiveness ]
            * interaction_factor_4
ENDRULE

RULE 504030
IF          fifth_proposed_measure ==  conservation_devices
AND         water_use device ==        toilet
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100 ] *
            [ toilet_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 504032
IF          fifth_proposed_measure ==  conservation_devices
AND         water_use_device ==        shower
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100 ] *
            [ shower coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 504034
IF          fifth_proposed_measure ==  conservation_devices
AND         water_use_device ==        dishwasher
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_% / 100 ] *
            [ dishwasher_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 504036
IF          fifth_proposed_measure ==  conservation_devices
AND         water use device ==        clothes_washer
THEN        fifth_measure_effectiveness =
            interaction_factor_sp5 *
            [ washer_reduction_% / 100 ] *
            [ washer_relative % / 100 ] *
            [ washer_coverage_% / 100 ] *
            100 * interaction_factor_5
ENDRULE

RULE 504037
IF          fifth_proposed_measure ==  conservation_devices
AND         water_use_device ==        multiple_devices
THEN        fifth_measure_effectiveness =
            interaction_factor sp5 *
            [ first_device_effectiveness +
            second_device_effectiveness +
            third_device_effectiveness +
            forth_device_effectiveness +
            fifth_device_effectiveness ]
            * interaction_factor_5
ENDRULE

RULE 501850
IF          proposed_conservation_measure == multiple_measures
THEN        conservation_effectiveness =
            [ first_measure_effectiveness ] +
            [ second_measure_effectiveness ] +
            [ third_measure_effectiveness ] +
            [ forth_measure_effectiveness ] +
            [ fifth_measure_effectiveness ]
ENDRULE

RULE 501836
IF          TRUE
THEN        interaction_factor_2 =
interaction_factor_12
ENDRULE

RULE 501837
IF          TRUE
THEN        interaction_factor_3        =
interaction_factor_13 *  interaction_factor_23
ENDRULE

RULE 501838
IF          TRUE
THEN        interaction_factor_4        =
interaction_factor_14 * interaction_factor_24 * interaction_factor_34
ENDRULE

RULE 501839
IF          TRUE
THEN        interaction_factor_5        =
interaction_factor_15 * interaction_factor_25 * interaction_factor_35 *
interaction_factor_45
ENDRULE

RULE 501842
IF          previous_conservation_measure ==        none
OR          previous_conservation_measure ==        pricing_policy
OR          previous_conservation_measure ==        pressure_reduction
OR          previous_conservation_measure ==        leakage_control
OR          previous_conservation_measure ==        plumbing_codes
OR          previous_conservation_measure ==  conservation_devices
OR          previous_conservation_measure ==        metering
OR          previous_conservation_measure ==        water_rationing
OR          previous_conservation_measure ==education_programmes
OR          previous_conservation_measure ==water_use_restrictions
THEN        interaction_factor_p =        interaction_factor_ps
ENDRULE

RULE 501844
IF          previous_conservation_measure ==multiple_measures
THEN        interaction_factor_p = nteraction_factor_pm
ENDRULE

RULE 501846
IF          TRUE
THEN        interaction_factor_pm       =            interaction_factor_p1 *
            interaction_factor_p2 *
            interaction_factor_p3 *
            interaction_factor_p4 *
            interaction_factor_p5

ENDRULE

RULE 501280
IF          TRUE
THEN        interaction_factor_sp1      =
            interaction_factor_sp11 *
            interaction_factor_sp12 *
            interaction_factor_sp13
ENDRULE

RULE 501282
IF          TRUE
THEN        interaction_factor_sp2      =
            interaction_factor_sp21 *
            interaction_factor_sp22 *
            interaction_factor_sp23
ENDRULE

RULE 501284
IF          TRUE
THEN        interaction_factor_sp3      =
            interaction_factor_sp31 *
            interaction_factor_sp32 *
            interaction_factor_sp33
ENDRULE

RULE 501286
IF          TRUE
THEN        interaction_factor_sp4      =
            interaction_factor_sp41 *
            interaction_factor_sp42 *
            interaction_factor_sp43
ENDRULE

RULE 501288
```

```
IF        TRUE
THEN      interaction_factor_sp5     =
          interaction_factor_sp51 *
          interaction_factor_sp52 *
          interaction_factor_sp53
ENDRULE

RULE 501300
IF        second_proposed_measure    == none
THEN      interaction_factor_12      = 1
ENDRULE

RULE 501301
IF        second_proposed_measure    == none
OR        third_proposed_measure     == none
THEN      interaction_factor_13      = 1
ENDRULE

