A Systems Approach for the Selection of Appropriate Water Supply and Sanitation Infrastructure in Developing Communities

A Dissertation

Presented to

the faculty of the School of Engineering and Applied Science

University of Virginia

in partial fulfillment

of the requirements for the degree

Doctor of Philosophy

by

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December

2013

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is submitted in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

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Abstract

40% of the world's population lacks access to adequate supplies of water and sanitation to sustain human health. In fact, more than 780 million people lack access to safe water supplies and more than 2.5 billion lack access to basic sanitation. Appropriate technology for water supply and sanitation (Watsan) systems is critical for sustained access to these services. Current approaches for the selection of Watsan technologies in developing communities have a high failure rate. Based on a study done by the World Health Organization (WHO), 30% to 60% of Watsan installed infrastructures in developing countries are not operating.

This research presents an original framework for the selection of appropriate Watsan technologies for developing communities. The proposed decision model has three components. The first component is a standardized model, the capacity factor analysis (CFA), used for the assessment of a community's capacity to manage a municipal sanitation service (MSS) such as, drinking water supply (DWS), wastewater and sewage treatment (WST), and management of solid waste (MSW). The assessment of the community's capacity is based on seven capacity factors (CF) that capture the community's capacity level (CCL) to manage a MSS. The CFA uses five capacity levels to assess the overall capacity of a community to operate and manage sustainably an MSS. The second component of the decision model is a database of Watsan technologies with proven sustainability in developing communities. The Watsan technologies are classified using a statistical learning technique, the support vector machines (SVM) model applied to classification problems. The classification of Watsan technologies is defined by a metric, the technology requirement level (TRL). This metric defines the capacity level a community must have to operate and maintain sustainably a given Watsan technology. The third component of the decision model is the appropriate matching model. The matching model selects from the database appropriate Watsan technology options that have a TRL metric consistent with the host community CCL metric, and that are implemented and operating sustainably in communities that have a similar regional specificity and profile as the host community. Case studies are used to demonstrate the applicability and the performance of the decision model.

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LIST OF ACRONYMS

CF – Capacity Factor

CFA – Capacity Factor Analysis

CCL – Community Capacity Level

DWS – Drinking Water Supply

DC – Developing Communities

DSS – Decision Support System

MSS – Municipal Sanitation Services

MSW – Management of Solid Waste

ODA – Overseas Development Assistance

SVM – Support Vector Machine

TRL – Technology Requirement Level

UNDP – United Nations Development Program

UNICEF – United Nations Children's Fund

Watsan – Water Supply and Sanitation

WB – World Bank

WHO – World Health Organization

WST – Wastewater, Sewage, and Treatment

Acknowledgements

I would like to start by thanking Dr. Yacov Haimes, for accepting to chair the committee of this dissertation, and for his continuous help and support as graduate student, and as faculty member at Piedmont Virginia Community College. I would like also to thank Dr. Garrick Louis for giving me this unique opportunity to study at The University of Virginia, Systems and Information Engineering Department, and for his continuous support. I would like to thank Dr. Alfredo Garcia, for his directions and advices in my first steps in machine learning.

I would like to express my gratitude to M. Najib Guedira, head of the Moroccan Social Development Agency (ADS), for giving me the opportunity and support to visit several villages in Morocco, funded by ADS.

I would like also to thank my former students, Nicholas Goddeau, Marc Hansen, and Dustin Widmann for their assistance.

Finally, I would like to thank the members of my family, my mother for her constant encouragements, my wife, Majida Bargach, and our sons Neil and Ryan, for their love and patience.

Chapter 1. Introduction

1.1 Situation

Access to safe drinking water and basic sanitation has been a major concern for the international community for the past four decades. Though overwhelmingly problems of lower-income countries, the lack of access to improved water supply and sanitation services affects poor communities in both lower and higher income countries. Several major initiatives have been tried over the years to increase the access to these basic services. The latest among them are the Millennium Development Goals (MDG), and more specifically the MDG Target 7C. This goal calls for halving the proportion of the world population without access to safe drinking water and basic sanitation by 2015 (baseline 1990). Since the adoption of the United Nations MDG in 2000, more than 2 billion people have gained access to safe drinking water and 1.8 billion people have gained access to improved sanitation. The WHO-UNICEF Joint Monitoring Program (JMP) for water supply and sanitation reports every two years on the world status of access to drinking water supply and sanitation and on the progress of the United Nations MDG. In its 2012, update the WHO-UNICEF JMP reports that the access drinking water target was met in 2010, since the proportion of the world population lacking access to drinking water decreased from 24% in 1990 to 11% in 2010. These results indicate that the target was achieved five years ahead of schedule. Most of those who gained access to improved drinking water reside in urban areas, and currently only 4% of the world urban population lack access to improved drinking water sources. But for those who have gained access, reports suggest that services are not reliable, due to several issues of service quality. The water supply services are often intermittent, which increases the risk of contamination for the population and associated health problems.

Furthermore, and even though the access to drinking water target has been met, 780 million people remain without access to an improved water source. The majority of this population, 83%, lives in rural areas (WHO-UNICEF, 2013).

As for access to basic sanitation, unfortunately the world is off track for reaching the target. The world population lacking access to basic sanitation decreased from 51% in 1990 to 37% in 2010. If current trends continue, the world will not meet the sanitation target by 2015 (25% of the world population without access to basic sanitation), since the projections show that 33% of the world population will still be unserved (WHO-UNICEF, 2012). In its most recent update, the WHO reports that 2.5 billion people still lack access to improved sanitation. The majority of these people, 70%, lives in rural area and relies on open defecation.

The lack of access to these basic municipal sanitation services (MSS) has devastating impacts on human health, the environment, and the economies of the affected regions.

1.2 Health Effects

The lack of access to basic municipal sanitation services has detrimental effects on human health. Four main groups of diseases are linked to unsafe drinking water, unclean domestic environment, and improper excreta disposal:

- Waterborne diseases, caused by the ingestion of contaminated water, include cholera, typhoid, dysentery, and diarrheal diseases.
- Water-washed diseases, due to poor hygiene and skin or eye contact with contaminated water, include trachoma and tick-borne diseases.
- Water-based diseases, caused by parasites found in intermediate organisms living in water, include schistosomiasis and intestinal helminths.

- Water-related diseases, caused by insects which breed in contaminated water, include malaria and yellow fever.

Table 1.1 presented below shows estimated of morbidity and mortality of water-related diseases and the relationship of the diseases to water supply and sanitation conditions. Diarrheal disease is the second leading cause of death in children under five years of age. In 2008, the disease killed 1.5 million children in the world (WHO, 2009). This disease most often results from contaminated water and food. Malaria is another water-related disease that has devastating consequences on human health. This disease is caused to poor water management, water storage operations and drainage. In 2010, there were about 216 million cases of malaria diseases in the world, which resulted in about 655,000 deaths (WHO, 2010). The number of deaths from water-related diseases range from 2 million to 12 million per year based upon estimates available in the literature. According to Gleick, current best estimates appear to fall between 2 and 5 million deaths per year (Gleick, 2002).

Table 1-1: Estimates of Morbidity and Mortality of Water-Related Diseases

Diseases	Estimated Morbidity (episodes per year or people infected)	Estimated Mortality (deaths per year)	Relationship of Disease to Water and Sanitation Conditions
Diarrheal diseases	1,000,000,000	3,300,000	Strongly related to unsanitary excreta disposal, poor personal and domestic hygiene, unsafe drinking water
Infection with intestinal helminths	1,500,000,000 (people infected)	100,000	Strongly related to unsanitary excreta disposal, poor personal and domestic hygiene
Schistosomiasis	200,000,000 (people infected)	200,000	Strongly related to unsanitary excreta disposal and absence of nearby sources of safe water
Dracunculiasis	100,000	-	Strongly related to unsafe drinking water
Trachoma	150,000,000	-	Strongly related to lack of face washing, often due to absence of nearby sources of safe water
Malaria	400,000,000	1,500,000	Related to poor water management, water storage, operation of water points and drainage
Dengue fever	1,750,000	20,000	Related to poor solid waste management, water storage, operations of drainage
Poliomyelitis	114,000	-	Related to unsanitary excreta disposal, poor personal and domestic hygiene, unsafe drinking water
Trypanosomiasis	275,000	130,000	Related to the absence of nearby sources of safe water
Bancroftian filariasis	72,800,000	-	Related to poor water management, water storage, operations of water points and drainage
Onchocerciasis	17,700,000	40,000	Related to poor water management in large-scale projects

Source: WHO (1996)

1.3 Economic Effects

Inadequate sanitation or lack of access to improved sanitation services causes considerable economic losses. Several studies analyzed the evidence of the adverse economic impacts of deficient sanitation. These impacts include cost associated with treating diseases and contaminated water, as well as losses in education, productivity, and tourism. Inappropriate water supply and sanitation services result in poor health conditions of the affected population. Indeed this situation is a vicious cycle; the affected families have to spend from their already scarce resources in health care costs to treat the water-related diseases. This expenditure limits further their resources for nutrition, which increases their vulnerability and leads again to poor health.

A study in Pakistan found that populations living in areas without access to improved sanitation services spent six times more on medical treatments than populations enjoying access to improved sanitation (WaterAid, 2006).

Poor sanitation also affects the overall economy of countries whose populations lack access to improved water supply and sanitation. Not only are important resources spent on health care costs to treat water-related diseases, but also is a significant economic income lost every year due to missed school and working days due to ill-health.

A report on the adverse economic impacts of inadequate sanitation in India shows that in 2006, water-related diseases cost the Indian economy 73 million working days that year (WaterAid, 2006). Researchers found that inadequate water supply and sanitation services led to Indian economic losses equivalent to about 6.4 % of India’s GDP in 2006, at US $53.8 billion (Anupam Tyagi et al, 2008).

Another study conducted in Southeast Asia found that the economic cost of a lack of access to water supply and sanitation services amounted to approximately $9.2 billion (2005 prices) in Cambodia, Indonesia, the Philippines, and Vietnam, which represented about 2% of the combined total GDP of these countries (Hutton et al., 2008).

A more recent study on economic impacts of poor sanitation in Africa shows similar conclusions. 18 African countries are losing about US $5.5 billion every year due to inadequate sanitation. These figures could be much larger as the study only deals with losses due to premature deaths, health care costs, and losses in productivity (WSP, 2012). Finally, economic studies of the World Bank over the last 15 years have shown that poor water supply and sanitation services result in losses between 0.5 and 7.2 % of the GDP of developing countries. As reported in the World Bank economic studies and presented in Figure 1-1, the economic costs exceeds 5% of the GDP of countries in Asia (Bangladesh, Cambodia, and India). These costs are related to the health care costs due to water and sanitation related diseases, time spent to access services, pollution of water resources, and adverse impacts on tourism industry (SWA, 2012).

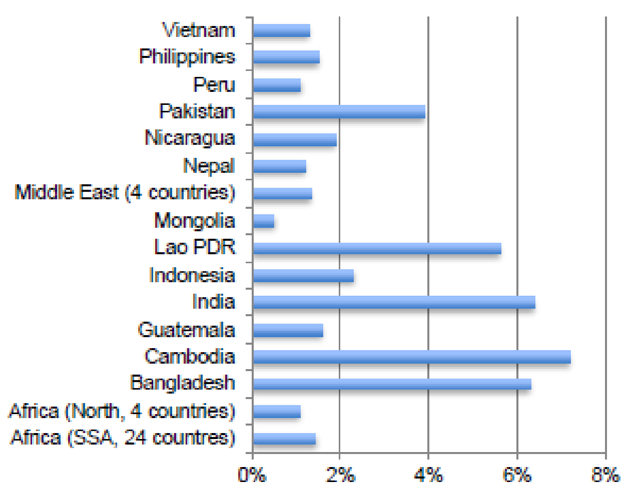


Figure 1-1: Cost of Poor Sanitation as a Percentage of GDP

(Source: SWA, 2012)

1.4 Environmental Effects

Poor sanitation is a major threat to the environment. In areas where the population does not have access to improved sanitation services, wastewater is released directly into rivers or lakes or into ground. This action results in the contamination of ecosystems and the environment. In urban environments, poor management of wastewater and solid waste presents a multiplicity of concerns from favorable grounds for diseases development to contributing to pollution of water, air and soil. The threats also include the degradation of the urban environment when there is arbitrary disposal of solid wastes and liquid wastes. The environmental harms include the contamination of groundwater by leachate from unlined open dumps and the contamination of rivers, streams, and other surface waters, which are often sources of drinking water.

Poor wastewater and solid waste management also results in the loss of important biodiversity. In the case of coastal areas not served by improved sanitation services, sewage and solid wastes are dumped directly into the ocean. This action contributes to the rise of the level of nitrogen in seawater, which causes overgrowth of algae. This overgrowth, in turn, results in the asphyxia and death of coral reefs by restricting their exposure to sunlight.

In developing countries, about 90 percent of sewage is released untreated into the environment, which results in polluting waters and killing plants and fish. This situation has dramatic consequences on the health of the populations who depend upon wells and river streams for their drinking water needs. It results also in important economic losses for the populations whose income depends upon fishing (UN-Water, 2008).

1.5 Millennium Development Goals

There have been significant efforts to address the problem of access to basic sanitation services at the national and international level since the 1970s. The most significant among these efforts was the United Nations International Drinking Water Supply and Sanitation Decade (IDWSSD) 1981-1990 led by the United Nations Development Program (UNDP) and the World Bank (WB). The goal of this initiative was to achieve full coverage of the world population by the end of the decade. Unfortunately, and despite many efforts, this goal was not achieved, and in just over a decade after the end of IDWSSD, its modest gains have been eroded. Indeed, the percentage of the population in developing countries that were not served by improved water and sanitation services declined from 56% to 31%, and 54% to 44%, respectively, between 1980 and 1990. However, from 1990 to 2000, the percentage of developing countries' populations not served by improved water services declined only from 31% to 24%, and, in the case of improved sanitation services, it actually increased from 44% to 51% (WHO/UNICEF, 2000). Having learned from these previous experiences, the United Nations (UN), in its aim to reduce poverty in the world, then established a set of development goals. During the Millennium Summit in 2000, the UN members adopted a set of commitments defined by the UN Millennium Development Goals (MDGs). The overarching goal of the UN MDGs is to reduce the proportion of people living in poverty by half by 2015. The MDGs consist of 8 goals, 18 targets, and 48 indicators, covering the period from 1990 to 2015. Lack of access to safe water and improved sanitation is recognized as part of the problem of the world poverty. This issue is addressed by MDG 7 - Target 7.C which aims to "Halve by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation". However the analysis of the current situation indicates that existing approaches to provide these basic services are failing because the percentage of underserved populations remains unacceptably high, especially in the case of sanitation services. The Millennium Development Goals (MDG), their targets, and the respective indicators for monitoring progress are presented in Table 1-2 below.

Table 1-2: MDG and Their Indicators for Monitoring Progress

Millennium Development Goals (MDGs)	
Goals and Targets (from the Millennium Declaration)	**Indicators for monitoring progress**
Goal 1: Eradicate extreme poverty and hunger	
Target 1.A: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day	1.1 Proportion of population below $1 (PPP) per day 1.2 Poverty gap ratio 1.3 Share of poorest quintile in national consumption
Target 1.B: Achieve full and productive employment and decent work for all, including women and young people	1.4 Growth rate of GDP per person employed 1.5 Employment-to-population ratio 1.6 Proportion of employed people living below $1 (PPP) per day 1.7 Proportion of own-account and contributing family workers in total employment
Target 1.C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	1.8 Prevalence of underweight children under-five years of age 1.9 Proportion of population below minimum level of dietary energy consumption
Goal 2: Achieve universal primary education	
Target 2.A: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	2.1 Net enrolment ratio in primary education 2.2 Proportion of pupils starting grade 1 who reach last grade of primary 2.3 Literacy rate of 15-24 year-olds, women and men
Goal 3: Promote gender equality and empower women	
Target 3.A: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	3.1 Ratios of girls to boys in primary, secondary and tertiary education 3.2 Share of women in wage employment in the non-agricultural sector 3.3 Proportion of seats held by women in national parliament
Goal 4: Reduce child mortality	
Target 4.A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	4.1 Under-five mortality rate 4.2 Infant mortality rate 4.3 Proportion of 1 year-old children immunised against measles
Goal 5: Improve maternal health	
Target 5.A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio	5.1 Maternal mortality ratio 5.2 Proportion of births attended by skilled health personnel
Target 5.B: Achieve, by 2015, universal access to reproductive health	5.3 Contraceptive prevalence rate 5.4 Adolescent birth rate 5.5 Antenatal care coverage (at least one visit and at least four visits) 5.6 Unmet need for family planning

Table 1-2 (continued)

Goal 6: Combat HIV/AIDS, malaria and other diseases	
Target 6.A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS	6.1 HIV prevalence among population aged 15-24 years 6.2 Condom use at last high-risk sex 6.3 Proportion of population aged 15-24 years with comprehensive correct knowledge of HIV/AIDS 6.4 Ratio of school attendance of orphans to school attendance of non-orphans aged 10-14 years
Target 6.B: Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it	6.5 Proportion of population with advanced HIV infection with access to antiretroviral drugs
Target 6.C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	6.6 Incidence and death rates associated with malaria 6.7 Proportion of children under 5 sleeping under insecticide-treated bednets 6.8 Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs 6.9 Incidence, prevalence and death rates associated with tuberculosis 6.10 Proportion of tuberculosis cases detected and cured under directly observed treatment short course
Goal 7: Ensure environmental sustainability	
Target 7.A: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources Target 7.B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss	7.1 Proportion of land area covered by forest 7.2 CO2 emissions, total, per capita and per $1 GDP (PPP) 7.3 Consumption of ozone-depleting substances 7.4 Proportion of fish stocks within safe biological limits 7.5 Proportion of total water resources used 7.6 Proportion of terrestrial and marine areas protected 7.7 Proportion of species threatened with extinction
Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	7.8 Proportion of population using an improved drinking water source 7.9 Proportion of population using an improved sanitation facility
Target 7.D: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers	7.10 Proportion of urban population living in slums
Goal 8: Develop a global partnership for development	
Target 8.A: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system Includes a commitment to good governance, development and poverty reduction – both nationally and internationally Target 8.B: Address the special needs of the least developed countries Includes: tariff and quota free access for the least developed countries' exports; enhanced programme of debt relief for heavily indebted poor countries (HIPC) and cancellation of official bilateral debt; and more generous ODA for countries committed to poverty reduction	*Some of the indicators listed below are monitored separately for the least developed countries (LDCs), Africa, landlocked developing countries and small island developing States.* Official development assistance (ODA) 8.1 Net ODA, total and to the least developed countries, as percentage of OECD/DAC donors' gross national income 8.2 Proportion of total bilateral, sector-allocable ODA of OECD/DAC donors to basic social services (basic education, primary health care, nutrition, safe water and sanitation) 8.3 Proportion of bilateral official development assistance of OECD/DAC donors that is untied 8.4 ODA received in landlocked developing countries as a proportion of their gross national incomes 8.5 ODA received in small island developing States as a proportion of their gross national incomes.

Table 1-2 (continued)

Target 8.C: Address the special needs of landlocked developing countries and small island developing States (through the Programme of Action for the Sustainable Development of Small Island Developing States and the outcome of the twenty-second special session of the General Assembly) Target 8.D: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term	8.6 Net ODA, total and to the least developed countries, as percentage of OECD/DAC donors' gross national income 8.7 Proportion of total bilateral, sector-allocable ODA of OECD/DAC donors to basic social services (basic education, primary health care, nutrition, safe water and sanitation) 8.8 Proportion of bilateral official development assistance of OECD/DAC donors that is untied 8.9 ODA received in landlocked developing countries as a proportion of their gross national incomes 8.10 ODA received in small island developing States as a proportion of their gross national incomes Market access 8.11 Proportion of total developed country imports (by value and excluding arms) from developing countries and least developed countries, admitted free of duty 8.12 Average tariffs imposed by developed countries on agricultural products and textiles and clothing from developing countries 8.13 Agricultural support estimate for OECD countries as a percentage of their gross domestic product 8.14 Proportion of ODA provided to help build trade capacity Debt sustainability 8.15 Total number of countries that have reached their HIPC decision points and number that have reached their HIPC completion points (cumulative) 8.16 Debt relief committed under HIPC and MDRI Initiatives 8.17 Debt service as a percentage of exports of goods and services
Target 8.E: In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries	8.18 Proportion of population with access to affordable essential drugs on a sustainable basis
Target 8.F: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications	8.19 Fixed telephone lines per 100 inhabitants 8.20 Mobile cellular subscriptions per 100 inhabitants 8.21 Internet users per 100 inhabitants

Source: http://mdgs.un.org/unsd/mdg/host.aspx?Content=indicators/officiallist.htm

The MDGs and targets come from the Millennium Declaration signed by 189 countries, including 147 heads of State and Government in September 2000. The MDGs and targets are unified and should be considered as a whole. They embody a partnership between the developed countries and the developing countries to create an environment which is aimed at eliminating poverty and promoting development.

Chapter 2. Problem Definition

2.1 General Definitions

2.1.1 Municipal Sanitation Service

In this research, the term municipal sanitation service refers to any of the three basic sanitation services, namely, drinking water supply (DWS), wastewater sewage and treatment (WST) or management of solid waste (MSW). Figure 2.1 illustrates the three municipal sanitation services.

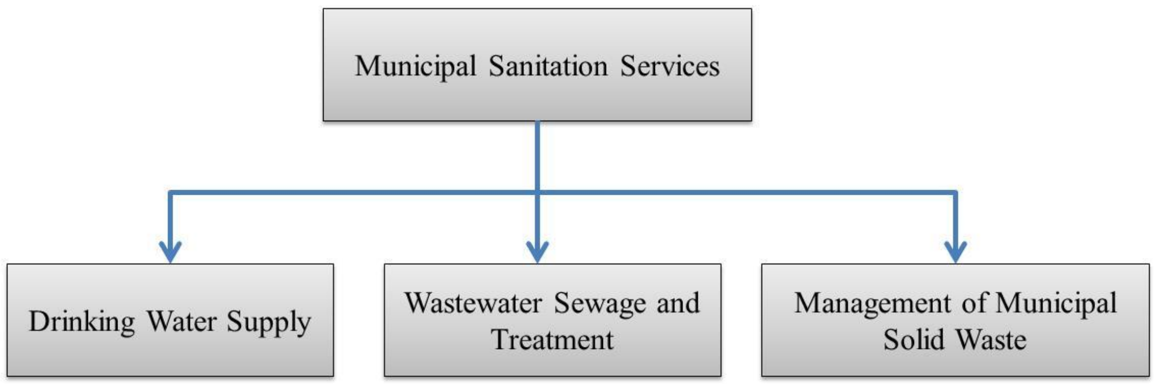


Figure 2-1: Municipal Sanitation Services

A general description the three sanitation services presented hereafter is adapted from the US Census Bureau.

- Drinking water supply (DWS) is the construction, operation, and maintenance of public water systems, including production, acquisition, and distribution of water to general public for residential, commercial, and industrial use.
- Wastewater and sewage service (WST) is defined as the provision, operation, and maintenance of sanitary and storm sewers systems, sewage disposal, and treatment facilities.

- Solid waste management (MSW) is defined as the collection, removal, and disposal of garbage, refuse, hazardous, and other solid wastes.

2.1.2 Capacity and Capacity Building

Capacity is defined as “the ability of individuals, organizations or systems to perform an appropriate function effectively, efficiently and sustainably “(Milen, 2001). During the past two decades, capacity building mainly focused on the training of individuals and development of institutions. International development organizations, such as the UNDP and the World Bank, have focused capacity building on development cooperation, and more specifically, technical cooperation. The results of this experience are documented by (Hopkins, 1994), who draws the following conclusions:

- Technical cooperation was conducted by a project approach, and it has led to a myriad of poorly connected projects.
- Technical cooperation was a good and reliable tool in providing direct support for operations.
- The record is poor when it comes to the transfer of know-how and capacity building.

Operations and maintenance of infrastructure have been neglected in a great number of developing countries. The WHO estimates that 30% to 60% of existing water and sanitation systems are not operational, which has an important impact on the well-being of the concerned population (Brikke et al., 1995). From the analysis of failure in development cooperation, new concepts of capacity buildings have emerged. They are based mainly on two elements:

- The emphasis on the local community;

- The performance and the capacity of an organization or a system are influenced by both internal and external factors.

The United Nations Development Program and the International Institute for Hydraulic and Environmental Engineering, (UNDP, 1991) have defined capacity building in the water sector as:

- The creation of an enabling environment with appropriate policy and legal frameworks;
- Institutional development, including community participation (of women in particular);
- Human resources development and strengthening of managerial systems.

2.1.3 Sustainability

Goal # 7 of the eight Millennium Development Goals (MDGs), is to "ensure environmental sustainability: water and sanitation" (UNGA, 2001). Sustainability is a widely used term in different contexts. In development, sustainability implies that a system:

- Provides an improvement in quality of life for most of the population
- Conserves impacted ecosystems.

Sustainable development has also been defined by the Brundland Commission as "a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WEDC, 1987). This condition could be achieved only "if economic and social systems encourage environmental stewardship of resources for the long term, with acknowledging the interdependency of social justice, economic well-being, and environmental preservation" (Haughton, 1999).

In the case of drinking water supply, sustainability means:

- Water resources are not overexploited;
- Facilities are maintained in a condition that provides reliable service;
- Service is provided for successive generations at the required level.

2.1.4 Developing Communities

The World Bank (WB) classification of countries by income is used as basis to define developing communities. The WB proposes a classification of countries by gross national income (GNI) per capita. This classification is based upon the 2012 GNI per capita, calculated using the WB Atlas method. There are four groups of countries in this classification: low income, $1035 or less; lower middle income, $1036 - $4,085; upper middle income, $4,086 - $12,615; and high income, $12,615 or more (World Bank, 2013). The classification of countries by GNI is summarized in Table 2.1. The WB classifies all low-income and middle-income economies as developing economies. (World Bank, 2013).

In order to avoid the potential of misleading association with income, the term developing community will be used instead of lower-income community. A developing community is one which lacks the capacity to provide sustained access to adequate levels of one or more basic human services to its residents with its own resources. The basic human services are air, water, food, shelter, sanitation, household energy, and personal security. Sustained access is uninterrupted access to scheduled levels of service over the planning horizon of the system that provides the service. For the purpose of this research, a community is defined as a group of people that occupy a single defined geographic area, and are supposed to receive public services like water supply and sanitation from a common jurisdiction.

Table 2-1: Classification of Countries

Group	Low Income ($)	Lower Middle Income ($)	Upper Middle Income ($)	High Income ($)
GNI per Capita	1,025 or less	1,026-4,035	4,036 – 12,475	12,0476 or more

Source: World Bank (2013)

2.1.5 Appropriate Technology

The idea of *appropriate technology* was defined initially by the concept of *intermediate technology*, and developed by economists such as Schumacher (Akabue, 2000). Indeed *intermediate technology* was designed for Third World countries as a substitute to the capital-intensive technology of modern industry. However, this concept of *intermediate technology* showed its limits because it suggested that these technologies were inferior or second-rate (Kaplinski, 1990) and also because it conveyed only the economic and engineering aspects of the technology. Appropriate technology has been practiced for many decades, but it has evolved recently into a development approach for community development problems. This approach to community development, through appropriate technology, consists of a body of knowledge, techniques, and a core philosophy. The underlying philosophy is defined as a complete systems approach to development that is both self-adaptive and dynamic. As Dunn (1978) defines it, “Appropriate technology not only best suits the conditions and needs of a community but allows its users to become more skilled and wealthier. They can then both afford and use more sophisticated and expensive technical means as they build their capacity.”

Therefore, appropriate technology should suit the conditions and needs of a community at a given stage in its development and allow its members to build their capacity to be able to select and manage more sophisticated technologies for their needs in the future.

The concept of appropriate technology used in this research applies the same approach to community development. This approach is based on the fact that appropriate technology is an effective way to shift to modern technology, and therefore is a transitional and not a static approach. This notion also suggests that all alternatives should be researched to "best fit" the community's needs without limiting the choices to only "low-level" technology options. Communities within the same country may have different capacities, and therefore their needs will be addressed by the appropriate technological approach.

2.2 Access to Water Supply and Sanitation Services

To achieve the MDG 7 - target 7.C, the numbers of new water and sanitation facilities required are stunning. In Africa, 440 million people must have access to safe water and sanitation by 2015. Furthermore, the rate of failure of installed Watsan infrastructure is too high to achieve a sustainable access to the basic sanitation services. According to Jan and Brikke (1995), 30% to 60 % of Watsan infrastructures in the world are not operating. Most of these failed systems are in Africa, Asia, and Latin America and the Caribbean. Estimates suggest that of the 250,000 hand pumps installed in Africa, fewer than half of them are functioning (HTN, 2003).

Despite important efforts that have been made during the past four decades to address this issue and the progress made as reported in the most recent WHO-UNICEF report (WHO-UNICEF, 2012), these achievements could be unsustainable if we do not provide the appropriate solution for the Watsan systems to be implemented. The problem we propose to address in this research is to improve the decision making process for the Watsan technology selection for access to water supply and sanitation services in developing countries.

2.3 High Rate of Failure

Indeed in developing countries, too many Watsan infrastructures often fail only a few years after construction. Despite important efforts to provide access to MSS in developing countries, the high rate of failure of Watsan infrastructure has greatly affected the access to water supply and sanitation services in developing communities. Inappropriate technology is one of the most commonly cited reasons for the relatively high rate of failure of Watsan systems in developing countries (Black, 1998). Case studies refer to a shortage of spare parts, unreliable power supply, cost of chemicals and other supplies, lack of institutional support, failure to charge fees for service, and the exclusion of women as caretakers of the infrastructure among the reasons the infrastructure and its associated technology were inappropriate for the local community in which they were installed (UNDP-WB, 1997). A more recent study of the International Institute for the Environment and Development reports that too many water supply infrastructures in Africa are not sustainable. The water and sanitation foundation Fairwater estimates that 50,000 water supply infrastructures in Africa are not functional, often only few years after construction. Recent surveys in the Menaca region of Mali show that 80 percent of wells were dysfunctional, and in Northern Ghana, 58 percent of water points needed repair (IIED, 2009). To the extent that inappropriate technology is a significant factor in the failure of infrastructure systems, what is needed is a proven, objective, adaptable set of guidelines that communities and infrastructure financing agencies can use to select contextually appropriate Watsan technologies for developing communities.

2.4 Community-Based Approach

Community-based approaches have shown encouraging results in sustained access to water supply and sanitation services in developing communities. A research conducted by the Social Capital Initiative at the World Bank has studied the effectiveness of community-based approach in water projects. This study was conducted in Central Java through a survey of 1100 households in 44 villages. The conclusion of the research shows that the community-based approach improves the performance and impact of water supply services. The research further shows that involving community members in the early stages of the project, such as the design process, and allowing them to make the final decisions about the technology and service level results in better performance and success of water projects (Isham, 1999).

The community-based approach in water supply and sanitation services promotes the contribution of village households in the construction, operation, and maintenance of the Watsan infrastructure. This contribution results in better performance and impact of the services in the long run. The community-based approach could be even more effective in communities with high levels of social capital. Indeed with active village groups and associations, the community-based approach encourages the participation of village members in the service design and implementation of monitoring mechanisms. This approach results in more sustainable services, as the community members are more willing to pay and maintain the water supply and sanitation services.

2.5 Selection Problem

Another challenge developing communities face during the selection process is the very large numbers of Watsan technology options available for providing an MSS. Indeed, for DWS service, every technology option is constituted by five unit processes; namely a *source*, a *device*, a *treatment*, a *storage* and a *distribution*. Figure 2.2 below presents the five unit processes for DWS service.

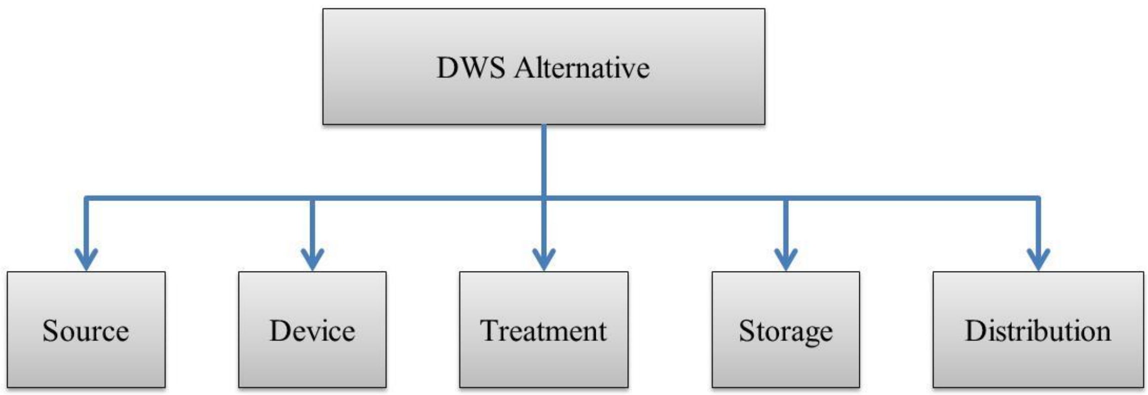


Figure 2-2: DWS Unit Processes

For DWS service, the unit process *source* could be one the following:

- for *rainwater*
    - rooftop rainwater harvesting catchment
    - storage dams
- for *groundwater*
    - spring water collection
    - dug well
    - drilled well
- for *surface water*
    - protected side intake

- river-bottom intake
- floating intake

Similarly many alternatives exist for each of the unit processes *device, treatment, storage, and distribution*. The number of possible alternatives to provide DWS service is obtained by combining the unit processes together. When we combine the different unit processes to constitute a feasible DWS technology option or alternative, the number of options to provide safe drinking water is estimated to be more than 774 alternatives. The inventory of the technology options for DWS is presented in Appendix G. Therefore, the problem we propose to address in this research is also a selection problem. Indeed the model we present here will assist developing communities in selecting an appropriate Watsan technology option that they can operate and manage sustainably from the large number of available DWS alternatives.

2.6 Scope

An important component of the definition of this problem is its scope. Indeed the model presented in this research is limited to the use by developing communities. It focuses exclusively on the access to basic municipal sanitation services by developing communities living in rural and low-income urban areas. In this research, we propose to use the WB classification of developing economies as a basis for the definition of developing communities. Furthermore, developing communities could be living in any of the four groups of countries defined in the WB classification: low income, lower middle income, higher middle income, or high income; developing communities might also not necessarily be solely in low income or lower middle income countries only.

The current status of access to municipal sanitation services (MSS) in a developing community is also a key point in addressing the scope of the problem. The community could already have a basic MSS and wish to expand it or could be at a stage where no formal MSS is available to the population. In either of these two cases, the proposed model must be able to assist a developing community in the selection of appropriate Watsan technologies to provide access to basic MSS.

Chapter 3. Literature Review

Water supply and sanitation services continue to be lacking mainly in developing countries. Previous programs to address this issue from the early sixties to the late eighties have relied on massive centralized investments, including the International Drinking Water Supply and Sanitation Decade (IDWSS), from 1981 to 1990. The goal of the IDWSSD was to achieve full coverage of the world population for water supply and sanitation services. At the end of the decade, and despite the fact that more than 1.2 billion people gained access to water supply and almost 770 million to improved sanitation, about 1.1 billion people still suffered inadequate access to water supply and 2.4 billion lacked appropriate sanitation (WHO, 1990). Unfortunately, the only success achieved during the IDWSSD was to keep pace with the growth of the population in most underserved regions. Among the key lessons learned at the end of the decade was, as reported by Choguill, “the importance of comprehensive and balanced country-specific approaches to the water and sanitation problems” (Choguill, 1993). In other words, community-based approaches were strongly recommended in addressing water and sanitation problems. In the 1990s, new approaches were adopted, with a shift from large centralized projects led by government and international development agencies to community-based projects led by local organizations and the private sector. Despite some success with these new approaches, the number of people without adequate water supply and sanitation services remains as large as it was a decade ago (Palaniappan et al. 2008).

3.1 Policy Approaches

The analysis of the past water and sanitation policies and strategies of overseas development assistance (ODA) and developing countries show that they were inadequate and unsuccessful. Until the early nineties, the approaches adopted were mainly project-specific and little sharing of information and experiences related to water and sanitation policies between ODA organizations and developing countries occurred (Grover, 1998). At the end of the IDWSSD in 1990, ODA organizations and developing countries began to share best practices and knowledge acquired through experience with water and sanitation policies. Table 3-1 below presents the evolution of water and sanitation policies and strategies since the early sixties, with the key issues of their foci.

Table 3-1: Evolution of Water Sector Development Policies and Strategies

Period	**Overall description of policy and strategy thinking among donor agencies**	**Landmark events with impact on international water policies**	**Emphasis on selected issues and aspects**
1950-1960	Recognizing the importance of water and sanitation for better health and development. Most developing countries were still under colonial water management.	First bilateral donor agencies established	Health aspects
1961-1970	Series of water crisis and linkage of the crises with population growth. Free or heavily subsidized water in many developing countries. Post-colonial efforts for independence and self-reliance by developing countries.	Regional development bank (ADB, AfDB, IADB) established.	Technical aspects. Water production.
1971-1980	UN initiative and preparation of the water decade with a series of international conferences. This period still followed the classical public health paradigm of engineering solution in tackling the challenge. Water as social good.	UN Conference on Human Environment (Stockholm, 1972). UNEP established (1972). UN Water Conference (Mar del Plata, 1977). UNDP-WB Water and Sanitation Program established (1978). UNCHS (Habitat) established (1978). Hydrology decade.	Technical aspects. Project implementation . Social aspects. Rural water supply. Urban sanitation.
1981-1990	Major international effort through the Water Decade activities. Supply-driven approach (SDA). Introduction of low-cost affordable technologies, capacity building, and the realization that community participation is the key for sustainable projects. Decentralization. Water was considered as an economic good. Yet, emphasis was on the public health aspects of water supply and sanitation.	International drinking water supply and sanitation decade (IDWSSD, 1981-1990). Global consultation on safe water and sanitation for the 1990s (New Delhi, 1990). UN General Assembly (1990). Water Supply and Sanitation Collaborative Council WSSCC, 1990).	Technical aspects. Project implementation . Operation and maintenance. Social aspects. Economic value of water. Capacity building. Rural water supply and sanitation. Handpump technology.

Table 3-1 (continued)

1991-2000	Post Water Decade period with some frustration on modest decade achievements. CSD6 considered water one of two important issues. In the UN Special Session for Rio+5 in 1997, water supply and sanitation was identified as the priority area for UN and all organizations concerned. Yet, there has been a reduction in actual global investment in WSS. Water and sanitation as a basic human need. Management and use of water as a part of environmental protection and sustainable development. Concern about water scarcity and pollution. Management of water at the lowest possible level. Customer orientation. Demand-driven approach (DDA). Demand-responsive approach (DRA). Development of the World Water Vision until 2025.	UNDP Capacity Building Symposium (Delft, 1991). Nordic Freshwater Initiative (1991). International Conference on Water and the Environment (Dublin, 1992). UNCED Earth Summit (Rio, 1992). Rio Declaration. Agenda 21. CSD. Drinking Water and Environmental Sanitation Conference & Ministerial meeting (Noordwijk, 1994). UN Conference on Population and Development (Cairo, 1994). World Summit for Social Development (Copenhagen, 1995). Habitat II (Istanbul, 1996) World Food Summit (Rome, 1996). World Water Council (WWC, 1996) and Global Water Partnership (GWP, 1996). First World Water Forum (Marrakesh, 1997). Second World Water Forum (The Hague, 2000) World Water Vision (2000). Vision 21 (2000). Iguacu Action Programme (2000). UN Millennium Assembly (New York, 2000). UN Millennium Declaration 2000.	Environmental aspects. NGO and CBO role becoming stronger. Role of women. Gender issues. Water as economic good. Institutional strengthening. Poverty alleviation. Urban and peri-urban water supply and sanitation.
2001-	Implementation and empowering the Vision. Increased responsibility to user communities, governments as facilitators. Networking and partnership approaches. Advocacy. Attention to water scarcity in certain regions. Transboundary water resources. Water conflicts. River basin mgt. Water supply and sanitation as a basic human right.	International Conference on Freshwater (Bonn, 2001). World Summit on Sustainable Development (WSSD, Rio+10, Johannesburg, 2002). Third World Water Forum (Kyoto, 2003). International Freshwater Decade Year 2003.	Private sector. Hygiene and sanitation. Tradable water rights. Water allocation. Hydrosolidarity. Water security. Water ethics. IWRM. Good governance.

Source: Seppälä, 2002

In his review of effective water and sanitation policy reform implementation, Seppälä identified the major approaches and changes in water and sanitation policies over the last decades. The summary of the changes are presented in Table 3-2 below (Seppälä, 2002).

Table 3-2: Major Approach Changes in Water and Sanitation Policies

Old Thinking	→	New Thinking
Water development		Water allocation
Emphasis on water quality		Emphasis on water quality or quality-quantity
Water and sanitation as basic human needs		Water and sanitation as basic human rights
Water as social good		Water as an economic good
Centralized management and administration		decentralized management and administration
Government (state) provision		Government facilitation
Administrative domain		Service domain
Supply-driven approach		Demand-driven approach: demand-responsive approach (DRA)
Water supply		Water services
Production (agency) orientation		Customer appreciation
Hardware projects		Software projects

Source: Seppälä, 2002

In terms of policy approaches to solve the problems of access to safe drinking water and improved sanitation, two major shifts have taken place in recent years. The first one was a shift of approach from supply-driven to demand-led at the project level. Indeed supply-driven Watsan interventions have not succeeded in providing developing communities with sustainable MSS. Communities that did not play a role in the selection and implementation of Watsan technologies did not feel a sense of ownership of the project. On the other hand, demand-led approaches require communities to take a leading role, and have shown much more success in delivering sustainable access to basic water supply and sanitation services (Breslin, 2003).

At the international development organizations level, has occurred a shift of donor support from a project-based approach to a budget support one. The project-based approach, where individual donor governments funded their own development initiatives in developing countries, led to some notable successes. However too many cases of projects where water and sanitation conditions were not improving after few years remained. The logic behind the move to budget support is to help developing country governments assume more responsibility for their people, and to build their capacity to deliver services to their entire populations. The budget support approach contributes to promote good governance and to enhance capacities within developing countries (Koeberle, 2006).

3.2 Technology Solutions

Many support tools are available to assist practitioners, community members, and government agencies in the selection, implementation, and maintenance of technologies for water supply and sanitation services. In a recent report of the Woodrow Wilson Center and the Pacific Institute, Palaniappan et al. (2008) completed a review of 120 existing support resources for the selection of technologies for Watsan practitioners. Five types of support tools were identified: evaluation tools, process guides, technical briefs, technical references, and policy papers. After reviewing these 120 decision support resources, Palaniappan et al. selected 18 of them that provide the most comprehensive decision-making supports to water and sanitation practitioners. Table 3-3 below summarizes these support resources that are the closest to an optimal water supply and sanitation decision-making support tool.

Table 3-3: Support Resources to WSS Decision-Making Support Tool

Authors	Decision-Making Support Tools
Australian Agency for International Development	Safe water guide for the Australian aid program (2005).
Brikke, F. and Bredero M.	Linking technology choice with O&M in the context of community water supply and sanitation (WHO, 2003).
Cotruvo , J. et al.	Providing safe drinking water in small systems: Technology, operations, and economics (NSF, WHO and PAHO, 1999).
Department of Water Affairs and Forestry, South Africa.	Introductory guide to appropriate solutions for water and sanitation (2004).
Deverill et al.	Designing water supply and sanitation projects to meet demand in rural and peri-urban communities (2002).
Huuhtanen, S. and Laukkanen, A.	Guide to working in sanitation and hygiene for those working in developing countries (2006).
Lantage et al.	Household water treatment and safe storage options in developing countries: Review of current implementation practices (2007).
ROLAC – UNEP	Recommendations on basic sanitation and municipal wastewater for Latin America & the Caribbean (2003).
Skinner, B. - WELL	Small-scale water supply: a review of technologies (2003).
Smet, J. Van Wijk, C. – IWSC	Small community water supplies (2002).
UNEP	International source book on environmentally sound technologies for wastewater and stormwater management (2000).
UNICEF	Towards better programming: A sanitation handbook (1997).

Table 3-3 (continued)

Authors	Decision-Making Support Tools
UNICEF	Towards better programming: A water handbook (1999).
Finney, B.A. and Gearheart, R.A – University of Humboldt	Water and wastewater technologies appropriate for reuse model.
WELL	WELL Technical briefs.
WELL	Guidance document on water supply and sanitation programmes (1998).
World Bank	Manual on low cost sanitation technologies for Ger Areas, Mongolia (2006).
WSP and WUP	Water and sanitation for all: A practitioners' "companion" (2003).

Source: Palaniappan et al. (2008)

Palaniappan et al. identified four important components within these 18 support resources that constitute the key characteristics of an ideal decision-making support tool: Sector, Locale, Topics, and User. The definitions of these components as provided by Palaniappan are reported below:

- "Sector, represents the area of focus of the support resources such as water supply, drinking water treatment, sanitation, wastewater treatment, and hygiene.
- Locale, indicates a support resource that targets the location of the community, which is captured by the regional specificity and the types of communities (rural, peri-urban, urban).
- Topics, includes information on construction, O&M, community involvement, cost, evaluation and monitoring, scalability and replicability, and case studies.
- User, refers to the user interface of the support resource that allows users to specify the conditions of the community through inputs to provide outputs that are relevant based on the community's conditions" (Palaniappan et al. 2008).

The conclusion of this review shows that there exists a need for a decision-making support tool to assist Watsan practitioners in identifying, evaluating, and choosing a technology option that best suits the conditions and needs of a community. The most common missing elements among the support resources evaluated were social factors, regional specificity, and project replicability. Other missing items were information on cost and financing and an effective user interface.

Chapter 4. Proposed Approach

4.1 Goal and Objectives

The goal of this research is to develop a decision making model for selecting appropriate Watsan technologies to provide sustained access to water supply and sanitation services for developing communities. This goal is achieved through four objectives:

1) To develop a systemic and objective method for assessing a community's capacity level (CCL) to manage a MSS,
2) To develop a method for the classification of Watsan technologies with the technology requirement level (TRL) metric, by using machine learning algorithms, such as Support Vector Machine (SVM),
3) To develop a decision support system (DSS) with database of Watsan technologies, classified by the MSS they provide and ranked by the technology requirement level (TRL) needed to operate and manage them sustainably,
4) To develop a reliable and reproducible procedure, within the DSS, for the selection of appropriate Watsan technology options that matches the community's capacity level (CCL).

4.2 Proposed Approach

To achieve this goal and these objectives, we propose a decision model with a framework that uses the same pedagogy as the risk analysis one, namely, assessment, evaluation, and management. The decision model with its three main components is presented in Figure 4-1. The decision component #1 of the model is the *Assessment* component. It provides decision tools for the selection of appropriate Watsan alternatives. The decision component # 2 is the *Evaluation*, which is used to evaluate and rank the set of Watsan alternatives selected in decision component # 1. Finally, the third decision component, the *Management* component, provides guidance for the implementation of the Watsan technologies selected for an integrated municipal sanitation service.

This research focuses mainly on the first component of the decision model. Indeed component #1 provides tools for the assessment of a community's capacity to operate and maintain sustainably a municipal sanitation service, and for the selection of appropriate Watsan technology options that match the assessed community's capacity. The decision making process is achieved with the combination of two modules of component #1: the *Capacity Factor Analysis* (CFA) module, used for the assessment of a community's capacity level (CCL) to manage a MSS, and the *Decision Support System* (DSS) with a database of Watsan technologies classified by the MSS they provide and ranked by the technology requirement level (TRL) needed to operate them sustainably.

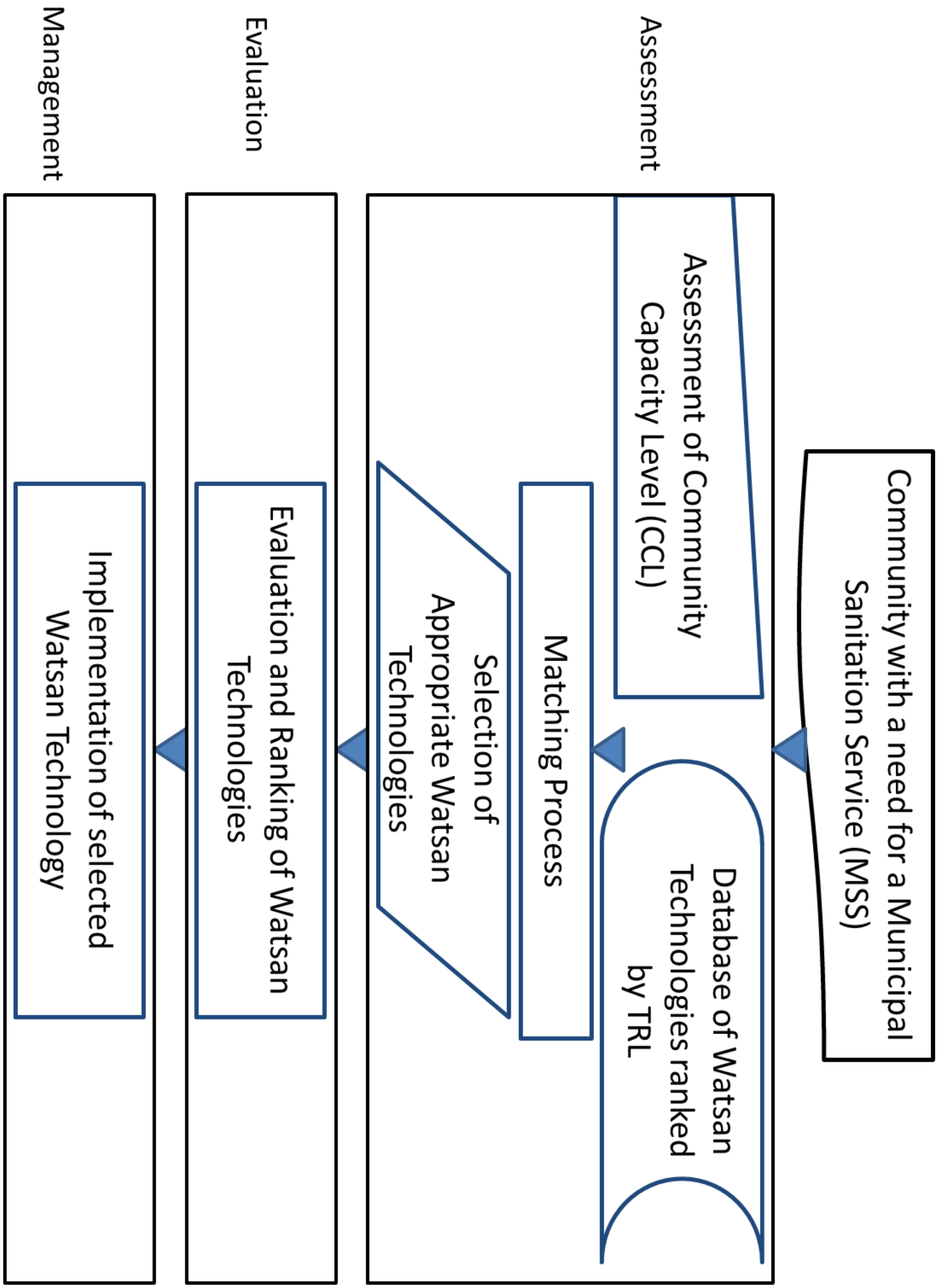


Figure 4-1: Decision Model for the Selection of Appropriate Watsan Technologies

Louis proposed to use eight capacity factors to capture a community's ability to operate and manage sustainably an MSS (Louis, 2003a – Louis, 2003b). These eight CF are gleaned from the literature on appropriate technology and explanatory factors for the success or failure of Watsan infrastructure in developing communities. These CF are *service, institutional, human resources, technical, economic, energy, environment, and social/cultural*. Louis and Bouabid have developed a method for assessing a community's capacity to manage Watsan infrastructures (Bouabid, 2004 – Louis and Bouabid, 2004). The assessment of the community's capacity to manage water supply and sanitation systems is performed with the eight capacity factors (CF). The model used for the assessment of these CFs is the capacity factor analysis model (CFA). Guidelines of the CFA model have been developed for the three MSSs. The guidelines for the assessment of the capacity factors of a community for the three MSSs are presented in Appendix A, Appendix B, and Appendix C respectively. These guidelines allow one to determine the *Community's Capacity Level* (CCL) for a host community, based on the assessment of its capacity factors.

The second module of the decision component #1 used in the selection process is a DSS with a database of Watsan technologies classified by the MSS they provide and ranked by the *Technology Requirement Level* (TRL) needed to operate and maintain them sustainably. The database includes for each MSS provided, an inventory of Watsan infrastructures successfully implemented and operating in developing communities, classified by their TRL and with the profile of their host communities. This database of Watsan options implemented and operating sustainably in developing communities with the profiles and CCLs of their host communities constitutes the central element of the decision component #1. The two modules of component #1, the CFA and the DSS, are then used by a matching algorithm to select appropriate Watsan technology options that can be used to provide a sustainable MSS to a host community.

Chapter 5. Community's Capacity Level Assessment

5.1 Assessment Approach

The assessment of the overall community's capacity to operate and manage sustainably an MSS is performed with the assessment of the capacity factors of the community. In this proposed approach, eight capacity factors have been identified as playing a key role in the sustainability of municipal sanitation services in developing communities. The eight capacity factors identified for the assessment of the community are used as core criteria in this proposed model for the selection of appropriate Watsan technologies to provide sustainable municipal sanitation services. These capacity factors and their constituents are defined for each municipal sanitation service, namely drinking water supply (DWS), wastewater sewage and treatment (WST), and management of solid waste (MSW). Benchmarks and international standards for the constituents of the eight CFs are used to assess the CFs. The assessment of the CFs is conducted on a scale of five capacity levels, each of which corresponds to one of the five stages of development of a community regarding its capacity of managing an MSS. These eight CFs as offered by Louis (Louis, 2002) are presented in Figure 5-1.

Figure 5-1 illustrates the developing community with the eight capacity factors and their respective constituents used for the assessment of the community's capacity to operate and maintain a municipal sanitation service (MSS).

The method developed for the assessment of the community's CFs for operating and maintaining an MSS is presented in the following section and constitutes the Capacity Factor Analysis (CFA) model.

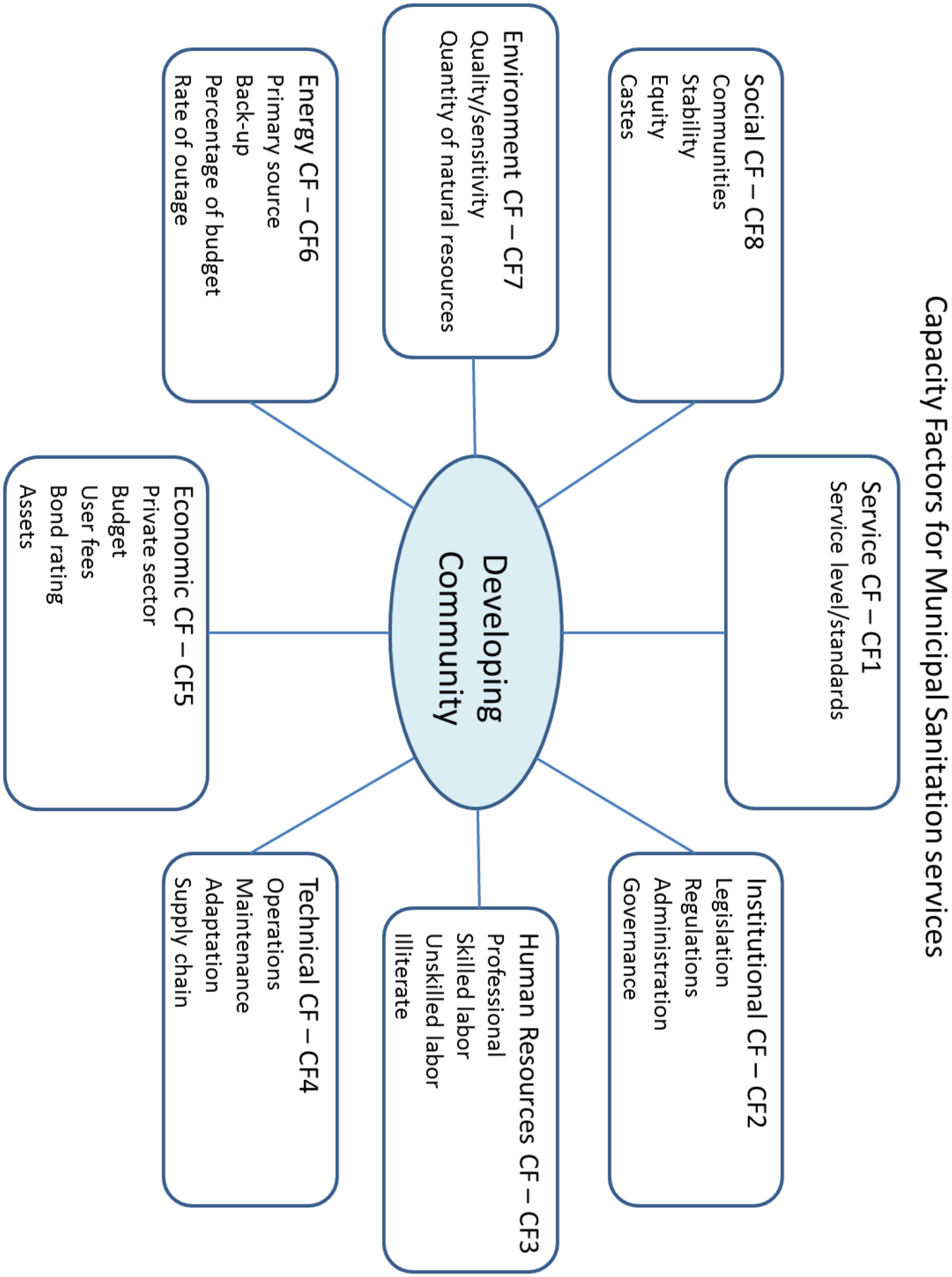


Figure 5-1: Community Capacity Factors that Influence Sustainability of MSS

5.2 Capacity Factor Analysis

In risk analysis, quantitative risk assessment builds on the probabilities and outcomes of undesirable events. One method used to dissect the probability axis into sections is the fractile method. Each fractile relates to an outcome based on experts' evidence assessment (Haimes, 1998). The probability density function (pdf) is then constructed on the basis of the knowledge generated through the fractile method. In the discrete case, the pdf is divided into n segments of consequences x_i, each related to a probability p_i, such that the expected value E[x] is defined by:

$$E[x] = \sum_{i=1}^{n} x_i p_i \qquad \text{for } i = 1, \ldots, n$$ **Equation 5-1**

In capacity assessment, the fractile method is used to partition the capacity factor space. The community's capacity factor score is the outcome of the assessment. Each capacity factor is scored on a 100 points scale derived from the weighted sum of its constituents assessment scores. An adaptation of the weighted sum model (WSM) method is used for the score of the assessment of the capacity factor. The WSM method is the most commonly used approach, especially in single dimensional problems (Triantaphyllou, 2000). The WSM is adapted for our purpose from Equation 5-2, which is used to compare m different alternatives for the selection of the one that has the maximum score:

$$A_{WSM-Score} = \max \sum_{j=1}^{n} a_{ij} w_{ij} \qquad \text{for } i = 1, 2, \ldots, m$$ **Equation 5-2**

Where $A_{\text{WSM-score}}$ is the WSM score of the best alternative, n is the number of decision criteria, a_{ij} is the actual value of the *i*th alternative and w_{ij} is the weight of importance of the *j*th criteria.

