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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

WATER SUPPLY AND ENVIRONMENTAL ENGINEERING STREAM

Decision Support System Tool for the Evaluation of Sustainability of Rural Water Supply Services

By

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Advisor

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The undersigned have examined the thesis entitled DECISION SUPPORT SYSTEM TOOL FOR THE EVALUATION OF SUSTAINABILITY OF RURAL WATER SUPPLY SERVICES presented by **Alazar Negash**, a candidate for the degree of Master of Science and hereby certify that it is worthy of acceptance.

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Abstract

Since the globe managed to deliver the Sustainable Development Goals (SDGs) to the platform to replace the Millennium Development Goals (MDGs), Sustainability has become a global concern. Even though the world achieved in meeting the MDG target for drinking water, we have to sustain the water supply services, especially the rural water supply services to ensure a change in the livelihood of the rural poor.

The main objective of this study is to formulate a DSS tool that can aid the rural water supply engineer and planner in decision making regarding to the sustainability of rural water supply services.

Three modules that comprises functionalities for data input, data analysis (data query) and display of results are employed in the computer program development using visual basic programming language by Microsoft Visual Studio Express. A user-friendly interface helps the navigation of the software easy. The DSS tool identifies the sustainability status of a particular water supply services and further goes to identify the factors behind it from the most affecting factor to the least affecting factor in a descending order. The DSS tool further scrutinizes and contrasts between different water supply sources in a district to decide which water source is more sustainable than other water sources presented in a woreda/district.

The Rural Water Supply Sustainability Evaluation DSS tool is applied on specific sites. The results are sustainability scoring values per the FIETS factor, per date, location and per administrative area (zone, district or sub-district levels).The results show increased social participation contributing to increased sustainability, schemes with distribution are more sustainable than isolated on spot schemes and increased cost recovery of the services contributing to increased sustainability of the rural water supply services.

It is recommended that, community contribution and social participation, ensuring cost recovery and developing services with distribution schemes than isolated spot schemes should be practiced to ensure sustainability of rural water supply services.

This thesis work is dedicated to my parents, Yimenashu Getaneh and Negash Horecha.

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First and Foremost, I present my praise to my saviour and God, for that he is my strength, my joy, my life, my all and without him, I would fall.

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Acronyms

DALYs-Disability Adjusted Life Years

DSS-Decision Support System

FDRE-Federal Democratic Republic of Ethiopia

GoE- Government of Ethiopia

JMP-Joint Monitoring Program of WHO/UNICEF for water supply and sanitation

lpcd- litres per capita per day

MDGs-Millennium Development Goals

MOWE-Ministry of Water and Energy

O&M-Operation and Maintenance

RWSN-Rural Water Supply Network

RWSS-Rural Water Supply Services

SDGs-Sustainable Development Goals

USD$-United States Dollar

UNDP-United Nations Development Program

UNICEF-United Nations Children's Fund

WaSH-Water Supply, Sanitation and Hygiene

WaSHCO-Water Supply, Sanitation and Hygiene Committee

WHO-World Health Organization

WIF-WaSH Implementation Framework

1 Introduction

Sustainability has emerged as a major issue as the global rally of the Millennium Development Goals ended in 2015. World attentions are turned towards the post-2015 agenda to deliver the Sustainable Development Goals (SDGs), sustainability being a global concern. The transformation of the globe's rally from the MDGs to the SDGs is no surprise because; it is the lack of sustainable development that endangers the world right now and the world tomorrow.

It was in 2000 that the MDGs were officially established following the Millennium Summit, where all 189 United Nations member states adopted the United Nations Millennium Declaration, from which the development goals were derived. With eight international development goals, 21 targets, and a series of measurable indicators for each target, the MDGs have been a platform of a global effort towards improving social and economic conditions in the world's poorest countries (United Nations General Assembly, 2001).

Halving, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation was the third target from the MDG-7 (ensure environmental sustainability) and the tenth target out of all the 21 targets of the MDGs. Being so, sustainability of water supply and sanitation has remained a top priority in improving the livelihood of the rural poor (United Nations General Assembly, 2001).

The MDGs drinking water targets are achieved by 147 countries, and 95 countries achieved the MDG sanitation target. Whereas, 77 countries managed to meet both the MDG water and sanitation target. Though this figure shows that the world still needs improvement in sanitation, the MDG achievements are remarkable and brought out changes in the past 15 years (JMP, 2015).

From the seventeen goals of the SDG, the one that describes the goal of water and sanitation-goal 6 thrives to achieve universal and equitable access to safe and affordable drinking water for all by 2030. It further outline the importance of integrated water resource management at all levels which this thesis tries to incorporate (United Nations General Assembly, 2015).

Global rallies such as the MDGs and SDGs involve different sectors for collaboration and hence need integration and sectorial coordination for their fulfilments. According to (Walsh, 1993), Decision Support Systems enables decision makers to tackle problems and reach optimal solutions in an integrated approach. Hence application of DSS should be practiced in supporting global rallies such as MDGs and SDGs.

Ensuring Sustainable water services in the rural areas has always been a significant difficulty and a researchable area .The decision problems arising from this such as deciding which rural water source is more sustainable over the others are as much challenging as the problem itself since analysing the different constraints of technical, social and financial background needs a careful literature review and thorough investigation.

Having a decision support system that can aid decision making regarding which water service is more sustainable over the other and which government district is doing a good management set of practices over the other to exchange best practices.

There are a number of DSSs addressing sustainability of rural WASH services of which about 25 of them are assessed in this thesis's literature review. From the reviewed literature, there is only one done with Ethiopian context which is (Gebrie, 2012).This thesis will add its contribution for more works that can address the rural Ethiopian context.

The main purpose of this thesis is to develop a decision support system tool that can assist engineers and planners in identifying the factors behind the sustainability of rural water supply services by integrating technical, financial, social, institutional and environmental aspects.

2 Statement of the Problem

Even though the global MDG target for drinking water was met in 2010 prior to the deadline (2015), 16% of the rural population of the world and 51% of the rural population in Ethiopia is without improved drinking water and eight out of ten people still lives without improved drinking water sources in rural areas (JMP, 2015).

As poor as it is sustainability of rural water supply services in sub Saharan Africa is a problem and an economic deficit. The problem ranges from all kinds of factors, from the technical insufficiency to the financial incapability, the social in cooperativity and lack of management with the institutions and water boards to the lack of access and availability of water to the rural poor in the environmental aspects. To address this problems a number of studies such as (Lockwood, et al., 2003), (Denis, 2013) and (DWA,IRC, 2014) found that there is a dire need of addressing the multiple factors with integrated DSS tools.

A global study on 126,251 water points from 37 countries showed that 20% are non-functional and 10% are functional with problems (Akvo, 2015).According to (Ellert, et al., 2013), 30 to 40 percent of rural water supply systems in Africa are not functioning at any time. With average of 36% and 60% in some places, hand pumps in sub Saharan Africa are non-operational (JMP, 2011; RWSN, 2008). The causing factors for this could arise from different multiple aspects and include limited demand , lack of affordability, limited sustainability of community management structures, inadequate supply chains for equipment and spare parts, insufficient government support and environmental issues (Harvey, 2008).

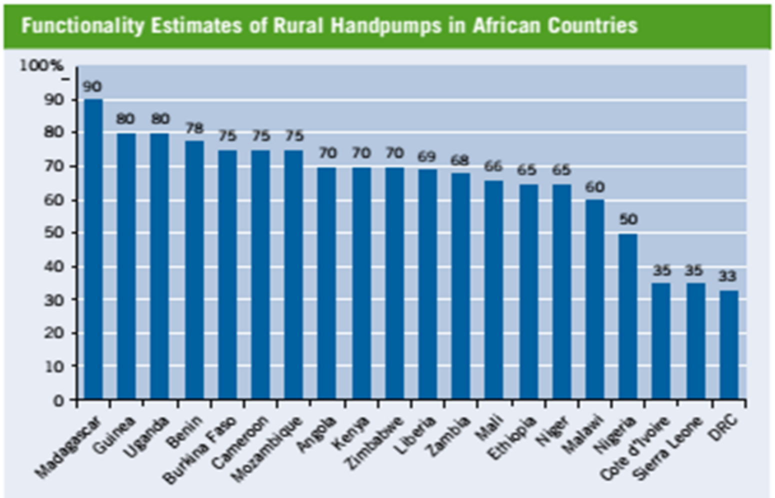

Figure 1 Functionality Estimates of Rural Hand pumps in African Countries, Adapted from (Ellert, et al., 2013) (RWSN, 2010)

A survey done by European court of auditors in six sub-Saharan countries found that rural water supply projects were sustainable in terms of technical terms where the installed equipment working properly but have problems in meeting the beneficiaries' needs and a non-tariff revenue have to be ensured in addition to institutional strength (European Court of Auditors, 2012).

The sustainability of rural water supply services is poor in Ethiopia like all Sub-Saharan Africa countries. In 2010 the Ministry of Water, Irrigation and Energy has reported non-functionality levels of rural water schemes in 10 regions ranging from 18% to 35% with an average 20% non-functionality:

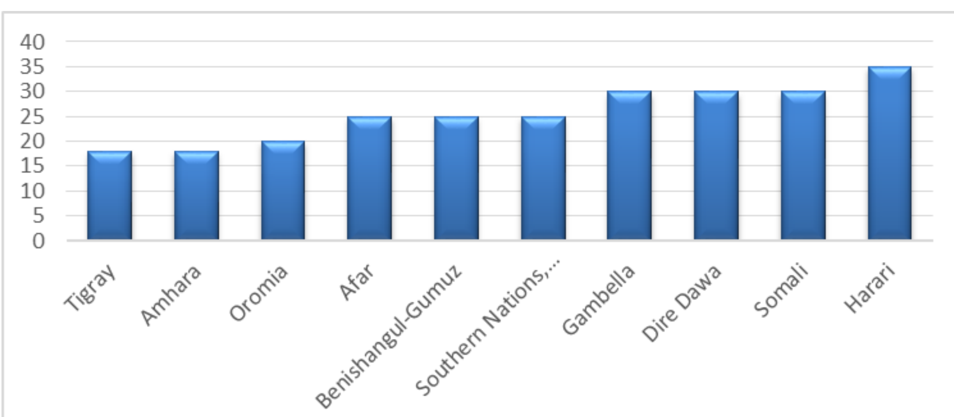

Figure 2 Regional Non-Functionality of Schemes for the Base Line Year 2010.Source (MOWE, 2011)

An evaluation conducted on 2015 by tetra-tech showed that 43% of hand pumps studied in Amhara, Oromia and Tigray regions are non-functional (Tetra Tech, 2015).

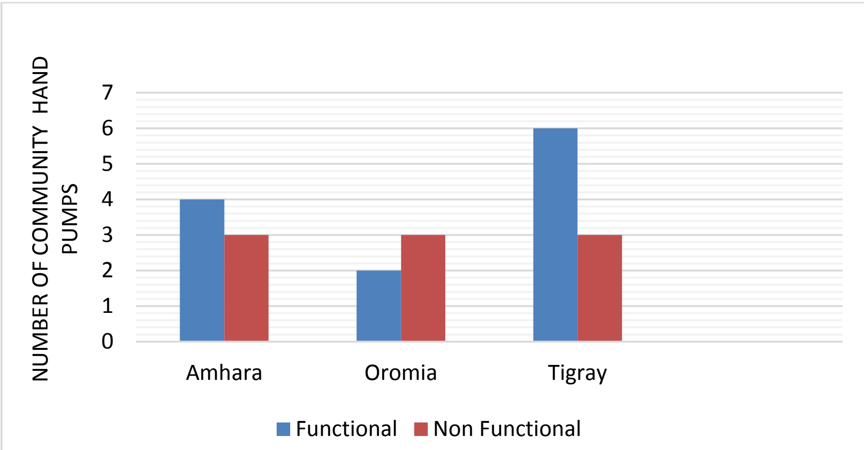

Figure 3 Status of community hand pumps by regions (Tetra Tech, 2015)

In 2014, Welle and Williams found 38.6% non-functionality out of a survey of 57 diverse water schemes (Welle & Williams, 2014).According to the National Water Inventory (NWI), 25.5% of above 93,000 water supply schemes in Ethiopia were non-functional. Stephen Stawicki surveyed 91 water schemes in Farta and West Estie woredas and found 17.5% were not functioning and 10% were functioning with difficulties (Stawicki, 2012). Migbar Assefa found that 33% of rural water supply schemes are non-functional at any time in Ethiopia (Assefa, 2013).This alarming below 50 percent results of sustainability in Ethiopia shows the calibre of the problem and the dire need of management and decision making in alleviating and keeping the water sources more sustainable.

Harold Lockwood carried out a comprehensive literature review on sustainability of rural water services and pointed out 20 factors affecting the sustainability of rural water supply and sanitation services. These factors are categorized into five called: Technical factors, Financial factors, Community and Social factors, Institutional and Policy factors and Environmental factors (Lockwood, et al., 2003).The results show a dire need for an integrated DSS tool to analyse the different factors and reach a decision.

According to (Calow, et al., 2013) , managing the rural water supply services with transparency and accountability is a key factor to ensure sustainability. Monopolistic position of some drilling companies over a region, Biased selection of licensing or registration practice and procedure for drilling companies, Distortions in use of monitoring information (e.g., coverage) for political or funding ends, Risk in shift to local-level procurement under decentralization are some of the high corruption risk areas in Policy Making, Planning, and Budgeting in the Ethiopian Rural Water Supply Sector (Calow, et al., 2013).

(Gebrie, 2012) developed a Decision Support System tool and concluded that ensuring sustainability of rural water supply systems needs a paradigm shift in the thinking of improved water supply where the following points are incorporated: the quantity of the supply should be more than 20l/c/d to 40 to 50 l/c/d, a shift from isolated source schemes to rural water schemes with distribution and that the tariff models should ensure cost-recovery of rural water services and not only the operation and maintenance cost (Gebrie, 2012) .

3 Objective of the Study

3.1 General Objective

To develop a DSS tool that can support decision making by analysing the sustainability status and factors influencing the sustainability of rural water supply services.

3.2 Specific Objectives

- To develop a system module that contrasts between the given water sources and identify the more sustainable water source in a district.
- To develop a system module that can identify factors associated with sustainability of rural water supply services.
- To promote the use of DSS tools in the evaluation of rural water supply services.

4 Literature Review

4.1 The Paradigms of Sustainability

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

The concept of 'needs', in particular, the essential needs of the world's poor, to which overriding priority should be given; and

The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

(United Nations World Commission on Environment and Development, 1987)

On 1992, The United Nations conference on environment and development was held at Rio de Janeiro. The summit was a milestone in its internationality and the outcome of it 'The Rio Declaration', explained Sustainable Development as a set of 27 international principles. Economic, Environment and Social development was identified as interdependent pillars of Sustainable development (United Nations Conference on Environment and Development, 1992). The action plan of the Rio declaration, Agenda 21 outlined information, integration and participation as key building blocks of sustainable development. Agenda 21 identified that participation of the public in decision making as a fundamental prerequisite for sustainable development (United Nations Conference on Environment and Development, 1992).

After ten years of the Rio declaration, the world summit on sustainable development was held in Johannesburg which builds much on the Rio principles and bringing the globe together for partnership in implementing sustainable development (World Summit on Sustainable Development, 2002).

On 2012, the 3rd international conference on sustainable development, the Rio+20 or Earth summit 2012 was held at the same city of Rio de Janeiro which hosted the 1992 Earth summit with an outcome document of the future we want. Leaders of the Globe reaffirmed their willingness for sustainable development and integrate the 3 pillars of development and promote the implementation of Agenda 21 (United Nations Conference on Sustainable Development, 2012).The issue of sustainable development goals (SDGs) is promoted to continue after the MDGs with the establishment of 17 set of goals in 2015 where Goal 6 states “Ensure availability and sustainable management of water and sanitation for all” (United Nations General Assembly, 2015).

4.2 Characteristics of Sustainable Water Supply Services

“Sustainability is about what consumers receive! Delivering services is far more complex than delivering a piece of infrastructure. You need to monitor the service delivered, check water quality, repair, upgrade and replace – the daily concerns for delivering a water service. Financing, fee setting, planning, regulation and monitoring performance are part of securing the service in the long term. That is a hell of a job; that is about governance, about management, about policy making and enforcement, about capacities and transparency. That is a lot more complex than providing and/or replacing pieces of infrastructure. But it is the only way to go”.

(Shouten, 2012)

A rural WASH service is sustainable “when it is capable of supplying an appropriate level of benefits during an extensive time period after the withdrawal of all forms of support from the external agency.” (OECD,DAC, 1997) in (Lockwood, et al., 2003).

(Webster, et al., 1999) stated that sustainability in the context of rural water supply and sanitation projects is the continuous functioning of both the hardware (physical) and software (non-physical) components of the system. It is the continuance of benefits from the system once the external hardware and software assistance have been phased out.

Hardware sustainability components of a rural water supply are:-Appropriate Technology which must include easiness and simplicity of the scheme in terms of its construction and operation using locally available materials, Standardisation which includes increasing the technical capacity of the scheme care takers and Convenience in terms of the type of technology. Software components of a rural water supply scheme include all the social, economic, cultural and political components of the scheme (Webster, et al., 1999).

According to (Brikké, 2000),A WaSH-service is sustainable when: It is functioning and in use, able to deliver appropriate level of benefits, continue functioning for long time, if costs are recovered at local level, operated and maintained locally with limited but feasible external support.

Harvey and Skinner defined the sustainability of water services as: Minimal external inputs in long-term; Financing of operation and maintenance by users; and Continued flow of benefits over a long period. According to (Harvey & Skinner, 2001), sustainable water supply projects have 5 dimensions which are: Technical, Financial, Environmental, Social and Institutional.

According to (Harvey & Reed, 2004), a water service is sustainable if the water sources are not over-exploited, and reliable adequate water supply is provided to all users where the service delivery process is cost effective (Harvey & Reed, 2004).

A sustainable water service is a continued accessible water provision for users in terms of both quantity and quality. The specific indicators of sustainable water service are:-Quantity, measured in litres per capita per day (lpcd), Quality, in terms of one or more separate indicators of chemical and biological quality, Distance from a household or centre of a community to a water point, Number of people sharing a source, often termed 'crowding', Reliability, in terms of the proportion of the time the service functions to its prescribed level (Moriarty, et al., 2011).

Lockwood and Smits formulated building blocks towards more sustainability service delivery. According to them, building blocks such as: professionalization of community management, increased recognition and promotion of alternative service provider options, sustainability indicators and targets, post-construction support to service providers, capacity support to decentralized government (to the service authorities), Learning and sharing of experience, planning for asset management, financial planning frameworks to cover all life cycle costs, regulation of rural services and service providers should be ensured to deliver a sustainable water supply service (Lockwood & Smits, 2011).

According to (Gebrie, 2012) for a rural water supply service to be sustainable: the quantity of the supply should be more than 20l/c/d to 40 to 50 l/c/d, a shift from isolated source schemes to rural water schemes with distribution and that the tariff models should ensure cost-recovery of rural water services and not only the operation and maintenance cost.

According to (Schweitzer, et al., 2014) the four essential criteria for a tool to assess the sustainability of WASH services are:-

1. Track record: a tool must be applied to the WASH sector (water/sanitation or hygiene projects/programmes).
2. Specific content: the content of the tool should be in the form of a checklist of questions, a frame work of indicators and sub-indicators.
3. Clear and reproducible process: a tool should contain a process, including explicit instructions for its application.
4. Synthesis data to produce an output: Tools must have, as part of their method, an element of analysis that results in the synthesis of a unique output that can be easily interpreted by the appropriate stakeholder audience.

4.3 Health Burden Due To Unimproved and Unsustainable Rural Water Supply Services

The burden of diseases caused by unsafe drinking water and unimproved sanitation and hygiene has always been huge. In Africa, inadequate WaSH is possibly the most damaging health problem after Malaria and HIV/AIDS (Bartram & Cairncross, 2010). Meeting the water and sanitation Millennium Development Goal (MDG) targets would save around 40 billion working days globally by alleviating time losses due to reliance on distant services (Hutton, et al., 2007; Calow, et al., 2013). If infectious diarrhoea alone can be prevented by improved water and sanitation facilities, the global households would save USD$565 million and national health budgets USD $11 billion in treatment costs (Hutton & Haller, 2004).

Diseases due to Inadequate access to water supply and sanitation and poor hygiene practices such as Diarrhoea accounts for 2.5 million child deaths annually, and around six per cent of the worldwide disease burden in terms of disability-adjusted life years (DALYs) (Pruss Ustun, et al., 2008; Bartram & Cairncross, 2010).The use of improved drinking water and sanitation has a significant disease reduction, mainly diarrhoea. Diarrhoeal diseases episodes could be reduced by 10% in average, if the globe uses improved drinking water and sanitation (JMP, 2004).

The JMP report of 2015 (JMP, 2015) states that some 161 million children suffers from chronic malnutrition linked to water supply, sanitation and hygiene. More than 340,000 under 5 children die annually (around 1000 per day) from diarrhoeal diseases due to unsafe drinking water and poor sanitation and hygiene.

Improved WaSH could prevent 842,000 deaths every year. The major tropical diseases like trachoma, schistosomiasis and intestinal worms that affect more than 1.5 billion people annually are majorly contributed by poor WaSH (JMP, 2015).

4.4 Existing Decision Support Systems Regarding Rural Water Supply Services

A DSS is a computer-based information system where models and data are combined in order to solve semi-structured and some unstructured problems with extensive involvement of a user (Turban, et al., 2005), (Averweg, 2012).

DSS is a methodology where decision making is supported through an interactive, flexible, adaptable computer based information system (CBIS) easily developed to supporting a solution (Waghmode & Jamsandekar, 2014). (Walsh, 1993), stated that Decision Support Systems always involve a user interface, model and a database. Decision Support systems that was developed in the past in the rural water supply sector are mentioned below.

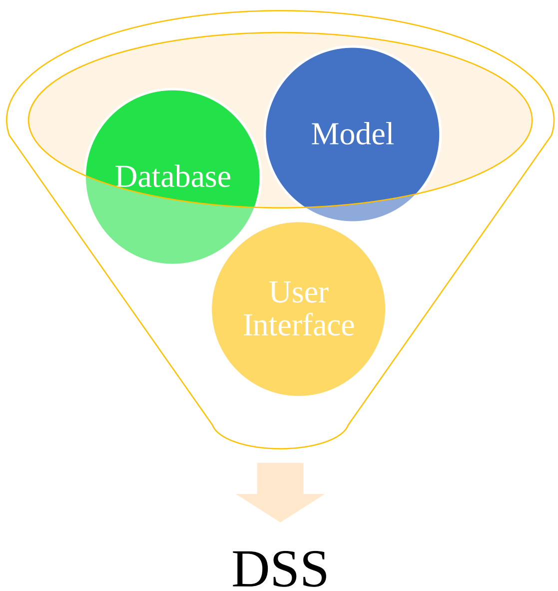

Figure 4 Components of a Decision Support System Adopted From (Walsh, 1993)

RWS-DSS

The RWS-DSS (Rural Water Supply Decision Support System) software was developed by Water Research Commission of South Africa in 1998 and consists of a DSS shell written in delphi code and allow users to further develop the software. The computer program is a benefit in the planning and implementation of rural water supply projects in South African context by applying assessment of feasibility of rural water supply services and preparing business plans (Water Research Commission of South Africa, 1998).