RULE 501302
IF        second_proposed_measure    == none
OR        third_proposed_measure     == none
OR        forth_proposed_measure     == none
THEN      interaction_factor_14 =    1
ENDRULE

RULE 501303
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
OR        forth_proposed_measure     ==     none
OR        fifth_proposed_measure     ==     none
THEN      interaction_factor_15      =      1
ENDRULE


RULE 501310
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
THEN      interaction_factor_23      =      1
ENDRULE

RULE 501311
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
OR        forth_proposed_measure     ==     none
THEN      interaction_factor_24      =      1
ENDRULE

RULE 501313
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
OR        forth_proposed_measure     ==     none
OR        fifth_proposed_measure     ==     none
THEN      interaction_factor_25      =      1
ENDRULE

RULE 501317
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
OR        forth_proposed_measure     ==     none
THEN      interaction_factor_34      =      1
ENDRULE


RULE 501318
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
OR        forth_proposed_measure     ==     none
OR        fifth_proposed_measure     ==     none
THEN      interaction_factor_35      =      1
ENDRULE

RULE 501321
IF        second_proposed_measure    ==     none
OR        third_proposed_measure     ==     none
OR        forth_proposed_measure     ==     none
OR        fifth_proposed_measure     ==     none
THEN      interaction_factor_45      =      1
ENDRULE

RULE 501325
IF        first_previous_measure     ==     none
THEN      interaction_factor_p1      =      1
ENDRULE

RULE 501330
IF        first_previous_measure     ==     none
OR        second_previous_measure    ==     none
THEN      interaction_factor_p2      =      1
ENDRULE