In the capacity factor assessment, the score of the *i*th capacity factor f_i is calculated with Equation 5-3, presented hereafter.

$$f_i = \sum_{j=1}^{n} C_{ij} w_{ij}$$ **Equation 5-3**

Where C_{ij} is the score of the *j*th constituent of the *i*th capacity factor, and w_{ij} is the weight of the constituent C_{ij}. In the presentation of this method, the weights w_{ij} of the constituents C_{ij} of the *i*th capacity factor are equal, thus, $w_{ij} = 1/n$, for $j = 1,\ldots, n$. The assessment is conducted for the eight CFs, and a score is calculated for each one.

Once the CFs have been assessed, they can be used to rate the overall community's capacity to manage and operate an MSS. The determination of the community's capacity is based on decision rules under uncertainty techniques. In risk analysis, in the absence of any knowledge of probabilities, identification of the expected value is impossible. Thus the decision rules commonly used for this situation are the Pessimistic Rule (Maximin or Minimax Criterion), the Optimistic Rule (Maximax Criterion), and the Hurwitz Rule, which is a compromise between the two extreme criteria (Haimes, 1998).

Similarly, in the proposed approach, the assessment of the community's capacity is carried out by using the principle of the *Maximin*. Based on the adage "a chain is only as strong as its weakest link," this method assigns to the overall capacity of the community a score equal to the strength of its weakest capacity factor. Thus, this approach is pessimistic, and focuses on the weakest capacity factor of the community. This conservative rule for rating a community's capacity to manage a given MSS seeks to maximize the likelihood that the Watsan technology option the community will select will be appropriate to its current management's capacity. Equation 5-4 presents the value function used in this approach for the assessment of the overall capacity of the community.

$$C_A = \min(f_i) \quad \text{for } i = 2, \ldots, 8 \qquad \textbf{Equation 5-4}$$

Where, C_A is the community's assessed capacity, and f_i is the score of the *i*th capacity factor. This method is applied for each of the three municipal sanitation services, DWS, WST, and MSW, where specific constituents are defined for the capacity factors. The community's capacity assessment provides an evaluation of its overall capacity level to operate and maintain a given MSS. The score of the overall capacity of the community on the 100-points CF's scale is then converted into a score on a five-point scale that constitutes the community capacity level (CCL). The CCL score is the metric used in this model to assess the current stage of development of the community related to the operations and maintenance of a given MSS. The conversion of the C_A score into the CCL score is presented in Table 5-2.

Table 5-1: Conversion of Community Assessment Score to CCL Metric

Community Assessment Score (C_A)	Community Capacity Level (CCL)
0 – 20	1
21 – 40	2
41 – 60	3
61 – 80	4
81 - 100	5

The CCL metric uses a five-level scale for the classification of developing communities that correspond to the five possible stages of development of a community in providing one of the three municipal sanitation services: DWS, WST, and MSW. The CCL levels, their interpretation, and corresponding community stage of development are presented Table 5-3 below.

Table 5-2: CCL Metric Interpretation and Description

CCL	Interpretation	Community Profile
1	High Entropy	Initial stage where there is no formal public service provided
2	Pre-Community	Local service provided with no regulatory or administrative control
3	Community-Based	Distributed public service is provided with minimal controls
4	Centralized	Regional service is provided with adequate controls
5	Diversified	A combination of regional and community-based service is provided with improved controls

The score obtained after the conversion constitutes the community's capacity level of the host community and concludes the assessment procedure of the community's capacity. Once the CCL of the developing community has been established, it can be used in the next step of the decision model presented in Figure 4.1, the matching process. The CCL of the community is a key criterion in the selection of appropriate Watsan technology options from the database of Watsan technologies.

The CFA model presented in this section is used to assess the community's capacity level or CCL. Guidelines of the CFA model are presented in Appendices A, B, and C. Appendix A presents the guideline for the assessment of the capacity factors of a community regarding the DWS service, Appendix B presents the guideline for the assessment of the capacity factors of a community for the WST service, and Appendix C presents the guideline for the assessment of the capacity factors of a community regarding the MSW service (Bouabid, 2004). In each of these three guidelines, the assessment of the capacity factors is done with the assessment of their respective constituents using international standards and benchmarks on a five-level scale. The first

CF, the *Service* capacity, is assessed with the ratio of the number of units of service per capita available to residents over the number of units of service per capita required for a minimum acceptable health standard. For example, in the case of the drinking water supply (DWS), the WHO recommends 40 l/d/c as minimum quantity of water supply for an acceptable health concern (Howard et al., 2003). This value is the benchmark against which the *Service* capacity factor of a community is assessed for DWS service.

In the CFA model, the assessment of the *Service* CF is used to assess the deficiency of the corresponding MSS, while the seven other CFs are assessed to determine the overall capacity of the community to manage an MSS sustainably. The assessment of the seven other CFs is performed with specific guidelines for each MSS. Each CF consists of a set of constituents. The assessment of each capacity factor is performed with the assessment of its individual constituents against a set of benchmarks and standards. For each constituent of a CF, an assessment of the community is performed and a score is determined. The level of performance and the current capacity of the community regarding a specific CF's constituent are used to determine the score received by the assessed constituent. A five level scale from 0 – 100 is applied to assist the user during the assessment procedure. Each constituent of the capacity factors receives a score ranging from 1 to 100. The score represents a percentage comparison to the corresponding benchmarks associated with the CF's constituent.

The overall score of a CF is then computed with the weighted average sum of its individual constituent scores. The weighted sum model presented in Equation 5-3 is used to calculate the score of a given capacity factor, $\mathrm{f}_i = \sum_{j=1}^{n} C_{ij} w_{ij}$, where, f_i is the score of the ith capacity factor, C_{ij} is the score of the jth constituent of the ith capacity factor, and w_{ij}

is the weight of the constituent C_{ij}. The weight coefficients are such as $0 < w_{ij} < 1$, and $\sum_{j=1}^{n} w_{ij} = 1$. The weighting of the constituents of the CF can be done by consultation with decision makers in the host community.

Once the seven CFs are assessed, their scores are used to rate the overall capacity of the community to manage an MSS. The determination of the community assessment C_A score is obtained using Equation 5-4, $C_A = \min(f_i)$ for $i = 2, \ldots, 8$.

This conservative approach for rating a community's capacity forces the community to select Watsan technology options that are consistent with its lowest management's capacity. Thus the community is assured of its ability to manage the selected Watsan technology options, and progress to more sophisticated systems as it builds its capacity. The Service CF is not used in the evaluation of the overall community's capacity since it is the factor that we try to improve with this model.

5.3 Example of CFA Model for DWS Service

To illustrate the use of the CFA model, an example of the assessment of three CFs for the DWS service is presented in Figure 5-2. The assessment of these CFs is conducted with the guideline of the CFA model for DWS (Appendix A). The three CFs presented are the *Service, Institutional*, and *Human Resources* capacity factors. For each CF, a set of constituents is used to assess the capacity of the community to operate and maintain a drinking water supply service. The assessment is accomplished by comparing each constituent to a benchmark and a score is determined on a five-level scale with scores ranging from 0 to100, according to the result of the comparison.

In the example in Figure 5-2, the first CF, the *service* CF, is assessed based on the estimate of the quantity of water available per day and per capita. The *service* CF receives a score from 0 – 100 based on the result. For example if the quantity of water available per capita is 25 liters per day, the *service* CF will simply receive a score of 25.

The assessment of the second CF, the *institutional* CF, is performed through the assessment of its five constituents, the *body of legislation*, *associated regulations*, *administrative agencies*, *administrative processes*, and *governance*. Each constituent is assessed using the guidelines in Figure 5-2. For example, if the *body of legislation*, the *associated regulations*, and the *administrative processes* for DWS service were at the basic level, the *body of legislation*, *associated regulations* and *administrative processes* constituents will receive scores between 21 and 40. According to these assumptions, these scores reflect the fact that a national law concerning the management of drinking water supply exists, but it does not influence the construction of a DWS infrastructure system at the local community. These scores reflect also that there could be some legislation present but it may not be robust enough to represent active local enforcement. Similarly *associated regulations* for DWS could exist at the regional level, but they may not be actively applied to the design, construction, or management of DWS system at the local level. Rather, an informal administrative process by which the local village association attempts to comply with the regional and national regulations and law may be the driving force behind any actions taken.

Table 5-3: Guideline for the Assessment of Three CFs for DWS

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**							
C_{11}	Sevice Level	W_{11}	< 20 l/d/c	21 - 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	
f_1	Score Service CF						$\Sigma C_{ij} w_j =$	0
2	**Institutional**							
C_{21}	Body of legislation	W_{21}	None	Basic	Intermediate	Complete	Advanced	
C_{22}	Associated regulations	W_{22}	None	Basic	Intermediate	Complete	Advanced	
C_{23}	Administrative agencies	W_{23}	None	National	Regional	District	Local	
C_{24}	Administrative processes	W_{24}	None	Basic	Intermediate	Complete	Advanced	
C_{25}	Governance	W_{25}	None	National	Regional	State	Local	
f_3	Score Institutional CF						$\Sigma C_{ij} w_j =$	0
3	**Human Resources**							
C_{31}	Professionals	W_{31}	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	
C_{32}	Skilled Labor	W_{32}	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technician	
C_{33}	Unskilled Labor	W_{33}	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	
C_{34}	Illiterate	W_{34}	Caretaker I	Caretaker II	Caretaker III			
f_3	Score Human Resources CF						$\Sigma C_{ij} w_j =$	0

Finally, if administrative agencies for DWS services are available at the regional level and governance is applied at the national level for example, then, the two constituents, *administrative agencies* and *governance*, will receive a score between 41 and 60, and between 21 and 40, respectively. These examples comprise the illustration of the process for the assessments of the constituents of the *institutional* CF. The overall score of the CF is then calculated, by the weighted sum of the five constituents, using Equation 5-3. It this illustration, the computed *institutional* CF score is 34.

Similarly, the assessment of the *human resources CF* is conducted with the assessments of its four constituents, namely, *professionals, skilled labor, unskilled labor,* and *illiterate*. Using the same guideline presented in Figure 5-2, and based on the human resources capacities available in the local community, a scoring of the constituents is performed. The assessment of the constituents of the *human resources* CF is straightforward since the scores received are established according to the human resources and qualifications available at the local level. The weighted sum is then used to compute the overall score of the *human resources* CF. In Appendix A, the complete guideline for assessing the CFs of a community for capability of operating and maintaining a DWS service is presented with a comprehensive description of all eight CFs and their respective constituents. Similar guidelines are provided in Appendix B and Appendix C for the assessment of a community's CFs for the operations and maintenance of the two other MSSs, namely WST and MSW services.

Chapter 6. Classification of Watsan Technologies

6.1 Classification Method

In the framework of the decision model proposed in this research, the second module of component #1 is the DSS with a database of Watsan technologies ranked by their technology requirement level to operate and maintain them sustainably. The classification of Watsan technologies proposed in this model is made using a metric, the *Technology Requirement Level* (TRL). The TRL score uses a five-level scale that is consistent with the one used in the assessment of a community's capacity level or CCL. Ahmad (2004) proposed a method for the classification of Watsan technologies using four criteria and a three-level scoring scale. The method provided a ranking of Watsan technologies based on the scoring of the following four criteria: cost, energy, technical requirements, and institutional requirements. This approach for the classification of Watsan technologies provided a measure that was not adequately objective because it was based on one evaluation of the four criteria used, and with an over emphasis on the technical and institutional ones. Nevertheless, the metric's name, TRL, proposed by Ahmad (2004) for the classification of Watsan technologies, will be used in our own classification method presented hereafter. Indeed, to provide a more systemic and objective method for the classification of Watsan technologies, we propose a different approach. The classification method proposed in this research is based on a machine learning classification tool such as support vector machine (SVM) method for classification. SVM is based on statistical learning theory, and is one of the most successful classification methods in machine learning.

In SVM, the learning machine is given a training set of examples including their inputs and known outputs (classes). The SVM algorithm then uses the training set to predict the classification of other elements given their known inputs and unknown outputs or classes (Cristianini et al., 2000).

6.2 Support Vector Machine

A simple illustration of a SVM model is for a two-class or binary case. For example, we have a set of elements that we want to classify in two different categories or classes. Many possibilities to separate or classify these elements could be applied. We are considering a linear classifier to separate the two sets. In the Figure 6-1 below, we can see some of the options for separating the set of data points with a linear classifier.

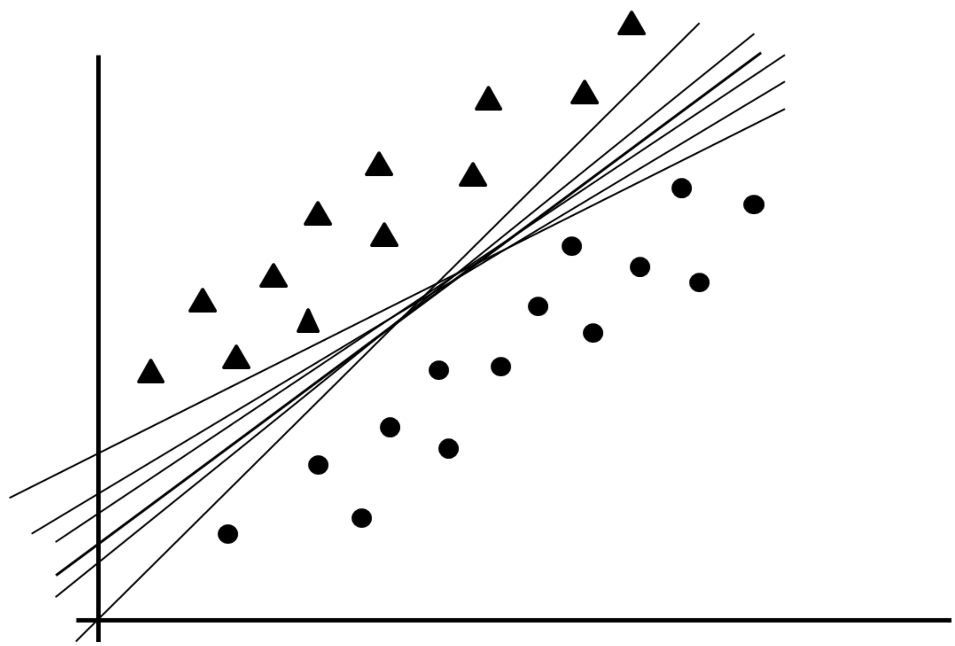


Figure 6-1: Illustration of Possibilities of Linear Separation

The goal of the SVM algorithm is to determine the optimal "separation" between the two classes of elements. The optimal line or hyperplane that will separate the two classes will be the one with the maximum margin. The margin of a linear classifier is the width of the boundary that could be increased before hitting a datapoint from each set. The margin of a linear classifier is represented in Figure 6.2.

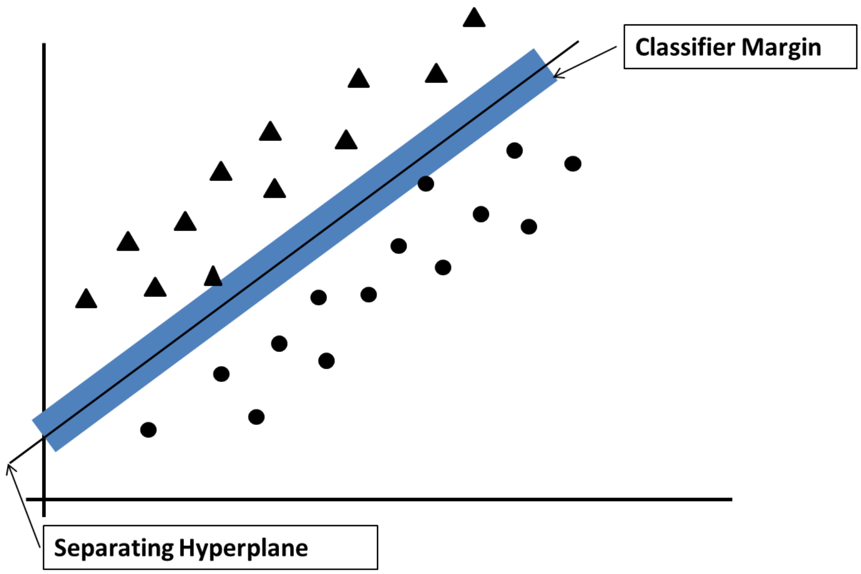


Figure 6-2: Classifier Margin for a Linear Case

Mathematically, the problem is formulated as follow. We can separate the two classes by a function which is induced from available elements with well-defined classes. These elements are used as a training set, constituted by known inputs and outputs values. The input set can be defined by a vector: $\mathbf{x} = (x_1, x_2, x_3, \ldots, x_n) \in \Re^n$. The output y can take only two values in the case of the two class classification, for example $y \in \{-1, 1\}$. The training set is used to establish the relationship between the inputs and a single output defined by a function f. If we consider the case where f is a real-valued linear function, the function f is defined by Equation 6-1:

$$f(x) = \langle \mathbf{w}.\mathbf{x} \rangle + b = \sum_{i=1}^{n} w_i x_i + b \qquad \textbf{Equation 6-1}$$

where $(\mathbf{w}, b) \in R^n \times R$ are the parameters that control the function. The quantities **w** and b are the *weight vector* and the *bias*. The training set will be then separated into two classes from which a geometric interpretation explains that the input space, X, is split into two parts by a hyperplane defined by $\langle \mathbf{w}.\mathbf{x} \rangle + b = 0$. Two other hyperplanes defined by $\langle \mathbf{w}.\mathbf{x} \rangle + b = +1$ and $\langle \mathbf{w}.\mathbf{x} \rangle + b = -1$ define the margin of the classifier. Figure 6-3 below illustrates the separating hyperplanes and the margin that touches an element from each of the two classes. These elements are the support vectors. As we can see in Figure 6-3, the support vectors are the datapoints up against which the margin pushes.

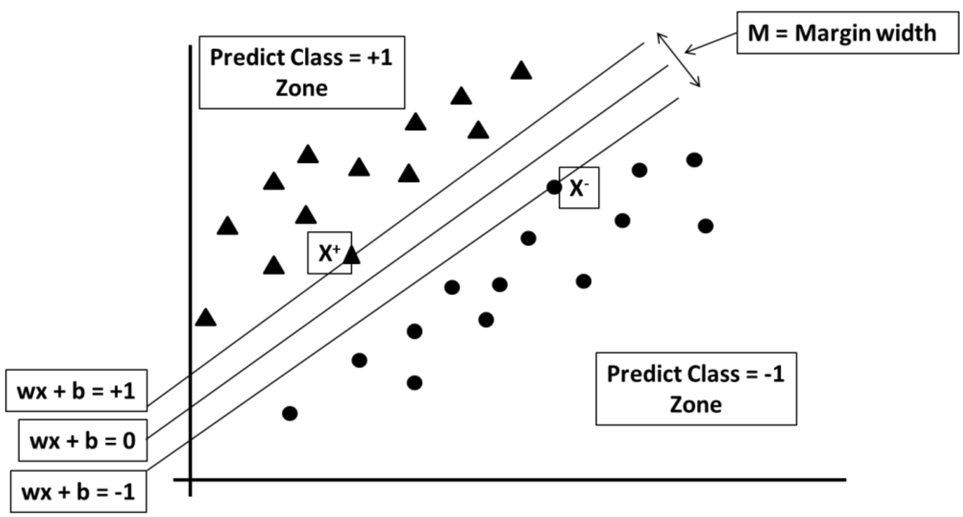


Figure 6-3: Maximum Margin for a Two-Dimensional Training Set

This illustration is the simplest kind of SVM called Linear SVM. Its mathematical formulation results in an optimization problem as follow.

Given $\mathbf{w}.\mathbf{x}^+ + b = +1$

and $\mathbf{w}.\mathbf{x}^- + b = -1$

which results in $\mathbf{w}.(\mathbf{x}^+ - \mathbf{x}^-) = 2$

The margin is defined by: $\frac{(x^+ - x^-).w}{|w|} = \frac{2}{|w|}$

The goal is to classify all training data such as:

$wx_i + b \geq 1$ if $y_i = +1$

$wx_i + b \leq 1$ if $y_i = -1$

$y_i\,(wx_i + b) \geq 1$ for all i,

and maximize the margin $M = \frac{2}{|w|}$, which is equivalent to minimizing $\frac{1}{2}\mathbf{w}^T\mathbf{w}$

Thus, the problem is to optimize a quadratic function subject to linear constraints and to solve for **w** and b. The formulation of the problem is such that (Taboureau, 2008):

for all $\{(\mathbf{x}_i, y_i)\}$

Minimize $\mathbf{\Phi}(\mathbf{w}) = ½\,\mathbf{w}^T\mathbf{w}$

Subject to $y_i\,(wx_i + b) \geq 1$

The solution involves the construction of a dual problem where a Lagrange multiplier α_i is associated with every constraint in the primary problem. The dual problem is therefore:

Find $\alpha_1, \alpha_2, \ldots, \alpha_N$

such that $Q(\boldsymbol{\alpha}) = \Sigma\, \alpha_i - ½\Sigma\Sigma\, \alpha_i\alpha_j y_i y_j\, \mathbf{x}_i^T\mathbf{x}_j$ is maximized

given that $\mathbf{w} = \Sigma\alpha_i y_i \mathbf{x}_i$, and

- $\Sigma\alpha_i y_i = 0$
- $\alpha_i \geq 0$ for all α_i

The solution of the dual problem has the form:

$\mathbf{w} = \Sigma\alpha_i y_i \mathbf{x}_i$ $b = y_k - \mathbf{w}^T\mathbf{x}_k$ for any $\mathbf{x}_k$ such that $\alpha_k \neq 0$

The Lagrange multiplier $\alpha_i \neq 0$ indicates that $\mathbf{x}_i$ is a support vector.

The classification function f(x) has the form:

$$f(\mathbf{x}) = \Sigma\alpha_i y_i \mathbf{x}_i^T \mathbf{x} + b \qquad \textbf{Equation 6-2}$$

The classification function in Equation 6-2 relies on the inner product $\mathbf{x}_i^T\mathbf{x}$, between the test point to be classified, **x**, and the support vectors, $\mathbf{x}_i$.

In our classification problem of Watsan technologies, we need a multi-class classifier, since we have five TRL levels or five classes. The generalization to the multi-class is obtained for an output domain, $y = \{1, 2, 3, ..., m\}$. To each of the m classes are associated a weight vector and a bias value (w_i, b_i), where $i \in \{1, 2,.., m\}$.

The decision function is given by Equation 6-3 (Cristianini et al. 2000).

$$c(\mathbf{x}) = \arg \max_{i \leq 1 \leq m} (\langle \mathbf{w}_i .\ \mathbf{x} \rangle + b_i) \qquad \textbf{Equation 6-3}$$

The geometric interpretation of the classification is the association of a hyperplane to each class, and the association of a new point, **x,** to the class whose hyperplane is the furthest from it. In the case of multi-class SVM, the input space is split into m regions. Several algorithms for multi-class SVM already exist and use the basic procedure developed for two-class models. The classification tool used in this research is the Weka workbench. It is a machine learning platform with SVM algorithms for multi-class classification that uses pair-wise classification methods.

6.3 Watsan Technologies Classification

In this problem, we want to classify the Watsan technology options that are used for DWS, WST, and MSW services. To illustrate the application of SVM classification, the method is applied to DWS technologies. An inventory of all the technology options used for DWS in developing communities is presented in Appendix G. In this inventory, 774 options are identified for providing DWS services to developing communities. SVM algorithms require a training set of elements or a set of instances with well-defined classes. The training set is used by the SVM algorithm to learn how to classify data sets of elements with unknown classes. In our problem, we used a set of 50 DWS technology options with a known TRL as a training set. The unit processes of the DWS technology options of the training set are the inputs and their known TRL is the output or class in the SVM model.

6.3.1 Selection of Training Set

The selection of the DWS technology options to constitute a training set is done randomly. Indeed uniform random sampling is the optimal robust selection approach for the training data selection in SVM (Wang, 2005). We decided to use a set of 50 DWS technology options from the 774 available ones. The application of the RANDI function in MATLAB is used for the selection of the random sample. Random sampling in MATLAB is performed with the RANDI function that generates *n* integer values from the uniform distribution of the set 1 : *m*. The MATLAB syntax for this function is:

RANDI (*m*, 1, *n*)

where *m* is the total number of options available, which is 774 in our case, and *n* is the number of values to select. In our problem we decided to select 50 instances out of the 774 for the training set. The MATLAB code is:

```
>> RANDI (774, 1, 50)
```

The result is a selection of 50 numbers from 1 to 774 that correspond to the DWS technology options numbers. This selection of a random set of DWS technology options was then submitted to Watsan experts for classification.

6.3.2 Watsan Experts Survey

To define the TRL of the DWS technology options of the training set, we submitted to a group of Watsan experts, selected from among practitioners and academics in the Watsan disciplines, the set of DWS options. We submitted to them the set of 50 DWS technology options selected randomly, and asked them to rank them. The classification of the Watsan technologies uses a five-level scoring scale consistent with the one used for the assessment of the community capacity's level. The metric used for the scoring of the technology requirement level is the TRL. The consistency between the scoring of a community's CCL and the Watsan technologies' TRL will allow the use of a matching process to relate a community's assessed CCL to a set of Watsan technologies that the community can operate and maintain sustainably for their MSS needs. The technology requirement level (TRL) five-level scale used is presented in Table 6-1 below.

Table 6-1: Technology Requirement Level Metric: TRL - Scale

Level	1	2	3	4	5
Description	Very Low	Low	Moderate	High	Very High

The results of the survey were compiled and an average TRL score was calculated for each DWS option of the training set. The resulting training set of Watsan options with known TRL is presented in Table 6-2. The results of the survey of Watsan experts provided us with a training set of Watsan DWS technology options with known TRL.

Table 6-2: Training Set of DWS Technology Options

Options #	Source	Device	Treatment	Storage	Distribution	TRL
12	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	steel_tank	domestic_connection	2
14	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
47	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3
50	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
56	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	3
60	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	3
66	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
78	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	4
118	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	3
140	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
157	dug_well	rope_and_bucket	household_slow_sand_filter	steel_tank	public_standpost	1
161	dug_well	rope_and_bucket	household_slow_sand_filter	plastic_tank	public_standpost	1
180	dug_well	rope_pump	boiling	ferrocement_tank	domestic_connection	2
242	drilled_well	bucket_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
261	drilled_well	bucket_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
262	drilled_well	bucket_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
287	drilled_well	rope_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
307	drilled_well	suction_plunger_handpump	boiling	plastic_tank	public_standpost	2
322	drilled_well	suction_plunger_handpump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
343	drilled_well	direct_action_pump	household_slow_sand_filter	steel_tank	public_standpost	2
381	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
418	drilled_well	deep_well_piston_pump	domestic_chlorination	plastic_tank	domestic_connection	3
467	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3
518	protected_side_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	domestic_connection	3
520	protected_side_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
523	protected_side_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3
532	protected_side_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3
533	protected_side_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	3
555	river-bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
561	river-bottom_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
570	river-bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
582	river-bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
595	river-bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
614	floating_intake	centrifugal_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3
615	floating_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
621	floating_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
628	floating_intake	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	4
642	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
646	floating_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	4
662	floating_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	4
673	sump_intake	deep_well_piston_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	3
682	sump_intake	deep_well_piston_pump	boiling	plastic_tank	domestic_connection	3
710	sump_intake	submersible_pump	boiling	ferrocement_tank	domestic_connection	3
714	sump_intake	submersible_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	3
724	sump_intake	submersible_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	4
727	sump_intake	submersible_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3
732	sump_intake	submersible_pump	domestic_chlorination	plastic_tank	domestic_connection	3
734	sump_intake	submersible_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	4

This training set for the SVM classification model of Watsan technology options is constituted of DWS options with defined attributes (source, device, storage, treatment, distribution) and known class (TRL). The classification by TRL of the Watsan technology options will be developed for the three categories of Watsan technology options. Each category is constituted by technologies used to provide one of the three municipal sanitation services, namely DWS, WST, and MSW. Once the classification process is completed, the results are used to develop a database of Watsan technology options ranked by the MSS they provide, sorted by their TRL, and with information on the communities operating them. The information on the communities comprises their profile defined by their capacity factors and CCL, and their regional specificity and settlement type. The regional specificity provides information on the availability of natural resources and the settlement type informs the user on the urban settlement type where the community is located. The database of Watsan technologies is presented in the following chapter.

6.4 Weka Classification Tools

The classification tools used in this research are available in Weka workbench. Weka workbench is a collection of machine learning algorithms and data processing tools developed by the University of Waikato in New Zealand. It is developed in Java and distributed under the terms of GNU General Public License (Witten, 2005). The workbench includes all the standard data mining problems: classification, regression, clustering, association rule mining, and attribute selection. For our Watsan technologies classification problem, we used the Weka workbench. Weka classification tools require the data to be in Attribute – Relation File Format (ARFF). Therefore, the data file of elements to be classified needs to be prepared in the specific format used by Weka. The ARFF file has three parts: a relation, a set of attributes, and the instances or data to be classified. The relation represents the name of the file; the attributes are the set of features that characterize each individual element of the data set. The attributes could be nominal or numeric. Nominal attributes take values that are distinct symbols and serve just as names or labels. In other words, a rule using nominal attributes can only test for equality. Numeric attributes are numbers that could be real or integer values. Finally the last part of the ARFF file is the data set or instances to be classified. Each instance is defined by a set of specific attributes. The structure of an ARFF file is as follow:

@relation *name*

@attribute *name* numeric or nominal…

@data
instance 1
instance 2…

In our classification problem for DWS technology options, each instance of the DWS set has six attributes. The first five attributes represent the unit processes of each DWS technology option. These are all nominal attributes. The sixth and last attribute of each instance is the TRL score of the corresponding DWS technology option, which represents the class. This attribute is defined as a numeric attribute in the ARFF file and is a number from 1 to 5. The nominal attributes of the DWS technology options used in the ARFF file are the following:

- Attribute ***source***: rooftop_rainwater_harvesting, catchment_and_storage_dam, springwater_collection, dug_well, drilled_well, subsurface_harvesting, protected_side_intake, river_bottom_intake, floating_intake, sump_intake.

- Attribute ***device***: bucket, gravity, rope_and_bucket, bucket_pump, rope_pump, suction_plunger_handpump, direct_action_pump, deep_well_diaphragm_pump, deep_well_piston_pump, centrifugal_pump, submersible_pump, hydraulic_ram_pump.

- Attribute ***treatment***: boiling, household_slow_sand_filter, domestic_chlorination, storage_and_sedimentation, slow_sand_filtration, chlorination_in_piped_water_supply_system.

- Attribute ***storage***: concrete_lined_earthen_reservoir, reinforced_concrete_reservoir, elevated _reservoir, ferrocement_tank, plastic_tank, steel_tank.

- Attribute ***distribution***: public_standpost, domestic_connection.

Finally, the last part of the ARFF file of the training set contains the instances. The instances are the DWS technology options with known TRL metrics determined by the Watsan experts' survey. In the set of DWS technology options to be classified, the data are the DWS instances with unknown TRL metrics that need to be classified.

6.4.1 Classification of the Training Set

To select a classification function with the training set, we used the Weka workbench. This workbench provides a graphical user interface called *Explorer* that gives access to all of its tools through menu selections. A snapshot of *Weka Explorer* command window is presented in Figure 6-4 below. The first step in the classification process is to open the training set using the *open file* button in the *Preprocess* menu.

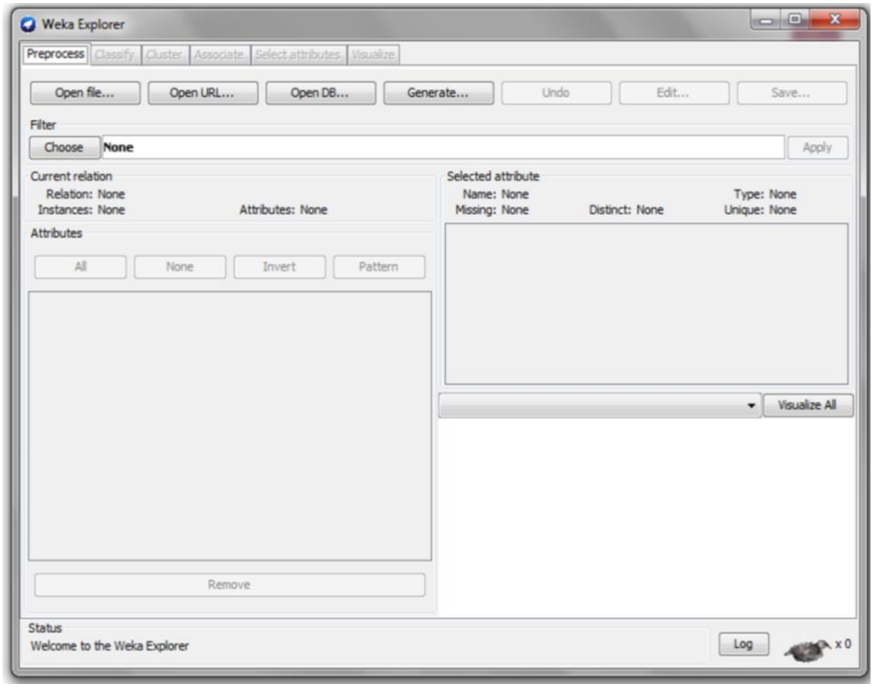


Figure 6-4: Snapshot of Weka Explorer in Graphic User Interface

In our classification problem, we uploaded the training set of DWS options, using the Weka *Open File* menu. The next step is to use the Weka *Classify* menu, and select the appropriate functions that best describe the relation between the attributes of each instance and their known corresponding classes in the training set. For classification with numeric classes, SVM regression algorithms must be used. Two classification functions from the Weka workbench were selected, SMOreg and KStar.

- SMOreg is a sequential minimal optimization algorithm for support vector regression. For multiclass classification, which is our case, SMOreg uses pairwise classification (Smola, A. et al., 1998).
- KStar algorithm is an instance-based classifier that uses the entropic distance measure between two instances to give a prediction of their classification (Cleary, J. et al., 1995).

The two algorithms were used with the DWS technology options training set, and the results of the classification were compared. The results of the classification were analyzed by comparing their respective coefficients of correlation and their relative absolute error rates.

- The KStar function has a coefficient of correlation of 99.69% and a relative absolute error of 7.46%.
- The SMOreg function has a coefficient of correlation of 93.07% and a relative absolute error of 37.91%.

The results of this classification of the training set with the performance of the two classification functions are presented in Appendix E. These results show that KStar performs better since its relative absolute error is 7.46%, while the SMOreg function has a relative absolute error of 37.92%.

For the classification of the test set of DWS technology options, we used the two functions and compared the results of their respective classifications. This approach was taken as a means to verify the outputs of the two classifiers, and evaluate the results of the classification.

6.4.2 Classification of the DWS Test Set

The classification of the DWS test set was conducted by dividing the set of 724 DWS options into 15 subsets with 48 instances each. The partition of the set of DWS options was done to have test sets of the same size as the training set to improve the accuracy of the classification process. The selection of the instances in the 15 subsets was done randomly using the same method used for the selection of the instances of the DWS options of the training set. The subsets obtained are presented in Appendix F.

The classification of the subsets of DWS options was then done using the Weka workbench and the KStar and SMOreg models selected in the previous step and with the relationships established by the training set. The results of the classification with the two functions were then compared. Most of the instances in the DWS sets were classified in the same class by the two functions. For the few instances that were classified differently by the two functions, we retained the class determined by the KStar function since it had a smaller absolute relative error when we tested it with the training set. The results of the classification of the entire set of DWS options with Weka are presented in Appendix F. The classification of the DWS set was then used to assign TRL scores to the DWS technology options in the database of Watsan technologies.

Similar classification can be done for the other Watsan technology options for WST and MSW to determine their TRL scores and upload their scores into the database of Watsan technology options.

6.4.3 Evaluation of the Performance of the Classifiers

Conducting an evaluation of the classifiers is important for the estimate of future performance of the classifiers. The evaluation of classifiers used in data mining and machine learning is usually conducted by comparing the error rate or accuracy (Drummond, 2006). For the evaluation of the performance of a two-class classifier, we use a *confusion matrix,* also called contingency table.

The following explains the procedure to construct a confusion matrix. Given a set of instances in two classes; for a classifier and an instance, four possible outcomes exist: if an instance is predicted as class A and it is classified in class A, it is counted as true positive (TP). If the instance is predicted as class A and it is classified in class B, it is counted as false negative (FN). Similarly, if an instance is predicted as class B and it is classified in class A, it is counted as false positive (FP). If the instance is predicted as class B and it is classified in class B, it is counted as true negative (TN). The confusion matrix is presented in Table 6-3 below.

Table 6-3: Confusion Matrix for Classifier Evaluation

Predicted as	**Class A**	**Class B**	**Total**
Class A (P)	True Positive (TP)	False Negative (FN)	P
Class B (N)	False Positive (FP)	True Negative (TN)	N

We use the results obtained in the confusion matrix to determine the performance evaluation indicators for the two classifiers used in the DWS Options classification, KStar, and SMOreg. The two indicators of performance used to evaluate the two classifiers are the Accuracy (ACC), and Matthews's Coefficient of Correlation (MCC).

- **Accuracy**: the accuracy of a classifier is determined by the following equation:

ACC = (TP + TN) / (P + N) **Equation 6-4**

The Accuracy of a classifier is a measure of the performance that provides the percent of correct decisions of the classifier.

- **Matthew's Coefficient of Correlation**: MCC is also used to evaluate the classification performance; it ranges between -1 and 1, where
    - 1 : perfect prediction
    - 0 : random prediction
    - -1: opposite to perfect prediction

$$MCC = \frac{T_P T_N - F_P F_N}{\sqrt{(T_P + F_N)(T_N + F_P)(T_P + F_P)(T_N + F_N)}}$$ **Equation 6-5**

To evaluate the two classifiers used in this research, we selected a set of DWS options from the training set that belong to two classes. Since a large number of DWS options of the *training set* are ranked with a TRL 2 and a TRL 3, we decided to choose a set of DWS options among these two groups. The *evaluation set* has 40 DWS options; seven of them are ranked with a TRL of 2, and 33 of them with a TRL of 3. The *evaluation set* is then split into two subsets of equal size. One subset is used as a *training subset*, and the second subset is used as *performance evaluation subset*. The two subsets, the *training subset* and the *performance evaluation subset*, are selected randomly from the *evaluation set*. The two subsets used for the evaluation of the classifiers are presented in Table 6-4 and 6-5 below.

Table 6-4: *Training Subset* for Classifiers Evaluation

Options #	Source	Device	Treatment	Storage	Distribution	TRL
12	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	steel_tank	domestic_connection	2
180	dug_well	rope_pump	boiling	ferrocement_tank	domestic_connection	2
261	drilled_well	bucket_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
307	drilled_well	suction_plunger_handpump	boiling	plastic_tank	public_standpost	2
47	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3
50	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
56	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	3
60	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	3
140	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
262	drilled_well	bucket_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
322	drilled_well	suction_plunger_handpump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
381	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
418	drilled_well	deep_well_piston_pump	domestic_chlorination	plastic_tank	domestic_connection	3
467	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3
518	protected_side_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	domestic_connection	3
520	protected_side_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
523	protected_side_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3
532	protected_side_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3
533	protected_side_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	3
555	river-bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
615	floating_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
673	sump_intake	deep_well_piston_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	3
682	sump_intake	deep_well_piston_pump	boiling	plastic_tank	domestic_connection	3
710	sump_intake	submersible_pump	boiling	ferrocement_tank	domestic_connection	3
732	sump_intake	submersible_pump	domestic_chlorination	plastic_tank	domestic_connection	3

Table 6-5: *Performance Evaluation Subset* for Classifiers Evaluation

Options #	Source	Device	Treatment	Storage	Distribution	TRL
14	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
242	drilled_well	bucket_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
343	drilled_well	direct_action_pump	household_slow_sand_filter	steel_tank	public_standpost	2
66	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
118	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	3
287	drilled_well	rope_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
561	river_bottom_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
570	river-bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
582	river-bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
595	river-bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
614	floating_intake	centrifugal_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3
621	floating_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
642	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
714	sump_intake	submersible_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	3
727	sump_intake	submersible_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3

The results of the classification of the two subsets used for the evaluation of the classifiers KStar and SMOreg are presented in Appendix H.

- **KStar Classifier**

The confusion matrix obtained for KStar classifier is presented in Table 6-6,

Table 6-6: Confusion Matrix for KStar Classifier

Predicted as	**TRL 2**	**TRL 3**	**Total**
TRL 2 (P)	2 (TP)	1 (FN)	3
TRL 3 (N)	1 (FP)	11 (TN)	12

- The accuracy of the KStar classifier is determined with Equation 6-4:

  ACC = (2 + 11)/(3+12) = 13/15 = 86.67%

- MCC for the KStar classifier is determined with Equation 6-5

$$MCC = \frac{2*11 - 1*1}{\sqrt{(2+1)(11+1)(2+1)(11+1)}}$$

$$MCC = \frac{21}{\sqrt{1296}} = \frac{21}{36} = 0.58$$

- **SMOreg Classifier**

Similarly, the confusion matrix for the SMOreg classifier is presented in Table 6-7,

Table 6-7: Confusion Matrix for SMOreg Classifier

Predicted as	TRL 2	TRL 3	Total
TRL 2 (P)	2 (TP)	1 (FN)	3
TRL 3 (N)	1 (FP)	11 (TN)	12

- The accuracy of the SMOreg classifier is determined with Equation 6-4:

  ACC = (2 + 11)/(3+12) = 13/15 = 86.67%

- *MCC* for the SMOreg classifier is determined with Equation 6-5

$$MCC = \frac{2*11-1*1}{\sqrt{(2+1)(11+1)(2+1)(11+1)}}$$

$$MCC = \frac{21}{\sqrt{1296}} = \frac{21}{36} = 0.58$$

We can conclude that the two classifiers perform identically. However, when used with the initial training set, KStar returned a classification with a coefficient of correlation of 99.69%, and a relative absolute error of 7.46%, while SMOreg had a coefficient of correlation of 93.07%, and a relative absolute error of 37.91%. As mentioned above, we used the two classifiers for the classification of the Watsan technology options. In most of the cases, the two classifiers returned the same classification of the DWS options. However, for the few cases where they did not, we gave more weight to KStar classification results for the decision of the class attribution.

Chapter 7. Database of Watsan Technology Options

7.1 Database Model

The database of water supply and sanitation technologies contains Watsan technology options for the three municipal sanitation services, namely, drinking water supply, wastewater sewage and treatment, and municipal solid waste. The database contains three tables of Watsan technologies; the first one holds the technology options for DWS; the second one for WST; and the last one for MSW. The Watsan technology options in each category are classified by the technology requirement level metric, and with information on developing communities operating them sustainably, when available. This information on developing communities includes the regional specificity and the settlement type where the communities are located. It includes also the assessment of the capacity factors related to their capacities to manage the three basic municipal sanitation services.

7.2 Classification of Watsan Technologies by TRL

The Watsan technology options for the three municipal sanitation services are ranked and classified with the technology requirement level (TRL) metric. The TRL of a Watsan technology option defines the technology level a community must have to operate and maintain sustainably a Watsan option. The classification of the Watsan options with the TRL metric was done using a machine learning algorithm, the Support Vector Machine model for classification. The TRL metric is used, in the decision support system, to match a developing community with a need for a municipal sanitation service to a set of Watsan technology options that the community can operate and maintain sustainably. The classification of Watsan technologies was presented in Chapter 6. The classification method was illustrated with the DWS technology options and the results of the classification were used to define the corresponding TRL of the DWS technology options. The set of DWS options with their TRL score was uploaded in the table of *DWS_Options* in the database. Similar methods can be applied to rank the WST and MSW technology options to obtain their TRL and use them in their respective tables in the database. The tables of Watsan technology options ranked by TRL are presented in Appendix G.

7.3 Regional Specificity

The Watsan DSS also contains data on developing communities operating Watsan technologies. The data on the developing communities include the CFs assessment results and the corresponding CCL, the regional specificity, and settlement type where the community is located. The data on the communities are used in the matching process to help determine the most appropriate Watsan technology options that best suit a community with a need for an MSS. The regional specificity used in this decision making model is based on the classification of the biogeographical provinces of the world (Udvardy, 1975). Udvardy has proposed a unified system for biogeographical and conservation purposes. This classification is based on eight biogeographical divisions of land and freshwater areas of the surface of the earth. These biogeographical divisions, called realms, are the highest taxonomic groups of this classification and represent continents or subcontinent-sized areas with unifying features of geography and fauna. Table 7.1 presents the eight biogeographical realms with their corresponding numbers from 1 to 8. For the database of Watsan technology options developed in this research, we used the entire set of realms in the *Regional Specificity* table. However, only six of the biogeographical realms, Palaearctic, Africotropical, Indomalayan, Oceanian, Australian, and Neotropical, comprise most of the world population with unmet demand for improved water supply and sanitation services.

Table 7-1: Biogeographical Realms

Number	Biogeographical Realms
1	Nearctic
2	Palearctic
3	Africotropical
4	Indomalayan
5	Oceanian
6	Australian
7	Antarctic
8	Neotropical

Source: Udvardy (1975)

Figure 7.1 presents the eight terrestrial biogeographical realms with their locations on the surface of the earth and the 14 biome types (Udvardy, 1975).

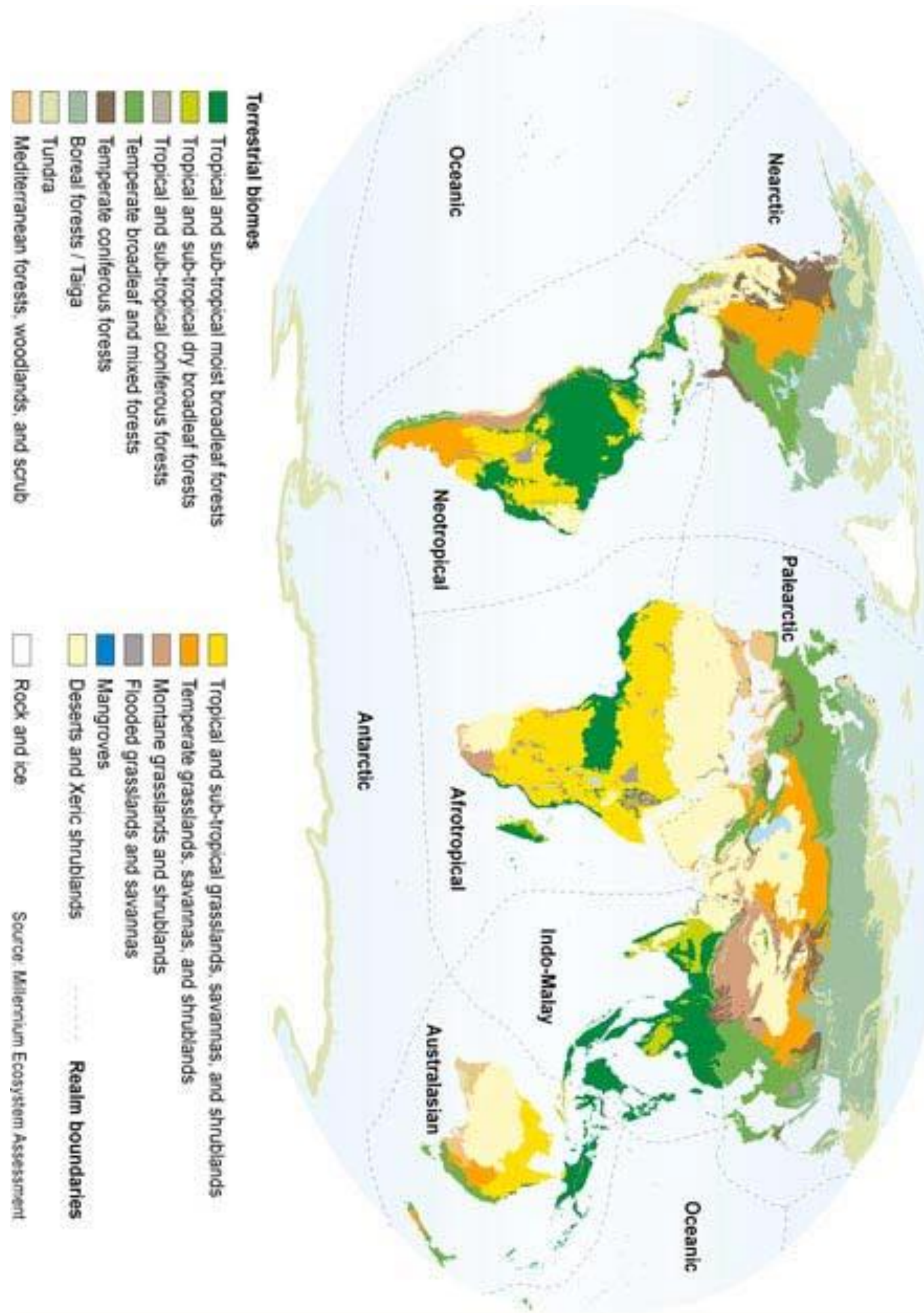


Figure 7-1: Terrestrial Biogeographical Realms and Biomes of the World

Udvardy (1975) - Source: Millennium Ecosystem Assessment -
http://www.unep.org/maweb/en/Index.aspx

The biogeographical realms are subdivided into 14 major formation types or biomes as proposed by Udvardy. These 14 biomes are presented in Table 7-2 below with their respective descriptions.

Table 7-2: Classification of Biome Types

Number	Biome Types
1	Tropical humid forests
2	Subtropical and temperate rain forests or woodlands
3	Temperate needle-leaf forests or woodlands
4	Tropical dry or deciduous forests (including monsoon forests) or woodlands
5	Temperate broad-leaf forests or woodlands, and subpolar deciduous thickets
6	Evergreen sclerophyllous forests, scrubs, or woodlands
7	Warm deserts or semi-deserts
8	Cold-winter (continental) deserts and semi-deserts
9	Tundra communities and barren arctic deserts
10	Tropical grasslands and savannas
11	Temperate grasslands
12	Mixed mountain and highland systems with complex zonation
13	Mixed island systems
14	Lake systems

Source: Udvardy (1975)

Finally the last classification subcategory of the regional specificity used by Udvardy is the province. Each realm is constituted of several provinces, numbered consecutively. The representation of the biogeographical provinces of the world as proposed by Udvardy is shown in Figure 7-2 below.

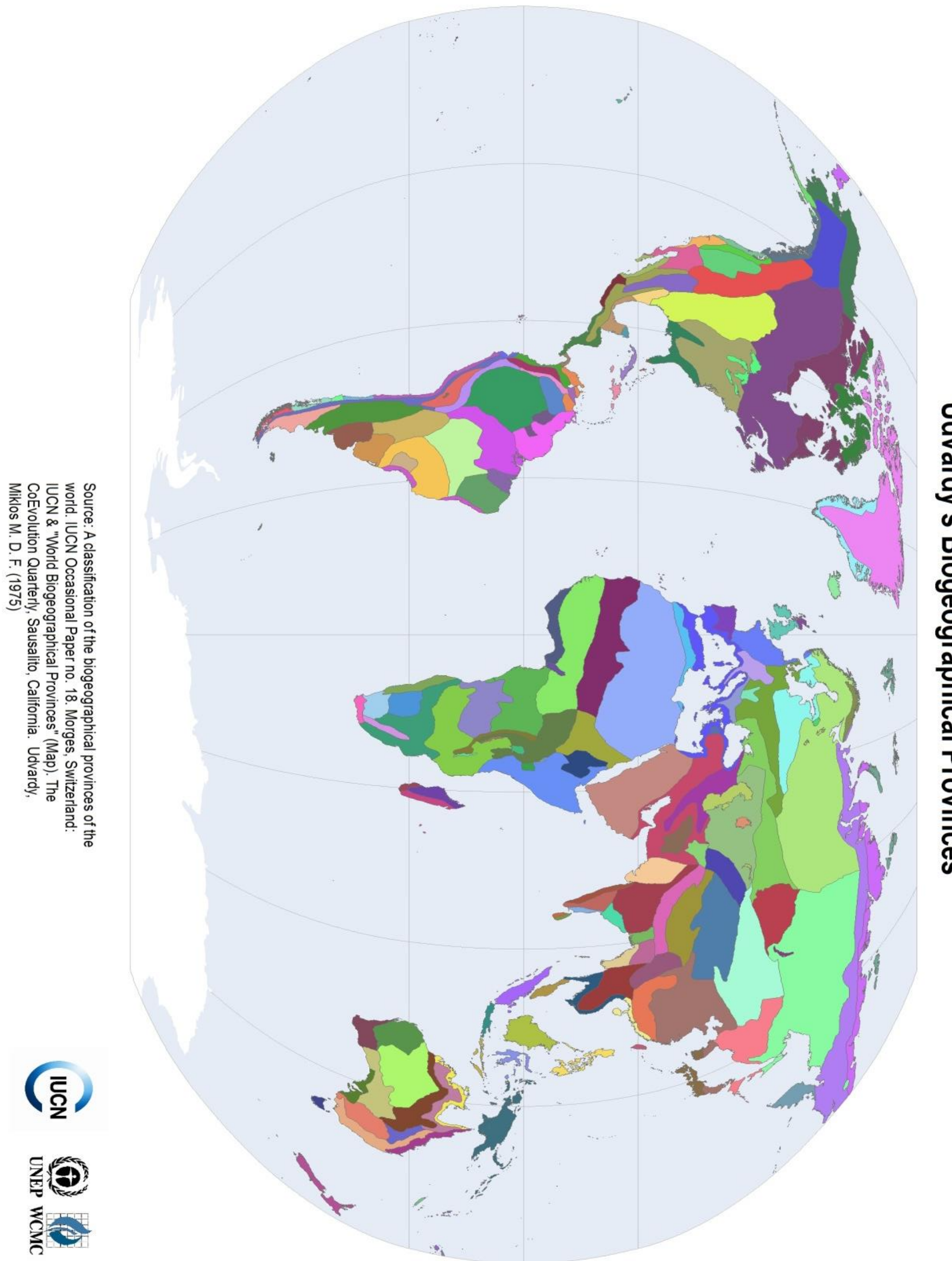


Figure 7-2: Biogeographical Provinces of the World

Source: Udvardy (1975)

The classification proposed by Udvardy, is defined by a sequence of six numbers, with two for the realm number, two for the province number and two for the biome number. The sequence is as follow: **# #** (Realm) **–** **# #** (Province) **–** **# # (**Biome).

For example an area of South America in the *Neotropical* realm (realm 08), located in a province of *Llanos* (province 27), within the biome *Tropical Grasslands and Savannas* (biome 10) will have the corresponding regional specificity code number: **08 - 27- 10**.