Water Aid's Sustainability Snapshot Tool

The United Kingdom based NGO, Water Aid developed a rapid sustainability assessment tool in its Malawi country program after a long trial and testing of the snapshot tool. The 'sustainability snapshot tool' is a simple screening tool of sustainability that consists of the three critical aspects of sustainability: Technical, Financial and Equipment and spare parts related issues (Sugden, 2003).

This tool assesses the general technical, financial and equipment-spare parts aspect of a rural water supply service in a brief but comprehensive manner to produce a score that represents a quick image of the sustainability status of a RWSS (Sugden, 2003). It's weakness is it's lack of depth and lack of integration of sectors other than technical and financial aspects. It's strength is, it's speed to quickly screen the sustainability status of a RWSS. Due to its quickness and its prolonged practice in Water Aid's wide global rural water supply construction experience, this snapshot is selected to validate the RWSS sustainability evaluation DSS tool.

NEATWORK

NEATWORK is a decision support stand-alone java program developed by Agua Para la Vida and LOGILAB for the design of gravity water distribution networks that are particularly found in rural areas. NEATWORK was developed in 2004. The rural water supply networks has to adapt two characteristics in general. These are;-

1. The driving level differences between the tank and the faucets may be minimal (the practical minimum may be as low as 2 meters)

2. The consumers generally need no water pressure at the exit of their faucets.

NEATWORK is especially useful in rural communities where mechanized and electric power are generally either unavailable, or unduly expensive. It aims at finding minimum material cost in operationally satisfactory solution.

The software consists of a design module and simulation module. In the design module Inputs such as The topography of the network, set of design parameters specifying faucet target flow, fraction of open faucets and service quality, Two parameter files, one for pipes, (available internal diameters, maximum working pressure, cost and equivalent moody roughness factor or nature of pipe material), and one for orifices (available diameters) and specification of constraints such as specified (pre-existing) pipe diameters along some segments are processed to produce outputs as design files that reproduces the topographic data and recommends pipe diameters for each segment and orifice diameters for some terminal segments.

The simulation module requires inputs such as: a design, the type of orifices to be used and the type of simulation mode. The outputs of the simulation module are main statistics on faucet flows, percentiles at faucets, water velocities in pipe segments, node pressures (Agua Para la Vida and LOGILAB, 2004).

NRWS

NRWS (Nilgiris Rural Water Supply) was developed by Daniel Olsen in 2005 to support planners around the study area in the process of identifying key issues in selecting sustainable water sources, and systematically guide to quantify the potential water sources. The NRWS was developed by Microsoft Excel using Visual Basics for Applications (VBA) programming language.

The DSS contains six modules that stands for different criteria in the evaluation of the potential water sources. These modules are water source yield, capital costs, cost and ease of operation and maintenance, impact of development, political and legal constraints, and water quality. The selected water sources are common in the Nilgiris district and are rooftop rainwater harvesting, check dams, reservoirs, springs, and dug wells.

Within the water source yield module two sub-sections are developed that focus on rainwater harvesting and check dam sources by gathering local hydrological data. For the rainwater harvesting source, an extensive database of precipitation data was developed for rain gauge stations across the district. The check dam source required a method for estimating stream flow, and a number of methodologies were compared (Olsen, 2005).

GOODwater

GOODwater is a software developed in Microsoft Excel using visual basics for applications programming language by Stephen Good in 2008. The computer program consists of five modules standing for main stages of a project life cycle, which are: site assessment, system design, planning and budgeting, project implementation and project evaluation. The software has options to use each of these modules individually.

The computer program has three subsections for each stage of a project. The first subsection deals with checklist of actions like pricing materials and organizing labor. The checklist is preferred to be completed by the user communities. The second subsection is where the user enters data gathered from the suggested actions and selects options of the system's completion. The final subsection produces a report for each module from the data and the selection of the second section. The reports include summaries of the analysis of GOODwater.

GOODwater is developed to support the implementation of gravity flow water projects by enabling the user to make decisions about the best course of action for a given project. It assess the optimality of the level of service while minimizing cost and maximizing sustainability (Good, 2008).

The Integrated Decision Support Tools for Rural Water Supply

The Integrated Decision Support Tools for Rural Water Supply was developed by (Gebrie, 2012).The model consists of a three stage decision support package which are linear/exponential regression, composite programming and system dynamics.

In the first stage of the DSS, two cost estimation equations for schemes at spot and with distribution was formulated based on exponential and linear regression methods. In the second stage, a composite programming model that analyses schemes based on multi-criteria of planning and physical development and sustainable operation and management of schemes was deployed and nine indexes were obtained by aggregation of 53 indicators. From the integration of these indexes, it was found out that spring with gravity distribution scores the highest sustainability index.

The final stage of the Integrated Decision Support Tools for Rural Water Supply was based on system dynamics and predicts the performance of a rural water supply scheme temporally. The DSS tool additionally show the effect of the water consumption pattern on scheme yield, health impact, income and long term sustainability (Gebrie, 2012).

Sustainability Assessment Tool (SAT)

Developed by the Swiss community of practice, AGUASAN, the SAT is a tool for reviewing existing interventions of programs and helps to support future WASH programs planning. With 22 indicators that have each 2 to 8 sub indicator questions, the SAT assesses the economic, environmental, institutional, knowledge, social, and technological aspects of a WASH program intervention. The tool was pilot tested during an assessment of rural water schemes in Kosovo in 2010 The SAT's strengths include: comprehensive assessment of sustainability across six areas, potential to be used as a pre-implementation tool, participatory process including local stakeholders, the outputs motivate stakeholders' dialogue and have the potential to inform, sector/policy development. The SAT's weaknesses are: limited application to date, involves a large number of indicators, focus is on conditions in the community, Relies on information derived from selected individuals (Schweitzer, et al., 2014).

Gender Analysis Snapshot (GAS)

The GAS was developed by the international NGO, CARE to explore the links between gender equity and WASH sustainability and project effectiveness in Northern Ghana. Twenty two indictors that focus on four areas (water resources, household decision making, access to public spaces and services, and woman empowerment) compose the GAS (CARE, 2013).

The indicators form 24 questions that are answered by two focus groups (one female group and one male group).An average of individual scores comes up with a final score for each indicator for the community and those scores will be ere aggregated for an overall score that ranges from 21 up to 90. Higher scores indicate higher levels of gender equity and lowers scores indicate lower levels of gender equity in the community. The GAS tool strengths are that the questions are straightforward, participatory processes ensure that the perspective of the community is represented, process can be embedded in both planning and monitoring activities and that it can provide insight into women and men's understanding of gender empowerment and equity. GAS Tool's limitation include that it requires specialist trained in participatory processes and facilitation skills, assumptions behind scoring arrangements in the sample framework are not clear, If utilized alone, the GAS may be overly simplistic (Schweitzer, et al., 2014).

The Governance Into Functionality Tool (GIFT)

The Governance into Functionality Tool is composed of twenty questions that covers four areas (participation, accountability, transparency, and cost recovery) to assess the effectiveness of community governance structures to maintain public water points. Key informant interviews or focus group discussions are the means to address the 20 indicator questions. Each indicator is scored from 1-3 and the indicator scores are aggregated for an area score and can further be presented as an overall score (percent).The GIFT's strengths include participatory process which captures the perspectives of community level stakeholders, once scored the aggregation process is straight forward, can be administered by non-WASH experts .GIFT's limitations are that the process of scoring of the indicators could be clarified and the focus of the GIFT is limited to the community level (Schweitzer, et al., 2014), (CARE, 2014).

Local Government IWRM Support Assessment

Developed by CARE, the Local Government Integrated Water Resources Management (IWRM) Support Assessment is a tool that assesses the support given by partner organizations to local governments in the East Africa Global Water Initiative (GWI) partnered districts (Schweitzer, et al., 2014).

Its key areas of assessment are policy, planning and implementation; personnel and finance; learning, harmonized information systems and monitoring & evaluation; coordination of relationships of District government downwards and upwards (with communities and regional/ national government).Indicators on these areas are scored on a scale 1-3 and Overall scores per area are sub-totaled per area and sub-total produced (CARE, 2009).

It's strengths include its simplicity to synthesis overall score and its potential to be adapted as a self- assessment tool by local governments. Whereas, the lack of clarity of the tool's contextualization requirements to apply in other areas is its limitation.

WASH Life-Cycle Assessment

It was developed by McConville as part of a master thesis and is used to evaluate completed water and sanitation projects. Its framework is composed of a matrix that consists five sustainability factors (Socio-cultural respect, community participation, political cohesion, economic sustainability, environmental sustainability)and five project life stages (needs assessment, conceptual design and feasibility, design and action planning, implementation, operation and maintenance) (McConville, 2006).

The methods of scoring include a checklist consisting 100 sustainability recommendation questions (4 per matrix element), a rating (0-4) for each matrix element that provides an overall sustainability score on a scale of 0-100 and a score for each project life stage and each sustainability factor (out of possible 20 points) presented on a radar diagram.

The tool has been applied in completed water and sanitation projects at Mali, Honduras, Benin and Uganda. The tool's strength include it's easy to use, stimulates reflection on sustainability factors within the context of the project life-cycle, framework is based on extensive literature review, can be used as either a self-assessment or a third party assessment The tool's limitations are that the scoring is highly dependent on the recommendations or checklist, which may require customization for each application (McConville, 2006).

Sustainability Monitoring Framework (SMF)

Developed by the Dutch WASH Alliance (DWA) which is a network of NGOs, the SMF is a tool that measures the extent to which each NGO contributes to sustainable WASH service delivery in their projects. It assesses the presence or absence of the Financial, Institutional, Environmental, Technical and Social (FIETS) factors with a proven impact on sustainability. (DWA,IRC, 2014)

The methods of computations are through primary data that is collected through surveys and focus group discussions which are used to determine a score (positive effect, negative effective, or no effect) for each indicator and is outputted as a series of Excel-based graphs presenting the results for each FIETS dimension. In addition, a 'reliability' score describes the number of questions that are answered and an overall sustainability score represents the aggregate of the five dimension scores.

The strengths of the tool are that it considers factors related to preconditions of sustainability, its flexibility, its automated results presented in an intuitive way, its good potential for scalability. Its limitations are its complexity of data entry and application of formula by organizations to produce results—potential for a more user-friendly programme. The SMF has been pilot tested in Uganda and Ghana by a total of nine organizations in collaboration with local authorities.

Wash Cost Tool

WASHCost Tool is a web based tool developed through the experiences of WASHCost, a five year action research initiative funded by the Bill & Melinda Gates Foundation that worked on the life-cycle costs of different WASH services in four countries: India, Burkina Faso, Ghana, and Mozambique. By using a life cycle approach, the tool assesses and compares the financial sustainability of different water and sanitation services and share those findings with different stakeholders. Using the availability of cost data for the area of concern, the tool helps stakeholders consider what the expected capital and recurrent expenditures will be for different technologies and service level (IRC, 2014).

The tool uses 9 indicators for water and 10 indicators for sanitation that assesses the context (country, population, and technology), cost (capital and recurrent), and service levels which are-latrine technology, permeability, environmental impact, usage, and reliability for sanitation and access, quantity, quality, and reliability for water supply. The user inputs data describing the above mentioned indicators and these inputs are compared with WASHCost benchmarks for a stated technology.

Summary reports are produced as output that can also be saved to a user dashboard or shared via a web-link. These reports contain information on the capital and recurrent expenditures (total and per person) that are presented against a service level categorization determined using WASHCost benchmarks: high, standard, sub-standard, and no service for water, and improved, basic, limited, and no service for sanitation.

The tool's strengths include its simple user interface, that it presents user inputted cost and service level information that is easy to interpret and the reports can be saved in an online dashboard and shared. Its limitations are that the quality of the results are based on accuracy and detail of user inputted data.

Planning Oriented Sustainability Assessment Tool (POSAF)

Developed in 2013, POSAF enables planners and stakeholders in participative definition of alternatives, technical feasibility study, participative criteria development, and analysis of trade-offs. The main idea behind the framework is the need to redefine sustainability for each planning scenario. The tool produces weighted criteria that reflect stakeholder inputs (Starkl, et al., 2013).

Its methodology is participatory process that is used to analyze different planning scenarios. A technical feasibility study followed by a participatory assessment is used to analyze trade-offs of the different scenarios and create quantitative criteria and weighting used for assessing future plans.

The outputs are weighted criteria consisting a visualization of the relationships between each stakeholder which is created through a complex statistical process. It has a graphical presentation of nodes that represent respondents, colors that represent their responses grouped through a qualitative process. The node shapes and lines reflect statistical relationships between the individual responses for each user. The tool has been applied in Mexico to aid in the choice of waste water technology.

Its strength include its participative process and its flexible framework where as its limitations are that it requires adaptation to the local context, it requires trained specialists to facilitate groups for data collection.

Sustainability Check

The sustainability check is a monitoring tool that assesses the sustainability of WASH facilities and make recommendations to programme managers. It was developed on 2008 by UNICEF Mozambique and comprises five weighted factors which are: institutional (10%), social (40%), financial (10%), technical (30%) and sanitation (10%).Indicators are defined for each factor and allocated a score based on responses to sub-indicator questions (Schweitzer, et al., 2014).

Data is collected through semis structured FGDs and semi structured surveys. Indicator scores are averaged to obtain a factor score and then an overall score aggregated to the provincial and programmatic level using averages. After the assessment scores and recommendations conveyed to inform decision makers. The tool’s strengths are that it’s repeated over the country for more than six times and its quantitative results provide a favorable atmosphere for friendly competition amongst districts.

Sustainability Index Tool (SIT)

In 2012 the USAID and Rotary International developed the SIT. The SIT assesses sustainability of WASH services from institutional, management, financial, technical and environmental point of view. Each factor consists sub-questions but without a weighting. Data is collected through site inspections, household and key informant interviews, focus group discussions at various levels (service, district, national), review of policy documents and technical standards and norms. After data is collected, results are presented as aggregate scores, graphically. It includes both urban and rural intervention and provides a rigorous quantitative assessment which makes it potential for scalability (Rotary International, USAID, 2012).

With a pdf guiding document and excel spread sheets the SIT assesses sustainability factors of services under the category of Water Supply, Sanitation and Hygiene and sub category of community reticulated systems, community hand pumps, utility water systems, water source protection, water pan systems, rail water harvesting, institutional sanitation, household sanitation, hygiene and hand washing promotion, household water treatment.

Tool for Planning, Predicting & Evaluating Sustainability (TOPPES)

TOPPES was developed in Ghana by the WSA (Water and Sanitation in Africa).The TOPPES predicts service delivery sustainability for WSA projects from socio-economic, service delivery, water resources /quality/ and environmental needs, technical, financial, O& M and institutional contexts where each factor has a number of indicators, totaling 23, which are scored by answering 92 yes/no sub-indicator questions. Scores are then weighted according to perceptions of importance that resulted from the field test (Schweitzer, et al., 2014).

As a methodology, a case study approach is used and judgmental sampling technique where a comprehensive list of communities with interventions is used to identify communities where data will be collected. After that Data is collected through focus group meetings with water committees, physical inspections, and in some cases information from district level is incorporated. TOPPES produces outputs that comes from sustainability score results labeled as sustainable, moderately sustainable or not sustainable.

Methodology for Participatory Assessment (MPA)

MPA is a social assessment tool that integrates qualitative and quantitative data and looks at the link between demand responsiveness, gender sensitive approaches, and sustainability.MPA creates a self-assessment framework where contributions of outcomes at the community level to institutional arrangements and national sector policies in terms of sustainability are assessed. The assessment of MPA is carried out by a multidisciplinary team of community members, representatives from the project agencies, field extension staff, sociologist, participatory development specialist with gender training and orientation skills, and water or sanitary engineer (Dayal, et al., 2000).

The tool has four areas of assessment for sanitation and seven for water which include sustained services, effective use, demand responsiveness, equity for women and poor, community management, institutional support, and policy support. The framework includes a total of 19 indicators each with 1-5 sub-indicators (total of 47 sub-indicators). Data is collected through Physical inspections, focus group discussions, stakeholder meetings, and key informant interview and the sustainability component scores are got as an output.

WASH Sustainability Sector Assessment Tool

This tool is developed by IRC and Aguaconsult under the Triple-S initiative and can be applied with differing levels, from a quick 'brainstorm' type approach to a structured workshop type approach. It makes an assessment of the WASH sector from a sustainability perspective in any given place. This tool provides a better understanding of programme design, priorities and decision-making within the context of the sector level as opposed to individual project level, as well as identifying key weaknesses (Schweitzer, et al., 2014).

There are eight areas which the tool focuses on and each area has a number of indicators: policy, legislation and institutions (5), financing (2), planning (3), transparency and accountability (3), capacity (2), sector learning and knowledge management (1), harmonization and alignment (2), and environment (1).Four guiding questions determine a single score, from 0 to 100, for each indicator and after that indicator scores are averaged for an area score. After the score is got, relative strengths or weaknesses of the WASH sector in a given country are summarized graphically through a bar chart for indicator scores and a radar diagram for the area scores.

Water, Sanitation And Hygiene Bottleneck Analysis Tool (WASH-BAT)

WASH BAT is a sector assessment tool developed by UNICEF and World Bank in 2011 with the aim of removing barriers at different service levels to sustainable and efficient WASH service delivery, and increase sector resources. It involves participatory process involving sector stakeholders and can be applied at national or sub-national level, to all aspects of WASH or to identify bottlenecks for specific sub-sectors (Schweitzer, et al., 2014).

It has thirty two enabling factors and each criteria scored between 0 and 1 by increments determined by user. Scores totaled and categorized by a traffic light system: 0 to 3.0 (red), 3.1 to 5.3 (orange) and 5.4 to 6.0 (green). A low score equates to the presence of a bottleneck. Bottlenecks, their causes and remedial activities identified. Costs of activities estimated, activity funding determined (fully-partially-not funded) and activities prioritized (high-medium-low-not a priority). Bounded and unbounded impact analyses can be generated and overall summary report produced containing Score Report, Funding Report and Activities Report.

Sub-Sector Score Card

Developed by the World Bank's Water and Sanitation Program (WSP), Each of the four scorecards consists of nine 'building blocks' of service delivery which are classified into three categories or 'pillars': 1) enabling conditions for putting services in place, 2) actions that relate to developing the services, and 3) functions that relate to sustaining the services (Schweitzer, et al., 2014).

Each building block is assessed against specific indicators (3 or 4 indicators per building block), which are different for each sub-sector and focus on areas of policy, planning, budget, expenditure, equity, output, O& M (water sub-sector only), markets (sanitation and hygiene sub-sectors only), uptake and use. Indicator scores (0, 0.5, or 1) are assigned based on relevant resource documents (e.g. strategies, policies, reports) or WASH expert knowledge. Indicator scores are converted into a score (0-3) for each of the nine building blocks, which are subsequently color coded (<1 = red, which means barrier to service delivery and requires immediate attention; 1-2 = yellow, hindering service delivery and requires attention; >2 = green, building block is in place and contributing positively). The sub-sector scorecards are utilized in the context of an overall sector assessment and colored graphic results indicating the status of each service delivery building block are presented.

Financing For Environmental, Affordable And Strategic Investments That Bring On Large-Scale Expenditure (FEASIBLE)

FEASIBLE is a computerized decision support tool developed by the Organization for Economic Co-operation and Development (OECD) and COWI. The tool aims for a strategic financial planning on public water supply, wastewater and sanitation infrastructures. The tool has 16 indicators across its four areas: solid waste (7), water supply (2, with nine sub-indicators), wastewater (2, with 10 sub indicators), and supply of finances (5) (OECD,COWI, 2010).

Data is collected using questionnaires, key stakeholder discussions, document reviews. After costs are assessed at the service level, taking into account affordability constraints for households and public budget limitations, estimated expenditures are predicted for capital investment, management, and operation and maintenance using various service delivery scenarios.

Results are outputted on technical aspects, expenditure needs, financing and financing gap, with the option to view aggregated values for water supply and wastewater areas. The tool has been applied with urban contexts on more than fifteen countries.

Technology Applicability Framework (TAF) and Technology Introduction Process (TIP)

The TAF and TIP were created by the WASHTech consortium on 2011, with the aim of obtaining a clear picture of the applicability, scalability and sustainability of individual WASH technologies that are implemented in a specific context and identifying the links between technologies and investment models that are used to introduce these technologies (Olschewski, 2013).

The tool provides comprehensive assessment of sustainability across six areas of social, economic, environmental, institutional, technological, and knowledge aspects and each areas have one indicator in three kinds of perspectives which are:-1. user/buyer, 2. producer/provider or 3. regulator/investor/facilitator. Each of these indicators which are numbered 18 has two to six sub-indicators making the questions to a total of 57 (Olschewski, 2013).

Data is collected through desk study of secondary data and focus group meetings with key stakeholders, as well as limited household surveys using joint field visits. Scoring of the indicators is done by the focus groups involving all key actors. They answer the guiding questions on a scale of 3 levels (negative, neutral, positive). Answers are aggregated qualitatively and the 18 indicator scores are presented in a traffic light system (green = positive, yellow = neutral and red = negative). If there is disagreement in the group or the basis for the scoring is unclear a black icon and a question mark are used.

Water For Life Sustainability Rating

This tool assesses an organization's capacity for implementing sustainable projects. There are 22 indicators; each with a series of 2-11 sub-indicator questions. Data is collected through judgement sampling in a case study approach. The tool was pilot tested in Honduras in 2011 where 4 communities were randomly selected out of a total of 159 water projects and between 2-16 households were visited in each community (35 households total). Information provided by the implementing organization that is the focus of the evaluation is triangulated with data obtained through interviews with water boards, random household visits, community focus groups, and infrastructure inspections. Each yes/no question has a designation of 'basic' or 'high', and based upon the responses for each an overall score is determined qualitatively. A quantitative score can be determined by assigning numerical values to the Likert categories and calculating a percentage and a four-colour scheme graphic is provided for each indicator as well as for the overall score (Schweitzer, et al., 2014).

Result of the tool's pilot assessment in Honduras showed decreased financial capacity of rural communities to cover the replacement costs for aging systems. Due to that the implementation organization created a loan program to finance water supply rehabilitation costs by the communities.