RULE 501332
IF        first_previous_measure     ==     none
OR        second_previous_measure    ==     none
```

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OR        third_previous_measure     ==          none
THEN      interaction_factor_p3      =           1
ENDRULE

RULE 501334
IF        first_previous_measure     ==          none
OR        second_previous_measure    ==          none
OR        third_previous_measure     ==          none
OR        forth_previous_measure     ==          none
THEN      interaction_factor_p4      =           1
ENDRULE

RULE 501336
IF        first_previous_measure     ==          none
OR        second_previous_measure    ==          none
OR        third_previous_measure     ==          none
OR        forth_previous_measure     ==          none
OR        fifth_previous_measure     ==          none
THEN      interaction_factor_p5      =           1
ENDRULE

RULE 501852
IF        proposed_conservation_measure ==       metering
AND       interaction_factor_p       ==          0
THEN      conservation_effectiveness =           0
ENDRULE

RULE 501854
IF        proposed_conservation_measure == metering
THEN      conservation_effectiveness =
          [ interaction_factor_p      ] *
          [ metering_reduction_% / 100 ] *
          [ metering_coverage_% / 100  ] *
          100
ENDRULE

RULE 501856
IF        proposed_conservation_measure == education_programmes
AND       interaction_factor_p          == 0
THEN      conservation_effectiveness    = 0
ENDRULE

RULE 501858
IF        proposed_conservation_measure == education_programmes
THEN      conservation_effectiveness =
          [ interaction_factor_p       ] *
          [ education_reduction_% / 100 ] *
          [ education_coverage_% / 100  ] *
          100
ENDRULE

RULE 501860
IF        proposed_conservation_measure == pricing_policy
AND       interaction_factor_p          ==    0
THEN      conservation_effectiveness    =     0
ENDRULE

RULE 501862
IF        proposed_conservation_measure == pricing_policy
THEN      conservation_effectiveness =
          [ interaction_factor_p ] *
          [ pricing_reduction_% / 100 ] *
          [ pricing_coverage_% / 100  ] *
          100
ENDRULE

RULE 501864
IF        proposed_conservation_measure == leakage_control
AND       interaction_factor_p       ==          0
THEN      conservation_effectiveness =           0
ENDRULE

RULE 501866
IF        proposed_conservation_measure == leakage_control
THEN      conservation_effectiveness =
          [ interaction_factor_p ] *
          [ leakage_reduction_% / 100 ] *
          [ leakage_coverage_% / 100  ] *
          100
ENDRULE

RULE 501868
IF        proposed_conservation_measure          ==
          conservation_devices
AND       interaction_factor_p       ==          0
THEN      conservation_effectiveness =           0
ENDRULE

RULE 501869
IF        proposed_conservation_measure          ==
          conservation_devices
AND       water_use_device                       ==       toilet
AND       toilet_reduction_%                     == 0
THEN      conservation_effectiveness =           0
```

```
ENDRULE

RULE 501870
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use_device                       ==
            toilet
THEN        conservation_effectiveness  =
            interaction_factor_p  *
            [ toilet_reduction_% / 100 ] *
            [ toilet_relative_% / 100 ] *
            [ toilet_coverage_% / 100 ] *
            100
ENDRULE

RULE 501871
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use_device                       ==
            shower
AND         shower_reduction_%                     == 0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501872
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use_device                       ==
            shower
THEN        conservation_effectiveness  =
            interaction_factor_p  *
            [ shower_reduction_% / 100 ] *
            [ shower_relative_% / 100 ] *
            [ shower_coverage_% / 100 ] *
            100
ENDRULE

RULE 501873
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use_device                       ==
            dishwasher
AND         dishwasher reduction_%                 == 0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501876
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use device                       ==
            dishwasher
THEN        conservation_effectiveness  =
            interaction factor_p  *
            [ dishwasher_reduction_% / 100 ] *
            [ dishwasher_relative_% / 100 ] *
            [ dishwasher_coverage_% / 100 ] *
            100
ENDRULE

RULE 501877
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use_device                       ==
            clothes_washer
AND         washer_reduction_%                     == 0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501878
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use device                       ==
            clothes_washer
THEN        conservation_effectiveness  =
            interaction factor_p  *
            [ washer_reduction_% / 100 ] *
            [ washer_relative_% / 100 ] *
            [ washer_coverage_% / 100 ] *
            100
ENDRULE

RULE 501880
IF          proposed_conservation_measure          ==
            conservation_devices
AND         water_use device                       ==
            multiple devices
THEN        conservation_effectiveness  =
            [ interaction_factor_p ] *
            [ first_device_effectiveness  +
            second_device_effectiveness  +
            third_device_effectiveness  +
            forth_device_effectiveness  +
            fifth_device_effectiveness  ]
ENDRULE
```

```
RULE 501882
IF          proposed_conservation_measure          ==