The regional specificity identification used in the Watsan technologies database developed in this research adopts the same classification proposed by Udvardy. Therefore, the same sequence of number will be used to identify the regional specificity of a community in the database. Appendix I contains the complete description of the regional specificity classifications for all the regions of the world, and the corresponding table of code numbers for the regional specificities used in the Watsan database.

7.4 Settlement Type

Another important criterion used in the Watsan database is the type of settlement of the community. We will use three categories of settlement types to identify a developing community: urban settlement, peri-urban settlement, and rural settlement. The classification of the settlement type is determined by several criteria. According to UN-Habitat (2011), there is no formal universal definition of urban areas that has been adopted by national governments or by the international community. In fact, the estimate of the number of inconsistencies in the definitions of urban areas as reported by the UN-Habitat report (UN-Habitat, 2011) is presented in Table 7-3 below.

Table 7-3: Inconsistent Urban Definitions

Number	Classification	Description
114	Administrative considerations	Equates urban areas with State/Provincial capitals or municipalities (local jurisdictions)
51	Population size and Density	Size: Variations from 200 to 50,000 inhabitants
39	Socio-Economic Criteria	Proportion of the labor force employed in non-agricultural activities or availability of urban amenities
12	No Explanation	No defined Criteria

Source: (Un-Habitat, 2011)

As we can see in Table 7-3, 114 different definitions of an urban area that use administrative considerations such as the local jurisdictions exist, 51 definitions of an urban area that use the population size and density exist, 39 definitions of an urban area that use socio-economic criteria exist, and 12 definitions that have no explanation or defined criteria exist.

The settlement type we propose to use in the Watsan database will use the definitions presented in Table 7-4 below. However the determination of the settlement type such as urban, peri-urban, and rural will be determined on a case-by-case basis drawing from the definitions of the settlement types of the host country of every developing community.

Table 7-4: Settlement Types

Area	**Urban (1)**		**Peri-Urban (2)**		**Rural (3)**	
Formality / **Density**	**Formal (1)**	**Informal (2)**	**Formal (1)**	**Informal (2)**	**Formal (1)**	**Informal (2)**
Low (1)	Lots	Squatters	Lots	Squatters	Village	Squatters
High (2)	Tenements	Ghetto	Tenements	Shanty town	Town	Shanty town

Nevertheless in terms of access to municipal sanitation services, we can propose accepted definitions and differences between peri-urban and rural areas.

Peri-urban areas are located between consolidated urban areas, and rural areas. According to NETSSAF, the Peri-urban components for access to MSS are the following: “more sanitation providers, more equipped in infrastructures, less space for construction, higher opportunity for market development and possible intervention of decentralized national water and sanitation services”.

Rural areas are located outside towns and cities. They are characterized by low population densities and small size. Rural areas are also characterized by poor access to infrastructure facilities such as markets, schools, and hospitals. In terms of access to MSS, and according to NETSSAF, the rural components are: “poor infrastructures, no service providers, more space for construction, low population density, higher need for training, bigger potential for reuse of sanitation by-products, worse institutional representation” (NETSSAF, 2008).

Figure 7-3 below illustrates the spatial distribution of the three main area types of human settlements.

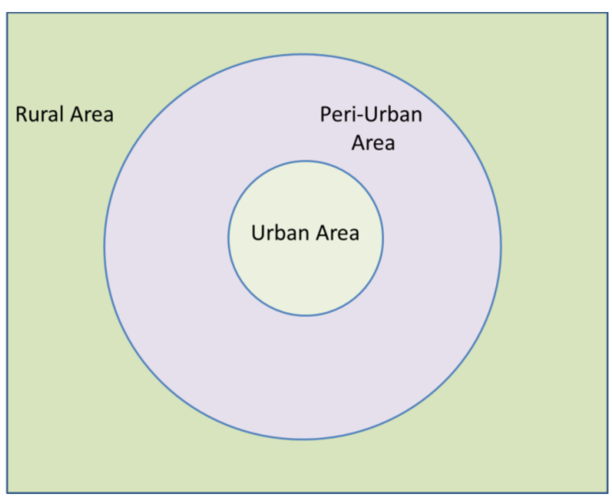


Figure 7-3: Settlement – Area Types

In the Watsan database, we used the following sequence to identify a community's settlement type according to the descriptions provided in Table 7-4. The sequence for the settlement type uses three digits: the first one for the area type, the second one for the formality type, and the third one for the population density:

(Area) - # (Formality) - # (Density)

For example a community located in a peri-urban area, settled in a formal jurisdiction, and with a high density of population will have the following number sequence for its settlement type in the database: 2 – 1 – 2.

7.5 Community Profile

The other important information in the Watsan technologies database is related to the profile of the communities that have implemented and are operating the Watsan technologies. As defined in Chapter 5, the profile of a community is defined by the seven capacity factors and their related constituents. The eighth capacity factor, the service CF is not used in the database since it only represents the deficiency of the service at the time of the assessment. The seven capacity factors used in the database are CFs are presented in Table 7-5 below:

Table 7-5: Capacity Factors for Municipal Sanitation Services

#	Capacity Factors	Constituents
2	Institutional	Legislation (standards) Regulations (by agencies) Administration (agencies/processes) Governance (federal, regional, and local)
3	Human Resources	Professional Skilled labor Unskilled labor Literacy rate
4	Technical	Operations Maintenance Adaptation (upgrading) Supply chain (availability of spare parts)
5	Economic / Financial	Private sector percentage role in service Budget User fees from community users Bond rating to fund projects Asset values
6	Energy	Primary source Back up Percentage of budget dedicated to energy Rate of power outage
7	Environmental	Quality–sensitivity (footprint, carrying capacity) Quantity of natural resources
8	Social / Cultural	Communities Stability Equity Castes

Ideally, once the database developed in this research is completed, most of the Watsan technology options stored in the database will be associated with developing communities operating them. The data of these communities, including the communities' profiles, their regional specificities, and their settlement types, will be used by the matching model for the selection of appropriate Watsan options. Once this stage of the development of the database is reached, the decision making model proposed in this research will be fully efficient.

7.6 Database of Watsan Technology Options

The DSS with the database of Watsan technology options is developed with MS Access software. Initially at this stage of this research, this DSS is not web accessible. However, it was designed with this feature in mind, and MS Access software offers the capability to push the DSS to the web and have the user interface web-based. The entity relationship diagram (ERD) retained for the design of the Watsan database is presented in Figure 7-4. As we can see, the Watsan database is structured with nine tables.

The first table is the *Community* table. It contains data on developing communities. Each instance in the *Community* table is defined by the name of the community, the country where it is located, and the regional specificity and settlement type identification. The *Community* table also contains data on Watsan technology options implemented and functioning in the developing communities. Every developing community can be at a stage of development regarding the municipal sanitation services it provides to the population where it operates one, two, or the three sanitation services. Therefore the *Community* table contains three fields: one for each the Watsan technology category, *DWS_ID*, *WST_ID*, and *MSW_ID*. Appendix I contains the *Community* table used in the Watsan database. The *Community* table will be populated continuously as new developing communities implement Watsan technology options for their MSS needs. As the data are collected, they will be added to the Watsan database.

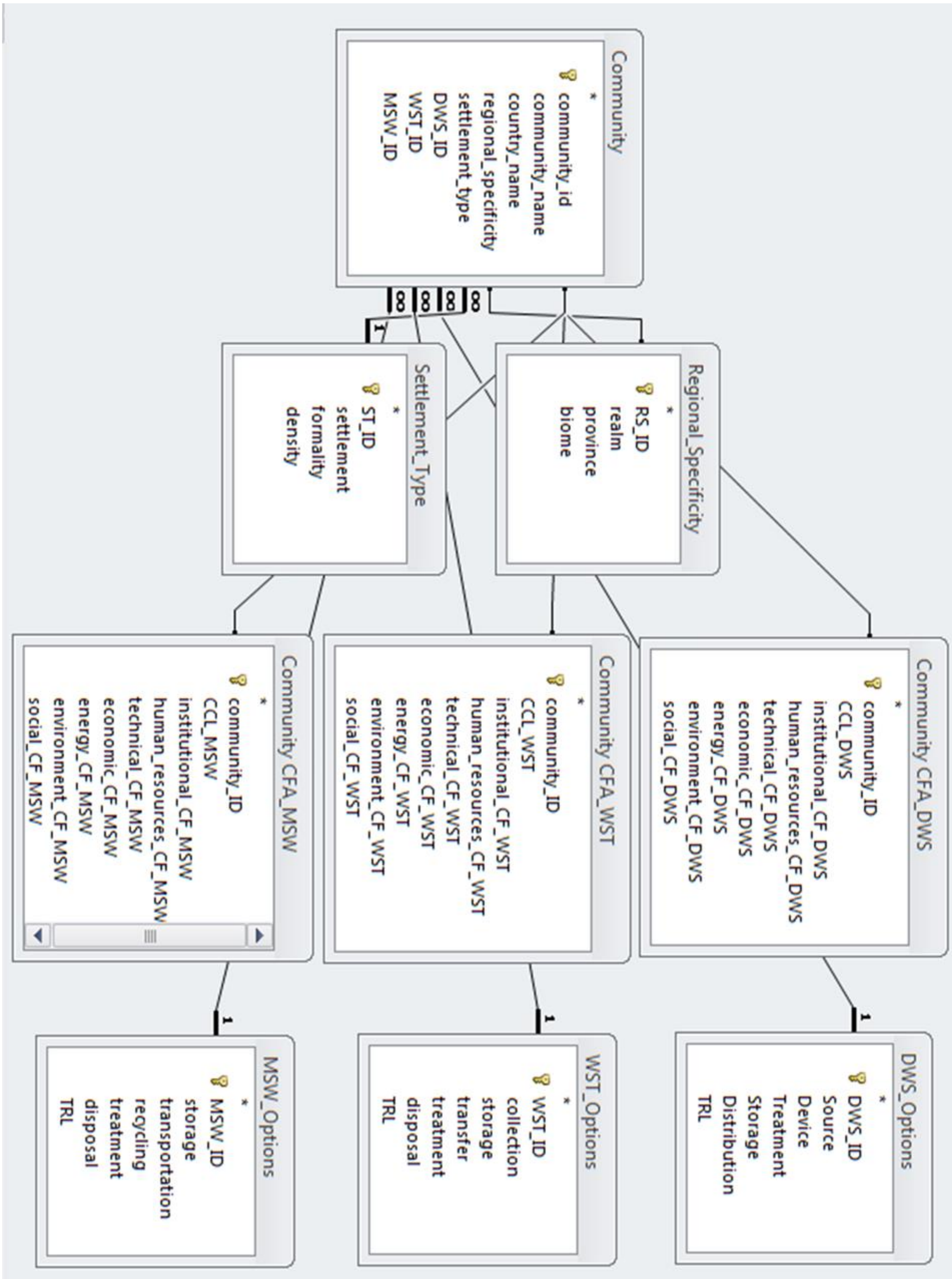


Figure 7-4: Entity Relationship Diagram of the Watsan Database

The second and third tables contain the *Regional Specificity* table, and the *Settlement Type* table. Every developing community is a located in a specific province within a defined realm, and in a determined settlement type. The *Regional Specificity* table contains all the regional specificities of the biogeographical regions of the world. Each instance in the *Regional Specificity* table is defined by a realm, a province, and a biome type, and has a specific *RS_ID* number. The *Settlement Type* table contains twelve instances that correspond to the twelve possible configurations of settlement type.

The third, fourth, and fifth tables in the ERD of the database contain developing communities' capacity factors assessment scores for the three MSSs. These tables also contain the resulting CCLs from the respective CFs assessments. These tables are labeled *Community CFA_DWS*, *Community CFA_WST*, and *Community CFA_MSW*.

Finally, the last three tables in the EDR contain the Watsan technology options: one for the DWS options, one with the WST options, and one for the MSW options. In each Watsan technologies table, an instance or a technology option is identified with an identification number, a set of unit processes, and a TRL score. At this stage in this research, the only Watsan table that is complete is the *DWS_Options* table. The two other tables, *WST_Options* table and *MSW_Options* table, require the completion of their classifications and the determination of their respective TRL scores that can be done using the same methodology applied for the DWS options.

Chapter 8. Appropriate Matching

8.1 Matching Model

The last step in component #1 of the decision model framework presented in Figure 4-1 is the matching process. An appropriate matching (AM) model for the selection of

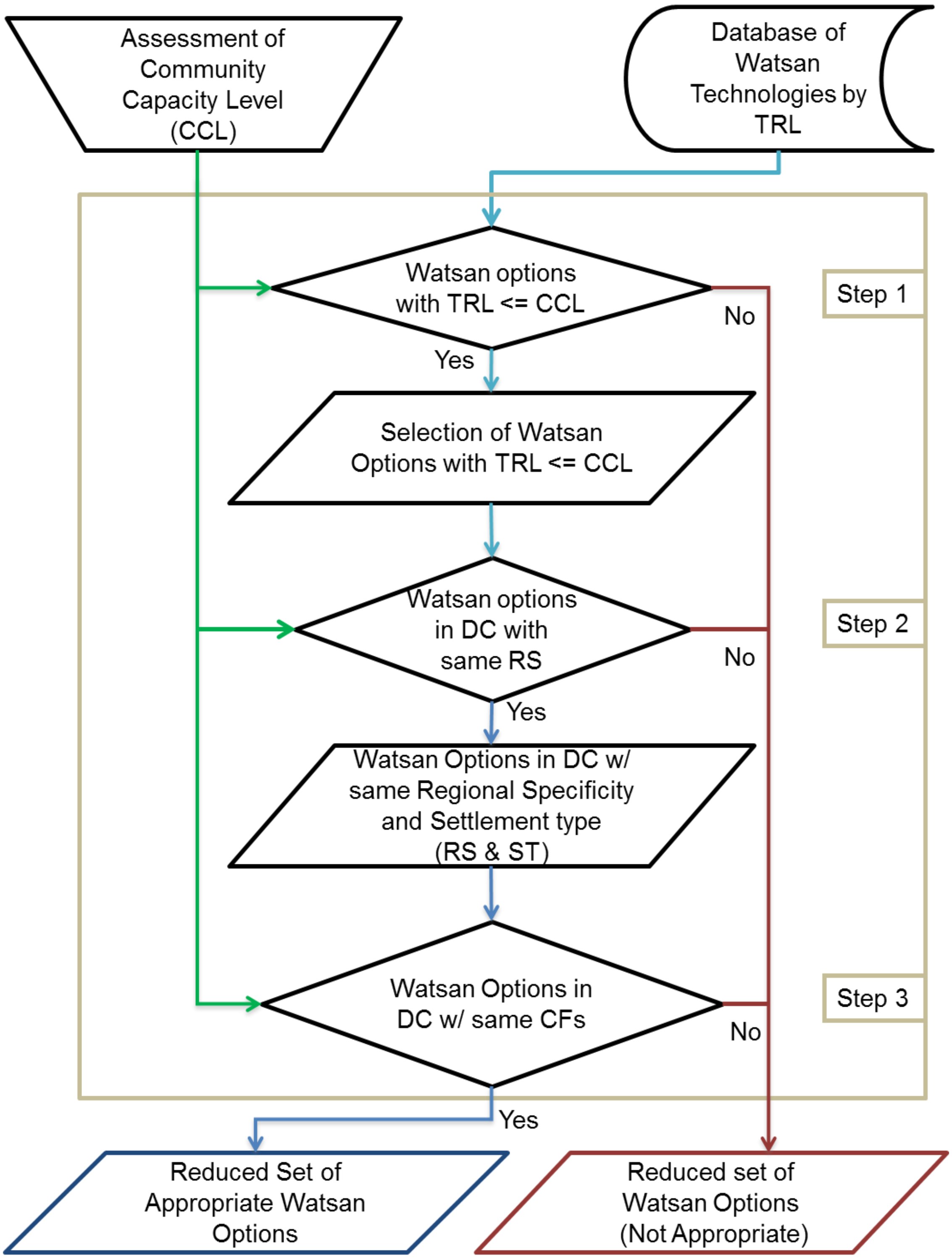


Figure 8-1: Matching Model for Selection of Watsan Options

appropriate Watsan options is proposed in Figure 8-1. The AM matching model is performed in three steps.

8.2 Procedure

First a community with a need for an MSS must complete assessment using the CFA guidelines of the corresponding MSS. Three CFA guidelines, one for each MSS exist, namely DWS, WST, and MSW. Once the assessment is completed, the results are used as inputs into the entry form of the decision support system (DSS). The DSS has three entry forms, one for each MSS, where the user will enter the CFA results of the corresponding MSS. The inputs into the entry form include the following items:

- Community name
- Settlement type, which includes the area, the formality, and the density
- Regional specificity defined by the biome type
- Capacity factors scores and the corresponding calculated *CCL* metric

An model of the entry form used in the case of DWS service is shown in Figure 8-2 below. In this case, the inputs into the entry form will be from the CFs assessment scores and the CCL metric for the DWS service.

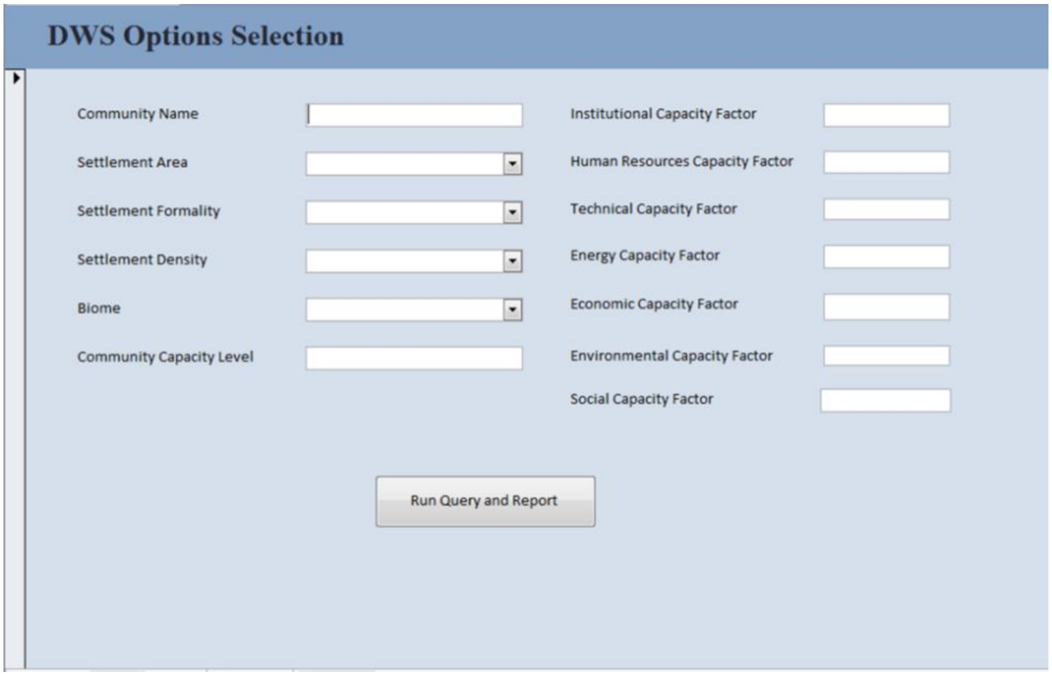


Figure 8-2: Appropriate Matching Entry Form for DWS Options Selection

Once the entry is completed, the AM process begins when the user presses the "Run Query and Report" button. The AM process is then performed following the three steps as shown in matching framework presented in Figure 8-1.

The first step of the matching process is done by selecting Watsan technology options that have a TRL metric equal to or lower than the assessed CCL metric of the host community. The AM model looks at Watsan options in the Watsan table of the corresponding MSS. The AM model selects from the table a set of Watsan technology options with a TRL metric that is less than or equal to the CCL entered.

The second step of the AM process is achieved with the selection of a subset of the Watsan options from the set of Watsan options obtained in the first step that are implemented in communities with similar regional specificity and settlement type as the target host community. In this process, the matching parameters are the biome type of the regional specificity of the community and the settlement type (ST) criterion.

The third and last step of the AM process is completed with a selection from the reduced subset of remaining candidates of a final set of Watsan options that have been implemented and operated by communities that have a profile similar to the one of the host community. In this final step of the AM process, the algorithm will compare the capacity factors (CFs) of the host community to the CFs of communities operating the Watsan options of the final subset. Only those Watsan options that have been implemented successfully in communities that have similar CFs will be selected. In this last step of the AM process, the comparison of the CFs is performed using a 1-5 level scale instead of a 1-100 scale. This more generalized scale provides more flexibility in the matching process without compromising the overall similarity of the capacities of the developing communities. For example, if the score of CF2 of the host community is 34, this score is in the level 2 on the 1-5 scale. The level 2 of the 1-5 scale includes CF scores ranging between 21 and 40. Therefore, any community with a CF2 score between 21 and 40 will have a similar CF2 score as the host's CF2 score. Table 8-1 below presents the correspondence between the CFs scores on 1-100 scale and on the 1-5 level scale.

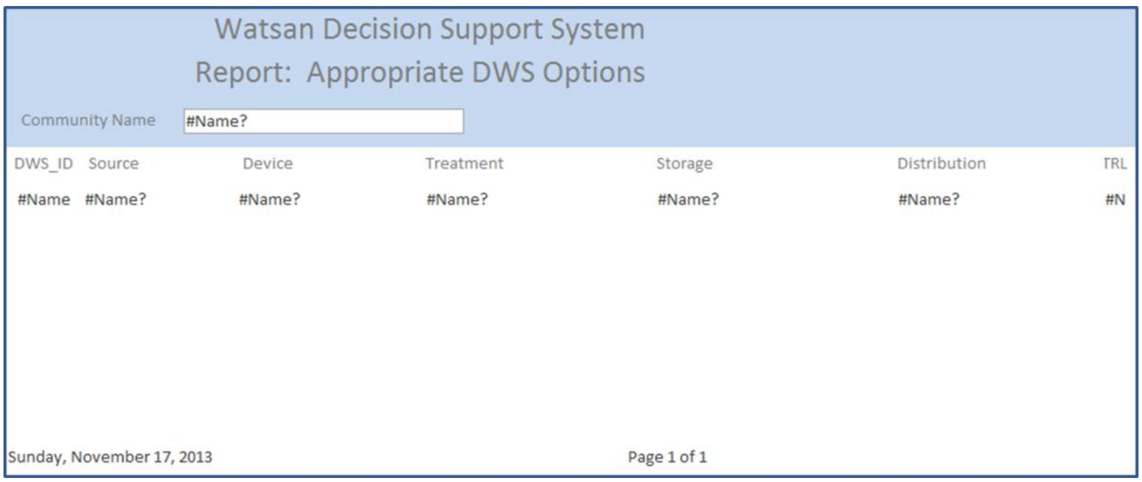
Table 8-1: Correspondence between CF Scores and the 1-5 Level Scale

CF Scores	1 - 20	21 - 40	41 – 60	61 – 80	81 - 100
1-5 Levels	1	2	3	4	5

At the end of the matching process, the AM model provides two possible outcomes of reduced set of Watsan technology options in the DSS reports:

- In the case where the AM algorithm goes successfully through the three search criteria of the matching process, the decision support system (DSS) delivers the

Appropriate DWS Options report. This report contains a set of appropriate Watsan technology options for the host community. The definition of appropriateness here is such that the selected Watsan technologies have a TRL score is less than or equal to the CCL score of the host community; the Watsan technologies are implemented in areas with similar regional specificities and settlement types. Furthermore, the Watsan technologies are operated and maintained sustainably by communities with profile similar to the host community. Figure 8-3 below presents a model of the *Appropriate DWS Options* report delivered by the DSS.



Watsan Decision Support System

Report: Appropriate DWS Options

Community Name #Name?

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
#Name	#Name?	#Name?	#Name?	#Name?	#Name?	#N

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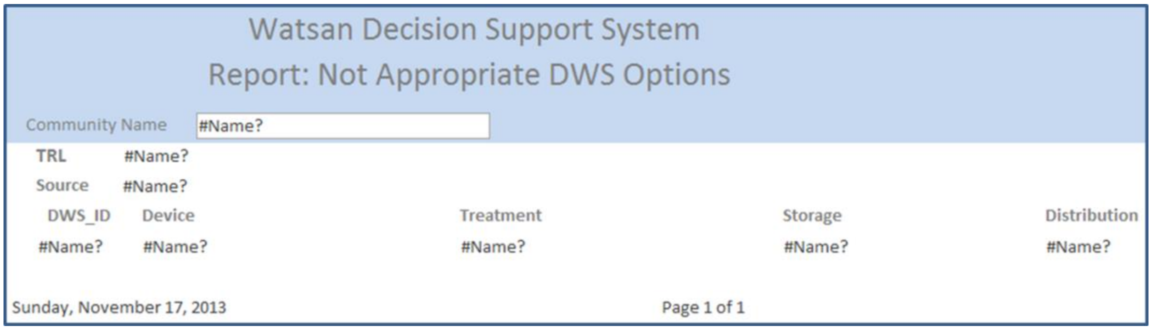
Figure 8-3: DSS – Report Appropriate DWS Options

- In case where the AM algorithm does not go through the entire selection process successfully, the DSS still delivers a reduced set of Watsan technology options in the *Not Appropriate DWS Options* report. The Watsan options delivered in this report matches the capacity of the community, defined by its *CCL* metric. However, these options are not guaranteed to be the most appropriate ones for the host community. Figure 8-4 below presents a model of ta *Not Appropriate DWS Options* report delivered by the DSS.



Watsan Decision Support System
Report: Not Appropriate DWS Options

Community Name #Name?

TRL #Name?
Source #Name?

DWS_ID	Device	Treatment	Storage	Distribution
#Name?	#Name?	#Name?	#Name?	#Name?

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Figure 8-4: DSS – Not Appropriate DWS Options Report

In the two DSS reports, the set of Watsan options are organized by the TRL metric first, and then by the unit process *source,* in the case of the DWS module of the DSS as presented in Figure 8-4. The reports present the Watsan options in alphabetical order, with their identification numbers, and their unit processes descriptions.

Chapter 9. Evaluation and Ranking of Watsan Technology Options

9.1 Decision-making Criteria

The framework of the decision model, as presented in Figure 4-1, includes three main components: the *Assessment* component, the *Evaluation* component, and the *Management* component. Component #2 of the decision model is the *Evaluation* component. It is used for the evaluation and the ranking of the set of Watsan technology options selected in the matching process. Multiple criteria decision making (MCDM) models could be used for the evaluation of the selected alternatives. Simon (1977) defines a decision making process with four phases: first the problem is structured and the influential parameters are identified. Second, the alternatives are evaluated based on the parameters identified earlier, thirdly a ranking is performed based upon the results of the evaluation of the alternatives. Finally, a control or verification completes the process

The first phase is therefore to identify the parameters or criteria that will form the decision making process. The Watsan technologies have several important parameters that should be taken into account for their sustainability. The determination of the parameters that influence the decision making process is conducted based upon the experience of World Bank/United Nations Development Program – Village Level Operations and Maintenance management (VLOM) project (Arlosoroff et al. 1987). The VLOM criteria for technology evaluation were: cost effective, robust, and reliable under field conditions; manufactured in-country primarily to ensure the availability of spare parts; easily maintained by a village caretaker applying minimal skills. The criteria used in this model for the evaluation of the selected Watsan alternatives are consistent with the ones used in the design of the VLOM project. They provide a comprehensive evaluation of the Watsan alternatives. The complete set of criteria proposed for the evaluation of the Watsan technology alternatives are the following: *service*, which relates to the performance of the Watsan options; *institutional*, which relates to regulations that apply to the Watsan option; *human resources*, which relates to village caretakers' skills required; *technical*, which relates to supply chain accessibility; *energy*, which relates to electrical power supply required; *economic*, which relates to the costs of the Watsan option; *environmental*, which relates to the natural resources needed for the Watsan option; and *social/cultural*, which relates to level of participation of all community stakeholders, especially the role of women in the implementation and use of the Watsan option. Table 9-1 summarizes the criteria used for the evaluation and ranking of the selected Watsan alternatives.

Table 9-1: Criteria for Evaluation and Ranking of Watsan Alternatives

#	Criteria	Description
x_1	Service	Performance of the Watsan alternatives (ex: liter/day, # coliforms/100 mL)
x_2	Institutional	Existence of regulations / standards for the use or implementation of Watsan alternative
x_3	Human resources	Skills level required for O&M of Watsan alternative
x_4	Technical	Supply chain required for O&M
x_5	Economic	Cost of Watsan (initial and O&M)
x_6	Energy	Power requirement per unit of output
x_7	Environment	Quantity of water available / land needed for Watsan alternative
x_8	Social/cultural	Participation rate of women in O&M of Watsan alternative*

* Participation of women is used as an indicator of participation of all subgroups (caste, tribe, and ethnicity) in the community.

9.2 Decision-making model

The MCDM model proposed to evaluate the Watsan alternatives is a simple decision matrix. The model uses the eight criteria x_1 - x_8 to evaluate the Watsan alternatives, as presented in Table 9-1. The detailed matrix with the eight criteria and their corresponding weights used for the evaluation of the Watsan alternatives is presented in Table 9-2. Each individual criterion has a specific weight. The determination of the criteria's weights will be established by the decision makers in the host community. The results of the weighted scores received by each Watsan option will lead to its ranking. The community can then make an informed decision about which Watsan alternative to implement to provide the needed MSS.

Table 9-2: Decision Matrix for Watsan Options Evaluation

		Scores								
		Options	**Option #1**		**Option #2**		**….**		**Option #n**	
#	**Criteria**	**Weight %**	Score	Weighted Score	Score	Weighted Score			Score	Weighted Score
1	**Service** *System Outputs (/day)* *Quality* *Access* *Subtotal*									
2	**Institutional** *Authority requirements* *Regulations* *Process* *Program* *Subtotal*									
3	**Human Resources** *Professional* *Skilled* *Unskilled* *Subtotal*									
4	**Technical** *Spare parts* *Chemicals* *Specialized services* *Subtotal*									
5	**Economic** *Initial cost* *Cost / Output* *Subtotal*									
6	**Energy** *Power intensity needed* *Power reliability* *Subtotal*									
7	**Environment** *Natural resources need* *Subtotal*									
8	**Social / Cultural** *Women participation* *Subtotal*									
Total Score			**Score Option #1**		**Score Option #2**		**…**		**Score Option #n**	

The evaluation of the Watsan alternatives resulting from the appropriate matching process is also an important step in the procedure of selecting an appropriate Watsan option. Indeed, the evaluation of the Watsan options by the community's decision makers or the Watsan practitioners permits the review of each alternative delivered in the

Appropriate Options report. Furthermore, the evaluation allows key personnel to analyze an alternative's performance and suitability to the environment, and resources required in the host community.

Chapter 10. Implementation of Selected Watsan Options

The last component of the Watsan decision model presented in Figure 4-1 is the *Management* component. It is used to assist developing community organizations in the resource allocation process for the development of municipal sanitation services. Integrated water and sanitation services have proved to be more efficient and cost effective than managing the three sanitation services separately. As an example, in the case of the city of Philadelphia, integrated water and sanitation management provided an effective and sustainable approach to water and sanitation systems construction and operation (Kramek et al., 2007).

The resources allocation process for the development of sanitation infrastructure can be facilitated by the use of the *Management* component of the Watsan decision model. This component could be developed using an impact–based sequential resources allocation model. This model allows making the appropriate proportional annual investment for each of the three Watsan infrastructures in order to eliminate the deficit in all of the services over the planned lifecycle of the integrated sanitation system. The optimal resource allocation for investing simultaneously in the three MSSs is defined at each budget period. The proportion of resource allocation to each MSS could be defined based upon the impact of the deficiency of the MSS on the health, the economy, and the environment of the host community. The third component of the decision model was not the main focus in this research and subsequent research papers proposed by Magpili and

Louis have explored some options for the resources allocation tasks in integrated sanitation services (Magpili, 2003), (Louis and Magpili 2005).

Chapter 11. Test Bed

The field research accompanying this study has been conducted mainly in Morocco. The data collected in the field research includes technical specifications on the Watsan technology options used by developing communities for DWS principally and the profiles of the communities operating them. The data on the profiles of the developing communities also include their regional specificities, and their settlement types. The data collected were used to populate the *Community* table of the Watsan options database. The data on the developing communities of the field study are presented in Appendix J.

11.1 Case studies in Morocco

Several villages of Morocco were studied for the test bed of the decision support model. As we can see in Figure 11-1, Morocco is located in the *Palearctic* realm (02).

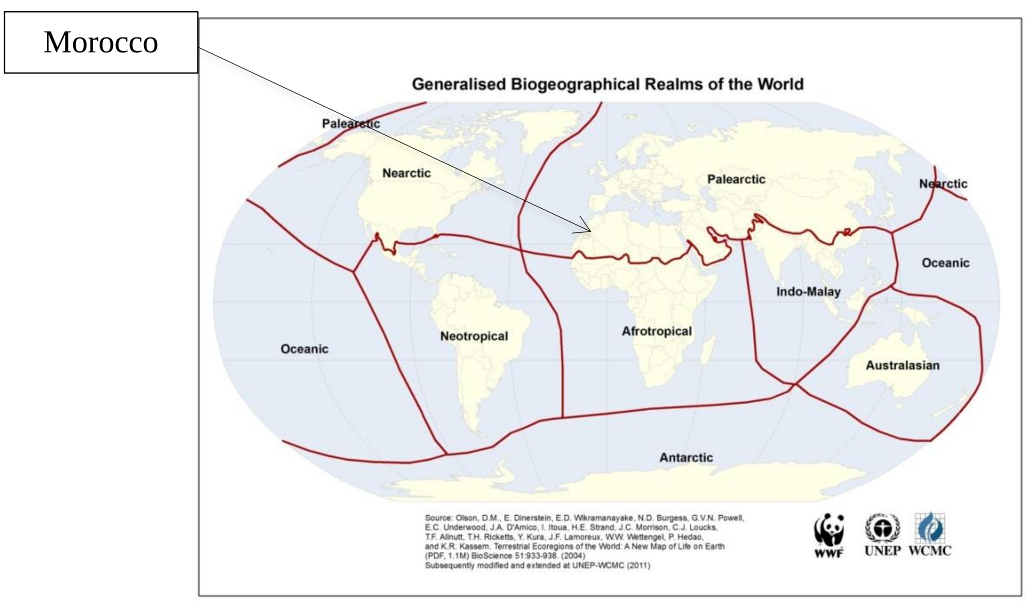


Figure 11-1: Palearctic Realm of the World

Source: Olson et al. (2011)

Furthermore, as we can see in Figure 11-2, Morocco has three biogeographical provinces. Each province presents features related to different biomes.

- In the North, we find the *Mediterranean Sclerophyllous* province (17), with a biome type *Woodland / Scrubland* (6). The regional specificity identification is 021706.
- In the Center, we find the *Atlas Steppe* province (28), with a biome type *Temperate Grassland* (11), and the corresponding regional specificity identification is 022811.
- In the South, we find the *Sahara* province (18), with a biome type *Subtropical Desert* (7), and regional specificity identification 021807.

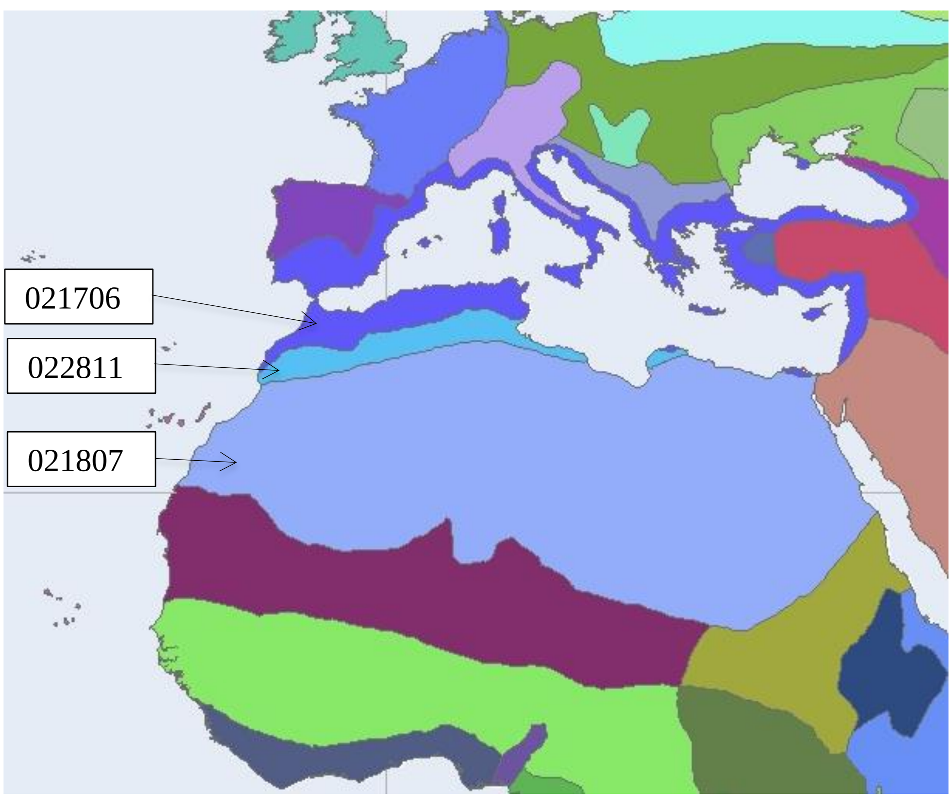


Figure 11-2: Regional Specificity of Morocco's Provinces

The data collection was conducted thanks to the assistance of a Moroccan development agency, the Agence de Developpement Social (ADS). The ADS has funded hundreds of development projects in Morocco since it started its activity in 2000. Initially the ADS funded principally infrastructure projects such as rural roads, and water supply infrastructures before it shifted its activities to micro-financing for developing communities in Morocco.

The villages used in the test bed of this research were selected among communities funded by ADS, which have installed Watsan options, and have operated the corresponding MSS sustainably for at least two years after the implementation of the infrastructure. The data collected in this field research were related to the profiles and the specificities of the communities living in the villages. The data collected have been used to evaluate the performance of the decision support system (DSS).

11.2 Evaluation of the Decision Tools

The evaluation of the performance of the decision tools developed in this research was conducted with two evaluation procedures. The first evaluation was done with the data collected from the field research in Morocco to test the CFA model, and the second evaluation was completed with generated data to test the performance of the decision support system.

11.2.1 CFA Evaluation - Developing Communities in Morocco

In the first evaluation of the decision tools, we used data collected in developing communities in Morocco. The evaluation was conducted by assessing the communities' capacity factors with the CFA guideline and by verifying if the TRL scores of the Watsan technology options implemented by the developing communities match their assessed

CCL scores. The aim of this evaluation was to verify if the selection of the Watsan technology options implemented by the communities was appropriate or not. We used six developing communities in Morocco among the communities who received funding from the ADS for their Watsan infrastructures.

- **Community #1: Douar Lemlaqite**

  Douar Lemlaqite is a community located in a village in the North of Morocco in the Province of *Sidi Kacem*. The community is located in the *Mediterranean Sclerophyllous* province (17), with a biome type *scrubs_or_woodlands* (06). Its regional specificity identification is *RS_ID* 021706. The community has a population of 1306. The settlement type of the community is as follow: rural area, formal, and low density. The corresponding *ST_ID* is 311.

We performed the assessment of the CFs of *Douar Lemlaqite* community with the DWS CFA guideline, and recorded the results on the *Data Collection – Developing Community* form. The complete assessment of the CFs of the *Douar Lemlaqite* community is reported in Appendix K. Table 11-1 below shows the scores received by the CFs of *Douar Lemlaqite* community.

Table 11-1: CFs Scores - Douar Lemlaqite Community

CF #	Capacity Factor	Score
1	Service	51
2	Institutional	43
3	Human Resources	33
4	Technical	36
5	Economic	33
6	Energy	46
7	Environment	45
8	Social	59

The CCL of the *Douar Lemlaqite* community is determined based upon the lowest score received by the CFs. The lowest scores received is the one of the *Economic* CF: 33. Therefore the corresponding CCL of *Douar Lemlaqite* community is at a level 2.

Douar Lemlaqite community has implemented a DWS option made of the following unit processes presented in Table 11- 2.

Table 11-2: DWS Option – Douar Lemlaqite Community

DWS_ID	Source	Device	Treatment	Storage	Distribution
222	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection

The Watsan technology options, *DWS_ID* 222, used by the community has a TRL score of 4. Therefore, we observe that in the case of *Douar Lemlaqite* community, the DWS technology option selected does not match the capacities of the community. We can conclude that *Douar Lemlaqite* community is at risk of not being able to operate and maintain their DWS infrastructure in the long run.

- **Community #2: Douar Chibte**

Douar Chibte is a community located in a village in the north of Morocco in the Province of *Boulmane*. The community is located in the *Mediterranean Sclerophyllous* province (17), with a biome type *scrubs_or_woodlands* (06). Its regional specificity identification is *RS_ID* 021706. The community has a population of 190. The settlement of the community is as follow: rural area, formal, and low density. The corresponding *ST_ID* is 311.

The assessment of the CFs of *Douar Chibte* community was performed using the CFA guideline for DWS. The complete assessment of the CFs is reported in Appendix K and the results of the CFs scores are presented in Table 11-3.

Table 11-3: CFs Scores – Douar Chbite Community

CF #	Capacity Factor	Score
1	Service	51
2	Institutional	37
3	Human Resources	31
4	Technical	39
5	Economic	30
6	Energy	48
7	Environment	48
8	Social	49

The CCL of *Douar Chbite* community is determined based upon the lowest score received by its CFs. The lowest scores received are the one of *Economic* CF: 30. Therefore the corresponding CCL of *Douar Chbite* community is at a level 2.

Douar Chbite community has implemented a DWS option made of the following unit processes presented in Table 11-4.

Table 11-4: DWS Option – Douar Chbite Community

DWS_ID	Source	Device	Treatment	Storage	Distribution
584	springwater_collection	gravity	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection

The Watsan technology options, *DWS_ID* 584, used by the community has a TRL score of 3. We note that the DWS technology option used by *Douar Chbite* community does not match its capacities. We can conclude that *Douar Chbite* community is at risk of not being able to operate and maintain the DWS infrastructure in the long run.

- **Community #3: Douar Ait Khabach**

Douar Ait Khabach is a community located in a village in the North of Morocco in the Province of *Boulmane*. The community is located in the *Mediterranean Sclerophyllous* province (17), with a biome type *scrubs_or_woodlands* (06). Its regional specificity identification is *RS_ID* 021706. The community has a population of 840. The settlement of the community is as follow: rural area, formal, and low density. The corresponding *ST_ID* is 311.

The assessment of the CFs of *Douar Ait Khabach* community was performed using the CFA guideline for DWS. The results of the assessment of the CFs are reported in Appendix K, and a summary of the CFs scores is presented in Table 11-5.

Table 11-5: CFs Scores – Douar Ait Khabach Community

CF #	Capacity Factor	Score
1	Service	45
2	Institutional	43
3	Human Resources	41
4	Technical	43
5	Economic	41
6	Energy	46
7	Environment	53
8	Social	46

The CCL of *Douar Ait Khabach* community is determined based upon the lowest score received by the CFs. The lowest score received are the ones of the *Human Resources* CF, and of the *Economic* CF, 41. Therefore, the CCL of *Douar Ait Khabach* community is at a level 3.

Douar Ait Khabach community has implemented a DWS option made of the following unit processes presented in Table 11-6.

Table 11-6: DWS Option – Douar Ait Khabach Community

DWS_ID	Source	Device	Treatment	Storage	Distribution
344	dug_well	submersible_pump	domestic_chlorination	elevated_reservoir	domestic_connection

The Watsan technology options, *DWS_ID* 344, used by the community has a TRL score of 3. We note that the DWS technology option, selected and implemented by *Douar*

Ait Khabach community, matches its capacities. We can conclude that, the DWS technology option selected by *Douar Ait Khabach* community should be sustainable.

- **Community #4: Douar Ait Bou Ahmed**

Douar Ait Bou Ahmed is a community located in a village in the Center of Morocco in the Province of Haouz. The community is located in the *Palearctic* realm, in the *Atlas_steppe* province (28), with a biome type *Temperate_grassland* (11). Its regional specificity identification is *RS_ID* 022811. The community has a population of 800. The settlement of the community is as follow: rural area, formal, and low density. The corresponding *ST_ID* is 311.

The assessment of the CFs of *Douar Ait Bou Ahmed* community was performed using the CFA guideline for DWS. The complete assessment of the CFs is reported in Appendix K, and the results of the CFs scores are presented in Table 11-7.

Table 11-7: CFs Scores – Douar Ait Bou Ahmed Community

CF #	Capacity Factor	Score
1	Service	30
2	Institutional	42
3	Human Resources	41
4	Technical	43
5	Economic	43
6	Energy	41
7	Environment	48
8	Social	61

The CCL of *Douar Ait Bou Ahmed* community is determined based upon the lowest score received by the CFs. The lowest scores received are the ones of the *Human Resources* CF, and the *Energy* CF, 41. Therefore the CCL of *Douar Ait Bou Ahmed* community is at a level 3.

Douar Ait Bou Ahmed community has implemented a DWS option made of the following unit processes presented in Table 11- 8.

Table 11-8: DWS Option – Douar Ait Bou Ahmed Community

DWS_ID	Source	Device	Treatment	Storage	Distribution
232	drilled_well	submersible_pump	domestic_chlorination	elevated_reservoir	domestic_connection

The Watsan technology options, *DWS_ID* 232, used by the community has a TRL score of 3. We note that the DWS technology option, selected and implemented by *Douar Ait Bou Ahmed* community, matches its capacities. We can conclude that, in the case of *Douar Ait Bou Ahmed* community, the DWS technology option selected should be sustainable.

- **Community #5: Douar Taschert**

Douar Taschert is a community located in a village in the Center of Morocco in the Province of Haouz. The community is located in the *Palearctic* realm, in the *Atlas_steppe* province (28), with a biome type *Temperate_grassland* (11). Its regional specificity identification is *RS_ID* 022811. The settlement of the community is as follow: rural area, formal, and low density. The corresponding *ST_ID* is 311. The community has a population of 840.

The assessment of the CFs of the *Douar Taschert* community was performed using the CFA guideline for DWS. The results of the assessment of the CFs are reported in Appendix K, and a summary of the CFs scores is presented in Table 11-9.

Table 11-9: CFs Scores – Douar Taschert Community

CF #	Capacity Factor	Score
1	Service	45
2	Institutional	46
3	Human Resources	41
4	Technical	46
5	Economic	42
6	Energy	43
7	Environment	55
8	Social	61

The CCL of *Douar Taschert* community is determined based upon the lowest score received by the CFs. The lowest scores received is the one of the *Human Resources* CF, 41. Therefore the CCL of *Douar Taschert* community is at a level 3.

Douar Taschert community has implemented a DWS option made of the following unit processes presented in Table 11- 10.

Table 11-10: DWS Option – Douar Taschert Community

DWS_ID	Source	Device	Treatment	Storage	Distribution
228	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection

The Watsan technology options, *DWS_ID* 228, used by the community has a TRL score of 3. We note that the DWS technology option, selected and implemented by *Douar Taschert* community, matches its capacities. We can conclude that, in the case of *Douar Taschert* community, the DWS technology option selected should be sustainable.

- **Community #6: Douar Ait Said**

Douar Ait Said is a community located in a village in the Center of Morocco in the Province of Haouz. The community is located in the *Atlas_steppe* province (28), with a biome type *Temperate_grassland* (11). Its regional specificity identification is *RS_ID*

022811. The settlement of the community is as follow: rural area, formal, and low density. The corresponding *ST_ID* is 311. The community has a population of 330.

The assessment of the CFs of the *Douar Ait Said* community was performed using the CFA guideline for DWS. The results of the assessment of the CFs are reported in Appendix K, and a summary of the CFs scores is presented in Table 11-11.

Table 11-11: CFs Scores – Douar Ait Said Community

CF #	Capacity Factor	Score
1	Service	25
2	Institutional	42
3	Human Resources	31
4	Technical	43
5	Economic	41
6	Energy	41
7	Environment	45
8	Social	52

The CCL of *Douar Ait Said* community is determined based upon the lowest score received by the CFs. The lowest score received is the one of the *Human Resources* CF, 31. Therefore the CCL of *Douar Taschert* community is at a level 2.

Douar Ait Said community has implemented a DWS option made of the following unit processes presented in Table 11- 12.

Table 11-12: DWS Option – Douar Ait Said Community

DWS_ID	Source	Device	Treatment	Storage	Distribution
96	drilled_well	centrifugal_pump	domestic_chlorination	elevated_reservoir	domestic_connection

The Watsan technology option used by the community is *DWS_ID* 96, and has a TRL score of 3. We note that the DWS technology option, selected and implemented by *Douar Ait Said* community, does not match its capacities. We can conclude that *Douar Ait Said* community is at risk of not being able to operate and maintain their DWS infrastructure in the long run.

11.2.2 DSS Evaluation - Simulation

The Watsan DSS has three entry forms, one for each of the three MSSs. The evaluation of the performance of the Watsan DSS was done with the DWS module. The *DWS Options Selection* entry form of the DWS module is shown in Figure 11-3.

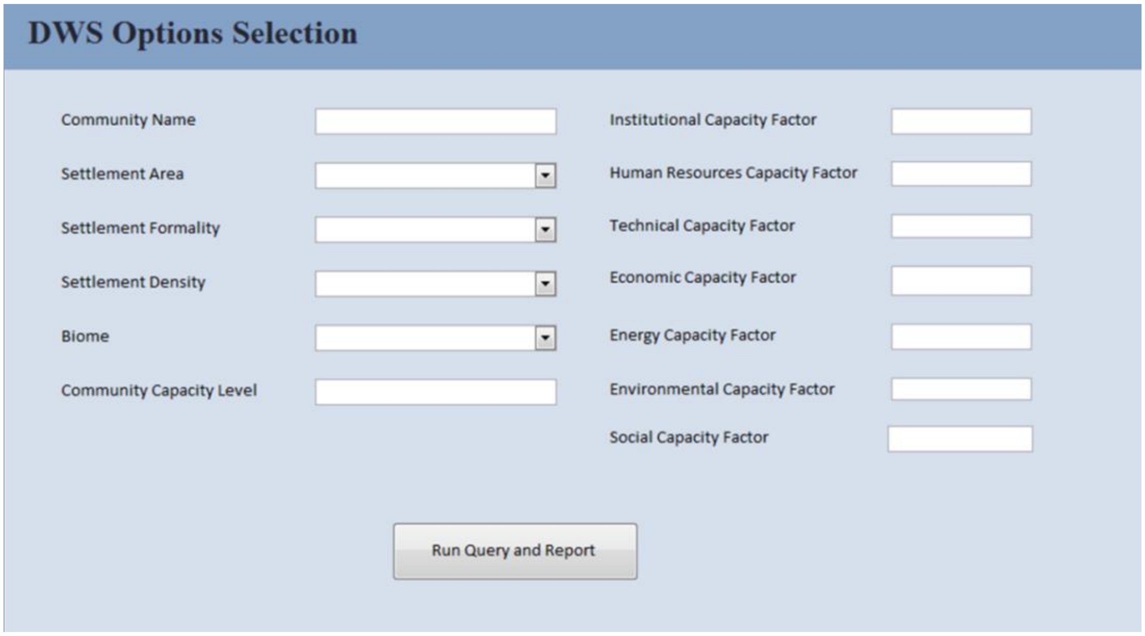


Figure 11-3: DWS Options Selection Form

To evaluate the performance of the DWS module of the Watsan DSS, we used some realistic data of developing communities that we generated. We then simulated the Watsan options selection process in the DSS, and analyzed the reports delivered.

The data of developing communities are entered into the DSS though its entry form, and the execution of the AM program starts by pressing the *Run Query and Report* button. Two reports are produced by the DSS. The first report is delivered if the AM algorithm works successfully through the three search criteria, namely, the CCL, the regional specificity and settlement type, and the CFs. The report, delivered in this case, contains a set of appropriate Watsan options. It is labeled *Appropriate DWS Options* report, in the case of the DWS module of the DSS.

Otherwise, if one of three search criteria is not satisfied, a second report is delivered by the DSS. The second report contains a set of Watsan options that matches the profile of the community defined by its *CCL* metric only. This second report is termed *Not Appropriate DWS Options* in the case of the DWS module of the DSS.

- **Simulation #1**

The data used in *Simulation #1* correspond to a developing community living in a location with a regional specificity defined by a biome type: *scrubs_or_woodlands*. The corresponding biome identification is 06. The community settlement is *rural*, *formal*, and with *low density*. The resultant *ST_ID* is 311. The data of the *Simulation#1* community are entered into the *DWS Options Selection* entry form in the DSS DWS module. The data entered also include the community CFs and its resulting CCL score. The data are presented in Table 11-13 below.

Table 11-13: CFs Developing community – Simulation #1

CF #	Capacity Factor	Score
2	Institutional	42
3	Human Resources	45
4	Technical	47
5	Economic	41
6	Energy	43
7	Environment	55
8	Social	59

Figure 11-4 below presents the entry form where the community data are entered. The search is launched by pressing the *Run Query and Report* button on the entry form. The results of the search are delivered in two reports. The first report is the *Appropriate DWS Options* report. It is the report that provides to the users a selection of appropriate Watsan options for their water and sanitation infrastructure needs.

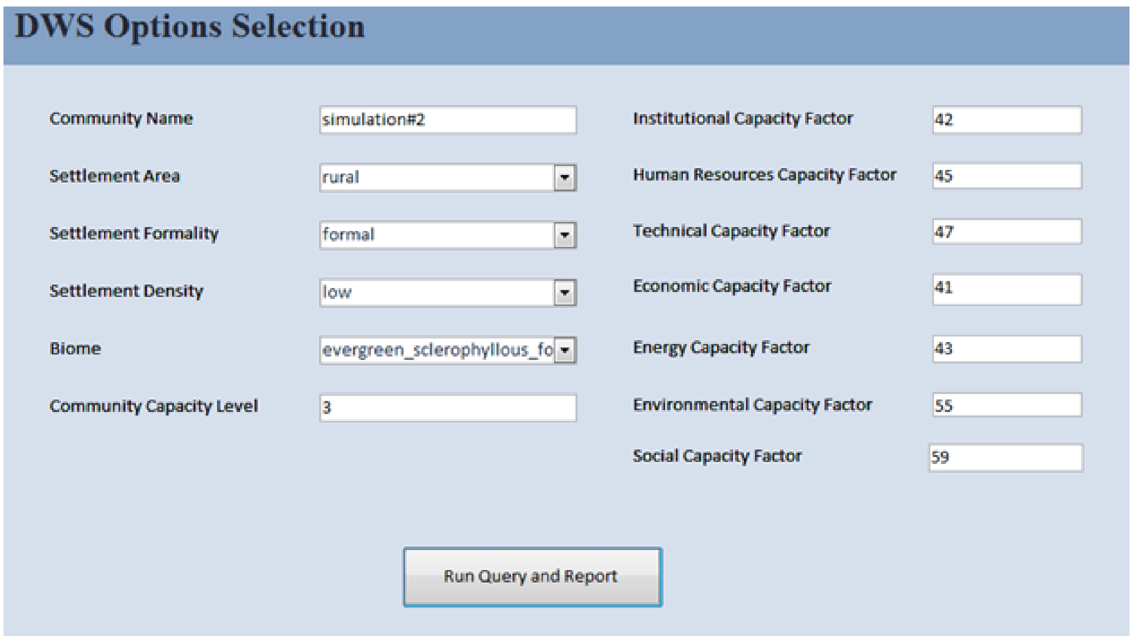
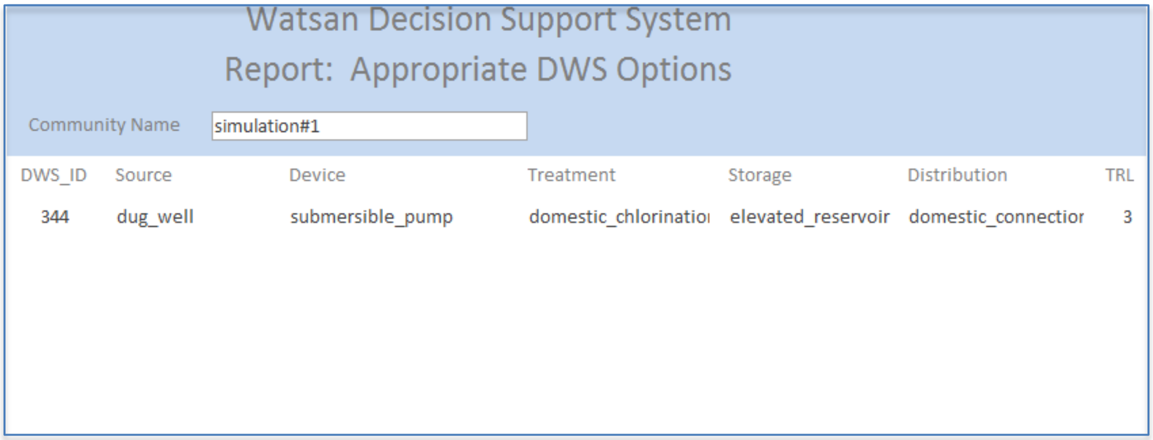


Figure 11-4: Watsan DSS - DWS Options Selection Entry Form – Simulation #1

In this simulation, we got only one appropriate DWS options in the report as we can see in Figure 11-5.