Sustainability Self-Assessment

The Sustainability Self-Assessment tool is developed due to the common consensus reached by over 100 stakeholders from 50 organizations to create a common set of sustainability principles. These principles became the WASH sustainability Charter which is being hosted by the Sustainable WASH.org (Schweitzer, et al., 2014).

The Sustainability Self-Assessment tool is an organization-wide assessment process that help to determine an organization's performance across four guiding areas (Policy, knowledge, coordination, and monitoring and learning), to reveal where policies and practices support sustainable WASH service delivery and the greatest opportunities for improvement.

A series of questions are formulated and individuals or groups respond to these questions in an online platform. Each area has a number of indicators: policy (3), knowledge (1), coordination (3), and monitoring and learning (2). There are 2-4 guiding questions for each indicator; however the respondent(s) is required to enter a single score, from 0 to 100 for each of the 9 indicators. Scores for each of the four areas (policy, knowledge, coordination, and monitoring and learning) presented in bar chart form and recommendations and resources to guide remedial action where called for.

5 Conceptual Framework

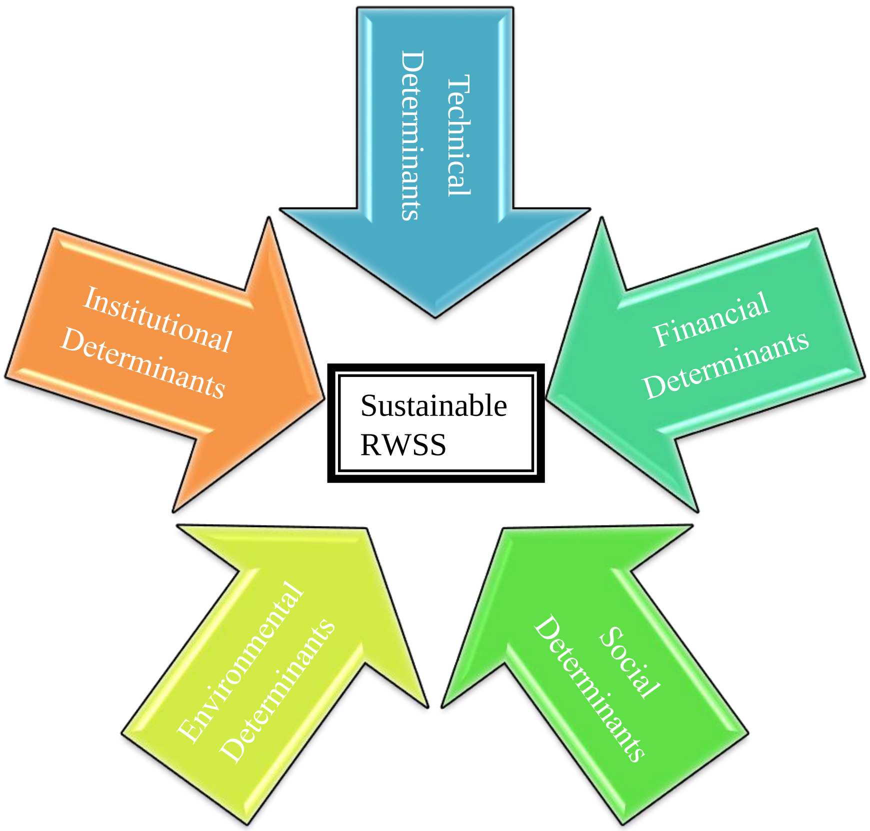

Figure 5 Conceptual Framework Of Sustainable Rural Water Supply Services.

According to the Dutch WASH Alliance (DWA), sustainability of WASH services have five major areas collectively called as the 'FIETS' which are financial, institutional, environmental, technical and social aspects (DWA,IRC, 2014).

As described by important studies on the area of rural water supply sustainability such as (Lockwood, et al., 2003), (Brikké, 2000) and (Abrams, et al., 1998) the important determinants of the sustainability of RWSS are Technical, Financial, Social, Institutional and Environmental as described below:

Technical Determinants: Physical condition of the system such as construction quality, presence of leak in the pipe, presence of crack in concrete floor.

Financial Determinants: Financial management of the system like tariff amount and tariff model ability to cover the O&M costs, tariff model ability in ensuring cost recovery, finance book keeping system of the service etc.

Social Determinants: Public participation during the project initiation, public contribution in cash or in kind, community willingness to sustain the system, community satisfaction with the system, women participation in WASHCO.

Institutional Determinants: Presence of training on operation and maintenance, spare parts supply chain management, maximum days without repairing damage services etc.

Environmental Determinants: Water source characteristics of the service such as accessibility of the service, water availability of the service in both dry and wet seasons, water quality etc.

6 Research Methods, Materials and Procedures

6.1 DSS Tool Design

The preferred computer programming language to design the DSS tool is visual basic because it is a method simple for building user interfaces, flexible to apply and efficient in that it can interface with codes written in C++ or #C programming language. The visual basic programming language is written by the integrated development environment of Visual Studio 2013. Since it is intended to make the DSS tool a windows desktop application, it is created by windows forms application part of visual basic. The DSS tool is given name to be called Rural Water Supply Sustainability Evaluation DSS tool or SUSWAT in short.

The software is designed by integrating the required information, tools, models and decision-making procedures in a user-friendly interface system. The software consists three main levels of process which comprises functionalities for data input, data analysis (data query) and display of results.

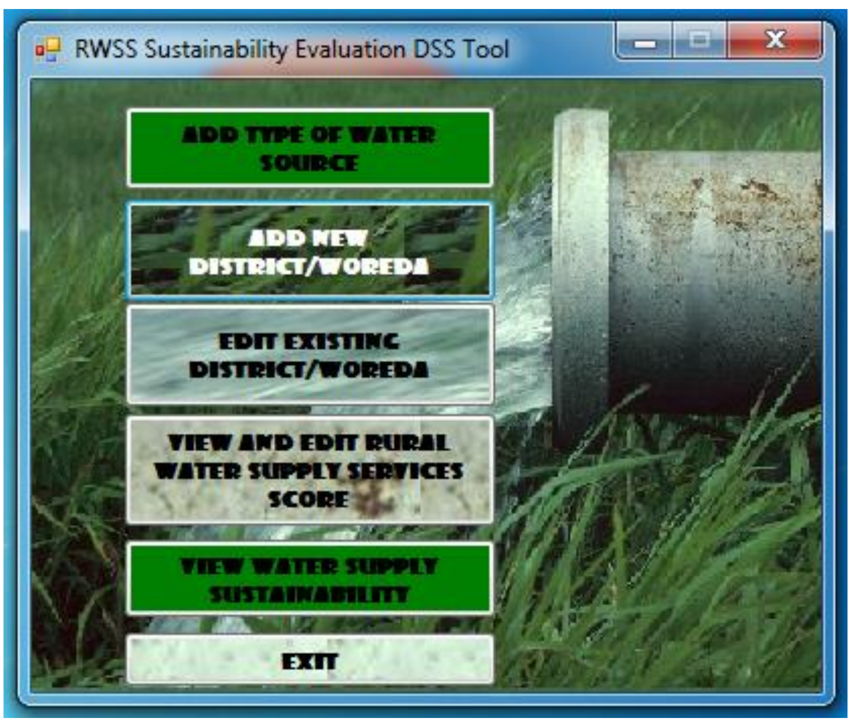

Figure 6 The user interface applied as home page in the RWSS sustainability evaluation DSS tool

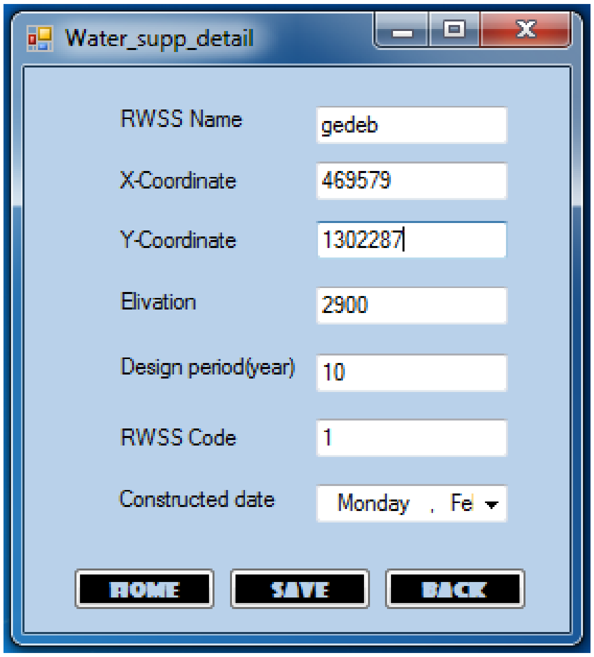

Figure 7 Data entry module of the RWSS sustainability evaluation DSS tool

The algorithm of the software can be summarized as:-

- first the system lists woredas/ districts from the database
- when the user selects from the woreda/ districts list
- the system searches from database by the name of the woreda/ district to get the id
- then the system selects list of water supplies registered by that id and displays it
- when the user selects the water supply and ok button
- the system selects the questions from question table and fill the label that holds the question
- the system selects all the choices content from choice, table puts it on an array that holds it and fill the labels
- the system selects all the answers for the choices by value ,puts it on an array given for that specific woreda/district and water supply from wor Sup Ques table
- the system calculates the choice with the respective value and fills the table for result
- the system calculates the average for the answers given for specific criteria type and displays the average

- whenever the user navigates from criteria to criteria the system loads a new question , choice and value and updates the table for result with new averages
- when user selects another choice form the choice radio button the system changes the value of that choice to the array of choice values loaded from the table
- when user clicks save
- the choice array changes will be cross checked with a backup choice array that holds the original unchanged value pulled from database
- if there is a change the system displays a confirmation pop up box
- else the system displays no change has been made message
- if the user saves a change all the user choice value will be stored for the respective woreda/ district using the woreda id.

The graphical representation of the algorithm of the software is shown in the diagram below:-

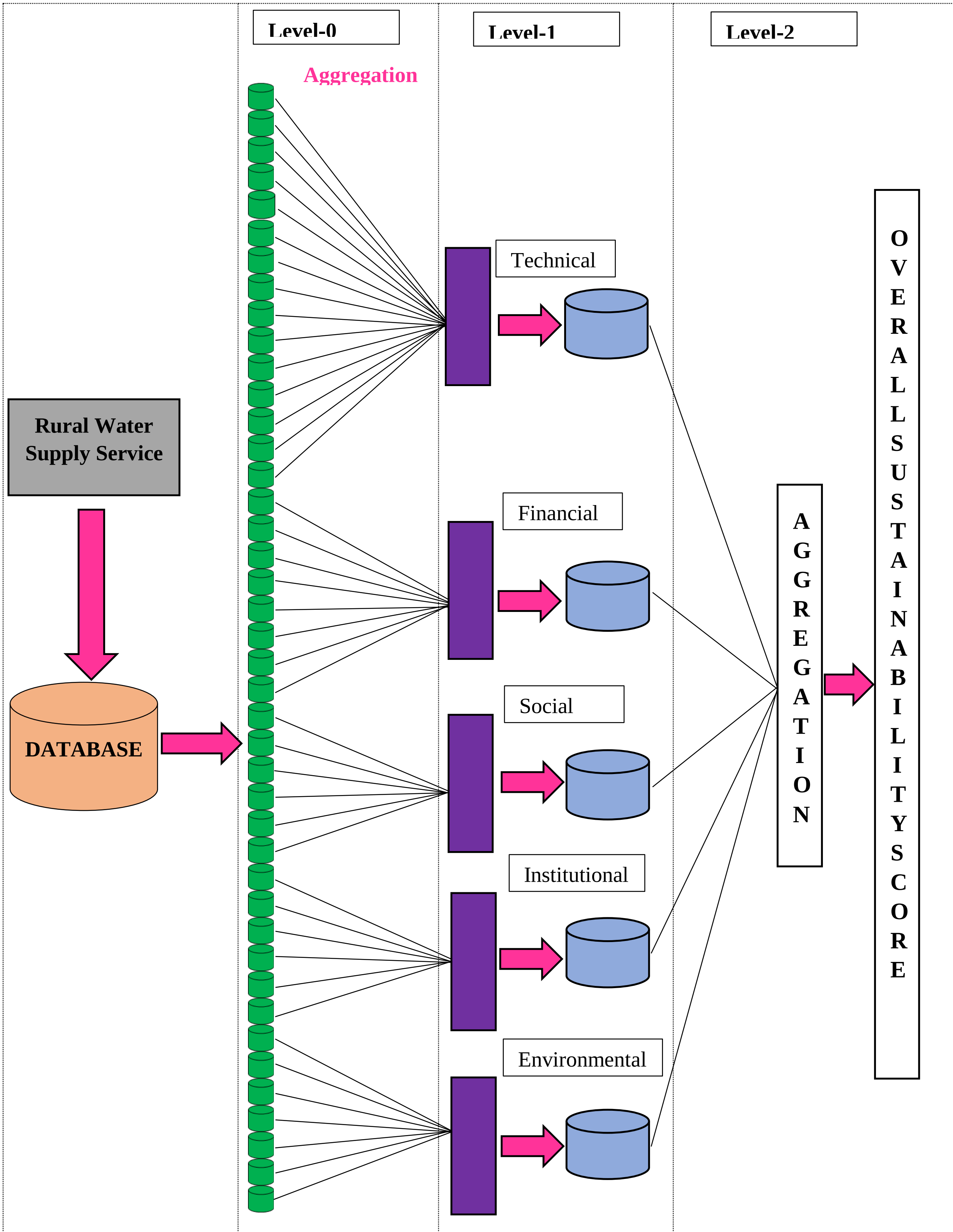

Figure 8 Graphical presentation of the algorithm for the RWSS sustainability evaluation DSS tool

As shown in the above figure, three premises were used in the design of the DSS tool architecture. Firstly, the system is built based on forty two significant indicators of sustainability which are presented below in tabular form:

• Service functionality, • working hours, • system defect, • breakdowns per year, • leakage, • assigned person, • water loss design consideration, • minimum water pressure, • break pressure tank/pressure reducing valves, • minimum head loss in system, • electricity availability, • water metered, • water metered versus water consumed, • unaccounted for water, • maximum pressure in system tariff cost, • tariff setting, • differential tariff, • punitive measures, • financial book keeping system, • bank account,	• tariff per m^3, • tariff versus household income • community consultation, • community contribution, • women in WASHCO, • community satisfaction, • tariff level perception, • willingness to pay, • days without repair, • spare parts availability, • construction supervision form, • water technician availability, • training on operation and maintenance, • training on procurement management, • seasonal water availability, • chlorine addition, • contamination risk, • lpcd consumption, • waiting time, • water source conservation • Residual chlorine.

These indicators that are based on literature from (Adams, 2012), (Schweitzer, 2009) and (Sara & Katz, 1998) are divided into five factors called: Technical, Financial, Social, Institutional and Environmental.

Indicators of Sustainability

Technical Aspects

(Sara & Katz, 1998) described that physical condition of a system is measured by indicators such as construction quality, pressure level in the system and presence of leakage or defect in pipes.

(The World Bank Office Manila, 2012) stated that in designing a rural water supply system, 15% of water loss for Non-revenue water should be considered. It further explains that head loss should be in the range 0.50m/1,000m-10m/1,000m and the water pressure in the range 3m-70m.

Ethiopian design criteria states a pressure reducing valve or break pressure tank should be used in order to reduce the high pressure into the allowable range which is 2m-5m in a public tap (MOWR, 2006).

Financial Aspects

According to (Fonseca, 2003) for a water service to be sustainable there must be full cost recovery including operation and maintenance and replacement costs.

The national guideline for tariff setting referring the World Bank states that a tariff is affordable if the bill does not exceed 5% of the household's income. It further explains Tariffs of about 0.40$ per m^3 which is around 8 Ethiopian birr per m^3 using the current exchange rate of 21 birr per 1 USD are sufficient to cover O&M costs in low income sub-Saharan countries where Ethiopia is located (MOWE, 2013). (The World Bank Office Manila, 2012) states the tariff rates should not exceed 5% of the average income of households in the service area.

Social Aspects

According to the universal access plan of rural water supply of Ethiopia, for all proposed WaSH activities the community should be consulted involving issues such as: public discussion, agreement on the service, selection of preferred alternatives among feasible options, consultation that need to involve women about water point location, commitment of the community to share in the investment cost (MOWE, 2011). The Rural UAP further explains that the community should contribute at least 5% in cash and 5% in labor and kind.

(Lockwood, et al., 2003) pointed out the involvement of women, user satisfaction and willingness to pay of the community should be incorporated in the social assessment of sustainability of RWSS.

Institutional Aspects

(Sara & Katz, 1998) noted the importance of proper institutional arrangement to keep RWSS functioning. They also point out that training is vital to ensure sustainability.

Monopolistic position of some drilling companies over a region, Biased selection of licensing or registration practice and procedure for drilling companies, Distortions in use of monitoring information (e.g., coverage) for political or funding ends, Risk in shift to local-level procurement under decentralization are some of the high corruption risk areas identified in the study conducted by. (Calow, et al., 2013).

Environmental Aspects

It is estimated that more than 50% of rural inhabitants will use boreholes, tube wells, protected springs and protected wells in 2020. Of these sources only boreholes and tubewells are considered resilient to climate changes. Unless properly managed these sources could fail to be sustainable even though they can resist climate change (JMP, 2011).

The One WaSH national program that is being implemented in the country defines rural water supply access as 15 liters per capita per day with in 1.5 km radius (FDRE, 2013).

According to (JMP, 2008) water consumption will be fair if the time to collect water is less than 30 minutes.

The (WHO, 1997) established a format for risk-based assessment of drinking water quality where questions are structured to answer yes to indicate reasonable risk to contamination and no to indicate negligible risk.

The design criteria by Ministry of Water and Energy of Ethiopia states that the free chlorine residual range should be in the range between 0.2-0.5mg/l (MOWR, 2006).

Secondly, the system has the capacity to analyze the sustainability indicators scores and the weighting factors and automatically generate an overall sustainability score. From similar studies of (Schweitzer, 2009), (Adams, 2012) and (Lockwood, et al., 2003), the overall sustainability score for a rural water supply service is obtained by multiplying the indicator score comprising three kinds of scores(0,0.5 and 1) in which 1 represents likely sustainable rural water supply services, 0.5 represent less likely sustainable and 0 represents unlikely sustainable rural water supply services. Adapting a weighting factor from (Lockwood, et al., 2003) and (Adams, 2012), the overall sustainability score is computed by this equation.

Overall Sustainability Score =Sustainability Indicator Score ×Weighting factor   Equation 1

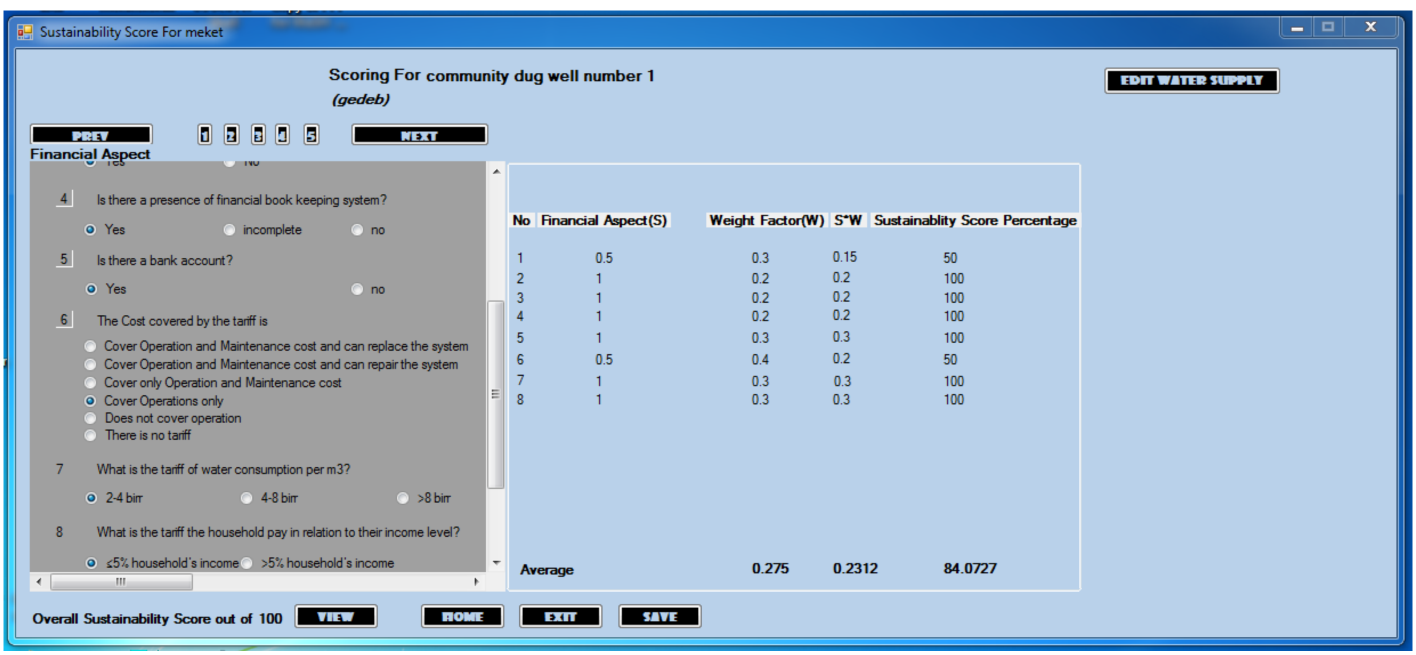

Figure 9 The RWSS sustainability evaluation DSS tool computing the sustainability scores

Based on the overall sustainability score, the DSS tool analyze and decide a rural water supply service to be **"likely sustainable"** if the sustainability score is above 66% , **"less likely sustainable"** if the scheme is between 33%-66% and **"unlikely sustainable"** if the rural water supply service is below 33%.