            water_rationing
AND         interaction_factor_p                   == 0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501884
IF          proposed_conservation_measure == water_rationing
THEN        conservation_effectiveness  =
            interaction_factor_p  *
            [ rationing_reduction_% / 100 ] *
            [ rationing_coverage_% / 100 ] *
            100
ENDRULE

RULE 501886
IF          proposed_conservation_measure          ==
            plumbing_codes
AND         interaction_factor_p        ==         0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501888
IF          proposed_conservation_measure == plumbing_codes
THEN        conservation_effectiveness  =
            interaction_factor_p  *
            plumbing_reduction_% / 100 ] *
            [ plumbing_coverage_% / 100 ] *
            100
ENDRULE

RULE 501890
IF          proposed_conservation_measure          == pressure_reduction
AND         interaction_factor_p                   == 0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501892
IF          proposed_conservation_measure          == pressure_reduction
THEN        conservation_effectiveness  =
            interaction_factor_p  *
            [ pressure_reduction_% / 100 ] *
            [ pressure_coverage_% / 100 ] *
            100
ENDRULE

RULE 501894
IF          proposed_conservation_measure          ==
            water_use_restrictions
AND         interaction_factor_p                   ==        0
THEN        conservation_effectiveness  =          0
ENDRULE

RULE 501896
IF          proposed_conservation_measure          ==
water_use_restrictions
THEN        conservation_effectiveness  =
            interaction_factor_p  *
            [ restrictions_reduction_% / 100 ] *
            restrictions_coverage_% / 100 ] *
            100
ENDRULE

RULE 501898
IF          TRUE
THEN        rationing_reduction_% =     12.5
ENDRULE

RULE 501900
IF          TRUE
THEN        plumbing_reduction_%        = 20
ENDRULE

RULE 501902
IF          TRUE
THEN        pressure_reduction_% =      5
ENDRULE

RULE 501904
IF          TRUE
THEN        restrictions_reduction_%    = 10
ENDRULE

RULE 501905
IF          TRUE
THEN        metering_reduction_% =      0
ENDRULE

RULE 501910
IF          TRUE
THEN        leakage_reduction_% =       15
ENDRULE
```

```
RULE 501911
IF          TRUE
THEN        education_reduction_% =    5
ENDRULE

RULE 501912
IF          tariff_type      ==        rising_block_tariff
THEN        pricing_reduction_% =      15
ENDRULE

RULE 501914
IF          tariff_type      ==        flat_rate_tariff
THEN        pricing_reduction_% =      1.45
ENDRULE

RULE 501916
IF          tariff_type      ==        seasonal_rate_tariff
THEN        pricing_reduction_% =      12.5
ENDRULE

RULE 501918
IF          tariff_type      ==        peak_hour_rate_tariff
THEN        pricing_reduction_% =      10
ENDRULE

RULE 501920
IF          tariff_type      ==        falling_block_tariff
THEN        pricing_reduction_% =      5
ENDRULE

RULE 501922
IF          TRUE
THEN        shower_reduction_% =
            [ [ existing_shower_flow -
            proposed_shower_flow ] /
            existing_shower_flow ] * 100
ENDRULE

RULE 501924
IF          existing_shower_flow        <=
            proposed_shower_flow
THEN        shower_reduction_%          =        0
ENDRULE

RULE 501926
IF          TRUE
THEN        dishwasher_reduction_%      =
            [ [ existing_dishwasher_capacity
            proposed_dishwasher_capacity ]
            / existing_dishwasher_capacity ] * 100
ENDRULE

RULE 501928
IF          existing_dishwasher_capacity<=
            proposed_dishwasher_capacity
THEN        dishwasher_reduction_%      =        0
ENDRULE

RULE 501930
IF          TRUE
THEN        washer_reduction_% =
            [ [ existing_washer_capacity
            - proposed_washer_capacity ]
            / existing_washer_capacity] * 100
ENDRULE

RULE 501932
IF          existing_washer_capacity    <=
            proposed_washer_capacity
THEN        washer_reduction_% =        0
ENDRULE

RULE 501934
IF          TRUE
THEN        bathtub_reduction_% =
            [ [ existing_bathtub_flow -
            proposed_bathtub_flow ] /
            existing_bathtub_flow ] * 100
ENDRULE

RULE 501936
IF          TRUE
THEN        bathroom_reduction_% =
            [ [ existing_bathroom_flow -
            proposed_bathroom_flow ] /
            existing_bathroom_flow ] * 100
ENDRULE

RULE 501938
IF          TRUE
THEN        kitchen_reduction_% =
            [ [ existing_kitchen_flow -
            proposed_kitchen_flow ] /
            existing_kitchen_flow ] * 100
ENDRULE

RULE 501940
IF          TRUE
THEN        hosepipe_reduction_% =
            [ [ existing_hosepipe_flow -
            proposed_hosepipe_flow ] /
            existing_hosepipe_flow ] * 100
ENDRULE

RULE 501941
IF          existing_sprinkler_flow     <=
            proposed_sprinkler_flow
THEN        sprinkler_reduction_% =     0
ENDRULE

RULE 501942
IF          TRUE
THEN        sprinkler_reduction_% =
            [ [ existing_sprinkler_flow -
            proposed_sprinkler_flow ] /
            existing_sprinkler_flow ] * 100
ENDRULE

RULE 501944
IF          existing_bathtub_flow <=    proposed_bathtub_flow
THEN        bathtub_reduction_% =       0
ENDRULE

RULE 501946
IF          existing_bathroom_flow <=   proposed_bathroom_flow
THEN        bathroom_reduction_% =      0
ENDRULE

RULE 501948
IF          existing_kitchen_flow <=    proposed_kitchen_flow
THEN        kitchen_reduction_% =       0
ENDRULE

RULE 501950
IF          existing_hosepipe_flow <=   proposed_hosepipe_flow
THEN        hosepipe_reduction_% =      0
ENDRULE

RULE 501952
IF          existing_sprinkler_flow <=  proposed_sprinkler_flow