Watsan Decision Support System
Report: Appropriate DWS Options

Community Name simulation#1

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
344	dug_well	submersible_pump	domestic_chlorinatioı	elevated_reservoir	domestic_connectior	3

Figure 11-5: Watsan DSS - Appropriate DWS Options Report – Simulation

Indeed, at its current stage of development, there are not enough data in the *Community* table for the Watsan DSS. The DSS will deliver more options and will reach its full potential once the *Community* table will be expanded with more data on developing communities.

The second report delivered by the Watsan DSS is the *Not Appropriate DWS Options* report. In this simulation, this report contains a set of DWS options with TRL levels ranging from a 1 to 3. Indeed, the only search criterion used in this case is TRL ≤ CCL. Since the CCL score of *Simulation #1* community is 3, DWS options with TRL 1, TRL2, and TRL 3 are proposed in the report. Since the set of DWS options suggested in the second report is too large, we are presenting the first page only in Figure 11-6.

Watsan Decision Support System
Report: Not Appropriate DWS Options

Community Name: simulation#1

TRL: 1

Source: dug_well

DWS_ID	Device	Treatment	Storage	Distribution
285	rope_and_bucket	boiling	ferrocement_tank	public_standpost
287	rope_and_bucket	boiling	plastic_tank	public_standpost
289	rope_and_bucket	boiling	reinforced_concrete_reserv	public_standpost
291	rope_and_bucket	boiling	steel_tank	public_standpost
292	rope_and_bucket	boiling	steel_tank	domestic_connection
293	rope_and_bucket	domestic_chlorination	ferrocement_tank	public_standpost
295	rope_and_bucket	domestic_chlorination	plastic_tank	public_standpost
297	rope_and_bucket	domestic_chlorination	reinforced_concrete_reserv	public_standpost
299	rope_and_bucket	domestic_chlorination	steel_tank	public_standpost
301	rope_and_bucket	household_slow_sand_filter	ferrocement_tank	public_standpost
303	rope_and_bucket	household_slow_sand_filter	plastic_tank	public_standpost
304	rope_and_bucket	household_slow_sand_filter	plastic_tank	domestic_connection
305	rope_and_bucket	household_slow_sand_filter	reinforced_concrete_reserv	public_standpost

Figure 11-6: Watsan DSS – Not Appropriate DWS Options Report – Simulation #1

The DWS options presented in the report are sorted by TRL first, *Source* type, and then by *Device* type in alphabetical order.

- **Simulation #2**

  The data used in second simulation correspond to a developing community living in a location with a regional specificity defined by a biome type *temperate_grassland*, which corresponds to a *Biome_ID* 11. *Simulation #2* community is located in a rural area, in a formal and with a low density settlement. The corresponding *ST_ID* is 311.

The data related to *Simulation #2* community are then entered into the DSS DWS module. Similarly to the previous simulation, the data include the regional specificity and settlement type of the community, as well as its assessed CFs and CCL scores.

The DWS Options Selection entry form is presented in Figure 11-7 below.

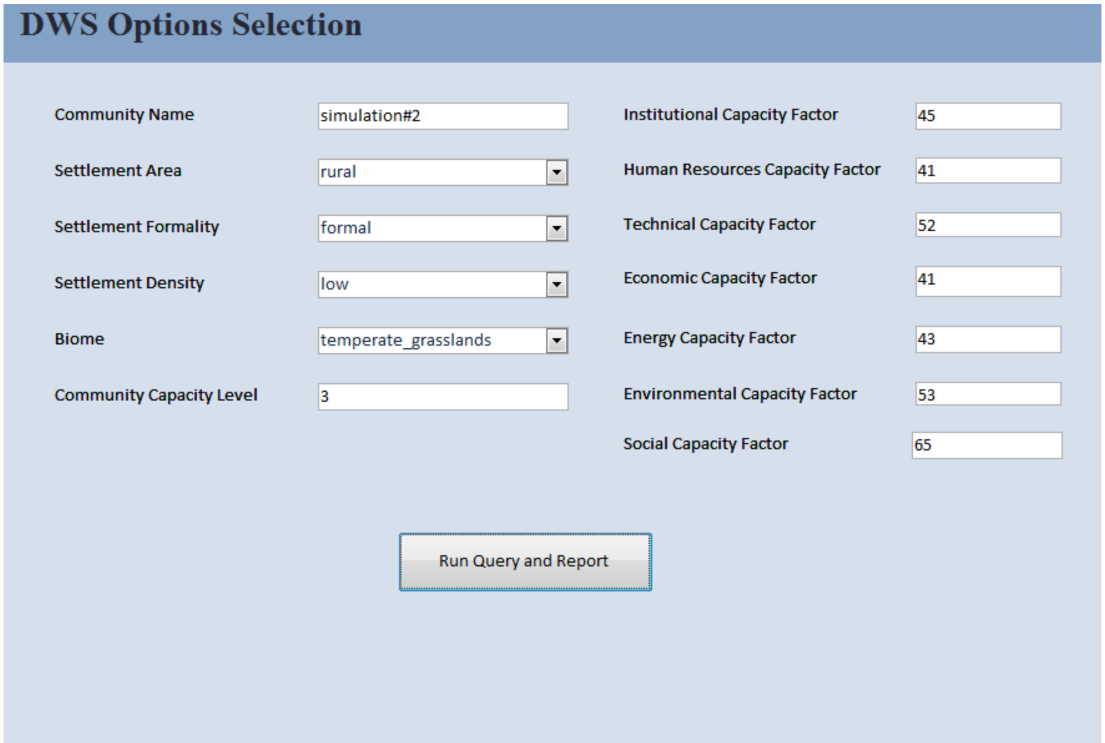
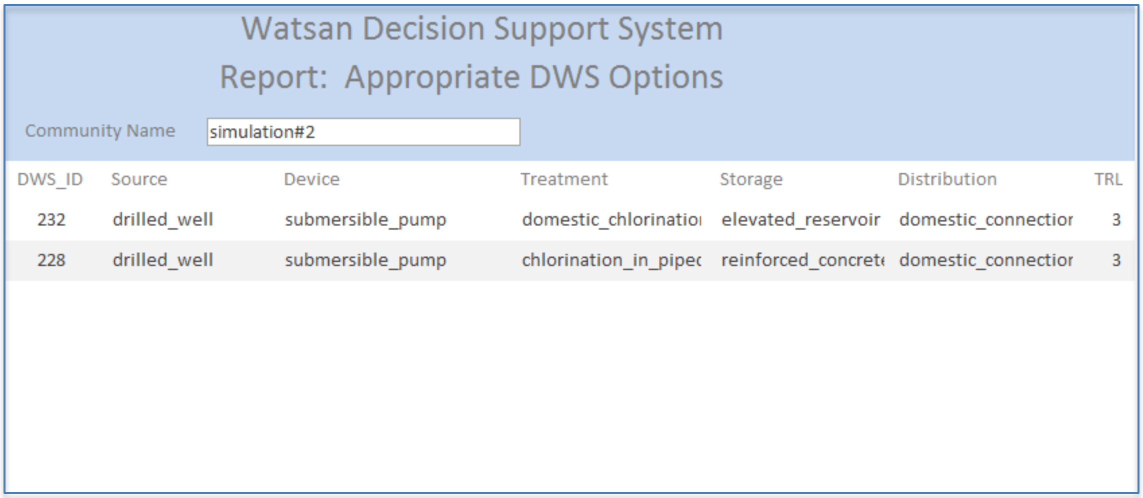


Figure 11-7: Watsan DSS - DWS Options Selection Entry Form – Simulation #2

In this second simulation, the *Appropriate DWS Options* report delivered contains two DWS options appropriate to *Simulation #2* community. Figure 11-8 presents a snapshot of the report. A second report is delivered by the DSS that contains a set of DWS options with TRL levels ranging from 1 to 3. The result delivered in the second report corresponds to the fact that the only search criterion achieved in the appropriate matching process is TRL $\leq$ CCL.



Watsan Decision Support System
Report: Appropriate DWS Options

Community Name: simulation#2

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
232	drilled_well	submersible_pump	domestic_chlorinatio	elevated_reservoir	domestic_connectior	3
228	drilled_well	submersible_pump	chlorination_in_pipe	reinforced_concret	domestic_connectior	3

Figure 11-8: DSS – Appropriate DWS Options Report – Simulation #2

At the end of these two simulations, we can conclude that the Watsan DSS can be a great tool in assisting Watsan practitioners and developing community organizations in the selection of appropriate Watsan technology options. However, to reach its full potential, the Watsan DSS *Community* table requires more data on communities operating Watsan infrastructures successfully in diverse regions of the world.

Chapter 12. Conclusion

The goal of this research was to provide water supply and sanitation practitioners and developing community organizations with decision-making support tools that will allow them to choose, among the numerous available options, the most appropriate ones for securing access to safe drinking water and improved sanitation. The decision support tools proposed in this research address most of the missing elements identified by Palaniappan in the recent evaluation on existing support resources tools for water supply and sanitation technologies selection (Palaniappan et al., 2008).

The framework of the decision model proposed in this research is constituted by three components: the *Assessment* component for the selection of appropriate Watsan technologies, the *Evaluation* component for their evaluation and ranking, and the *Management* component for the resources allocation and implementation of the selected Watsan technology options. This research focused mainly on the first component of the decision model, the *Assessment* component.

The *Assessment* component is structured around two main modules: the *Capacity Factor Analysis* (CFA) model, and the Watsan decision support system (DSS).

The CFA model is used for the assessment of the community's capacity to operate and maintain sustainably a MSS. CFA guidelines are used for the assessment of the capacity factors of a community. The assessment of the CFs is done based on the capacity of the community to operate and maintain each of the three MSSs, namely DWS, WST, and MSW. The scores of the CFs are used to determine the overall community's capacity level defined by the CCL metric. Guidelines for the assessment of the CFs of a community were developed for the three MSSs and are presented in Appendices A, B, and C.

The Watsan DSS developed in this research contains a database of Watsan technology options classified by the MSS they provide, and ranked by the TRL metric. The classification of the Watsan technology options was accomplished using machine learning algorithms. Two classifiers, SMOreg and KStar from Weka machine learning workbench, were used for the classification. The performances of the two classifiers were evaluated using two indicators, the accuracy (ACC), and Matthews's Coefficient of Correlation (MCC). The results of the evaluation showed similar performances for the two classifiers. These two classifiers were used for the classification of the DWS technology options. The results of the classification of the DWS technology options were then used to determine their corresponding TRL metric, and the complete set of DWS options was entered in the Watsan technology options database. At this stage in this research, the tables of the Watsan technology options for WST and MSW services need to be completed with their TRL scoring. This work will be conducted in future research on this decision support tool.

The Watsan DSS database also contains data on developing communities operating Watsan options sustainably. The data include the profiles, the regional specificities, and the settlement types of the communities.

An appropriate matching (AM) algorithm was developed along with the Watsan technology options database in the Watsan DSS. The AM process allows the selection of reduced set of appropriate Watsan technology options requiring a technology level to operate them that matches the community's CCL metric. The AM algorithm employs selection criteria that include the capacity factors scores, the CCL metric, the regional specificity, and the settlement type of a host community.

The decision support tools performance was evaluated in several case studies of developing communities in Morocco, and in simulations with generated data.

In the case studies of developing communities in Morocco, the CFA model was used to verify whether the Watsan technology options implemented matched the communities' capacities or not. In three of the six cases presented, we noted that the communities' CCL scores match the TRL scores of the Watsan technologies implemented. This suggests that the likelihood of sustainability of the sanitation services in these communities is important. In the other cases, where the CCL scores of the communities did not match the TRL scores of the Watsan technology used, the model suggests a risk of having a sanitation service not sustainable.

The second evaluation of the performance of the decision tools developed in this research was conducted with the DSS. This evaluation was performed with simulation data. The results of the evaluation show that the DSS performed as expected. In the two simulations used for the evaluation, the data entered corresponded to developing communities located in biome types, and profiles similar to the ones of some communities whose data are in the *Community* table of the Watsan DSS. The DSS delivered few appropriate DWS options in the two simulations due to the small number of data on developing communities currently in the database. Indeed, the Watsan DSS will achieve its full potential when a complete database will be developed, with more data on developing communities operating Watsan options in diverse geographic areas of the world. The data collection on developing communities will be conducted in future research with the contribution of Watsan partners and international organizations such as *Engineers without Borders*.

In conclusion, the contributions of this research provide water and sanitation practitioners and developing community organizations in developing countries with decision support tools for the selection of appropriate Watsan technology options for municipal sanitation services. The decision support tools presented in this research are the following:

- CFA model, with its guidelines for the assessment of a developing community's capacity to manage a specific MSS system such as DWS, WST, and MSW.

- Watsan DSS, decision support system with a database of Watsan technology options for the three MSSs, ranked by their TRL metric and with data of communities operating them sustainably.
- Appropriate matching tools within the Watsan DSS for the selection of reduced set of appropriate Watsan technology options.

Future work will allow this decision support tool to be accessible to Watsan practitioners and developing community organizations in developing countries through a web-based interface. This web-based user interface could be developed with several languages options such as English, French, and Spanish.

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Appendices

Appendix A: Capacity Factor Analysis – Guideline for Drinking Water Supply

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**							
C_{11}	**Sevice Level**	W_{11}	< 20 l/d/c	21 - 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	
f_1	**Score Service CF**						$\Sigma C_{ij} w_j =$	**0**
2	**Institutional**							
C_{21}	**Body of legislation**	W_{21}	None	Basic	Intermediate	Complete	Advanced	
C_{22}	**Associated regulations**	W_{22}	None	Basic	Intermediate	Complete	Advanced	
C_{23}	**Administrative agencies**	W_{23}	None	National	Regional	District	Local	
C_{24}	**Administrative processes**	W_{24}	None	Basic	Intermediate	Complete	Advanced	
C_{25}	**Governance**	W_{25}	None	National	Regional	State	Local	
f_3	**Score Institutional CF**						$\Sigma C_{ij} w_j =$	**0**
3	**Human Resources**							
C_{31}	**Professionals**	W_{31}	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	
C_{32}	**Skilled Labor**	W_{32}	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technicican	
C_{33}	**Unskilled Labor**	W_{33}	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	
C_{34}	**Illiterate**	W_{34}	Caretaker I	Caretaker II	Caretaker III			
f_3	**Score Human Resources CF**						$\Sigma C_{ij} w_j =$	**0**

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
4	**Technical**							
C_{41}	**Operations**	W_{41}	Water use	Pumping water	Pumping water Read meters	Monitor pumping systems Read meters Control water quality	Monitor pumping systems Read meters Control water quality Monitor network	
C_{42}	**Maintenance**	W_{42}	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	
C_{43}	**Adaptation**	W_{43}	None	Rarely	Occasionally	Usually	Frequently	
C_{44}	**Supply Chain**	W_{44}	None	National supplier	Regional supplier	Local supplier	Local supplier National manufacturer	
f_4	**Score Technical CF**						$\Sigma C_{ij} w_j =$	**0**
5	**Economic and Financial**							
C_{51}	**Private sector %**	W_{51}	None	International	National	Regional	Local	
C_{52}	**Bonds Rating**	W_{52}	None	National	Regional	District	Local	
C_{53}	**User fees**	W_{53}	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	
C_{54}	**Budget**	W_{54}	None	Basic accounting	Annual	Quaterly	Monthly	
C_{55}	**Asset values**	W_{55}	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	
C_{56}	**Debt**	W_{56}	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	
f_5	**Score Economic / Financial CF**						$\Sigma C_{ij} w_j =$	**0**

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
6	**Energy**							
C_{61}	**Primary source**	W_{61}	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	
C_{62}	**Back up**	W_{62}	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	
C_{63}	**% of Budget**	W_{63}	Very high	High	Moderate	Low	Very Low	
C_{64}	**Rate of outage**	W_{64}	Very High	High	Moderate	Low	very low	
f_6	**Score Energy CF**						$\Sigma C_{ij} w_j =$	**0**
7	**Environmental**							
C_{71}	**Quality / Sensitivity:**	W_{71}	Very low	Low	Moderate	High	Very high	
C_{72}	**Quantity / Availability**	W_{72}	Very low	Low	Moderate	High	Very high	
f_7	**Score Environmental CF**						$\Sigma C_{ij} w_j =$	**0**
8	**Social and Cultural**							
C_{81}	**Communities**	W_{81}	Very low	Low	Intermediate	High	Very high	
C_{82}	**Stability**	W_{82}	Very low	Low	Intermediate	High	Very high	
C_{83}	**Equity**	W_{83}	Very low	Low	Intermediate	High	Very high	
C_{84}	**Castes**	W_{84}	Very high	High	Intermediate	Low	Very low	
C_{85}	**Participation of Women**	W_{85}	Very Low	Low	Intermediate	High	Very High	
f_8	**Score Social Cultural CF**						$\Sigma C_{ij} w_j =$	**0**

SERVICE CF

The quantity of water delivered and used for households is a fundamental element for human life. Access to water services form a key component in the UNDP Human Poverty Index for developing countries (UNDP, 1999). The amount of water delivered influences hygiene and public health. To date the World Health Organization has not provided guidance of the quantity of water that is required to insure acceptable level of health. Among the United Nation's MDGs, the goal #7 has an objective "to halve the proportion of people who are unable to reach or to afford safe drinking water by 2015" (UN, 2000). However, the quantity of water that should be supplied is not specified. The WHO/UNICEF Joint Monitoring Program suggests reasonable access as being "the availability of at least 20 liters per person per day from a source within one kilometer of the users dwelling" (WHO/UNICEF, 2000). Even if this quantity of water provides the basic access for consumption and hygiene, it doesn't allow laundry and bathing. Furthermore at this level of service, there is a high level of health concern (Howard, 2003). Based on an exhaustive review of the different uses and needs of water supply for households, an average quantity of 50 liters per person per day meets the need for consumption and hygiene with a low level of health concern to the community. The water supply may be delivered through one tap on-plot, or within 100 meters. At this service level, all basic personal and food hygiene are assured, as well as laundry and bathing. For a continuous process of development, this level of service could be increased gradually to reach an optimal level of water supply, which should be 100 liters per person per day. This water supply will be delivered through multiple taps continuously, and will meet all the needs from consumption and hygiene. At this level of service, the level of health concern is very low. After (Howard, 2003), the different levels of service with the corresponding health concerns are presented in Table below.

Table: Summary of requirement for water service level to promote health

Service Level	Access Measure	Needs meet	Level of Health Concern
No access (quantity collected often below 5 l/c/d)	More than 1000 m or 30 minutes total collection time	Consumption - Cannot be assured Hygiene - not possible (unless practised at source)	Very high
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000 m or 5 to 30 minutes total collection time	Consumption - should be assured Hygiene - handwashing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediat access (average quantity about 50 l/c/d)	Water delivered through one tap on-plot (or within 100 m or 5 minutes total collection time	Consumption - assured Hygiene - all basic personal and food hygiene assured: laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption - all needs met Hygiene - all needs should be met	Very low

Source: Howard et al., 2003

INSTITUTIONAL CF

The *Institutional* Capacity factor is defined by five constituents: *Body of legislation, Associated regulation*, *Administrative authority*, *Administrative process,* and *Governance.*

- **Body of legislation**

The first constituent of the *Institutional* CF is the *Body of Legislation*. Drinking water quality depends upon the existence of adequate legislation, supported by regulatory standards and codes that specify the quality of water supplied. In both developed and developing countries worldwide, the starting point for the setting of water quality standards is the World Health Organization guidelines (Fewtrell et al. 2001). These guidelines are based upon large scientific consensus. The term guideline is deliberately used, since they are not international standards. In the process of adaptation of the guidelines in a community, it should be taken into account the social, economic, and environmental local factors. Thus the resulting standards may differ from the original guidelines from one country to another. Also, since in many developing countries, there are no standard or legislation for safe drinking water, the implementation of the guideline can be done under general welfare or health legislation. The guidelines adopt a clear policy from the outset that microbiological quality must be the key water quality priority. And the first step in the implementation of water regulation should be the focus on bacteriological aspect of drinking water quality. The guideline values for bacteriological quality of drinking water are presented in the table below:

Table: Guideline Values for Bacteriological Quality

Guideline values for bacteriological quality[a]

Organisms	Guideline value
All water intended for drinking	
E.coli or thermotolerant coliform bacteria [b,c]	Must not be detectable in any 100-ml sample
Treated water entering the distribution system	
E.coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample
Treated water in the distribution system	
E.coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period.

[a] Immediate investigative action must be taken if either E.coli or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling: if these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation

[b] Although E.coli is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confimatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particulary in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

[c] It is recognozed that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-test targets for the progressive improvement of water supplies.

Source: WHO, 1997

The legislation should include the specification of the authority that will be in charge of these regulations and in particular (WHO, 1984):

Scope of the authority;

- Delegation of powers to administer the law to specified agencies;
- Provision for the establishment and amendment of regulations for the

development, production, maintenance, and distribution of safe drinking-water;

- Provision for enforcement.

- **Associated regulation**

The public health authority can have jurisdiction to review, and inspect the water supplied to the community (Dezuane, 1997). In developing countries, usually the public health department has regional agencies well implemented in the country. These agencies could provide the required regulations for safe drinking water. The operations of inspection, sampling, monitoring and enforcing the legislation could be supplied by the national health authority and its regional agencies.

- **Administrative authority**

In many developing countries, the health department and the education department are well implemented and supported by the central government and by international organizations, as UNICEF and WHO. The health department can take advantage from its regional agencies to monitor the drinking water quality and to enforce the legislation. From (DeZuane, 1997), the figure presents a model of organization for a health authority that could be in charge of the drinking water quality regulation.

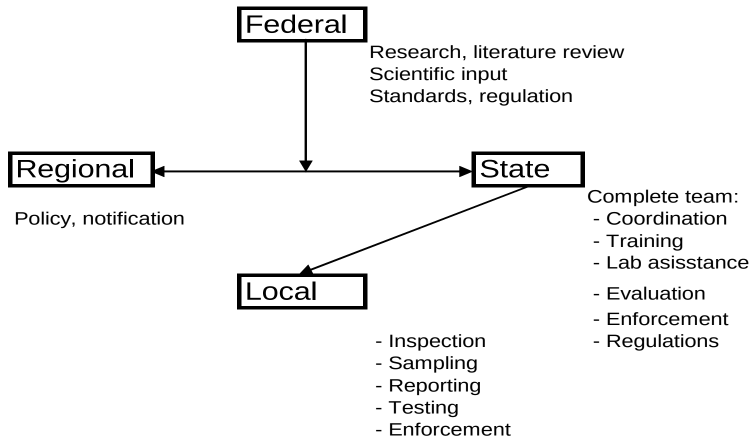


Figure: Organization of Health Authority

Source: Adapted from DeZuane (1997)

➢ **Administrative process**

The administrative processes that should be implemented are basically related to the surveillance of drinking-water quality. These are defined as a continuous and vigilant public health assessment and overview of the safety and acceptability of drinking water supplies (WHO, 1976). The process of surveillance of water quality depends on the level of the economic development of the community or the country where it has to be implemented. The scarcity of resources in LIC suggests the need to develop surveillance program by stages or levels. Thus, a pragmatic approach is to develop an administrative process for surveillance of water quality adapted to the actual existing resources of the community or the region. Then, the process will be consolidated and developed by stages to the ultimate desired level of surveillance. The table below presents five levels of administrative process for drinking water control, from an initial level I, proposed for communities that have no basic surveillance program to a level V, which is the complete process, similar to those in countries that have virtually eliminated water-borne disease associated with community water supplies.

Table: Surveillance of Drinking Water Quality by Level of Development

Level of Surveillance	Brief Description	Country Situation
1	Initial	Programme proposed for adoption in developing countries that at present have no formulated surveillance programme or responsibility
2	Basic	Programme proposed for adoption in developing countries that at present have a nominal programme with severe limitations on its scope and effectiveness
3	Intermediate	Programme proposed for adoption in developing countries that at present have an established programme in major cities only
4	Complete	Programme proposed for adoption in developing countries that at present have an established nationwide programme and seek to increase the effectiveness of surveillance
5	Advanced	Programme similar to those in use in developed countries that have generally eliminated water-borne disease in community water supplies

Source: WHO (1976)

Given the level of development of the community, administrative processes for drinking water control could be defined and implemented.

- **Governance**

Good governance is a key element for sustainable development. It helps to strengthen democracy and human rights, and to promote economic prosperity and social cohesion. It contributes to reduce poverty, enhance environmental protection and deepen confidence in government and public administration. Good governance is a continued process, where all the following components should be improved continuously (The EU and the WSSD, 2002). The criteria that have to be assessed for the *Governance* constituent are:

- Legal claims and effective access to judicial and administrative proceedings;
- Transparency and accountability;
- Effective mobilization against corruption and terrorism.

With respect to the delivery of MSS, governance refers to the defined authority, responsibilities, and accountability of the entity providing the service. The ownership, operation, management reporting, and funding of this entity may be public (government) or private (non-government), as illustrated in the figure below:

	Public			Private		
	Local Govt	Regional Govt	National Govt	Non-Govt Agency	Corporation	Community Group
Own - Authority						
Operate - Responsabilities						
Manage - Accountability						

Figure: Governance of MSS

HUMAN RESOURCES CF

One of the most important capacity factors for a sustainable sanitation service for a community is the human resource factor. The constituents of the *Human Resources* CF are *Professional*, *Skilled labor*, *Unskilled labor*, and *Illiterate*.

- **Professional**

The professional disciplines most directly involved in drinking-water supply are engineering, management, sanitation science, and laboratory practice. After (Lloyd, 1991), the number of personnel will be proportional to the population to be served and to the level of service provided. The professionals are also administrative manager, lawyer, and public relation manager.

- **Skilled labor**

Skilled labors are technician, electrician, mechanic, and plumber able to maintain and operate water supply systems in a sustainable manner. Qualifications and training of staff is therefore important. Personnel constituents are determined by the importance of the water supply systems to operate. Administrative personnel with skills to collect revenue, run bank accounts, keep books and make payments for services, parts, salaries etc, are important skilled labor as well.

- **Unskilled labor - Literate**

The unskilled labors are workers with basic maintenance knowledge as cleaning, basic plumbing, masonry, and painting. It includes also personnel able to read water meters and to accomplish administrative task in offices.

- **Unskilled labor – Illiterate**

This last category of personnel includes all the personnel available in the community that could be involved in manual labor, digging trenches, carrying loads, general work in either the implementation of water supply systems as well as their maintenance.

The constituents of the *Human Resources* CF are defined for DWS service by service level. The human resource capacity factor is assessed at the current level of development of the community. This will determine what capacity is available for ensuring operation and maintenance of a sustainable DWS service at the local level. In the table below, we present the *Human Resources* CF constituents for sustainable water supply systems.

3	**Human Resources**						
C_{31}	**Professionals**	None	Accountant	Administrative supervisor	Administrative manager	Administrative manager	
				Health scientist	Health scientist	Health scientist	
				Accountant	Accountant	Accountant	
					Engineer	Engineer	
						Public relations manager	
						Lawyer	
C_{32}	**Skilled Labor**	None	Mechanic	Maintenance technician	Maintenance technician	Maintenance technician	
				Laboratory technician	Laboratory technician	Laboratory technician	
				Water systems operator	Water systems operator	Water systems operator	
				Water meter reader	Health inspector	Health inspector	
					Administrative assistant	Administrative assistant	
					Water meter leader	Water meter leader	
						IT technicican	
C_{33}	**Unskilled Labor**	Craftsman	Clerk	Clerk	Clerk	Clerk	
			plumber	Water systems worker I	Water systems worker II	Water systems worker III	
C_{34}	**Illiterate**	Caretaker I	Caretaker II	Caretaker III			
f_3	**Score Human Resources CF**					$\Sigma C_{ij} w_j =$	**0**

TECHNICAL CF

Technical capacity is related to the capacity of the DWS service to operate in the long term. This includes the following functions: operations, maintenance, upgrading or adaptation, and supplies. The assessment of this capacity factor is critical for the sustainability of the service. Great attention should be given to the choice of the technology in the design phase, according to the capacity of the community to operate and to maintain the system. In 1981 the UNDP and the World Bank introduced the concept VLOM, Village Level Operation and Maintenance. It was related to the hand pump project where the goal was that it could be operated and maintained by the community. In the guidelines of VLOM which can be applied to all water supply technologies in LIC, (Arlosoroff et al., 1987) recommend that the hardware should be:

- Easy to maintain by village caretakers;
- Manufactured in the country, so the spare parts will be available;
- Robust and reliable;
- Standardized to take advantage of economies of scale;
- Low in capital and recurrent cost.

➢ **Operations**

Operations refer to the everyday running and handling of a water supply system. These operations may differ widely from a water supply system to another. It could be a person responsible for opening and closing valves to divert the water in a spring water capture system, to a crew of operators supervising and running a large water supply system.

➢ **Maintenance**

The maintenance consists of sequences of operations required to sustain the water supply system in a proper working condition.

Water supply systems maintenance can be divided into three categories:

- Preventive maintenance consists of operations as cleaning, lubricating and renewing parts that do not require major repairs. This type of maintenance include also detecting and reporting to proper authority abnormal conditions.
- Corrective maintenance consists of minor repair and replacement of broken parts to keep the water supply system operating.
- Crisis maintenance refers to unplanned operations to emergency breakdowns of components of the water supply system.

These maintenance operations could be handled by the service itself or outsourced to contractor in the local community under the DWS service supervision.

- **Adaptation**

Adaptation and modification refers to the capacity to make modifications and small changes on the equipment of the water supply systems. This constituent measures the capacity of the community to address specific technical constraints. These adaptations could be handled by the service itself or outsourced under its supervision.

- **Supply**

Availability of spare parts is a major element in the sustainability of a water supply system. The availability of local and regional suppliers of spare parts should be considered when decision is made on the suitability of a technology or a scheme. This should include not only mechanical and electrical parts, but also lubricants, chemicals and tools.

From the previous description the technical capacity factor, there are five levels used for the assessment of the constituents of the *Technical* CF presented in the table below:

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
4	**Technical**						
C_{41}	**Operations**	Water use	Pumping water	Pumping water Control water quality Read meters	Monitor pumping systems Control water quality Read meters	Monitor pumping systems Control water quality Read meters Monitor network	
C_{42}	**Maintenance**	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	
C_{44}	**Supply Chain**	None	National supplier	Regional supplier	Local supplier	Local supplier National manufacturer	
f_4	**Score Technical CF**					$\Sigma C_{ij} w_j =$	**0**

ECONOMIC/FINANCIAL CF

The *Economic and Financial* CF, refers to the economical capacity of the community and the financial situation of the municipal sanitation services. The constituents of the *Economic and Financial* CF used in the assessment are the *Private Sector%* providing sanitation services, and the *Bonds Rating* which may allow the community to access to the financial market for its investment. While the financial capacity is described by the *User fees,* the *Budget,* the *Assets value* and the *Debt*.

- **Private sector %**

Since the mid-80s, the private sector became a major contributor to the development of sanitation services in developing countries. In water and sanitation services, the cumulative private sector expenditure in sanitation projects was $25 billion between 1990 and 1997, compared with 297 million in the period 1984 – 1990 (Silva, 1998). The studies done on this subject show that private sector investment in water and sanitation can provide interesting alternative to low and middle income countries to ease their burden of investment in basic infrastructure. However privatization should obey certain rule to preserve affordability of water supply service. The *Private Sector* constituent is defined by service level based on the allowance to the private sector to provide the water supply service to communities, and on the percentage of private sector contribution in water supply services.

- **Bond ratings**

The bond market to fund project infrastructure in developing countries emerged in the 1990s. This market remains relatively small but has gained in maturity regarding the importance of projects recently funded by bonds. The total issuance volume worldwide has been about $25 billion in 2000 – 2001 (Dailami, 2003). About one third is attributed to bonds issued for projects in developing countries. The long-term prospects of this market look very promising given the needs in infrastructure in developing countries. The assessment of the *Bonds Rating* constituent is made based on the availability of municipal bonds and their eventual rating.

- **User fees**

User fees mean the monthly fees collected from each user in return for supplying potable water that conforms to the drinking water standards defined. To provide a sustainable water supply service, the community should accept user fees. These user fees will help cover the running cost and eventually the construction cost of the water supply system. An estimate of the running cost could be done easily. It will include the facility workers payroll, the spare parts cost for maintenance, and the chemicals cost for water treatment. The estimate of the water unit cost is obtained by dividing the total running cost per month, by the monthly average demand of unit of water from the community. The equation below defines the water unit cost:

$$\text{Water Unit Cost} = \frac{Total\ Running\ Cost}{Total\ Demand\ Units}$$

The recovery of the construction cost of the water supply system could be part of the user fees, based on what source of financing has been used for the funding of the project. If the source used was a government grant, a donation from an international donor or a fund raising among the community, the cost recovery will consist of depreciation to replace the hardware at the end of its service life. User fees will be the water unit cost and an additional reserve for future development and for contingency repairs due to breakdowns of the water supply system. Different types of user fees or rating are provided, based on different type rate, from flat to increasing one. The assessment of the *User Fees* constituent is done, based on the affordability of the service and the willingness of the users to pay for it.

- **Budget**

Assessment of the *Budget* constituent consists of the level of detail in the budget for capital and O&M items, and the extent to which the annual budget request is funded, either from government allocation or from user fees.

- **Asset Values**

Assets constituent refers to those things of monetary value that the community possesses. Assets have physical existence, such as cash, equipment, real estate, and stocks.

The assessment of the *Asset* constituent is done by listing each item of facilities, equipment, vehicles, inventory of supplies and spare parts, and real estate owned by the service provider. Land and facilities may be listed on a map using GIS. The rated capacity, age, manufacturer, maintenance schedule, cost, and depreciated values of each item are also recorded.

➢ **Debt**

The assessment of the *Debt* constituent is made by using the debt rating. The debt rating indicates the issuer's ability to meet its financial obligations to security holders when due. The ratings are assigned to debt and preferred stocks. Similarly, the constituents for the Debt are defined by stage of development and presented in the table below:

5	Economic and Financial						
C_{51}	**Private sector %**	None	International	National	Regional	Local	
C_{52}	**Bonds Rating**	None	National	Regional	State	Local	
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	
C_{54}	**Budget**	None	Basic accounting	Annual	Quaterly	Monthly	
C_{55}	**Asset values**	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	
C_{56}	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	
f_5	**Score Economic / Financial CF**					$\Sigma C_{ij} w_j =$	**0**

ENERGY CF

The *Energy* CF is defined by four constituents: *Primary source, Back-up source, Percentage of budget,* and *Rate of outage.*

➢ **Primary source**

The primary source of energy for water supply systems is usually electricity. However the source of the electricity provided could have different origin, from conventional source distributed by over-head transmission lines from power plant, to non-conventional as wind power generator system, or solar electric system. The assessment of the *Primary source* constituent is made based on the constituents defined by stage of development

➢ **Back-up**

The back-up source of a primary source is usually a diesel emergency power generator. It should provide enough energy to keep the water supply plant operating for short period lasting at least the average time period of outage in the local community. The storage unit of the water supply system should have a sufficient capacity to avoid shortage of supply. The assessment of the *Back-up* constituents is made based upon the availability of backup sources and the affordability at each service level.

- **% of budget**

The percentage of budget refers to the share the energy in the total cost of the water supply service. To provide a sustainable service, the constituents for the share of energy in the service budget are defined by service level.

- **Rate of outage**

The *Rate of outage* constituent refers to the frequency of interruption of the energy delivery. The *Rate of outage* constituent is defined by the rate of interruption in the electrical network in the area where the water supply system will be implemented, and the lasting time of this outage.

The constituents of the *Energy* CF are defined by service level and are presented in the table below:

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
6	**Energy**						
C_{61}	**Primary source**	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	
C_{62}	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	
C_{63}	**% of Budget**	Very high	High	Moderate	Low	Very Low	
C_{64}	**Rate of outage**	Very High	High	Moderate	Low	very low	
f_6	**Score Energy CF**					$\Sigma C_{ij} w_j =$	**0**

ENVIRONMENTAL & NATURAL RESOURCES CF

- **Quality/Sensitivity**

The *Quality/Sensitivity* constituent of the *Environment* CF is defined by the carrying capacity. The *Environment* CF measures the difference between the ambient environmental quality and the standard quality established or desired for the area. The Environment CF is a measure of the carrying capacity of the local air, and soil media as well as local aesthetics such as noise, odor, traffic, greenery to support the MSS.

- **Quantity**

The *Quantity* constituent of the *Environment* CF refers to the natural resources available for the service in the community. In the assessment of DWS, it is related to the quantity of fresh water available for the water supply system. The assessment of the *Quantity* constituent is made, given the availability of fresh water for water supply in the environment of the community. A great availability will have a high score.

The constituents for the *Environment* CF are presented in the table below by service level. A high score for carrying capacity, which is the *Quality/Sensitivity* constituent, corresponds to a great capacity of the community and its ecosystem to sustain environmental stress. A high score for the *Quantity* constituent refers to an important availability of surface or ground water. The table below summarizes the assessment of the constituents of the *Environment* CF.

7	**Environmental**						
C_{71}	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	
C_{72}	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	
f_7	**Score Environmental CF**					$\Sigma C_{ij} w_j =$	**0**

SOCIAL/CULTURAL CAPACITY FACTOR

- **Communities**

The *Communities* constituent of the *Social/Cultural* CF refers to the capacity of organization existing among the community. The constituent is based on the organizational capacity among the members of the community. The involvement of members of the community in association and organization provide a strong capacity to the community to develop a sustainable service. In the assessment of this constituent, the more the community is organized, the highest its *Communities* constituent score will be.

- **Stability**

The *Stability* constituent of the *Social/Cultural* CF is defined by the level of transience among residents in the community. It refers to the presence of a system of housing within the community but also to the stability of the residents within the community.

The assessment of the *Stability* constituent is done based on the level of transience within the community. A community with a high transient level will have a low capacity.

- **Equity**

The *Equity* constituent of the *Social/Cultural* CF refers to the access of water for all the members of a community. It is related to the idea to have “some water for all instead of all the water for some”. The *Equity* constituent is defined based upon the access to the service independently of the social class of the households.

- **Castes**

The *Castes* constituent of the *Social/Cultural* CF refers to the fact that certain households within a community can be excluded from the service provided, as a result of ethnic marginalization. The *Castes* constituent captures this fact and the assessment made is related to the existence of exclusion of part of the community from the service provided for social identity or ethnic reason. The elements for the *Castes* constituent are defined by service level. The assessment of the *Castes* constituent is obtained from the existence or the importance of this phenomenon among the community.

- **Participation of Women**

Women and girls are often in charge of water provision in LIC. Based on the lessons learnt from the IDWSSD, they should play a major role in water supply management. Therefore the assessment of the *Participation of Women* constituent is an important one. The table below presents the constituents for the *Social/Cultural* CF by service level.

8	**Social and Cultural**						
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	
C_{84}	**Castes**	Very high	High	Intermediate	Low	Very low	
C_{85}	**Participation of Women**	Very Low	Low	Intermediate	High	Very High	
f_8	**Score Social Cultural CF**					$\Sigma C_{ij} w_j =$	**0**

Appendix B: Capacity Factor Analysis – Wastewater Sewage and Treatment (WST)

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**							
C_{11}	**Sevice Level**	W_{11}	< 20 l/d/c	21 - 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	
f_1	**Score Service CF**						$\Sigma C_{ij} w_j =$	**0**
2	**Institutional**							
C_{21}	**Body of legislation**	W_{21}	None	Basic	Intermediate	Complete	Advanced	
C_{22}	**Associated regulation**	W_{22}	None	Basic	Intermediate	Complete	Advanced	
C_{23}	**Administrative agencies**	W_{23}	None	National	Regional	District	Local	
C_{24}	**Administrative processes**	W_{24}	None	Basic	Intermediate	Complete	Advanced	
C_{25}	**Governance**	W_{25}	None	National	Regional	State	Local	
f_3	**Score Institutional CF**						$\Sigma C_{ij} w_j =$	**0**
3	**Human Resources**							
C_{31}	**Professionals**	W_{31}	None	Collection Supervisor	Collection supervisor Treatment supervisor	Engineer Chemist Administrative Collection/treatment super	Engineer Chemist Administrative manager Collection/treatment superv.	
C_{32}	**Skilled Labor**	W_{32}	None	Mechanic Clerck	Laboratory technician Mechanic Clerk Electrician	Laboratory technician Maintenance technician Operator Administrative assistant	Laboratory technician Maintenance technician Operator Administrative assistant IT technician	
C_{33}	**Unskilled Labor**	W_{33}	None	Maintenance worker I	Maintenance worker II Plant worker	Maintenance assistant I Operator assistant I	Maintenance assistant II Operator assistant II	
C_{34}	**Illiterate**	W_{34}	None	Caretaker	Maintenance helper			
f_3	**Score Human Resources CF**						$\Sigma C_{ij} w_j =$	**0**

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
4	**Technical**							
C_{41}	**Operations**	W_{41}	None	Individual disposal	Collection Pumping Preliminary treatment	Collection Pumping Complete treatment Bacteriological analysis	Monitoring pumping stations Monitoring treatments Bacteriological analysis Chemical/Biological analysis	
C_{42}	**Maintenance**	W_{42}	None	Septic tank pump	Clean collector systems Maintain pumps	Collector systems Station pumps Treatment equipments	Collector systems Station pumps Treatment equipments IT systems	
C_{43}	**Adaptation**	W_{43}	None	Rarely	Occasionally	Usually	Frequently	
C_{44}	**Supply Chain**	W_{44}	None	National supplier	Regional supplier	National manufacturer Regional distributor	National manufacturer Local distributor	
f_4	**Score Technical CF**						$\Sigma C_{ij} w_j =$	**0**
5	**Economic and Financial**							
C_{51}	**Private sector %**	W_{51}	None	International	National	Regional	Local	
C_{52}	**Bonds Rating**	W_{52}	None	National	Regional	State	Local	
C_{53}	**User fees**	W_{53}	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	
C_{54}	**Budget**	W_{54}	None	Basic accounting	Annual	Quaterly	Monthly	
C_{55}	**Asset values**	W_{55}	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	
C_{56}	**Debt**	W_{56}	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	
f_5	**Score Economic Financial CF**						$\Sigma C_{ij} w_j =$	**0**

	Capacity Factors	Weights	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
6	**Energy**							
C_{61}	**Primary source**	W_{61}	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	
C_{62}	**Back up**	W_{62}	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	
C_{63}	**% of Budget**	W_{63}	Very high	High	Moderate	Low	Very Low	
C_{64}	**Rate of outage**	W_{64}	Very High	High	Moderate	Low	very low	
f_6	**Score Energy CF**						$\Sigma C_{ij} w_j =$	**0**
7	**Environmental**							
C_{71}	**Quality and Sensitivity:**	W_{71}	Very low	Low	Moderate	High	Very high	
C_{72}	**Quantity**	W_{72}	Very low	Low	Moderate	High	Very high	
f_7	**Score Environmental CF**						$\Sigma C_{ij} w_j =$	**0**
8	**Social and Cultural**							
C_{81}	**Communities**	W_{81}	Very low	Low	Intermediate	High	Very high	
C_{82}	**Stability**	W_{82}	Very low	Low	Intermediate	High	Very high	
C_{83}	**Equity**	W_{83}	Very low	Low	Intermediate	High	Very high	
C_{84}	**Castes**	W_{84}	Very high	High	Intermediate	Low	Very low	
C_{85}	**Participation of Women**	W_{85}	Very Low	Low	Intermediate	High	Very High	
f_8	**Score Social CF**						$\Sigma C_{ij} w_j =$	**0**

SERVICE CAPACITY

(Qasim, 1999) suggests that municipal wastewater is the general term to use for liquid waste collected from residential, commercial, and industrial areas, and conveyed with sewage system to a treatment plant.

In the case of low-income communities where sewage systems are used, the wastewater is mainly the liquid waste collected from households. When assessing the capacity of the WST, the quantity of liquid waste is derived largely from the water supply. The quantity of wastewater to be treated is roughly equal to the quantity of water supplied. However, and depending on the geographic situation of the community to serve, storm water could be also considered in the assessment of the service capacity.

Treatment of wastewater means removal of pollutants from the water. One of the principles in wastewater management is to prevent pollutants entering the water in the first place. Thus, one needs to ensure that storm water run-off passes through surfaces that are as far as possible free from any wastes. Therefore, collection of solid waste is an important part of storm water management and wastewater prevention.

The assessment of the capacity of the wastewater and sewage treatment service is made following the general use. Qasim reports that many designers frequently assume that the average rate of wastewater flow, including a potential infiltration/inflow, is equal to the average rate of water consumption (Qasim, 1999). However, since a portion of water supplied does not reach the sewers, the capacity for this service could be designed from 80 to 100 % of the quantity of water supplied per capita per day. Thus, the capacity of the wastewater service will be defined based on the DWS service level provided to the community. The capacity of the wastewater treatment plant will be defined, given the technology selected and the time of treatment required by this latter.

The table presents the service capacity constituents by service level for WST service.

Table: WST Service CF Constituents by Service Level

Level	Service Level	Quantity of water
1	Poor Access	< 20 l/d/c
2	Basic Access	20 - 40 l/d/c
3	Intermediate Access	40 - 60 l/d/c
4	Good Access	61 - 80 l/d/c
5	Optimal Access	> 80 l/d/c

INSTITUTIONAL CAPACITY

The assessment of the *Institutional* CF for the WST service is similar to the one made for the DWS service. The components are: *Body of legislation, Associated regulation, Administrative authority, Administrative process,* and *Governance*.

- **Body of Legislation:**

The body of legislation for wastewater and sewage service is related to the legal framework for the discharge of wastewater to surface and ground waters and to publicly-owned sewage systems. In the US, the legislation is known by the Clean Water Act and its subsequent amendments. The specific legislation for water pollution control is the National Pollution Discharge Elimination System (NPDES). In developing countries, such legal framework often does not exist and most of the wastewaters are discharged without treatment.

Since many developing countries face a shortage of fresh water not only for drinking but also for irrigation, a legal framework should be set for the reuse of treated wastewater for agriculture.

- **Associated Regulation:**

In the case where the WST service is based on a sewage system connected to most of the households of the community, a regulation should be set for the control of the discharges of the wastewater into waters. This associated regulation for WST may be from two types: Discharge of pollutants into waters and wastewater reuse for irrigation. The regulation of discharge of pollutants into surface or ground waters should control water pollution by regulating point sources that discharge pollutants into surface waters. The table below provides a classification of level of pollution for surface waters, and could be used as guideline for the quality of water seeks out by the community.

Table: River Pollution Classification

Class	Description	DO. & BOD*	Characteristics
Class I	Unpolluted or recovered from pollution	BOD < 3 mg/L	No toxic or suspended discharges which affect the river
Class II	Doubtful quality and needing improvement	BOD > 3 mg/L, toxic and reduced DO in dry flow times	BToxic and suspended discharges occur but have no major effect on biota
Class III	Poor quality, improvement is a matter of some urgency	DO < 50% for considerable periods	River changed in character, suspected of being actively toxic. Subject to serious complaint
Class IV	Grossly polluted rivers	BOD > 12 mg/L, completely deoxygenated	Incapable of supporting fish life, grossly offensive

*DO = dissolved oxygen; BOD = biochemical oxygen demand
(based on National Water Council (UK) classification, 1970)

The regulation for reuse of wastewater in agriculture could be of prime importance for many developing countries. Furthermore in the absence of surface water nearby the community where the wastewater treated could be discharged, the alternative to use it for agriculture is an interesting one.

- **Administrative Authority:**

As for the DWS, the health department could be the administrative authority for the control and the enforcement of regulations related to discharge of wastewater and reuse of wastewater in agriculture. Regional and local agencies of the health department could enforce these regulations. However, in countries where department of environment exists, the administrative authority could be regional and local agencies of this department. Furthermore River Basin Agencies in some countries are also the administrative authority for WST regulations.

- **Administrative Processes:**

The *Administrative Processes* constituent is related to how the administrative authority manages the application and enforces the regulation for discharge of wastewater. The constituents are defined based on the efficiency of the organization of the administrative authority.

- **Governance:**

The *Governance* constituent is similar to the one presented for DWS.

The constituents of the *Institutional* CF are presented in the table below, and are defined by service level.

2	Institutional							
C_{21}	Body of legislation	W_{21}	None	Basic	Intermediate	Complete	Advanced	
C_{22}	Associated regulation	W_{22}	None	Basic	Intermediate	Complete	Advanced	
C_{23}	Administrative agencies	W_{23}	None	National	Regional	State	Local	
C_{24}	Administrative processes	W_{24}	None	Basic	Intermediate	Complete	Advanced	
C_{25}	Governance	W_{25}	None	National	Regional	State	Local	
f_3	Score Institutional CF						$\Sigma C_{ij} w_j =$	0

HUMAN RESOURCES CAPACITY

The WST *Human Resources* CF is related to the human resources involved in the operations and management of the WST service. Similarly as for the DWS, the constituents of the *Human Resources* CF are: *Professional, Skilled Labor, Unskilled Labor* and *Illiterate*. An organizational chart for WST service is presented in Figure below to illustrate WST human resources constituents for a service level 5.

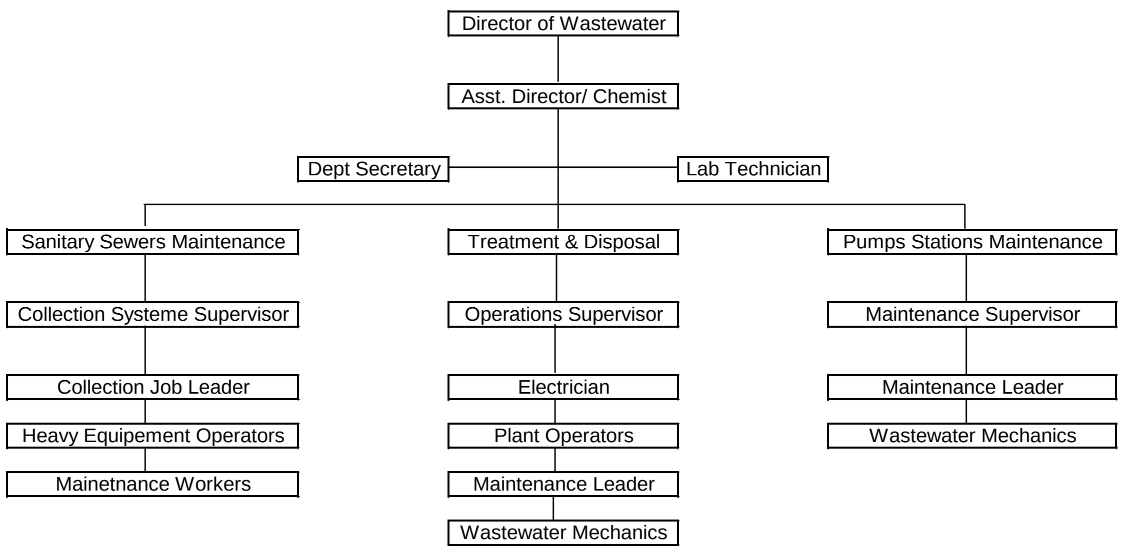


Figure: WST Service Organizational Chart Service level 5

The constituents of the *Human Resources* CF are the following:

- **Professional**

The professional tasks involved in wastewater service are engineering, management, and laboratory practice.

- **Skilled labor**

Skilled labors are the operator, electrician, mechanic, and lab technician able to maintain and operate wastewater systems. As for DWS service, qualifications and license are often required to operate wastewater systems. Similarly as for DWS, administrative personnel with skills to collect revenue, and keep books are also part of the skilled labor.

➢ **Unskilled labor - Literate**

The unskilled labors are labor with basic maintenance knowledge as cleaning, masonry, and painting. It includes also personnel able to accomplish uncomplicated administrative task in offices.

➢ **Unskilled labor - Illiterate**

This last category of personnel includes all the personnel available in the community that could be involved in either the implementation of wastewater systems as well as their maintenance as caretaker. The constituents for the Human Resources Capacity are defined in a similar approach as for DWS. The *Human Resources* CF constituents by service level are presented in the table below.

3	**Human Resources**							
C_{31}	**Professionals**	W_{31}	None	Collection Supervisor	Collection supervisor	Engineer	Engineer	
					Treatment supervisor	Chemist	Chemist	
						Administrative	Administrative manager	
						Collection/treatment superv.	Collection/treatment superv.	
C_{32}	**Skilled Labor**	W_{32}	None	Mechanic	Laboratory technician	Laboratory technician	Laboratory technician	
				Clerck	Mechanic	Maintenance technician	Maintenance technician	
					Clerk	Operator	Operator	
					Electrician	Administrative assistant	Administrative assistant	
							IT technician	
C_{33}	**Unskilled Labor**	W_{33}	None	Maintenance worker I	Maintenance worker II	Maintenance assistant I	Maintenance assistant II	
					Plant worker	Operator assistant I	Operator assistant II	
C_{34}	**Illiterate**	W_{34}	None	Caretaker	Maintenance helper			
f_3	**Score Human Resources CF**						$\Sigma C_{ij} w_j =$	**0**

TECHNICAL CAPACITY

The Technical Capacity Factor is constituted by the following components: *Operation*, *Maintenance, Adaptation*, and *Supply Chain*.

- **Operations**

There are several types of operations in the WST service: Pumping the wastewater throughout the collection system. Performing chemical and biological analysis of municipal wastewater, industrial effluent, treatment plant processes, and receiving streams. Performing bacteriological analyses of wastewater treatment facility. Performing wastewater treatments to reduce the level of pollutants before discharging the wastewater into surface or ground waters, or for a direct reuse in agriculture.

- **Maintenance:**

The operations of maintenance are basically cleaning the sanitary sewers and the lift stations, monitoring of the infiltration and inflow, and repairing the pipes. The operations of maintenance consist also of maintaining the lift stations pumps, and the wastewater facility systems.

- **Adaptation:**

The *Adaptation* constituent refers to the capacity to design and realize modification in the collection system, and in wastewater facility systems. The assessment of the *Adaptation* constituent is derived from the capacity of the available human resources or local contractors to performing development or change in the wastewater systems.

- **Supply Chain:**

The *Supply Chain* constituent refers to the supplier network required for the sustainability of the operations and the maintenance of the wastewater systems. The most needed supplies are pipes, spare parts for the pumping station and the wastewater treatment plant, and chemicals.

The assessment of the *Technical* CF is made by using the technical capacity constituents by service level presented in the table below.

	Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
4	**Technical**							
C_{41}	**Operations**	W_{41}	None	Individual disposal	Collection	Collection	Monitoring pumping stations	
					Pumping	Pumping	Monitoring treatments	
					Preliminary treatment	Complete treatment	Bacteriological analysis	
						Bacteriological analysis	Chemical/Biological analysis	
C_{42}	**Maintenance**	W_{42}	None	Septic tank pump	Clean collector system	Collector systems	Collector systems	
					Maintain pumps	Station pumps	Station pumps	
						Treatment equipments	Treatment equipments	
							IT systems	
C_{43}	**Adaptation**	W_{43}	None	Rarely	Occasionally	Usually	Frequently	
C_{44}	**Supply Chain**	W_{44}	None	National supplier	Regional supplier	National manufacturer	National manufacturer	
						Regional distributor	Local distributor	
f_4	**Score Technical CF**						$\Sigma\ C_{ij}\ w_j =$	**0**

ECONOMIC/ FINANCIAL CAPACITY

The assessment of the *Economic/Financial* CF is similar to the one presented for DWS assessment. The constituents by service level are similar to the ones of the DWS service. However for WST, the technology selected could be based on individual systems as septic tank and in that case there will be no user fees to collect. In that case, the assessment should be done without taking into account the *User fees* constituent. However, maintenance fees for the cleaning of the individual disposal systems each couple of year may exist. For the general case, the assessment is done using the table below.

5	**Economic and Financial**							
C_{51}	**Private sector %**	W_{51}	None	International	National	Regional	Local	
C_{52}	**Bonds Rating**	W_{52}	None	National	Regional	State	Local	
C_{53}	**User fees**	W_{53}	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	
C_{54}	**Budget**	W_{54}	None	Basic accounting	Annual	Quaterly	Monthly	
C_{55}	**Asset values**	W_{55}	None	Equipement	Equipement	Equipement	Equipement	
					Real estate	Real estate	Real estate	
						Cash	Cash	
							Stocks	
C_{56}	**Debt**	W_{56}	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	
f_5	**Score Economic Financial CF**						$\Sigma\ C_{ij}\ w_j =$	**0**

ENERGY CAPACITY

The assessment of the *Energy* CF of WST is similar to the one made for DWS. However, the *Energy* CF for WWS could be less critical as for DWS. Depending on the type of technology selected for the wastewater sewage and treatment plant, it could be not required to use electricity in the treatment processes or at least not often as for the DWS service. The table below shows the constituents for the *Energy* CF.