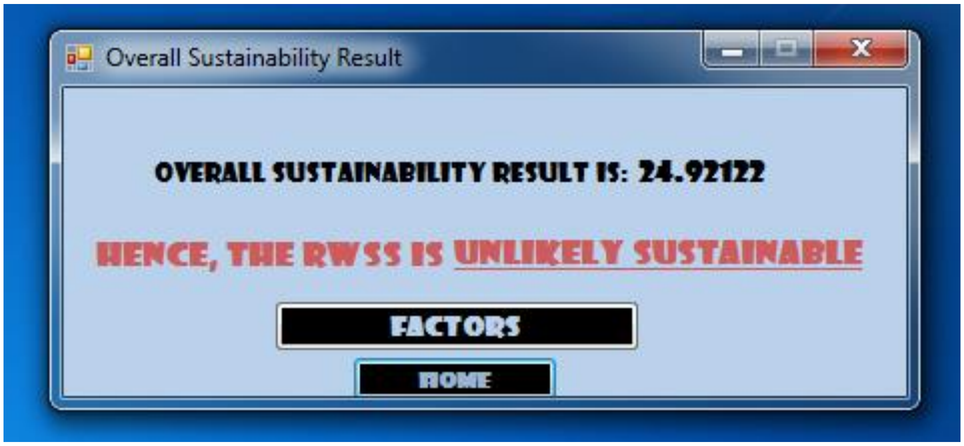

Figure 10 The RWSS sustainability evaluation DSS tool presenting the overall sustainability score result

In (Lockwood, et al., 2003) sustainability assessment study commissioned by the world bank, hundreds of literature on sustainability of rural water supply were reviewed accompanying desk review and field work also. This study found the most influencing factors of a particular RWSS. According to Lockwood the above 5 factors of sustainability doesn't influence the sustainability of RWSS in an equal manner. Some weigh more in terms of their impact on sustainability of RWSS. Due to this significance (Lockwood, et al., 2003) classified the factors based on the weight given to them as shown below and this thesis took (Lockwood, et al., 2003)'s weighting factors as a start point and identified its own weighting factors.

Table 1-Lockwood's Weighting Factors of Sustainability (Lockwood, et al., 2003)

Category	Factor	Rating
	Maintenance-Preventative	2
	Spare parts availability	2
	Maintenance-major repairs or replacement	4
Technical	Electricity supply and affordability	4
	Standardization of components (especially from hand pumps)	4

	Tools and equipment availability (especially from hand pumps)	4
Financial	Adequate tariff for recurrent costs	1
	Adequate tariff for capital replacement cost or system expansion	3
	Community management capacity	2
Community and Social	User satisfaction, motivation and willingness to pay	2
	Involvement of women	3
	Social capital or cohesion	3
	Continued training and capacity building	3
	External follow-up support	1
	Continued training and support to sanitation and hygiene education interventions	2
	Private sector involvement in goods, services and management contracts	3
Institutional and policy	Legal frameworks for recognition of water committees and ownership	3
	Supportive policy and regulatory environment	3
	Clarity over roles for Operation and management	4
Environmental	Water source production, quality and conservation	2

Table 2- Weighting Factors of Sustainability Used in This Software, Adapted from (Lockwood, et al., 2003)

Category	Factor	Rating
	Service Functionality	4
	Working Hours	3
	System Defect	3
	Breakdowns Per Year	3
	Leakage	3
Technical	Assigned Person	1
	Water loss design consideration	1
	Minimum Water Pressure	1
	Break Pressure Tank/Pressure Reducing Valves	1
	Minimum Head Loss in system	1
	Electricity availability	1
	Water metered	1

	Water metered versus water consumed	1
	Unaccounted for water	1
	Maximum pressure in system	1
	Tariff Cost	4
	Tariff Setting	3
Financial	Differential Tariff	2
	Punitive Measures on those who don’t pay tariff	2
	Financial Book Keeping System	2
	Bank Account Presence	3
	Tariff per m^3	3
	Tariff versus household income	3
	Community Consultation	3
	Community Contribution	2
Social	Women In WASHCO	2
	Community Satisfaction	3
	Tariff Level Perception	3
	Willingness To Pay	3
	Days Without Repair	3
	Spare Parts Availability	3
Institutional	Construction Supervision Form	1
	Water Technician Availability	3
	Training On Operation And Maintenance	2
	Training On Procurement Management	4
	Seasonal Water Availability	3
	Chlorine Addition	3
	Contamination Risk	3
Environmental	Lpcd Consumption	3
	Waiting Time	3
	Water Source Conservation	3
	Residual chlorine	3

Table 3-Weighting Factors Used in This Study That Are Similar to Lock Wood’s Weighting Factors

	Weighting factor
Highly Critical Importance	4
Critical Importance	3
Less Critical Importance	2
Limited Importance	1

Thirdly, the system has the capacity to contrast between the different factors and rank in order the factors that influence the overall sustainability score of the rural water supply service. The factor that score least among the five factors shows the sector of rural water supply service where more work needs to be done.

The RWSS Sustainability Evaluation DSS tool also shows which water source is more sustainable than other water sources presented in a woreda/district. This is useful in identifying the most sustainable water source in a woreda by analyzing the different water sources in type and in quantity.

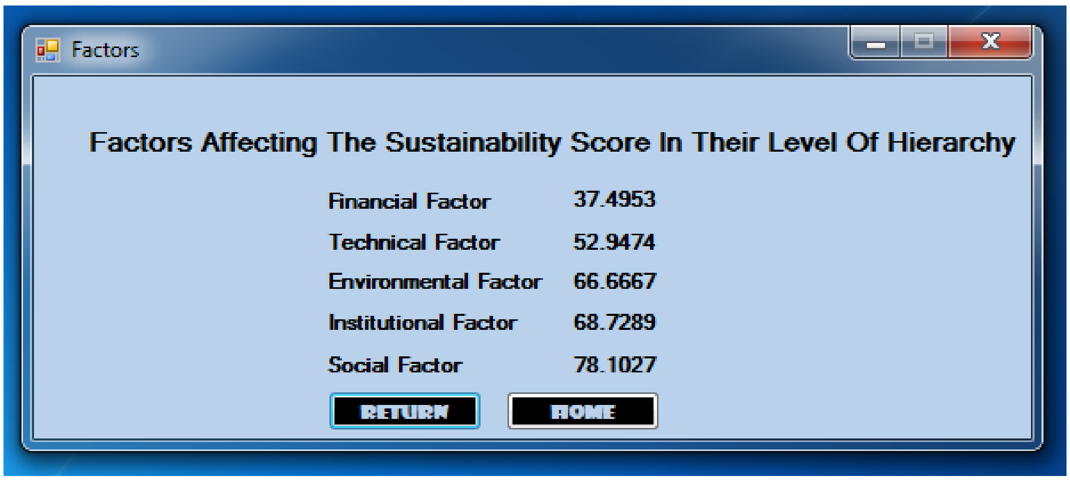

Figure 11 The RWSS sustainability evaluation DSS tool showing the factors that affect the sustainability of rural water supply services in descending order

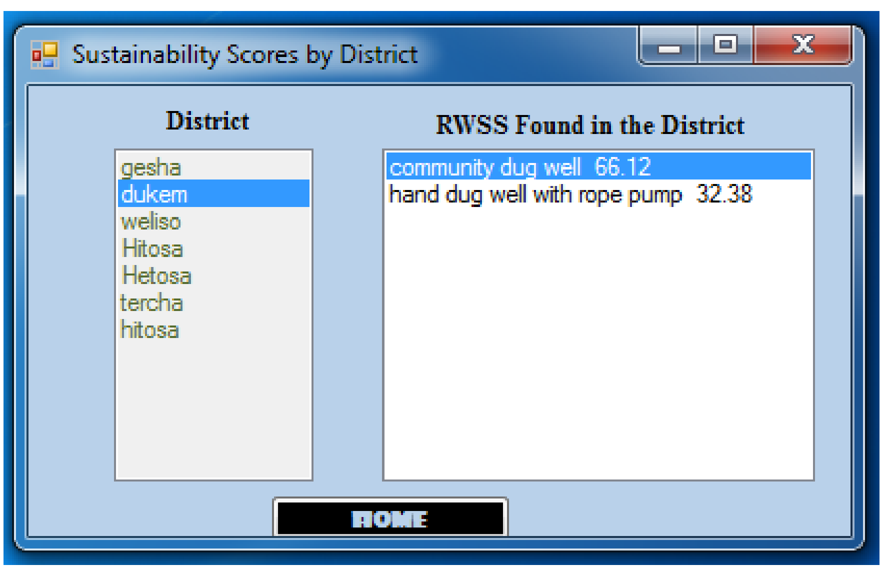

Figure 12 Sustainability scores of every water supply source categorized by their type in a sample district

The forty two sustainability indicators used in the development of the software along with their questions are presented in Appendix B of this thesis document.

6.1.1 Error Handling

There are various error handling features for the software to avoid Garbage in Garbage Out phenomenon in computer programming. A message box is flashed to stop the user from entering invalid data. If the user entered a null data and try to use the software, the RWSS Sustainability Evaluation Software blocks the next step as shown in the figure below:-

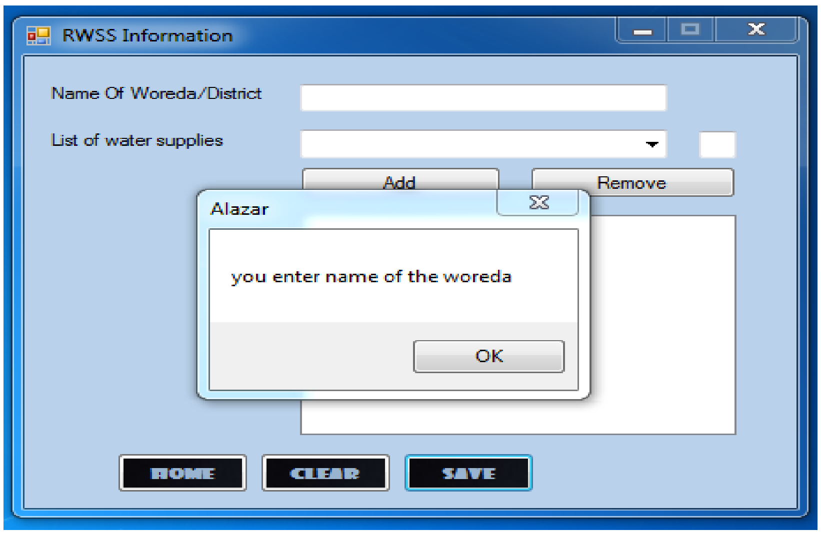

Figure 13 Error pop-up message that emerges when null data is tried to be saved

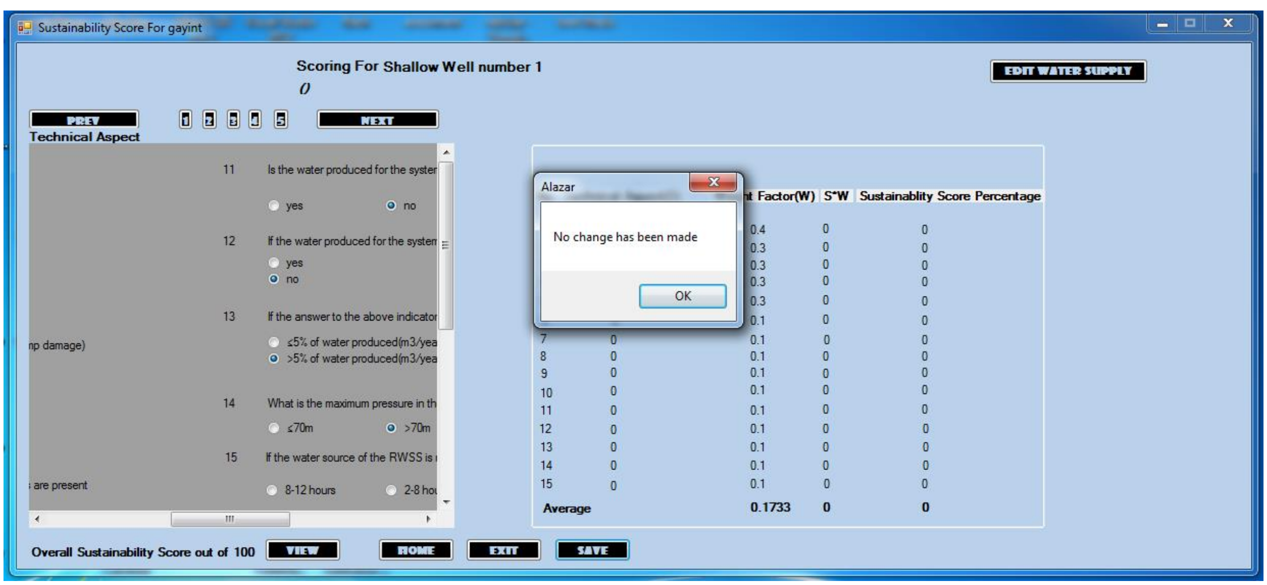

Figure 14 Message that appears when null data is going for execution

7 Results and Discussion

The RWSS Sustainability Evaluation DSS Tool/SUSWAT was applied on different areas that have different rural water supply schemes. After primary and secondary data collection (through the structured indicator questionnaires and observation checklist of the WHO sanitary inspection form) was made, the data were entered in the DSS tool for a real time analysis.

A total of eleven rural water supply schemes categorized into four types of water sources were tested using the DSS tool. Ten of the RWSS are found in North Wollo Zone of Amhara region and one is at Arsi Zone, Oromia region. Out of The Ten RWSS found in North Wollo Zone Seven of the schemes are hand dug wells with hand pump, two shallow wells and one spring at spot. One RWSS (Multi-village water supply scheme) is located at Arsi zone of Oromia region, Hitosa Woreda.

7.1 The Gonde- Iteya Multi-Village Water Supply Scheme

The Gonde-Iteya Multi village water supply scheme is found in Hitosa district located at 160 km south east of Addis Ababa and 25 km north east from zonal capital of Arsi zone, Assela. The district capital is Iteya, located at 140 km from Addis Ababa.

Figure 15-Data collection for the inputs of the DSS tool being conducted in the Gonde- Iteya Multi Village Water Supply Scheme

The sustainability scores obtained in applying the DSS tool on the Gonde-Iteya Multi village water supply scheme are 68.18 on technical aspects, 100 on financial aspects, 90.62 on social aspects, 90.62 on institutional aspects and 78.57 on environmental aspects. The factor with the highest sustainability score is financial aspect scoring 100 whereas the factor with the lowest sustainability score is technical aspect followed by environmental aspect, with the rest scoring above 90. The overall sustainability score is 85.60.

The Gonde Iteya Multi village water supply scheme started service on 2000. Since then new connections continued to be added. The increasing number of users on the schemes generate money for the water board making it financially sustainable. On the contrary the demand in the system is not properly balanced with supply because, even though the Gonde Iteya Multi village water supply scheme presently serves around 100,000 people, it was originally designed to serve 65,248 people. As a result it is facing water strain where water interruptions occur at times. The system ages more than 15 years and there should be more fund on the replacement of old systems since old pipes are prone to leakage causing water shortage in the system.

Hence the technical aspects like ensuring enough water pressure in the system, repairing damage systems and replacing worn out pipes should be stressed along with environmental aspects such as water source conservation activities for the water source yield not to be depleted in Gonde Iteya Multi village water supply scheme.

After testing the DSS tool, the results of the RWSS Sustainability Evaluation DSS Tool was matched with the result obtained from Water Aid’s Sustainability Snapshot to test its reliability and ensure quality of results. The pearson product moment correlation coefficient was used to correlate the RWSS Sustainability Evaluation DSS Tool scores with Water AID Snapshot scores. The pearson product moment correlation coefficient equation is shown below.

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

The overall sustainability scores results of the RWSS Sustainability Evaluation DSS Tool and Water Aid’s Sustainability Snapshot were obtained to be 85.60 and 88.89 out of 100, respectively.

The RWSS Sustainability Evaluation DSS Tool resulted with overall sustainability score of 85.90 by assessing 5 different factors(Technical, Financial, Social, Institutional and Environmental) while the Water Aid Sustainability snapshot resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

The scores obtained from the two tools were correlated by the pearson-product moment correlation and correlation coefficient of r=0.99 was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below.

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	68.18	4648.5124	66.67	4444.8889	4545.5606
Financial	100	10000	100	10000	10000
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	85.4	7327.36	88.89	7901.4321	7608.984
Summation	353.78	31975.87	355.56	32346.32	32154.54

From the table: $\sum x_i$=353.78, $\sum x_i^2$=31975.87, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=32154.54, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*32069.43 - 352.57*355.56}{\sqrt{4*31804.97 - 352.57^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.99}}$$

7.2 Gedebu Shallow Well

Located at 469579 X, 1302287 Y and 2959 m elevation, Gedebu is a shallow well with a depth of 40 m and found in Meket Woreda, North Wello zone. According to the RWSS Sustainability Evaluation DSS tool scores, Gedebu shallow well is a likely sustainable well with overall sustainability score of 79.4 and sectoral sustainability scores of 49.9 Social, 74.98 Financial, 85.7 Environmental, 90.62 Institutional and 96.19 Technical aspects.

Figure 16-Gedebu Shallow Well

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.98 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	61.3	3757.69	66.67	4444.88	4086.87
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	79.4	6304.36	88.89	7901.43	7057.86
Summation	336.89	29314.57	355.56	32346.32	30763.73

From the table: $\sum x_i$=336.89, $\sum x_i^2$=29314.57, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=30763.73, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*30763.73 - 336.89*355.56}{\sqrt{4*29314.57 - 336.89^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.98}}$$

7.3 Difraw Shallow Well

Located at 463067 X, 1306140 Y and 2914 m elevation, Difraw is a shallow well with a depth of 35 m and found in Meket Woreda, North Wello zone. According to the RWSS Sustainability Evaluation DSS tool scores, Difraw shallow well is a likely sustainable well with overall sustainability score of 90.46 and sectoral sustainability scores of 78.56 Environmental, 90.62 Institutional, 93.2 Financial, 93.73 Social and 96.19 Technical aspects.

Figure 17-Difraw Shallow Well

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation, a correlation coefficient of r=0.99 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	74.98	5622.00	66.67	4444.88	4998.91
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	90.46	8183.01	88.89	7901.43	8040.98
Summation	361.63	33057.53	355.56	32346.32	32658.90

From the table: $\sum x_i$=361.63, $\sum x_i^2$=33057.53, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=32658.90, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*32658.90 - 361.63*355.56}{\sqrt{4*33057.53 - 361.63^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.99}}$$

7.4 Wochit Beso Hand Dug Well with Hand Pump

Located at 458225 X, 1305151 Y and 2887m elevation, Wochit Beso Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wello zone. According to the RWSS Sustainability Evaluation DSS tool scores, Wochit Beso Hand Dug Well is a likely sustainable well with overall sustainability score of 93.25 and sectoral sustainability scores of 85.7 Environmental, 90.62 Institutional, 93.73 Social, 96.19 Technical and 100 Financial aspects.

Figure 18-Wochit Beso Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation, a correlation coefficient of r=0.55 between the two tools was obtained which shows a moderately positive correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below.

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	66.67	4444.88	6412.98
Financial	100	10000	100	10000	10000
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	93.25	8695.56	88.89	7901.43	8288.99
Summation	389.44	37948.08	355.56	32346.32	34701.97

From the table: $\sum x_i$=389.44, $\sum x_i^2$=37948.08, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=34701.97, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*34701.97 - 389.44*355.56}{\sqrt{4*37948.08 - 389.44^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.55}}$$

7.5 Dirfo Hand Dug Well with Hand Pump

Located at 469234 X, 1294733 Y and 2842 m elevation, Dirfo Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Dirfo Hand Dug Well is a likely sustainable well with overall sustainability score of 84.4 and sectoral sustainability scores of 65.6 Social, 84.07 Financial, 85.7 Environmental, 90.62 Institutional and 96.19 Technical aspects.

Figure 19-Dirfo Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.81 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	84.07	7067.76	66.67	4444.88	5604.94
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	84.4	7123.36	88.89	7901.43	7502.31
Summation	364.66	33443.64	355.56	32346.32	32726.26

From the table: $\sum x_i$=364.66, $\sum x_i^2$=33443.64, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=32726.26, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*32726.26 - 364.66*355.56}{\sqrt{4*33443.64 - 364.66^2}\sqrt{4*32346.32 - 355.56^2}}$$

$= \underline{\underline{0.81}}$

7.6 Tunchweha Hand Dug Well with Hand Pump

Located at 468011 X, 1293950 Y and 2962m elevation, Tunchweha Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Tuncweha Hand Dug Well is a likely sustainable well with overall sustainability score of 71.78 and sectoral sustainability scores of 25 Social, 61.38 Financial, 85.7 Environmental, 90.62 Institutional and 96.19 Technical aspects.

Figure 20-Tunchweha Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.92 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	61.38	3767.50	66.67	4444.88	4092.20
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	71.78	5152.36	88.89	7901.43	6380.52
Summation	329.35	28172.39	355.56	32346.32	30091.72

From the table: $\sum x_i$=329.35, $\sum x_i^2$=28172.39, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=30091.72, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*30091.72 - 329.35*355.56}{\sqrt{4*28172.39 - 329.35^2}\sqrt{4*32346.32 - 355.56^2}}$$

$= \underline{\underline{0.92}}$

7.7 Addis Amba Hand Dug Well with Hand Pump

Located at 475357 X, 1294750 Y and 2886 elevation, Addis Amba Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Addis Amba Hand Dug Well is a likely sustainable well with overall sustainability score of 87.75 and sectoral sustainability scores of 84.07 Financial, 84.65 Technical, 85.7 Environmental, 90.62 Institutional and 93.73 Social aspects.

Figure 21-Addis Amba Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid’s Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.52 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	84.65	7165.62	100	10000	8465
Financial	84.07	7067.76	66.67	4444.88	5604.94
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	87.75	7700.06	88.89	7901.43	7800.09
Summation	356.47	31933.45	355.56	32346.32	31870.04

From the table: $\sum x_i$=356.47, $\sum x_i^2$=31933.45, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=31870.04, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*31870.04 - 356.47*355.56}{\sqrt{4*31933.45 - 356.47^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.52}}$$

7.8 Dens Hand Dug Well with Hand Pump

Located at 492188 X, 1298292 Y and 2448 elevation, Dens Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Dens Hand Dug Well is a likely sustainable well with overall sustainability score of 86.37 and sectoral sustainability scores of 74.98 Financial, 84.36 Social, 85.7 Environmental, 90.62 Institutional and 96.19 Technical aspects.

Figure 22-Dens Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.97 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	74.98	5622.00	66.67	4444.88	4998.91
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	86.37	7459.77	88.89	7901.43	7677.42
Summation	357.54	32334.29	355.56	32346.32	32295.34

From the table: $\sum x_i$=357.54, $\sum x_i^2$=32334.29, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=32295.34, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*32295.34 - 357.54*355.56}{\sqrt{4*32334.29 - 352.57^2}\sqrt{4*32346.32 - 355.56^2}}$$

$=\underline{\underline{0.97}}$

7.9 Boya Hand Dug Well with Hand Pump

Located at 503891 X, 1301849 Y and 3194 elevation, Boya Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Boya Hand Dug Well is a likely sustainable well with overall sustainability score of 77.89 and sectoral sustainability scores of 56.24 Social, 71.43 Environmental, 74.98 Financial, 90.62 Institutional and 96.19 Technical aspects.

