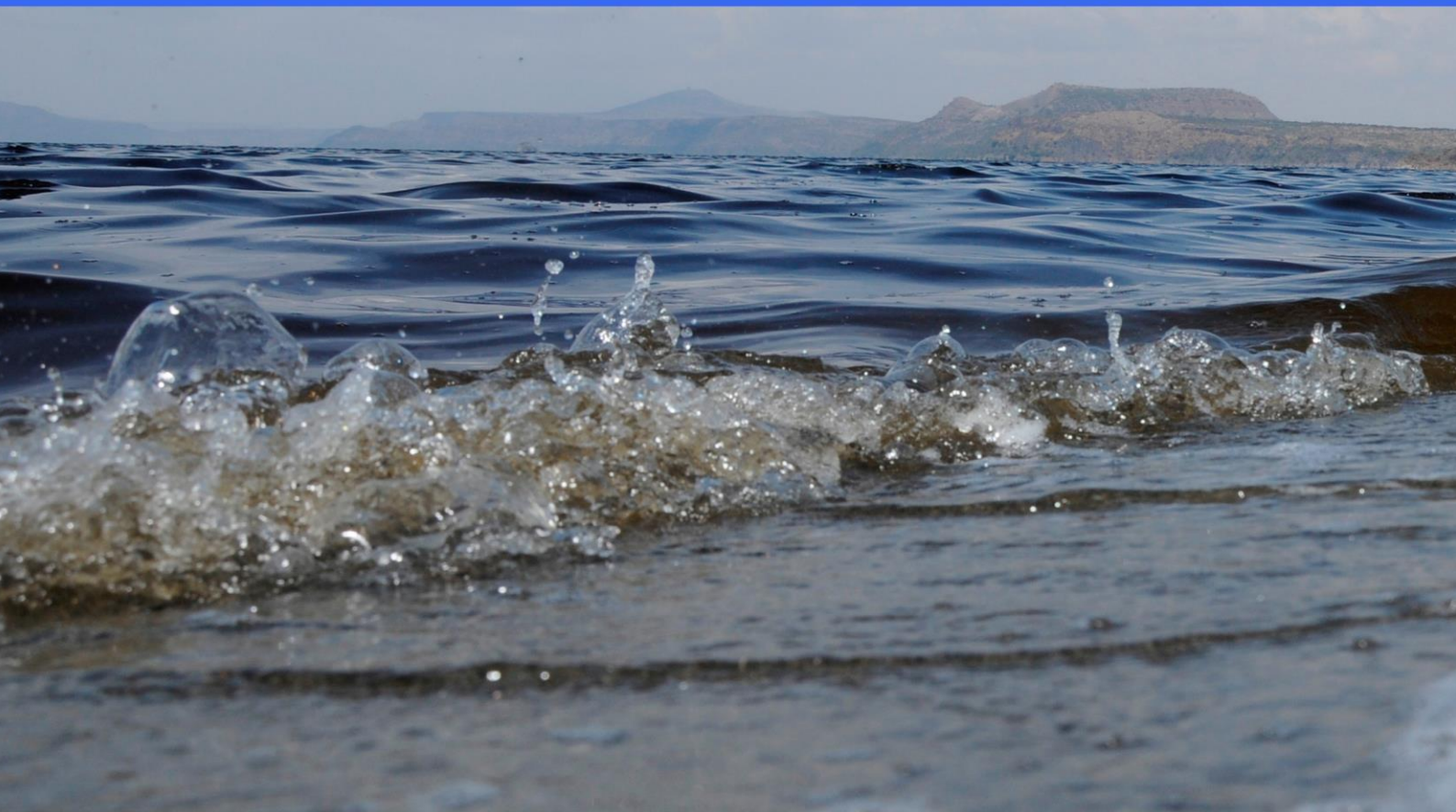




Improving available information and drilling success rate at Afar Regional State Government



Disclaimer

The designations employed and the presentation of the material throughout this document do not imply the expression of any opinion whatsoever on the part of UNESCO or unicef, concerning legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries. Opinions expressed are the opinions of the authors as individual experts only.

This report was produced in July 2015, at UNESCO Addis Ababa Liaison Office, Addis Ababa, Ethiopia.

Contributors

The documents include contributions from Seifu Kebede and Zennaw Tessema (Summary reports and proposals), as well as of Dessie Nedaw and Asefa Kumsa. Scientific and technical editing was supported by Benno Böer and Akintunde Akinsanya.

Contents

1. Summary Report	2
2. External Evaluation Report	20
3. Proposal I	37
4. Proposal 2	47

Summary report

Summary report on improving drilling success rate in the Afar Region

**(Elidar, Erepti and Atsbi Woredas)
UNESCO-Addis, June 2015**

1. Introduction

Background: Groundwater is the main source of rural and urban water supply in the arid lowlands of Ethiopia. In recent years, the number of water wells drilled has dramatically increased through the intervention of various international and local initiatives. However, the success rate of drilling productive wells in arid lowlands is still very low (30-50%), even by sub Saharan standard. The failure in pinpointing productive sites is primarily attributed to lack of adequate scientific information as well as complexity of hydrogeology of the region.

A joint UNICEF-UNESCO pilot project on improving drilling success rate in the Afar region was conducted during 2013-14. The project was implemented in two phases. During the first phase, all existing information (geology, hydrogeology, hydrology, geophysics) were gathered and base maps of hydrogeology and geology were produced at scale of 1:250000. Most prolific aquifer areas as well as areas with complex hydrogeology were identified. Three Woredas with known water scarcity and complex hydrogeology were selected for further detailed groundwater investigation. The selected woredas were: Elidar- located along Ethio-Djibouti border, Erepti- located south west of Dallol depression and Atsbi- located in the escarpment bordering Afar and Tigray. The detailed groundwater investigation was conducted in the second phase of the project.

The objectives of the second phase of the project were:

- Prepare detailed hydrogeological map of the three selected woredas
- Identify potential water bearing rock formations and structures
- Estimate groundwater availability through recharge analysis
- Determine water quality of the groundwater bodies for water use

The second phase of the project aims to increase drilling success rate. A combination of methodologies including conventional hydrogeological survey, water point inventory, geophysical investigation (Vertical

Electrical Sounding) and radar and optical remote sensing were used to attain the objectives outlined above and select sites for drilling of productive wells. The anticipated drilling success rate for the proposed wells is also postulated.

The findings of the two years study are summarized in three volumes: geophysics, remote sensing and hydrogeology. The hydrogeology report integrates all historical and newly generated data and information derived from therein. The hydrogeology report and maps have presented groundwater potential zones and suggested drilling sties. The report also proposed some test wells drilling in order to validate the maps and predictions.

Key hydrogeology challenges in the Afar region: The Afar region is underlain by volcanic rocks. The rocks were formed contemporaneously with rift formation. The volcanic stratigraphy is complex (later extent is discontinuous, thickness of rock units are non uniform, and cross cutting and dissection by rift structures disrupts the rocks). The dissection by the numerous sets of faults results in a series of 'horst' and 'graben' structures. Often the graben structures are filled by thick alluvo – lacustrine sediments. Thickness reaches order of 1-2 km (example in the Tendaho graben). As a result of this complex geology, two hydrogeological challenges exit: identification of the right place to drill and high salinity that is imparted by dissolution of the sediments in the various grabens and by evaporative enrichment of recharge water. Both are challenging to predict.

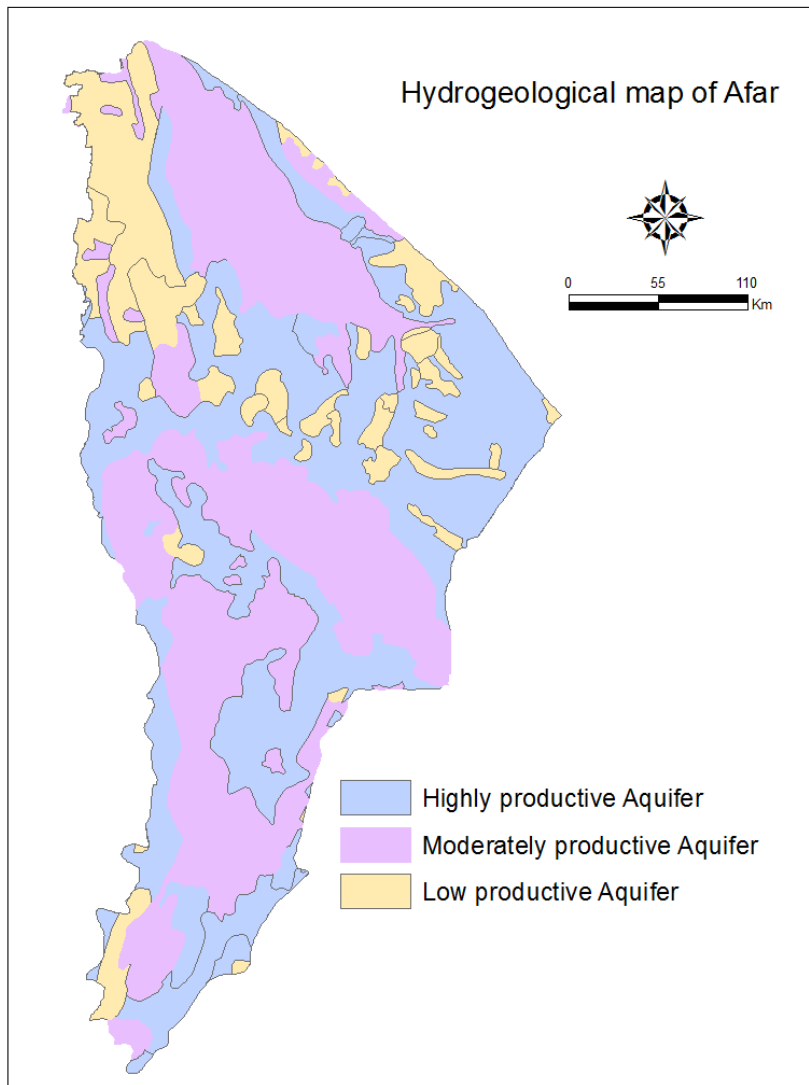
Regional Hydrogeology of Afar: The region is characterized by arid to semi arid climate with low rainfall (<100 mmyr-1) and high evaporation (>2500 mmyr-1). Streams are usually seasonal and few are perennial carrying flash flood from the highlands. Saline lakes fed by groundwater mark the lowest places in the Afar region.