	Capacity Factors	Weights	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
6	**Energy**							
C_{61}	**Primary source**	W_{61}	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	
C_{62}	**Back up**	W_{62}	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	
C_{63}	**% of Budget**	W_{63}	Very high	High	Moderate	Low	Very Low	
C_{64}	**Rate of outage**	W_{64}	Very High	High	Moderate	Low	very low	
f_6	**Score Energy CF**						$\Sigma C_{ij} w_j =$	0

ENVIRONMENTAL/NATURAL RESOURCES CAPACITY

The assessment of the *Environmental* CF is made by assessing its two constituents: *Quality/Sensitivity* and *Quantity*. The *Quality/Sensitivity* constituent of the *Environmental* CF in the case of WST is also defined by the carrying capacity. However, here the carrying capacity is related to the stress that wastewater and sewage management processes impose on local ecosystems. These impacts are felt primarily on surface waters that receive discharges from wastewater treatment plants, and groundwater systems that must attenuate drainage from septic systems. In cases where solids from human waste are applied to the land, the carrying capacity refers to the soil ecosystem’s capacity to attenuate any biological pathogens or chemical loading in the waste material. The *Quantity* constituent of the *Environmental* CF is related to the amount and loading of wastewater that the environment could receive. It may also be related to the land available for a wastewater treatment plant. The constituents by service level are defined similarly as for DWS and are presented in the table below.

7	**Environmental**							
C_{71}	**Quality and Sensitivity:**	W_{71}	Very low	Low	Moderate	High	Very high	
C_{72}	**Quantity**	W_{72}	Very low	Low	Moderate	High	Very high	
f_7	**Score Environmental CF**						$\Sigma C_{ij} w_j =$	**0**

SOCIAL/CULTURAL CAPACITY

The assessment of the *Social/Cultural* CF for WST is similar to the assessment of the *Social/Cultural* CF of DWS. The constituents *Communities* and *Stability* are assessed in the same way as for the DWS service. However, the constituents *Equity* and *Castes* have a specific assessment for WST.

- **Equity**

Indeed, the *Equity* constituent for WST is related to the access to WST for all the members of the community. As for DWS, the assessment of the *Equity* constituent is related to the fact that the service is provided not based on social class but on an equal and rational way. The assessment is based on the constituent by service level.

- **Castes**

The *Castes* constituent for WST refers to the fact that certain members of the community can be excluded from the service provided. The assessment of this constituent is close to the *Equity* constituent. However, in this case, the inequity of the service provided is more due to social identity or ethnic reason. Furthermore in the case of WST, caste also refers to the laborers who collect and clean septic tanks. For example in India this work is done by members of the “Untouchables” caste (O’Neill, Allard, 2003).

The assessment is done given the existence of this phenomenon within the community. The more this phenomenon exists, the lower the score of this constituent will be.

- **Participation of Women**

In WST the participation of women in the decision making process is less critical than for the DWS. However because of the impact of WST on hygiene and health, women should be involved in the alternatives selection for the service (Jacobson, J., 1992).

The table below presents the constituents

8	**Social and Cultural**							
C_{81}	**Communities**	W_{81}	Very low	Low	Intermediate	High	Very high	
C_{82}	**Stability**	W_{82}	Very low	Low	Intermediate	High	Very high	
C_{83}	**Equity**	W_{83}	Very low	Low	Intermediate	High	Very high	
C_{84}	**Castes**	W_{84}	Very high	High	Intermediate	Low	Very low	
C_{85}	**Participation of Women**	W_{85}	Very Low	Low	Intermediate	High	Very High	
f_8	**Score Social CF**						$\Sigma\, C_{ij}\, w_j =$	**0**

Appendix C: Capacity Factor Analysis – Management of Solid Waste (MSW)

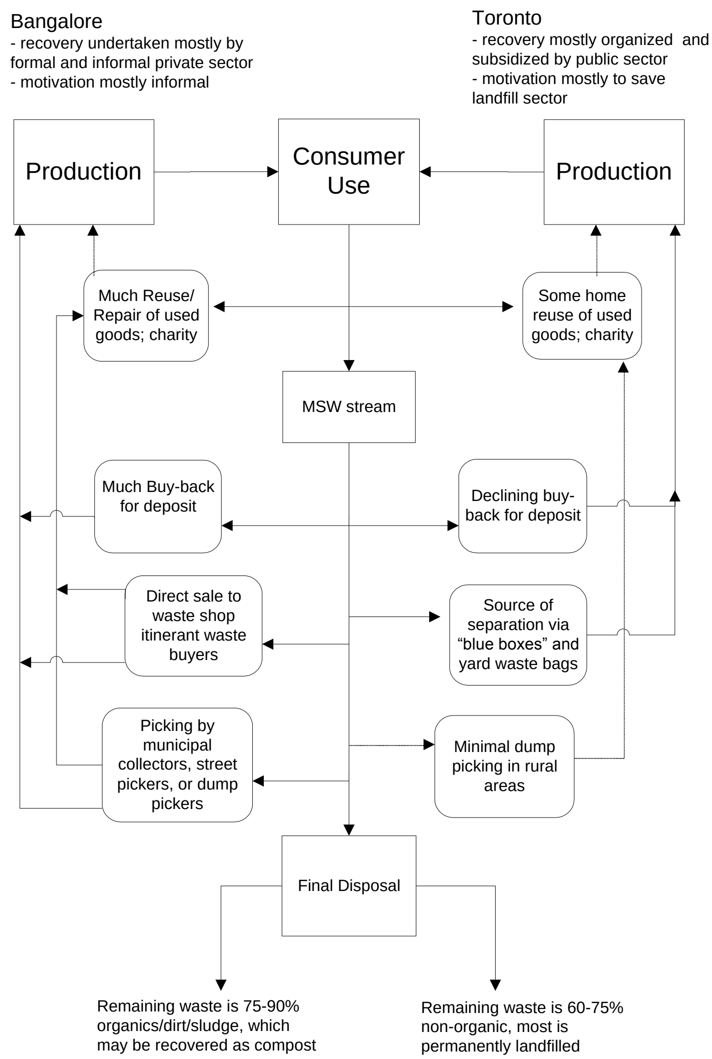
Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
Service							
Sevice Level	W_{11}	< 0.5kg/d/c	0.5 kg/d/c	0.5 - 0.9 kg/d/c	0.9 - 1.8 kg/d/c	> 1.8 kg/d/c	
Score Service CF						$\Sigma C_{ij} w_j =$	**0**
Institutional							
Body of legislation	W_{21}	None	Basic	Intermediate	Complete	Advanced	
Associated regulation	W_{22}	None	Basic	Intermediate	Complete	Advanced	
Administrative agencies	W_{23}	None	National	Regional	District	Local	
Administrative processes	W_{24}	None	Basic	Intermediate	Complete	Advanced	
Governance	W_{25}	None	National	Regional	State	Local	
Score Institutional CF						$\Sigma C_{ij} w_j =$	**0**
Human Resources							
Professionals	W_{31}	None	Landfill supervisor	Landfill supervisor Administrative supervisor	Landfill manager Civil engineer Geologist Administrative supervisor	Landfill manager Civil engineer Geologist Administrative manager Lawyer	
Skilled Labor	W_{32}	None	Truck mechanic Clerk	Mechanic Electrician Landfill operator Administrative Assistant	Maintenance technician Facility leader Landfill operator Collection operator	Maintenance technician Facility leader Landfill operator Collection operator	
Unskilled Labor	W_{33}	None	Truck driver	Collection worker Landfill worker	Street cleaner operator I	Street cleaner operator II	
Illiterate	W_{34}	Collection worker I	Collection worker II	Street sweeper I	Street sweeper II	Street sweeper III	
Score Human Resources CF						$\Sigma C_{ij} w_j =$	**0**

Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
Technical							
Operations	W_{41}	None	Collection Open dump	Collection Landfill Recycling	Collection Station transfer Landfill Recycling	Waste reduction Collection Station transfer Landfill Recycling	
Maintenance	W_{42}	None	Truck	Collection truck Landfill equipment Recycling equipment	Collection truck Landfill equipment Recycling equipment Transfer equipment	Collection truck Landfill equipment Recycling equipment Transfer equipment Control systems	
Adaptation	W_{43}	None	Rarely	Occasionally	Usually	Frequently	
Supply Chain	W_{44}	None	National supplier	Regional supplier	National manufacturer Regional supplier	National manufacturer Local supplier	
Score Technical CF						$\Sigma C_{ij} w_j =$	**0**
Economic and Financial							
Private sector %	W_{51}	None	International	National	Regional	Local	
Bonds Rating	W_{52}	None	National	Regional	State	Local	
User fees	W_{53}	None	None	Uniform flat rate	Uniform flat rate	Uniform flat rate	
Budget	W_{54}	None	Basic accounting	Annual	Tracked annually	Tracked quaterly	
Asset values	W_{55}	None	Real estate	Real estate Equipment	Real estate Equipment Cash	Real estate Equipment Cash - Stocks	
Debt	W_{56}	None	Rating (cc)	Rating (bb)	Rating (bbb)	Rating (a-aa)	
Score Economic / Financial CF						$\Sigma C_{ij} w_j =$	**0**

Capacity Factors	Weights	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
Energy							
Primary source	W_{61}	None	Non Conventional	Conventional Electricity	Electricity Mid voltage	Electricity Mid voltage	
Back up	W_{62}	None	Generator < 5HP	Generator < 10 HP	Generator < 50 HP	Generator > 50 HP	
% of Budget	W_{63}	Very High	High	Moderate	Low	Very Low	
Rate of outage	W_{64}	Very High	High	Moderate	Low	Very low	
Score Energy CF						$\Sigma C_{ij} w_j =$	**0**
Environmental Capacity							
Quality and Sensitivity:	W_{71}	Very low	Low	Moderate	High	Very high	
Quantity	W_{72}	Very low	Low	Moderate	High	Very high	
Score Environmental CF						$\Sigma C_{ij} w_j =$	**0**
Social and Cultural							
Communities	W_{81}	Very low	Low	Moderate	High	Very high	
Stability	W_{82}	Very low	Low	Moderate	High	Very high	
Equity	W_{83}	Very low	Low	Moderate	High	Very high	
Castes	W_{84}	Very high	High	Moderate	Low	Very low	
Participation of Women	W_{85}	Very Low	Low	Moderate	High	Very high	
Score Social Cultural CF						$\Sigma C_{ij} w_j =$	**0**

SERVICE CAPACITY

Municipal solid waste, commonly known as trash or garbage, consists of everyday items as food, product packaging, grass clipping, furniture, clothing, and bottles. However there are major differences between solid waste generated in developed countries and in developing countries. These differences are not only in the quantities of solid waste but also in the type of waste. In developing countries, the waste generated is dense and has high moisture content. It is basically originated from fruits and vegetables. On the other hand, in developed countries, solid waste is much paper and plastic. Thus these differences have profound effects on the technology that can be successfully applied for both collection and disposal. The chart presented in the figure below shows the differences between solid wastes generated in Toronto, a city of a high developed country (HID), Canada and solid wastes generated in Bangalore, a city of a developing country (LIC), India (IETC/UNEP, 1996). In the chart, we can see that at the disposal stage, the waste generated in the developing country is for 75% to 90 % organic, sludge and dirt, and can be recovered as compost. On the other hand, at the disposal stage, the waste generated in the developed country is for 60% to 75 % non-organic waste, and has to be permanently land filled.



<u>Source</u>: IETC/UNEP, 1996

Figure: Solid Waste Composition in HDC and LIC

In low-income countries, the average quantity of solid waste generated per capita and per day differs from one country to another, but also inside a country, between rural and urban areas. As for DWS and WST assessment, a minimum capacity service and an optimal capacity service is defined for the MSW. Based on (UN, 2001), the annual solid waste production in the least developing countries is less than 200 kg per person. In average, a rate generation of 0.5 kg/d/c is adopted for the lowest income community, generally living in rural areas in low-income countries, and an average rate of 1.4 kg/d/c for the highest income community and the largest cities in low and middle-income countries. The assessment of the *Service* CF is done using the MSW *Service* CF constituents presented in the following table.

Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
Service						
Sevice Level	< 0.5kg/d/c	0.5 kg/d/c	0.5 - 0.9 kg/d/c	0.9 - 1.8 kg/d/c	> 1.8 kg/d/c	
Score Service CF					$\Sigma C_{ij} w_j =$	0

INSTITUTIONAL CAPACITY

The MSW *Institutional* CF refers to the legal framework that regulates and enforces the MSW operations. The constituents of the *Institutional* CF are *Body of Legislation*, *Associated Regulations*, *Administrative Authority*, *Administrative Process*, and *Governance*.

Few developing countries have developed MSW regulations and laws, however in the past recent years, some major developing countries as China, India and South Africa have developed guidelines and constituents management for solid waste disposal, including landfills, composting and incineration.

- **Body of Legislation**

The MSW *Body of Legislation* constituent refers to the national laws that regulate solid waste management from collection, recycling, composting and disposal. For example China has recently developed guidelines (Johannessen, 1999), which set criteria such as minimum distance of landfill to drinking water sources, limitations on geological formations and constituents for hydrological surveys.

The assessment of the *Body of Legislation* constituent is done given the existence of laws and standards from basic to advanced ones.

- **Associated regulations**

The *Associated Regulations* constituent for solid waste management is essential for safe and clean environment, and for sustainable development. In China's guidelines for MSW management recently developed, the licensing procedure for landfills requires an environmental impact assessment (EIA) approved from the local Environmental Protection Bureau, which is advised by a competent technical institute. In Chile, the government has also introduced guidelines and regulations including EIA and leachate management. The assessment of the *Associated Regulations* constituent is done, giving the existence of MSW regulations at the national, regional or local level.

- **Administrative Authority**

The *Administrative Authority* constituent of the *Institutional* CF refers to the authority which enforces the laws, promotes programs for best practices in MSW, and provides technical assistance for MSW and recycling. The administrative authority in developing countries is usually an agency reporting to the Department of Environment, the Department of Health, or Department of Urban Construction.

In Developed Countries, the administrative authority is usually the local Department of Public Works of the city or the county. The assessment of the *Administrative Authority* constituent is done, based on the existence of the authority, at the national, regional or local level.

- **Administrative Process**

The *Administrative Process* constituent is related to how the administrative authority manages and enforces the regulations for collection and disposal of solid waste. The assessment is made given the efficiency of the administrative authority in handling its service. The assessment is made regarding how well-organized the administrative authority is at enforcing the regulations and protecting the environment.

➢ **Governance**

The constituent *Governance* is similar to the one presented for DWS and WST. The same criteria used for the assessment of DWS and WST are used for the assessment of MSW. The constituents of the Institutional CF are defined by service level in the following table.

Institutional						
Body of legislation	None	Basic	Intermediate	Complete	Advanced	
Associated regulation	None	Basic	Intermediate	Complete	Advanced	
Administrative agencies	None	National	Regional	State	Local	
Administrative processes	None	Basic	Intermediate	Complete	Advanced	
Governance	None	National	Regional	State	Local	
Score Institutional CF					$\Sigma C_{ij} w_j =$	**0**

HUMAN RESOURCES CAPACITY

The Human Resources Capacity Factor in MSW refers to the professional, skilled and unskilled labor and illiterate personnel whom are involved in the day-to-day operations of the MSW service.

➢ **Professional**

The assessment of *Professional* constituent is performed based on professionals involved in the operations and maintenance of the MSW systems are geologist, civil engineer, sanitary engineers, and landfill manager and supervisor. The professional are also lawyers, administrative manager and public relations manager.

- **Skilled Labor**

The *Skilled Labor* constituent in MSW systems operations and maintenance are collection truck driver, mechanic, electrician and sanitary technician. These skilled labors are involved in collection and landfill operations in general, and in transfer station, recycling, and composting operations and maintenance depending on the MSW systems used in the community. The skilled labors are also the administrative assistants, and accountants,

- **Unskilled Labor - Literate**

The *Unskilled Labors* constituent in MSW are defined by landfill dumper and tractor operators. There are also operators in transfer station, composting and recycling facilities. Inexperienced mechanics and electricians involving in the operations and maintenance of the MSW systems are also defined as unskilled labors as well as the clerks and assistant in charge of basic administrative tasks.

- **Unskilled labor - Illiterate**

The last category of human resources involved in the operations of MSW is the collection workers, the street sweepers, and the landfill workers. Illiterate workers are also involved in the day to day operations of MSW systems using station transfer, recycling, or composting facilities. The MSW human resource capacity factor is assessed given the current level of development of the community. The constituent *Unskilled Labor* constituent is defined for the sanitation service systems by service level. This will determine what capacity is available for ensuring operation and maintenance of a sustainable MSW service at the local level. The table below presents *Human Resources* CF constituents for sustainable MSW systems based on the service level seek out.

Human Resources						
Professionals	None	Landfill supervisor	Landfill supervisor	Landfill manager	Landfill manager	
			Administrative supervisor	Civil engineer	Civil engineer	
				Geologist	Geologist	
				Administrative supervisor	Administrative manager	
					Lawyer	
Skilled Labor	None	Truck mechanic	Mechanic	Maintenance technician	Maintenance technician	
		Clerk	Electrician	Facility leader	Facility leader	
			Landfill operator	Landfill operator	Landfill operator	
			Administrative Assistant	Collection operator	Collection operator	
Unskilled Labor	None	Truck driver	Collection worker	Street cleaner operator I	Street cleaner operator II	
			Landfill worker			
Illiterate	Collection worker I	Collection worker II	Street sweeper I	Street sweeper II	Street sweeper III	
Score Human Resources CF					$\Sigma C_{ij} w_j =$	**0**

TECHNICAL CAPACITY

The MSW Technical Capacity Factor of the community is based on the four following constituents: *Operations, Maintenance*, *Adaptation*, and *Supply Chain*.

- **Operations**

In municipal solid waste, the principal operations are collection, transfer, treatment and disposal. Collection is one of the most important parts of the process in MSW. It is estimated to represent about 50% of the total cost of collection and disposal by sanitary landfill (Salvato, 1992). The frequency of collection depends on several factors, as climate, socio-economic status, and local contractor responsibility. However, for poor community, slum, and ghetto areas, it is usually required to have collection of solid waste at least twice a week. Tight-body open trucks are still used for collection in LIC. However, automatic loading trucks with packer to compact refuse are replacing the former in large cities in developing countries.

Transfer Station could be required in the case of large cities with fewer acceptable solid waste disposal sites available. Indeed, when the transfer of waste from small collection trucks to large transportation trucks to haul the waste to more distant disposal sites becomes less expensive, it justifies the creation of transfer station.

Treatment and Disposal are the final stage of the MSW operations. The most common treatments of MSW are incineration with energy recovery, composting, and sanitary landfill with land reclamation. The solid waste disposal methods include open dump, controlled landfill, and sanitary landfill. Recycling of solid waste and waste reduction should also be important elements of a sound solid waste management policy. The assessment of the *Operations* constituent of the Technical CF is performed based on the level of operations that can be performed at the community level.

- **Maintenance**

This second constituent of the Technical CF is the *Maintenance*. The operations of maintenance depend on the technologies selected for the MSW management. It could be simply the regular maintenance of the collection trucks and their cleaning to a more complex maintenance of a MSW facility like a transfer station, an incinerator with energy recovery, a recycling facility, or a sanitary landfill. In the case of the use of transfer station the maintenance will consist of the cleaning of the loading area, the lubrication of equipment of transfer, and the repairs. The assessment of the *Maintenance* constituent will be performed based on the level of maintenance tasks that can be done at the local level.

- **Adaptation**

The *Adaptation* constituent refers to the capacity of modification and adjustment made to the equipment of MSW to address specific needs. Here again the capacity of adaptation depends on the technology used in the MSW systems. The assessment of the *Adaptation* constituent is done based on the capacity of design, development and supervision of modifications or upgrading available at the community level.

- **Supply Chain**

The fourth constituent of the Technical CF refers to the availability of supplies and materials for the day-to-day operations and maintenance of MSW systems. The supplies are the spare parts and lubricants for the equipment of collection, the equipment of treatment, and the equipment used on the landfill. The assessment of the *Supply Chain* component is done based on the availability of the spare parts and materials at the national, the regional or the local level. In the case of availability of supplies at the local level, the constituent will receive a high score in the assessment. The Assessment of the Technical CF for the MSW is made using the technical capacity factor constituents by service level presented in the table below.

Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
Technical						
Operations	None	Collection	Collection	Collection	Waste reduction	
		Open dump	Landfill	Station transfer	Collection	
			Recycling	Landfill	Station transfer	
				Recycling	Landfill	
					Recycling	
Maintenance	None	Truck	Collection truck	Collection truck	Collection truck	
			Landfill equipment	Landfill equipment	Landfill equipment	
			Recycling equipment	Recycling equipment	Recycling equipment	
				Transfer equipment	Transfer equipment	
					Control systems	
Adaptation	None	Rarely	Occasionally	Usually	Frequently	
Supply Chain	None	National supplier	Regional supplier	National manufacturer	National manufacturer	
				Regional supplier	Local supplier	
Score Technical CF					$\Sigma C_{ij} w_j =$	**0**

ECONOMIC/ FINANCIAL CAPACITY

The assessment of the *Economic / Financial* CF for the MSW is similar to the ones made for DWS and WST. The constituents of the *Economic / Financial* CF are defined by service level, and presented in the table below. However there is specificity for the *User Fees* constituent in the case of MSW. Usually a flat rate is applied for collection fees instead of increasing rate as applied for DWS and WST. The table below presents the constituents for the *Economic / Financial* CF.

Economic and Financial						
Private sector %	None	International	National	Regional	Local	
Bonds Rating	None	National	Regional	State	Local	
User fees	None	None	Uniform flat rate	Uniform flat rate	Uniform flat rate	
Budget	None	Basic accounting	Annual	Tracked annually	Tracked quaterly	
Asset values	None	Real estate	Real estate Equipment	Real estate Equipment Cash	Real estate Equipment Cash - Stocks	
Debt	None	Rating (cc)	Rating (bb)	Rating (bbb)	Rating (a-aa)	
Score Economical Financial CF					$\Sigma C_{ij} w_j =$	**0**

ENERGY CAPACITY

The assessment of the Energy CF in the MSW case is similar to the one made for the DWS and WST. The assessment of the Energy CF uses the same capacity constituents by service level. As for WST, and depending on the technologies selected for the MSW systems, the Energy CF could be less critical than for DWS. The table below presents the constituents for the Energy CF.

Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
Energy						
Primary source	None	Non Conventional	Conventional Electricity	Electricity Mid voltage	Electricity Mid voltage	
Back up	None	Generator < 5HP	Generator < 10 HP	Generator < 50 HP	Generator > 50 HP	
% of Budget	Very High	High	Moderate	Low	Very Low	
Rate of outage	Very High	High	Moderate	Low	Very low	
Score Energy CF					$\Sigma C_{ij} w_j =$	**0**

ENVIRONMENT / NATURAL RESOURCES CAPACITY

The Environment Capacity Factor has two constituents: Quality/Sensitivity and Quantity.

- **Quality/Sensitivity**

This *Quality/Sensitivity* constituent refers to the carrying capacity of the environment. It refers to the size of the population that could live without degrading the natural environment, and the amount of solid waste generated. The carrying capacity is thus an indirect measure of the level of stress that the ecosystem can sustain, given the amount of solid waste generated by the community. The assessment of the *Quality/sensitivity* constituent is made based on the carrying capacity of the environment around the community. The more the environment of the community can sustain the stress, the greater the capacity will be. For MSW, environmental stress arises from landfill gazes, leachate from landfills, emission from incinerators and recycling facilities, odors from MSW facilities, traffic, noise, flies, birds and other aesthetic blights from MSW operations, and disease vectors from accumulated MSW.

- **Quantity**

The assessment of the constituent *Quantity* of the Environment CF, in the case of MSW, is of prime importance. The availability of sites for landfill is often an acute problem, not only because of the opposition of local community to disposal site but also for the specific geological constituents for the landfill soil. The assessment of the Quantity component is done given the availability and the soil characteristics of the sites for waste disposal. The constituents for the Environment CF are presented in the table below.

Environmental Capacity						
Quality and Sensitivity:	Very low	Low	Moderate	High	Very high	
Quantity	Very low	Low	Moderate	High	Very high	
Score Environmental CF					$\Sigma C_{ij} w_j =$	**0**

SOCIAL/CULTURAL CAPACITY

The constituents of the Social/Cultural Capacity Factor are *Communities*, *Stability*, *Equity*, *Castes*, and *Participation of Women*. The constituents are assessed in the same way as for DWS and WST. However, the constituent *Castes* may have a more specific assessment in the case of MSW. Indeed in some developing countries, the castes phenomenon could be important and its assessment may provide important information for the MSW systems selection. This was discussed in the section of WST for the case of Untouchables in India. The constituents for the Social / Cultural CF are presented in the table below.

Social and Cultural						
Communities	Very low	Low	Moderate	High	Very high	
Stability	Very low	Low	Moderate	High	Very high	
Equity	Very low	Low	Moderate	High	Very high	
Castes	Very high	High	Moderate	Low	Very low	
Participation of Women	Very Low	Low	Moderate	High	Very high	
Score Social Cultural CF					$\Sigma C_{ij} w_j =$	**0**

Appendix D: ARFF File - Training Set of DWS Options

```
@relation rank

@attribute source {rooftop_rainwater_harvesting, catchment_and_storage_dam, springwater_collection, dug_well, drilled_well, subsurface_harvesting, protected_side_intake, river_bottom_intake, floating_intake, sump_intake}
@attribute device {bucket, rope_and_bucket, bucket_pump, rope_pump, suction_plunger_handpump, direct_action_pump, deep_well_diaphragm_pump, deep_well_piston_pump, centrifugal_pump, submersible_pump, hydraulic_ram_pump}
@attribute treatment {boiling, household_slow_sand_filter, domestic_chlorination, storage_and_sedimentation, slow_sand_filtration, chlorination_in_piped_water_supply_system}
@attribute storage {concrete_lined_earthen_reservoir, reinforced_concrete_reservoir, elevated_steel_reservoir, ferrocement_tank, plastic_tank, steel_tank}
@attribute distribution {public_standpost, domestic_connection}
@attribute TRL real

@data
rooftop_rainwater_harvesting,bucket,household_slow_sand_filter,steel_tank,domestic_connection,2
rooftop_rainwater_harvesting,bucket,household_slow_sand_filter,ferrocement_tank,domestic_connection,2
catchment_and_storage_dam,hydraulic_ram_pump,domestic_chlorination,elevated_steel_reservoir,public_standpost,3
catchment_and_storage_dam,hydraulic_ram_pump,domestic_chlorination,ferrocement_tank,domestic_connection,3
catchment_and_storage_dam,hydraulic_ram_pump,storage_and_sedimentation,reinforced_concrete_reservoir,domestic_connection,3
catchment_and_storage_dam,hydraulic_ram_pump,storage_and_sedimentation,ferrocement_tank,domestic_connection,3
catchment_and_storage_dam,hydraulic_ram_pump,slow_sand_filtration,reinforced_concrete_reservoir,domestic_connection,3
catchment_and_storage_dam,hydraulic_ram_pump,chlorination_in_piped_water_supply_system,elevated_steel_reservoir,domestic_connection,4
springwater_collection,hydraulic_ram_pump,storage_and_sedimentation,elevated_steel_reservoir,domestic_connection,3
springwater_collection,hydraulic_ram_pump,chlorination_in_piped_water_supply_system,ferrocement_tank,domestic_connection,3
dug_well,rope_and_bucket,household_slow_sand_filter,steel_tank,public_standpost,1
dug_well,rope_and_bucket,household_slow_sand_filter,plastic_tank,public_standpost,1
dug_well,rope_pump,boiling,ferrocement_tank,domestic_connection,2
drilled_well,bucket_pump,boiling,reinforced_concrete_reservoir,domestic_connection,2
drilled_well,bucket_pump,domestic_chlorination,reinforced_concrete_reservoir,public_standpost,2
drilled_well,bucket_pump,domestic_chlorination,reinforced_concrete_reservoir,domestic_connection,3
drilled_well,rope_pump,household_slow_sand_filter,plastic_tank,public_standpost,3
drilled_well,suction_plunger_handpump,boiling,plastic_tank,public_standpost,2
drilled_well,suction_plunger_handpump,domestic_chlorination,reinforced_concrete_reservoir,domestic_connection,3
drilled_well,direct_action_pump,household_slow_sand_filter,steel_tank,public_standpost,2
drilled_well,deep_well_diaphragm_pump,domestic_chlorination,reinforced_concrete_reservoir,public_standpost,3
drilled_well,deep_well_piston_pump,domestic_chlorination,plastic_tank,domestic_connection,3
subsurface_harvesting,deep_well_piston_pump,domestic_chlorination,plastic_tank,public_standpost,3
protected_side_intake,centrifugal_pump,domestic_chlorination,elevated_steel_reservoir,domestic_connection,3
protected_side_intake,centrifugal_pump,domestic_chlorination,ferrocement_tank,domestic_connection,3
protected_side_intake,centrifugal_pump,storage_and_sedimentation,concrete_lined_earthen_reservoir,public_standpost,3
protected_side_intake,centrifugal_pump,storage_and_sedimentation,plastic_tank,domestic_connection,3
protected_side_intake,centrifugal_pump,slow_sand_filtration,concrete_lined_earthen_reservoir,public_standpost,3
river_bottom_intake,centrifugal_pump,boiling,reinforced_concrete_reservoir,public_standpost,3
river_bottom_intake,centrifugal_pump,boiling,plastic_tank,public_standpost,3
river_bottom_intake,centrifugal_pump,household_slow_sand_filter,ferrocement_tank,domestic_connection,3
river_bottom_intake,centrifugal_pump,domestic_chlorination,plastic_tank,domestic_connection,3
river_bottom_intake,centrifugal_pump,slow_sand_filtration,reinforced_concrete_reservoir,public_standpost,3
floating_intake,centrifugal_pump,boiling,concrete_lined_earthen_reservoir,domestic_connection,3
floating_intake,centrifugal_pump,boiling,reinforced_concrete_reservoir,public_standpost,3
floating_intake,centrifugal_pump,boiling,plastic_tank,public_standpost,3
floating_intake,centrifugal_pump,household_slow_sand_filter,elevated_steel_reservoir,domestic_connection,4
floating_intake,centrifugal_pump,domestic_chlorination,plastic_tank,domestic_connection,3
floating_intake,centrifugal_pump,storage_and_sedimentation,reinforced_concrete_reservoir,domestic_connection,4
floating_intake,centrifugal_pump,slow_sand_filtration,plastic_tank,domestic_connection,4
sump_intake,deep_well_piston_pump,boiling,concrete_lined_earthen_reservoir,public_standpost,3
sump_intake,deep_well_piston_pump,boiling,plastic_tank,domestic_connection,3
sump_intake,submersible_pump,boiling,ferrocement_tank,domestic_connection,3
sump_intake,submersible_pump,household_slow_sand_filter,concrete_lined_earthen_reservoir,domestic_connection,3
sump_intake,submersible_pump,domestic_chlorination,concrete_lined_earthen_reservoir,domestic_connection,4
sump_intake,submersible_pump,domestic_chlorination,elevated_steel_reservoir,public_standpost,3
sump_intake,submersible_pump,domestic_chlorination,plastic_tank,domestic_connection,3
sump_intake,submersible_pump,storage_and_sedimentation,concrete_lined_earthen_reservoir,domestic_connection,4
```

Appendix E: Results Classification - Training Set DWS Options

=== Run information ===
Scheme: weka.classifiers.lazy.KStar -B 20 -M a
Relation: rank
Instances: 48
Attributes: 6
source
device
treatment
storage
distribution
TRL

Test mode:evaluate on training data
== Classifier model (full training set) ===
KStar Beta Verion (0.1b).
Copyright (c) 1995-97 by Len Trigg (trigg@cs.waikato.ac.nz).
Java port to Weka by Abdelaziz Mahoui (am14@cs.waikato.ac.nz).
KStar options : -B 20 -M a
Time taken to build model: 0 seconds

=== Predictions on training set ===

inst#,	actual,	predicted,	error
1	2	2.001	0.001
2	2	2.007	0.007
3	3	3.008	0.008
4	3	3.007	0.007
5	3	3.013	0.013
6	3	3.006	0.006
7	3	3.007	0.007
8	4	3.96	-0.04
9	3	3.007	0.007
10	3	3.005	0.005
11	1	1.006	0.006
12	1	1.013	0.013
13	2	2.009	0.009
14	2	2.096	0.096
15	2	2.153	0.153
16	3	2.847	-0.153
17	3	2.975	-0.025
18	2	2.022	0.022
19	3	2.988	-0.012
20	2	2	0
21	3	2.95	-0.05

22	3	2.999	-0.001
23	3	2.998	-0.002
24	3	3.009	0.009
25	3	3.001	0.001
26	3	3.001	0.001
27	3	3.015	0.015
28	3	3	0
29	3	2.999	-0.001
30	3	2.993	-0.007
31	3	2.999	-0.001
32	3	3.008	0.008
33	3	3	0
34	3	3.022	0.022
35	3	3.007	0.007
36	3	3	0
37	4	3.962	-0.038
38	3	3.09	0.09
39	4	3.95	-0.05
40	4	3.898	-0.102
41	3	3	0
42	3	3	0
43	3	3.007	0.007
44	3	3.149	0.149
45	4	3.84	-0.16
46	3	3.008	0.008
47	3	3.089	0.089
48	4	3.909	-0.091

=== Evaluation on training set ===

=== Summary ===

Correlation coefficient	0.9969
Mean absolute error	0.0313
Root mean squared error	0.0559
Relative absolute error	7.4625 %
Root relative squared error	8.5535 %
Total Number of Instances	48

```
=== Run information ===

Scheme: weka.classifiers.functions.SMOreg -C 1.0 -N 0 -I
"weka.classifiers.functions.supportVector.RegSMOImproved -L 0.001 -W 1 -P 1.0E-12 -
T 0.001 -V" -K "weka.classifiers.functions.supportVector.PolyKernel -C 250007 -E 1.0"
Relation:     rank
Instances:    48
Attributes:   6
              source
              device
              treatment
              storage
              distribution
              TRL
Test mode: evaluate on training data

=== Classifier model (full training set) ===
SMOreg
weights (not support vectors):
 -       0.0855 * (normalized) source=rooftop_rainwater_harvesting
 +       0.063  * (normalized) source=catchment_and_storage_dam
 -       0.122  * (normalized) source=springwater_collection
 -       0.4057 * (normalized) source=dug_well
 +       0.0635 * (normalized) source=drilled_well
 +       0.1866 * (normalized) source=subsurface_harvesting
 -       0.1081 * (normalized) source=protected_side_intake
 +       0.0165 * (normalized) source=river_bottom_intake
 +       0.2034 * (normalized) source=floating_intake
 +       0.1883 * (normalized) source=sump_intake
 -       0.0855 * (normalized) device=bucket
 +       0.0289 * (normalized) device=rope_and_bucket
 -       0.2058 * (normalized) device=bucket_pump
 +       0.2268 * (normalized) device=rope_pump
 +       0      * (normalized) device=suction_plunger_handpump
 -       0.1083 * (normalized) device=direct_action_pump
 +       0.1249 * (normalized) device=deep_well_diaphragm_pump
 +       0.0018 * (normalized) device=deep_well_piston_pump
 +       0.1118 * (normalized) device=centrifugal_pump
 -       0.0355 * (normalized) device=submersible_pump
 -       0.059  * (normalized) device=hydraulic_ram_pump
 -       0.1434 * (normalized) treatment=boiling
 -       0.1192 * (normalized) treatment=household_slow_sand_filter
 -       0.0174 * (normalized) treatment=domestic_chlorination
 +       0.0444 * (normalized) treatment=storage_and_sedimentation
 +       0.0435 * (normalized) treatment=slow_sand_filtration
 +       0.192  * (normalized) treatment=chlorination_in_piped_water_supply_system
```

```
+       0.0664 * (normalized) storage=concrete_lined_earthen_reservoir
-       0.0576 * (normalized) storage=reinforced_concrete_reservoir
+       0.1255 * (normalized) storage=elevated_steel_reservoir
-       0.021  * (normalized) storage=ferrocement_tank
-       0.0584 * (normalized) storage=plastic_tank
-       0.0549 * (normalized) storage=steel_tank
+       0.1249 * (normalized) distribution
+       0.5526

Number of kernel evaluations: 1176 (99.442% cached)
Time taken to build model: 0.03 seconds

=== Predictions on training set ===

inst#,    actual, predicted, error
    1      2          1.997     -0.003
    2      2          2.099      0.099
    3      3          2.994     -0.006
    4      3          2.929     -0.071
    5      3          3.005      0.005
    6      3          3.115      0.115
    7      3          3.002      0.002
    8      4          3.997     -0.003
    9      3          2.999     -0.001
   10      3          3.003      0.003
   11      1          1.005      0.005
   12      1          0.995     -0.005
   13      2          2.003      0.003
   14      2          2.002      0.002
   15      2          2.006      0.006
   16      3          2.38      -0.62
   17      3          2.996     -0.004
   18      2          2.243      0.243
   19      3          2.998     -0.002
   20      2          2.001      0.001
   21      3          2.998     -0.002
   22      3          3.001      0.001
   23      3          2.996     -0.004
   24      3          3.368      0.368
   25      3          2.929     -0.071
   26      3          3.001      0.001
   27      3          3.002      0.002
   28      3          2.999     -0.001
   29      3          2.44      -0.56
   30      3          2.437     -0.563
   31      3          2.997     -0.003
```

32	3	3.19	0.19
33	3	3	0
34	3	3.747	0.747
35	3	3	0
36	3	2.998	-0.002
37	4	3.997	-0.003
38	3	3.751	0.751
39	4	3.939	-0.061
40	4	3.933	-0.067
41	3	2.997	-0.003
42	3	2.997	-0.003
43	3	2.998	-0.002
44	3	3.332	0.332
45	4	3.638	-0.362
46	3	3.441	0.441
47	3	3.263	0.263
48	4	3.823	-0.177

=== Evaluation on training set ===

=== Summary ===

Correlation coefficient 0.9307

Mean absolute error 0.1288

Root mean squared error 0.2477

Relative absolute error 30.7085 %

Root relative squared error 37.9175 %

Total Number of Instances 48

Appendix F: Classification of 15 Subsets of DWS Options

Set1						TRL	Kstar		SMO	
40	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**3**	3.147	3	2.793	3
41	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	**3**	2.91	3	2.788	3
59	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	**3**	3.005	3	2.796	3
62	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	public_standpost	**3**	3.011	3	2.783	3
65	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	domestic_connection	**3**	3.11	3	2.985	3
66	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	**3**	3.023	3	2.98	3
83	springwater_collection	hydraulic_ram_pump	boiling	plastic_tank	public_standpost	**3**	2.724	3	1.807	2
97	springwater_collection	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	**3**	3.017	3	2.206	2
102	springwater_collection	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	3.004	3	2.401	2
117	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	**3**	3.017	3	2.602	3
126	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	**3**	3.033	3	2.806	3
133	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	**3**	3.042	3	2.99	3
140	dug_well	rope_and_bucket	boiling	ferrocement_tank	domestic_connection	**2**	2.1	2	0.84	1
167	dug_well	rope_pump	boiling	ferrocement_tank	public_standpost	**2**	2.027	2	1.787	2
169	dug_well	rope_pump	boiling	plastic_tank	domestic_connection	**2**	2.107	2	1.99	2
176	dug_well	rope_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**2**	1.876	2	2.164	2
225	dug_well	submersible_pump	domestic_chlorination	plastic_tank	domestic_connection	**4**	3.732	4	2.577	3
239	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	2.078	2	2.97	3
293	drilled_well	suction_plunger_handpump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**3**	2.64	3	2.675	3
305	drilled_well	suction_plunger_handpump	domestic_chlorination	steel_tank	domestic_connection	**3**	2.989	3	2.865	3
311	drilled_well	suction_plunger_handpump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	**3**	3.059	3	3.071	3
315	drilled_well	direct_action_pump	boiling	steel_tank	domestic_connection	**2**	2.393	2	1.834	2
320	drilled_well	direct_action_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	**2**	2.442	2	1.832	2
333	drilled_well	direct_action_pump	domestic_chlorination	steel_tank	public_standpost	**2**	2.096	2	2.007	2
340	drilled_well	direct_action_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	**3**	3.205	3	2.421	2
360	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	**3**	3.384	3	3.384	3
384	drilled_well	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	2.516	3	2.798	3
392	drilled_well	deep_well_piston_pump	domestic_chlorination	steel_tank	public_standpost	**3**	2.764	3	2.793	3
395	drilled_well	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	3.001	3	3.01	3
437	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	**3**	2.909	3	2.995	3
476	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	public_standpost	**3**	2.974	3	2.23	2
486	protected_side_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	2.919	3	2.607	3
492	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	**3**	3.016	3	2.624	3
563	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	**3**	3.092	3	3.21	3
580	floating_intake	centrifugal_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	**3**	3.005	3	3.202	3
591	floating_intake	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	**4**	3.767	4	3.788	4
606	floating_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	**3**	3.484	3	3.983	4
617	floating_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	**4**	3.785	4	3.795	4
631	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	**3**	3.061	3	3.981	4
645	sump_intake	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	2.162	2	3.169	3
649	sump_intake	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	**3**	2.698	3	3.172	3
673	sump_intake	submersible_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	**4**	3.917	4	3.996	4
678	sump_intake	submersible_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**4**	3.882	4	3.793	4
706	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	domestic_connection	**4**	3.958	4	4.599	5
710	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	**4**	3.811	4	4.808	5
713	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	**4**	3.651	4	4.189	4

Set2						TRL	Kstar		SMOreg	
4	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	domestic_connection	**2**	2.021	2	1.619	2
124	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	**3**	3.003	3	2.578	3
143	dug_well	rope_and_bucket	boiling	concrete_lined_earthen_reservoir	public_standpost	**2**	1.691	2	0.829	1
154	dug_well	rope_and_bucket	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	**3**	2.851	3	1.234	1
171	dug_well	rope_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	**2**	2.105	2	2.192	2
181	dug_well	rope_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	**3**	2.727	3	2.569	3
188	dug_well	rope_pump	domestic_chlorination	plastic_tank	public_standpost	**2**	2.439	2	2.163	2
197	dug_well	submersible_pump	boiling	steel_tank	domestic_connection	**3**	2.629	3	2.192	2
202	dug_well	submersible_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	**3**	2.916	3	2.191	2
239	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	2.078	2	2.97	3
248	drilled_well	bucket_pump	domestic_chlorination	steel_tank	domestic_connection	**3**	2.996	3	3.182	3
249	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	public_standpost	**3**	2.992	3	2.983	3
250	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	3.001	3	3.191	3
278	drilled_well	rope_pump	domestic_chlorination	ferrocement_tank	public_standpost	**3**	2.943	3	3.009	3
282	drilled_well	rope_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	2.996	3	3.206	3
289	drilled_well	suction_plunger_handpump	boiling	ferrocement_tank	domestic_connection	**3**	2.632	3	2.493	2
304	drilled_well	suction_plunger_handpump	domestic_chlorination	steel_tank	public_standpost	**3**	2.585	3	2.657	3
307	drilled_well	suction_plunger_handpump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	2.994	3	2.874	3
310	drilled_well	suction_plunger_handpump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	2.775	3	2.863	3
314	drilled_well	direct_action_pump	boiling	steel_tank	public_standpost	**2**	2.031	2	1.626	2
319	drilled_well	direct_action_pump	boiling	plastic_tank	domestic_connection	**3**	2.791	3	1.838	2
326	drilled_well	direct_action_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**2**	2.452	2	2.22	2
347	drilled_well	deep_well_diaphragm_pump	boiling	plastic_tank	public_standpost	**2**	2.337	2	2.597	3
355	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	2.66	3	2.979	3
357	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	plastic_tank	public_standpost	**3**	2.749	3	2.974	3
363	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	steel_tank	domestic_connection	**3**	2.989	3	3.182	3
376	drilled_well	deep_well_piston_pump	boiling	plastic_tank	public_standpost	**2**	2.431	2	2.416	2
397	drilled_well	deep_well_piston_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	2.999	3	2.999	3
419	drilled_well	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	**3**	2.978	3	2.951	3
433	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	2.21	2	2.991	3
452	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	plastic_tank	public_standpost	**3**	2.99	3	3.191	3
476	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	public_standpost	**3**	2.974	3	2.23	2
493	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	**3**	3.043	3	2.832	3
505	protected_side_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	public_standpost	**3**	2.998	3	2.798	3
527	river_bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	**3**	3.045	3	2.641	3
553	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	**3**	3.037	3	3.006	3
559	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	public_standpost	**3**	2.996	3	2.987	3
570	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	**3**	3.004	3	3.598	4
573	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	**3**	3.174	3	3.622	4
576	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	**3**	2.996	3	3.401	3
592	floating_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	3.124	3	3.382	3
601	floating_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	domestic_connection	**3**	3.364	3	4	4
604	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	3.04	3	3.381	3
667	sump_intake	submersible_pump	boiling	ferrocement_tank	public_standpost	**3**	3.079	3	3.213	3
672	sump_intake	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	**4**	3.87	4	3.811	4

Set3						TRL	Kstar inst#,	actual,	predicted,		SMOreg inst#,	actual,	predi
8	rooftop_rainwater_harvesting	bucket	boiling	plastic_tank	domestic_connection	**2**	1	?	2.339	2	1	?	1.914
9	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**2**	2	?	2.081	2	2	?	1.614
33	catchment_and_storage_dam	hydraulic_ram_pump	boiling	plastic_tank	domestic_connection	**3**	3	?	3.113	3	3	?	2.439
38	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	**3**	4	?	3.642	4	4	?	3.063
40	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	5	?	2.999	3	5	?	2.624
57	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	elevated_steel_reservoir	public_standpost	**3**	6	?	3.067	3	6	?	3.18
67	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	**3**	7	?	3.075	3	7	?	3.177
87	springwater_collection	hydraulic_ram_pump	boiling	elevated_steel_reservoir	public_standpost	**3**	8	?	2.991	3	8	?	2.061
101	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	public_standpost	**2**	9	?	2.255	2	9	?	1.582
104	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	**3**	10	?	3.027	3	10	?	2.331
107	springwater_collection	hydraulic_ram_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	**3**	11	?	2.999	3	11	?	2.439
112	springwater_collection	hydraulic_ram_pump	domestic_chlorination	plastic_tank	domestic_connection	**3**	12	?	3.025	3	12	?	2.262
145	dug_well	rope_and_bucket	boiling	reinforced_concrete_reservoir	public_standpost	**2**	13	?	1.834	2	13	?	0.925
157	dug_well	rope_and_bucket	household_slow_sand_filter	steel_tank	public_standpost	**1**	14	?	1.006	1	14	?	1.005
211	dug_well	submersible_pump	boiling	ferrocement_tank	public_standpost	**2**	15	?	2.465	2	15	?	0.841
225	dug_well	submersible_pump	household_slow_sand_filter	plastic_tank	public_standpost	**1**	16	?	1.22	1	16	?	0.802
246	drilled_well	bucket_pump	boiling	ferrocement_tank	domestic_connection	**2**	17	?	2.182	2	17	?	2.112
272	drilled_well	rope_pump	boiling	reinforced_concrete_reservoir	domestic_connection	**2**	18	?	2.217	2	18	?	3.3
273	drilled_well	rope_pump	boiling	steel_tank	public_standpost	**2**	19	?	2.409	2	19	?	2.934
295	drilled_well	rope_pump	domestic_chlorination	ferrocement_tank	public_standpost	**3**	20	?	2.712	3	20	?	3.414
310	drilled_well	suction_plunger_handpump	boiling	concrete_lined_earthen_reservoir	domestic_connection	**3**	21	?	2.596	3	21	?	2.992
331	drilled_well	direct_action_pump	boiling	reinforced_concrete_reservoir	public_standpost	**2**	22	?	2.431	2	22	?	1.921
387	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	23	?	2.91	3	23	?	2.996
401	drilled_well	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**2**	24	?	2.519	2	24	?	2.323
449	subsurface_harvesting	deep_well_piston_pump	boiling	ferrocement_tank	public_standpost	**3**	25	?	2.94	3	25	?	2.73
453	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**3**	26	?	2.824	3	26	?	2.693
478	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	**3**	27	?	3.041	3	27	?	3.555
511	protected_side_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	**3**	28	?	2.742	3	28	?	2.136
516	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	**3**	29	?	3.033	3	29	?	2.819
526	protected_side_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	**3**	30	?	3.373	3	30	?	3.004
532	protected_side_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	domestic_connection	**3**	31	?	3.015	3	31	?	3.002
550	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	**3**	32	?	3.011	3	32	?	3.557
563	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	**3**	33	?	2.951	3	33	?	2.884
570	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	34	?	2.999	3	34	?	2.997
572	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**3**	35	?	3.052	3	35	?	2.885
576	river_bottom_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	**3**	36	?	3.046	3	36	?	3.192
603	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	**3**	37	?	2.999	3	37	?	3.818
606	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	**4**	38	?	3.157	4	38	?	3.821
645	floating_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	**3**	39	?	3.44	3	39	?	3.564
658	floating_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	domestic_connection	**4**	40	?	3.86	4	40	?	4.485
673	sump_intake	deep_well_piston_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	**3**	41	?	3	3	41	?	2.997
676	sump_intake	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	domestic_connection	**3**	42	?	2.956	3	42	?	3
686	sump_intake	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	**3**	43	?	3.012	3	43	?	3.072
687	sump_intake	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	44	?	2.116	2	44	?	2.706
690	sump_intake	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	45	?	2.855	3	45	?	3.182
700	sump_intake	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	46	?	3.1	3	46	?	3.488
714	sump_intake	submersible_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	**3**	47	?	3.149	3	47	?	3.332

							Kstar				SMOreg		
Set4						TRL	inst#,	actual, predicted,			inst#,	actual, predic	
4	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	domestic_connection	2	1	?	2.018	2	1	?	1.925
22	rooftop_rainwater_harvesting	bucket	domestic_chlorination	ferrocement_tank	domestic_connection	2	2	?	2.117	2	2	?	2.404
25	catchment_and_storage_dam	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	3	?	2.969		3	?	2.067
28	catchment_and_storage_dam	hydraulic_ram_pump	boiling	elevated_steel_reservoir	domestic_connection	3	4	?	3.624		4	?	2.991
35	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3	5	?	2.905		5	?	2.139
44	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	3	6	?	3.15	3	6	?	2.886
46	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	7	?	3.026	3	7	?	2.819
51	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	plastic_tank	public_standpost	3	8	?	2.984		8	?	2.442
93	springwater_collection	hydraulic_ram_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	3	9	?	2.946		9	?	1.884
96	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3	10	?	2.994		10	?	1.959
113	springwater_collection	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	11	?	2.991		11	?	2.262
122	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3	12	?	3.014		12	?	2.447
124	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	3	13	?	3.061	3	13	?	2.822
125	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3	14	?	2.967		14	?	2.072
131	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	public_standpost	3	15	?	2.886		15	?	2.07
137	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	public_standpost	3	16	?	3.235	3	16	?	3.067
141	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3	17	?	2.957	3	17	?	2.516
219	dug_well	submersible_pump	household_slow_sand_filter	steel_tank	public_standpost	1	18	?	1.114	1	18	?	0.812
234	dug_well	submersible_pump	domestic_chlorination	elevated_steel_reservoir	domestic_connection	2	19	?	3.193		19	?	2.033
245	drilled_well	bucket_pump	boiling	ferrocement_tank	public_standpost	2	20	?	2.204	2	20	?	1.738
246	drilled_well	bucket_pump	boiling	ferrocement_tank	domestic_connection	2	21	?	2.182	2	21	?	2.112
251	drilled_well	bucket_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2	22	?	2.182	2	22	?	1.7
265	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	public_standpost	2	23	?	2.187	2	23	?	2.116
284	drilled_well	rope_pump	household_slow_sand_filter	steel_tank	domestic_connection	2	24	?	2.423		24	?	3.381
301	drilled_well	suction_plunger_handpump	boiling	reinforced_concrete_reservoir	public_standpost	2	25	?	2.224	2	25	?	2.245
306	drilled_well	suction_plunger_handpump	boiling	ferrocement_tank	domestic_connection	2	26	?	2.49		26	?	2.73
307	drilled_well	suction_plunger_handpump	boiling	plastic_tank	public_standpost	2	27	?	2.022	2	27	?	2.243
351	drilled_well	direct_action_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2	28	?	2.517		28	?	2.299
358	drilled_well	direct_action_pump	domestic_chlorination	plastic_tank	domestic_connection	3	29	?	2.981	3	29	?	2.671
359	drilled_well	direct_action_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	2	30	?	2.443		30	?	2.67
382	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	31	?	2.958	3	31	?	3.373
383	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	steel_tank	public_standpost	3	32	?	2.881	3	32	?	3.006
384	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	steel_tank	domestic_connection	3	33	?	2.94	3	33	?	3.381
416	drilled_well	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3	34	?	2.984	3	34	?	3.113
425	drilled_well	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3	35	?	2.773	3	35	?	2.691
427	drilled_well	centrifugal_pump	boiling	plastic_tank	public_standpost	3	36	?	2.683	3	36	?	2.578
488	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3	37	?	2.992		37	?	4.009
534	protected_side_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	domestic_connection	3	38	?	3.06	3	38	?	3.373
548	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	4	39	?	3.147		39	?	3.996
555	river_bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	40	?	2.999		40	?	2.44
591	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	public_standpost	3	41	?	2.995	3	41	?	3.001
602	river_bottom_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	3	42	?	3.4	3	42	?	3.373
615	floating_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	43	?	3.007	3	43	?	3
623	floating_intake	centrifugal_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	3	44	?	3.106	3	44	?	3.445
659	floating_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3	45	?	3.213		45	?	3.671
672	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	4	46	?	3.448		46	?	4.379
706	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3	47	?	3.064	3	47	?	2.888

							Kstar				SMOreg		
Set5						**TRL**	inst#,	actual, predicted,			inst#,	actual, predi	
48	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	elevated_steel_reservoir	domestic_connection	**3**	1	?	3.295	3	1	?	3.369
49	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	public_standpost	**3**	2	?	2.999	3	2	?	2.555
88	springwater_collection	hydraulic_ram_pump	boiling	elevated_steel_reservoir	domestic_connection	**3**	3	?	3.049		3	?	2.436
113	springwater_collection	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	4	?	2.991		4	?	2.262
144	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	domestic_connection	**3**	5	?	3.062	3	5	?	3.264
200	dug_well	rope_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**2**	6	?	2.138	2	6	?	2.381
202	dug_well	rope_pump	domestic_chlorination	plastic_tank	domestic_connection	**2**	7	?	2.718		7	?	2.269
213	dug_well	submersible_pump	boiling	plastic_tank	public_standpost	**2**	8	?	2.295		8	?	0.729
219	dug_well	submersible_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	9	?	1.114	1	9	?	0.812
233	dug_well	submersible_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	**2**	10	?	2.969		10	?	1.659
255	drilled_well	bucket_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**2**	11	?	2.312	2	11	?	1.81
280	drilled_well	rope_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	**3**	12	?	2.517		12	?	3.672
291	drilled_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	**3**	13	?	2.578		13	?	3.304
293	drilled_well	rope_pump	domestic_chlorination	steel_tank	public_standpost	**3**	14	?	2.532		14	?	3.312
341	drilled_well	direct_action_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**2**	15	?	2.103	2	15	?	1.993
348	drilled_well	direct_action_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**2**	16	?	2.577		16	?	2.365
360	drilled_well	direct_action_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	**3**	17	?	3.134	3	17	?	3.045
363	drilled_well	deep_well_diaphragm_pump	boiling	steel_tank	public_standpost	**2**	18	?	2.46		18	?	2.628
381	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	**3**	19	?	2.95	3	19	?	2.998
460	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**3**	20	?	2.961	3	20	?	3.065
487	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	**3**	21	?	2.857		21	?	3.635
489	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	**3**	22	?	2.976		22	?	3.736
500	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	**3**	23	?	2.952	3	23	?	2.551
508	protected_side_intake	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	**3**	24	?	3.401	3	24	?	3.063
509	protected_side_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	25	?	2.914		25	?	2.249
511	protected_side_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	**3**	26	?	2.742		26	?	2.136
530	protected_side_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	**3**	27	?	3.034	3	27	?	3.114
537	protected_side_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	**3**	28	?	3.009	3	28	?	3.176
544	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	domestic_connection	**3**	29	?	3.068		29	?	3.819
552	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	**3**	30	?	3.066	3	30	?	3.445
570	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	31	?	2.999	3	31	?	2.997
586	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	**3**	32	?	3.577		32	?	3.378
596	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	**3**	33	?	3.087	3	33	?	3.375
598	river_bottom_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	domestic_connection	**3**	34	?	3.289		34	?	3.924
602	river_bottom_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	**3**	35	?	3.4		35	?	3.373
605	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	**3**	36	?	2.999		36	?	3.446
612	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	**3**	37	?	3.066		37	?	3.818
622	floating_intake	centrifugal_pump	boiling	plastic_tank	domestic_connection	**3**	38	?	3.238		38	?	3.373
641	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	39	?	3.031	3	39	?	3.376
662	floating_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	**4**	40	?	3.898		40	?	3.933
666	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	**4**	41	?	3.732		41	?	4.381
687	sump_intake	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	42	?	2.116		42	?	2.706
701	sump_intake	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	43	?	2.986	3	43	?	3.001
705	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	public_standpost	**3**	44	?	2.986	3	44	?	2.513
713	sump_intake	submersible_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	**3**	45	?	3.104	3	45	?	2.958

							Kstar				SMOreg		
Set6						**TRL**	inst#,	actual,	predicted		inst#,	actual,	pred
3	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	public_standpost	**2**	1	?	2.114	2	1	?	1.55
14	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	domestic_connection	**2**	2	?	2.007	2	2	?	2.099
51	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	3	?	2.984	3	3	?	2.442
53	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	4	?	3.006	3	4	?	2.817
56	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	**3**	5	?	3.013	3	5	?	3.005
65	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	**3**	6	?	2.999	3	6	?	2.628
68	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	elevated_steel_reservoir	domestic_connection	**3**	7	?	3.394	3	7	?	3.551
69	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	public_standpost	**3**	8	?	3.008	3	8	?	2.738
74	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	domestic_connection	**3**	9	?	3.069	3	9	?	3.374
112	springwater_collection	hydraulic_ram_pump	domestic_chlorination	plastic_tank	domestic_connection	**3**	10	?	3.025	3	10	?	2.262
113	springwater_collection	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	11	?	2.991	3	11	?	2.262
132	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	domestic_connection	**3**	12	?	3.187	3	12	?	2.445
141	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	**3**	13	?	2.957	3	13	?	2.516
150	dug_well	rope_and_bucket	boiling	ferrocement_tank	domestic_connection	**2**	14	?	2.093	2	14	?	1.409
158	dug_well	rope_and_bucket	household_slow_sand_filter	steel_tank	domestic_connection	**1**	15	?	1.083	1	15	?	1.38
161	dug_well	rope_and_bucket	household_slow_sand_filter	plastic_tank	public_standpost	**1**	16	?	1.013	1	16	?	0.995
163	dug_well	rope_and_bucket	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	**1**	17	?	1.035	1	17	?	1.369
222	dug_well	submersible_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	**3**	18	?	3.147	3	18	?	1.728
229	dug_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	**3**	19	?	2.684	3	19	?	1.109
266	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	20	?	2.87	3	20	?	2.49
279	drilled_well	rope_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	**3**	21	?	2.701	3	21	?	3.298
284	drilled_well	rope_pump	household_slow_sand_filter	steel_tank	domestic_connection	**3**	22	?	2.423	3	22	?	3.381
292	drilled_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	**3**	23	?	2.923	3	23	?	3.678
307	drilled_well	suction_plunger_handpump	boiling	plastic_tank	public_standpost	**2**	24	?	2.022	2	24	?	2.243
308	drilled_well	suction_plunger_handpump	boiling	plastic_tank	domestic_connection	**2**	25	?	2.207	2	25	?	2.618
310	drilled_well	suction_plunger_handpump	boiling	concrete_lined_earthen_reservoir	domestic_connection	**2**	26	?	2.596	2	26	?	2.992
378	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**3**	27	?	2.874	3	27	?	3.065
382	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	**3**	28	?	2.958	3	28	?	3.373
391	drilled_well	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	public_standpost	**2**	29	?	2.616	2	29	?	2.251
397	drilled_well	deep_well_piston_pump	boiling	plastic_tank	public_standpost	**2**	30	?	2.42	2	30	?	2.248
401	drilled_well	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**2**	31	?	2.519	2	31	?	2.323
434	drilled_well	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	32	?	2.978	3	32	?	3.138
458	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	33	?	2.676	3	33	?	3.177
460	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**3**	34	?	2.961	3	34	?	3.065
470	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	**3**	35	?	3.299	3	35	?	3.558
475	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	plastic_tank	public_standpost	**3**	36	?	2.988	3	36	?	3.181
497	protected_side_intake	centrifugal_pump	boiling	elevated_steel_reservoir	public_standpost	**3**	37	?	2.996	3	37	?	2.615
507	protected_side_intake	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	**3**	38	?	3.108	3	38	?	2.688
521	protected_side_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	39	?	2.976	3	39	?	2.442
566	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	**3**	40	?	3.088	3	40	?	2.887
640	floating_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	**3**	41	?	3.097	3	41	?	3.863
657	floating_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	**3**	42	?	3.324	3	42	?	4.11
665	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	**3**	43	?	3.071	3	43	?	4.007
679	sump_intake	deep_well_piston_pump	boiling	ferrocement_tank	public_standpost	**3**	44	?	2.986	3	44	?	2.735
711	sump_intake	submersible_pump	boiling	plastic_tank	public_standpost	**3**	45	?	2.899	3	45	?	2.511

							Kstar				SMOreg		
Set7						TRL	inst#,	actual,	predicted,	e	inst#,	actual,	predicted, e
10	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2	1	?	2.024	2	1	?	1.989
15	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	plastic_tank	public_standpost	2	2	?	2.052	2	2	?	1.612
30	catchment_and_storage_dam	hydraulic_ram_pump	boiling	ferrocement_tank	domestic_connection	3	3	?	2.998	3	3	?	2.551
52	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3	4	?	3.007	3	4	?	2.929
55	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3	5	?	3.004	3	5	?	2.63
61	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	plastic_tank	public_standpost	3	6	?	2.968	3	6	?	2.628
66	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3	7	?	3.007	3	7	?	3.002
79	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3	8	?	3.222	3	8	?	3.183
80	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3	9	?	3.277	3	9	?	3.558
94	springwater_collection	hydraulic_ram_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3	10	?	3.019	3	10	?	2.258
114	springwater_collection	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	11	?	3.179	3	11	?	2.636
127	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	3	12	?	3.019	3	12	?	2.622
152	dug_well	rope_and_bucket	boiling	plastic_tank	domestic_connection	1	13	?	2.004	1	13	?	1.297
154	dug_well	rope_and_bucket	boiling	concrete_lined_earthen_reservoir	domestic_connection	2	14	?	2.474	2	14	?	1.671
158	dug_well	rope_and_bucket	household_slow_sand_filter	steel_tank	domestic_connection	1	15	?	1.083	1	15	?	1.38
169	dug_well	rope_and_bucket	domestic_chlorination	ferrocement_tank	public_standpost	1	16	?	1.373	1	16	?	1.413
214	dug_well	submersible_pump	boiling	plastic_tank	domestic_connection	2	17	?	2.758	2	17	?	1.104
226	dug_well	submersible_pump	household_slow_sand_filter	plastic_tank	domestic_connection	2	18	?	2.433	2	18	?	1.176
246	drilled_well	bucket_pump	boiling	ferrocement_tank	domestic_connection	2	19	?	2.182	2	19	?	2.112
251	drilled_well	bucket_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2	20	?	2.182	2	20	?	1.7
282	drilled_well	rope_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3	21	?	2.779	3	21	?	3.373
286	drilled_well	rope_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3	22	?	2.587	3	22	?	3.483
293	drilled_well	rope_pump	domestic_chlorination	steel_tank	public_standpost	3	23	?	2.532	3	23	?	3.312
309	drilled_well	suction_plunger_hand	boiling	concrete_lined_earthen_reservoir	public_standpost	2	24	?	2.119	2	24	?	2.617
313	drilled_well	suction_plunger_hand	household_slow_sand_filter	steel_tank	public_standpost	2	25	?	2.002	2	25	?	2.326
335	drilled_well	direct_action_pump	boiling	ferrocement_tank	public_standpost	2	26	?	2.219	2	26	?	2.031
342	drilled_well	direct_action_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2	27	?	2.503	2	27	?	2.368
379	drilled_well	deep_well_diaphragm	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	3	28	?	2.671	3	28	?	3.065
388	drilled_well	deep_well_diaphragm	domestic_chlorination	plastic_tank	domestic_connection	3	29	?	2.992	3	29	?	3.37
409	drilled_well	deep_well_piston_pu	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	3	30	?	2.647	3	30	?	2.695
414	drilled_well	deep_well_piston_pu	domestic_chlorination	steel_tank	domestic_connection	3	31	?	2.977	3	31	?	3.012
421	drilled_well	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	32	?	2.888	3	32	?	2.581
431	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	3	33	?	2.901	3	33	?	3.203
448	subsurface_harvesting	deep_well_piston_pu	boiling	steel_tank	domestic_connection	3	34	?	2.872	3	34	?	3.003
450	subsurface_harvesting	deep_well_piston_pu	boiling	ferrocement_tank	domestic_connection	3	35	?	2.745	3	35	?	3.105
454	subsurface_harvesting	deep_well_piston_pu	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3	36	?	2.925	3	36	?	3.067
457	subsurface_harvesting	deep_well_piston_pu	household_slow_sand_filter	ferrocement_tank	public_standpost	3	37	?	2.804	3	37	?	2.803
497	protected_side_intake	centrifugal_pump	boiling	elevated_steel_reservoir	public_standpost	3	38	?	2.996	3	38	?	2.615
498	protected_side_intake	centrifugal_pump	boiling	elevated_steel_reservoir	domestic_connection	3	39	?	3.059	3	39	?	2.99
511	protected_side_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	40	?	2.742	3	40	?	2.136
513	protected_side_intake	centrifugal_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	41	?	3	3	41	?	2.816
576	river_bottom_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	42	?	3.046	3	42	?	3.192
577	river_bottom_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3	43	?	3	3	43	?	3.367
628	floating_intake	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	4	44	?	3.962	4	44	?	3.997
635	floating_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3	45	?	3.014	3	45	?	3.378
640	floating_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3	46	?	3.097	3	46	?	3.863
695	sump_intake	deep_well_piston_pu	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3	47	?	2.862	3	47	?	3.003
714	sump_intake	submersible_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	3	48	?	3.149	3	48	?	3.332

							Kstar				SMOreg		
Set8						TRL	inst#,	actual, predicted, e			inst#,	actual, predic	
32	catchment_and_storage_dam	hydraulic_ram_pump	boiling	plastic_tank	domestic_connection	3	1	?	3.113	3	1	?	2.439
42	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	2	?	3.121	3	2	?	2.512
59	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3	3	?	3.003	3	3	?	2.74
78	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	4	4	?	3.96	4	4	?	3.997
83	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	3	5	?	3.431	3	5	?	3.445
141	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3	6	?	2.957	3	6	?	2.516
145	dug_well	rope_and_bucket	boiling	reinforced_concrete_reservoir	public_standpost	1	7	?	1.834	1	7	?	0.925
163	dug_well	rope_and_bucket	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	1	8	?	1.035	1	8	?	1.369
165	dug_well	rope_and_bucket	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	1	9	?	1.718	1	9	?	1.303
224	dug_well	submersible_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	2	10	?	2.613	2	10	?	1.289
225	dug_well	submersible_pump	household_slow_sand_filter	plastic_tank	public_standpost	1	11	?	1.22	1	11	?	0.802
259	drilled_well	bucket_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	2	12	?	2.361	2	12	?	2.072
269	drilled_well	bucket_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	2	13	?	2.201	2	13	?	2.378
276	drilled_well	rope_pump	boiling	ferrocement_tank	domestic_connection	2	14	?	2.12	2	14	?	3.41
279	drilled_well	rope_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	3	15	?	2.701	3	15	?	3.298
288	drilled_well	rope_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	16	?	2.969	3	16	?	3.371
304	drilled_well	suction_plunger_handpump	boiling	steel_tank	domestic_connection	2	17	?	2.426	2	17	?	2.628
322	drilled_well	suction_plunger_handpump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	18	?	2.988	3	18	?	2.998
338	drilled_well	direct_action_pump	boiling	plastic_tank	domestic_connection	2	19	?	2.594	2	19	?	2.293
339	drilled_well	direct_action_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	2	20	?	2.4	2	20	?	2.292
358	drilled_well	direct_action_pump	domestic_chlorination	plastic_tank	domestic_connection	3	21	?	2.981	3	21	?	2.671
368	drilled_well	deep_well_diaphragm_pump	boiling	plastic_tank	domestic_connection	3	22	?	2.625	3	22	?	2.992
370	drilled_well	deep_well_diaphragm_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3	23	?	2.715	3	23	?	3.367
371	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3	24	?	2.89	3	24	?	2.693
401	drilled_well	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2	25	?	2.519	2	25	?	2.323
432	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	3	26	?	3.735	3	26	?	3.577
441	drilled_well	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3	27	?	2.762	3	27	?	3.069
448	subsurface_harvesting	deep_well_piston_pump	boiling	steel_tank	domestic_connection	3	28	?	2.872	3	28	?	3.003
492	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3	29	?	3.034	3	29	?	3.999
500	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3	30	?	2.952	3	30	?	2.551
504	protected_side_intake	centrifugal_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	3	31	?	3.101	3	31	?	2.885
514	protected_side_intake	centrifugal_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	32	?	3.043	3	32	?	3.191
521	protected_side_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3	33	?	2.976	3	33	?	2.442
529	protected_side_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3	34	?	3.003	3	34	?	2.74
544	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	domestic_connection	4	35	?	3.068	4	35	?	3.819
563	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	3	36	?	2.951	3	36	?	2.884
573	river_bottom_intake	centrifugal_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	37	?	2.999	3	37	?	3.19
593	river_bottom_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	3	38	?	3.003	3	38	?	3.372
596	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3	39	?	3.087	3	39	?	3.375
602	river_bottom_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	3	40	?	3.4	3	40	?	3.373
606	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	4	41	?	3.157	4	41	?	3.821
658	floating_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	domestic_connection	4	42	?	3.86	4	42	?	4.485
705	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	43	?	2.986	3	43	?	2.513

							Kstar				SMOreg		
Set9						TRL	inst#,	actual,	predicted,		inst#,	actual,	pred
7	rooftop_rainwater_harvesting	bucket	boiling	plastic_tank	public_standpost	2	1	?	2.614	2	1	?	1.539
21	rooftop_rainwater_harvesting	bucket	domestic_chlorination	ferrocement_tank	public_standpost	2	2	?	2.219	2	2	?	2.03
22	rooftop_rainwater_harvesting	bucket	domestic_chlorination	ferrocement_tank	domestic_connection	2	3	?	2.117	2	3	?	2.404
53	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	4	?	3.006	3	4	?	2.817
55	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3	5	?	3.004	3	5	?	2.63
64	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	3	6	?	3.074	3	6	?	3.377
69	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3	7	?	3.008	3	7	?	2.738
89	springwater_collection	hydraulic_ram_pump	boiling	ferrocement_tank	public_standpost	3	8	?	2.918	3	8	?	1.622
112	springwater_collection	hydraulic_ram_pump	domestic_chlorination	plastic_tank	domestic_connection	3	9	?	3.025	3	9	?	2.262
113	springwater_collection	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	10	?	2.991	3	10	?	2.262
114	springwater_collection	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	11	?	3.179	3	11	?	2.636
138	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	3	12	?	3.299	3	12	?	3.442
141	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3	13	?	2.957	3	13	?	2.516
154	dug_well	rope_and_bucket	boiling	concrete_lined_earthen_reservoir	domestic_connection	2	14	?	2.474	2	14	?	1.671
156	dug_well	rope_and_bucket	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	1	15	?	1.454	1	15	?	1.372
174	dug_well	rope_and_bucket	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	2	16	?	3.086	2	16	?	2.049
214	dug_well	submersible_pump	boiling	plastic_tank	domestic_connection	3	17	?	2.758	3	17	?	1.104
246	drilled_well	bucket_pump	boiling	ferrocement_tank	domestic_connection	2	18	?	2.182	2	18	?	2.112
252	drilled_well	bucket_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2	19	?	2.51	2	19	?	2.075
265	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	public_standpost	2	20	?	2.187	2	20	?	2.116
268	drilled_well	bucket_pump	domestic_chlorination	plastic_tank	domestic_connection	2	21	?	2.916	2	21	?	2.378
270	drilled_well	bucket_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	22	?	2.921	3	22	?	2.752
370	drilled_well	deep_well_diaphragm_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3	23	?	2.715	3	23	?	3.367
381	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3	24	?	2.95	3	24	?	2.998
401	drilled_well	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2	25	?	2.519	2	25	?	2.323
408	drilled_well	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	26	?	2.97	3	26	?	2.696
426	drilled_well	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3	27	?	2.75	3	27	?	3.065
431	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	3	28	?	2.901	3	28	?	3.203
435	drilled_well	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	29	?	2.763	3	29	?	2.651
437	drilled_well	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3	30	?	2.611	3	30	?	2.959
444	drilled_well	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3	31	?	3.022	3	31	?	3.331
447	subsurface_harvesting	deep_well_piston_pump	boiling	steel_tank	public_standpost	3	32	?	2.884	3	32	?	2.628
459	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	33	?	2.907	3	33	?	2.69
463	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	steel_tank	public_standpost	3	34	?	2.98	3	34	?	3.006
484	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	plastic_tank	domestic_connection	3	35	?	3.174	3	35	?	3.553
521	protected_side_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3	36	?	2.976	3	36	?	2.442
527	protected_side_intake	centrifugal_pump	storage_and_sedimentation	elevated_steel_reservoir	public_standpost	3	37	?	3.01	3	37	?	3.179
537	protected_side_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	3	38	?	3.009	3	38	?	3.176
577	river_bottom_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3	39	?	3	3	39	?	3.367
593	river_bottom_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	3	40	?	3.003	3	40	?	3.372
629	floating_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3	41	?	3.119	3	41	?	3.183
656	floating_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	4	42	?	3.781	4	42	?	3.936
668	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	4	43	?	3.792	4	43	?	4.931
677	sump_intake	deep_well_piston_pump	boiling	steel_tank	public_standpost	3	44	?	2.97	3	44	?	2.633
690	sump_intake	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3	45	?	2.855	3	45	?	3.182
693	sump_intake	deep_well_piston_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	46	?	3.058	3	46	?	3.375

							Kstar				SMOreg		
Set10						**TRL**	inst#,	actual,	predicted,		inst#,	actual,	predic
21	rooftop_rainwater_harvesting	bucket	domestic_chlorination	ferrocement_tank	public_standpost	**2**	1	?	2.219	2	1	?	2.03
25	catchment_and_storage_dam	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	public_standpost	**3**	2	?	2.969	3	2	?	2.067
39	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	3	?	2.901	3	3	?	2.249
43	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	**3**	4	?	2.863	3	4	?	2.511
57	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	elevated_steel_reservoir	public_standpost	**3**	5	?	3.067	3	5	?	3.18
64	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	**3**	6	?	3.074	3	6	?	3.377
99	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**3**	7	?	2.797	3	7	?	1.694
131	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	public_standpost	**3**	8	?	2.886	3	8	?	2.07
132	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	domestic_connection	**3**	9	?	3.187	3	9	?	2.445
133	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	**3**	10	?	2.991	3	10	?	2.444
171	dug_well	rope_and_bucket	domestic_chlorination	plastic_tank	public_standpost	**1**	11	?	1.177	1	11	?	1.3
239	dug_well	submersible_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**2**	12	?	3.199	2	12	?	1.481
253	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	13	?	2.002	2	13	?	1.709
272	drilled_well	rope_pump	boiling	reinforced_concrete_reservoir	domestic_connection	**2**	14	?	2.217	2	14	?	3.3
277	drilled_well	rope_pump	boiling	plastic_tank	public_standpost	**3**	15	?	2.615	3	15	?	2.923
316	drilled_well	suction_plunger_handpump	household_slow_sand_filter	ferrocement_tank	domestic_connection	**3**	16	?	2.712	3	16	?	2.803
333	drilled_well	direct_action_pump	boiling	steel_tank	public_standpost	**2**	17	?	2.023	2	17	?	1.929
355	drilled_well	direct_action_pump	domestic_chlorination	ferrocement_tank	public_standpost	**2**	18	?	2.401	2	18	?	2.409
367	drilled_well	deep_well_diaphragm_pump	boiling	plastic_tank	public_standpost	**2**	19	?	2.324	2	19	?	2.618
373	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	steel_tank	public_standpost	**2**	20	?	2.085	2	20	?	2.701
405	drilled_well	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	**2**	21	?	2.479	2	21	?	2.433
423	drilled_well	centrifugal_pump	boiling	elevated_steel_reservoir	public_standpost	**3**	22	?	2.805	3	22	?	3.13
460	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	**3**	23	?	2.961	3	23	?	3.065
469	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	**3**	24	?	2.989	3	24	?	3.184
472	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	steel_tank	domestic_connection	**3**	25	?	3.034	3	25	?	3.566
473	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	**3**	26	?	2.979	3	26	?	3.294
488	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	**3**	27	?	2.992	3	27	?	4.009
491	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	**3**	28	?	2.988	3	28	?	3.624
505	protected_side_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	**3**	29	?	2.938	3	29	?	2.139
506	protected_side_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	**3**	30	?	3.212	3	30	?	2.513
517	protected_side_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	**3**	31	?	3	3	31	?	2.993
524	protected_side_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	**3**	32	?	3.068	3	32	?	3.376
546	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	**3**	33	?	3.186	3	33	?	3.447
558	river_bottom_intake	centrifugal_pump	boiling	elevated_steel_reservoir	domestic_connection	**3**	34	?	3.123	3	34	?	3.364
577	river_bottom_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	**3**	35	?	3	3	35	?	3.367
581	river_bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	36	?	2.991	3	36	?	2.815
582	river_bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	**3**	37	?	3.008	3	37	?	3.19
596	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	**3**	38	?	3.087	3	38	?	3.375
611	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	**3**	39	?	2.989	3	39	?	3.444
633	floating_intake	centrifugal_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	**3**	40	?	3.034	3	40	?	3.75
641	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	**3**	41	?	3.031	3	41	?	3.376
660	floating_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	**4**	42	?	3.723	4	42	?	4.046
665	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	**3**	43	?	3.071	3	43	?	4.007
674	sump_intake	deep_well_piston_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	**3**	44	?	3.058	3	44	?	3.372
677	sump_intake	deep_well_piston_pump	boiling	steel_tank	public_standpost	**3**	45	?	2.97	3	45	?	2.633
694	sump_intake	deep_well_piston_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	**3**	46	?	3.637	3	46	?	3.75
709	sump_intake	submersible_pump	boiling	ferrocement_tank	public_standpost	**3**	47	?	2.998	3	47	?	2.623

							Kstar						SMOreg
Set11						TRL	inst#,	actual, predicted, e			inst#,	actual, predic	
22	rooftop_rainwater_harvesting	bucket	domestic_chlorination	plastic_tank	domestic_connection	2	1	?	2.557	2	1	?	2.292
112	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	plastic_tank	public_standpost	3	2	?	2.914	3	2	?	2.073
126	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3	3	?	3.002	3	3	?	2.518
128	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	public_standpost	3	4	?	3.235	3	4	?	3.067
129	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	3	5	?	3.299	3	5	?	3.442
156	dug_well	rope_and_bucket	domestic_chlorination	steel_tank	domestic_connection	2	6	?	1.607	2	6	?	1.685
162	dug_well	rope_and_bucket	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	2	7	?	3.086	2	7	?	2.049
167	dug_well	rope_pump	boiling	ferrocement_tank	public_standpost	2	8	?	2.026	2	8	?	1.628
203	dug_well	submersible_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	2	9	?	3.123	2	9	?	1.478
207	dug_well	submersible_pump	household_slow_sand_filter	steel_tank	domestic_connection	2	10	?	2.038	2	10	?	1.187
213	dug_well	submersible_pump	household_slow_sand_filter	plastic_tank	domestic_connection	2	11	?	2.433	2	11	?	1.176
217	dug_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	2	12	?	3.154	2	12	?	1.484
219	dug_well	submersible_pump	domestic_chlorination	steel_tank	domestic_connection	2	13	?	3.143	2	13	?	1.492
233	drilled_well	bucket_pump	boiling	plastic_tank	public_standpost	2	14	?	2.215	2	14	?	1.625
251	drilled_well	bucket_pump	domestic_chlorination	plastic_tank	public_standpost	2	15	?	2.286	2	15	?	2.003
301	drilled_well	suction_plunger_handpump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	2	16	?	2.36	2	16	?	2.69
318	drilled_well	direct_action_pump	boiling	plastic_tank	public_standpost	2	17	?	2.219	2	17	?	1.918
348	drilled_well	deep_well_diaphragm_pump	boiling	plastic_tank	domestic_connection	3	18	?	2.625	3	18	?	2.992
355	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3	19	?	2.634	3	19	?	2.803
361	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	20	?	2.958	3	20	?	3.373
396	drilled_well	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3	21	?	2.926	3	21	?	2.626
423	subsurface_harvesting	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	22	?	2.949	3	22	?	2.62
427	subsurface_harvesting	deep_well_piston_pump	boiling	ferrocement_tank	public_standpost	3	23	?	2.94	3	23	?	2.73
428	subsurface_harvesting	deep_well_piston_pump	boiling	ferrocement_tank	domestic_connection	3	24	?	2.745	3	24	?	3.105
430	subsurface_harvesting	deep_well_piston_pump	boiling	plastic_tank	domestic_connection	3	25	?	2.989	3	25	?	2.992
453	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3	26	?	3.036	3	26	?	3.556
465	subsurface_harvesting	deep_well_piston_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3	27	?	2.992	3	27	?	4.009
507	protected_side_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3	28	?	3.002	3	28	?	2.627
527	river_bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3	29	?	3.001	3	29	?	2.814
548	river_bottom_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3	30	?	2.984	3	30	?	2.928
566	river_bottom_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3	31	?	3.003	3	31	?	3.11
575	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	domestic_connection	4	32	?	3.39	4	32	?	4.37
576	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3	33	?	2.993	3	33	?	3.556
594	floating_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	34	?	2.992	3	34	?	3.071
601	floating_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	domestic_connection	4	35	?	3.358	4	35	?	4.302
609	floating_intake	centrifugal_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	4	36	?	3.8	4	36	?	4.488
626	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	4	37	?	3.732	4	37	?	4.381
637	sump_intake	deep_well_piston_pump	boiling	steel_tank	domestic_connection	3	38	?	2.992	3	38	?	3.008
649	sump_intake	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	39	?	2.652	3	39	?	2.695
652	sump_intake	deep_well_piston_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	4	40	?	3.637	4	40	?	3.75
659	sump_intake	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3	41	?	2.986	3	41	?	3.001
663	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	42	?	2.986	3	42	?	2.513
681	sump_intake	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	43	?	3.408	3	43	?	3.266
690	sump_intake	submersible_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	4	44	?	3.686	4	44	?	4.001
696	sump_intake	submersible_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	domestic_connection	4	45	?	3.618	4	45	?	3.82
699	sump_intake	submersible_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	3	46	?	3.013	3	46	?	3.623

							Kstar						SMOreg
Set12						TRL	inst#,	actual, predicted, er			inst#,	actual, predic	
50	catchment_and_storage_	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	1	?	3.112	3	1	?	3.191
92	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3	2	?	2.954	3	2	?	2.069
120	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3	3	?	2.979	3	3	?	2.182
161	dug_well	rope_and_bucket	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	1	4	?	1.437	1	4	?	1.674
181	dug_well	rope_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	2	5	?	2.466	2	5	?	2.337
185	dug_well	rope_pump	domestic_chlorination	steel_tank	domestic_connection	2	6	?	2.314	2	6	?	2.279
193	dug_well	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2	7	?	2.581	2	7	?	1.106
194	dug_well	submersible_pump	boiling	steel_tank	public_standpost	2	8	?	1.678	2	8	?	0.74
234	drilled_well	bucket_pump	boiling	plastic_tank	domestic_connection	2	9	?	2.23	2	9	?	2
236	drilled_well	bucket_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	2	10	?	2.201	2	10	?	2.374
240	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	domestic_connection	2	11	?	2.314	2	11	?	2.083
241	drilled_well	bucket_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2	12	?	2.312	2	12	?	1.81
247	drilled_well	bucket_pump	domestic_chlorination	steel_tank	public_standpost	2	13	?	2.158	2	13	?	2.014
258	drilled_well	rope_pump	boiling	steel_tank	domestic_connection	2	14	?	2.259	2	14	?	3.309
279	drilled_well	rope_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3	15	?	2.788	3	15	?	3.788
294	drilled_well	suction_plunger_handpump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3	16	?	2.928	3	16	?	2.693
310	drilled_well	suction_plunger_handpump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	17	?	2.596	3	17	?	2.995
333	drilled_well	direct_action_pump	domestic_chlorination	steel_tank	public_standpost	2	18	?	2.058	2	18	?	2.307
341	drilled_well	deep_well_diaphragm_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	19	?	2.874	3	19	?	2.62
365	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3	20	?	2.965	3	20	?	3.483
368	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	21	?	2.949	3	21	?	3.37
397	drilled_well	deep_well_piston_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	22	?	2.837	3	22	?	3.001
403	drilled_well	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3	23	?	2.773	3	23	?	2.691
421	drilled_well	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3	24	?	2.806	3	24	?	2.956
425	subsurface_harvesting	deep_well_piston_pump	boiling	steel_tank	public_standpost	3	25	?	2.884	3	25	?	2.628
447	subsurface_harvesting	deep_well_piston_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	3	26	?	3.299	3	26	?	3.558
471	protected_side_intake	centrifugal_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3	27	?	3.014	3	27	?	2.813
487	protected_side_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3	28	?	2.995	3	28	?	2.623
489	protected_side_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	29	?	3.078	3	29	?	2.511
522	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3	30	?	3.011	3	30	?	3.557
540	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	31	?	2.889	3	31	?	2.51
546	river_bottom_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3	32	?	3	3	32	?	3.367
563	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3	33	?	3.087	3	33	?	3.375
586	floating_intake	centrifugal_pump	boiling	plastic_tank	domestic_connection	3	34	?	3.238	3	34	?	3.373
595	floating_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	35	?	3.565	3	35	?	3.445
600	floating_intake	centrifugal_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3	36	?	3.144	3	36	?	3.928
607	floating_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3	37	?	3.44	3	37	?	3.564
619	floating_intake	centrifugal_pump	slow_sand_filtration	elevated_steel_reservoir	domestic_connection	4	38	?	3.86	4	38	?	4.485
622	floating_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	public_standpost	3	39	?	3.44	3	39	?	3.559
629	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3	40	?	3.067	3	40	?	4.117
658	sump_intake	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3	41	?	3.1	3	41	?	3.488
660	sump_intake	deep_well_piston_pump	domestic_chlorination	plastic_tank	domestic_connection	3	42	?	3.028	3	42	?	3.375
675	sump_intake	submersible_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3	43	?	2.923	3	43	?	2.696
681	sump_intake	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	44	?	3.408	3	44	?	3.266
688	sump_intake	submersible_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	4	45	?	3.73	4	45	?	3.451
690	sump_intake	submersible_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	4	46	?	3.686	4	46	?	4.001
693	sump_intake	submersible_pump	storage_and_sedimentation	plastic_tank	public_standpost	3	47	?	3.223	3	47	?	3.074

							KStar					SMOreg	
Set13						TRL	inst#,	actual,	predicte		inst#,	actual,	predicted, e
12	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	public_standpost	2	1	?	2.007	2	1	?	1.724
57	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3	2	?	3.031	3	2	?	3.002
60	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	3	3	?	3.075	3	3	?	3.177
70	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	public_standpost	4	4	?	3.587	4	4	?	3.622
76	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	domestic_connection	4	5	?	3.729	4	5	?	3.82
167	dug_well	rope_pump	boiling	ferrocement_tank	public_standpost	2	6	?	2.026	2	6	?	1.628
184	dug_well	rope_pump	domestic_chlorination	steel_tank	public_standpost	2	7	?	1.611	2	7	?	1.905
187	dug_well	rope_pump	domestic_chlorination	ferrocement_tank	domestic_connection	2	8	?	2.138	2	8	?	2.381
194	dug_well	submersible_pump	boiling	steel_tank	public_standpost	2	9	?	1.678	2	9	?	0.74
208	dug_well	submersible_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	2	10	?	1.85	2	10	?	1.353
228	drilled_well	bucket_pump	boiling	reinforced_concrete_reservoir	public_standpost	2	11	?	2.14	2	11	?	1.628
239	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	public_standpost	2	12	?	2.00	2	12	?	1.709
241	drilled_well	bucket_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2	13	?	2.31	2	13	?	1.81
250	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	domestic_connection	2	14	?	2.87	2	14	?	2.49
251	drilled_well	bucket_pump	domestic_chlorination	plastic_tank	public_standpost	2	15	?	2.28	2	15	?	2.003
253	drilled_well	bucket_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	2	16	?	2.20	2	16	?	2.378
255	drilled_well	rope_pump	boiling	reinforced_concrete_reservoir	public_standpost	2	17	?	2.60	2	17	?	2.926
263	drilled_well	rope_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	3	18	?	2.70	3	18	?	3.298
265	drilled_well	rope_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3	19	?	2.87	3	19	?	2.998
294	drilled_well	suction_plunger_handpump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3	20	?	2.92	3	20	?	2.693
297	drilled_well	suction_plunger_handpump	household_slow_sand_filter	ferrocement_tank	public_standpost	2	21	?	2.31	2	21	?	2.428
319	drilled_well	direct_action_pump	boiling	plastic_tank	domestic_connection	2	22	?	2.59	2	22	?	2.293
332	drilled_well	direct_action_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	23	?	2.92	3	23	?	2.673
373	drilled_well	deep_well_piston_pump	boiling	steel_tank	domestic_connection	3	24	?	2.68	3	24	?	2.634
402	drilled_well	centrifugal_pump	boiling	elevated_steel_reservoir	domestic_connection	3	25	?	3.01	3	25	?	3.505
422	drilled_well	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3	26	?	3.02	3	26	?	3.331
438	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	27	?	2.96	3	27	?	3.065
477	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3	28	?	2.95	3	28	?	2.551
493	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	29	?	3.03	3	29	?	2.819
506	protected_side_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	domestic_connection	3	30	?	3.06	3	30	?	3.373
519	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_steel_reservoir	public_standpost	3	31	?	3.04	3	31	?	3.622
527	river_bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3	32	?	3.00	3	32	?	2.814
530	river_bottom_intake	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3	33	?	2.99	3	33	?	2.55
542	river_bottom_intake	centrifugal_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	3	34	?	2.99	3	34	?	3.19
550	river_bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3	35	?	2.99	3	35	?	2.815
551	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3	36	?	3.01	3	36	?	3.375
609	floating_intake	centrifugal_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	4	37	?	3.8	4	37	?	4.488
635	sump_intake	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3	38	?	2.95	3	38	?	3
649	sump_intake	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	39	?	2.65	3	39	?	2.695
654	sump_intake	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	40	?	3.12	3	40	?	3.378
655	sump_intake	deep_well_piston_pump	domestic_chlorination	steel_tank	public_standpost	3	41	?	2.91	3	41	?	3.011
657	sump_intake	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	public_standpost	3	42	?	2.98	3	42	?	3.113
659	sump_intake	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3	43	?	2.98	3	43	?	3.001
666	sump_intake	submersible_pump	boiling	elevated_steel_reservoir	domestic_connection	3	44	?	3.11	3	44	?	3.437
685	sump_intake	submersible_pump	domestic_chlorination	plastic_tank	public_standpost	3	45	?	3.03	3	45	?	2.889
705	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	3	46	?	3.37	3	46	?	3.891
712	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3	47	?	3.11	3	47	?	4.004

							Kstar				SMOreg			
Set14						TRL	inst#,	actual, predicted, er			inst#,	actual, predicted, error		
98	springwater_collection	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	1	?	3.009	3	1	?	2.264	
109	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	elevated_steel_reservoir	public_standpost	3	2	?	3.004	3	2	?	2.624	
118	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	elevated_steel_reservoir	public_standpost	3	3	?	3.019	3	3	?	2.622	
119	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	elevated_steel_reservoir	domestic_connection	3	4	?	3.059	3	4	?	2.996	
152	dug_well	rope_and_bucket	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	2	5	?	1.669	2	5	?	1.744	
155	dug_well	rope_and_bucket	domestic_chlorination	steel_tank	public_standpost	1	6	?	1.046	1	6	?	1.311	
193	dug_well	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3	7	?	2.581	3	7	?	1.106	
217	dug_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	8	?	3.154	3	8	?	1.484	
239	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	public_standpost	3	9	?	2.002	3	9	?	1.709	
257	drilled_well	rope_pump	boiling	steel_tank	public_standpost	2	10	?	2.409	2	10	?	2.934	
260	drilled_well	rope_pump	boiling	ferrocement_tank	domestic_connection	2	11	?	2.12	2	11	?	3.41	
275	drilled_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	12	?	2.923	3	12	?	3.678	
320	drilled_well	direct_action_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	2	13	?	2.4	2	13	?	2.292	
359	drilled_well	deep_well_diaphragm_	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	3	14	?	2.671	3	14	?	3.065	
373	drilled_well	deep_well_piston_pum	boiling	steel_tank	domestic_connection	3	15	?	2.686	3	15	?	2.634	
390	drilled_well	deep_well_piston_pum	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3	16	?	2.593	3	16	?	2.629	
402	drilled_well	centrifugal_pump	boiling	elevated_steel_reservoir	domestic_connection	3	17	?	3.012	3	17	?	3.505	
403	drilled_well	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3	18	?	2.773	3	18	?	2.691	
409	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	3	19	?	2.901	3	19	?	3.203	
410	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	4	20	?	3.735	4	20	?	3.577	
419	drilled_well	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3	21	?	2.762	3	21	?	3.069	
421	drilled_well	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3	22	?	2.806	3	22	?	2.956	
425	subsurface_harvesting	deep_well_piston_pum	boiling	steel_tank	public_standpost	3	23	?	2.884	3	23	?	2.628	
427	subsurface_harvesting	deep_well_piston_pum	boiling	ferrocement_tank	public_standpost	3	24	?	2.94	3	24	?	2.73	
442	subsurface_harvesting	deep_well_piston_pum	domestic_chlorination	steel_tank	domestic_connection	3	25	?	2.987	3	25	?	3.381	
470	protected_side_intake	centrifugal_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	3	26	?	2.996	3	26	?	2.438	
492	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3	27	?	2.912	3	27	?	2.444	
496	protected_side_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3	28	?	2.976	3	28	?	2.442	
533	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	public_standpost	3	29	?	2.951	3	29	?	2.884	
541	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	30	?	3.052	3	30	?	2.885	
551	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3	31	?	3.01	3	31	?	3.375	
570	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	3	32	?	2.999	3	32	?	3.818	
585	floating_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3	33	?	3.08	3	33	?	3.485	
591	floating_intake	centrifugal_pump	household_slow_sand_filter	elevated_steel_reservoir	public_standpost	4	34	?	3.76	4	34	?	3.622	
595	floating_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	4	35	?	3.565	4	35	?	3.445	
617	floating_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	4	36	?	3.781	4	36	?	3.936	
625	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3	37	?	3.071	3	37	?	4.007	
631	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3	38	?	3.06	3	38	?	4.004	
639	sump_intake	deep_well_piston_pum	boiling	ferrocement_tank	domestic_connection	3	39	?	2.965	3	39	?	3.11	
660	sump_intake	deep_well_piston_pum	domestic_chlorination	plastic_tank	domestic_connection	3	40	?	3.028	3	40	?	3.375	
664	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3	41	?	3.064	3	41	?	2.888	
677	sump_intake	submersible_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	42	?	2.685	3	42	?	2.583	
708	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3	43	?	3.345	3	43	?	3.894	

						TRL	Kstar				SMOreg		
Set15							inst#,	actual, predicted, er			inst#,	actual, predic	
3	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	public_standpost	2	1	?	2.114	2	1	?	1.55
4	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	domestic_connection	2	2	?	2.018	2	2	?	1.925
18	rooftop_rainwater_harvesting	bucket	domestic_chlorination	steel_tank	domestic_connection	2	3	?	2.037	2	3	?	2.303
33	rooftop_rainwater_harvesting	bucket	domestic_chlorination	steel_tank	domestic_connection	2	4	?	2.037	2	4	?	2.303
46	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	public_standpost	3	5	?	2.999	3	5	?	2.555
50	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	6	?	3.112	3	6	?	3.191
59	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3	7	?	2.999	3	7	?	2.628
64	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	public_standpost	3	8	?	2.982	3	8	?	2.625
67	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	domestic_connection	3	9	?	3.069	3	9	?	3.374
68	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3	10	?	3.255	3	10	?	3.073
75	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	concrete_lined_earthen_reservoir	public_standpost	3	11	?	3.431	3	11	?	3.445
77	springwater_collection	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	public_standpost	3	12	?	2.91	3	12	?	1.512
90	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	3	13	?	3.09	3	13	?	2.508
104	springwater_collection	hydraulic_ram_pump	domestic_chlorination	plastic_tank	domestic_connection	3	14	?	3.025	3	14	?	2.262
110	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3	15	?	2.991	3	15	?	2.185
152	dug_well	rope_and_bucket	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	2	16	?	1.669	2	16	?	1.744
183	dug_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	2	17	?	2.64	2	17	?	2.271
191	dug_well	rope_pump	domestic_chlorination	concrete_lined_earthen_reservoir	domestic_connection	3	18	?	2.816	3	18	?	2.643
202	dug_well	submersible_pump	boiling	concrete_lined_earthen_reservoir	public_standpost	2	19	?	2.83	2	19	?	1.103
209	dug_well	submersible_pump	household_slow_sand_filter	elevated_steel_reservoir	domestic_connection	3	20	?	3.147	3	20	?	1.728
226	dug_well	submersible_pump	domestic_chlorination	concrete_lined_earthen_reservoir	public_standpost	2	21	?	3.199	2	21	?	1.481
232	drilled_well	bucket_pump	boiling	ferrocement_tank	domestic_connection	2	22	?	2.182	2	22	?	2.112
236	drilled_well	bucket_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	2	23	?	2.201	2	23	?	2.374
240	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	domestic_connection	2	24	?	2.314	2	24	?	2.083
241	drilled_well	bucket_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2	25	?	2.312	2	25	?	1.81
244	drilled_well	bucket_pump	household_slow_sand_filter	plastic_tank	domestic_connection	2	26	?	2.713	2	26	?	2.073
258	drilled_well	rope_pump	boiling	steel_tank	domestic_connection	2	27	?	2.259	2	27	?	3.309
296	drilled_well	suction_plunger_handpump	household_slow_sand_filter	steel_tank	domestic_connection	2	28	?	2.401	2	28	?	2.701
344	drilled_well	deep_well_diaphragm_pump	boiling	steel_tank	domestic_connection	2	29	?	2.41	2	29	?	3.003
355	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3	30	?	2.634	3	30	?	2.803
361	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3	31	?	2.958	3	31	?	3.373
371	drilled_well	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2	32	?	2.337	2	32	?	2.625
407	drilled_well	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3	33	?	2.704	3	33	?	2.653
425	subsurface_harvesting	deep_well_piston_pump	boiling	steel_tank	public_standpost	3	34	?	2.884	3	34	?	2.628
455	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3	35	?	3.041	3	35	?	3.555
457	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	steel_tank	domestic_connection	3	36	?	2.971	3	36	?	3.564
482	protected_side_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3	37	?	2.938	3	37	?	2.139
508	protected_side_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3	38	?	3.196	3	38	?	3.001
540	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	39	?	2.889	3	39	?	2.51
610	floating_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3	40	?	3.232	3	40	?	3.674
614	floating_intake	centrifugal_pump	slow_sand_filtration	concrete_lined_earthen_reservoir	public_standpost	3	41	?	3.071	3	41	?	3.933
617	floating_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	4	42	?	3.781	4	42	?	3.936
621	floating_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	4	43	?	3.723	4	43	?	4.046
626	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	4	44	?	3.732	4	44	?	4.381
631	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3	45	?	3.06	3	45	?	4.004
636	sump_intake	deep_well_piston_pump	boiling	steel_tank	public_standpost	3	46	?	2.97	3	46	?	2.633
650	sump_intake	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3	47	?	2.997	3	47	?	3.07
672	sump_intake	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3	48	?	3.115	3	48	?	2.96

Appendix G: Database – Table DWS Options with TRL Scores

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
1	catchment_and_storage_dam	hydraulic_ram_pump	boiling	elevated_reservoir	public_standpost	3
2	catchment_and_storage_dam	hydraulic_ram_pump	boiling	elevated_reservoir	domestic_connection	4
3	catchment_and_storage_dam	hydraulic_ram_pump	boiling	ferrocement_tank	public_standpost	3
4	catchment_and_storage_dam	hydraulic_ram_pump	boiling	ferrocement_tank	domestic_connection	3
5	catchment_and_storage_dam	hydraulic_ram_pump	boiling	plastic_tank	public_standpost	3
6	catchment_and_storage_dam	hydraulic_ram_pump	boiling	plastic_tank	domestic_connection	3
7	catchment_and_storage_dam	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
8	catchment_and_storage_dam	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
9	catchment_and_storage_dam	hydraulic_ram_pump	boiling	steel_tank	public_standpost	3
10	catchment_and_storage_dam	hydraulic_ram_pump	boiling	steel_tank	domestic_connection	3
11	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
12	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	4
13	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
14	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
15	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
16	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
17	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
18	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3
19	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	3
20	catchment_and_storage_dam	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3
21	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
22	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
23	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
24	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
25	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	plastic_tank	public_standpost	3
26	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	plastic_tank	domestic_connection	3
27	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
28	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
29	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	steel_tank	public_standpost	3
30	catchment_and_storage_dam	hydraulic_ram_pump	domestic_chlorination	steel_tank	domestic_connection	3
31	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
32	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3
33	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
34	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
35	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
36	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
37	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
38	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
39	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	steel_tank	public_standpost	2
40	catchment_and_storage_dam	hydraulic_ram_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
41	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
42	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
43	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
44	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
45	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	public_standpost	3
46	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
47	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
48	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
49	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	steel_tank	public_standpost	3
50	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	steel_tank	domestic_connection	3
51	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3
52	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	3
53	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3
54	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	3
55	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	plastic_tank	public_standpost	3
56	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3
57	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3
58	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	3
59	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	steel_tank	public_standpost	3
60	catchment_and_storage_dam	hydraulic_ram_pump	storage_and_sedimentation	steel_tank	domestic_connection	3
61	drilled_well	bucket_pump	boiling	ferrocement_tank	public_standpost	2
62	drilled_well	bucket_pump	boiling	ferrocement_tank	domestic_connection	2
63	drilled_well	bucket_pump	boiling	plastic_tank	public_standpost	2
64	drilled_well	bucket_pump	boiling	plastic_tank	domestic_connection	2
65	drilled_well	bucket_pump	boiling	reinforced_concrete_reservoir	public_standpost	2
66	drilled_well	bucket_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
67	drilled_well	bucket_pump	boiling	steel_tank	public_standpost	2
68	drilled_well	bucket_pump	boiling	steel_tank	domestic_connection	2
69	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	public_standpost	2
70	drilled_well	bucket_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
71	drilled_well	bucket_pump	domestic_chlorination	plastic_tank	public_standpost	2
72	drilled_well	bucket_pump	domestic_chlorination	plastic_tank	domestic_connection	3
73	drilled_well	bucket_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
74	drilled_well	bucket_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
75	drilled_well	bucket_pump	domestic_chlorination	steel_tank	public_standpost	2
76	drilled_well	bucket_pump	domestic_chlorination	steel_tank	domestic_connection	3
77	drilled_well	bucket_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
78	drilled_well	bucket_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
79	drilled_well	bucket_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
80	drilled_well	bucket_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
81	drilled_well	bucket_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
82	drilled_well	bucket_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
83	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	public_standpost	2
84	drilled_well	bucket_pump	household_slow_sand_filter	steel_tank	domestic_connection	2

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
85	drilled_well	centrifugal_pump	boiling	elevated_reservoir	public_standpost	3
86	drilled_well	centrifugal_pump	boiling	elevated_reservoir	domestic_connection	3
87	drilled_well	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3
88	drilled_well	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3
89	drilled_well	centrifugal_pump	boiling	plastic_tank	public_standpost	3
90	drilled_well	centrifugal_pump	boiling	plastic_tank	domestic_connection	3
91	drilled_well	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
92	drilled_well	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
93	drilled_well	centrifugal_pump	boiling	steel_tank	public_standpost	3
94	drilled_well	centrifugal_pump	boiling	steel_tank	domestic_connection	3
95	drilled_well	centrifugal_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
96	drilled_well	centrifugal_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
97	drilled_well	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
98	drilled_well	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
99	drilled_well	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3
100	drilled_well	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
101	drilled_well	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
102	drilled_well	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
103	drilled_well	centrifugal_pump	domestic_chlorination	steel_tank	public_standpost	3
104	drilled_well	centrifugal_pump	domestic_chlorination	steel_tank	domestic_connection	3
105	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
106	drilled_well	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	4
107	drilled_well	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
108	drilled_well	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
109	drilled_well	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
110	drilled_well	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
111	drilled_well	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
112	drilled_well	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
113	drilled_well	centrifugal_pump	household_slow_sand_filter	steel_tank	public_standpost	2
114	drilled_well	centrifugal_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
115	drilled_well	deep_well_diaphragm_pump	boiling	ferrocement_tank	public_standpost	2
116	drilled_well	deep_well_diaphragm_pump	boiling	ferrocement_tank	domestic_connection	2
117	drilled_well	deep_well_diaphragm_pump	boiling	plastic_tank	public_standpost	2
118	drilled_well	deep_well_diaphragm_pump	boiling	plastic_tank	domestic_connection	3
119	drilled_well	deep_well_diaphragm_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
120	drilled_well	deep_well_diaphragm_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
121	drilled_well	deep_well_diaphragm_pump	boiling	steel_tank	public_standpost	2
122	drilled_well	deep_well_diaphragm_pump	boiling	steel_tank	domestic_connection	2
123	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
124	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
125	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	plastic_tank	public_standpost	3
126	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	plastic_tank	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
127	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
128	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
129	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	steel_tank	public_standpost	3
130	drilled_well	deep_well_diaphragm_pump	domestic_chlorination	steel_tank	domestic_connection	3
131	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
132	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
133	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
134	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
135	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
136	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
137	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	steel_tank	public_standpost	2
138	drilled_well	deep_well_diaphragm_pump	household_slow_sand_filter	steel_tank	domestic_connection	2
139	drilled_well	deep_well_piston_pump	boiling	ferrocement_tank	public_standpost	2
140	drilled_well	deep_well_piston_pump	boiling	ferrocement_tank	domestic_connection	3
141	drilled_well	deep_well_piston_pump	boiling	plastic_tank	public_standpost	2
142	drilled_well	deep_well_piston_pump	boiling	plastic_tank	domestic_connection	3
143	drilled_well	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	public_standpost	2
144	drilled_well	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
145	drilled_well	deep_well_piston_pump	boiling	steel_tank	public_standpost	2
146	drilled_well	deep_well_piston_pump	boiling	steel_tank	domestic_connection	2
147	drilled_well	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
148	drilled_well	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
149	drilled_well	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3
150	drilled_well	deep_well_piston_pump	domestic_chlorination	plastic_tank	domestic_connection	3
151	drilled_well	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
152	drilled_well	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
153	drilled_well	deep_well_piston_pump	domestic_chlorination	steel_tank	public_standpost	3
154	drilled_well	deep_well_piston_pump	domestic_chlorination	steel_tank	domestic_connection	3
155	drilled_well	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
156	drilled_well	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
157	drilled_well	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
158	drilled_well	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
159	drilled_well	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
160	drilled_well	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
161	drilled_well	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	2
162	drilled_well	deep_well_piston_pump	household_slow_sand_filter	steel_tank	domestic_connection	2
163	drilled_well	direct_action_pump	boiling	ferrocement_tank	public_standpost	2
164	drilled_well	direct_action_pump	boiling	ferrocement_tank	domestic_connection	2
165	drilled_well	direct_action_pump	boiling	plastic_tank	public_standpost	2
166	drilled_well	direct_action_pump	boiling	plastic_tank	domestic_connection	3
167	drilled_well	direct_action_pump	boiling	reinforced_concrete_reservoir	public_standpost	2
168	drilled_well	direct_action_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
169	drilled_well	direct_action_pump	boiling	steel_tank	public_standpost	2
170	drilled_well	direct_action_pump	boiling	steel_tank	domestic_connection	2
171	drilled_well	direct_action_pump	domestic_chlorination	ferrocement_tank	public_standpost	2
172	drilled_well	direct_action_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
173	drilled_well	direct_action_pump	domestic_chlorination	plastic_tank	public_standpost	2
174	drilled_well	direct_action_pump	domestic_chlorination	plastic_tank	domestic_connection	3
175	drilled_well	direct_action_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
176	drilled_well	direct_action_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
177	drilled_well	direct_action_pump	domestic_chlorination	steel_tank	public_standpost	2
178	drilled_well	direct_action_pump	domestic_chlorination	steel_tank	domestic_connection	2
179	drilled_well	direct_action_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
180	drilled_well	direct_action_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
181	drilled_well	direct_action_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
182	drilled_well	direct_action_pump	household_slow_sand_filter	plastic_tank	domestic_connection	2
183	drilled_well	direct_action_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
184	drilled_well	direct_action_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2
185	drilled_well	direct_action_pump	household_slow_sand_filter	steel_tank	public_standpost	2
186	drilled_well	direct_action_pump	household_slow_sand_filter	steel_tank	domestic_connection	2
187	drilled_well	rope_pump	boiling	ferrocement_tank	public_standpost	2
188	drilled_well	rope_pump	boiling	ferrocement_tank	domestic_connection	2
189	drilled_well	rope_pump	boiling	plastic_tank	public_standpost	2
190	drilled_well	rope_pump	boiling	plastic_tank	domestic_connection	2
191	drilled_well	rope_pump	boiling	reinforced_concrete_reservoir	public_standpost	2
192	drilled_well	rope_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
193	drilled_well	rope_pump	boiling	steel_tank	public_standpost	2
194	drilled_well	rope_pump	boiling	steel_tank	domestic_connection	2
195	drilled_well	rope_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
196	drilled_well	rope_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
197	drilled_well	rope_pump	domestic_chlorination	plastic_tank	public_standpost	3
198	drilled_well	rope_pump	domestic_chlorination	plastic_tank	domestic_connection	3
199	drilled_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
200	drilled_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
201	drilled_well	rope_pump	domestic_chlorination	steel_tank	public_standpost	2
202	drilled_well	rope_pump	domestic_chlorination	steel_tank	domestic_connection	3
203	drilled_well	rope_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
204	drilled_well	rope_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
205	drilled_well	rope_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
206	drilled_well	rope_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
207	drilled_well	rope_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
208	drilled_well	rope_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
209	drilled_well	rope_pump	household_slow_sand_filter	steel_tank	public_standpost	2
210	drilled_well	rope_pump	household_slow_sand_filter	steel_tank	domestic_connection	2

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
211	drilled_well	submersible_pump	boiling	elevated_reservoir	public_standpost	3
212	drilled_well	submersible_pump	boiling	elevated_reservoir	domestic_connection	3
213	drilled_well	submersible_pump	boiling	ferrocement_tank	public_standpost	2
214	drilled_well	submersible_pump	boiling	ferrocement_tank	domestic_connection	3
215	drilled_well	submersible_pump	boiling	plastic_tank	public_standpost	2
216	drilled_well	submersible_pump	boiling	plastic_tank	domestic_connection	3
217	drilled_well	submersible_pump	boiling	reinforced_concrete_reservoir	public_standpost	2
218	drilled_well	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
219	drilled_well	submersible_pump	boiling	steel_tank	public_standpost	2
220	drilled_well	submersible_pump	boiling	steel_tank	domestic_connection	3
221	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
222	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	4
223	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
224	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
225	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
226	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
227	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
228	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3
229	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	2
230	drilled_well	submersible_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3
231	drilled_well	submersible_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
232	drilled_well	submersible_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
233	drilled_well	submersible_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
234	drilled_well	submersible_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
235	drilled_well	submersible_pump	domestic_chlorination	plastic_tank	public_standpost	2
236	drilled_well	submersible_pump	domestic_chlorination	plastic_tank	domestic_connection	3
237	drilled_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
238	drilled_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
239	drilled_well	submersible_pump	domestic_chlorination	steel_tank	public_standpost	2
240	drilled_well	submersible_pump	domestic_chlorination	steel_tank	domestic_connection	3
241	drilled_well	submersible_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
242	drilled_well	submersible_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3
243	drilled_well	submersible_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
244	drilled_well	submersible_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
245	drilled_well	submersible_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
246	drilled_well	submersible_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
247	drilled_well	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
248	drilled_well	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
249	drilled_well	submersible_pump	household_slow_sand_filter	steel_tank	public_standpost	2
250	drilled_well	submersible_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
251	drilled_well	submersible_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
252	drilled_well	submersible_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	4

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
253	drilled_well	submersible_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
254	drilled_well	submersible_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
255	drilled_well	submersible_pump	slow_sand_filtration	plastic_tank	public_standpost	3
256	drilled_well	submersible_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
257	drilled_well	submersible_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
258	drilled_well	submersible_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
259	drilled_well	submersible_pump	slow_sand_filtration	steel_tank	public_standpost	2
260	drilled_well	submersible_pump	slow_sand_filtration	steel_tank	domestic_connection	3
261	drilled_well	suction_plunger_handpump	boiling	ferrocement_tank	public_standpost	2
262	drilled_well	suction_plunger_handpump	boiling	ferrocement_tank	domestic_connection	2
263	drilled_well	suction_plunger_handpump	boiling	plastic_tank	public_standpost	2
264	drilled_well	suction_plunger_handpump	boiling	plastic_tank	domestic_connection	2
265	drilled_well	suction_plunger_handpump	boiling	reinforced_concrete_reservoir	public_standpost	2
266	drilled_well	suction_plunger_handpump	boiling	reinforced_concrete_reservoir	domestic_connection	2
267	drilled_well	suction_plunger_handpump	boiling	steel_tank	public_standpost	2
268	drilled_well	suction_plunger_handpump	boiling	steel_tank	domestic_connection	2
269	drilled_well	suction_plunger_handpump	domestic_chlorination	ferrocement_tank	public_standpost	2
270	drilled_well	suction_plunger_handpump	domestic_chlorination	ferrocement_tank	domestic_connection	3
271	drilled_well	suction_plunger_handpump	domestic_chlorination	plastic_tank	public_standpost	2
272	drilled_well	suction_plunger_handpump	domestic_chlorination	plastic_tank	domestic_connection	3
273	drilled_well	suction_plunger_handpump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
274	drilled_well	suction_plunger_handpump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
275	drilled_well	suction_plunger_handpump	domestic_chlorination	steel_tank	public_standpost	2
276	drilled_well	suction_plunger_handpump	domestic_chlorination	steel_tank	domestic_connection	3
277	drilled_well	suction_plunger_handpump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
278	drilled_well	suction_plunger_handpump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
279	drilled_well	suction_plunger_handpump	household_slow_sand_filter	plastic_tank	public_standpost	2
280	drilled_well	suction_plunger_handpump	household_slow_sand_filter	plastic_tank	domestic_connection	3
281	drilled_well	suction_plunger_handpump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
282	drilled_well	suction_plunger_handpump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
283	drilled_well	suction_plunger_handpump	household_slow_sand_filter	steel_tank	public_standpost	2
284	drilled_well	suction_plunger_handpump	household_slow_sand_filter	steel_tank	domestic_connection	2
285	dug_well	rope_and_bucket	boiling	ferrocement_tank	public_standpost	1
286	dug_well	rope_and_bucket	boiling	ferrocement_tank	domestic_connection	2
287	dug_well	rope_and_bucket	boiling	plastic_tank	public_standpost	1
288	dug_well	rope_and_bucket	boiling	plastic_tank	domestic_connection	2
289	dug_well	rope_and_bucket	boiling	reinforced_concrete_reservoir	public_standpost	1
290	dug_well	rope_and_bucket	boiling	reinforced_concrete_reservoir	domestic_connection	2
291	dug_well	rope_and_bucket	boiling	steel_tank	public_standpost	1
292	dug_well	rope_and_bucket	boiling	steel_tank	domestic_connection	1
293	dug_well	rope_and_bucket	domestic_chlorination	ferrocement_tank	public_standpost	1
294	dug_well	rope_and_bucket	domestic_chlorination	ferrocement_tank	domestic_connection	2

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
295	dug_well	rope_and_bucket	domestic_chlorination	plastic_tank	public_standpost	1
296	dug_well	rope_and_bucket	domestic_chlorination	plastic_tank	domestic_connection	2
297	dug_well	rope_and_bucket	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	1
298	dug_well	rope_and_bucket	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	2
299	dug_well	rope_and_bucket	domestic_chlorination	steel_tank	public_standpost	1
300	dug_well	rope_and_bucket	domestic_chlorination	steel_tank	domestic_connection	2
301	dug_well	rope_and_bucket	household_slow_sand_filter	ferrocement_tank	public_standpost	1
302	dug_well	rope_and_bucket	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
303	dug_well	rope_and_bucket	household_slow_sand_filter	plastic_tank	public_standpost	1
304	dug_well	rope_and_bucket	household_slow_sand_filter	plastic_tank	domestic_connection	1
305	dug_well	rope_and_bucket	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	1
306	dug_well	rope_and_bucket	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2
307	dug_well	rope_and_bucket	household_slow_sand_filter	steel_tank	public_standpost	1
308	dug_well	rope_and_bucket	household_slow_sand_filter	steel_tank	domestic_connection	1
309	dug_well	rope_pump	boiling	ferrocement_tank	public_standpost	2
310	dug_well	rope_pump	boiling	ferrocement_tank	domestic_connection	2
311	dug_well	rope_pump	boiling	plastic_tank	public_standpost	2
312	dug_well	rope_pump	boiling	plastic_tank	domestic_connection	2
313	dug_well	rope_pump	boiling	reinforced_concrete_reservoir	public_standpost	2
314	dug_well	rope_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2
315	dug_well	rope_pump	boiling	steel_tank	public_standpost	2
316	dug_well	rope_pump	boiling	steel_tank	domestic_connection	2
317	dug_well	rope_pump	domestic_chlorination	ferrocement_tank	public_standpost	2
318	dug_well	rope_pump	domestic_chlorination	ferrocement_tank	domestic_connection	2
319	dug_well	rope_pump	domestic_chlorination	plastic_tank	public_standpost	2
320	dug_well	rope_pump	domestic_chlorination	plastic_tank	domestic_connection	3
321	dug_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
322	dug_well	rope_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
323	dug_well	rope_pump	domestic_chlorination	steel_tank	public_standpost	2
324	dug_well	rope_pump	domestic_chlorination	steel_tank	domestic_connection	2
325	dug_well	rope_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
326	dug_well	rope_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
327	dug_well	rope_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
328	dug_well	rope_pump	household_slow_sand_filter	plastic_tank	domestic_connection	2
329	dug_well	rope_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
330	dug_well	rope_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2
331	dug_well	rope_pump	household_slow_sand_filter	steel_tank	public_standpost	1
332	dug_well	rope_pump	household_slow_sand_filter	steel_tank	domestic_connection	2
333	dug_well	submersible_pump	boiling	elevated_reservoir	public_standpost	3
334	dug_well	submersible_pump	boiling	elevated_reservoir	domestic_connection	3
335	dug_well	submersible_pump	boiling	ferrocement_tank	public_standpost	2
336	dug_well	submersible_pump	boiling	ferrocement_tank	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
337	dug_well	submersible_pump	boiling	plastic_tank	public_standpost	2
338	dug_well	submersible_pump	boiling	plastic_tank	domestic_connection	3
339	dug_well	submersible_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
340	dug_well	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
341	dug_well	submersible_pump	boiling	steel_tank	public_standpost	2
342	dug_well	submersible_pump	boiling	steel_tank	domestic_connection	3
343	dug_well	submersible_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
344	dug_well	submersible_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
345	dug_well	submersible_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
346	dug_well	submersible_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
347	dug_well	submersible_pump	domestic_chlorination	plastic_tank	public_standpost	2
348	dug_well	submersible_pump	domestic_chlorination	plastic_tank	domestic_connection	3
349	dug_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
350	dug_well	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
351	dug_well	submersible_pump	domestic_chlorination	steel_tank	public_standpost	2
352	dug_well	submersible_pump	domestic_chlorination	steel_tank	domestic_connection	3
353	dug_well	submersible_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	2
354	dug_well	submersible_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3
355	dug_well	submersible_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
356	dug_well	submersible_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
357	dug_well	submersible_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
358	dug_well	submersible_pump	household_slow_sand_filter	plastic_tank	domestic_connection	2
359	dug_well	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
360	dug_well	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
361	dug_well	submersible_pump	household_slow_sand_filter	steel_tank	public_standpost	2
362	dug_well	submersible_pump	household_slow_sand_filter	steel_tank	domestic_connection	2
363	floating_intake	centrifugal_pump	boiling	elevated_reservoir	public_standpost	3
364	floating_intake	centrifugal_pump	boiling	elevated_reservoir	domestic_connection	4
365	floating_intake	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3
366	floating_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3
367	floating_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
368	floating_intake	centrifugal_pump	boiling	plastic_tank	domestic_connection	3
369	floating_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
370	floating_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
371	floating_intake	centrifugal_pump	boiling	steel_tank	public_standpost	3
372	floating_intake	centrifugal_pump	boiling	steel_tank	domestic_connection	3
373	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
374	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	4
375	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
376	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
377	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
378	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
379	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
380	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	4
381	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	3
382	floating_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	4
383	floating_intake	centrifugal_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
384	floating_intake	centrifugal_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
385	floating_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
386	floating_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
387	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3
388	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
389	floating_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
390	floating_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
391	floating_intake	centrifugal_pump	domestic_chlorination	steel_tank	public_standpost	3
392	floating_intake	centrifugal_pump	domestic_chlorination	steel_tank	domestic_connection	3
393	floating_intake	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
394	floating_intake	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	4
395	floating_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
396	floating_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
397	floating_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
398	floating_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	4
399	floating_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
400	floating_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	4
401	floating_intake	centrifugal_pump	household_slow_sand_filter	steel_tank	public_standpost	2
402	floating_intake	centrifugal_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
403	floating_intake	centrifugal_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
404	floating_intake	centrifugal_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	4
405	floating_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
406	floating_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	4
407	floating_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	public_standpost	3
408	floating_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	4
409	floating_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
410	floating_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	4
411	floating_intake	centrifugal_pump	slow_sand_filtration	steel_tank	public_standpost	3
412	floating_intake	centrifugal_pump	slow_sand_filtration	steel_tank	domestic_connection	4
413	floating_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3
414	floating_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	4
415	floating_intake	centrifugal_pump	storage_and_sedimentation	elevated_reservoir	public_standpost	3
416	floating_intake	centrifugal_pump	storage_and_sedimentation	elevated_reservoir	domestic_connection	4
417	floating_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3
418	floating_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	4
419	floating_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	public_standpost	3
420	floating_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
421	floating_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3
422	floating_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	4
423	floating_intake	centrifugal_pump	storage_and_sedimentation	steel_tank	public_standpost	3
424	floating_intake	centrifugal_pump	storage_and_sedimentation	steel_tank	domestic_connection	4
425	protected_side_intake	centrifugal_pump	boiling	elevated_reservoir	public_standpost	3
426	protected_side_intake	centrifugal_pump	boiling	elevated_reservoir	domestic_connection	3
427	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3
428	protected_side_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3
429	protected_side_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
430	protected_side_intake	centrifugal_pump	boiling	plastic_tank	domestic_connection	3
431	protected_side_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
432	protected_side_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
433	protected_side_intake	centrifugal_pump	boiling	steel_tank	public_standpost	3
434	protected_side_intake	centrifugal_pump	boiling	steel_tank	domestic_connection	3
435	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
436	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	3
437	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
438	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
439	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
440	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
441	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
442	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3
443	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	3
444	protected_side_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3
445	protected_side_intake	centrifugal_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
446	protected_side_intake	centrifugal_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
447	protected_side_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
448	protected_side_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
449	protected_side_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3
450	protected_side_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
451	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
452	protected_side_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
453	protected_side_intake	centrifugal_pump	domestic_chlorination	steel_tank	public_standpost	3
454	protected_side_intake	centrifugal_pump	domestic_chlorination	steel_tank	domestic_connection	3
455	protected_side_intake	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
456	protected_side_intake	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3
457	protected_side_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
458	protected_side_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
459	protected_side_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
460	protected_side_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
461	protected_side_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
462	protected_side_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
463	protected_side_intake	centrifugal_pump	household_slow_sand_filter	steel_tank	public_standpost	2
464	protected_side_intake	centrifugal_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
465	protected_side_intake	centrifugal_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
466	protected_side_intake	centrifugal_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	3
467	protected_side_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
468	protected_side_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
469	protected_side_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	public_standpost	3
470	protected_side_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
471	protected_side_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
472	protected_side_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
473	protected_side_intake	centrifugal_pump	slow_sand_filtration	steel_tank	public_standpost	3
474	protected_side_intake	centrifugal_pump	slow_sand_filtration	steel_tank	domestic_connection	3
475	protected_side_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3
476	protected_side_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	3
477	protected_side_intake	centrifugal_pump	storage_and_sedimentation	elevated_reservoir	public_standpost	3
478	protected_side_intake	centrifugal_pump	storage_and_sedimentation	elevated_reservoir	domestic_connection	3
479	protected_side_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3
480	protected_side_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	3
481	protected_side_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	public_standpost	3
482	protected_side_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3
483	protected_side_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3
484	protected_side_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	3
485	protected_side_intake	centrifugal_pump	storage_and_sedimentation	steel_tank	public_standpost	3
486	protected_side_intake	centrifugal_pump	storage_and_sedimentation	steel_tank	domestic_connection	3
487	river_bottom_intake	centrifugal_pump	boiling	elevated_reservoir	public_standpost	3
488	river_bottom_intake	centrifugal_pump	boiling	elevated_reservoir	domestic_connection	3
489	river_bottom_intake	centrifugal_pump	boiling	ferrocement_tank	public_standpost	3
490	river_bottom_intake	centrifugal_pump	boiling	ferrocement_tank	domestic_connection	3
491	river_bottom_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3
492	river_bottom_intake	centrifugal_pump	boiling	plastic_tank	domestic_connection	3
493	river_bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
494	river_bottom_intake	centrifugal_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
495	river_bottom_intake	centrifugal_pump	boiling	steel_tank	public_standpost	3
496	river_bottom_intake	centrifugal_pump	boiling	steel_tank	domestic_connection	3
497	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
498	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	3
499	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
500	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
501	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
502	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
503	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
504	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
505	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	3
506	river_bottom_intake	centrifugal_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3
507	river_bottom_intake	centrifugal_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
508	river_bottom_intake	centrifugal_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
509	river_bottom_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
510	river_bottom_intake	centrifugal_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
511	river_bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	public_standpost	3
512	river_bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3
513	river_bottom_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
514	river_bottom_intake	centrifugal_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
515	river_bottom_intake	centrifugal_pump	domestic_chlorination	steel_tank	public_standpost	3
516	river_bottom_intake	centrifugal_pump	domestic_chlorination	steel_tank	domestic_connection	3
517	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
518	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3
519	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
520	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
521	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
522	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
523	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
524	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
525	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	steel_tank	public_standpost	2
526	river_bottom_intake	centrifugal_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
527	river_bottom_intake	centrifugal_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
528	river_bottom_intake	centrifugal_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	3
529	river_bottom_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
530	river_bottom_intake	centrifugal_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
531	river_bottom_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	public_standpost	3
532	river_bottom_intake	centrifugal_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
533	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
534	river_bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
535	river_bottom_intake	centrifugal_pump	slow_sand_filtration	steel_tank	public_standpost	3
536	river_bottom_intake	centrifugal_pump	slow_sand_filtration	steel_tank	domestic_connection	3
537	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	public_standpost	3
538	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	concrete_lined_earthen_reservoir	domestic_connection	3
539	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	public_standpost	3
540	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	ferrocement_tank	domestic_connection	3
541	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	public_standpost	3
542	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	plastic_tank	domestic_connection	3
543	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	public_standpost	3
544	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	reinforced_concrete_reservoir	domestic_connection	4
545	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	steel_tank	public_standpost	3
546	river_bottom_intake	centrifugal_pump	storage_and_sedimentation	steel_tank	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
547	rooftop_rainwater_harvesting	bucket	boiling	ferrocement_tank	public_standpost	2
548	rooftop_rainwater_harvesting	bucket	boiling	ferrocement_tank	domestic_connection	2
549	rooftop_rainwater_harvesting	bucket	boiling	plastic_tank	public_standpost	3
550	rooftop_rainwater_harvesting	bucket	boiling	plastic_tank	domestic_connection	2
551	rooftop_rainwater_harvesting	bucket	boiling	reinforced_concrete_reservoir	public_standpost	2
552	rooftop_rainwater_harvesting	bucket	boiling	reinforced_concrete_reservoir	domestic_connection	2
553	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	public_standpost	2
554	rooftop_rainwater_harvesting	bucket	boiling	steel_tank	domestic_connection	2
555	rooftop_rainwater_harvesting	bucket	domestic_chlorination	ferrocement_tank	public_standpost	2
556	rooftop_rainwater_harvesting	bucket	domestic_chlorination	ferrocement_tank	domestic_connection	2
557	rooftop_rainwater_harvesting	bucket	domestic_chlorination	plastic_tank	public_standpost	2
558	rooftop_rainwater_harvesting	bucket	domestic_chlorination	plastic_tank	domestic_connection	2
559	rooftop_rainwater_harvesting	bucket	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	2
560	rooftop_rainwater_harvesting	bucket	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	2
561	rooftop_rainwater_harvesting	bucket	domestic_chlorination	steel_tank	public_standpost	2
562	rooftop_rainwater_harvesting	bucket	domestic_chlorination	steel_tank	domestic_connection	2
563	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	public_standpost	2
564	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	domestic_connection	2
565	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	plastic_tank	public_standpost	2
566	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	plastic_tank	domestic_connection	2
567	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
568	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	2
569	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	steel_tank	public_standpost	2
570	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	steel_tank	domestic_connection	2
571	springwater_collection	gravity	boiling	ferrocement_tank	public_standpost	3
572	springwater_collection	gravity	boiling	ferrocement_tank	domestic_connection	3
573	springwater_collection	gravity	boiling	plastic_tank	public_standpost	3
574	springwater_collection	gravity	boiling	plastic_tank	domestic_connection	3
575	springwater_collection	gravity	boiling	reinforced_concrete_reservoir	public_standpost	3
576	springwater_collection	gravity	boiling	reinforced_concrete_reservoir	domestic_connection	3
577	springwater_collection	gravity	boiling	steel_tank	public_standpost	2
578	springwater_collection	gravity	boiling	steel_tank	domestic_connection	3
579	springwater_collection	gravity	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
580	springwater_collection	gravity	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
581	springwater_collection	gravity	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
582	springwater_collection	gravity	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
583	springwater_collection	gravity	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
584	springwater_collection	gravity	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3
585	springwater_collection	gravity	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	2
586	springwater_collection	gravity	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3
587	springwater_collection	gravity	domestic_chlorination	ferrocement_tank	public_standpost	3
588	springwater_collection	gravity	domestic_chlorination	ferrocement_tank	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
589	springwater_collection	gravity	domestic_chlorination	plastic_tank	public_standpost	3
590	springwater_collection	gravity	domestic_chlorination	plastic_tank	domestic_connection	3
591	springwater_collection	gravity	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
592	springwater_collection	gravity	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
593	springwater_collection	gravity	domestic_chlorination	steel_tank	public_standpost	2
594	springwater_collection	gravity	domestic_chlorination	steel_tank	domestic_connection	3
595	springwater_collection	gravity	household_slow_sand_filter	ferrocement_tank	public_standpost	2
596	springwater_collection	gravity	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
597	springwater_collection	gravity	household_slow_sand_filter	plastic_tank	public_standpost	2
598	springwater_collection	gravity	household_slow_sand_filter	plastic_tank	domestic_connection	3
599	springwater_collection	gravity	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
600	springwater_collection	gravity	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
601	springwater_collection	gravity	household_slow_sand_filter	steel_tank	public_standpost	2
602	springwater_collection	gravity	household_slow_sand_filter	steel_tank	domestic_connection	2
603	springwater_collection	gravity	slow_sand_filtration	ferrocement_tank	public_standpost	3
604	springwater_collection	gravity	slow_sand_filtration	ferrocement_tank	domestic_connection	3
605	springwater_collection	gravity	slow_sand_filtration	plastic_tank	public_standpost	3
606	springwater_collection	gravity	slow_sand_filtration	plastic_tank	domestic_connection	3
607	springwater_collection	gravity	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
608	springwater_collection	gravity	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
609	springwater_collection	gravity	slow_sand_filtration	steel_tank	public_standpost	2
610	springwater_collection	gravity	slow_sand_filtration	steel_tank	domestic_connection	3
611	springwater_collection	hydraulic_ram_pump	boiling	elevated_reservoir	public_standpost	3
612	springwater_collection	hydraulic_ram_pump	boiling	elevated_reservoir	domestic_connection	3
613	springwater_collection	hydraulic_ram_pump	boiling	ferrocement_tank	public_standpost	3
614	springwater_collection	hydraulic_ram_pump	boiling	ferrocement_tank	domestic_connection	3
615	springwater_collection	hydraulic_ram_pump	boiling	plastic_tank	public_standpost	2
616	springwater_collection	hydraulic_ram_pump	boiling	plastic_tank	domestic_connection	3
617	springwater_collection	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
618	springwater_collection	hydraulic_ram_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
619	springwater_collection	hydraulic_ram_pump	boiling	steel_tank	public_standpost	2
620	springwater_collection	hydraulic_ram_pump	boiling	steel_tank	domestic_connection	3
621	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
622	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	3
623	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
624	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
625	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
626	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
627	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
628	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3
629	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	3
630	springwater_collection	hydraulic_ram_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3

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631	springwater_collection	hydraulic_ram_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
632	springwater_collection	hydraulic_ram_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
633	springwater_collection	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
634	springwater_collection	hydraulic_ram_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
635	springwater_collection	hydraulic_ram_pump	domestic_chlorination	plastic_tank	public_standpost	3
636	springwater_collection	hydraulic_ram_pump	domestic_chlorination	plastic_tank	domestic_connection	3
637	springwater_collection	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
638	springwater_collection	hydraulic_ram_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
639	springwater_collection	hydraulic_ram_pump	domestic_chlorination	steel_tank	public_standpost	3
640	springwater_collection	hydraulic_ram_pump	domestic_chlorination	steel_tank	domestic_connection	3
641	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
642	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3
643	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
644	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
645	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
646	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
647	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
648	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
649	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	steel_tank	public_standpost	2
650	springwater_collection	hydraulic_ram_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
651	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
652	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	3
653	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
654	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
655	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	public_standpost	3
656	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
657	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
658	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
659	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	steel_tank	public_standpost	2
660	springwater_collection	hydraulic_ram_pump	slow_sand_filtration	steel_tank	domestic_connection	3
661	subsurface_harvesting	deep_well_piston_pump	boiling	ferrocement_tank	public_standpost	3
662	subsurface_harvesting	deep_well_piston_pump	boiling	ferrocement_tank	domestic_connection	3
663	subsurface_harvesting	deep_well_piston_pump	boiling	plastic_tank	public_standpost	3
664	subsurface_harvesting	deep_well_piston_pump	boiling	plastic_tank	domestic_connection	3
665	subsurface_harvesting	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
666	subsurface_harvesting	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
667	subsurface_harvesting	deep_well_piston_pump	boiling	steel_tank	public_standpost	3
668	subsurface_harvesting	deep_well_piston_pump	boiling	steel_tank	domestic_connection	3
669	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
670	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
671	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3
672	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	plastic_tank	domestic_connection	3

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673	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
674	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
675	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	steel_tank	public_standpost	3
676	subsurface_harvesting	deep_well_piston_pump	domestic_chlorination	steel_tank	domestic_connection	3
677	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
678	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
679	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	3
680	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
681	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
682	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
683	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	2
684	subsurface_harvesting	deep_well_piston_pump	household_slow_sand_filter	steel_tank	domestic_connection	2
685	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
686	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
687	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	plastic_tank	public_standpost	3
688	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
689	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
690	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
691	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	steel_tank	public_standpost	3
692	subsurface_harvesting	deep_well_piston_pump	slow_sand_filtration	steel_tank	domestic_connection	3
693	sump_intake	deep_well_piston_pump	boiling	ferrocement_tank	public_standpost	3
694	sump_intake	deep_well_piston_pump	boiling	ferrocement_tank	domestic_connection	3
695	sump_intake	deep_well_piston_pump	boiling	plastic_tank	public_standpost	3
696	sump_intake	deep_well_piston_pump	boiling	plastic_tank	domestic_connection	3
697	sump_intake	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
698	sump_intake	deep_well_piston_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
699	sump_intake	deep_well_piston_pump	boiling	steel_tank	public_standpost	3
700	sump_intake	deep_well_piston_pump	boiling	steel_tank	domestic_connection	3
701	sump_intake	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
702	sump_intake	deep_well_piston_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
703	sump_intake	deep_well_piston_pump	domestic_chlorination	plastic_tank	public_standpost	3
704	sump_intake	deep_well_piston_pump	domestic_chlorination	plastic_tank	domestic_connection	3
705	sump_intake	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
706	sump_intake	deep_well_piston_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
707	sump_intake	deep_well_piston_pump	domestic_chlorination	steel_tank	public_standpost	3
708	sump_intake	deep_well_piston_pump	domestic_chlorination	steel_tank	domestic_connection	3
709	sump_intake	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	2
710	sump_intake	deep_well_piston_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
711	sump_intake	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
712	sump_intake	deep_well_piston_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
713	sump_intake	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	2
714	sump_intake	deep_well_piston_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
715	sump_intake	deep_well_piston_pump	household_slow_sand_filter	steel_tank	public_standpost	2
716	sump_intake	deep_well_piston_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
717	sump_intake	deep_well_piston_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
718	sump_intake	deep_well_piston_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
719	sump_intake	deep_well_piston_pump	slow_sand_filtration	plastic_tank	public_standpost	3
720	sump_intake	deep_well_piston_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
721	sump_intake	deep_well_piston_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
722	sump_intake	deep_well_piston_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
723	sump_intake	deep_well_piston_pump	slow_sand_filtration	steel_tank	public_standpost	2
724	sump_intake	deep_well_piston_pump	slow_sand_filtration	steel_tank	domestic_connection	3
725	sump_intake	submersible_pump	boiling	elevated_reservoir	public_standpost	3
726	sump_intake	submersible_pump	boiling	elevated_reservoir	domestic_connection	3
727	sump_intake	submersible_pump	boiling	ferrocement_tank	public_standpost	3
728	sump_intake	submersible_pump	boiling	ferrocement_tank	domestic_connection	3
729	sump_intake	submersible_pump	boiling	plastic_tank	public_standpost	3
730	sump_intake	submersible_pump	boiling	plastic_tank	domestic_connection	3
731	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	public_standpost	3
732	sump_intake	submersible_pump	boiling	reinforced_concrete_reservoir	domestic_connection	3
733	sump_intake	submersible_pump	boiling	steel_tank	public_standpost	3
734	sump_intake	submersible_pump	boiling	steel_tank	domestic_connection	3
735	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	public_standpost	3
736	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	elevated_reservoir	domestic_connection	3
737	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	public_standpost	3
738	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	ferrocement_tank	domestic_connection	3
739	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	plastic_tank	public_standpost	3
740	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	plastic_tank	domestic_connection	3
741	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	public_standpost	3
742	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	reinforced_concrete_reservoir	domestic_connection	3
743	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	steel_tank	public_standpost	3
744	sump_intake	submersible_pump	chlorination_in_piped_water_supply_system	steel_tank	domestic_connection	3
745	sump_intake	submersible_pump	domestic_chlorination	elevated_reservoir	public_standpost	3
746	sump_intake	submersible_pump	domestic_chlorination	elevated_reservoir	domestic_connection	3
747	sump_intake	submersible_pump	domestic_chlorination	ferrocement_tank	public_standpost	3
748	sump_intake	submersible_pump	domestic_chlorination	ferrocement_tank	domestic_connection	3
749	sump_intake	submersible_pump	domestic_chlorination	plastic_tank	public_standpost	3
750	sump_intake	submersible_pump	domestic_chlorination	plastic_tank	domestic_connection	3
751	sump_intake	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	public_standpost	3
752	sump_intake	submersible_pump	domestic_chlorination	reinforced_concrete_reservoir	domestic_connection	3
753	sump_intake	submersible_pump	domestic_chlorination	steel_tank	public_standpost	3
754	sump_intake	submersible_pump	domestic_chlorination	steel_tank	domestic_connection	3
755	sump_intake	submersible_pump	household_slow_sand_filter	elevated_reservoir	public_standpost	3
756	sump_intake	submersible_pump	household_slow_sand_filter	elevated_reservoir	domestic_connection	3

DWS_ID	Source	Device	Treatment	Storage	Distribution	TRL
757	sump_intake	submersible_pump	household_slow_sand_filter	ferrocement_tank	public_standpost	3
758	sump_intake	submersible_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3
759	sump_intake	submersible_pump	household_slow_sand_filter	plastic_tank	public_standpost	2
760	sump_intake	submersible_pump	household_slow_sand_filter	plastic_tank	domestic_connection	3
761	sump_intake	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	public_standpost	3
762	sump_intake	submersible_pump	household_slow_sand_filter	reinforced_concrete_reservoir	domestic_connection	3
763	sump_intake	submersible_pump	household_slow_sand_filter	steel_tank	public_standpost	2
764	sump_intake	submersible_pump	household_slow_sand_filter	steel_tank	domestic_connection	3
765	sump_intake	submersible_pump	slow_sand_filtration	elevated_reservoir	public_standpost	3
766	sump_intake	submersible_pump	slow_sand_filtration	elevated_reservoir	domestic_connection	3
767	sump_intake	submersible_pump	slow_sand_filtration	ferrocement_tank	public_standpost	3
768	sump_intake	submersible_pump	slow_sand_filtration	ferrocement_tank	domestic_connection	3
769	sump_intake	submersible_pump	slow_sand_filtration	plastic_tank	public_standpost	3
770	sump_intake	submersible_pump	slow_sand_filtration	plastic_tank	domestic_connection	3
771	sump_intake	submersible_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3
772	sump_intake	submersible_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3
773	sump_intake	submersible_pump	slow_sand_filtration	steel_tank	public_standpost	3
774	sump_intake	submersible_pump	slow_sand_filtration	steel_tank	domestic_connection	3

Appendix H: Evaluation Performance of the Classifiers – Test Set

Options #	Source	Device	Treatment	Storage	Distribution	TRL	Predicted by Kstar	Predicted by SMOreg
14	rooftop_rainwater_harvesting	bucket	household_slow_sand_filter	ferrocement_tank	domestic_connection	2	2	2
242	drilled_well	bucket_pump	boiling	reinforced_concrete_reservoir	domestic_connection	2	3	3
343	drilled_well	direct_action_pump	household_slow_sand_filter	steel_tank	public_standpost	2	2	2
66	catchment_and_storage_dam	hydraulic_ram_pump	slow_sand_filtration	reinforced_concrete_reservoir	domestic_connection	3	3	3
118	springwater_collection	hydraulic_ram_pump	storage_and_sedimentation	elevated_steel_reservoir	domestic_connection	3	3	3
287	drilled_well	rope_pump	household_slow_sand_filter	plastic_tank	public_standpost	3	2	2
561	river_bottom_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3	3	3
570	river-bottom_intake	centrifugal_pump	household_slow_sand_filter	ferrocement_tank	domestic_connection	3	3	3
582	river-bottom_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3	3	3
595	river-bottom_intake	centrifugal_pump	slow_sand_filtration	reinforced_concrete_reservoir	public_standpost	3	3	3
614	floating_intake	centrifugal_pump	boiling	concrete_lined_earthen_reservoir	domestic_connection	3	3	3
621	floating_intake	centrifugal_pump	boiling	plastic_tank	public_standpost	3	3	3
642	floating_intake	centrifugal_pump	domestic_chlorination	plastic_tank	domestic_connection	3	3	3
714	sump_intake	submersible_pump	household_slow_sand_filter	concrete_lined_earthen_reservoir	domestic_connection	3	3	3
727	sump_intake	submersible_pump	domestic_chlorination	elevated_steel_reservoir	public_standpost	3	3	3

```
=== Run information ===
Scheme:weka.classifiers.functions.SMOreg -C 1.0 -N 0 -I "weka.classifiers.functions.
supportVector.
RegSMOImproved -L 0.001 -W 1 -P 1.0E-12 -T 0.001 -V" -K "weka.classifiers.functions.
supportVector.
PolyKernel -C 250007 -E 1.0"
Relation:     evaluation
Instances:    25
Attributes:   6
              source
              device
              treatment
              storage
              distribution
              TRL
Test mode:user supplied test set: size unknown (reading incrementally)
=== Classifier model (full training set) ===

weights (not support vectors):
 -       0.2115 * (normalized) source=rooftop_rainwater_harvesting
 +       0.0458 * (normalized) source=catchment_and_storage_dam
 +       0.0607 * (normalized) source=springwater_collection
 -       0.343  * (normalized) source=dug_well
 -       0.0463 * (normalized) source=drilled_well
 +       0.2043 * (normalized) source=subsurface_harvesting
 -       0.0243 * (normalized) source=protected_side_intake
 +       0.1023 * (normalized) source=river_bottom_intake
 +       0.1022 * (normalized) source=floating_intake
 +       0.1098 * (normalized) source=sump_intake
 -       0.2115 * (normalized) device=bucket
 +       0      * (normalized) device=rope_and_bucket
 -       0.0841 * (normalized) device=bucket_pump
 -       0.343  * (normalized) device=rope_pump
 -       0.0837 * (normalized) device=suction_plunger_handpump
 +       0      * (normalized) device=direct_action_pump
 +       0.1692 * (normalized) device=deep_well_diaphragm_pump
 +       0.2114 * (normalized) device=deep_well_piston_pump
 +       0.1802 * (normalized) device=centrifugal_pump
 +       0.055  * (normalized) device=submersible_pump
 +       0.1064 * (normalized) device=hydraulic_ram_pump
 -       0.0837 * (normalized) treatment=boiling
 -       0.2115 * (normalized) treatment=household_slow_sand_filter
 +       0.0757 * (normalized) treatment=domestic_chlorination
```

```
+   0.079  * (normalized) treatment=storage_and_sedimentation
+   0.0798 * (normalized) treatment=slow_sand_filtration
+   0.0607 * (normalized) treatment=chlorination_in_piped_water_supply_system
+   0.1692 * (normalized) storage=concrete_lined_earthen_reservoir
+   0.2059 * (normalized) storage=reinforced_concrete_reservoir
+   0     * (normalized) storage=elevated_steel_reservoir
-   0.0769 * (normalized) storage=ferrocement_tank
-   0.0868 * (normalized) storage=plastic_tank
-   0.2115 * (normalized) storage=steel_tank
+   0.2528 * (normalized) distribution
0.5944

Number of kernel evaluations: 325 (99.314% cached)
Time taken to build model: 0.02 seconds

=== Predictions on test split ===

inst#,   actual, predicted, error
    1       ?     2.136
    2       ?     2.839
    3       ?     2.125
    4       ?     3.285
    5       ?     3.093
    6       ?     1.907
    7       ?     2.706
    8       ?     2.841
    9       ?     3.119
   10       ?     3.163
   11       ?     3.215
   12       ?     2.706
   13       ?     3.119
   14       ?     2.97
   15       ?     2.835

=== Evaluation on test set ===
=== Summary ===

Total Number of Instances              0
Ignored Class Unknown Instances              15
```

```
=== Run information ===
Scheme:weka.classifiers.lazy.KStar -B 20 -M a
Relation:     evaluation
Instances:    25
Attributes:   6
              source
              device
              treatment
              storage
              distribution
              TRL

Test mode:user supplied test set: size unknown (reading incrementally)
=== Classifier model (full training set) ===
KStar Beta Verion (0.1b).
Copyright (c) 1995-97 by Len Trigg (trigg@cs.waikato.ac.nz).
Java port to Weka by Abdelaziz Mahoui (am14@cs.waikato.ac.nz).
KStar options : -B 20 -M a
Time taken to build model: 0 seconds

=== Predictions on test split ===

inst#,    actual, predicted, error
    1        ?      2.016
    2        ?      2.905
    3        ?      2.322
    4        ?      2.998
    5        ?      2.995
    6        ?      2.258
    7        ?      2.944
    8        ?      2.884
    9        ?      2.993
   10        ?      2.994
   11        ?      2.958
   12        ?      2.944
   13        ?      2.993
   14        ?      2.952
   15        ?      2.969

=== Evaluation on test set ==

=== Summary ===
Total Number of Instances              0
Ignored Class Unknown Instances               15
```

Appendix I: Classification of Biogeographical Provinces of the World (Udvardy, 1975)

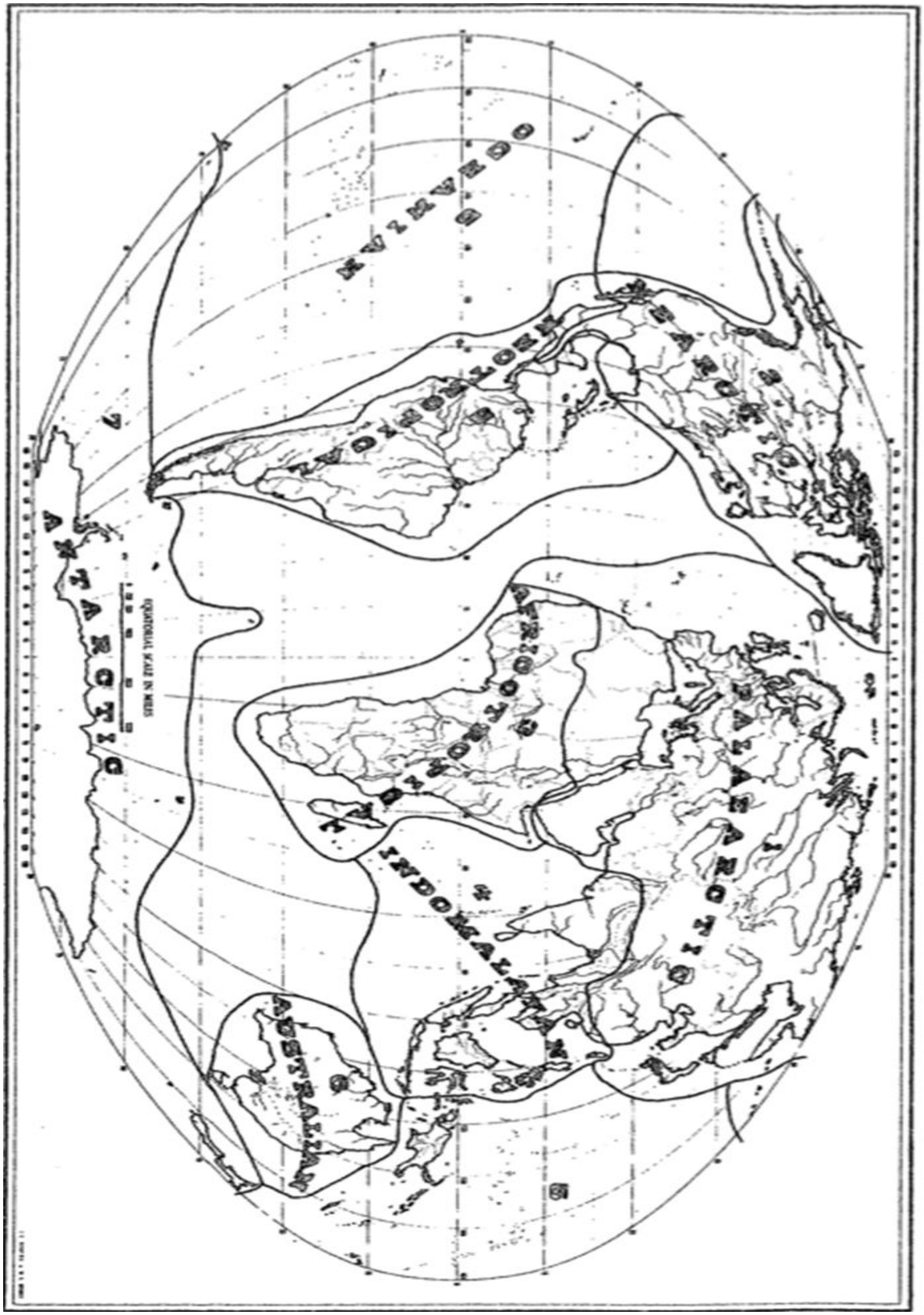
The unifying system for Biogeographical classification proposed by Udvardy uses three divisions; the major taxa are the Biogeographical realms. Each realm is divided into chief and dominant ecosystems called Biomes and finally, within each Biome are provinces. The provinces of each realm are numbered consecutively, and are ordinated according to the numerical sequence of the biome types. The order of the provinces is geographic, following as much as possible from north to south, and from west to east. The table below presents the eight realms proposed by Udvardy. In the regional specificity of developing community, only five realms are considered, given that most of the developing communities lacking access to safe drinking water and improved sanitation in the world live in areas within these five realms. The numbering sequence used for the regional specificity is the same as the one proposed by Udvardy: Realm # – Province # – Biome #. The eight Biogeographical realms are presented in the table below.

Biogeographical Realms of the World

Number	Biogeographical realms
1	Nearctic
2	Palearctic
3	Africotropical
4	Indomalayan
5	Oceanian
6	Australian
7	Antarctic
8	Neotropical

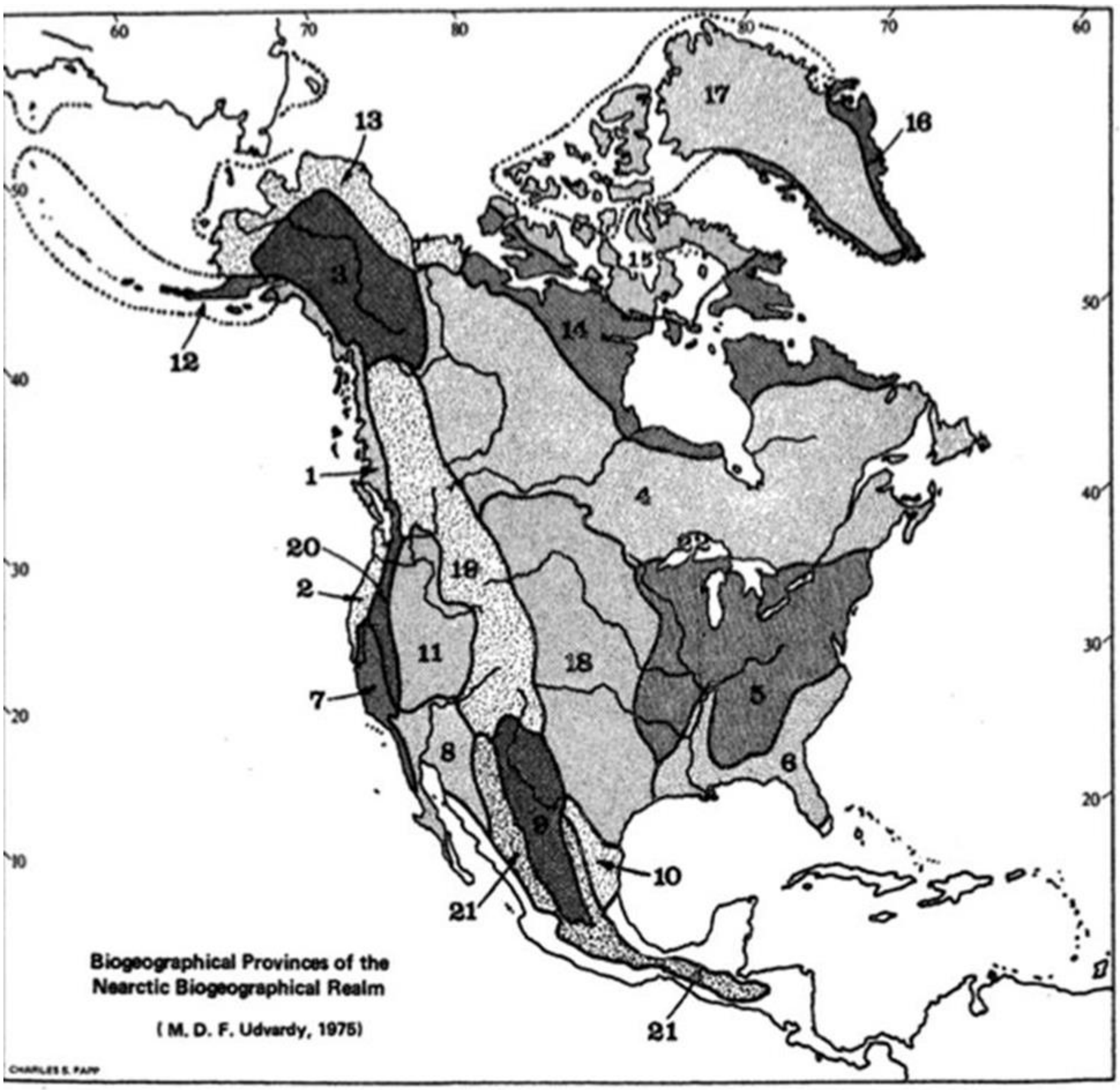
Source: Udvardy (1975)

Their geographic location is shown on the map overleaf below. Each realm is located in one the major continent or subcontinent of the earth.


PALAEARCTIC
AFROTROPICAL
INDOMALAYAN
AUSTRALIAN
ANTARCTIC
EQUATORIAL SCALE IN MILES

Nearctic Biogeographical Realm

The twelve provinces of the Nearctic realm are shown in the figure below.



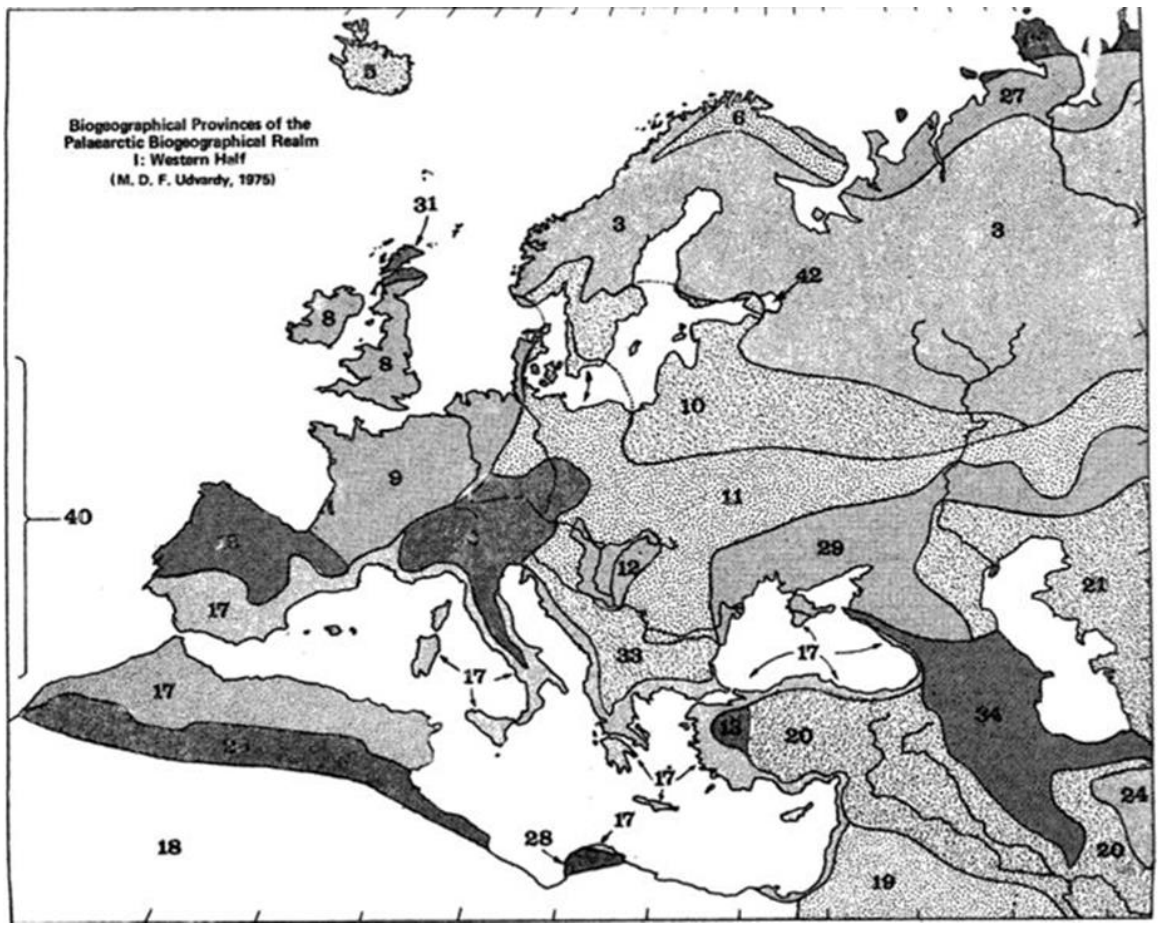
The biomes types and names of the twelve provinces of the Nearctic realm are presented in the table below. The *Regional Specificity* ID used in the Watsan database is also presented in the table below.

RS_ID	realm	province	biome
10102	nearctic	sitkan	subtropica_and_temperate_rain_forests_or_woodlands
10202	nearctic	oregonian	subtropica_and_temperate_rain_forests_or_woodlands
10303	nearctic	yukon_taiga	temperate_needle_leaf_forests_or_woodlands
10403	nearctic	canadian_taiga	temperate_needle_leaf_forests_or_woodlands
10505	nearctic	eastern_forest	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
10605	nearctic	austroriparian	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
10706	nearctic	californian	evergreen_sclerophyllous_forests_scrubs_or_woodlands
10807	nearctic	sonoran	warm_deserts_or_semi_deserts
10907	nearctic	chihuahuan	warm_deserts_or_semi_deserts
11007	nearctic	tamaulipan	warm_deserts_or_semi_deserts
11108	nearctic	great_basin	cold_winter_continental_deserts_and_semi_deserts
11209	nearctic	aleutian_islands	tundra_communities_and_barren_arctic_desert
11309	nearctic	alaska_tundra	tundra_communities_and_barren_arctic_desert
11409	nearctic	canadian_tundra	tundra_communities_and_barren_arctic_desert
11509	nearctic	arctic_archipelago	tundra_communities_and_barren_arctic_desert
11609	nearctic	greenland_tundra	tundra_communities_and_barren_arctic_desert
11709	nearctic	arctic_desert_and_icecap	tundra_communities_and_barren_arctic_desert
11811	nearctic	grasslands	temperate_grasslands
11912	nearctic	rocky_mountains	mixed_mountain_and_highland_systems_with_complex_zonation
12012	nearctic	sierra_cascade	mixed_mountain_and_highland_systems_with_complex_zonation
12112	nearctic	madrean_cordilleran	mixed_mountain_and_highland_systems_with_complex_zonation
12214	nearctic	great_lakes	lake_systems

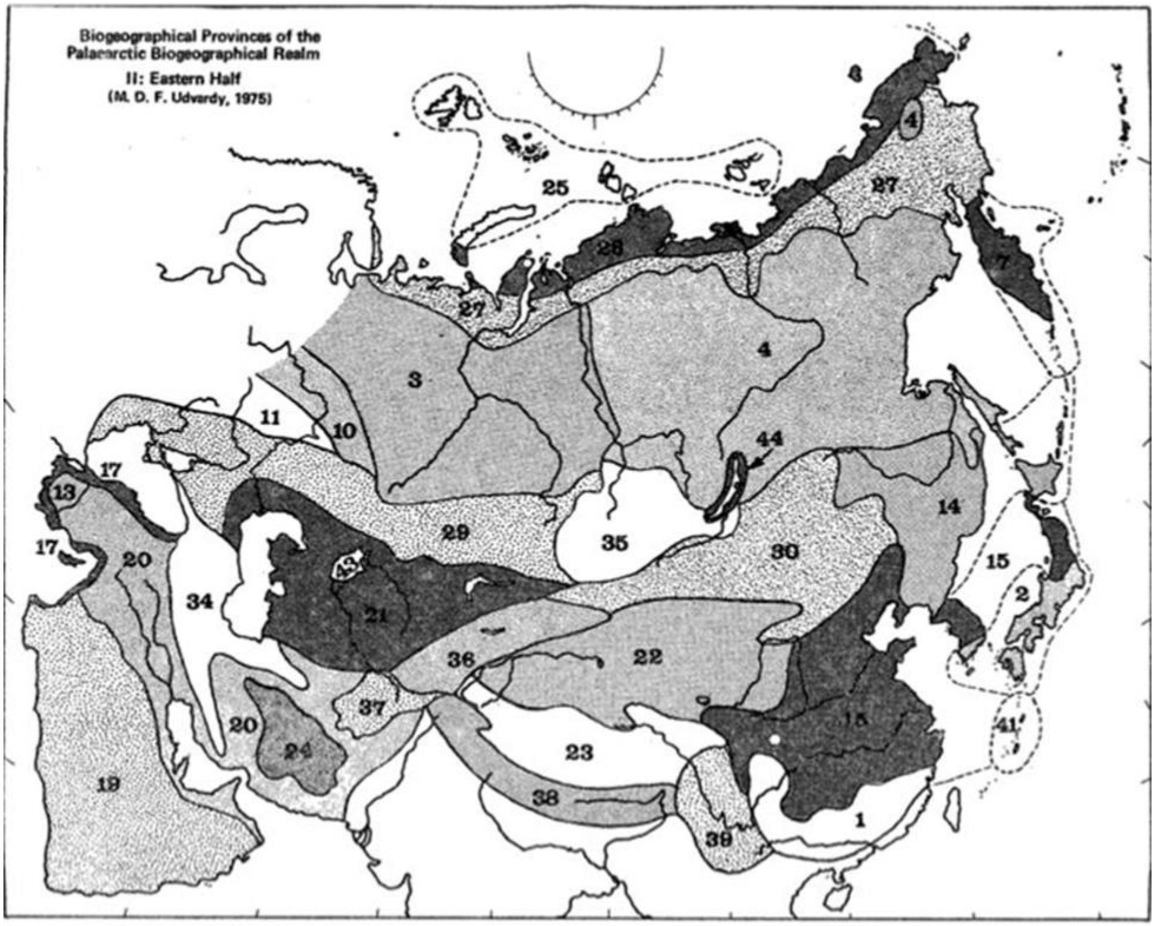
Palearctic Biogeographical Realm

The Palaearctic realm is divided into two parts: The Western half and the Eastern half

Western Half



Eastern Half

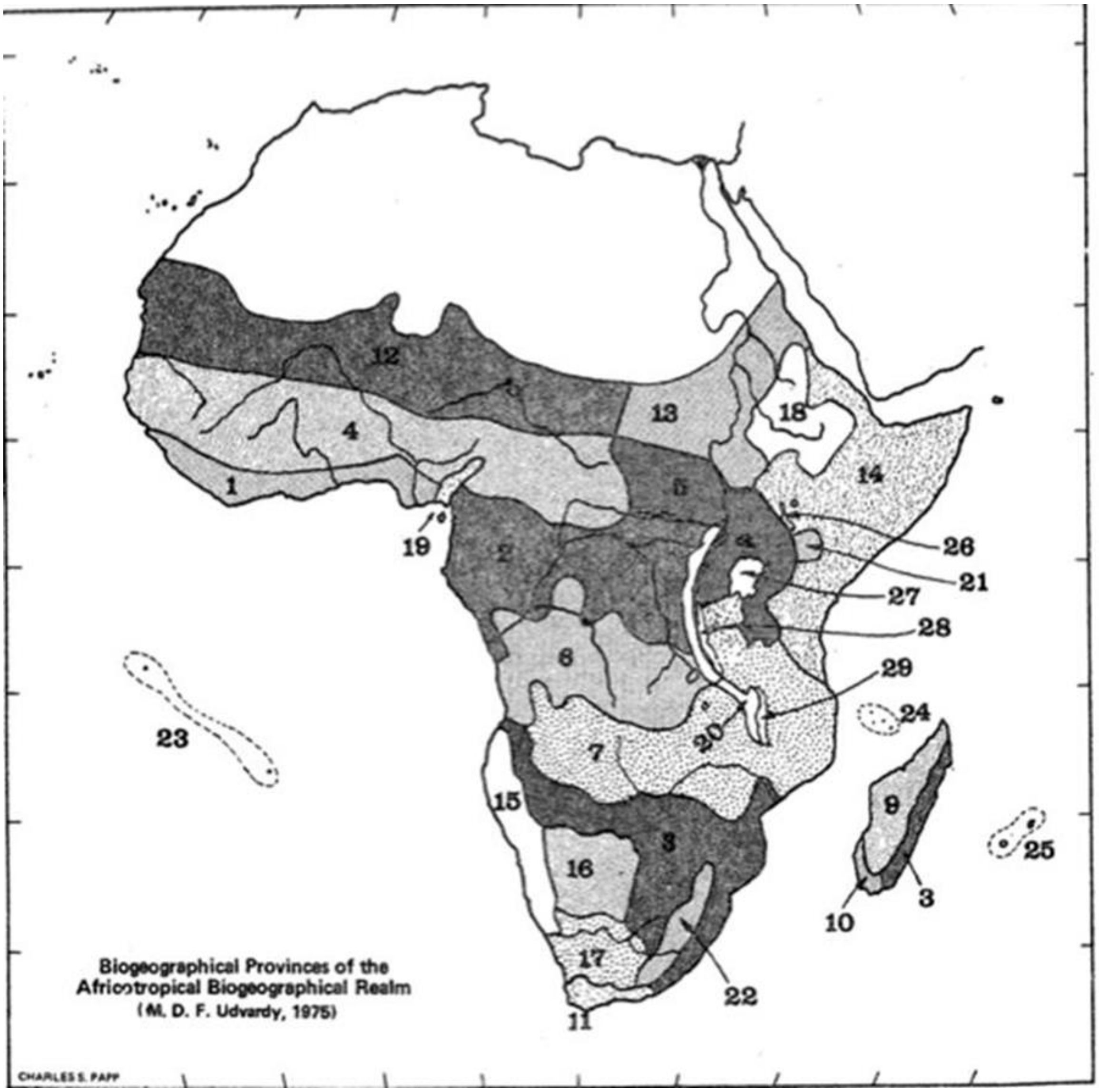


There are a total of 44 provinces in the Palearctic realm. There are presented in the following table. Each province is defined by its biome type.

RS_ID	realm	province	biome
20102	palearctic	chinese_subtropical_forest	subtropica_and_temperate_rain_forests_or_woodlands
20202	palearctic	japanese_evergreen_forest	subtropica_and_temperate_rain_forests_or_woodlands
20303	palearctic	west_eurasian_taiga	temperate_needle_leaf_forests_or_woodlands
20403	palearctic	east_siberian_taiga	temperate_needle_leaf_forests_or_woodlands
20505	palearctic	icelandian	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
20605	palearctic	subarctic_birchwoods	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
20705	palearctic	kamchatkan	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
20805	palearctic	british_islands	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
20905	palearctic	atlantic	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
21005	palearctic	boreonemoral	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
21105	palearctic	middle_european_forest	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
21205	palearctic	pannonian	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
21305	palearctic	west_anatolian	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
21405	palearctic	manchu_japanese_mixed_forest	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
21506	palearctic	oriental_deciduous_forest	evergreen_sclerophyllous_forests_scrubs_or_woodlands
21606	palearctic	iberian_highlands	evergreen_sclerophyllous_forests_scrubs_or_woodlands
21706	palearctic	mediterranean_sclerophyll	evergreen_sclerophyllous_forests_scrubs_or_woodlands
21807	palearctic	sahara	warm_deserts_or_semi_deserts
21907	palearctic	arabian_desert	warm_deserts_or_semi_deserts
22008	palearctic	anatolian_iranian_desert	cold_winter_continental_deserts_and_semi_deserts
22108	palearctic	turanian	cold_winter_continental_deserts_and_semi_deserts
22208	palearctic	takla_makan_gobi_desert	cold_winter_continental_deserts_and_semi_deserts
22308	palearctic	tibetan	cold_winter_continental_deserts_and_semi_deserts
22409	palearctic	iranian_desert	tundra_communities_and_barren_arctic_desert
22509	palearctic	arctic_desert	tundra_communities_and_barren_arctic_desert
22609	palearctic	higharctic_tundra	tundra_communities_and_barren_arctic_desert
22711	palearctic	lowarctic_tundra	temperate_grasslands
22811	palearctic	atlas_steppe	temperate_grasslands
22911	palearctic	pontian_steppe	temperate_grasslands
23011	palearctic	mongolian_manchurian_steppe	temperate_grasslands
23112	palearctic	scottish_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23212	palearctic	central_european_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23312	palearctic	balkan_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23412	palaearctic	caucaso_iranian_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23512	palaearctic	altai_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23612	palaearctic	pamir_tian_shan_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23712	palaearctic	hindu_kush_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23812	palaearctic	himalayan_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
23912	palaearctic	szechwan_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
24013	palaearctic	macaronesian_islands	mixed_island_systems
24113	palaearctic	ryukyu_islands	mixed_island_systems
24214	palaearctic	lake_ladoga	lake_systems
24314	palaearctic	aral_sea	lake_systems
24414	palaearctic	lake_baikal	lake_systems

Africotropical Biogeographical Realm

The Africotropical realm with its provinces is shown in the figure below.

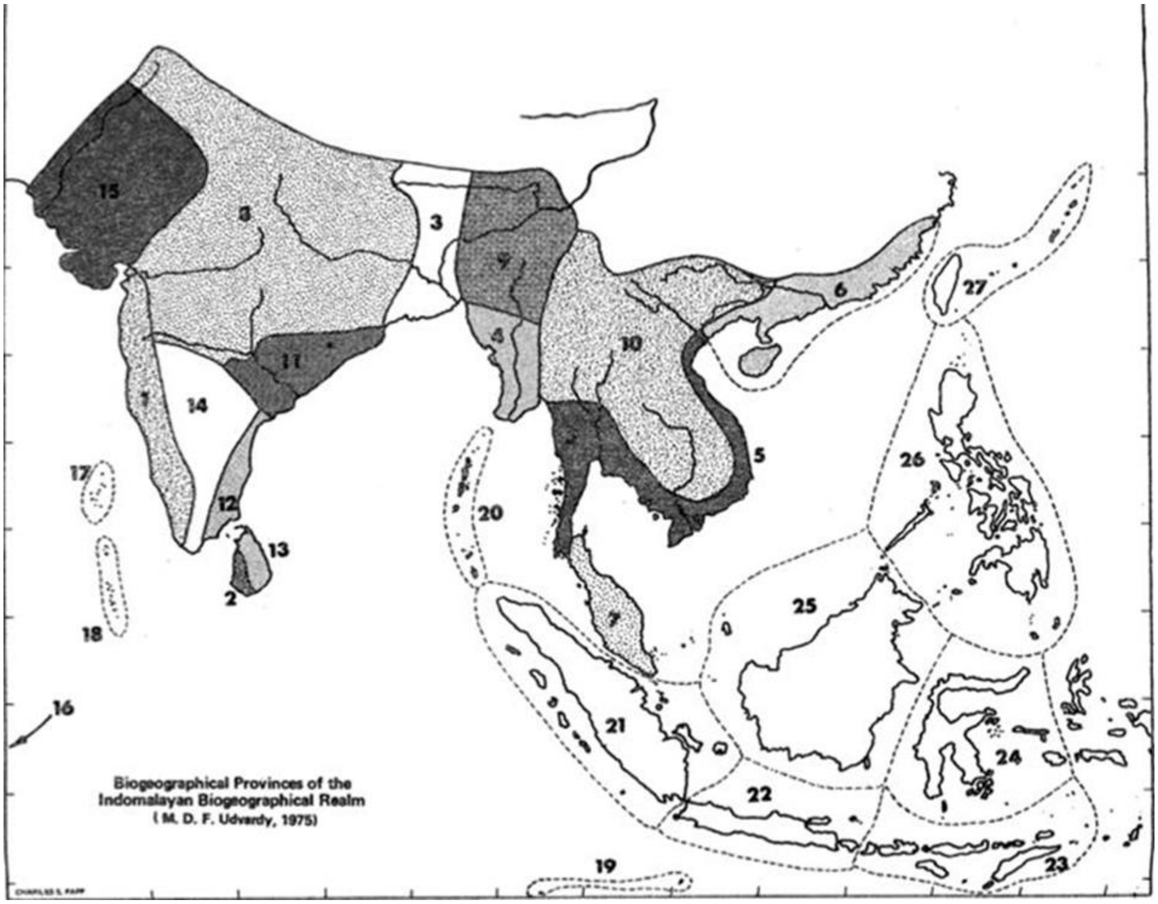


There are 29 provinces in the Africotropical realm. There are presented in the table below with their respective biome type.

RS_ID	realm	province	biome
30101	africotropical	guinean_rain_forest	tropical_humid_forests
30201	africotropical	congo_rain_forest	tropical_humid_forests
30301	africotropical	malagasy_rain_forest	tropical_humid_forests
30404	africotropical	west_african_woodland_savana	tropical_dry_or_deciduous_forests_or_woodlands
30504	africotropical	east_african_woodland_savana	tropical_dry_or_deciduous_forests_or_woodlands
30604	africotropical	congo_woodland_savana	tropical_dry_or_deciduous_forests_or_woodlands
30704	africotropical	miombo_woodland_savana	tropical_dry_or_deciduous_forests_or_woodlands
30804	africotropical	south_african_woodland_savana	tropical_dry_or_deciduous_forests_or_woodlands
30904	africotropical	malagasy_woodland_savana	tropical_dry_or_deciduous_forests_or_woodlands
31004	africotropical	malagasy_thorn_forest	tropical_dry_or_deciduous_forests_or_woodlands
31106	africotropical	cape_sclerophyll	evergreen_sclerophyllous_forests_scrubs_or_woodlands
31207	africotropical	western_sahel	warm_deserts_or_semi_deserts
31307	africotropical	eastern_sahel	warm_deserts_or_semi_deserts
31407	africotropical	somalian	warm_deserts_or_semi_deserts
31507	africotropical	namib	warm_deserts_or_semi_deserts
31607	africotropical	kalahari	warm_deserts_or_semi_deserts
31707	africotropical	karroo	warm_deserts_or_semi_deserts
31812	africotropical	ethiopian_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
31912	africotropical	guinean_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
32012	africotropical	central_african_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
32112	africotropical	east_african_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
32212	africotropical	south_african_highlands	mixed_mountain_and_highland_systems_with_complex_zonation
32313	africotropical	ascension_and_st_helene_islands	mixed_island_systems
32413	africotropical	comores_islands_and_aldabra	mixed_island_systems
32513	africotropical	mascarene_islands	mixed_island_systems
32614	africotropical	lake_rudolf	lake_systems
32714	africotropical	lake_ukerewe	lake_systems
32814	africotropical	lake_tanganyika	lake_systems
32914	africotropical	lake_malawi	lake_systems

Indomalayan Biogeographical Realm

The Indomalayan realm with its provinces is shown in the figure below.

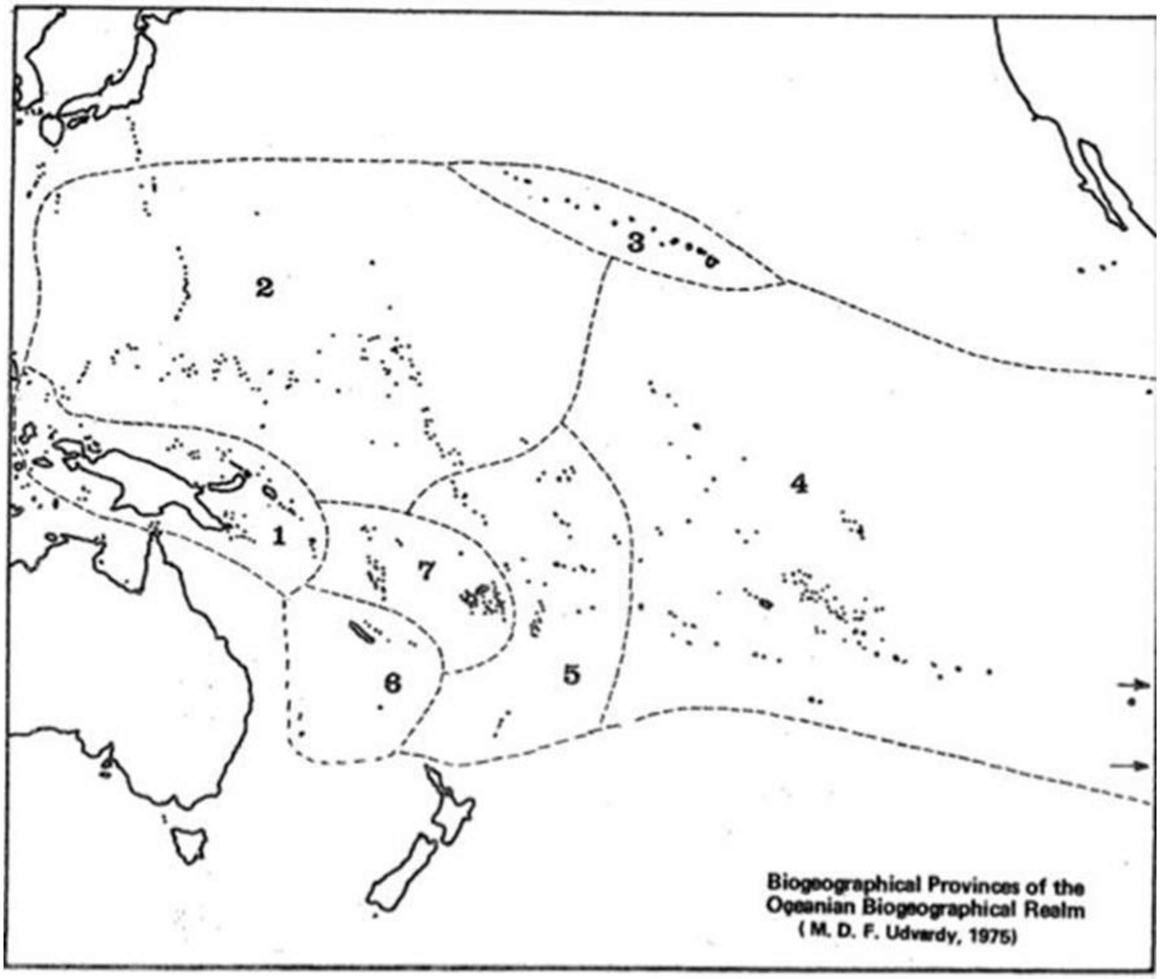


There are 27 provinces in the Indomalayan realm. There are presented in the table below with their respective biome type.

RS_ID	realm	province	biome
40101	indomalayan	malabar_rain_forest	tropical_humid_forests
40201	indomalayan	ceylonese_rain_forest	tropical_humid_forests
40301	indomalayan	bengalian_rain_forest	tropical_humid_forests
40401	indomalayan	burman_rain_forest	tropical_humid_forests
40501	indomalayan	indochinese_rain_forest	tropical_humid_forests
40601	indomalayan	south_chinese_rain_forest	tropical_humid_forests
40701	indomalayan	malayan_rain_forest	tropical_humid_forests
40804	indomalayan	indus_ganges_monsoon_forest	tropical_dry_or_deciduous_forests_or_woodlands
40904	indomalayan	burma_monsoon_forest	tropical_dry_or_deciduous_forests_or_woodlands
41004	indomalayan	thailandian_monsoon_forest	tropical_dry_or_deciduous_forests_or_woodlands
41104	indomalayan	mahanadian	tropical_dry_or_deciduous_forests_or_woodlands
41204	indomalayan	coromandel	tropical_dry_or_deciduous_forests_or_woodlands
41304	indomalayan	ceylonese_monsoon_forest	tropical_dry_or_deciduous_forests_or_woodlands
41404	indomalayan	deccan_thorn_forest	tropical_dry_or_deciduous_forests_or_woodlands
41507	indomalayan	thar_desert	warm_deserts_or_semi_deserts
41612	indomalayan	seychelles_and_amirantes_islands	mixed_mountain_and_highland_systems_with_complex_zonation
41712	indomalayan	laccadives_islands	mixed_mountain_and_highland_systems_with_complex_zonation
41812	indomalayan	maldives_and_chagos_islands	mixed_mountain_and_highland_systems_with_complex_zonation
41912	indomalayan	cocos_keeling_and_christmas_islands	mixed_mountain_and_highland_systems_with_complex_zonation
42012	indomalayan	andaman_and_nicobar_islands	mixed_mountain_and_highland_systems_with_complex_zonation
42112	indomalayan	sumatra	mixed_mountain_and_highland_systems_with_complex_zonation
42212	indomalayan	java	mixed_mountain_and_highland_systems_with_complex_zonation
42312	indomalayan	lesser_sunda_islands	mixed_mountain_and_highland_systems_with_complex_zonation
42412	indomalayan	celebes	mixed_mountain_and_highland_systems_with_complex_zonation
42512	indomalayan	borneo	mixed_mountain_and_highland_systems_with_complex_zonation
42612	indomalayan	philippines	mixed_mountain_and_highland_systems_with_complex_zonation
42712	indomalayan	taiwan	mixed_mountain_and_highland_systems_with_complex_zonation

Oceanian Biogeographical Realm

The Oceanian realm with its provinces is shown in the figure below.

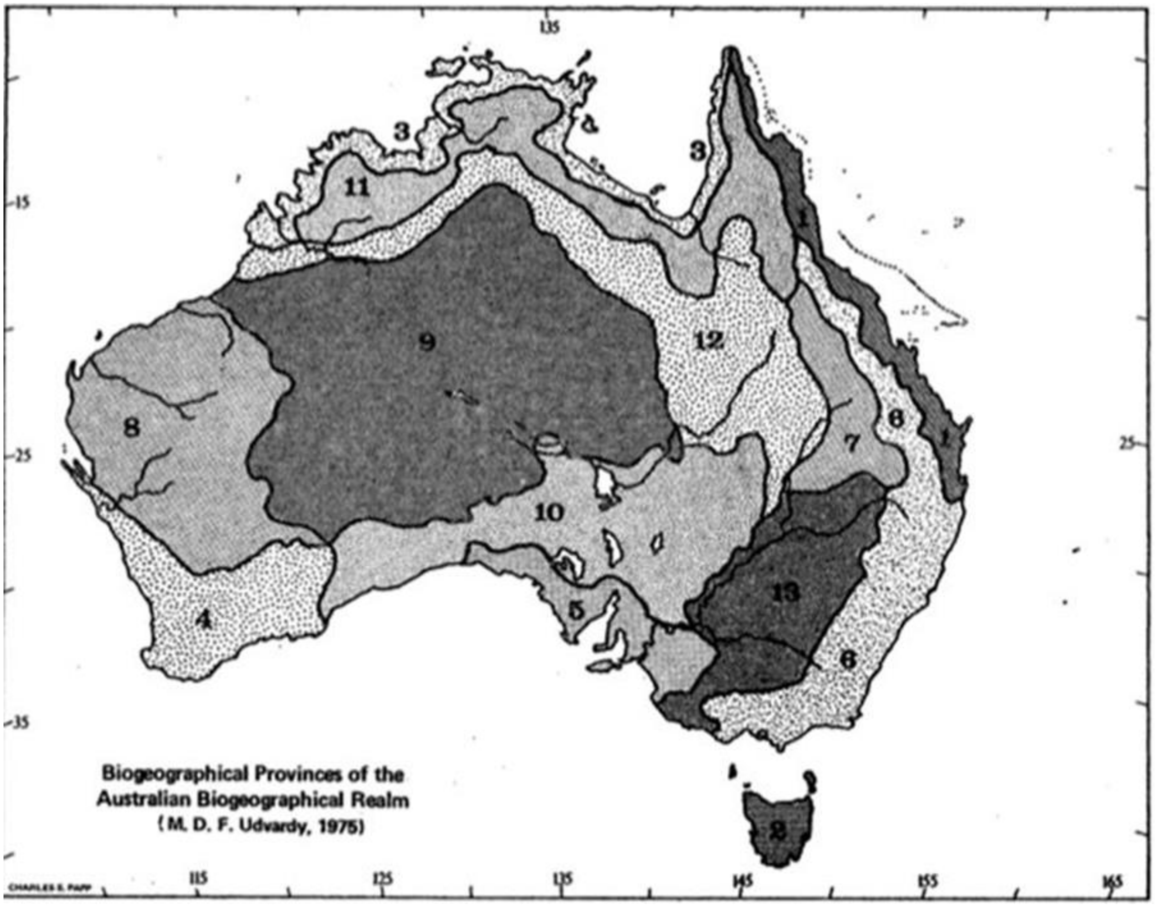


There are 7 provinces in the Oceanian realm. There are presented in the table below with their respective biome type.

RS_ID	realm	province	biome
50113	oceanian	papuan	mixed_island_systems
50213	oceanian	micronesian	mixed_island_systems
50313	oceanian	hawaiian	mixed_island_systems
50413	oceanian	southeastern_polynesian	mixed_island_systems
50613	oceanian	new_caledonian	mixed_island_systems
50713	oceanian	east_caledonian	mixed_island_systems

Australian Biogeographical Realm

The Australian realm with its provinces is shown in the figure below.

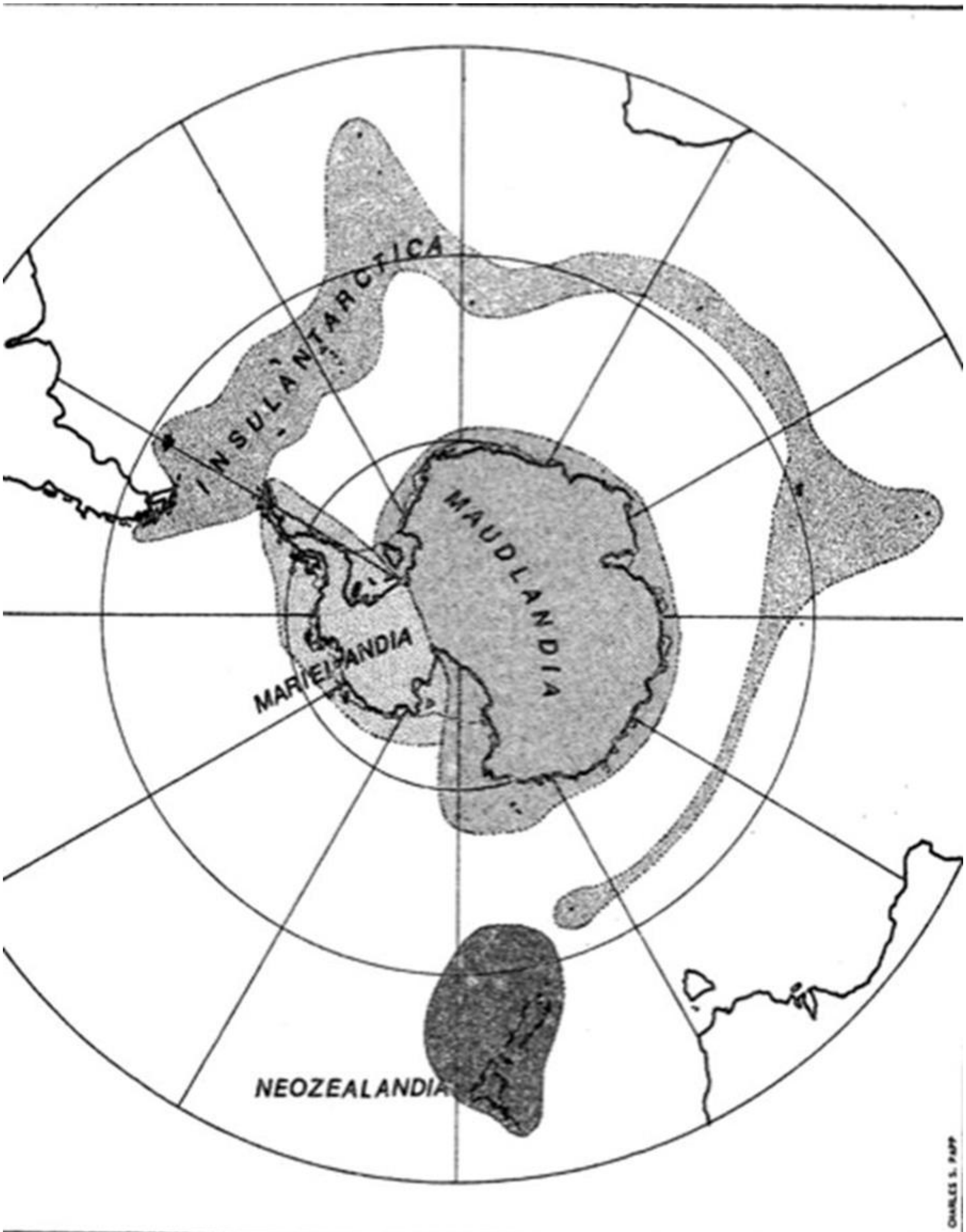


There are 13 provinces in the Australian realm. There are presented in the table below with their respective biome type.

RS_ID	realm	province	biome
60101	australian	quennsland_coastal	tropical_humid_forests
60202	australian	tasmanian	subtropica_and_temperate_rain_forests_or_woodlands
60304	australian	northern_coastal	tropical_dry_or_deciduous_forests_or_woodlands
60406	australian	western_sclerophyll	evergreen_sclerophyllous_forests_scrubs_or_woodlands
60506	australian	southern_sclerophyll	evergreen_sclerophyllous_forests_scrubs_or_woodlands
60606	australian	eastern_sclerophyll	evergreen_sclerophyllous_forests_scrubs_or_woodlands
60706	australian	brigalow	evergreen_sclerophyllous_forests_scrubs_or_woodlands
60807	australian	western_mulga	warm_deserts_or_semi_deserts
60907	australian	central_desert	warm_deserts_or_semi_deserts
61007	australian	southern_mulga_saltbush	warm_deserts_or_semi_deserts
61110	australian	northern_savana	tropical_grasslands_and_savannas
61210	australian	northern_grasslands	tropical_grasslands_and_savannas
61311	australian	eastern_grasslands_and_savana	temperate_grasslands

Antarctic Biogeographical Realm

The Antarctic realm with its provinces is shown in the figure below.

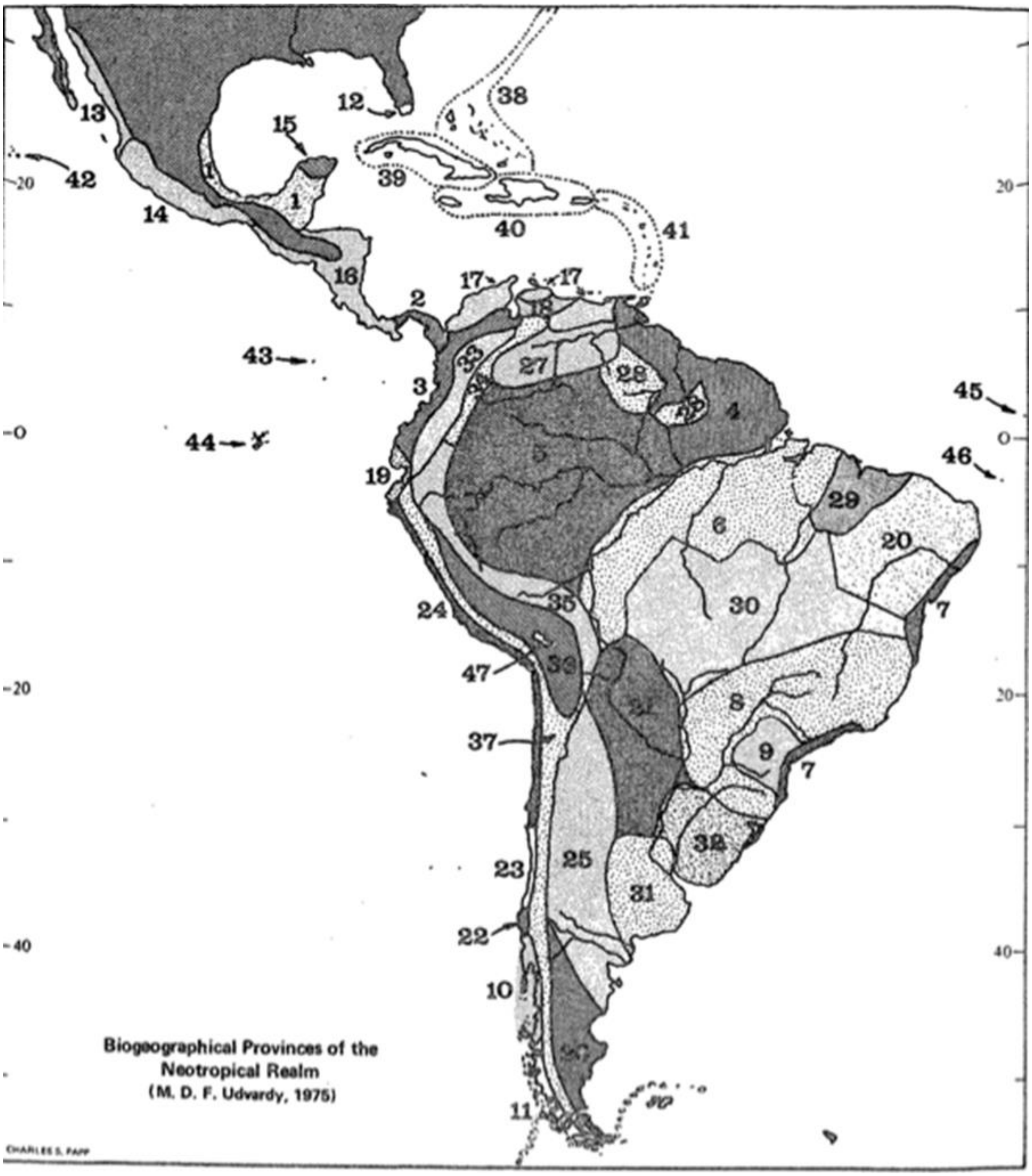


There are 4 provinces in the Australian realm. There are presented in the table below with their respective biome type.

RS_ID	realm	province	biome
70102	antarctic	neozealandia	subtropica_and_temperate_rain_forests_or_woodlands
70209	antarctic	maudlandia	tundra_communities_and_barren_arctic_desert
70309	antarctic	marielandia	tundra_communities_and_barren_arctic_desert
70409	antarctic	insulantarctica	tundra_communities_and_barren_arctic_desert

Neotropical Biogeographical Realm

The Neotropical realm with its provinces is shown in the figure below.



Biogeographical Provinces of the
Neotropical Realm
(M. D. F. Udvardy, 1975)

There are 47 provinces in the Neotropical realm. There are presented in the table below with their respective biome type.

RS_ID	realm	province	biome
80101	neotropical	campechean	tropical_humid_forests
80201	neotropical	panamanian	tropical_humid_forests
80301	neotropical	colombian_coastal	tropical_humid_forests
80401	neotropical	guyanan	tropical_humid_forests
80501	neotropical	amazonian	tropical_humid_forests
80601	neotropical	madeiran	tropical_humid_forests
80701	neotropical	serra_do_mar	tropical_humid_forests
80802	neotropical	brazilian_rain_forest	subtropica_and_temperate_rain_forests_or_woodlands
80902	neotropical	brazilian_planalto	subtropica_and_temperate_rain_forests_or_woodlands
81002	neotropical	valdivian_forest	subtropica_and_temperate_rain_forests_or_woodlands
81102	neotropical	chilean_nothofagus	tropical_dry_or_deciduous_forests_or_woodlands
81204	neotropical	everglades	tropical_dry_or_deciduous_forests_or_woodlands
81304	neotropical	sinaloan	tropical_dry_or_deciduous_forests_or_woodlands
81404	neotropical	guerreran	tropical_dry_or_deciduous_forests_or_woodlands
81504	neotropical	yucatecan	tropical_dry_or_deciduous_forests_or_woodlands
81604	neotropical	central_american	tropical_dry_or_deciduous_forests_or_woodlands
81704	neotropical	venezuelan_dry_forest	tropical_dry_or_deciduous_forests_or_woodlands
81804	neotropical	venezuelan_deciduous_fo	tropical_dry_or_deciduous_forests_or_woodlands
81904	neotropical	equadorian_dry_forest	tropical_dry_or_deciduous_forests_or_woodlands
82004	neotropical	caatinga	tropical_dry_or_deciduous_forests_or_woodlands
82104	neotropical	gran_chaco	temperate_broad_leaf_forests_or_woodlands_and_subpolar_deciduous_thickets
82205	neotropical	chilean_araucaria_forest	evergreen_sclerophyllous_forests_scrubs_or_woodlands
82306	neotropical	chilean_sclerophyll	warm_deserts_or_semi_deserts
82407	neotropical	pacific_desert	warm_deserts_or_semi_deserts
82507	neotropical	monte	warm_deserts_or_semi_deserts
82607	neotropical	patagonian	cold_winter_continental_deserts_and_semi_deserts
82710	neotropical	llanos	tropical_grasslands_and_savannas
82810	neotropical	campos_limpos	tropical_grasslands_and_savannas
82910	neotropical	babacu	tropical_grasslands_and_savannas
83010	neotropical	campos_cerrados	tropical_grasslands_and_savannas
83111	neotropical	argentinian_pampas	temperate_grasslands
83211	neotropical	uruguayan_pampas	temperate_grasslands
83312	neotropical	northern_andean	mixed_mountain_and_highland_systems_with_complex_zonation
83412	neotropical	colombian_montane	mixed_mountain_and_highland_systems_with_complex_zonation
83512	neotropical	yungas	mixed_mountain_and_highland_systems_with_complex_zonation
83612	neotropical	puna	mixed_mountain_and_highland_systems_with_complex_zonation
83712	neotropical	southern_andean	mixed_mountain_and_highland_systems_with_complex_zonation
83813	neotropical	bahamas_bermudan	mixed_island_systems
83913	neotropical	cuban	mixed_island_systems
84013	neotropical	greater_antillean	mixed_island_systems
84113	neotropical	lesser_antillean	mixed_island_systems
84213	neotropical	revilla_gigedo_island	mixed_island_systems
84313	neotropical	cocos_island	mixed_island_systems
84413	neotropical	galapagos_islands	mixed_island_systems
84513	neotropical	fernando_de_noronja_isla	mixed_island_systems
84613	neotropical	south_trinidade_island	mixed_island_systems
84714	neotropical	lake_titicaca	lake_systems

Appendix J: Database - Table of Developing Communities

community_id	Country_Name	County_Name	Community_Name	RS_ID	ST_ID	DWS_ID	WST_ID	MSW_ID
8	Morocco	Boulemane	Douar_Ait_Khabach	21706	311	344	0	0
7	Morocco	Boulemane	Douar_Chbite	21706	311	584	0	0
9	Morocco	Haouz	Douar_Ait_Bou_Ahmed	22811	311	232	0	0
11	Morocco	Haouz	Douar_Ait_Said	22811	311	96	0	0
10	Morocco	Haouz	Douar_Ait_Taschert	22811	311	228	0	0
6	Morocco	Sidi_Kacem	Douar_Lemlaqite	21706	311	222	0	0

Appendix K: Evaluation Performance DSS - Case Studies Developing Communities – Morocco

Data Collection – Developing Community

Community Name	Douar Lemlaqite – ADS #1450		
Country	Morocco		
Region	Province Sidi Kacem – commune Rmilate		
Regional Specificity	**Realm**	**Province**	**Biome**
	Palearctic	*Mediterranean Sclerophyllous*	*Woodland / Scrubland land*
RS_ID	021706		
Settlement Type	**Area**	**Formality**	**Density**
	Rural	Formal	low
ST_ID	311		
Population	1300		
MSS	**DWS**	**WST**	**MSW**
	X	-	-
	Watsan Technology Options		
DWS	drilled_well / submersible_pump / chlorination/ elevated_reservoir / domestic_connection DWS_ID: 222 TRL: 4 Specification pump: 5.5 hp with pump booster. DWS is installed at 1.8 km from village		
WST			
MSW			

Guideline CFA – DWS

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C_{11}	Sevice Level	< 20 l/d/c	20- 40 l/d/c	40 - 60 l/d/c	60 - 80 l/d/c	> 80 l/d/c	51
f_1	Score Service CF					$\Sigma C_{ij} w_j =$	**51**
2	**Institutional**						
C_{21}	Body of legislation	None	Basic	Intermediate	Complete	Advanced	25
C_{22}	Associated regulations	None	Basic	Intermediate	Complete	Advanced	20
C_{23}	Administrative agencies	None	National	Regional	District	Local	65
C_{24}	Administrative processes	None	Basic	Intermediate	Complete	Advanced	25
C_{25}	Governance	None	National	Regional	State	Local	81
f_3	Score Institutional CF					$\Sigma C_{ij} w_j =$	**43**
3	**Human Resources**						
C_{31}	Professionals	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	35
C_{32}	Skilled Labor	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technician	35
C_{33}	Unskilled Labor	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	35
C_{34}	Illiterate	Caretaker	Caretaker	Caretaker III			25
f_3	Score Human Resources CF					$\Sigma C_{ij} w_j =$	**33**
4	**Technical**						
C_{41}	Operations	Water use	Pumping water	Pumping water Read meters	Monitor pumping systems Read meters Control water quality	Monitor pumping systems Read meters Control water quality Monitor network	45
C_{42}	Maintenance	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	30
C_{43}	Adaptation	None	Rarely	Occasionally	Usually	Frequently	25
C_{44}	Supply Chain	None	National supplier	Regional supplier	Local supplier	Local supplier National manufacturer	45
f_4	Score Technical CF					$\Sigma C_{ij} w_j =$	**36**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
5	**Economic and Financial**						
C_{51}	Private sector %	None	International	National	Regional	Local	20
C_{52}	Bonds Rating	None	National	Regional	State	Local	10
C_{53}	User fees	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	50
C_{54}	Budget	None	Basic accounting	Annual	Quaterly	Monthly	35
C_{55}	Asset values	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	50
C_{56}	Debt	None	National	Rating (bb)	Rating (bbb)	Rating (a-aaa)	35
f_5	Score Economic / Financial CF					$\Sigma C_{ij} w_j =$	**33**
6	**Energy**						
C_{61}	Primary source	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	50
C_{62}	Back up	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	45
C_{63}	% of Budget	Vey high	High	Moderate	Low	Very low	45
C_{64}	Rate of outage	Very high	High	Moderate	Low	very low	42
f_6	Score Energy CF					$\Sigma C_{ij} w_j =$	**46**
7	**Environmental**						
C_{71}	Quality / Sensitivity:	Very low	Low	Moderate	High	Very high	45
C_{72}	Quantity / Availability	Very low	Low	Moderate	High	Very high	45
f_7	Score Environmental CF					$\Sigma C_{ij} w_j =$	**45**
8	**Social and Cultural**						
C_{81}	Communities	Very low	Low	Intermediate	High	Very high	45
C_{82}	Stability	Very low	Low	Intermediate	High	Very high	50
C_{83}	Equity	Very low	Low	Intermediate	High	Very high	50
C_{84}	Castes	Very high	High	Intermediate	Low	Very low	65
C_{85}	Participation of Women	Very low	Low	Intermediate	High	Very high	25
f_8	Score Social Cultural CF					$\Sigma C_{ij} w_j =$	**59**
		C_A = Management Level = Min(f_i)			**for i = 2 to 8**	**C_A =**	**33**

Data Collection – Developing Community

Community Name	Douar Chbite – ADS #1321		
Country	Morocco		
Region	Province Boulemane – commune Municipalite Boulemane		
Regional Specificity	**Realm**	**Province**	**Biome**
	Palearctic	*Mediterranean Sclerophyllous*	*Woodland / Scrubland land*
RS_ID	021706		
Settlement Type	**Area**	**Formality**	**Density**
	Rural	Formal	low
ST_ID	311		
Population	190		
MSS	**DWS**	**WST**	**MSW**
	X	-	-
	Watsan Technology Options		
DWS	springwater_collection / gravity / chlorination_in_piped_water_supply_system / reinforced_concrete_reservoir / domestic_connection DWS_ID: 584 TRL: 3		
WST			
MSW			

Guideline CFA – DWS

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C_{11}	**Sevice Level**	< 20 l/d/c	21 - 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	51
f_1	**Score Service Capacity**					$\Sigma C_{ij} w_j =$	**51**
2	**Institutional**						
C_{21}	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	10
C_{22}	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	10
C_{23}	**Administrative agencies**	None	National	Regional	District	Local	55
C_{24}	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	25
C_{25}	**Governance**	None	National	Regional	State	Local	85
f_3	**Score Institutional Capacity**					$\Sigma C_{ij} w_j =$	**37**
3	**Human Resources**						
C_{31}	**Professionals**	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	32
C_{32}	**Skilled Labor**	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technicican	20
C_{33}	**Unskilled Labor**	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	35
C_{34}	Illiterate	Caretaker I	Caretaker II	Caretaker III			35
f_3	**Score Human Resources CF**					$\Sigma C_{ij} w_j =$	**31**
4	**Technical**						
C_{41}	**Operations**	Water use	Pumping water	Pumping water Read meters	Monitor pumping systems Read meters Control water quality	Monitor pumping systems Read meters Control water quality Monitor network	50
C_{42}	**Maintenance**	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	35
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	25
C_{44}	**Supply Chain**	None	National supplier	Regional supplier	National manufacturer Regional supplier	National manufacturer Local supplier	45
f_4	**Score Technical CF**					$\Sigma C_{ij} w_j =$	**39**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
5	**Economic and Financial**						
C_{51}	**Private sector %**	None	International	National	Regional	Local	15
C_{52}	**Bonds Rating**	None	National	Regional	State	Local	10
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	50
C_{54}	**Budget**	None	Basic accounting	Annual	Quaterly	Monthly	35
C_{55}	**Asset values**	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	35
C_{56}	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	35
f_4	**Score Economic / Financial CF**					$\Sigma C_{ij} w_j =$	**30**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
6	**Energy Capacity**						
C_{61}	**Primary source**	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	30
C_{62}	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	20
C_{63}	**% of Budget**	Very high	High	Moderate	Low	Very Low	70
C_{64}	**Rate of outage**	Very High	High	Moderate	Low	very low	70
f_6	**Score Energy CF**					$\Sigma C_{ij} w_j =$	**48**
7	**Environmental Capacity**						
C_{71}	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	45
C_{72}	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	50
f_7	**Score Environmental CF**					$\Sigma C_{ij} w_j =$	**48**
8	**Social and Cultural**						
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	45
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	45
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	65
C_{84}	**Castes**	Very high	High	Intermediate	Low	Very low	65
C_{85}	**Participation of Women**	Very Low	Low	Intermediate	High	Very High	25
f_8	**Score Social Cultural CF**					$\Sigma C_{ij} w_j =$	**49**
		C_A = Management Level = Min(f_i)			**for i = 2 to 8**	**C_A =**	**30**

Data Collection – Developing Community

Community Name	Douar Ait Khabach – ADS #1354		
Country	Morocco		
Region	Province Boulemane – commune Guigou		
Regional Specificity	**Realm**	**Province**	**Biome**
	Palearctic	*Mediterranean Sclerophyllous*	*Woodland / Scrubland*
RS_ID	021706		
Settlement Type	**Area**	**Formality**	**Density**
	Rural	Formal	low
ST_ID	311		
Population	840		
MSS	**DWS**	**WST**	**MSW**
	X	-	-
	Watsan Technology Options		
DWS	dug_well, submersible_pump, chlorination, elevated_reservoir, domestic_connection DWS_ID: 344 - TRL: 3 pump: 10 hp power generator elevated reservoir: 48 m^3		
WST			
MSW			

Guideline CFA – DWS

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C_{11}	**Sevice Level**	< 20 l/d/c	20- 40 l/d/c	40 - 60 l/d/c	60 - 80 l/d/c	> 80 l/d/c	45
f_1	**Score Service CF**					$\Sigma C_{ij} w_j =$	**45**
2	**Institutional**						
C_{21}	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	25
C_{22}	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	30
C_{23}	**Administrative agencies**	None	National	Regional	State	Local	50
C_{24}	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	30
C_{25}	**Governance**	None	National	Regional	State	Local	81
f_3	**Score Institutional CF**					$\Sigma C_{ij} w_j =$	**43**
3	**Human Resources**						
C_{31}	**Professionals**	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	38
C_{32}	**Skilled Labor**	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technicican	35
C_{33}	**Unskilled Labor**	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	55
C_{34}	**Illiterate**	Caretaker I	Caretaker II	Caretaker III			35
f_3	**Score Human Resources CF**					$\Sigma C_{ij} w_j =$	**41**
4	**Technical**						
C_{41}	**Operations**	Water use	Pumping water	Pumping water Read meters	Monitor pumping systems Read meters Control water quality	Monitor pumping systems Control water quality Read meters Monitor network	55
C_{42}	**Maintenance**	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	35
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	35
C_{44}	**Supply Chain**	None	National supplier	Regional supplier	Local supplier	Local supplier National manufacturer	45
f_4	**Score Technical CF**					$\Sigma C_{ij} w_j =$	**43**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
5	**Economic and Financial**						
C_{51}	**Private sector %**	None	International	National	Regional	Local	20
C_{52}	**Bonds Rating**	None	National	Regional	State	Local	10
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	60
C_{54}	**Budget**	None	Basic accounting	Annual	Quaterly	Monthly	60
C_{55}	**Asset values**	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	55
C_{56}	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	38
f_5	**Score Economic / Financial CF**					$\Sigma C_{ij} w_j =$	**41**
	Capacity Factors	**1 - 20**	**21 - 40**	**41 - 60**	**61 - 80**	**81 - 100**	**Score**
6	**Energy**						
C_{61}	**Primary source**	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	30
C_{62}	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	45
C_{63}	**% of Budget**	Very high	High	Moderate	Low	Very Low	45
C_{64}	**Rate of outage**	Very High	High	Moderate	Low	very low	65
f_6	**Score Energy CF**					$\Sigma C_{ij} w_j =$	**46**
7	**Environmental**						
C_{71}	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	50
C_{72}	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	55
f_7	**Score Environmental CF**					$\Sigma C_{ij} w_j =$	**53**
8	**Social and Cultural**						
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	42
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	50
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	50
C_{84}	**Castes**	Very high	High	Intermediate	Low	Very low	65
C_{85}	**Participation of Women**	Very Low	Low	Intermediate	High	Very High	25
f_8	**Score Social Cultural CF**					$\Sigma C_{ij} w_j =$	**46**

		C_A = Management Level = Min(f_i)	**for i = 2 to 8**	**C_A =**	**41**

Data Collection – Developing Community

Community Name	Douar Ait Bou Ahmed – ADS #337		
Country	Morocco		
Region	Province Haouz – Commune Oulad Mtaa		
Regional Specificity	**Realm**	**Province**	**Biome**
	Palearctic	Atlas_steppe	Temperate_grasslands
RS_ID	022811		
Settlement Type	**Area**	**Formality**	**Density**
	rural	Formal	low
ST_ID	311		
Population	800		
MSS	**DWS**	**WST**	**MSW**
	X		
	Watsan Technology Options		
DWS	drilled_well / submersible_pump / domestic_chlorination / elevated_reservoir / domestic_connection DWS_ID: 232 – TRL: 3 well: 160 m submersible_pump: 7.5 hp elevated reservoir: 12 m		
WST			
MSW			

Guideline CFA – DWS

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C_{11}	**Sevice Level**	< 20 l/d/c	20- 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	30
f_1	**Score Service CF**					$\Sigma C_{ij} w_j =$	**30**
2	**Institutional**						
C_{21}	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	20
C_{22}	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	17
C_{23}	**Administrative agencies**	None	National	Regional	State	Local	50
C_{24}	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	35
C_{25}	**Governance**	None	National	Regional	State	Local	90
f_3	**Score Institutional CF**					$\Sigma C_{ij} w_j =$	**42**
3	**Human Resources**						
C_{31}	**Professionals**	None	Accountant	Administrative supervisor	Administrative manager	Administrative manager	38
				Health scientist	Health scientist	Health scientist	
				Accountant	Accountant	Accountant	
					Engineer	Engineer	
						Public relations manager	
						Lawyer	
C_{32}	**Skilled Labor**	None	Mechanic	Maintenance technician	Maintenance technician	Maintenance technician	35
				Laboratory technician	Laboratory technician	Laboratory technician	
				Water systems operator	Water systems operator	Water systems operator	
				Water meter reader	Health inspector	Health inspector	
					Administrative assistant	Administrative assistant	
					Water meter leader	Water meter leader	
						IT technicican	
C_{33}	**Unskilled Labor**	Craftsman	Clerk	Clerk	Clerk	Clerk	55
			plumber	Water systems worker I	Water systems worker II	Water systems worker III	
C_{34}	**Illiterate**	Caretaker I	Caretaker II	Caretaker III			35
f_3	**Score Human Resources CF**					$\Sigma C_{ij} w_j =$	**41**
4	**Technical**						
C_{41}	**Operations**	Water use	Pumping water	Pumping water	Monitor pumping systems	Monitor pumping systems	50
				Read meters	Read meters	Read meters	
					Control water quality	Control water quality	
						Monitor network	
C_{42}	**Maintenance**	None	Clean water systems	Check water systems	Maintain water systems	Maintain water systems	30
			Minor repair	Major repair	Major repair	Major repair	
					Maintain water meter	Maintain water meter	
						Maintain IT systems	
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	45
C_{44}	**Supply Chain**	None	National supplier	Regional supplier	Local supplier	Local supplier	45
						National manufacturer	
f_4	**Score Technical CF**					$\Sigma C_{ij} w_j =$	**43**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
5	**Economic and Financial**						
C_{51}	**Private sector %**	None	International	National	Regional	Local	30
C_{52}	**Bonds Rating**	None	National	Regional	State	Local	5
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	55
C_{54}	**Budget**	None	Basic accounting	Annual	Quaterly	Monthly	70
C_{55}	**Asset values**	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	60
C_{56}	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	35
f_5	**Score Economic / Financial CF**					$\Sigma C_{ij} w_j =$	**43**
6	**Energy**						
C_{61}	**Primary source**	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	50
C_{62}	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	10
C_{63}	**% of Budget**	Very high	High	Moderate	Low	Very Low	50
C_{64}	**Rate of outage**	Very High	High	Moderate	Low	very low	55
f_6	**Score Energy CF**					$\Sigma C_{ij} w_j =$	**41**
7	**Environmental**						
C_{71}	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	50
C_{72}	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	45
f_7	**Score Environmental CF**					$\Sigma C_{ij} w_j =$	**48**
8	**Social and Cultural**						
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	65
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	70
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	65
C_{84}	**Castes**	Very high	High	Intermediate	Low	Very low	82
C_{85}	**Participation of Women**	Very Low	Low	Intermediate	High	Very High	25
f_8	**Score Social Cultural CF**					$\Sigma C_{ij} w_j =$	**61**

	C_A = Management Level = Min(f_i)	**for i = 2 to 8**	**C_A =**	**41**

Data Collection – Developing Community

Community Name	Douar Dar Taschert – ADS #348		
Country	Morocco		
Region	Province Al Haouz – Commune Dar Jamaa		
Regional Specificity	**Realm**	**Province**	**Biome**
	Palearctic	Atlas_steppe	Temperate_grasslands
RS_ID	022811		
Settlement Type	**Area**	**Formality**	**Density**
	Rural	Formal	low
ST_ID	311		
Population	840		
MSS	**DWS**	**WST**	**MSW**
	X		
	Watsan Technology Options		
DWS	Drilled_well / submersible_pump/ chlorination_in_piped_water_supply_system / reinforced_concrete_reservoir / domestic_connection DWS_ID: 228 – TRL: 3 Well: 50 m Pump: 5.5 hp		
WST			
MSW			

Guideline CFA – DWS

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C_{11}	**Sevice Level**	< 20 l/d/c	21 - 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	45
f_1	**Score Service CF**					$\Sigma C_{ij} W_j =$	**45**
2	**Institutional**						
C_{21}	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	5
C_{22}	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	30
C_{23}	**Administrative agencies**	None	National	Regional	State	Local	55
C_{24}	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	55
C_{25}	**Governance**	None	National	Regional	State	Local	85
f_3	**Score Institutional CF**					$\Sigma C_{ij} W_j =$	**46**
3	**Human Resources**						
C_{31}	**Professionals**	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	37
C_{32}	**Skilled Labor**	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technicican	35
C_{33}	**Unskilled Labor**	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	55
C_{34}	**Illiterate**	Caretaker I	Caretaker II	Caretaker III			35
f_3	**Score Human Resources CF**					$\Sigma C_{ij} W_j =$	**41**
4	**Technical**						
C_{41}	**Operations**	Water use	Pumping water	Pumping water Read meters	Monitor pumping systems Read meters Control water quality	Monitor pumping systems Read meters Control water quality Monitor network	50
C_{42}	**Maintenance**	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	35
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	45
C_{44}	**Supply Chain**	None	National supplier	Regional supplier	Local supplier	Local supplier National manufacturer	55
f_4	**Score Technical CF**					$\Sigma C_{ij} W_j =$	**46**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
5	**Economic and Financial**						
C_{51}	**Private sector %**	None	International	National	Regional	Local	20
C_{52}	**Bonds Rating**	None	National	Regional	State	Local	10
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	55
C_{54}	**Budget**	None	Basic accounting	Annual	Quaterly	Monthly	75
C_{55}	**Asset values**	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	55
C_{56}	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	35
f_5	**Score Economic / Financial CF**					$\Sigma C_{ij} w_j =$	**42**
6	**Energy**						
C_{61}	**Primary source**	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	45
C_{62}	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	5
C_{63}	**% of Budget**	Very high	High	Moderate	Low	Very Low	55
C_{64}	**Rate of outage**	Very High	High	Moderate	Low	very low	65
f_6	**Score Energy CF**					$\Sigma C_{ij} w_j =$	**43**
7	**Environmental**						
C_{71}	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	45
C_{72}	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	65
f_7	**Score Environmental CF**					$\Sigma C_{ij} w_j =$	**55**
8	**Social and Cultural**						
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	65
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	65
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	70
C_{84}	**Castes**	Very high	High	Intermediate	Low	Very low	85
C_{85}	**Participation of Women**	Very Low	Low	Intermediate	High	Very High	21
f_8	**Score Social Cultural CF**					$\Sigma C_{ij} w_j =$	**61**
		C_A = Management Level = Min(f_i)			**for i = 2 to 8**	**C_A =**	**41**

Data Collection – Developing Community

Community Name	Douar Ait Said – ADS #325		
Country	Morocco		
Region	Province Haouz – commune Lalla Takerkoust		
Regional Specificity	**Realm**	**Province**	**Biome**
	Palearctic	Atlas Steppe	Temperate grassland
RS_ID	022811		
Settlement Type	**Area**	**Formality**	**Density**
	Rural	Formal	Low
ST_ID	311		
Population	330		
MSS	**DWS**	**WST**	**MSW**
	X		
	Watsan Technology Options		
DWS	Drilled_well / centrifugal_pump / elevated_reservoir / domestic_chlorination / domestic_connection DWS_ID: 96 – TRL: 3 Well in river: 31 m Power generator		
WST			
MSW			

Guideline CFA – DWS

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
1	**Service**						
C_{11}	**Sevice Level**	< 20 l/d/c	21 - 40 l/d/c	41 - 60 l/d/c	61 - 80 l/d/c	> 81 l/d/c	25
f_1	**Score Service CF**					$\Sigma C_{ij} w_j =$	**25**
2	**Institutional**						
C_{21}	**Body of legislation**	None	Basic	Intermediate	Complete	Advanced	10
C_{22}	**Associated regulations**	None	Basic	Intermediate	Complete	Advanced	30
C_{23}	**Administrative agencies**	None	National	Regional	State	Local	55
C_{24}	**Administrative processes**	None	Basic	Intermediate	Complete	Advanced	32
C_{25}	**Governance**	None	National	Regional	State	Local	85
f_3	**Score Institutional CF**					$\Sigma C_{ij} w_j =$	**42**
3	**Human Resources**						
C_{31}	**Professionals**	None	Accountant	Administrative supervisor Health scientist Accountant	Administrative manager Health scientist Accountant Engineer	Administrative manager Health scientist Accountant Engineer Public relations manager Lawyer	32
C_{32}	**Skilled Labor**	None	Mechanic	Maintenance technician Laboratory technician Water systems operator Water meter reader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader	Maintenance technician Laboratory technician Water systems operator Health inspector Administrative assistant Water meter leader IT technicican	35
C_{33}	**Unskilled Labor**	Craftsman	Clerk plumber	Clerk Water systems worker I	Clerk Water systems worker II	Clerk Water systems worker III	35
C_{34}	**Illiterate**	Caretaker I	Caretaker II	Caretaker III			20
f_3	**Score Human Resources CF**					$\Sigma C_{ij} w_j =$	**31**
4	**Technical**						
C_{41}	**Operations**	Water use	Pumping water	Pumping water Read meters	Monitor pumping systems Read meters Control water quality	Monitor pumping systems Read meters Control water quality Monitor network	45
C_{42}	**Maintenance**	None	Clean water systems Minor repair	Check water systems Major repair	Maintain water systems Major repair Maintain water meter	Maintain water systems Major repair Maintain water meter Maintain IT systems	35
C_{43}	**Adaptation**	None	Rarely	Occasionally	Usually	Frequently	45
C_{44}	**Supply Chain**	None	National supplier	Regional supplier	Local supplier	Local supplier National manufacturer	45
f_4	**Score Technical CF**					$\Sigma C_{ij} w_j =$	**43**

	Capacity Factors	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100	Score
5	**Economic and Financial**						
C_{51}	**Private sector %**	None	International	National	Regional	Local	10
C_{52}	**Bonds Rating**	None	National	Regional	State	Local	35
C_{53}	**User fees**	None	Uniform flat rate	Single block rate	Increasing block rate	Diversified rate	50
C_{54}	**Budget**	None	Basic accounting	Annual	Quaterly	Monthly	65
C_{55}	**Asset values**	None	Equipement	Equipement Real estate	Equipement Real estate Cash	Equipement Real estate Cash Stocks	50
C_{56}	**Debt**	None	National	Rating (bb)	Rating (bbb)	Rating (a-aa)	35
f_5	**Score Economic / Financial CF**					$\Sigma C_{ij} w_j =$	**41**
6	**Energy**						
C_{61}	**Primary source**	None	Non conventional	Conventional electricity	Low voltage electricity	Mid voltage electricity	30
C_{62}	**Back up**	None	Generator < 5 HP	Generator < 10 HP	Generator < 25 HP	Generator > 25 HP	5
C_{63}	**% of Budget**	Very high	High	Moderate	Low	Very Low	45
C_{64}	**Rate of outage**	Very High	High	Moderate	Low	very low	85
f_6	**Score Energy CF**					$\Sigma C_{ij} w_j =$	**41**
7	**Environmental**						
C_{71}	**Quality / Sensitivity:**	Very low	Low	Moderate	High	Very high	45
C_{72}	**Quantity / Availability**	Very low	Low	Moderate	High	Very high	45
f_7	**Score Environmental CF**					$\Sigma C_{ij} w_j =$	**45**
8	**Social and Cultural**						
C_{81}	**Communities**	Very low	Low	Intermediate	High	Very high	65
C_{82}	**Stability**	Very low	Low	Intermediate	High	Very high	35
C_{83}	**Equity**	Very low	Low	Intermediate	High	Very high	65
C_{84}	**Castes**	Very high	High	Intermediate	Low	Very low	85
C_{85}	**Participation of Women**	Very Low	Low	Intermediate	High	Very High	10
f_8	**Score Social Cultural CF**					$\Sigma C_{ij} w_j =$	**52**

		C_A = Management Level = Min(f_i)	**for i = 2 to 8**	**C_A =**	**31**