Figure 23-Boya Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.86 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	x_iy_i
Technical	96.19	9252.51	100	10000	9619
Financial	74.98	5622.00	66.67	4444.88	4998.91
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	77.89	6066.85	88.89	7901.43	6923.64
Summation	349.06	30941.37	355.56	32346.32	31541.55

From the table: $\sum x_i$=349.06, $\sum x_i^2$=30941.37, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_iy_i$=31541.55, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*31541.55 - 349.06*355.56}{\sqrt{4*30941.37 - 349.06^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.86}}$$

7.10 Biret Afer Hand Dug Well with Hand Pump

Located at 435263 X, 1306536 Y and 2560 m elevation, Biret Afer Hand Dug Well is a Hand Dug well with a depth of 35 m and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Biret Afer Hand Dug Well is a likely sustainable well with overall sustainability score of 77.40 and sectoral sustainability scores of 53.13 Social, 61.38 Financial, 85.7 Environmental, 90.62 Institutional and 96.19 Technical aspects.

Figure 24-Biret Afer Hand Dug Well with Hand pump

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.97 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	61.38	3767.50	66.67	4444.88	4092.20
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	77.4	5990.76	88.89	7901.43	6880.08
Summation	334.97	29010.78	355.56	32346.32	30591.29

From the table: $\sum x_i$=334.97, $\sum x_i^2$=29010.78, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=30591.29, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*30591.29 - 334.97*355.56}{\sqrt{4*29010.78 - 334.97^2}\sqrt{4*32346.32 - 355.56^2}}$$

$= \underline{\underline{0.97}}$

7.11 Kega Weha Spot Spring

Located at 435263 X, 1298097 Y and 2496 m elevation, Kega Weha Spring is a spot spring with a (2.5*2.6*7) m spring box and found in Meket Woreda, North Wollo Zone. According to the RWSS Sustainability Evaluation DSS tool scores, Kega Weha Spot Spring is a likely sustainable spring with overall sustainability score of 75.29 and sectoral sustainability scores of 40.6 Social, 70.47 Financial, 78.56 Environmental, 90.62 Institutional and 96.19 Technical aspects.

Figure 25-Kega Weha Spring

The DSS tool scoring is correlated with Water Aid's Sustainability snapshot which resulted with overall sustainability score of 88.89 by assessing Technical, Financial, and Equipment and Spare parts aspects.

From the pearson-product moment correlation a correlation coefficient of r=0.88 between the two tools was obtained which shows a strong correlation between the DSS tool of this research and Water Aid's Sustainability Snapshot as shown below:-

	DSS Tool (x_i)	x_i^2	WATER AID's Sustainability Snapshot (y_i)	y_i^2	$x_i y_i$
Technical	96.19	9252.51	100	10000	9619
Financial	70.47	4966.02	66.67	4444.88	4698.23
Equipment and Spare parts	100	10000	100	10000	10000
Overall Sustainability Score	75.29	5668.58	88.89	7901.43	6692.52
Summation	341.95	29887.12	355.56	32346.32	31009.76

From the table: $\sum x_i$=341.95, $\sum x_i^2$=29887.12, $\sum y_i$=355.56, $\sum y_i^2$=32346.32, $\sum x_i y_i$=31009.76, n=4

Hence,

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}$$

$$= \frac{4*31009.76 - 341.95*355.56}{\sqrt{4*29887.12 - 341.95^2}\sqrt{4*32346.32 - 355.56^2}}$$

$$= \underline{\underline{0.88}}$$

From the real time analysis of the DSS tool, it is found out that increased social scores which represents community contribution and social participation contributing to increased sustainability scorings. This is similar with the findings of (Sharma, 2012) and (Hurst & Moges, 2013) where increased involvement and social participation of the community and increased community contribution majorly contributing to the sustainability of rural water supply services.

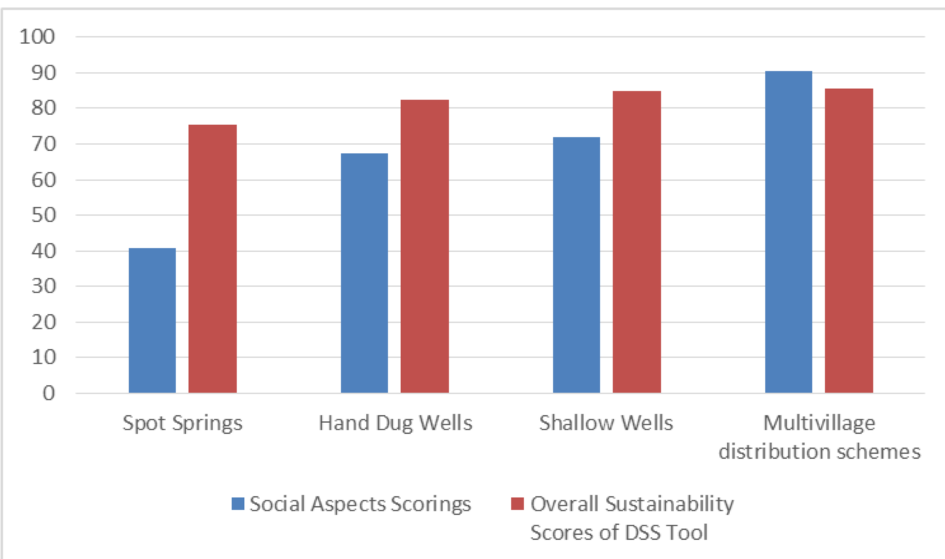

Figure 26-As social aspects scorings increase, overall sustainability scores of the DSS Tool increase

From the studied RWSS, it is found out that schemes with distribution are more sustainable than isolated on spot schemes. This is similar with the finding of (Gebrie, 2012) which remarks that a shift is needed from isolated source scheme to rural water schemes with distribution, to ensure sustainability in Ethiopia.

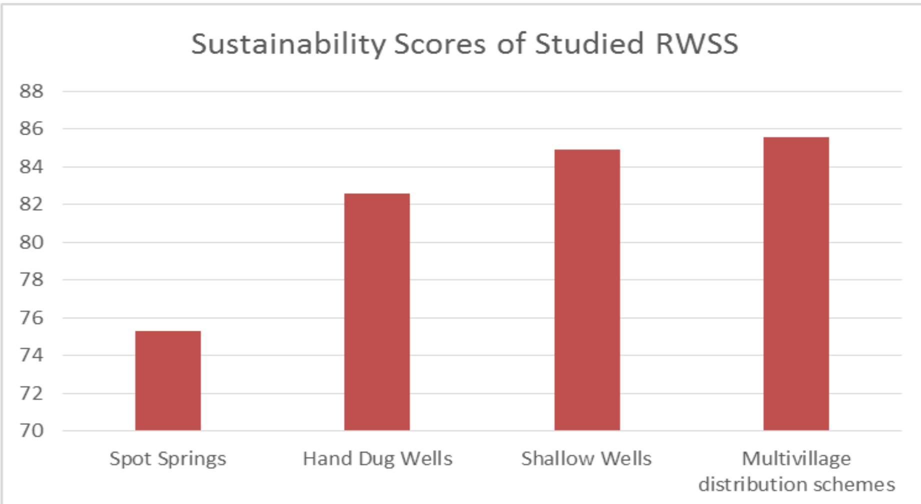

Figure 27-Sustainability scores of studied RWSS

It is found that ensuring cost recovery of the services highly contribute to the sustainability of the rural water supply services which is a similar finding with (Gebrie, 2012) that concludes tariff models should ensure cost recovery of rural water supply services and not only operation and maintenance costs.

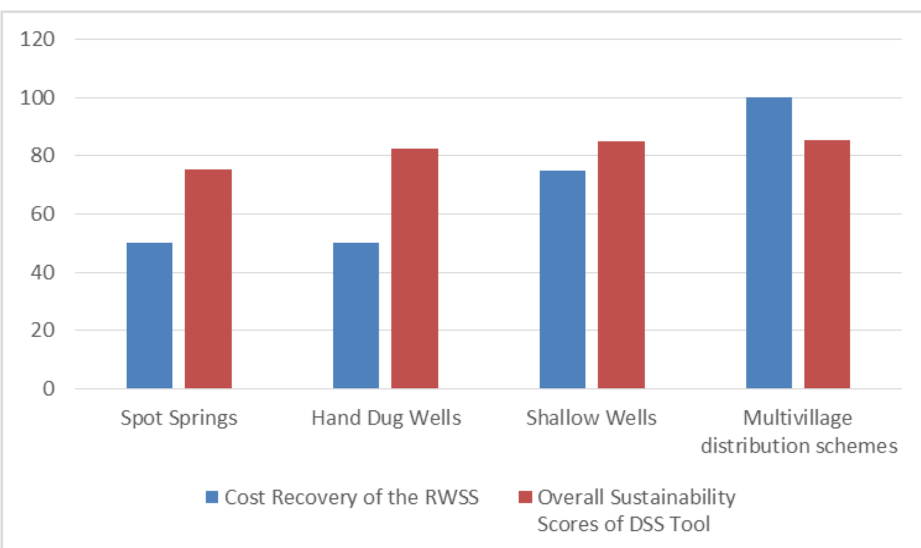

Figure 28- As cost recovery index scorings increase, overall sustainability scores of the DSS Tool increase

8 Conclusion and Recommendation

This thesis outputs a decision support system tool that helps the rural communities to achieve sustainability goals regarding water supply services. This is important because the sustainability of rural water supply services is a big concern in every areas of the globe and is where the world heads which the SDGs promise to deliver in terms of assuring access to water supply for all.

The RWSS Sustainability Evaluation DSS tool is a user friendly DSS that can aid engineers and planners in their decisions regarding rural water supply services. The application of the DSS tool not only points out the sustainability scores of RWSS but also identifies the factors behind the failure to achieve the likely sustainability score.

This DSS tool answers which water supply source in a woreda is most feasible in terms of sustainability and hence is preferable for construction. The computer program further answers which area of the RWSS sector needed to be upgraded in order to solve the sustainability issues in a district. The flexibility of the software makes it easy to analyse the sustainability of RWSS at district level, zone level, region level or national level.

The DSS tool assists project design in terms of delivering a sustainable WASH service. If applied on the onset of a project, it provides a baseline on the likelihood of WASH service sustainability. The DSS tool can be used as a monitoring tool when assessed at the different phases of a project and provide pointer on which aspects of the FIETS should be emphasized to improve the likelihood of sustainability. When administered at the project end, it helps to evaluate the sustainability of the completed WASH services. The DSS tool equips district and zonal authorities with the information and actions to be followed for next implementation period with regard to achieving sustainability.

RWSS Sustainability Evaluation DSS tool’s criteria validity was checked by comparing its results with a sustainability snapshot tool that is used by Water Aid, an international organization that widely works in the area of rural water supply. The results obtained was satisfactory. The computer program developed by this thesis is fully functional and can be applied to planning and implementation of rural water supply services.

Though the objectives of developing a DSS tool and testing it is met, due to financial constraints, more rural water supply services at the different regions of the country couldn't be incorporated in testing the DSS tool.

From the real time analysis of the DSS tool and its finding, it is concluded that increasing community contribution and social participation, ensuring cost recovery and developing services with distribution schemes than isolated spot schemes increases sustainability of rural water supply services.

It is recommended that the application of Sustainability DSS tools such as this study's tool should be incorporated in the planning, monitoring and evaluation of WASH projects. Additionally, community contribution and social participation, ensuring cost recovery and developing services with distribution schemes than isolated spot schemes should be practised to ensure sustainability of rural water supply services.

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APPENDICES

APPENDIX A User Manual

1. Introduction

This User guide shows the main features of the RWSS Sustainability Evaluation software to ensure good command and full application of the DSS tool for the user.

How to install RWSS Sustainability Evaluation DSS Tool

The user can start the application by installing the software in a folder located wherever he/she wants. To install the software first we open the setup folder and read the readme first script which guides us to run the windows installer setup package of the software where it directs us to the 'Welcome to install shield wizard'. We then go all through the 'next' buttons until installation is finished and after that we run the database script.bat file as administrator which completes the installation and creates a shortcut function of the software on the desktop ready to be used.

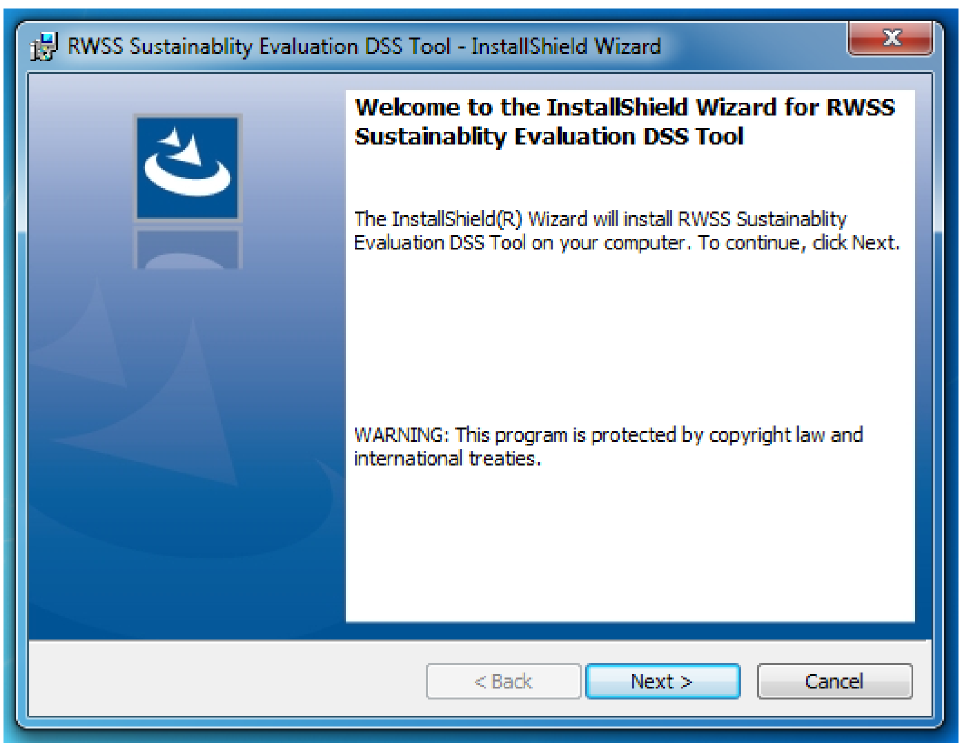
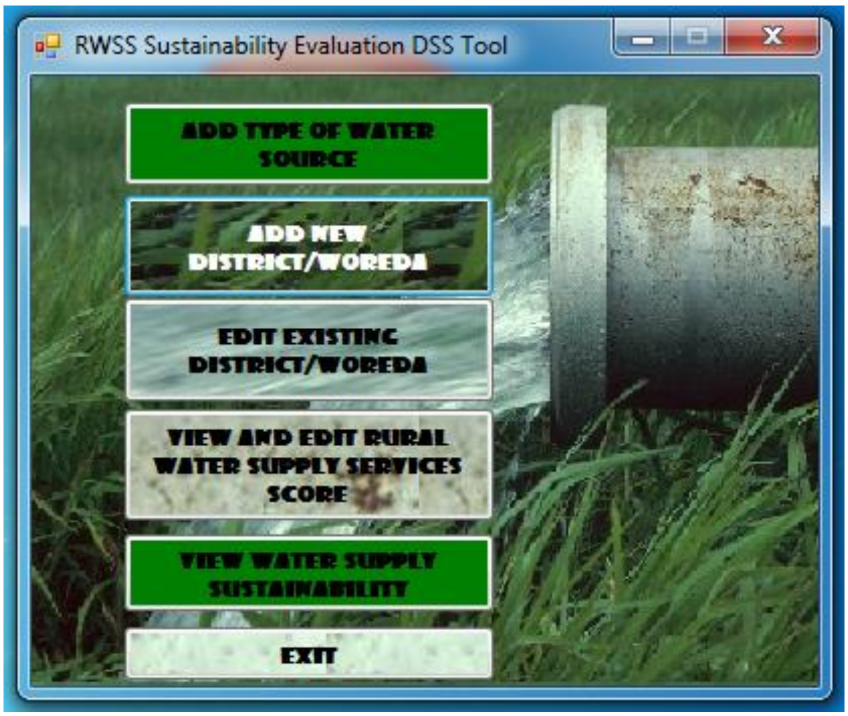


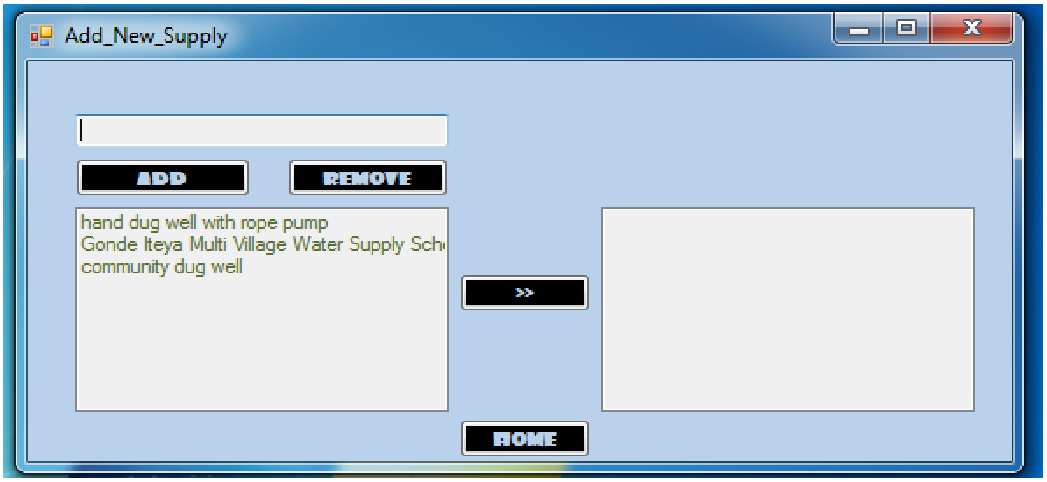
Figure 29-Install shield wizard of the RWSS Sustainability Evaluation DSS Tool

2. Software's User Interface

The RWSS Sustainability Evaluation DSS tool/Suswat uses an interface (graphical user interface) that is comprised of different buttons each representing an operation on a menu. The main RWSS window consists of tools to add new water source type, new district/ woreda that have a RWSS, edit existing rural water supply service, view and edit rural water supply service score, view water supply sustainability, and add a new type of water supply if needed as shown below.

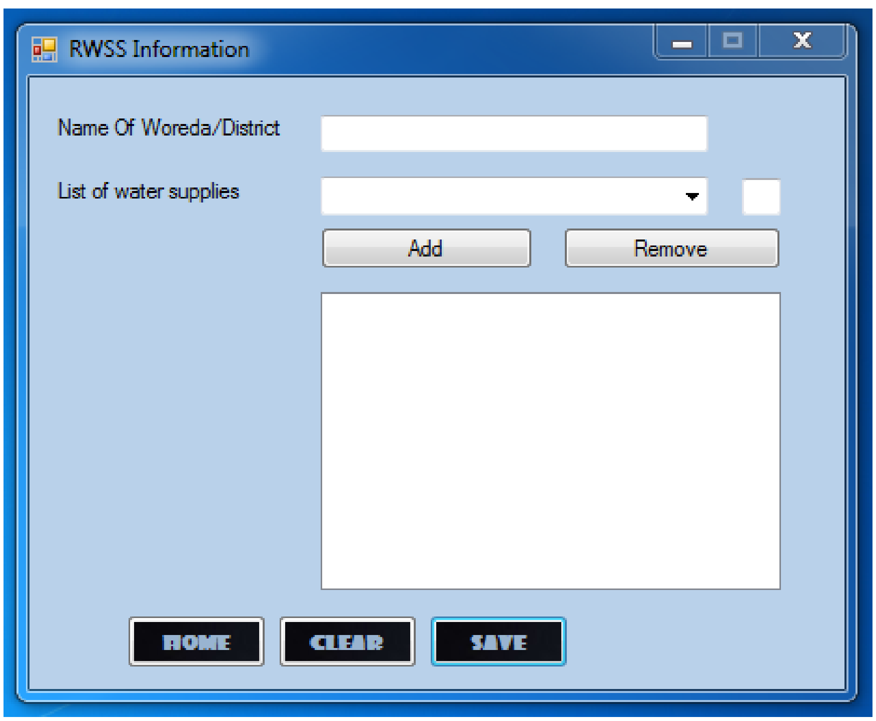


The 'Add Type of Water Source' operation button is the first step in the RWSS Sustainability Evaluation DSS tool where we type and store a type of water source, into the database. This function allows us to register a water scheme of all kind of ranges from hand dug well with hand pump to a spot spring.



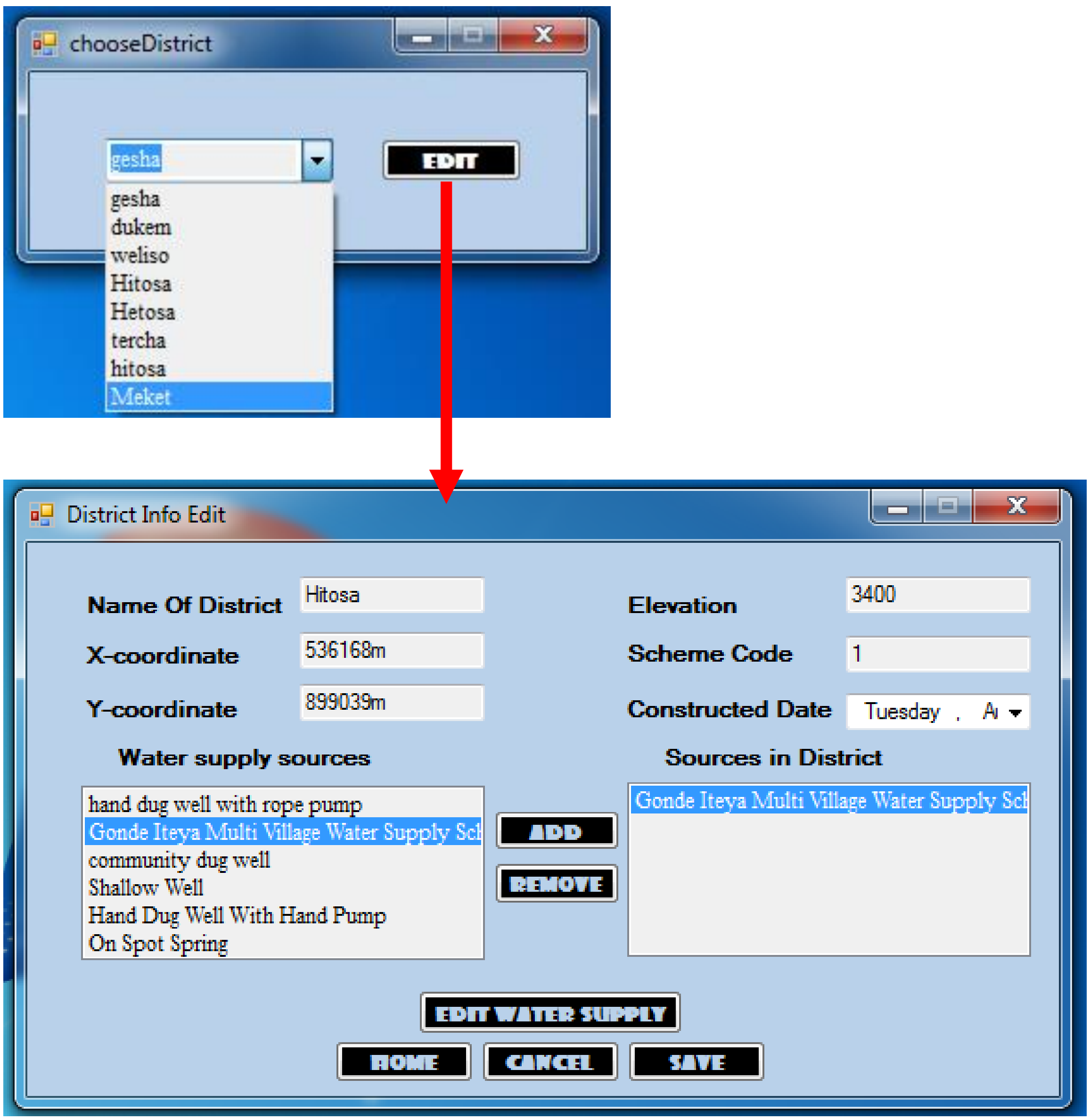
The second function from the main menu is adding a new district/woreda water supply service.