THEN        sprinkler_reduction_% =     0
ENDRULE

RULE 501954
IF          conservation_policy ==      modify_existing_toilets
AND         conservation_tool ==        damming_type
AND         [ damming_tool ==           ordinary_dams
OR          damming_tool ==             partitions ]
THEN        toilet_reduction_% =        30
ENDRULE

RULE 501955
IF          conservation_policy ==      modify_existing_toilets
AND         conservation_tool ==        displacement_type
AND         displacement_tool ==        plastic_bottle
THEN        toilet_reduction_% =        15
ENDRULE

RULE 501956
IF          conservation_policy ==      modify_existing_toilets
AND         conservation_tool ==        displacement_type
AND         displacement_tool ==        plastic_bag
THEN        toilet_reduction_% =        20
ENDRULE

RULE 501957
IF          conservation_poilcy ==      modify_existing_toilets
AND         conservation_tool ==        assortment_type
AND         assortment_tool ==          two_flushing_modes
THEN        toilet_reduction_% =        50
ENDRULE

RULE 501958
IF          conservation_policy ==      modify_existing_toilets
AND         conservation_tool ==        assortment_type
AND         assortment_tool ==          other_flushing_modes
THEN        toilet_reduction_% =        40
ENDRULE

RULE 501960
IF          conservation_policy ==      replace_existing_toilets
THEN        toilet_reduction_% =
            [ [ existing_toilet_capacity -
            proposed_toilet_capacity ] /
            existing_toilet_capacity ] * 100
ENDRULE
```

```
RULE 501962
IF      conservation_policy ==        replace_existing_toilets
AND     existing_toilet_capacity =    proposed_toilet_capacity
THEN    toilet_reduction_% =          0
ENDRULE

RULE 501964
IF      tools_criteria  ==            saving_effectiveness
THEN    conservation_tool =           assortment_type
ENDRULE

RULE 501966
IF      tools_criteria  ==            installation_difficulty
THEN    conservation_tool             =
        displacement_type
ENDRULE

RULE 501968
IF      tools_criteria  ==            cost
THEN    conservation_tool             =
        displacement_type
ENDRULE

RULE 501970
IF      tools_criteria  ==            durability
THEN    conservation_tool             =
        displacement_type
ENDRULE

RULE 501972
IF      conservation_tool ==          damming_type
THEN    damming_tool  =               ordinary_dams
ENDRULE

RULE 501974
IF      conservation_tool ==          displacement_type
THEN    displacement_tool =           plastic_bottle
ENDRULE

RULE 501976
IF      conservation_tool ==          assortment_type
THEN    assortment_tool =             two_flushing_modes
ENDRULE

RULE 501980
IF      TRUE
THEN    existing_toilet_capacity      =        9.0
ENDRULE

RULE 501981
IF      TRUE
THEN    proposed_toilet_capacity      =        7.5
ENDRULE

RULE 501984
IF      TRUE
THEN    existing_dishwasher_capacity=          40
ENDRULE

RULE 501985
IF      TRUE
THEN    proposed_dishwasher_capacity =         20
ENDRULE

RULE 501986
IF      TRUE
THEN    existing_washer_capacity      =        95
ENDRULE

RULE 501987
IF      TRUE
THEN    proposed_washer_capacity      =        70
ENDRULE

RULE 501312
IF      TRUE
THEN    toilet_relative_% =           27.5
ENDRULE

RULE 501314
IF      TRUE
THEN    dishwasher_relative_% =       1.25
ENDRULE

RULE 501316
IF      TRUE
THEN    washer_relative_% =           12
ENDRULE

RULE 501355
IF      TRUE
THEN    education_coverage_% =        100
ENDRULE
```

```
RULE 501356
IF      TRUE
THEN    pricing_coverage_% =          80
ENDRULE

RULE 501357
IF      TRUE
THEN    metering_coverage_% =         80
ENDRULE

RULE 501358
IF      TRUE
THEN    toilet_coverage_% =           60
ENDRULE

RULE 501365
IF      TRUE
THEN    dishwasher_coverage_% =       23.8
ENDRULE

RULE 501366
IF      TRUE
THEN    washer_coverage_% =           73.9
ENDRULE

RULE 502700
IF      [ c1        >         c2
AND     c1          >         c3
AND     c1          >         c4
AND     c1          >         c5
AND     c1          >         c6
AND     c1          >         c7
AND     c1          >         c8
AND     c1          >         c9 ]
THEN    proposed_conservation_measure = metering
ENDRULE

RULE 502702
IF      [ c2        >         c1
AND     c2          >         c3
AND     c2          >         c4
AND     c2          >         c5
AND     c2          >         c6
AND     c2          >         c7
AND     c2          >         c8
AND     c2          >         c9 ]
THEN    proposed_conservation_measure =        education_programmes
ENDRULE

RULE 502704
IF      [ c3        >         c1
AND     c3          >         c2
AND     c3          >         c4
AND     c3          >         c5
AND     c3          >         c6
AND     c3          >         c7
AND     c3          >         c8
AND     c3          >         c9 ]
THEN    proposed_conservation_measure = pricing_policy
ENDRULE

RULE 502706
IF      [ c4        >         c1
AND     c4          >         c3
AND     c4          >         c2
AND     c4          >         c5
AND     c4          >         c6
AND     c4          >         c7
AND     c4          >         c8
AND     c4          >         c9 ]
THEN    proposed_conservation_measure = leakage_control
ENDRULE

RULE 502708
IF      [ c5        >         c2
AND     c5          >         c3
AND     c5          >         c4
AND     c5          >         c1
AND     c5          >         c6
AND     c5          >         c7
AND     c5          >         c8
AND     c5          >         c9 ]
THEN    proposed_conservation_measure = water_rationing
ENDRULE

RULE 502710
IF      [ c6        >         c2
AND     c6          >         c3
AND     c6          >         c4
AND     c6          >         c5
AND     c6          >         c1
AND     c6          >         c7
```

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AND     c6      >       c8
AND     c6      >       c9 ]
THEN    proposed_conservation_measure =
        conservation_devices
ENDRULE

RULE 502712
IF      [ c7    >       c2
AND     c7      >       c3
AND     c7      >       c4
AND     c7      >       c5
AND     c7      >       c6
AND     c7      >       c1
AND     c7      >       c8
AND     c7      >       c9 ]
THEN    proposed_conservation_measure = pressure_reduction
ENDRULE

RULE 502714
IF      [ c8    >       c2
AND     c8      >       c3
AND     c8      >       c4
AND     c8      >       c5
AND     c8      >       c6
AND     c8      >       c1
AND     c8      >       c7
AND     c8      >       c9 ]
THEN    proposed_conservation_measure =
        water_use_restrictions
ENDRULE

RULE 502715
IF      [ c9    >       c2
AND     c9      >       c3
AND     c9      >       c4
AND     c9      >       c5
AND     c9      >       c6
AND     c9      >       c1
AND     c9      >       c7
AND     c9      >       c8 ]
THEN    proposed_conservation_measure = plumbing_codes
ENDRULE

RULE 502716
IF      time_period  ==  short_term
THEN    c9      =       0
ENDRULE

RULE 502717
IF      time_period  ==  long_term
THEN    c9      =       [ wc1 * 0.7 ] +
                        [ wc2 * 0.7 ] +
                        [ wc3 * 0.5 ] +
                        [ wc4 * 0.2 ]
ENDRULE

RULE 502718
IF      time_period  ==  long_term
THEN    c8      =       0
ENDRULE

RULE 502719
IF      time_period  ==  short_term
THEN    c8      =       [ wc1 * 0.5 ] +
                        [ wc2 * 0.6 ] +
                        [ wc3 * 0.6 ] +
                        [ wc4 * 0.3 ]
ENDRULE

RULE 502720
IF      time_period  ==  long_term
THEN    c1      =       [ wc1 * 0.1 ] +
                        [ wc2 * 0.8 ] +
                        [ wc3 * 0.1 ] +
                        [ wc4 * 0.8 ]
ENDRULE

RULE 502721
IF      time_period  ==  short_term
THEN    c1      =       0
ENDRULE

RULE 502722
IF      time_period  ==  short_term
THEN    c2      =       [ wc1 * 0.4 ] +
                        [ wc2 * 0.2 ] +
                        [ wc3 * 0.4 ] +
                        [ wc4 * 0.9 ]
ENDRULE

RULE 502723
IF      time_period          ==      long_term
THEN    c2                   =       0
ENDRULE
```

```
RULE 502724
IF      time_period  ==  long_term
THEN    c3      =       [ wc1 * 0.6 ] +
                        [ wc2 * 0.3 ] +
                        [ wc3 * 0.8 ] +
                        [ wc4 * 0.4 ]
ENDRULE

RULE 502725
IF      time_period  ==  short_term
THEN    c3      =       0
ENDRULE

RULE 502726
IF      time_period  ==  long_term
THEN    c4 =    [ wc1 * 0.3 ] +
                [ wc2 * 0.5 ] +
                [ wc3 * 0.3 ] +
                [ wc4 * 0.7 ]
ENDRULE

RULE 502727
IF      time_period  ==  short_term
THEN    c4      =       0
ENDRULE

RULE 502728
IF      time_period  ==  short_term
THEN    c5      =       [ wc1 * 0.8 ] +
                        [ wc2 * 0.4 ] +
                        [ wc3 * 0.9 ] +
                        [ wc4 * 0.1 ]
ENDRULE

RULE 502729
IF      time_period  ==  long_term
THEN    c5      =       0
ENDRULE

RULE 502730
IF      time_period  ==  long_term
THEN    c6      =       [ wc1 * 0.2 ] +
                        [ wc2 * 0.9 ] +
                        [ wc3 * 0.2 ] +
                        [ wc4 * 0.5 ]
ENDRULE

RULE 502731
IF      time_period  ==  short_term
THEN    c6      =       0
ENDRULE

RULE 502732
IF      time_period  ==  long_term
THEN    c7      =       0
ENDRULE

RULE 502734
IF      time_period  ==  short_term
THEN    c7      =       [ wc1 * 0.9 ] +
                        [ wc2 * 0.1 ] +
                        [ wc3 * 0.7 ] +
                        [ wc4 * 0.6 ]
ENDRULE

RULE 502740
IF      measure_first_criterion   ==   cost
THEN    wc1             =              0.36
ENDRULE

RULE 502742
IF      measure_second_criterion  ==   cost
THEN    wc1             =              0.29
ENDRULE

RULE 502744
IF      measure_third_criterion   ==   cost
THEN    wc1                       =    0.21
ENDRULE

RULE 502746
IF      measure_forth_criterion   ==   cost
THEN    wc1                       =    0.14
ENDRULE

RULE 502750
IF      measure_first_criterion   ==   measure_effectiveness
THEN    wc2                       =    0.36
ENDRULE

RULE 502752
IF      measure_second_criterion  ==   measure_effectiveness
```

```
THEN      wc2          =          0.29
ENDRULE

RULE 502754
IF        measure_third_criterion ==   measure_effectiveness
THEN      wc2          =          0.21
ENDRULE

RULE 502756
IF        measure_forth_criterion ==   measure_effectiveness
THEN      wc2          =          0.14
ENDRULE

RULE 502760
IF        measure_first_criterion ==   ease_of_application
THEN      wc3          =          0.36
ENDRULE

RULE 502762
IF        measure_second_criterion ==ease_of_application
THEN      wc3          =          0.29
ENDRULE

RULE 502764
IF        measure_third_criterion ==   ease_of_application
THEN      wc3          =          0.21
ENDRULE

RULE 502766
IF        measure_forth_criterion ==   ease_of_application
THEN      wc3          =          0.14
ENDRULE

RULE 502770
IF        measure first_criterion      == public_acceptence
THEN      wc4                          = 0.36
ENDRULE

RULE 502772
IF        measure_second_criterion     == public_acceptence
THEN      wc4                          = 0.29
ENDRULE

RULE 502774
IF        measure_third_criterion ==   public_acceptence
THEN      wc4                          = 0.21
ENDRULE

RULE 502776
IF        measure_forth_criterion ==   public_acceptence
THEN      wc4                          = 0.14
ENDRULE

RULE 502780
IF        time_period     ==        long_term
AND       measure_first_criterion ==   cost
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          pricing_policy
ENDRULE

RULE 502782
IF        time_period     ==        short_term
AND       measure_first_criterion      ==        cost
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          water_rationing
ENDRULE

RULE 502784
IF        time_period     ==        long_term
AND       measure_first_criterion ==   measure_effectiveness
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          conservation_devices
ENDRULE

RULE 502786
IF        time_period     ==        short_term
AND       measure_first_criterion ==   measure_effectiveness
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          water_use_restrictions
ENDRULE

RULE 502788
IF        time_period                           ==
          long_term
AND       measure_first_criterion               ==
          ease_of_application
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          pricing_policy
ENDRULE
```

```
RULE 502790
IF        time_period     ==        short_term
AND       measure_first_criterion ==   ease_of_application
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          water_rationing
ENDRULE

RULE 502792
IF        time_period     ==        long_term
AND       measure_first_criterion ==   public_acceptence
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          metering
ENDRULE