In the Afar regional state groundwater occurs in the following forms, a) Shallow and deep cold groundwater in fractures, sediments and basaltic aquifers, b) Deep geothermal waters with surface manifestation in the form of hot springs c) Riparian fresh groundwater along Awash river and major tributaries, **d)** Buried old river channels and Wadis and d) Fresh groundwater occurrences along the rift margins.

Regardless of the hydrogeological challenges some very prolific regional aquifers are also located in the Afar regional state and the Afar depression. The known and well mapped aquifers in the Afar depression include: Alluvial fans of the Dallol desert (Musley and Bada fans), The

intercalated alluvial and volcanic aquifers of Teru-Digdiga-Awura Depression, the Shinile Alluvial plain, the Alidegie alluvial-volcanic intercalated aquifer Plain, the dallol coalased alluvial fans, the Borkena-Kobo Girana and Raya alluvial valleys, the Tendaho graben, Wadi bed aquifers, the Aba Ala alluvial plain, etc.

The vast extent of the central part of Afar region is underlain by the Afar stratoid basalt. The Afar stratoid basalt is the least understood in terms of its water bearing properties.

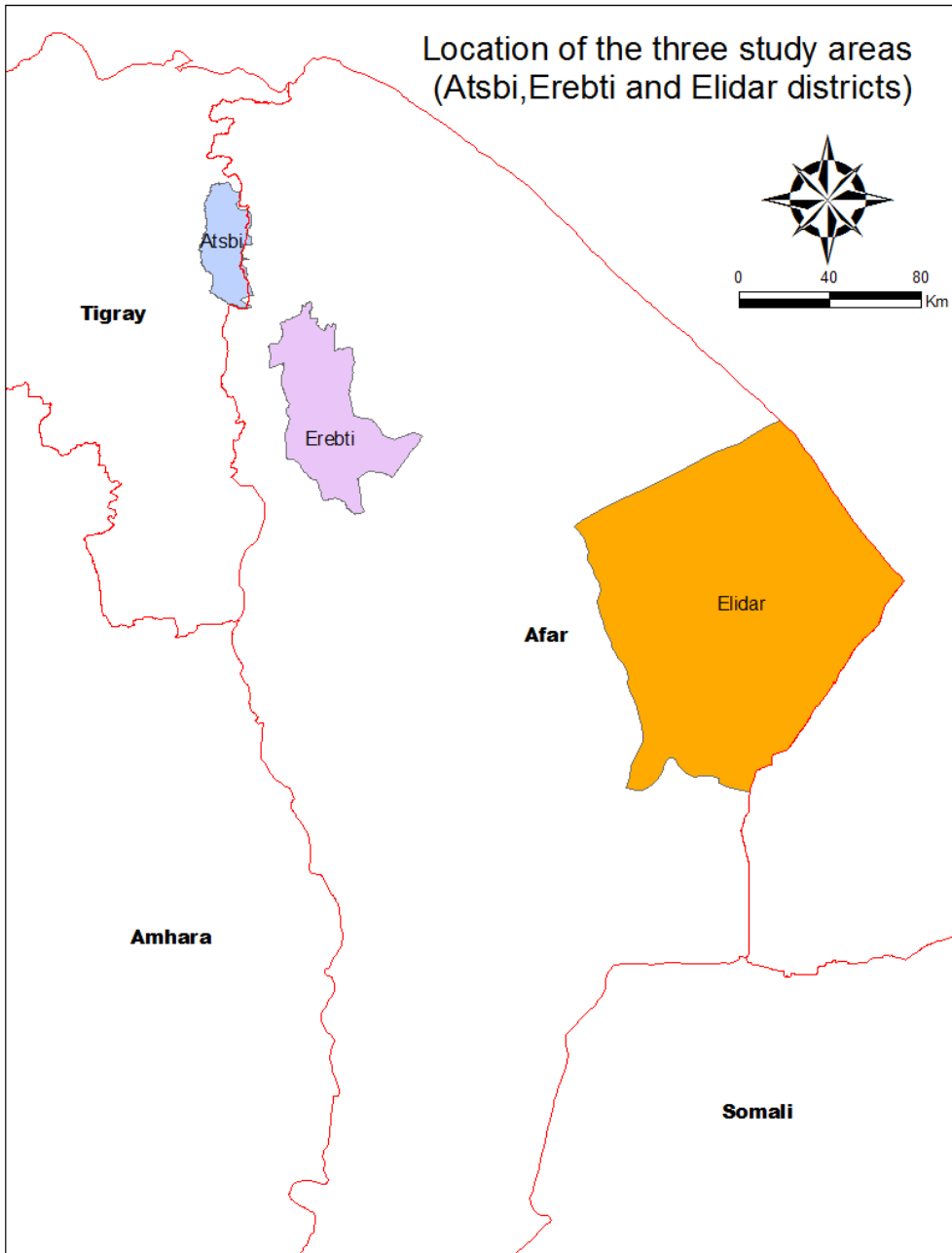


2. Methods and activities

An integrated methodology has been utilized to increase the knowledge bases of groundwater conditions in the three Woredas and thereby increase drilling success rate. The methodologies include: a) Collection and review of all pertinent data (total 260 water points inventoried in

three woredas), b) Field hydrogeological and geological data collection and mapping c) Geophysical survey by Vertical Electrical Sounding (a total of 295 VES points in there woredas) and, d) Radar and optical remote sensing supported by ground truthing.

The integration of the results coming out of the various methodologies has been done **iteratively**. Some of the steps taken in integration of the results were a) an overlay analysis for aquifer classification and identification, b) VES survey in high potential targets and c) identification of drilling target zones by combining VES survey and Remote Sensing results. In this specific activity the Remote Sensing was used to identify key geologic features such as fractures, wet zones and buried structures. It should be noted that the overlay analysis is meant to identify groundwater potential zones as well as to discriminate low groundwater potential sites. The parameters used in the overlay analysis were: geology, fractures, soil type, recharge rate, hydrographic network, and slope. Finally drilling sites for productive wells as well as test wells drilling were selected based on analysis and professional **judgment** of experts involved in this work.



3. Summary of hydrogeology of the three woredas

The following table summarizes the hydrogeological characteristics of the three Woredas.

Woreda	Hydrogeological Characteristics
Elidar	<p>The Elidar Woreda is underlain by two types of aquifers. These are a) Extensive fractured and vesicular scoriaceous basaltic (aka: Afar Stratoid Basalt) aquifers with high groundwater productivity (when groundwater is encountered). Highly productive wells localized on this aquifer are :Galafi ~20 l/s, Seilu ~10l/s, Gawa 10l/s, Teru: 49 l/s, Semera ~ 100l/s. Some intercalation of sediments are noted in some BH logs. It should be noted that this aquifer is extensive but not all part of the rock unit is water bearing. Water bearing zones are mostly localized in grabens and associated with fractures; b) Localized unconsolidated sediment aquifer with low to moderate groundwater productivity- these aquifers consists of alluvial, lacustrine and talus sediments; they are mainly recharged by floods during intensive rainfall; where they encounter regional groundwater they form good aquifers. Yield is in the order of 0 – 2 l/s. Salinity is highly variable in this aquifer and sometimes it is higher than the recommended WHO guidelines for drinking water use.</p> <p>Most promising drilling locations are:</p> <ul style="list-style-type: none"> • The alluvial fans where water accumulates from a relatively large contributing surface water catchment. Depending on the specific characteristics of the fan, drilling is advised at the top of the alluvial fan where coarse material is expected to support relatively concentrated groundwater recharge. • In the wadi beds where (during the wet period) fresh water flows. The most potential areas are locations where water accumulates from a relative large catchment, and where the slope is relatively small. • For deep borehole it is advised to drill wells in graben depressions and along fracture zones
Erepti	<p>Four hydro-stratigraphic zones can be identified. These are a) Moderate to high productive inter-granular aquifers consisting of alluvial fans and Lacustrine sediments , b) Low to moderate productive volcanic aquifers (fractured and/or weathered</p>

	<p>aquifers, c) Very low to moderate productive aquifers within fractured and/or karstic Mesozoic rocks and d) Aquicludes or very low productive aquifers (Basement rocks). Majority of the wells drilled in the area have shallow depth less than 100m and tapping the local groundwater. The geophysical survey (VES) results showed that thick alluvial or lacustrine deposits, in some locations up to 140m? Overlies the underlying highly fractured and or weathered rock though thickness variations as small as 5m are also recorded. The probable water bearing zones are inferred to be at an average depth of below about 100m.</p> <p>The recharge of the area from direct precipitation is very small (about 12mm/year) or almost negligible as compared to its high evapotranspiration. Therefore, the main groundwater recharge to the area is understood to be regional sources from the highlands or western plateaus and from flash floods emerging locally and from the highlands. Eight priority target areas have been delineated and identified based on the overlay analysis.</p>
Atsbi	<p>Three hydrostratigraphic units are identified. These are a) the basement complex rocks, b) the Mesozoic Limestone, shale and sandstone and c) the thin alluvial sediment mantling the depressions. Groundwater availability is limited and is restricted in small isolated depressions and in shear zones in the basement units.</p> <p>Groundwater in the area mostly exists in a restricted pattern and occurs largely in isolated and compartmentalized shallow systems susceptible to seasonal changes. The northern part of the area dominantly has shallow aquifer while the southern sedimentary unit supports deep groundwater which may not be reached by any economical drilling. Previous data suggest yield of the wells from the shallow depression are low mostly in the range of 1.5-2l/s. Annual groundwater recharge as estimated using different methods is about 63mm.</p>

Table1. Summary of hydrogeology of the three Woredas

4. Proposed production and test well drilling sites

The following tables (table 2 a, b, and c) list the location of potentially productive wells where drilling success rate could exceed 65%. The success probability is estimated based on expert judgment and should be re-evaluated once the drilling of the wells are complete.