This operation function is helpful to register a district with the exact number of RWSS in the district.

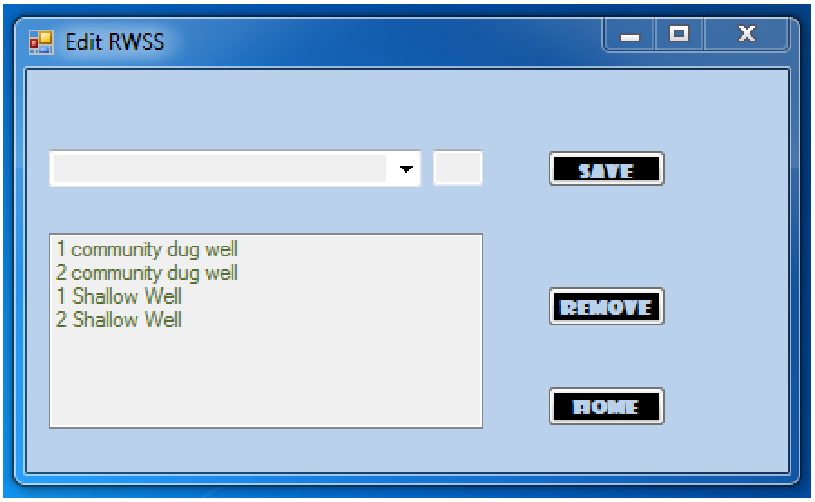


The third function of the RWSS Sustainability Evaluation DSS tool is to edit the registered districts.

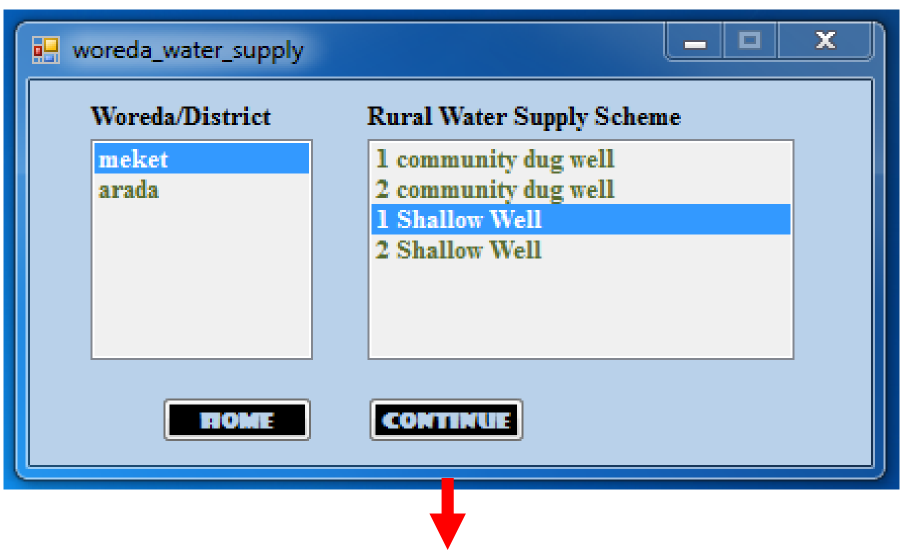
It allows to choose the particular RWSS among the districts and direct it to the editing platform which allows to edit the location related information stored about the RWSS and further allows the option to delete the added RWSS by clicking on the remove button.

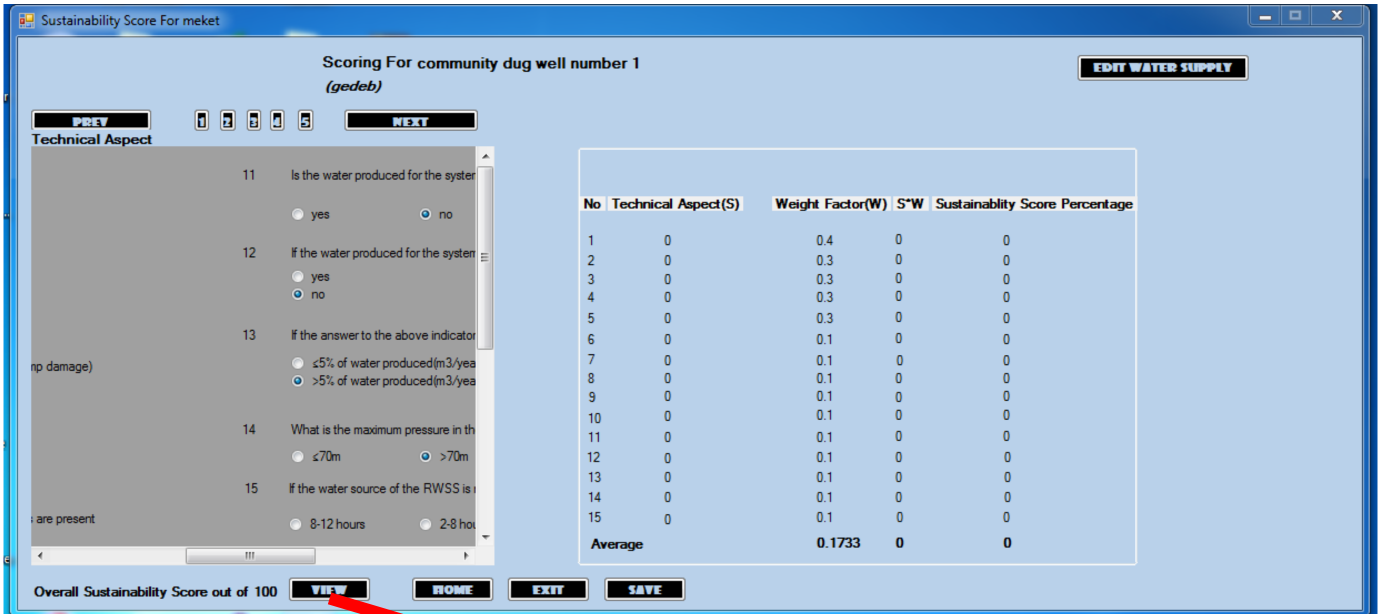


By clicking on the Edit Water Supply tool bar on the above workbench, the DSS tool is directed to the Edit RWSS platform where we can change the number of RWSS in the district.

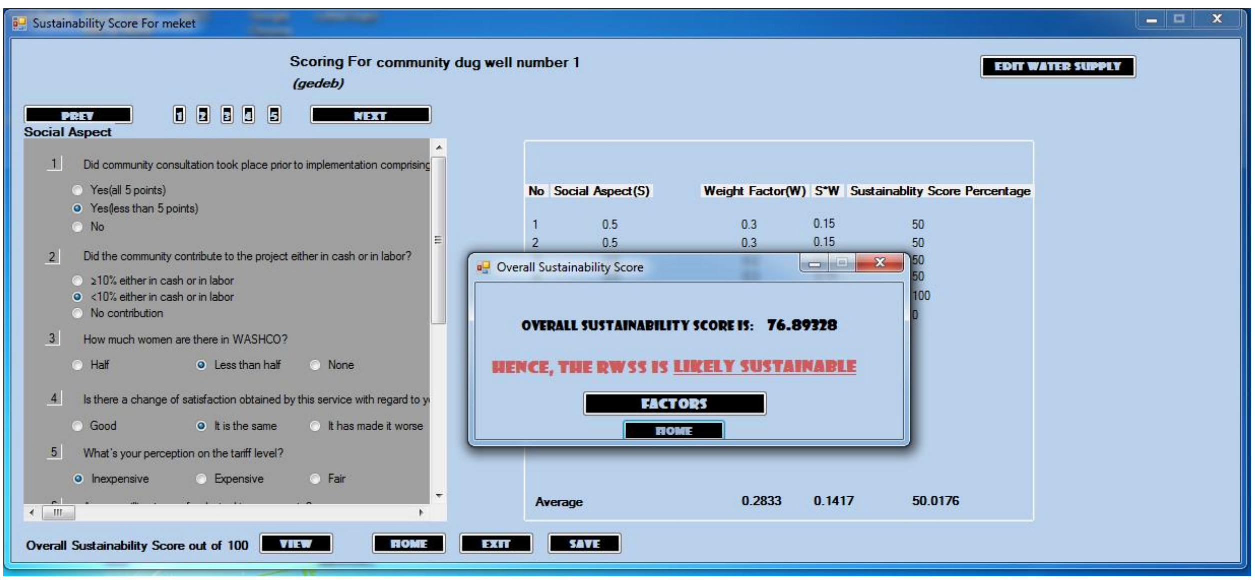


The fourth operation button, allows us to view and edit the RWSS sustainability evaluation scores and direct us to each sustainability factor indicators as shown below.

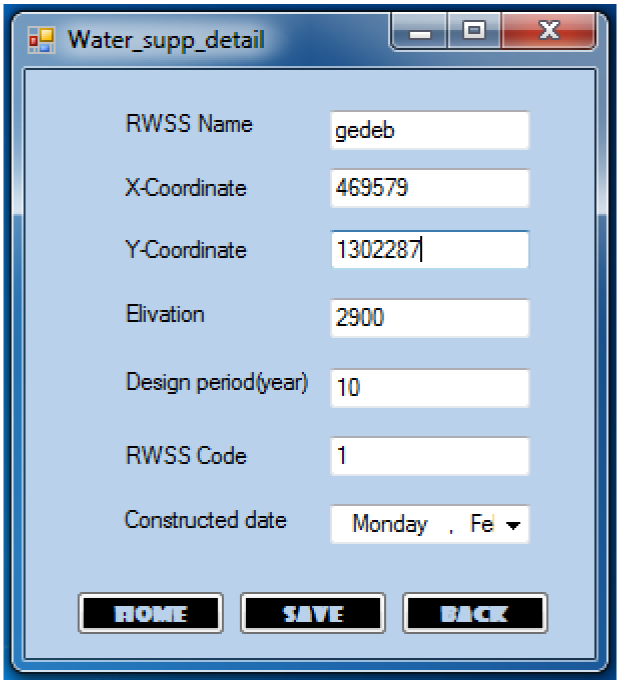




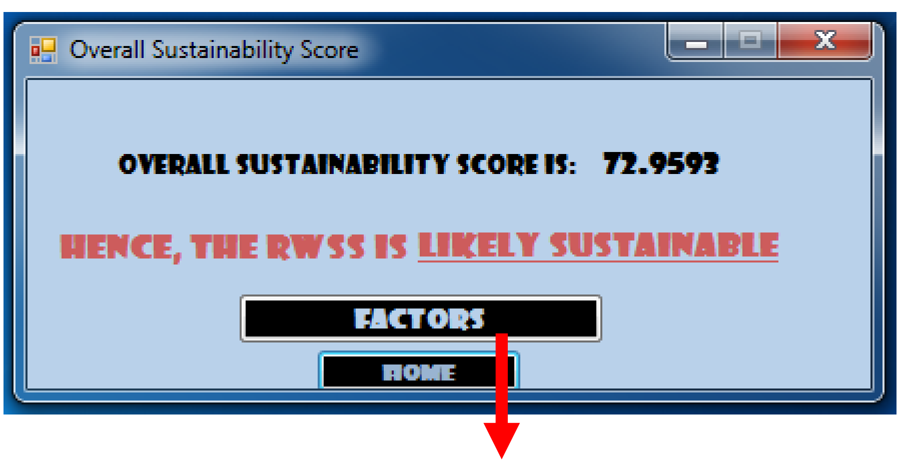
On the bottom of the above interface there is a view button that allows us to visualize the overall sustainability score of the RWSS as shown in the figure below.

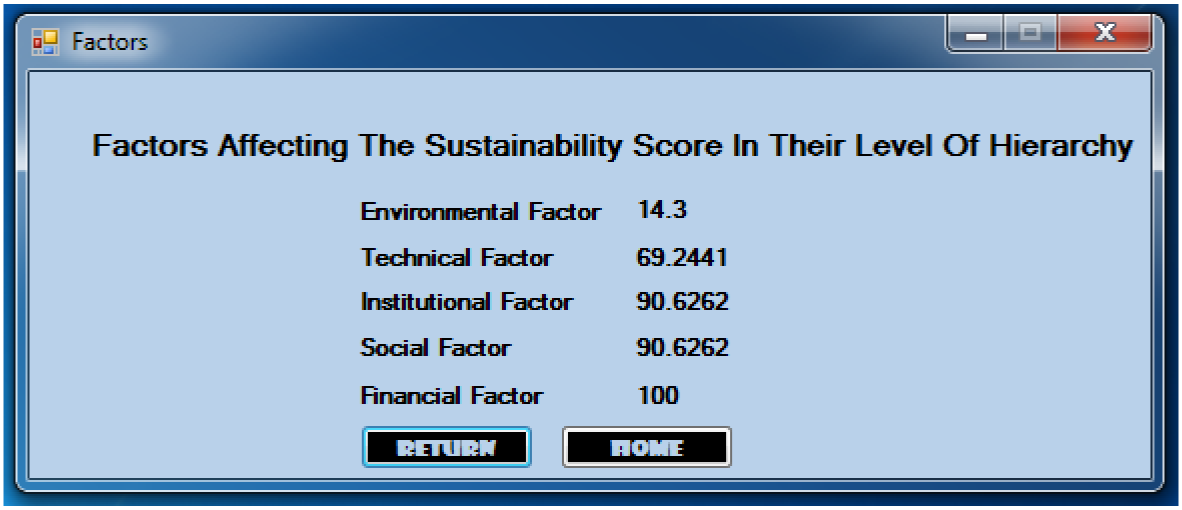


The Edit Water Supply function at the far right corner of the above workbench also stores every information including the x, y coordinates and elevation of the particular water supply service. It describes detail information of the RWSS including the name of the RWSS, X, Y, Z coordinates, the constructed date of the RWSS together with its design period and the identification code of the RWSS.



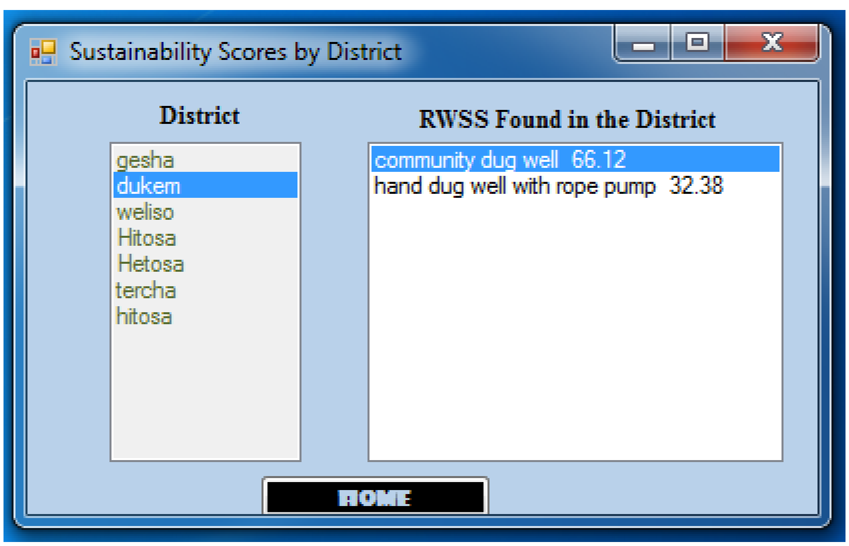
After we visualize the overall sustainability score we can view the factors that contributed to the score by clicking the factor button where a window pops up that shows the five factors that contributed to the overall sustainability score in their descending order from the highest to the lowest scores.





As we see from the figure after knowing which factor scored the lowest scores, we can infer which sector needs more focus in terms of increasing the sustainability of the particular RWSS sustainability score.

The fifth operation button, “view water sustainability” allows the overall sustainability score of a particular RWSS, to be aggregated along with the other RWSS found in a district and viewed per scheme. This operation identifies whether a Shallow well or Spring at a spot or any other water supply scheme is more sustainable in that particular district as shown in the figure below.



APPENDIX B. Sustainability Indicators

The sustainability indicator questions used in the development of this DSS tool are presented below:-

Technical Aspects

1. Is the system functioning?
    a. Yes
    b. Some parts are working and some don't
    c. No
2. How much hours per day averaged over week do the system work?
    a. 8-12 hours
    b. 2-8 hours
    c. 0-2 hours
3. Does the system contain any defect? (structural defect/faucet damage/pump damage)
    a. Yes
    b. No
4. Number of breakdowns per year?
    a. 0
    b. 1-3
    c. >4
5. Is there any exposed pipe leakage?
    a. Yes
    b. No leakage but cracks are present
    c. No
6. Is there an assigned person for daily operation and pump check?
    a. Yes

b. No

7. In designing the RWSS, how much percentage of total water demand is taken for water loss in the service?

    a. 15%

    b. <15%

8. What is the minimum water pressure in the farthest public faucet?

    a. 2-3m

    b. <2m

9. What is the minimum head loss in the system?

    a. 0.5m-10m/1000m

    b. <0.5m/1000m

    c. >10m/1000m

10. If the water source of the RWSS is motorized by pump, how much time of the day does the electricity works?

    a. 8-12 hours

    b. 2-8 hours

    c. 0-2 hours

11. Is the water produced for the system metered?

    a. Yes

    b. No

12. If the water produced for the system is metered, is it the same as the volume of water accounted for legitimate consumption?

    a. Yes

    b. No

13. If the answer to the above indicator is no, How much m^3/year is the difference?

    a. ≤5% of water produced(m^3/year)

   b. >5% of water produced(m^3/year)

14. What is the maximum pressure in the system?
    a. ≤70m
    b. >70m
15. Are there break pressure tanks or pressure reducing valves installed where there is high pressure in the RWSS?
    a. Yes
    b. No

Financial Aspects

1. Is the tariff set based on operation, maintenance and replacement cost?
    a. Yes
    b. Operation Only
    c. Other
2. Is there a differential tariff structure?
    a. Yes
    b. No
3. Is punitive measures taken on those who don’t pay tariff?
    a. Yes
    b. No
4. Is there a presence of financial book keeping system?
    a. Yes
    b. Incomplete
    c. No
5. Is there a bank account?
    a. Yes

b. No

6. The Cost covered by the tariff is:-

    a. Cover Operation and Maintenance cost and can replace the system

    b. Cover Operation and Maintenance cost and can repair the system

    c. Cover only Operation and Maintenance cost

    d. Cover Operations only

    e. Does not cover operation

    f. There is no tariff

7. What is the tariff of water consumption per m^3?

    a. 2-4 birr

    b. 4-8 birr

    c. >8 birr

8. What is the tariff the household pay in relation to their income level?

    a. ≤5% household’s income

    b. >5% household’s income

Social Aspects

1. Did community consultation took place prior to implementation comprising the following points?

    i. Public discussion on the alternative projects;

    ii. Agreement on the service level based on an understanding of the required community contribution

    iii. Selection of preferred alternative from among the various possible options

    iv. Consultation about the locations of water point (women needs to be involved); and

    v. Work out commitment of the community to share in the investment cost and where agreed communities to start mobilizing the case contribution

a. Yes(all 5 points)

b. Yes(less than 5 points)

c. No

2. Did the community contribute to the project either in cash or in labor?

a. ≥10% either in cash or in labor

b. <10% either in cash or in labor

c. No contribution

3. How much women are there in WASHCO?

a. Half

b. Less than half

c. None

4. Is there a change of satisfaction obtained by this service with regard to the user's prior experience?

a. Good

b. It is the same

c. It has made it worse

5. What's the user's perception on the tariff level

a. Expensive

b. Fair

c. Inexpensive

6. Are the user willing to pay for desired improvements?

a. Yes

b. No

c. Don't know

Institutional Aspects

1. What is the maximum day without repairing damaged systems?
   a. 1
   b. 2-5
   c. ≥ 6
2. Are there spare-parts available for purchase in a nearby location?
   a. At district level
   b. At Zonal level
   c. At Regional level
3. Do you have a construction supervision form?
   a. Yes
   b. No
4. Is there a hired, TVET trained water technician available?
   a. Yes
   b. No
5. Did the assigned person/plumber/operator receive any training on operation and maintenance of the schemes?
   a. Yes
   b. No
6. Did training provided on procurement management of RWSS?
   a. Yes
   b. No

Environmental Aspects

1. Is water available at all times of seasons?
    a. Yes
    b. No
2. Do you add chlorine?
    a. Yes
    b. Chlorine is added only once, when the service started
    c. No
3. What's the contamination risk score according to WHO sanitary inspection form (WHO, 1997)?
    a. Very High/High
    b. Intermediate
    c. Low
4. lpcd consumption

    How much jerican/ensira (liters) water do you collect?____

    What's the number of your household residents?_____

    lpcd= total collected water in a day/total family number

    a. >15lpcd
    b. 15lpcd
    c. <15lpcd
5. What is the time it take to collect water including the waiting (queuing) time?
    a. <30 minute
    b. 30 minute
    c. >30 minute

6. Are there activities being done to conserve the water source and the groundwater table (Land and Water conservation practices like contour bunds, planting trees)?
    a. Yes
    b. No

7. What is the minimum free chlorine residual available at the farthest point of the RWSS?
    a. 0.2mg/l-0.5mg/l
    b. <0.2mg/l
    c. >0.5mg/l

APPENDIX C. Water AID's Sustainability Snapshot

Financial 1 No funds available for maintenance when needed 2 Funds available but not sufficient for the most expensive maintenance process 3 Funds available and sufficient for the most expensive maintenance process
Technical skills 1 Technical skills not available* for maintenance when needed 2 Some technical skills for maintenance, but not for all 3 Technical skills for all maintenance processes available *Available in this context means available to an average community member within a reasonable time
Equipment and spare parts 1 Not available when needed 2 Available but not for all repairs 3 Available for all repairs