RULE 502794
IF        time_period     ==        short_term
AND       measure_first_criterion ==   public_acceptence
AND       measure_second_criterion     ==        none
THEN      proposed_conservation_measure         =
          education_programmes
ENDRULE
```

II.3 - List of tables

TABLE 10
first_proposed_measure
second_proposed_measure
interaction_factor_12

	education_programes	metering	pressure reduction	pricing_policy	water_rationing	water use restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 12
first_proposed_measure
third_proposed_measure
interaction_factor_13

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 13
first_proposed_measure
forth_proposed_measure
interaction_factor_14

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 14
first_proposed_measure
fifth_proposed_measure
interaction_factor_15

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water use restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 20
second_proposed_measure
third_proposed_measure
interaction_factor_23

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 21
second_proposed_measure
forth_proposed_measure
interaction_factor_24

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 22
second_proposed_measure
fifth_proposed_measure
interaction_factor_25

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 27
third_proposed_measure
forth_proposed_measure
interaction_factor_34

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 28
third_proposed_measure
fifth_proposed_measure
interaction_factor_35

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 33
forth_proposed_measure
fifth_proposed_measure
interaction_factor_45

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.6	0.9	1	0.8	1
metering	1	0	1	0	1	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	1	1	0	1	1	1	1	1
water_rationing	0.2	0	1	1	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	0.9	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.9	1	1	0.9	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 40
proposed_conservation_measure
previous_conservation_measure
interaction_factor_ps

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 42
proposed_conservation_measure
first_previous_measure
interaction_factor_pl

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 44
proposed_conservation_measure
second_previous_measure
interaction_factor_p2

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water use_restrictions	leakage control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 46
proposed_conservation_measure
third_previous_measure
interaction_factor_p3

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water use restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 48
proposed_conservation_measure
forth previous_measure
interaction_factor p4

	education_programes	metering	pressure reduction	pricing_policy	water_rationing	water_use restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage control	1	1	1	1	1	1	0	1	1
conservation devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 50
proposed_conservation_measure
fifth_previous_measure
interaction_factor_p5

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 52
first_proposed_measure
first_previous_measure
interaction_factor_sp11

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 54
first_proposed_measure
second_previous_measure
interaction_factor_sp12

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 56
first_proposed_measure
third_previous_measure
interaction_factor_sp13

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 58
second_proposed_measure
first_previous_measure
interaction_factor_sp21

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 60
second_proposed_measure
second_previous_measure
interaction_factor_sp22

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 62
second_proposed_measure
third_previous_measure
interaction_factor_sp23

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 64
third_proposed_measure
first_previous_measure
interaction_factor_sp31

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 66
third_proposed_measure
second_previous_measure
interaction_factor_sp32

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 68
third_proposed_measure
third_previous_measure
interaction_factor_sp33

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 70
forth_proposed_measure
first_previous_measure
interaction_factor_sp41

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 72
forth_proposed_measure
second_previous_measure
interaction_factor_sp42

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 74
forth_proposed_measure
third_previous_measure

i	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

nteraction_factor_sp43
ENDTABLE

TABLE 76
fifth_proposed_measure
first_previous_measure
interaction_factor_sp51

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 78
fifth_proposed_measure
second_previous_measure
interaction_factor_sp52

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0.2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

TABLE 80
fifth_proposed_measure
third_previous_measure
interaction_factor_sp53

	education_programes	metering	pressure_reduction	pricing_policy	water_rationing	water_use_restrictions	leakage_control	conservation_devices	plumbing_codes
education_programmes	0	1	1	1	0 2	0.9	1	0.9	1
metering	1	0	1	1	0	1	1	1	1
pressure_reduction	1	1	0	1	1	1	1	1	1
pricing_policy	1	0	1	1	1	0.9	1	0.9	1
water_rationing	0.6	1	1	0	0	0.6	1	1	1
water_use_restrictions	0.9	1	1	1	0.6	0	1	0	0
leakage_control	1	1	1	1	1	1	0	1	1
conservation_devices	0.8	1	1	1	1	0	1	0	1
plumbing_codes	1	1	1	1	1	0	1	1	0
none	1	1	1	1	1	1	1	1	1

ENDTABLE

Appendix III

III.1 - Input data file of per-capita consumption model

```
12
year consumption
1980 126.6
1981 130.0
1982 138.3
1983 136.6
1984 139.4
1985 131.6
1986 145.5
1987 141.6
1988 142.2
1989 143.3
1990 147.2
1995 153.7
```

III.2 - Input-data file of econometric-consumption model

```
7 7 'M' 'U'
1.0 10000 3.0 1.4 15 725 0.7 150
1.0 15000 2.0 1.5 20 650 0.6 200
1.0 20000 2.0 3.0 20 700 0.5 450
1.0 10000 2.0 2.5 15 555 0.5 300
1.0 25000 1.5 2.5 25 430 0.4 650
1.0 20000 1.5.3.0 20 450 0.5 550
1.0 20000 1.3 2.0 30 750 0.7 500
0 2 2 2 2 1 2
'none '
'income '
'adults '
'children '
'temprature'
'rainfall '
'price '
2.0
```

III.3 - Input-data file of population model

```
3
year population
1983 358.7
1988 362.8
1993 368.7
```

III.4 - Input-data file of occupancy-rate model

```
12
year occupancy rate
1980 2.79
1981 2.74
1982 2.68
1983 2.63
1984 2.64
1985 2.59
1986 2.56
1987 2.54
1988 2.52
1989 2.50
1990 2.49
1995 2.32
```