It should be noted the sites needs to be visited prior to mobilizing the drilling rigs as local accessibility was not observed in the field. The proposed depth of drilling for all wells is considered to be partial penetrating; and the saturation thickness is estimated to be 40 – 80m. In Elidar to fully understand the hydrogeology of the woreda, drilling of three exploratory/test wells is highly recommended. The location for the exploratory well is also given. The purpose of the test wells is to explore occurrence of regional groundwater under the extensive Elidar horst.

*Table 2a- Proposed production and test well sites for Elidar
NB: TA means – target area, see the main report for the hydrogeological map of the target area; TW means- test well meant to explore presence of regional groundwater flow underneath the Elidar horst.*

Elidar – proposed production and test well sites								
SN	X	Y	Grid Zone	Locality	Proposed drilling depth, m	Inferred water strike, m	Geology	Success probability (%)
TA3	770 174	1332 739	37	Upper Dobi	150	100+	Alluvial, Fractured basalt and scoria	80
TA3	781 536	1324 155	37	Central Dobi	100	20+	Alluvial, Fractured basalt and scoria	80
TA3	786 207	1319 105	37	Central Dobi	100	20+	Alluvial, Fractured basalt and	80

							scoria	
TA3	806 153	1318 851	37	Guma Graben	350	300+	Fractured basalt and scoria	70
TA4	175 203	1345 437	38	Gawa	150	100+	Fractured basalt and scoria	80
TA4	169 465	1345 790	38	Gawa	150	100+	Fractured basalt and scoria	80
TA4	160 807	1353 058	38	Gawa	150	100+	Fractured basalt and scoria	80
TA4	799 375	1341 149	37	Emino Graben	120	70+	Ignimbrite, Fractured basalt and scoria	70
TA4	780 897	1356 748	37	Upper Emino	130	75+	Ignimbrite, Fractured basalt and scoria	80
TA5	188 697	1361 956	38	Sula	300	240+	Fractured basalt and scoria	80
TA5	181 880	1362 326	38	Sula	260	210+	Fractured basalt and scoria	80
TA5	175 190	1365 719	38	Sula	200	150+	Fractured basalt and scoria	80
TA1	796 714	1402 161	37	Akule	110	60+	Fractured basalt and scoria	50
TA1	772	1410	37	Akule	100	55+	Fractured basalt and	50

	081	646					scoria	
TA1	772 675	1412 019	37	Akule	100	55+	Fractured basalt and scoria	50
TA2	758 363	1369 581	37	Galabulu	400	350+	Fractured basalt, Rhyolite and scoria	55
TA2	760 500	1391 976	37	Angesera	350	300+	Fractured basalt, Rhyolite and scoria	60
TA2	743 306	1397 878	37	Angesera	100	60+	Fractured basalt, Rhyolite and scoria	70
TW	814 098	1343 685	37	Elidar- Elidar Town	360	300+	Fractured basalt and scoria	65
TW	773 795	1322 819	37	Elidar- Decheto	400	350+	Fractured basalt and scoria	65
TW	199 333	1395 558	38	Bure	500	450+	Fractured basalt and scoria	65

Table 2b. Proposed production and test well sites for Atsbi

NB: + in Code means sites selected from remote sensing recommendations, VES not done??- Sites for which sufficient information doesn't information exists to propose drilling depth

Atsbi- Proposed production and test wells								
Code	X	Y	Grid Zone	Locality	Proposed drilling depth, m	Inferred water strike, m	Geology	Success probability (%)
G1-1	580 874	1543 983	37	Harasaw	80-100	10	Basment (Schist) with thin alluvial on top	80
G1-2	581 111	1545 581	37	Harasaw	80-100	5	"	80
G1-3	581 774	1545 007	37	Harasaw	80-100	5	"	80
G1-4	575 286	1547 486	37	Hadnet	100-150	5	Basment (Slates and phylites) with thin alluvial on top	80
G1-5	575 032	1547 139	37	Hadnet	100-150	10	"	80
G1-6	574 747	1546 129	37	Hadnet	100-150	10	"	80
G1-7	578 026	1536 331	37	Golgol	50-60	10	Basment (Schist) with thin alluvial on top	
G1-8	580 909	1538 217	37	Felegewoyni	50-60	5	"	80
G1-9	583 654	1538 980	37	Tsebayna	50-60	5	"	
G1-10	574 785	1520 193	37	Haik Mesal	180-200	10	Sandstone with siltstone beds	85

G1-11	575 553	1520 195	37	Haik Mesal	180-200	10	Basment (Schist) with thin alluvial on top	85
G1-12	574 788	1519 274	37	Haik Mesal	180-200	15	Sandstone with siltstone beds	85
G1-13	579 148	1519 843	37	Haik Mesal	180-200	15	Clastics and conglomerate	85
G1-14	582 431	1513 479	37	Era	150-180	30	Marl and Limestone	70
G1-15	578 721	1512 427	37	Era	150-180	30	"	70
G1-16	580 666	1512 740	37	Era	150-180	25	"	70
G1-17	576 804	1509 253	37	Desae	200-300	100	Mudstone and Limestone	60
G1-18	574 926	1509 792	37	Desae	200-300	70	Mudstone and Limestone	60
G2-2 ⁺	574 205	1535 025	37	Golgol	??	??	Basment (Slates and phylites) with thin alluvial on top	60
G2-3 ⁺	579 127	1527 894	37	South of Atsbi Town	??	??	"	65
G2-5 ⁺	578 772	1535 557	37	Golgol	??	??	Basment (Schist) with thin alluvial on top	65
G2-16 ⁺	583 771	1526 245	37	Mikael Imba	??	??	"	60

G2-18 ⁺	574 966	1540 886	37	South of Hadnet	??	??	Mudstone and Limestone	75
--------------------	------------	-------------	----	-----------------	----	----	------------------------	----

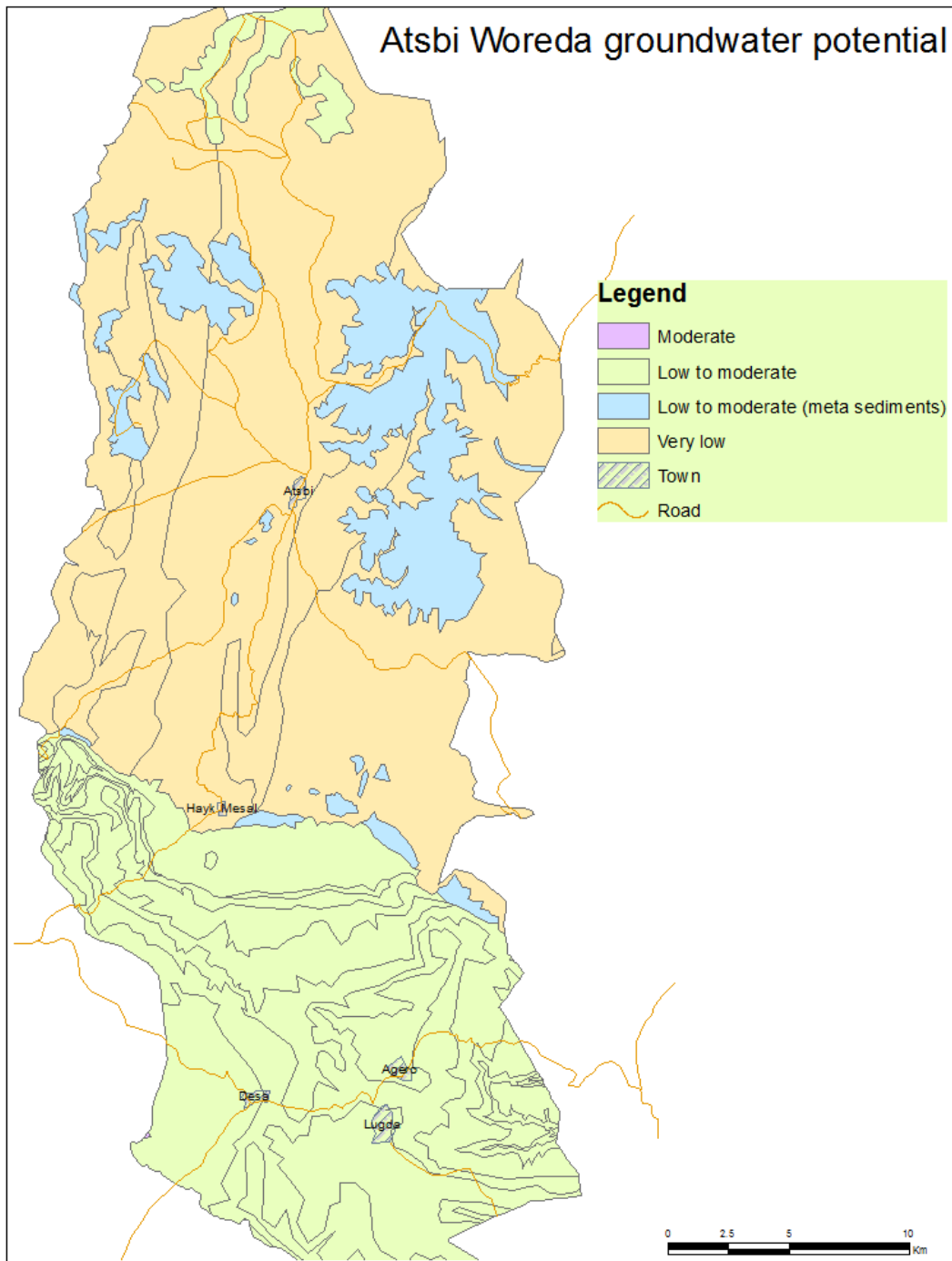
*Table 2c. Proposed production and test well sites for Erepti Woreda
NB: + in Code means sites selected from remote sensing recommendations, VES not done??- Sites for which sufficient information doesn't information exists to propose drilling depth*