Table 4-Sustainability Snapshot developed by Water Aid rates is a participatory process by which a composite score (1-unlikely to last beyond first breakdown, 2- unlikely to last beyond first major breakdown, and 3-likely to be sustained) for service in a community or area is derived by selecting one statement (1, 2, or 3) for each category: financial, technical skills, and equipment and spare parts *(Schweitzer, 2009)*, *(Sugden, 2003)*

APPENDIX D. WHO Sanitary Inspection Forms

I. OPEN DUG WELL

.0 GENERAL INFORMATION

		Name	Code
1.1	Location:		
	Region		
	Zone		
	Wereda		
	Town/village		
	Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0	**SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT**	**Risk (Y=1/N=0)**
2.1	Is there a latrine within 30 meters of the well?	
2.2	Is the nearest latrine on higher ground than the well?	
2.3	Is there any other sources of pollution (e.g. animal excreta & rubbish) within 30 meters of the well?	
2.4	Is the drainage poor, causing stagnant water with in 2 meters of the well?	
2.5	Is there a faulty drainage channel? Is it broken permitting ponding?	
2.6	Is the wall (parapet) around the well inadequate, allowing the surface water to enter the well?	
2.7	Is the concrete floor less than 1 m wide around the well?	
2.8	Are the walls of the well inadequately sealed at any point for 3 m below ground?	
2.9	Are there any cracks in the concrete floor around the well, which could permit water to enter the well?	
2.10	Are the robe & bucket left in such a position that they may become contaminated?	
2.11	Does the installation require fencing?	
	Total score of risks	**/ 11**

Contamination risk score:

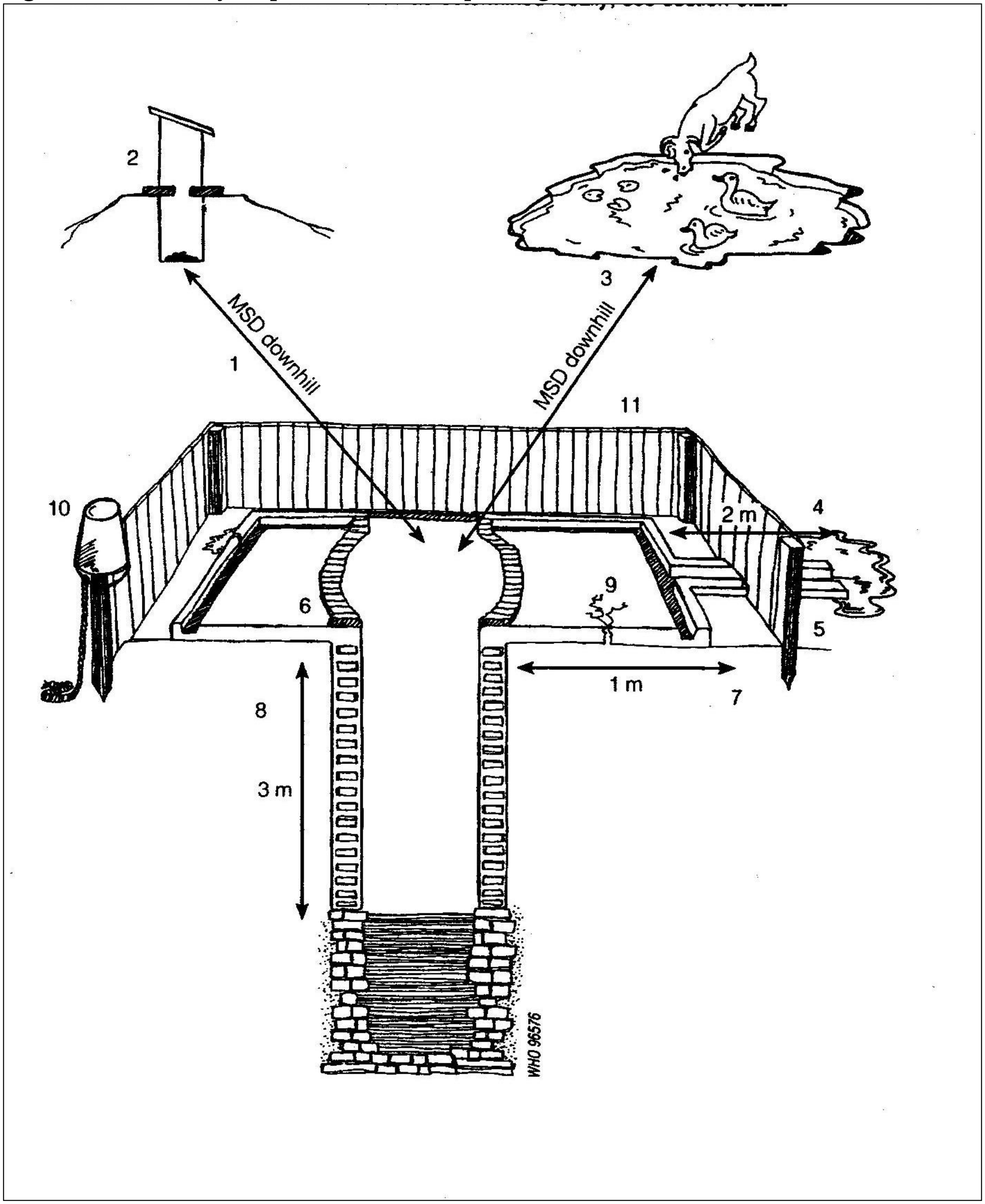
9-11	Very high
6-8	High
3-5	Intermediate
0-2	Low

3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ________ (list Nos 1 – 11)
And the authority advised on remedial action.

Signature of observer: ________

Figure-A3-1 Sanitary Inspection form for open dug-well



II. DUG WELL WITH WINDLASS AND PARTIAL COVER

1.0 GENERAL INFORMATION

1.1 Location:

	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0	**SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT**	**Risk (Y=1/N=0)**
2.1	Is there a latrine within 30 meters of the well?	
2.2	Is the nearest latrine on higher ground than the well?	
2.3	Is there any other sources of pollution (e.g. animal excreta & rubbish) within 30 meters of the well?	
2.4	Is the drainage poor, causing stagnant water with in 2 meters of the well?	
2.5	Is there a faulty drainage channel? Is it broken permitting ponding?	
2.6	Is the wall (parapet) around the well inadequate, allowing the surface water to enter the well?	
2.7	Is the concrete floor less than 1 m wide around the well?	
2.8	Are the walls of the well inadequately sealed at any point for 3 m below ground?	
2.9	Are there any cracks in the concrete floor around the well, which could permit water to enter the well?	
2.10	Are the robe & bucket left in such a position that they may become contaminated?	
2.11	Does the well require a cover?	
2.12	Does the installation require fencing?	
	Total score of risks	**/ 12**

Contamination risk score:

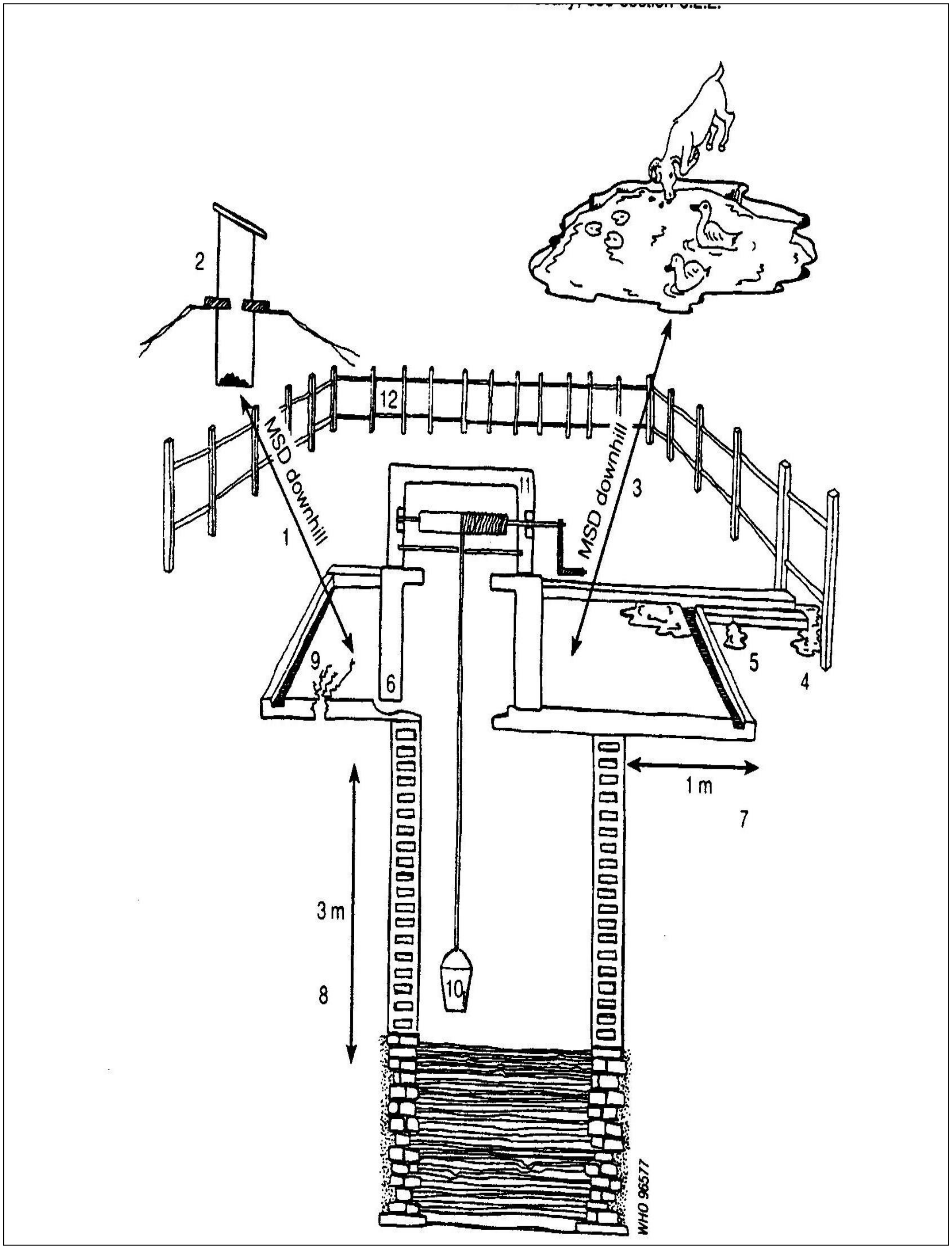
9-12	Very high
6-8	High
3-5	Intermediate
0-2	Low

3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ____________ (list Nos 1 – 12)
And the authority advised on remedial action.

Signature of observer: ____________

Figure-A3-2 Sanitary Inspection form for dug-well with windlass and partial cover



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III. COVERED DUG WELL WITH HAND-PUMP

1.0 GENERAL INFORMATION

1.1 Location:

	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0	**SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT**	**Risk (Y=1/N=0)**
2.1	Is there a latrine within 30 meters of the well and hand-pump?	
2.2	Is the nearest latrine on higher ground than the hand-pump?	
2.3	Is there any other sources of pollution (e.g. animal excreta & rubbish) within 30 meters of the hand-pump?	
2.4	Is the drainage poor, causing stagnant water within 2 meters of the hand-pump?	
2.5	Is there a faulty drainage channel? Is it broken, permitting ponding?	
2.6	Is the wall or fencing around the hand-pump inadequate, allowing animals in?	
2.7	Is the concrete floor less than 1 m wide all around the hand-pump?	
2.8	Is there any ponding on the concrete floor around the hand-pump?	
2.9	Are there any cracks in the concrete floor around the hand-pump, which could permit water to enter the hand-pump?	
2.10	Is the hand-pump loose at the point of attachment to the base so that water could enter the casing?	
2.11	Is the cover of the well unsanitary?	
2.12	Are the walls of the well inadequately sealed at any point for 3 m below ground level?	
	Total score of risks	**/ 12**

Contamination risk score:

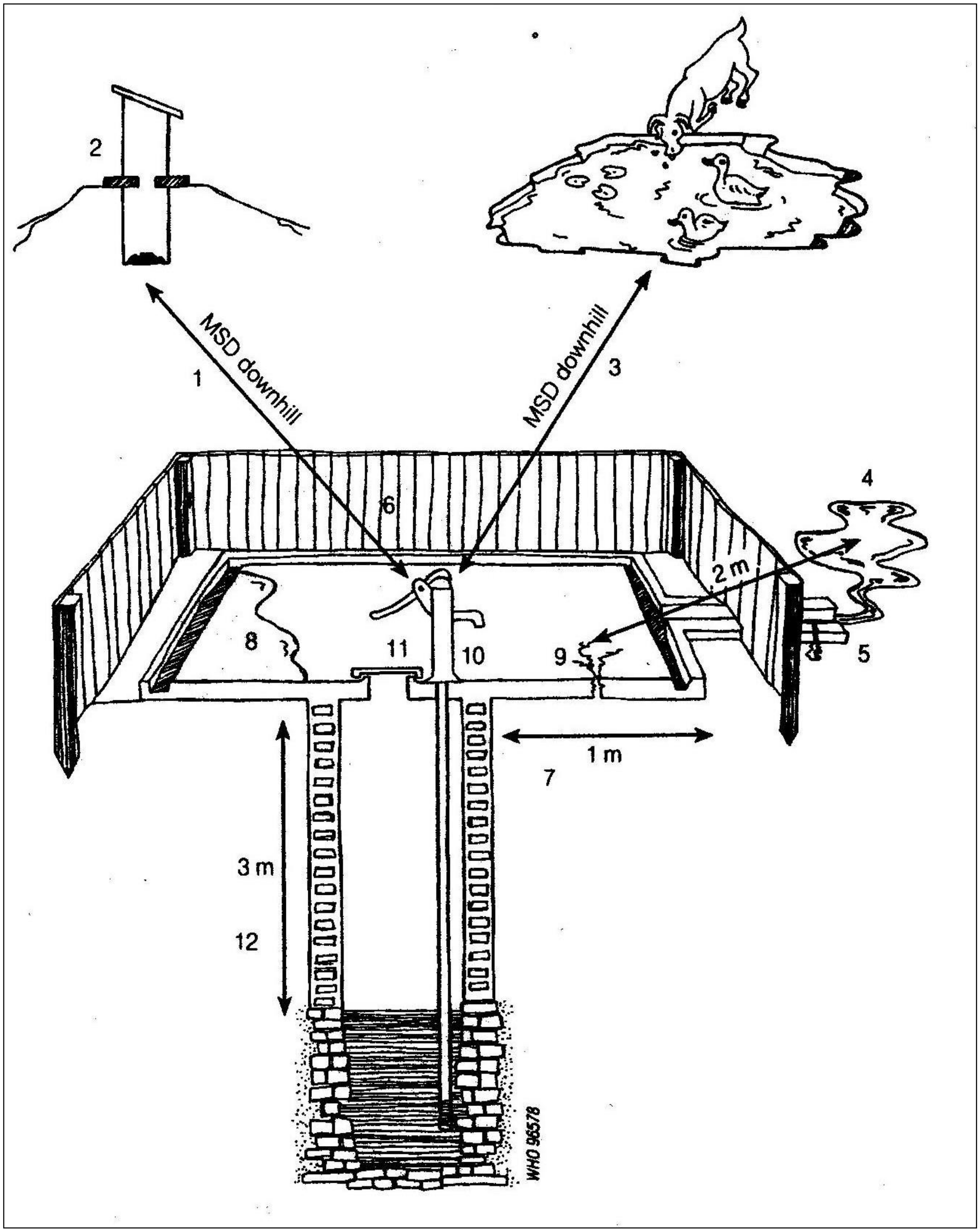
9-12	Very high
6-8	High
3-5	Intermediate
0-2	Low

3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ____________ (list Nos 1 – 12)
And the authority advised on remedial action.

Signature of observer: ____________

Figure-A3.3 Sanitary Inspection form for covered dug well with hand-pump



IV. TUBE-WELL WITH HAND-PUMP

1.0 GENERAL INFORMATION

		Name	Code
1.1	Location:		
	Region		
	Zone		
	Wereda		
	Town/village		
	Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0	**SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT**	**Risk (Y=1/N=0)**
2.1	Is there a latrine within 30 meters of the hand-pump?	
2.2	Is the nearest latrine on higher ground than the hand-pump?	
2.3	Is there any other source of pollution (e.g. animal excreta & rubbish) within 30 meters of the hand-pump?	
2.4	Is the drainage poor, causing stagnant water within 2 meters of the hand-pump?	
2.5	Is the hand-pump drainage channel faulty? Is it broken, permitting ponding?	
2.6	Is the fencing around the hand-pump inadequate, allowing animals in?	
2.7	Is the concrete floor less than 1 m wide all around the hand-pump?	
2.8	Is there any ponding on the concrete floor around the hand-pump?	
2.9	Are there any cracks in the concrete floor around the hand-pump, which could permit water to enter the well?	
2.10	Is the hand-pump loose at the point of attachment to the base so that water could enter the casing?	

Total score of risks **/ 10**

Contamination risk score:

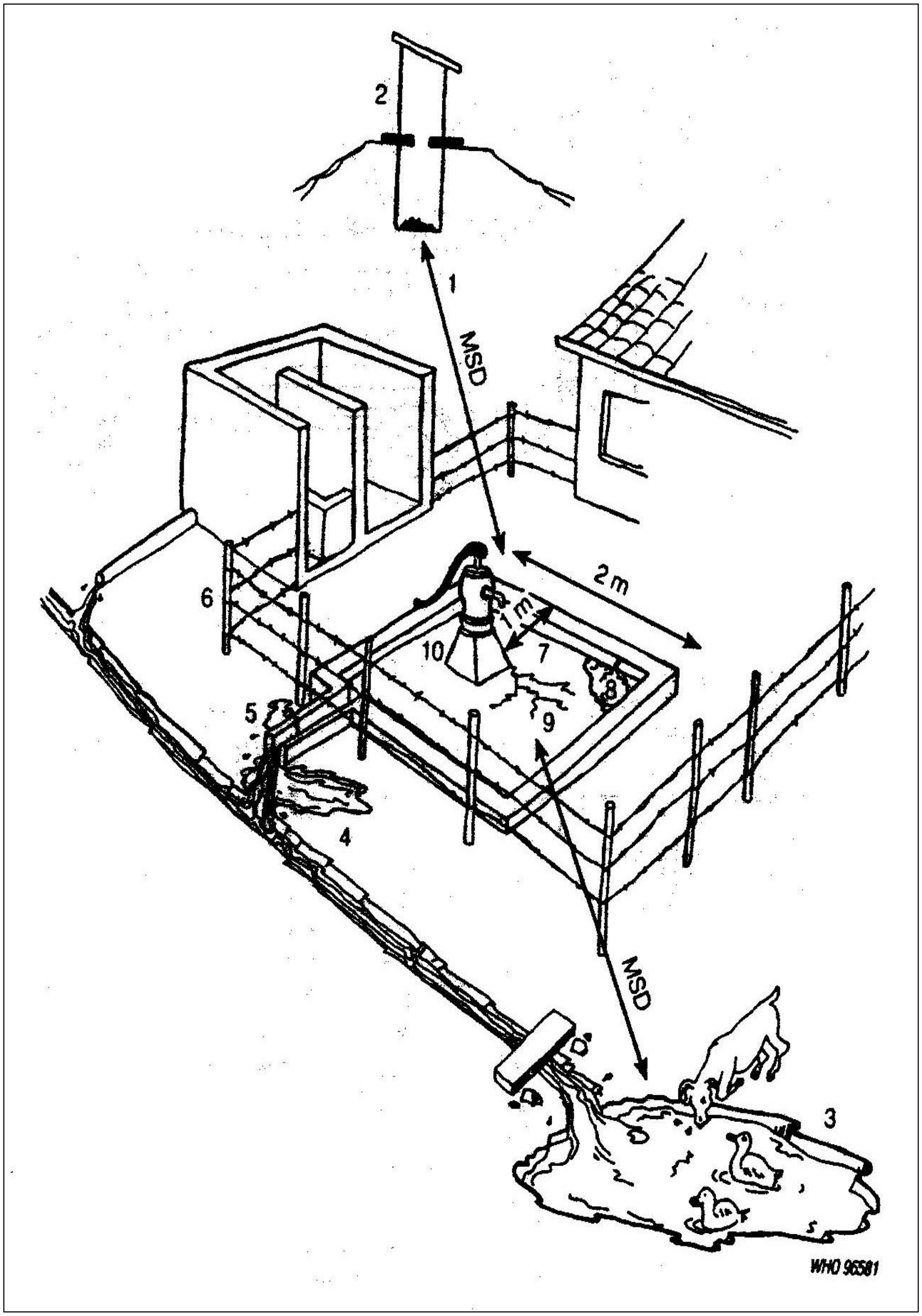
9-10	Very high
6-8	High
3-5	Intermediate
0-2	Low

3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ______ (list Nos 1 – 10)
And the authority advised on remedial action.

Signature of observer: ______

Figure-3A.4 Sanitary Inspection form for tube-well with hand-pump



• V. DEEP BOREHOLE WITH MECHANICAL PUMP

1.0 GENERAL INFORMATION

1.1 Location:

	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0	**SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT**	**Risk (Y=1/N=0)**
2.1	Is there a latrine or sewer within 30 meters of the pump house?	
2.2	Is the nearest latrine a pit latrine that percolates to soil, i.e. unsewered?	
2.3	Is there any other source of pollution (e.g. animal excreta & rubbish) within 30 meters of the borehole?	
2.4	Is there uncapped well within 30 m of the borehole?	
2.5	Is the drainage around the pump house faulty? Is it broken, permitting ponding and/or leakage to the ground?	
2.6	Is the fencing around the installation damaged in any way, which would permit any unauthorized entry or allowing animals access?	
2.7	Is the floor of the pump house permeable to water?	
2.8	Is the well seal unsanitary?	
2.9	Is the chlorination functioning properly?	
2.10	Is residual chlorine present at the sampling tap?	