Erepti- Proposed production and test wells								
Code	X	Y	Grid Zone	Locality	Proposed drilling depth	Sat depth	Geology	Success probability (%)
G1-1	613 131	146 341 6	37	Hunda Asengola	200 – 250	90	Limestone and sandstone intercalations	65
G1-2	613 716	146 454 1	37	“	200 – 250	60	“	65
G1-3	615 431	145 857 0	37	Bahri Plain/Maray	120 – 150	60	“	70
G1-4	616 413	145 649 2	37	Bahri Plain/Saso	120 – 150	90	Silt, sand and gravel	70
G1-5	618 307	145 562 6	37	“	120 – 150	80	“	70
G1-6	616 029	144 454 5	37	Boka	200 – 250 *		Limestone and sandstone intercalations	75
G1-7	622 294	145 481 2	37	Bahri Plain/Rehindas	120 – 150	100	Silt, sand and gravel	75
G1-8	625 207	145 399 2	37	“	120 – 150	90	“	75

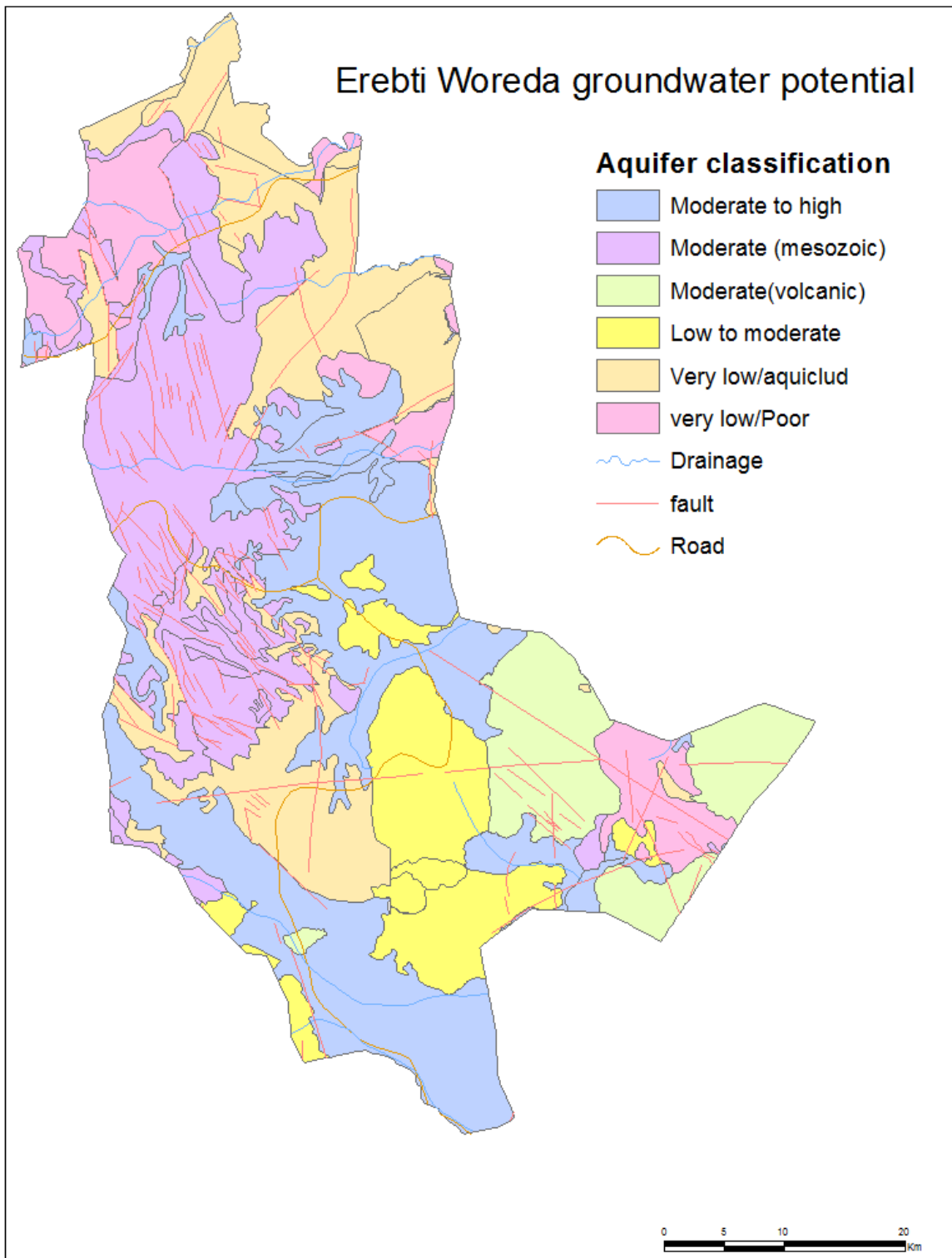
G1-9	628 953	145 241 6	37	Bahri Plain/ Bahadu	120 – 150	70	Weathered or fractured Basalt	75
G1-10	649 013	142 970 6	37	Southern edge of Haiten plain (Ebdora)	200 – 250 *		“	80
G1-11	631 036	142 058 6	37	Southern edge of Erebt Woreda, south of Andergolo	200 – 250 *		Silt, sand and gravel	80
G1-12	608 745	146 196 9	37	Hunda Asengola/S outh of Erebt Town	200 – 250	50	Limestone and sandstone intercalati ons	60
G2-2+	619 364	145 136 6	37	Rehidas Plain	??	??	Phillits and schists	60
G2-4+	620 960	143 904 3	37	Andergolo	??	??	Silt, sand and gravel	65
G2-6+	623 435	146 363 4	37	Bahri plain	??	??	“	65
G2-7+	624 921	146 704 5	37	“	??	??	“	65
G2-10+	610 067	148 448 5	37	Wesema	??	??	Limestone and sandstone intercalati ons	70
G2-14+	622 500	141 791 7	37	South of Andergolo- Agu shet area	??	??	Alluvial & volcanic	70

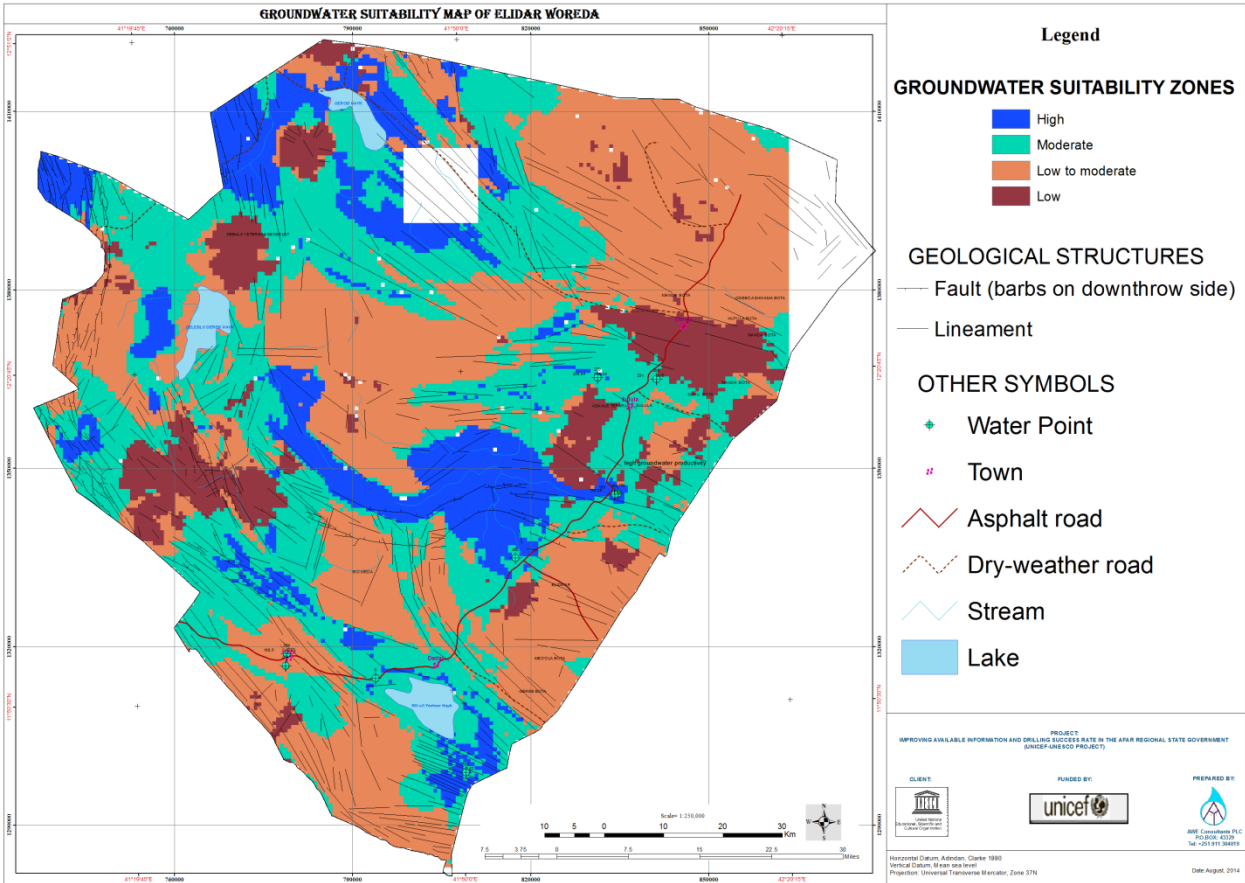
5. Conclusion

The combinations of methods applied have enabled to map potential areas and pinpointing of drilling sites of productive wells. The next step is to verify results of the study by drilling test wells at suggested sites. The successful cases of the project should be fine-tuned further and scaled up into other areas.



Erebti Woreda groundwater potential





External Evaluation Report

UNICEF-UNESCO Project

Evaluation of the project “Improving available Information and drilling success rate in Afar and Tigray regions”
External Review Report

7/1/2015

Dessie Nedaw and Asefa Kumsa
Short term consultants

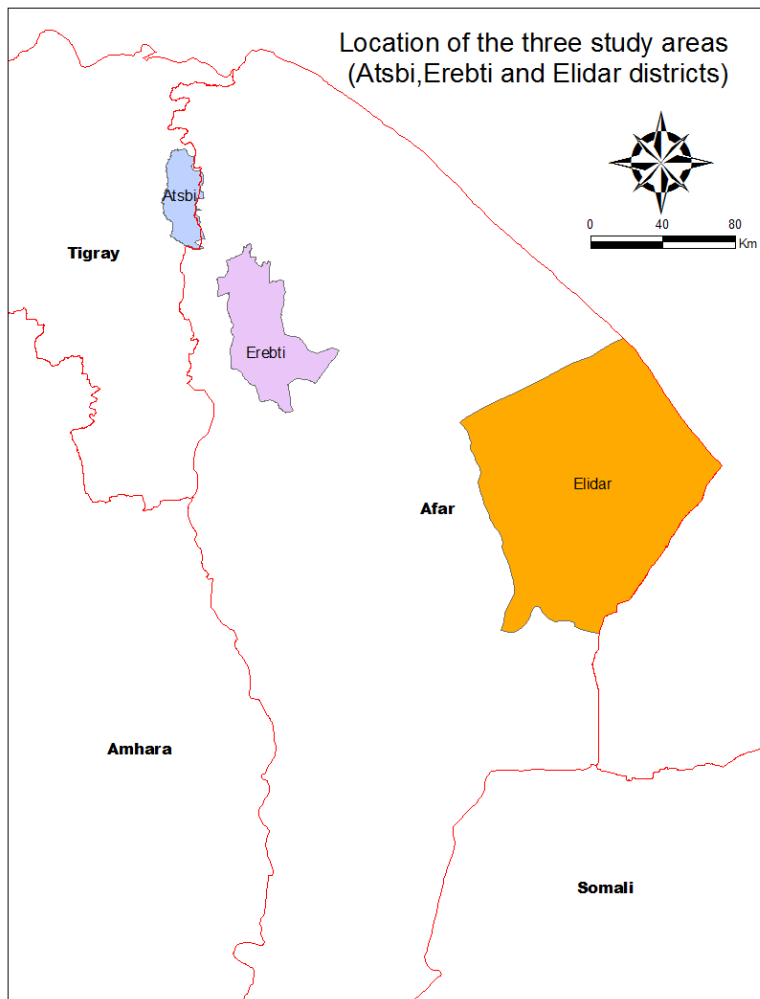
Abstract

In this document we provide a brief external review report of the final technical report on ‘improving available information and drilling success rate in two weredas of Afar Region (Elidar and Erebti) and in one wereda of Tigray region (Atsbi Womberta). The project was initiated by UNESCO Addis Ababa Office in collaboration with the Ministry of Water Irrigation and Energy under the sponsorship of UNICEF Addis Ababa. The project is intended to improving available information and drilling success rate in the target woredas where scarcity of data is the major challenge in understanding and utilizing the groundwater resources. Even where available, the information is incomplete, uneven and of poor quality. Further complicating the problem is the spatial and temporal variability of the resource as a result of extreme variability of the controlling factors such as geological formations and climate conditions. In order to overcome such challenges, an integrated approach with remote sensing and traditional field techniques that include (hydro)geological and geophysical investigations were applied. The results indicate that

potential areas, particularly for shallow groundwater, have been delineated and this will improve the drilling success rates substantially.

1. Background

UNESCO in collaboration with UNICEF is engaged in alleviating chronic poverty in marginalized societies. With this regard improving the water supply coverage among the pastoralists of Ethiopia has been seen as one intervention point. A project entitled “improving available information and drilling success rate in the Afar and Tigray regional state”, figure below. is one of the contributions with this regard. UNESCO entered a contractual agreement with the consultants to evaluate the overall project and submit a written report as per the term of reference. Accordingly this report is prepared.



Ethiopia is characterized by a highly diversified geology, topography and climate. Accordingly both surface water and groundwater resource availability is highly variable. The project area is characterized by complex geology, arid climate and highly variable topography. This has resulted in unprecedented challenges in water supply provision of the districts.

Drilling success rate is controlled by various factors including the geological condition (Bedrock versus sediment), Climatic situation (Humid versus Arid), level and depth of baseline hydrogeological knowledge and the expertise of the hydrogeologist and the drillers involved. In Ethiopia the national drilling success rate at the time of

drilling is estimated at 75 – 85 % (Carter et.al, 2006). Out of the” successful” wells commissioned, 31 % were estimated to be non functional (Carter et.al, 2006). The causes could be variable including but not limited to poor well design and lack of water in the aquifer.

The drilling success rate in Afar is far below the national average mainly because of the complex geological condition and the arid climate. It is reported to be not more than 50%. Moreover as the groundwater development expanded, search for groundwater will extend to hydrogeologically less favorable area reducing further the drilling success rate. This entails the use of both conventional and emerging technology and tools to locate productive groundwater resource essential. Therefore the present study which has used conventional hydrogeological investigation, geophysical investigation and remote sensing will improve the drilling success rate. The bench mark drilling success rate can be considered as 50 %.

Productive water well sitting in general is one of the most difficult tasks of hydrogeologists. When it comes to sitting well in little known area with limited accessibility, without reasonably large scale geological and hydrogeological map is even more difficult. With this regard Atsbi, Erebti and elidar Woredas have a limited accessibility and base line data. Moreover the arid climate limits recent groundwater recharge to the system. This all contributed to the low drilling success rate. The study particularly in Afar area both in Irebti and Illidar woreda is the first of its kind in the region. This will add a new knowledge with regard to groundwater potential of the region. The identified high potential zones will reduce the work required to site a productive well. This will highly minimize the effort required when starting from scratch and also improve

the drilling success rate. Based on this study the drilling success rate should improve to a moderate level.

2. Approach Followed in the project

Groundwater source is gaining more and more importance in Ethiopia in response to the ever increasing demand for drinking water supply purposes, particularly in areas with inadequate surface water resources in the arid and semiarid parts of the country. However, many drilled wells are being failed and abandoned attributed among several reasons to inadequate and lack of predrilling investigation and scientific information which otherwise would help in minimizing such risk of failures. Hence right investigation techniques in a systematic and scientific approach are essential in order to overcome such problems and minimize uncertainties leading to delineating the subsurface resource and increasing drilling success rates.

The use of different methods such as (hydro)geological information, geophysical and remote sensing data in an integrated approach is nowadays a worldwide practice helping the delineation of potential aquifers even in a complex natural environments thereby increasing the successes of drilling results in an area of interest.

The study conducted by UNESCO in the three water stressed weredas of Afar Region (Erebit and Elidar) and Tigray Region (Atsbi Womberta) (location map), used such conventional methods and approaches to finally identify specific locations for drilling that would definitely improve the success rate with more information organized and documented. The important elements of the integrated approach, remote sensing and traditional fieldwork techniques, were adopted and applied to assess the

hydrogeological condition of each Woreda. It starts by examining all relevant works and available information in and around each woreda at a regional level. They make use of the results of the PHASE I study to evaluate the regional geology and geological structures that control groundwater occurrence, movement and quality. The procedures followed are collection and review of secondary data, geological study and mapping, hydrometeorological study, geophysical investigation and interpretation of the results, hydrogeological study and finally data integration and interpretation. The hydrogeological information has been integrated with the geophysical findings to prepare operational maps. This will supplement the general hydrogeological map indicating the most promising groundwater zones in order of their priority. Therefore the methods employed are the conventional methods that can be used in all climatic and hydrogeological setting including arid and semi arid areas like the study woredas.

As the regional and local hydrogeological framework is well established in the studies, sitting a potentially productive well is possible as indicated by the study. Moreover the employed geophysical method (VES) is a well proven method to increase success rate. However, from the report it can be understood that the VES investigation was based on the regional and local (hydro)geological information and it does not seem to fully consider the result of remote sensing study as an input. The widely accepted integrated approach with remote sensing and more traditional fieldwork techniques in sequence of implementation is:

- Remote sensing: to help narrow down the search area and delineating potential areas in a cost- and time-effective way.
- (hydro)geological field validation and mapping: helps to

confirm the results of remote sensing study on a narrower area and/or further reduce the search area for next geophysical investigation work

- conduct geophysical investigation at the selected locations by remote sensing study and (hydro)geological field investigations to further reduce the search area and locate sites for well drilling
- carry out some test well drillings based on the scope and available financing

While all the techniques listed above were applied, the sequence was not maintained. It seems that the activities of remote sensing study and traditional field techniques were carried out independently. In the report and it is not clearly shown whether remote sensing helped in refining areas for further (hydro)geological and geophysical investigation. Rather it was mentioned that the sites for geophysical investigation were based on desk studies and field visits of geological and hydrogeological results. Remote sensing is believed to be the starting point in most hydrogeological study. This is mainly because of its advantage to observe large area at once (Synoptic View) and reaching inaccessible areas. It generally serves to identify primary and secondary indicators of groundwater. It will enable to identify recharge and discharge area. More over regional features which indirectly control the occurrence and movement of groundwater can be traced and visualized. The next work should involve field campaign including geological and geomorphologic mapping, inventorying of water points, measurement of features that control groundwater occurrence such as fracture opening, density, approximate grain size, level of friability, degree of cementing, existence of fragmented blocks and related features. After appropriate

sensitization of the field data with secondary information, appropriate sites for geophysical exploration should be selected based on prior hydrogeological knowledge. Then the geophysical data should be collected analyzed and interpreted with the help of geological and hydrogeological information. Finally a test well drilling should be conducted. The purpose of the well determines how much should it cost and how detail should the exploration and investigation be carried out. For water supply of a village with 20 to 50 households a well with 1 to 2 l/sec yield could be sufficient. To select a site for this type of well properly planned few days of field work could be enough. If the wells are planned for water supply of small towns or for irrigation purpose the use of geophysical investigation will improve the success rate.

Since test well drilling has not been conducted, quantitative evaluation of the improvements made using this particular investigation might be difficult. However, there is no doubt that considering the detail work conducted in both traditional and emerging tools and technologies, the drilling success rate will improve highly. The role of remote sensing in this regard is quite significant as it clearly outlines the terrain morphology to delineate recharge and discharge areas, lineaments including their densities and level of wetness. Accordingly the role it plays particularly in less accessible areas such as Afar is quite high, most importantly in order to identify anomalous vegetation and lineament density in otherwise arid environment is quite significant. The most important parameters that determine the success rates of drilling are the rock types, topographic position, density and cross cutting of fractures and relative location from recharge area.

In general, the methodologies adopted and applied in the project are

quite acceptable, meet the widely accepted standards and definitely improves the drilling success rates significantly. However in the future similar activities of UNESCO, we recommend that the result of remote sensing study should serve as an input and be integrated with traditional fieldwork for (hydro)geological and geophysical investigations. Few test wells would have been extremely useful for validating the results of this study thereby increasing our understanding of how much the success rates would be.

3. Evaluation of Hydrogeological Report

The hydrogeology report tries to address the main issues of the project that is increasing the success rate of water well drilling by using conventional methods, supplemented by emerging tools such as remote sensing and geophysical investigation. With this regard it has employed conventional methods to identify the different types of rocks and geological structures that enhance or inhibit the movement and/or storage of groundwater, the hydro meteorological parameters to estimate groundwater recharge and field and laboratory analysis to evaluate the usability of the water for different purposes.

As far as the general objectives are concerned it is clearly set. The specific objectives are rather redundant and too many.

Most hydrogeological investigation should employ methodologies that will help to evaluate the hydraulic properties of the rocks, the recharge potential of the area and the water quality for different purposes. With this regard previous works which has been compiled on the phase I part of this project and other relevant works in the area were reviewed and they have been utilized quite successfully. The available hydro-

meteorological data both from national meteorological agency and from international sources including the FAO climate estimator has been used to evaluate the groundwater recharge. In addition geological and hydrogeological field surveys were conducted. Independently conducted geophysical investigation and remote sensing analysis results were loosely used to improve the results.

The area is very well described from location, climate, drainage and surface water perspective. The typographic errors are common which can be easily corrected on the second edition. The land use and vegetation cover and the soil cover can be improved.

The woredas (districts) geology is described in detail suggesting the main lithology which controls groundwater occurrence to be metavolcanic and metasedimentary rocks and Mesozoic sedimentary rocks in Atsbi and volcanic rock and alluvial deposits in Afar region. The dominant geological structures in the area were described as shear zone, faults, fracture and fault bounded depression, which mainly serve as conduits, main passage way and sometimes interconnecting paths for groundwater.

Based on the remote sensing analysis shallow and deep groundwater were assessed. The shallow groundwater study has a higher confidence level than the deep groundwater study because of the limitation inherent in remote sensing technique. The study has identified several high potential zones. Some potential zones are described as already exploited and others are recommended for future exploitation. The main indicators for shallow groundwater availability have been derived from the geomorphology, the rainfall data, soil moisture and lineament density. Generally existence of lineaments that intersect perennial river,

larger catchment area and depth of weathering has been suggested as a means of increasing the success rate of water well drilling.

The geophysical investigation is quite detail. A number of vertical electrical sounding have been conducted and they have revealed the underlying formation to be variable from their groundwater potential perspective. In some instances the information acquired from geophysics was not fully integrated with the hydrogeological work. For example Habas area of geophysical report which is recommended for shallow groundwater in the south western side is not included in the final groundwater suitability and target area map of Atsbi womberta woreda.

The hydrogeological work seems an independent work mainly based on the geology, geomorphology and lineament density and drainage density. Existing pumping test data has been utilized to get quantitative values for hydraulic parameters only in illidar woredas. The other Woredas could also benefit from such quantitative analysis. The available data has been analyzed using overlay analysis in a GIS platform and finally resulted in priority areas.

The main shortfall with regard to methodology is the lack of integration with the remote sensing study. Generally the geophysical investigations are guided by the geological and hydrogeological works that will give recommendations for sites which need further elaboration particularly from the subsurface perspective. Moreover remote sensing should precede the field based hydrogeological investigation. The usual trend is regional analysis will be conducted by remote sensing and a detailed field geological and hydrogeological investigation will be carried out to verify and elaborate the remote sensing finding. From the report this relationship is not clearly stipulated.

The hydrogeological report of all the woredas have been organized in ten chapters preceded by an executive summary. It starts with background and introduction and closes with conclusion and recommendation. Most of the chapters are informative, descriptive and concise. Chapter four which deal with remote sensing and chapter five/six which deals with geophysics are extracted from the separate reports and treated as separate chapter in the hydrological report. It would be better if the hydrogeology report focuses on integrating the key findings of the geophysical and remote sensing study with that of the conventional hydrogeological investigations. Some of the concerns regarding the content of the hydrogeological report are:

- The reliability of precipitation data with short period of observation and highly erratic used in computing the water balance of the area may lead to wrong conclusions with regard to groundwater recharge in the area
- The role of geological structures (lineaments) in terms of recharge and groundwater storage is immense and this was discussed well. However, the possibility of groundwater loss through such structures as they might be deep seated or regionally interconnected requires future attention. Additional geophysical methods might be recommended to distinguish between productive and unproductive structures.
- Regional and local stratigraphic sequence and geological cross-sections greatly improve our understanding of the (hydro)geological knowledge of the areas, which is not included in this report.

- Conceptual model of how the groundwater controlling factors act together (recharge area, discharge area, storage area, depths, enhancing or disrupting structures, etc) is not well explained
- The possible productive well sites recommended by the geophysical exploration results were not fully considered to recommend production and test well sites.

4. Evaluation of Remote sensing Report

The Remote sensing report is organized with eight chapters. The first three chapters focus on the approach utilized and Describes the preparation of the input data for the conceptual model. This is followed by description of results with respect to shallow groundwater availability on the three selected woreda in Tigray and Afar. The finding of deep groundwater analysis is addressed on chapter seven and chapter eight presented the maps produced. Finally on chapter nine conclusion and recommendation was stated. Compared to the other reports the remote sensing report is concise both in volume and content and describes the important issues clearly. Therefore it can be rated as the best quality report compared to the hydrogeological and geophysical report. Some of the issues observed in the remote sensing report are:

- Too much dependence on model generated data such as precipitation data which may not represent the actual condition on the ground. Example, the precipitation value 361mm/y at Atsbi deviates from the average observed values (620mm/y) by NMA significantly
- The methods utilized to integrate the different building blocks to determine potential drilling locations is not clearly indicated

5. Evaluation of Geophysical Report

The geophysical investigation report is well organized in three separate volume one for each woreda. All the volumes consist of four chapter starting from introduction, followed by geophysical survey and the third chapter deals with results and interpretation. The objectives are clearly stated, the applied methodologies are clearly indicated and the results are clearly interpreted supported by geoelectric sections with anticipated depth of potential aquifers. The conclusions and recommendation also give indicated the location and depth of productive and test wells. However, it is not clearly indicated in the approach whether the result of remote sensing study has been used as in put for an initial geophysical site selection.

- We suggest if the geophysical report is combined in one volume as it has been done in the remote sensing.
- For future use of the maps and the reports the locations of the VES with their number should be indicated in reasonably appropriate scale map.
- It would be suggested to consider the results of remote sensing data as in put or at least appreciate how much it guided the geophysical investigation

In general the three separate reports can be compared as follows:

Description	Hydrogeology report	Geophysics report	Remote sensing report
Methodology	Well designed	Very well designed	Very well designed
Structure	Well organized	Well organized	Very well organized
Content	Comprehensive and exhaustive	Specific and exhaustive	Specific and exhaustive

6. Conclusion and recommendation

This project has contributed a lot by improving the information required to improve drilling success rate. Particularly the areas selected are highly water stressed and geologically and climatologically very challenging. The report and the associated maps are a plus when future well siting is conducted. The reviewers believe the project will improve the drilling success rate in the mentioned woredas in the future. Moreover the experiences gained in deliberating this project will be used for future similar tasks in different parts of the country.

The strength of the project includes its objective which is increasing the drilling success rate in the arid and semi arid part of the country. The endeavor is ambitious in such a way that it plans to address water related issues in one of the remote, less accessible, little known and data scarce area of the country. Under such condition the output will be quite beneficial for all aspects of sustainable development interventions. The reports, the maps produced and the GPS locations identified for

high groundwater potential areas are important deliverables that will contribute a lot to site productive and successful wells.

Afar, Somalia and other arid and semi arid regions of Ethiopia are characterized by major challenges with regard to adequate and safe water both for domestic use and small scale irrigation. Moreover these pastoralist areas have features which are particularly challenging with regard to favorable geology, groundwater recharge and acceptable quality as far as groundwater exploration and exploitation is concerned. Therefore scaling up this type of works is quite helpful to address major challenges with regard to water resource. We recommend starting with remote sensing at regional scale and further narrowing the area of investigation for field based investigation, followed by geophysics and test well drilling.

Generally all the three techniques have identified sites for future water well drilling. Remote sensing applied remotely sensed optical and radar data and delineated potential sites for drilling and groundwater development. Likewise geophysics has used VES method and recommended potential sites for groundwater development in reference to the vertical electrical sounding points. Finally the hydrogeological study conducted an overlay analysis by assigning weighted values for different factors such as geology, geomorphology, drainage density and geological structure and delineated groundwater potential areas, then used the VES data to select potential drilling sites.

Generally using independent techniques separately will lead to more assertive results if they result similar findings concerning groundwater potential which they do in this particular project. But most literatures and field experiences recommend fine tuning results obtained from remote

sensing using a field based hydrogeological investigation and this result could further be fine tuned by geophysical investigation. Therefore the final well site location will benefit the values which can be added by the different methodologies. In this study, however, the use of remote sensing as an input for the ground survey techniques has not been clearly elaborated.

The preparation of manuals, maps and reports that can be easily understandable by low level experts and non-specialized professionals who might directly benefit from the information will improve the value of the project.

Finally, test drilling in the delineated areas and recommended sites will be very useful as a follow up activity in order to evaluate the findings claimed by this project. While it is clear the information compiled would improve the drilling success substantially, it is not possible to proof how much success is achieved without drilling.

Proposal I

Scaling up “improving drilling success rates” and capacity building in Ethiopia

Background

Currently up to 80% of domestic water supply in Ethiopia comes from groundwater sources. Groundwater has been proven resources to support emergency water supply, urban water supply, livestock watering, and more recently shallow groundwater are identified as potential target for developing smallholder or household irrigation.

Nevertheless Ethiopia’s groundwater drilling program, particularly in arid areas of Afar, Somali, Oromia etc, is characterized by remarkable failure. The main sources of failure are a) negative wells upon drilling following poor site selection; b) yield reduction of boreholes after few years of service (generally less than 3 years) due to variety of factors (recharge decline, environmental degradation, clogging of wells due to poor maintenance, etc) c) poor design and construction of wells after drilling (lack of human capacity) and d) return of poor quality water in drilled wells. It is documented that in arid setting of Afar and Somali up to 50% of drilled wells return negative results, salinity is often in excess of WHO drinking water quality standard.

The challenges of drilling programs is much pronounced in arid and semi-arid region. Hydrogeological information is available for the arid regions, but is limited and fragmented. Failure rates in planned water development schemes are high. The cost of drilling in the Afar Somali regions is particularly high (reaching \$200/m due to the greater depth of the aquifers, remoteness and security issues). In addition there are challenges relating to groundwater quality such as salinity in some areas that makes it inappropriate for use.

On the other hand, it is proven where adequate geological information is available success rate of wells could be enhanced to 70%. Modern integrated technologies such as combination of radar and optical remote sensing, geological mapping, geophysical survey, water quality survey could increase success rate to more than 70%.

Description of the project area

The project will be conducted in six water short Woredas in Afar and Somali regional states. Target woredas (districts) for this study will be selected in consultation with regional water bureaus.

Objectives

1. Improve drilling success rate in six water short woredas in Afar and Somali regions by deploying state-of-the-art science that help to improve existing groundwater information: Out of ten water wells drilled in Afar and Somali regions, 7 or more wells could turn dry or saline, just because wells are drilled without having adequate groundwater information. Combination of appropriate methodologies including conventional and satellite data will be used to improve existing groundwater information thereby improving drilling success rates.
2. Assess and recommend suitable water quality remediation technologies: Over 60 % of groundwater in Afar and Somali regions is not suitable for consumption, because of high salinity and abnormal concentration of some constituents such as fluoride. Appropriate and cost effective water treatment technologies (both at household and community level) will be recommended based on detailed water quality survey in the selected six woredas.
3. Ten short tailor-made training courses will be given to 200 participants coming from all regions. Suggested list of courses are given below; further fine tuning will be done based on needs of the regions.

Methodology

Various complementary methodologies of groundwater exploration including remote sensing, GIS, and conventional methods will be applied to map occurrences of groundwater with high level of confidence. The project will be implemented in three phases consisting of deskwork, field surveying and geophysical investigations. During the deskwork stage; collection, compilation and interpretation of all existing pertinent data and literatures supported by satellite data interpretation will be conducted. In general the following work flow will be done:

- Collection, compilation and interpretation of all existing pertinent data and information
- Radar and optical remote sensing data interpretation
- Hydrogeological field survey (geological, water point inventory and sampling)
- Geophysical investigations
- Integration and interpretation of all data and information

The groundwater exploration will be supported by satellite images interpretation from a variety of sensors with different spectral, spatial and temporal characteristics. Low to medium resolutions images will be used to produce thematic maps covering large areas; while high spatial and spectral resolution images will be used for mapping target areas. Validation of satellite derived information will be done using independently obtained observations and measurements from satellite images and field surveying including GPR.

Ten short training courses each accommodating up to 20 students will be organized. Participants will be drawn from all nine regional states. Instructors will be recruited from local universities, consulting firms, freelance consultants, and from international research centers and universities.

Activities to be performed:

- Collect and review all existing pertinent studies and data
- Carry out radar and optical remote sensing data analysis and interpretation
- Conduct field hydrogeological survey and geophysical investigation
- Compile and interpret newly generated and existing data and information
- Conduct groundwater resource assessment
- Prepare groundwater resource maps and reports
- Provide 10 short training courses to about 200 participants from all regions (see the list below)
- Conduct awareness creation workshops and project evaluation meetings
- Disseminate results of the study to potential stakeholders and end-users

List of suggested short training courses:

1. Remote sensing ,GIS and Data management for water resources management
2. Hydro-geochemistry, water quality issues, and remediation technologies
3. Groundwater exploration (geology, hydrogeology, geophysics and remote sensing)
4. Groundwater resource assessment (hydraulic parameters, aquifer geometry, recharge estimation and water quality analysis)
5. Groundwater conceptual and numerical modelling
6. Integrated Water Resources Management (eco-hydrology, water harvest, recycling artificial recharge ,etc)
7. Water supply schemes and groundwater development
8. Groundwater development (well design, drilling, dug wells and spring development)
9. Development of multi-community water supply schemes and management

10. Water projects management (project designing ,coordination, tender document preparation ,evaluation and administration)

Expected outputs:

1. Inception report
2. Preliminary hydrogeological report and base maps
3. Intermediate hydrogeological report and maps
4. Final hydrogeological report and maps
5. Groundwater resource maps at 1:50,000 and 1:250,000 Scale
6. Water resource data base of the study areas in Afar and Somali regions
7. Two hundred trained personnel

Inputs

UNICEF donates 1,500,000 USD for implementation of the project, of which 1.2 million goes into groundwater exploration and mapping in six selected woredas in Afar and Somali regions and 300,000 USD will be used for organizing 10 national training workshops in which trainees from all regions will participate.

UNESCO's contributions will be in-kind contribution, in the form of providing project management services, office and office facilities estimated to cost 240,000 USD.

Project implementation and staff deployment:

The project will be implemented by UNESCO in close cooperation with UNICEF. A team of local consultants and postgraduate students will be utilized to collect and collate data and information and develop a report that will critically review the existing information and identify knowledge gaps, availability of information.

Six national consultants (companies or individual) will be involved in geophysical survey, water quality surveys, field hydrogeological and

geological mapping. An international consulting firm will contribute to the interpretation of satellite data. A project manager (a national senior hydrogeologist) will lead the project.

Project management and evaluation

UNESCO-Addis manages the day to day project implementation. The Ministry of Water, Irrigation and Energy (MWIE) Afar and Somali Regional Water Bureaus will serve as main counterparts.

A national project steering committee (PSC) consisting of the following members will oversee the project implementation.

1. Regional Water Bureaus of Afar and Somali
2. Ministry of Water, Irrigation, and Energy
3. Geological Survey of Ethiopia
4. Addis Ababa University
5. UNICEF
6. UNESCO

Finally, a stakeholders' validation workshop will be conducted at the end of the project to evaluate deliverables of the project.

Work plan

The project will take off in January 2016 and will be implemented during the next 2 years. The table below shows details of activities to be implemented over the course of the project.

Phases	Activities	Duration (Months)	Period	Output
Phase 1 (Desk work)	Collection ,validation and interpretation of all existing pertinent data and information	4	Jan2016 – Apr 2016	Preliminary hydrogeological report and base maps
	Collection, processing and interpretation of satellite data			
	Integration of existing and satellite derived information			
	Base map preparation			
	Preliminary report preparation			
Phase 2 (Field survey)	Field verification of deskwork studies	8	May 2016 – Dec 2016	Intermediate hydrogeological report and maps
	Hydrogeological survey, water point inventory and sampling			
	Collection of existing data from regional water bureaus and others			
	Chemical analysis			
	Reinterpretation of remote sensing data			
	Compilation and interpretation of data and information from deskwork and fieldwork			
	Selection of sites for geophysical			

	investigation			
	Preparation of hydrogeological map			
	Preparation of intermediate report			
Phase 3 (Final stage)	Field geophysical investigation	8	Jan 2017 - Sept 2017	Final hydrogeological report and maps
	Geophysical data interpretation and report preparation			
	Integration of geophysical data with phase 2 results			
	Final hydrogeological map preparations			
	Final hydrogeological report			
10 short training courses, each lasting for 2 weeks and open to 20 trainees per class from all regions	5	Every 2 months	200 trained personnel	
Stakeholders' validation workshop	2 days	Oct 2017	Minutes of meeting	

The deskwork involves data collection and processing from all possible sources including federal ministries, regional water bureaus and global data repositories. It is the most important stage used to define activities of the next stages. Conceptual hydrogeological models to be developed and data gaps identified at this stage are the basis for planning and effectively implementing the field work.

Budget

Activities	Budget (USD)
Inception workshop	30000
Staffing	76000
Project management and coordination	58000
International consultant and Purchase of Satellite images (RADAR images + Optical images)	320000
Base map purchase	10000
Database and digitization of maps	10000
Reproduction of reports and maps	20000
Field missions	20000
Transport fee (Field transport)	80000
International transport and DSA	50000
Field Hydrogeological Mapping	40000
Field geological mapping	40000
Geophysical survey	86400
Water point inventory	40000
Field water quality survey	11000
Laboratory water chemical analyses	39000
Field survey equipment	32000
Validation workshop	30000
Dissemination of results	22000
Training courses	300000

Miscellaneous	13034
Overhead cost (13%)	172566.4
Total	1,500,000

Proposal 2.

Assessment of climate resilient water resource development possibilities for vulnerable areas in the Awash River Basin

Background

Awash is an internal drainage basin where relatively intensive development activities are taking place. It hosts several agricultural activities including four sugar cane farms and factories: Wonji, Metehara , Kesem and Tendaho. The growing demand of water for irrigation and domestic use has put greater pressure on the finite water resource which is exacerbated by climate changes. The middle and lower Awash are frequently threatened by drought and seasonal flooding from the highlands. Preparedness to avert consequence of extreme climate is thus a must and imperative. The current study focus on assessment of climate resilient water resource development possibilities for vulnerable areas in the Awash River Basin

Description of the project area

The project area covers the entire Awash River basin. Much of Afar, some part of Somali, Oromia, Amhara and Tigray regional states situated in Awash basin will be covered by this study.

Objectives

Assess macro and meso-climatic data, major vegetation types, hydrology and water availability. Develop climate resilient water resource development strategic plan and projects proposals for the entire Awash River basin in order to enhance water security for human consumption , agriculture and ecosystem functioning.

Methodology

Chemical, isotope, and water balance modeling along with remote sensing and GIS methods will be applied in the assessment of water resource of the basin. All existing pertinent studies and data will also be thoroughly reviewed and integrated with this study. Existing time series climatic data will be studied and analyzed; new weather stations will be installed; vegetation (natural, anthropogenic and potential) will be studied and analyzed. Finally, plausible climate resilient water resource development plan and projects proposal will be developed based on assessment of water resources, climatic conditions and ecosystems of the basin.

Outcome

Inhabitants of the basin will have improved capacity and preparedness towards accessing sustainable water supply and conservation of eco-hydrological system of the basin.

There will be an improved understanding of climate and ecosystem changes and ecosystem management options with clear recommendations for climate change resilience.

Activities to be performed

- Collect and review all existing pertinent studies and data
- Carry out field data and sample collection campaigns
- Develop monthly water balance model using appropriate hydrological computer codes
- Investigate interaction of hydrology with ecosystem
- Compile previous and newly generated data and knowledge
- Prepare water resource reports and maps including ecosystems maps
- Develop climate resilient water resource development plan and projects proposals
- Provide a series of training workshops on eco-hydrology, water balance modeling ,climate change , environment ,etc
- Develop a documentary film on ecosystems

- Conduct awareness creation workshops and project evaluation meetings
- Disseminate results of the study to potential stakeholders and end-users

Inputs

WFP/OCHA/GEF/UNDP/SDG initiatives donate 2,000,000 USD for implementation of the project. UNESCO's contributions will be in-kind contribution, in the form of providing project management services, office and office facilities estimated to cost 360,000 USD. About 13 % of the project budget will be used to support UNESCO in the project management including covering cost of duty travels, meetings, etc.

UNESCO implements the project through the Federal Ministry of Water, Irrigation, and Energy, Regional Water Bureaus, selected Universities and Regional Eco-hydrology Center. Much of the work will be implemented by hired postgraduate students (M.Sc. and PhD) and consultants' from Africa including women. The counterpart institutions will receive the following supports to enable them to accomplish their tasks:

- Expert consultancy services
- Scientific equipment
- Analytical services
- Training

Outputs

The project will have the following outputs, but not limited to:

- 1. Water resource reports and maps including climate and ecosystem maps**
- 2. Climate resilient water resource development plan and projects proposals focusing on the following areas:**
 - Rain and surface water harvesting from natural and artificial catchments to enhance community water security
 - Surface and subsurface dams to augment water retention capacity
 - Impeding structures (check dams) to regulate flooding and enhance recharge to groundwater
 - Enhancement of groundwater storage capacity by hydro-fracturing and other means
 - Artificial recharge to enhance yield and improve groundwater quality
 - Improve water use efficiency in conveyance, reservoir, household and irrigation systems
 - Catchment rehabilitation by terracing and re-forestation to enhance recharge to groundwater and mitigate problems of flooding and siltation in the lowlands
 - Waste water recycling from household outlets, sewers and irrigation returns
 - Desalinization using reverse osmosis or other systems powered by electric, solar or wind power
 - Training and awareness creation workshops
 - Data and information dissemination using reports, flyers, leaflets , brochures and websites
- 3. A documentary film on ecosystems**

Beneficiaries

Over 10 million people and livestock population residing in Afar, Somali, Oromia, Amhara and Tigray Regional States, within Awash basin, will benefit from this study. Furthermore, water resource bureaus, ministries, Environmental Protection Agencies (EPAs), academia and individual researchers could use results of the project.

Project management

UNESCO-Addis manages the day to day project implementation. A national project steering committee (PSC) consisting of the following members will oversee the project implementation. PSC is the highest decision making body of the project:

1. Ministry of Water, Irrigation, and Energy (Regional Eco-hydrology Center)
2. Ministry of Environment and Forestry (MEF)
3. Regional Water Bureaus of Afar, Somali, Oromia, Amhara and Tigray regional states
4. Donors(WFP/OCHA/ GEF/UNDP)
5. UNESCO

Work plan

The project will start up in January 2016 and will take 2 years to implement.

Phases	Activities	Duration (Months)	Period	Output
Phase 1 (Desk work)	Collection and interpretation of all existing pertinent data and information	8	Jan2016 – Aug 2016	Preliminary water resource report and base maps
	Collection, processing and interpretation of satellite data			
	Integration of existing and satellite derived information			
	Carry out existing situation analysis			
	Develop preliminary climate resilient development scenarios			
	Preliminary report preparation			
Phase 2 (Field surveying)	Field verification of desk studies	4	Sept 2016 – Dec 2016	Final water resources report and maps
	Hydrogeological survey, water point inventory and sampling			
	Collection of existing data from regional water bureaus and others			
	Compilation and interpretation of data and information from deskwork and fieldwork			
	Carry out further analysis of existing situation and development scenarios			

	Preparation of final water resources report and maps			
Phase 3 (Final analysis)	Final field verification	12	Jan 2017 -Dec 2017	Final water resource development plan and project proposals
	Carry out further analysis of existing situation			
	Develop appropriate climate resilient water resources development plan			
	Develop appropriate climate resilient water resources development project proposals			
	Stakeholders' validation workshop		Sept 2017	Minutes of the meeting

Budget

Activities	Budget (USD)
Inception workshop	30000
Project management and coordination	150000
International consultant	300000
Purchase of satellite images and other data	100000
Procurement of field equipment including vehicles	400000
Field missions	80000
International transport and DSA	50000
Field hydrological survey	80000
Field geological mapping	40000
Geophysical survey	50000
Water point inventory	40000
Field water quality survey and laboratory chemical analyses	30000
Database , digitization of maps, reproduction of reports and maps	50000
Preparation of water resource reports and maps	30000
Preparation of climate resilient water resource development plan/program/template/guidelines	30000
Preparation of climate resilient water resource development project proposals	50000
Validation workshop	30000
Dissemination of results	30000

Training courses	150000
Miscellaneous	50000
Overhead cost (13%)	230100
Total	2,000,100

Groundwater is the main source of rural and urban water supply in the arid lowlands of Ethiopia. In recent years, the number of water wells that were drilled has dramatically increased through the intervention of various international and local initiatives. However, the success rate of drilling productive wells in arid lowlands is still very low at 30-50%, even by sub Saharan standards. The failure in pinpointing productive sites is primarily attributed to the lack of adequate scientific information as well as the complexity of hydrogeology of the region. A joint UNICEF-UNESCO pilot project on improving drilling success rate in the Afar region was conducted during 2013-15. The project was implemented in two phases.

During the first phase, all existing information, including geology, hydro-geology, hydrology, and geophysics, were gathered and base maps of hydro-geology and geology were produced at a scale of 1:250000. The most prolific aquifer areas as well as areas with complex hydro-geology were identified. Three woredas with known water scarcity and complex hydro-geology were selected for further detailed groundwater investigation. The selected woredas were: Elidar- located along the Ethio-Djibouti border, Erepti- located south west of the Dallol depression and Atsbi- located in the escarpment bordering Afar and Tigray. The detailed groundwater investigation was conducted in the second phase of the project. This summary report, external evaluation report, and follow-up proposals summarize the main findings and achievement of the project, and provide prospects for future interventions.