Total score of risks **/ 10**

Contamination risk score:

9-10	Very high
6-8	High
3-5	Intermediate
0-2	Low

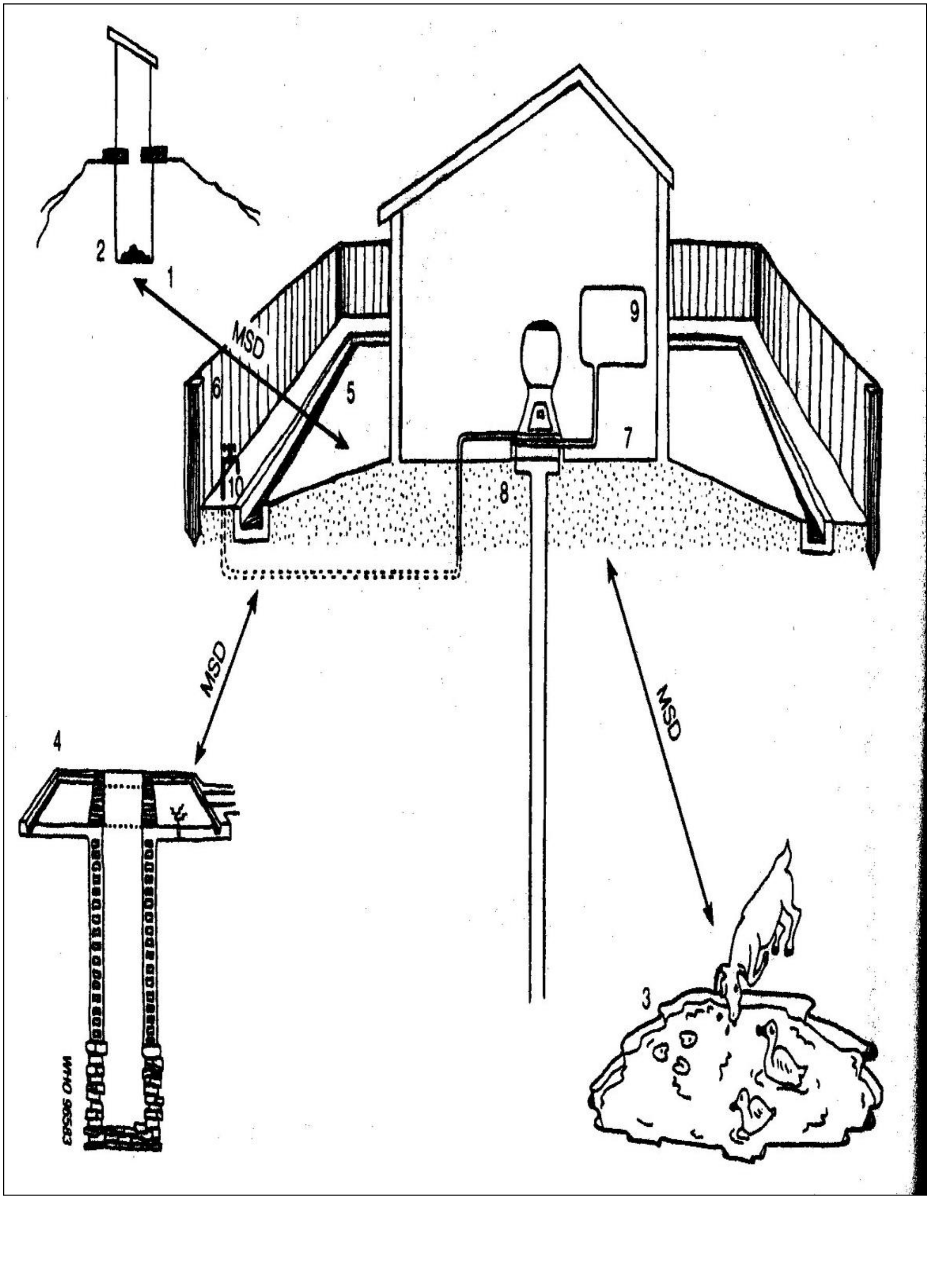
3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ______ (list Nos 1 – 10)

And the authority advised on remedial action.

Signature of observer: ______

Figure-3A-5 Sanitary Inspection form for deep borehole with mechanical pump



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VI. PROTECTED SPRING SOURCE

1.0 GENERAL INFORMATION

1.1 Location:

	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0	**SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT**	**Risk (Y=1/N=0)**
2.1	Is the spring sources unprotected by masonry or concrete wall or spring box and therefore open to surface contamination?	
2.2	Is the masonry protecting the spring source faulty?	
2.3	If there is a spring box, is there an unsanitary inspection cover in the masonry?	
2.4	Dose the spring box contain contaminating silt or animals?	
2.5	If there is an air vent in the masonry, is it unsanitary?	
2.6	If there is an overflow pipe, is it unsanitary?	
2.7	Is the area around the spring unfenced?	
2.8	Can animals have access to within 30 meters of the spring box?	
2.9	Does the spring lack a surface water diversion ditch above it, or (if present) is it non-functional?	
2.10	Is there any latrines up hills of the spring?	

Total score of risks **/ 10**

Contamination risk score:

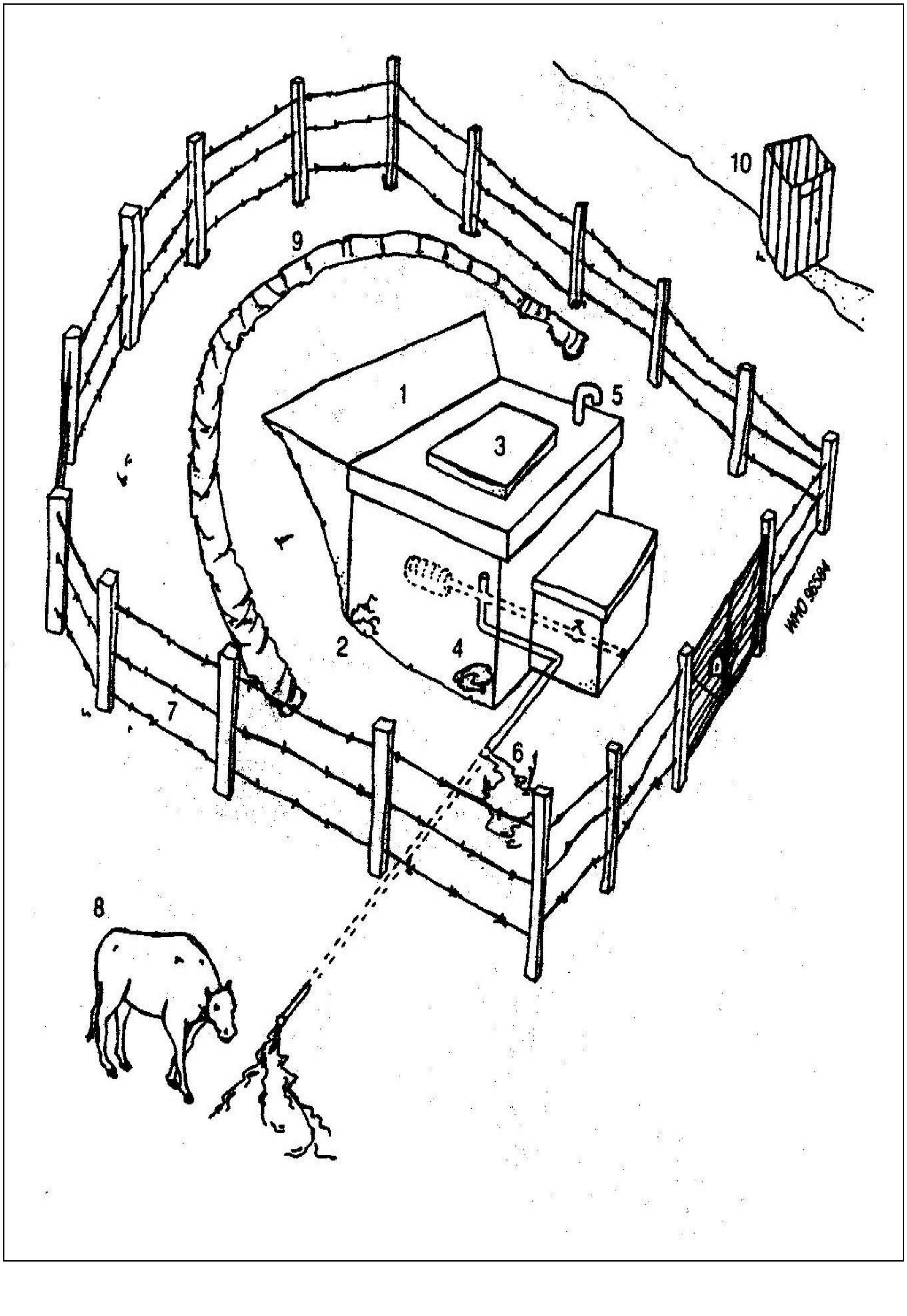
9-10	Very high
6-8	High
3-5	Intermediate
0-2	Low

3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ________ (list Nos 1 – 10)
And the authority advised on remedial action.

Signature of observer: ________

Figure-3A.6 Sanitary Inspection form for protected spring source



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VII. SURFACE WATER SOURCE AND ABSTRACTION

1.0 GENERAL INFORMATION

1.1 Location:

Location	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

	2.0 SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT	**Risk(Y=1/N=0)**
2.1	Is there any human habitation upstream, polluting the source?	
2.2	Is there any farm animals upstream, polluting the source?	
2.3	Is there any crop production or industrial pollution upstream?	
2.4	Is there a risk of landslide or mudflow (causing deforestation) in the catchments area?	
2.5	Is the intake installation unfenced?	
2.6	Is the intake unscreened?	
2.7	Does the abstraction point lack a minimum-head device (weir or dam to ensure minimum head of water)?	
2.8	Dose the system require a sand or gravel filter?	
2.9	If there is a filter, is it functioning badly?	
2.10	Is the flow uncontrolled?	

Total score of risks **/ 10**

Contamination risk score:

9-10	Very high
6-8	High
3-5	Intermediate
0-2	Low

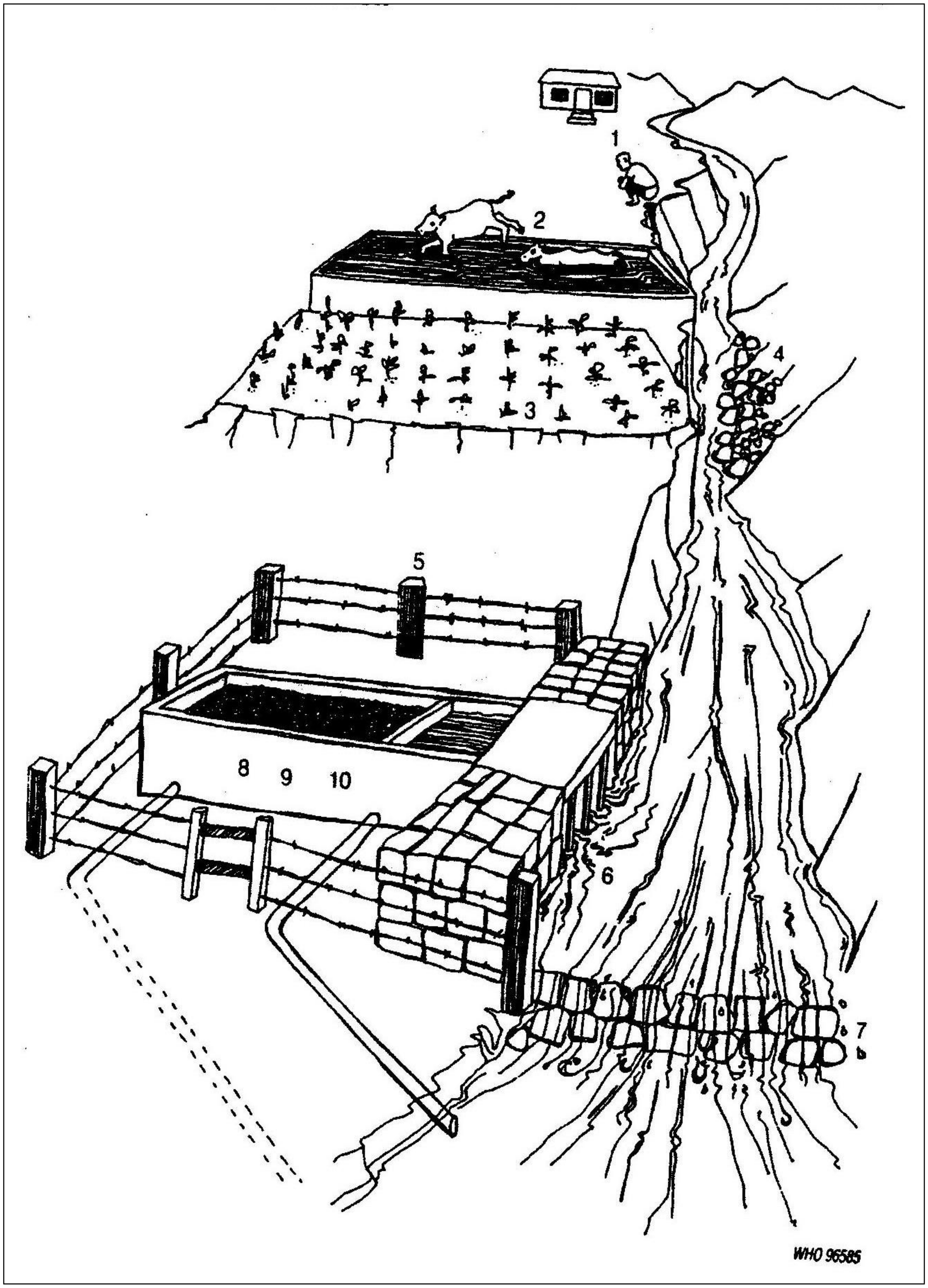
3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ____________ (list Nos 1 – 10)

And the authority advised on remedial action.

Signature of observer: ____________

Figure-A3.7 Sanitary inspection form for surface source and abstraction



VIII. PIPED DISTRIBUTION

1.0 GENERAL INFORMATION

1.1 Location:

	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site		

1.2	Date of visit	
1.3	Water sample taken?	
1.4	Faecal coliform grade	

2.0 SPECIFIC DIAGNOSTIC INFORMATION FOR ASSESSMENT

		Risk(Y=1/N=0))
2.1	Is there any point of leakage between source and reservoir?	
2.2	If there are any pressure break boxes, are their covers unsanitary?	
	If there is a reservoir:	
2.3	Is the inspection cover unsanitary?	
2.4	Are any air vents unsanitary?	
2.5	Is the reservoir cracked or leaking?	
2.6	Are there any leaks in the distribution system?	
2.7	Is the area around the tap-stand unfenced (or fencing incomplete)?	
2.8	Dose water accumulate near the tap-stand (requires improved drainage canal)?	
2.9	Are there human excreta within 30 m of the tap-stand?	
2.10	Is the plinth cracked or eroded?	
2.11	Does the tap leak?	

Total score of risks **/ 11**

Contamination risk score:

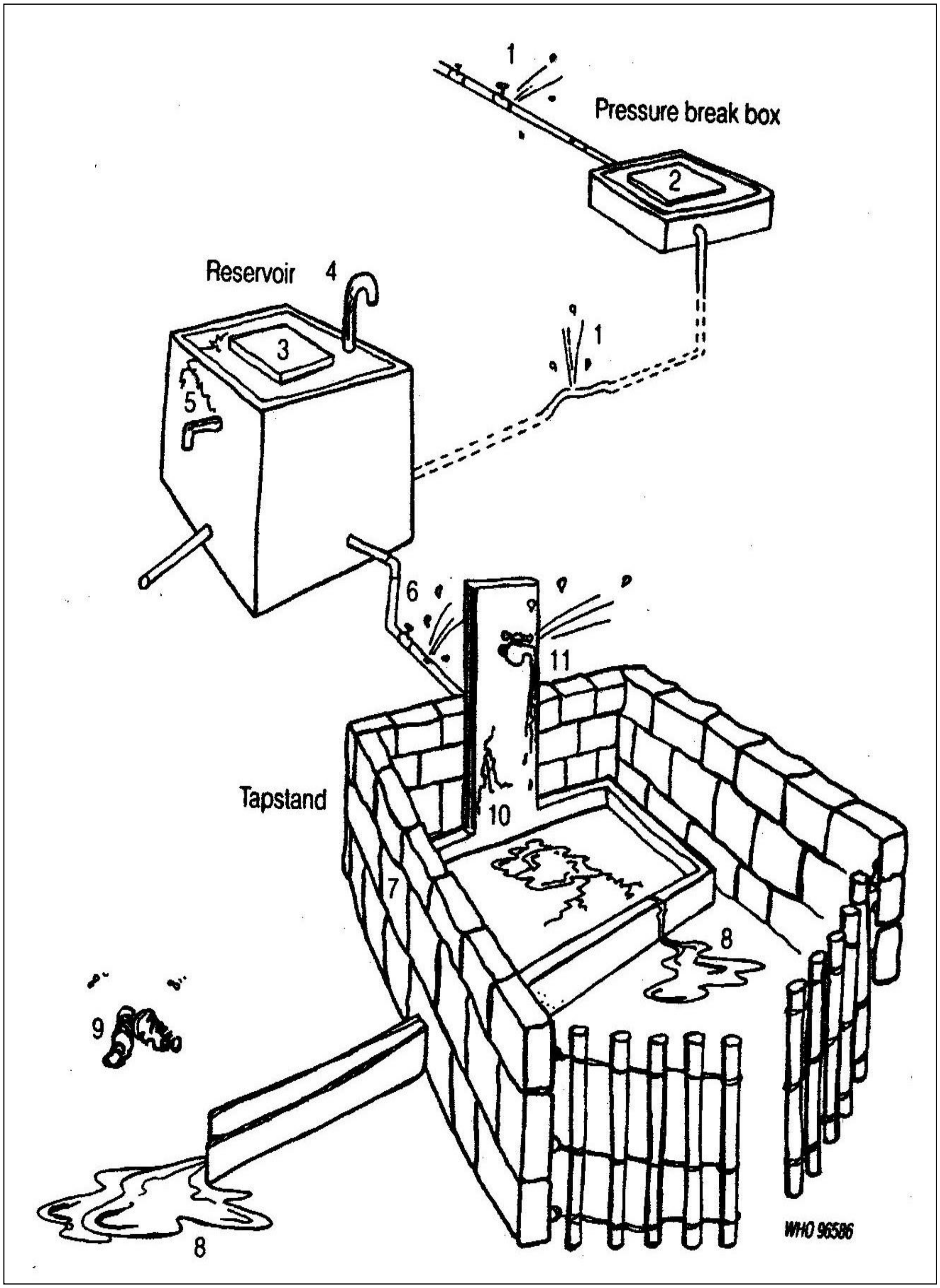
9-11	Very high
6-8	High
3-5	Intermediate
0-2	Low

3.0 RESULTS AND RECOMMENDATIONS

The following important points of risks were noted: ______ (list №s 1 – 11)
And the authority advised on remedial action.

Signature of observer: ______

Figure-A3.8 Sanitary inspection form for piped distribution



IX. WATER TREATMENT PLANT

1.0 GENERAL INFORMATION

1.1 **Location:**

	Name	Code
Region		
Zone		
Wereda		
Town/village		
Site of survey		

1.2 Date of survey
1.3 Survey carried out by: Name of person ______ Agency ______
1.4 Faecal coliform grade ______
1.5 Person in charge ______
1.6 Year started operation ______
1.7 Area served (km2) ______ Pop served ______
1.8 Treatment plant capacity (m3/d): Designed ______ Actual ______
1.9 Security of plant Fence (Y/N) ______ Guard (Y/N) ______

2.0 Source

•

2.1 Type of water source:

Reservoir	Stream	River	Lake	Well	Other

3.0 Intake

3.1 Is the intake adequate with respect to (Y/N):

- Location ______
- Structure ______
- Maintenance ______
- Pollution Sources in the vicinity ______

4.0 Treatment process employed

4.1 Fine screen ______

4.2 Grit chamber ______

4.3 Pre-sedimentation ______

4.4 Pre-disinfection/oxidation Chlorine ______ Ozone ______

4.5 Aeration ______

4.6 Coagulation & flocculation

Lime	Alum	Others

4.7 Sedimentation

Rectangular	Circular	Others

4.8 Filter

Slow	Rapid	Granular carbon

4.9 Disinfection

Chlorinated lime	THT	Chlorine gas

4.10 Other processes (specify)

5.0 Sedimentation

5.1	No. of Sedi tank	
5.2	Frequency of desludging	
5.3	Type of desludging facility	
5.4	Methode of desludging disposal	
5.5	General appearance of clarified water	

5.6 Turbidity (FTU) at inlet: [ ] NTU at outlet [ ]

6.0 Filtration

6.1	No. of filters	
6.2	Filtration rate (m3/h)	
6.3	Filter run (day)	
6.4	Depth of gravel (m)	
6.5	Depth of sand (m)	

7.0 Backwashing

7.1 Criteria used for initiating backwashing?

	Rate	Duration
Air scour:		
Water scour:		

7.2	Is the distribution of air and water in the sand bed even? (Y/N)	
7.3	Capacity of clean water for backwash (m3/h)	
7.4	Any mud ball and cracks in the filter bed?	
	Before backwash	
	After backwash	
7.5	Where does the wash water go?	

8.0 Chlorination

8.1	Any interruption in the chlorination?	
8.2	Frequency of interruption (No./year)	
8.3	Case of interruption:	
8.4	Type of chemical used	
8.5	Dosage of chemical	
8.6	Quantity of reserve stock of disinfection (kg)	
8.7	Storage condition	

9.0 Clear water tank(s)

9.1	No. of tanks	
9.2	Capacity of each tank(m3)	
9.3	Free residual chlorine (mg/l)	
9.4	PH	
9.5	Chemical used for pH adjustment & its dosage	
9.6	Any leak in the tank?	
9.7	Is the tank properly covered and locked?	
9.8	Any scum or foreign substance in the tank?	
9.9	Are air vents and overflow pipes protected by screens?	

10.0 Process Control

		Yes	No	Frequently
10.1	Jar test			
10.2	PH			
10.3	Free residual chlorine			
10.4	Color			
10.5	Turbidity			
10.6	Feacal coliform			
10.7	Other			

11.0 Record keeping

11.1	Chemical consumption	
11.2	Process control test	
11.3	Bacteriological examination	
11.4	Residual chlorine	
11.5	Others	

12.0 Personnel

12.1	No. of permanent staff	
12.2	Academic level of plant superintendent or the most senior treatment operator:	
12.3	Length of service in present water treatment plant:	
12.4	Total experience in water treatment:	

13.0 Complaints received

13.1	From operators:
13.2	From Management:

14.0	**Problems (if any) with:**	**Yes**	**No**	• **Description of problem**
14.1	Fine screen			
14.2	Grit chamber			
14.3	Pre-sedimentation			
14.5	Aeration			
14.6	Coagulation & flocculation			
14.7	Sedimentation			
14.8	Filtration			
14.9	Disinfection			
14.10	Other process			
14.11	Process control			
14.12	Record keeping			
14.13	Maintenance			

15.0 Flow diagram of water works (insert diagram)

16.0 Remedial measures recommended

16.1	Measures to be taken immediately:
16.2	Measures to be taken later on:

17.0 Have problems identified in the previous sanitary survey been corrected?

Signature of inspector: