Manual Well Drilling Investment Opportunity in Ethiopia

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Interventions that benefit the rural poor in Ethiopia could potentially improve the lives of almost 36 million rural poor people in the country. Approximately 83 percent of Ethiopia's population of 82.8 millionlivesin rural areas and 52 percent of the rural population live in poverty (IFADImproving smallholder farmers' agricultural productivity and access to water can increase their incomes, improvetheir food security, and provide water for livestock and domestic needs.

In many countries in Asia, Africa and Latin America, manual drilling of wells is one solution for farmers to reliablyand affordablyaccess shallow groundwater resources. Once a well is drilled and farmers have a variety of options forlifting the water ,; storing it, andapplyingitto their crops.

While manual well drilling is common in many countries in Asia, Africa and Latin America, it is not widely available in Ethiopia. Pilot efforts by International Development Enterprises (IDE) to test manual drilling were successful in the areas selected: these efforts demonstrated profitability for farmers, well drillers and well drilling apprentices;high demand among farmers for manually-drilled wells; and feasibility of manual drilling in the hydro-geological settings of the pilot areas.

To scale up these successes to meet the demand of farmers and to improve their access to water requiresinvestments in (a)creating a spatial database of key soil, hydrogeology, and water resources data and information, which enables an assessment of the potential scale of manual drilling as well as effective selection of areas with high potential for manual drilling; and (b) expanding private sector drilling in the country. These are explained below:

a. Manual drilling is viable only in specific hydro-geologic settings. With careful selection of areas in the pilot work, IDE had an 80% success rate in manual well drilling. There are, however,insufficiently detailed and accurate data, information, and maps regarding soil, hydrogeology, and water resources throughout Ethiopia to determine all locations that are suitablefor manual drilling. Investments of approximately US $3 million in mapping, data collection, ground-truthingand drilling of test wellsare needed to determineareas suitablefor manual drilling. These investments would result in a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to assess the potential scale of the industry and to effectively target areas of high potential. The database canalso be used to assess the potential and monitor impacts of a variety of investments in water access, utilization, and agricultural water management. Thus, establishing this database greatly increases the chances of success of a manual drilling industry and other agricultural water-related investments in Ethiopia.
b. In locations where data and maps show physical suitability for manual drilling and a potential customer base sufficiently large to support private sector manual drilling, further investments may be needed to support expansion of private sector drilling in Ethiopiathrough driller training; creating demand from farmers for manually-drilled wells; and stimulating smallholder agricultural value chains.If data and mapping show areas where manual drilling is not feasible at scale, further investments in private sector drilling would not be promoted in those areas.

Once the areas suitable for manual drilling are defined, it is then possible to estimate the potential scale (e.g. potential number of farmers reached) of manual drilling in the country, the costs to reach those farmers, and return on investments in scaling up private sector manual drilling.It is projected that external support for manual drilling could catalyze the sector within 3 to 5 years. In that timeframe, it is expected that private sector manual drilling enterprises and associated supply chain actors would be financially self-sustaining. It is estimated that a flourishing manual well-drilling industry, supported by ongoing training and certification, could provide groundwater access for over 75,000 farmers within five years and close to one million farmers within 15 years. Without external support, private sector manual drilling may advance independently, but in a significantly longer timeframe.

Agriculture in Ethiopia

As stated in the January 2010 "Agricultural Water Management National Situation Analysis Brief" for Ethiopia, smallholder farmers in the midland and highland areas of Ethiopia practice mixed farming systems,e.g. livestock and crop production are integrated and equally important; in the lowland areas of the country, agro-pastoral systems are less common; most farmers utilize pastoral systems. Single cropping is the norm in Ethiopia; double cropping is practiced along rivers. Women play an important role in agricultural production, which is predominantly subsistence, rainfed agriculture. The potential irrigable land is 3.7 to 4.3 million hectares, but actual irrigated is approximately 7-10% of this potential[1].

Smallholder farmers without access to water are limited to rainy season crop production. As rains can be unreliable, improving smallholders' access to water reduces their vulnerability and risks, increases their incomes, improves food security, and provides water for livestock and domestic needs. In many areas in Ethiopia, farmers cannot easily access water for irrigation. Some farmers dig wells by hand to access shallow groundwater for irrigation; these wells provide some access to water, but often the water yield is too low for effective irrigation. Mechanized well drilling can drill deep wells and reach high-yield strata, but this option is too expensive for the majority of individual small-scale farmers and communities in Ethiopia. Manual well drilling is one option that enables farmers to access shallow groundwater resources for irrigation at an affordable cost.

Background: Affordable Manual Well Drilling

Utilization of groundwater for crop production requires accessing groundwater from a hand-dug well, a manually drilled well, or a machine-drilled well.Both hand digging and manual drilling of wells rely on manual labor to access shallow groundwater resources. Table 1 provides a basic comparison of these three options. As shown in the table, each option is suited to a specific set of variables. Manual well drilling is the most appropriate low-cost option for individual smallholder farmers to access groundwater resources under specific geo-physical conditions.

	Hand Dug Wells	**Manually Drilled Wells**	**Mechanized Well Drilling**
Business Entry Costs	Very low cost for hand tools	Low cost: approximately $1,300 initial investment for business in Ethiopia	High cost (varies depending on the equipment)
Cost to Farmer	– Labor cost if dug by self or if use labor exchange – Low cost if hired labor (comparable to a manually drilled well); more expensive if lined	Low cost (approximately US $18 - $200 for 6-12 meters depth)	Approximately US $1,200 – US $1,600 for 6-12 meters depth
Benefits Women	– In many contexts, it is not socially acceptable for women to dig wells, so women do not dig their own well and do not use labor exchange for a well – Hiring well diggers may be an option to improve women's access to groundwater	Hiring manual drillers may be an option to improve women's access to groundwater	Financial barriers often restrict well drilling on women's plots
Accessibility of Service for Farm Households	– Wells are either constructed by experienced local well-diggers or by villagers themselves, sometimes involving labor exchange	Where private sector services have scaled up, local small-scale businesses drill boreholes in villages	– Motorized drilling rigs in many SSA countries are used for municipal, industrial, and domestic water supply development but are not affordable for

1 *Agricultural Water Management National Situation Analysis Brief*. January 2010. awm-solutions.iwmi.org

	Hand Dug Wells	Manually Drilled Wells	Mechanized Well Drilling
	– An estimated 31 million hand dug wells in Africa[2]		smallholders – Access to sites far from paved roads can be difficult for motorized drill rigs
Time / Labor Requirements	Very laborious and time consuming	Under ideal conditions, manual wells can be drilled and pumps installed in less than a day (average of 2-3 days)	Drilling is very fast, but transporting a motorized rig to a rural site can be time-consuming
Access to Water	– Depth of hand digging recorded up to 30 meters[3] – Difficult to dig below the water table without lining, which limits water yield	Under the right geo-physical conditions, depth up to 50 meters can be achieved with deep penetration into water table with good water yield in permeable stratum	Can access water at great depth
Applicability in different geophysical conditions	– Applicable in many geophysical conditions, with the exception of hard rock – In sandy soils, wells must be lined (which increases costs)	– Applicable in sand, loam, clay soils, as long as it penetrates the water table in permeable stratum – Not applicable if cobble or hard stone ≥ 5-10 cm or soft stone ≥ 20-30 cm thick	Can be used in most geophysical conditions

Using manually-drilled wells, smallholder farmers have installed millions of pumps mounted on tube-wells (drilled wells with pipe casing) to access shallow groundwater resources for irrigated farming in at least 20 countries around the world, including Bangladesh, the Ganges plain of India and Nepal, Bolivia, Chad, Madagascar, Mali, Nicaragua, Niger, Nigeria, northern Sudan and Uganda[4]. In Bangladesh, more than 8 million hand-drilled wells have been developed primarily by small-scale private enterprises[5]. In Niger, there are 50 manual drilling enterprises drilling wells primarily for irrigation; well diggers report demand for hand-drilled wells and little demand for hand dug wells[6]. In Nigeria, more than 100,000 wells have been manually drilled. In Sudan, manual drillers operate as private enterprises without government or other support.

In locations where private sector manual drilling is common, drillers charge for their expertise and service at negotiated rates dictated by competition. The cost for a manually drilled wellvaries depending on depth: drilling deeper requires additional time and labor, which increases the cost. The cost ranges from approximately US $18 to US $200, which is significantly less expensive than motorized drilling, which costs approximately US $1,200 – US $1,600 for 6-12 meters depth[7]. In Ethiopia, the average depth of wells drilled manually by IDE is 20 meters; the maximum depth is 36 meters. Manual drillers in Sudan typically drill to depths of 50 meters.

[2] *Africa wide water, sanitation and hygiene technology review.* (WASHTech Deliverable 2.1) [online] The Hague: WASHTech c/o IRC International Water and Sanitation Centre and Cranfield: Cranfield University, November 2011.

[3] *Africa wide water, sanitation and hygiene technology review.* (WASHTech Deliverable 2.1) [online] The Hague: WASHTech c/o IRC International Water and Sanitation Centre and Cranfield: Cranfield University, November 2011.

[4] http://www.rwsn.ch/prarticle.2005-10-25.9856177177/prarticle.2005-10-26.7220595116/prarticle.2005-11-15.6127855822/prarticle.2006-04-19.8252079688

[5] http://www.rwsn.ch/prarticle.2005-10-25.9856177177/prarticle.2005-10-26.7220595116/prarticle.2005-11-15.6127855822/prarticle.2006-04-19.8252079688

[6] *Case Study: Sustainable Transfer of Manual Well Drilling to the Private Sector in Niger*, Practica, Unicef, Enterprise Works/VITA

[7] "Best Practices in the Development of Small Scale Private Irrigation in West Africa". Onimus, Francois; Stephan Abric, Moise Sonou, Benedicte Augeard, 2010.

Once a well is drilled, farmers have a variety of pump options (e.g. treadle pumps, rope and washer pumps, motorized pumps) available for lifting water from the well; a variety of water storage technologies available for storing water; and a variety of water applications methods (e.g. drip or sprinkler) available to apply water to crops.

Efforts to scale-up the successes of manual drilling in Africa include:

- Unicef is mapping the feasibility of manual drilling in 12 countries in Sub-Saharan Africa: Chad, Madagascar, Niger, Sierra Leone, Central African Republic, Mauritania, Togo, Senegal, Benin, Ivory Coast, Liberia, and Mali[8].
- Organizations supporting manual drilling programs in Africa include Unicef; Winrock International (USA), Enterprise Works/VITA (USA); PRACTICA Foundation (The Netherlands); ADPP (Mozambique); Arrakis (The Netherlands); DAPP (Zambia); SHIPO (Tanzania)[9].
- Unicef has produced a series of technical notes on manual drilling, including “The Case for Manual Drilling in Africa”, “Professionalizing Manual Drilling in Africa” and technical support documents on methods, techniques, etc.[10]

One alternative to private sector manual well drilling is communal well drilling, whereby community members rotate drilling responsibilities and provide community labor for well drilling. This approach is common in countries where manual drilling is promoted for non-irrigation household needs. This approach minimizes households’ cash requirements, but does not incentivize the establishment of private sector businesses.

Manual Well Drilling in Ethiopia

In Ethiopia, low-cost manual well drilling is not widely available - there are no village-based private-sector craftsmen who can be hired by farmers to drill irrigation wells. In 2009, IDE started manual drilling pilot work in Ethiopia to determine the technical and financial feasibility of private sector manual drilling and to assess thedemand for wells amongst farmers. Following the pilot, IDE and partner organizations, introduced larger-scale efforts to create an industry of private well drillers. This has been possible because offinancial support from USAID and the Agricultural Water Management Landscape Analysis Project which is funded by the Bill &Melinda Gates Foundation., .

The goals were:

- To create an industry of private well drillers skilled in a variety of drilling techniques suitable for Ethiopia’s challenging geologic conditions;
- Tomap new areas with potential for manual drilling using GIS;
- To develop the necessary equipment in order to reduce the cost and improve the efficiency.

[8] http://www.unicef.org/wash/index_54332.html

[9] Hand Drilling Directory, Rural Water Supply Network, Unicef, WSP, Cost Effective Boreholes, Kerstin Danert, 2009.

[10] http://www.unicef.org/wash/index_54332.html

 

As a result of these efforts to initiate private sector manual drilling, from 2009 to the end of 2010, 175 manually drilled wells were completed[11]. By the end of 2011, 450 wells had been drilled; 20 drillers are certified and 9 drillers have purchased their own drilling equipment to start their own businesses.

These pilot efforts havedemonstrated that:

- The drilled wells provide irrigation water to small-scale farmers; in addition, many wells are also used by farmers and neighboring households for animal watering and domestic needs.
- Private sector manual well drilling businesses can operate profitably once someone is trained in technical manual drilling and business management skills.
- Creating a private-sector industry of affordable manual well drilling servicesis financially viable.
- Female farmers benefit from improved access to water. A well means they no longer have travel long distances to collect water for domestic use and crop production, which saves time and labor..

Regarding competing products and/or services, the International Water Management Institute (IWMI) conducted an analysis of the manual well drilling activities in Ethiopia and concluded that there is no substitute for manual drilling. Hand digging a well has a similar or slightly lower cost than manual drilling but a hand-dug well cannot be dug deeper than about 75 cm below the water table, unless a de-watering pump is used. Machine-drilled wells have the advantage of penetrating rock and reaching deeper strata, but are much more expensive (for example, the cost for one of the least expensive motorized drilling rigs is approximately US$10,200).

Pilot manual drilling pilot activities undertaken by IDE in Ethiopia demonstrated high potential for manual drilling in areas with suitable geo-physical conditions. In addition, there is huge demand among smallholder and larger-scale farmers to access groundwater: for every well drilled, an additional three farmers were interested in investing in a well. In addition, stakeholder consultations undertaken by the Agricultural Water Management Landscape Analysis project showed both interest in manual drilling and emerging financial support (e.g. from the World Bank, GIZ, PRACTICA, Water for All) for the sector. Further, the Government of Ethiopia sees manual well drilling as an effective and scalable way to develop Ethiopia's shallow groundwater reserves to benefit smallholder farmers. For example, with support from the World Food Program, the Government invited Sudanese manual well drilling craftsmen to train Ethiopian drillers.

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[11] More than 90 farmers paid to have wells drilled and pumps installed for irrigation; the remaining 85 wells were test/training/demonstration wells, where IDE paid for drilling and farmers or the community paid for the pump.

Building on data and information collected through the manual drilling pilot activities in Ethiopia, a private sector manual well drilling business model is described below.

In this model, private sector input suppliers and warehouses sell well drilling equipment and supplies, as well as irrigation pumps and accessories, to well drilling enterpriseswho are knowledgeable about local drilling conditions; experienced in drilling as well as selection and installation of irrigation pumps; and equipped with the knowledge, skills and tools needed to respond to farmers' requests to drill affordable wells.

Farmers pay the enterprise to drill a well and install a pump on their property. Theythen have improved access to water, which in turnincreasestheir crop productivity and the number of crops grown per year. Higher yields combined with market access can raisefarmers' incomes.

Financial products and services are available along the value chain and tailored to the needs of farmers and other enterprises in this model.

The key features of this model are summarized in Table 1and described below.

Table 1: Summary Well Drilling Estimated Investment and Income Summary in USD[12]

	Investment Cost	Additional Annual Income	Profit in Year 1
Farmer	$156	$490	$334
Well Driller	$1,247	$2,740	$1,493
Well Driller Apprentices[13]	$0	$667	$667

1. Farmers' Investment and Return. Farmers invest in a manually-drilled well, which provides affordable access to reliable irrigation water. The total cost to the farmer depends on the depth of the well and the choice of pump. At an average depth of 20 meters, the cost to the farmer is US $156 for the well and suction-only treadle pump. (In comparison, a larger-bore drilled well together with an engine pump costs approximately US $1,000.)Farmers also invest in improving their knowledge and skills to grow irrigated high-value crops for the market to recover their investment in the well. While numerous variables affect estimated cost and income figures (e.g. depth of water; market access; agricultural risks, smallholder agronomic knowledge), estimated additional income for a farmer with a manually-drilled well and a suction treadle pump and a 700 m^2 plot is approximately US $490[14]. This income pays for the well and the treadle pump within one year and provides an additional US $334 net income.

2. Well Drillers' and Apprentices' Investment and Return. Private well drillers invest in improving their knowledge and skills and establishing and operating a well drilling business. Drillers are qualified to drill, develop the well, and install a variety of pumps. The drilling enterprise owner manages all drilling activities; hires and supervises helpers at the drilling site; provides equipment and organizes transportation of equipment to the site; pays for miscellaneous costs (e.g. broken tools); cleans the well and installs casing/filter/gravel pack; develops the well and confirms that the water yield is acceptable; installs the pump; and collects payment from the farmer. Drillers

[12] In this document, exchange rates are calculated at 16.5 Birr to 1 US dollar.

[13] Calculated at an average of two apprentices at 60 and 80 birr per day for 200 days.

[14] Returns to land and labor are calculated as follows: if the farming household operates the treadle pump for 3 hours per day with a 5-meter water lift to irrigate a 700 m^2 plot and if the net return to land, labor and water is US $0.35/$m^2$, the net return per crop is US $245, or US $490 for 2 crop seasons per year. The cost of the well and the irrigation pump are US $156, so total net additional income of US $334.This assumes that the farm family contributes 110 person days of labor per crop season for 2 seasons (220 days per year total) for land clearing, seed preparation, irrigation, production, harvesting and selling.

know how to interact with customers, set drilling rates that provide a reasonable profit, and determine policies to cover the cost of failed wells and pay for broken equipment.

As an example of the process implemented during the well drilling pilot in Ethiopia, the driller and farmer discuss and agree on the cost to drill a well. An advance payment of US$18 (300 Birr) is paid; if the well is unsuccessful (e.g. if no permeable strata to sustain pump flow or if the water table is too deep), the driller refunds 50% of the advance. If the well is successful, a fee of US$2.40 (40 Birr) per meter is paid by the farmer to the driller, which pays for the driller and driller's apprentices' fees, amortized drilling equipment costs, driller team and transport. (An additional fee is charged to enlarge the hole if required for a rope or engine pump.) If the driller hits stone, the driller moves to a new site selected by farmer and drills again at no additional cost. The farmer pays for pump, casing, gravel pack, transport, etc.

The estimated profit for a lead well driller from well drilling and pump installation is US$1,493/year[15]. Many manual drillers operate their business during part of the year and continue to farm or work in another tradeduring the rainy season when drilling is difficult.

Lead well drillers hire and train apprentices, who become experienced with a wide range of drilling situations. Apprentices often establish their own profitable drilling businesses. Apprentices earn US $3.64 (60 Birr) per day and a junior apprentice earns US $3 (50 Birr) per day. Excluding the rainy season, when drilling is difficult, apprentices and helper can expect approximately 200 days of work each year.[16]

This income is competitive with alternative sources of income for unskilled labor where the rates are approximately US$3 (50 Birr) per day in Ziway town, so the lead drillers' income is 140% higher; the apprentice's income is 20% higher; and the junior apprentice's income is comparable to alternative sources of income for unskilled labor.

3. Supply Chain Profitability. Supply chain actors profit from the supply of parts required for drilling and inputs required by farmers who invest in their farm business. For example, the drilling enterprise owner purchases hand tools, drill pipe fittings, chains, ropes, and pulley from retail supply shops; each farmer purchases the PVC casing, eucalyptus, and the irrigation pump. Each drilling enterprise owner invests approximately US$1,247[17] in well drilling equipment each year, so supply chain actors profit when well drilling enterprises replace equipment and when the industry scales up in the country.

4. Financial Products and Services. Financial products and services are available throughout the value chain to enable farmers to invest in a well and to enable well drilling enterprises and supply chain enterprises to invest in establishing and growing their businesses.

There are numerous synergistic products and services that leverage farmers' investments in water access and increase farmers' incomes. These products and services include irrigation equipment, quality seeds, and support services for high-value crop production, soil management, and market access.

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[15] Well driller's annual profit of US $1,493 (Birr24,640) is calculated as US $17.77 (293 Birr) per well, with an average of 7 wells drilled manually per month for the entire year, or 84 wells per year. The key variables for calculating well driller's income are: the cost of equipment (US $1,247 [20,560 Birr] total or US $15 [245 Birr] per well) plus labor (US $1,333 [22,000 Birr] or US $16 [262 Birr] per well), the number of wells that can be drilled with each set of equipment (approximately 25 wells), and the average depth of the well.

[16] Assuming that there is no drilling in the 3 month rainy season and an average 5 day work week for the rest of the year there would be about 200 days of drilling by an enterprise each year. For an apprentice earning 60 birr a day the annual income for drilling work would be birr 12,000 ($ 727). Increasingly, the drillers pay their apprentices/helpers on a per meter drilled basis to provide greater incentive for efficient work. The per meter payment rate is estimated to approximate the average daily rate.

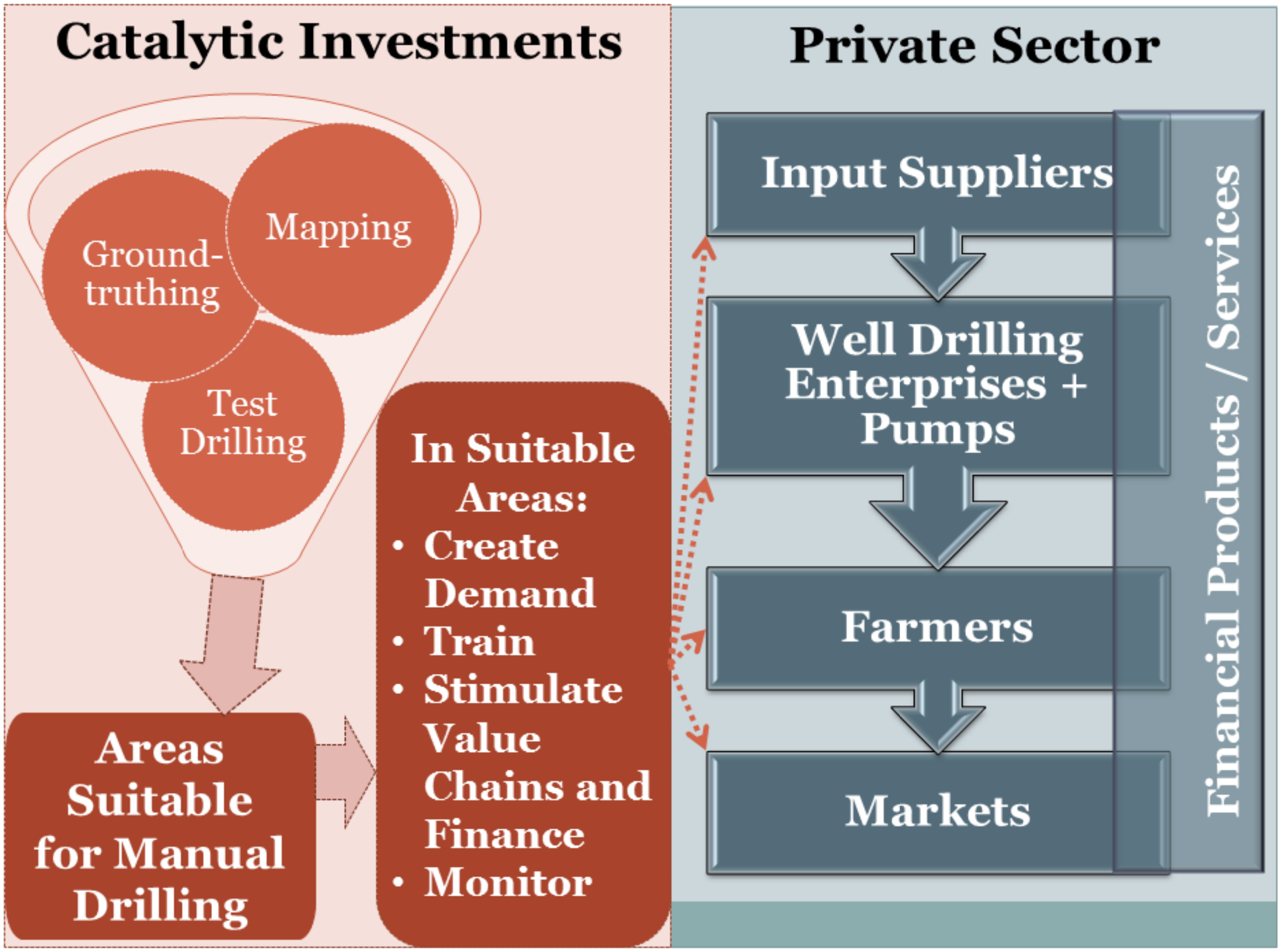
[17] Calculated at US $371 (6,122 Birr) per set of well drilling equipment, which drills approximately 25 wells, and each well driller drills approximately 84 wells/year.

The pilot manual drilling work demonstrated high demand; a high (80 percent) success rate in the pilot areas; and profitability for farmers, well drillers and well drilling apprentices.Based on the success of the pilot work in Ethiopia and building on experiences of private sector manual drilling worldwide, there is potential to scale up manual drilling in Ethiopia to increase smallholder farmers' access to water. As shown in Figure 1 and explained in more detail below, scaling up the pilot initiatives requires investments in two key areas:

1. Creating a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to identify areas suitable for manual drillingand to effectively target areas of high potential. Once suitable areas are identified, it is possible to estimate the potential scale (e.g. number of farmers reached) of manual drilling, costs to reach those farmers, and return on investment in scaling up private sector manual drilling. If data and mapping show areas where manual drilling is not feasible at scale, further investments in private sector drilling would not be promoted in those areas.
2. In locations where data and maps show physical suitability for manual drilling and a potential customer base sufficiently large to support private sector manual drilling, further investments may be needed to support expansion of private sector drilling in Ethiopia through training of drillers; creating demand from farmers for manually-drilled wells; and stimulating smallholder agricultural value chains.

It is projected that external support to manual drilling will catalyze the sector within 3 to 5 years. At that time, it is expected that input suppliers, manual drilling enterprises and pump suppliers, farmers, financial products and services, and output markets will be linked through financially self-sustaining value chains. It is estimated that a flourishing manual well-drilling industry, supported by ongoing training and certification, could provide groundwater access for over 75,000 farmers within five years and close to one million farmers within 15 years. Without external support, private sector manual drilling may advance independently, but in a significantly longer timeframe.

Figure 1: Catalytic Investments to Stimulate Private Sector Manual Drilling



Investments in a Spatial Database of Agricultural Water Information and Data

Manual drilling is viable only in specific hydro-geologic settings with suitable soil conditions: where well yields are sufficient for sustainable extraction of water resources for productive irrigation; where the water table is shallow; and where the water-bearing layers have sufficient permeability and thickness to provide the flow rate necessary for irrigation pumps. Sand, loam, and clay are generally easy to drill; compacted and cemented soils can often be drilled, but may require much more time and labor (and therefore additional cost) to drill. Manual drilling generally is not successful if boulders or stones larger than 5 cm are encountered or if drilling must penetrate hard stone layers more than 5-10 cm or soft stone layers of 20 or 30 cm thick.

Ethiopia has challenging geology for drilling when compared to river deltas and outwash plains in many countries in Asia and other African countries where manual well drilling proliferates. This challenging geology creates geographical limitations for manual drilling and can lead to increased costs if drilling failure rates are high. The manual drilling pilot work established that areas exist in Ethiopia with high potential for manual drilling due to shallow water and permeable soil layers. These areas are smaller than in the Gangetic Plain of Asia; however, with careful selection of areas, the success rate for manual drilling was approximately 80%.

Current data, information, and maps regarding soil, hydrogeology, and water resources for Ethiopia areinsufficiently detailed and accurate to determine specific locations that are suitable for manual drilling. Therefore, investments of approximately US $3 millionin field-level data collection on surface geology and aquifer conditions, together with mapping and drilling of test wills, are needed to determine areas suitable for manual drilling and to estimate the number of smallholder farmers who could potentially benefit from manually-drilled wells. These investments would result in a spatial database of agricultural water information and data, which can be used by the government, investors, well drillers and others to assess the potential scale of the industry and to effectively target areas of high potential. The database could also be used to assess potential and monitor impacts of a variety of investments in water access, utilization, and agricultural water management. Thus, establishing this database greatly increases the chances of success of a manual drilling industry and other related agricultural water investments in Ethiopia.

For areas where data collection, mapping and test well development demonstrate sufficiently large potential market size and customer base for manual drilling, further investments can accelerate expansion of private sector drilling (e.g. driller training and certification; creating supply chains; marketing to farmers to create demand; linking farmers to processing, storage andmarket opportunities). The information collected through the mapping work will be useful to support these expansion efforts because it will improve the likelihood of drilling success and lower the cost of driller training. For areas where a sufficiently large customer base cannot be reached to be financially viable using a private sector approach, further investments to scale up private sector manual drilling would not be recommended.

Investments needed to delineate the geographical limitations of manual drilling and to determine the potential number of farmers who can benefit from manual drilling are detailed in the process described below. Each step in this process results in a finer level of detail regarding the potential feasibility of manual drilling.

1. *Initial Nationwide Mapping*. Mapping of estimated shallow (<18 m) groundwater, rural population density, and geology throughout Ethiopia using digital data (images and terrain data from global sources, drilling logs from hand- or machine-drilled wells, soil and population data, etc) is necessary in order to select areas with higher potential for manual well drilling. The estimated cost for a team of GIS experts, hydro-geologists, manual drilling experts, etc. to develop maps for Ethiopia is US $60,000.

2. *Verifying Areas with Higher Potential*. In this stage, areas identified through the initial digital mapping stage as having high potential for manual drilling are visited for visual inspection and to adjust and refine the digital mapping analysis.

This inspection

- confirms that land use, landforms and topography are suitable for manual drilling;
- collects GPS elevation data and data on surface-to-static-water level depth in representative hand-dug wells; visually examines soil profiles in hand-dug wells;
- interviews well diggers and/or inspects well drilling logs (if available) to learn about the soil profile, variation experienced in digging other wells in the area, potential well yield and seasonal water level fluctuation.

Theprocess of verifying academic information can be divided into two phases. First, a team of international experts train national experts in the methodology. The approximate cost for this first phase is US$250,000.
Then the international and national expert teams jointly refine the initial maps based on detailed on the ground researchin areas highlighted from the first phase as having shallow groundwater potential. It would take several years to complete the second phase throughout the country at an estimated cost of US $1.3 million.

Through these two phases, the most promising areas for manual drilling would be identified for physical testing.

3. *Test Drilling*. For areas where initial mapping and verification confirm that surface characteristics are favorable for manual drilling, test drilling is used to validate potential. This establishes subsurface conditions and well yield; confirms surface-to-static water table depth; establishes that manual drilling techniques are viable with

the given soil conditions; determines the type of pump suitable to the conditions and confirms that there is sufficient flow of water for the desired pumping rate.

Test drilling information (e.g. vertical soil profiles, geological formations, depth to water table, water yield rate and water quality) is recorded in geo-referenced drilling logs (see Appendix 1 for a sample drilling log) and managed in a GIS database. These data are integrated into the preliminary maps and are used to identify the periphery where manual drilling/pumping is possible and to confirm locations for demonstrating and promoting manual drilling techniques.

Although test drilling can be done manually, mechanized test drilling using a trailer-mounted portable machine drilling rig is recommended for several reasons. Firstly, machine drilling provides information rapidly, permitting faster determination of the periphery of areas suitable for manual drilling. Secondly, it penetrates most geological formations to depths of at least 50 meters, including locations where manual drilling cannot proceed because of difficult drilling conditions. Therefore, machine drilling provides information regarding sub-surface conditions that is useful for multiple purposes. For example, in locations where stone is encountered, manual drilling would not be feasible, but the information from penetrating the stone formation would determine if machine drilling is feasible. As such, machine test drilling expands the value of the shallow groundwater mapping to include machine-drilled groundwater access for irrigation and domestic needs.

The estimated cost for two drilling teams to test drill 1,600 to 2,400 test wells in Ethiopia over five years is US$1.4 million[18]. While this does not comprehensively cover the country, it provides an extremely useful sample from which much information can be extrapolated for manual drilling and mechanized drilling for domestic and other needs.

<u>Investments to Acceleratea Private Sector Manual Drilling Industry</u>

Additional investments could accelerate expansion of private sector drilling in Ethiopia. This is particularly true for areas in Ethiopia where data collection, mapping and test well development demonstrate sufficiently large potential market size and customer base to scale up private sector manual drilling.,. Support to accelerate establishment of this sector can focus on training; creating demand for wells; stimulating value chains and value chain finance; and monitoring of risks, (as described below). It is possible to estimate the cost of these investments once the potential suitability domains for manual drilling are determined.

1. <u>Create Demand</u>. In Ethiopia, low cost drilling for irrigation is unknown. Poor farmers are reluctant to invest in an unknown solutionso there is little demand for manually-drilled wells. Demonstrations of manual drilling, model farm demonstrations, farmer-to-farmer visits, extension services, etc.could create customer demand. Through demonstrations and visits, smallholder farmers become aware of manual drilling, pump options, and potential income opportunities of higher-value irrigated crop production. Involving local and international organizations, as well as Woreda and local agricultural extension staff in manual drilling demonstrations also builds their knowledge of manual drilling as a technique to improve groundwater access. In addition to demonstrations, well drillers and government extension can promote manual drilling by providing information to farmers on the benefits and costs of manual drilling.

2. <u>Train</u>. To ensure that private-sector well drilling enterprises emerge to meet customer demand, training can be provided in business management and the technical aspects of manual drilling, which includes training in proper well development to guard against point-source contamination. In addition, a sufficient number of skilled manual well drillers are necessary to create competition, lower the price of drilling wells, maintain competitive

[18] One drilling team with a portable machine drilling rig can dill approximately 8-12 strategically placed wells per location at 20 locations per year. Therefore, two teams can drill 1,600 to 2,400 wells at 200 locations over 5 years. The cost estimate is calculated at $684,000 per team (including international technical assistance), for a total cost for 2 teams of US $1.4 million.

quality, etc. Therefore, investment in training increases the number of drillers and improves the skills of drillers. Once well drillers are trained and operating as successful businesses, it is expected that they will employ and train driller apprentices, so manual drilling businesses will self-replicate and scale up.

IDE initiated a field-based manual driller training program that recruits, trains and certifies manual drillers. This experience demonstrated that approximately four months are required for a driller trainee to be trained to the level of certification. Certified drillers are trained to provide technical support if needed and customers of certified drillers are provided a limited guarantee of workmanship. This helps to create a workforce of skilled and competitive drillers. A recently proposed training program for the Government of Ethiopia estimated the cost to establish and operate an intensive 4-month manual well driller training program at approximately US$950,000 for the first year and US$680,000 per year operating costs after the first year. This type of training program would greatly accelerate well drilling capacity. As detailed in Appendix 2, the potential impact of the training program is significant: as the number of trained drillers increases, the total number of wells drilled for smallholder farmers increases rapidly. It is estimated that 966,000 wells could be drilled after 15 years of conducting the training program.

Well drilling to access groundwater for irrigation is only one component of the irrigated crop production value chain for smallholders. Most smallholder farmers do not have experience with irrigation, so accelerating demand for manually-drilled wells involves training and support to farmers to grow and market irrigated high-value crops to increase their incomes. This training, whichincludes irrigated agricultural production (e.g. timing of market-oriented crop production, crop water requirements, soil management) and production output services (e.g. post harvest processing, storage, and aggregation and marketing), ensures that farmers capitalize on their investment in a well. The costs to train smallholder farmers to integrate irrigated cropping into their livelihood strategies are not included in this document.

3. Stimulate Value Chains and Finance. Catalyzingagricultural value chain includes stimulating supply chains for spare parts and equipment for manual drilling, aggregating small-farm production, and connecting farmers to quality input suppliers and output markets.Additional value chain considerations include linking farmers to manufacturers for direct sales, to retail input suppliers, and creating more effective supply chains for inputs and services needed by farmers for improved crop production (e.g. seed, fertilizer, irrigation pumps, high value agricultural knowledge).Ideally, manual well drilling supplies (e.g. metal pipes, wood, chains, clamps) are available in rural shops through private sector supply chains; however, dealers in rural areas are often reluctant to stock supplies and accessories for well drilling and pump installation due to low sales volumes. To address this issue, IDE Ethiopia tested various supply chain models. For example, IDE introduced warehousing, whereby IDE purchases and stores supplies and accessories (e.g. PVC pipe and glue, pipe connectors) in bulk in project areas. Manufacturers and dealers then purchase these goods at cost from the warehouse, which makes it easier for themto access quality materials in a timely fashion at lower prices. Investments may be needed to test a variety of supply chain models to determine the most cost-effective model for Ethiopia.

   Financial products and services are important to address financial constraints along the value chain, from manufacturing, to well drilling enterprises, to smallholder farmers' investments in manually-drilled wells. Institutions can be encouraged to provide agricultural finance through training and field visits, discussions and negotiations, farmer group formation, and providing capital input to microfinance institutions if needed in order to reduce risk.

4. Monitor. Several aspects of monitoring are important:
   - Well drillers should conduct regular visits to previously drilled wells and installed pumps to evaluate performance and to gather regular customer feedback from female and male farmers to ensure that well drilling products and servicesaddress their needs.

- The Government of Ethiopia should establish environmental monitoring measures. Since the manual drilling program taps the uppermost aquifer,which has the highest annual recharge, there is little danger that it will be damaged by over-pumping. There is, however, the possibility that high density of wells results in interference among wells and impacts intra-annual water supply, resulting in seasonal water conflicts. To avoid this, it is recommended that the minimum distance between wells and maximum number of wells per hectare be determined for each location and enforced by the government. It is recommended that the government establish and maintain a nation-wide database of water resource availability and quality and manual well drilling conditions in order to effectively monitor environmental risks (e.g. groundwater depletion and water quality impacts) associated with drilling and agricultural production.
- In addition, government, private sector and non-profit agricultural support programs need to expand training and support for safe agricultural chemical use both to reduce farmers’ costs and to protect the health of rural families and the natural environment.

Appendix 1: Drilling Log Report

Data Collect by	Berhanu	Serial #	AB01031001	Date Started/Completed (mm/dd/yy)	3/1/2010 -	3/2/2010

Location and Water Table

Latitude (dd.ddddd)	8.85643		
Longitude (dd.ddddd)	38.41524		
Elevation (m)	2068		
Static Water Level (m)	6	Date	3/5/2010
Static Water Level (m)		Date	
Static Water Level (m)		Date	
Static Water Level (m)		Date	

General Information

Owners Name:	Beyene Debiso
Village Name:	Awah Balo
Family Size (person):	8
Type of Pump Intalled:	SOTP (old design)
Well Primary Use:	Irrigation
Estimated Irrigated Area (m^2)	
Outcome:	Successful

Drilling Information

Drilling Type:	Simple Sludge
Bit Diameter (mm):	54
Casing Diameter (mm)	50
Augering Start Depth (m)	0
Augering End Depth (m)	0.75
Sludging Start Depth (m)	0.75
Sludging End Depth (m)	15
Total Drill Time (hr)	8.5
Drillers Name:	Awaka Tofese
Helpers Name	Aman and Kedir
Promblems Encountered Drilling:	
Type	None

None

Well Log Measurements from Surface

Drilled Depth (m):	15
Depth to Top of Filter (m)	11.5
Depth to Bottom of Filter (m)	14.5
Depth to Top of Gravel Pack (m)	2
Depth to Bottom of Gravel Pack (m)	15
Depth to Top of Sanitary Seal (m)	
Depth to Bottom of Sanitary Seal (m)	

Soil Log Key

Description	Texture		Compaction	
Clay, Sandy clay, Silty clay, Sandy clay loam Loam, Silty clay loam, Sand , Sandy loam, Loam Silty loam, Gravel, Rock, Pumice	Fine	f	Soft	S
	Meduim	m	Semi-Compact	SC
	Course	c	Compact	C

Permeablility		Casing		Fill	
Permeable	p	Blank Pipe	bp	Sanitary Seal	ss
Semi-permeable	sp	Filter	F	Cuttings	c
Non-permeable	np			Gravel/Sand	g/s

Soil Log Profile

Depth (m)	Description	Texture	Compaction	Permeability	Casing	Fill	Observations
0.0	Clay loam	f	C -	np -	bp -	c -	Black
0.25	Clay loam	f	C -	np -	bp -	c -	Black
0.5	Clay loam	f	C -	np -	bp -	c -	Black
0.75	Clay	f	SC -	np -	bp -	c -	White
1.0	Clay	f	SC -	np -	bp -	c -	White
1.5	Clay	f	SC -	np -	bp -	c -	White
2.0	Clay	f	SC -	np -	bp -	g/s -	White
2.5	Clay	f	SC -	np -	bp -	g/s -	Black and white
3.0	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
3.5	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
4.0	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
4.5	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
5.0	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
5.5	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
6.0	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
6.5	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
7.0	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
7.5	Sandy clay	m	SC -	sp -	bp -	g/s -	Black and white
8.0	Sandy clay	m	C -	sp -	bp -	g/s -	Black and white
8.5	Clay	f	C -	np -	bp -	g/s -	White
9.0	Clay	f	C -	np -	bp -	g/s -	White
9.5	Clay	f	C -	np -	bp -	g/s -	White
10.0	Clay	f	C -	np -	bp -	g/s -	White
10.5	Clay	f	C -	np -	bp -	g/s -	White
11.0	Clay	f	C -	np -	bp -	g/s -	White
11.5	Clay	f	S -	np -	bp -	g/s -	White
12.0	Sandy clay	m	S -	sp -	F -	g/s -	
12.5	Sandy clay	m	S -	sp -	F -	g/s -	
13.0	Sandy clay	m	S -	sp -	F -	g/s -	
13.5	Sandy clay	m	S -	sp -	F -	g/s -	
14.0	Sandy clay	m	S -	sp -	F -	g/s -	
14.5	Sand	c	S -	p -	F -	g/s -	
15.0	Sand	c	S -	p -	bp -	g/s -	
15.5							
16.0							
16.5							
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Additional Notes:

Photo	
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Appendix 2: Manual Drilling Training and Certification

IDE's manual well driller training program is field-based. Trainees start as driller helpers and move progressively from assistant driller to junior and senior assistant driller before becoming a lead driller. This process requires participation in drilling approximately 15 wells. After experience as a lead driller, the trainee attends a week-long classroom-based course covering the hydrogeology of manual well drilling, casing installation and well development. The driller's training is then considered complete but the driller will only receive an IDE certificate after he demonstrates competency by successfully managing a team in drilling 10 additional wells without direct supervision. It takes a minimum of 4 months for a trainee to be trained to the level of certification. Certified drillers are trained to provided technical support if needed and customers of certified drillers are provided a limited guarantee of workmanship. This helps to create an industry of quality, skilled and competitive drillers. Not all trained drillers are interested or able to manage a business; many prefer to work as drilling assistants.

The hands-on driller training includes developing pump installation skills; reaming 60 mm bore wells used for treadle pumps to 90 or 125 mm for installation of rope and washer pumps and engine driven pumpsets; installation of "small-bore (40 mm) pumps" for household water needs; developing diagnostic/remediation skills for situations where the well yield is less than desired; preparing tools for well development and determining if development is complete; and negotiation of business agreements by a driller with customers.

Regarding costs for manual well driller training program, a recently proposed training program for the Government of Ethiopia estimated the cost to establish and operate an intensive 4-month manual well driller training program at approximately US$950,000 for the first year and US$680,000 per year operating costs after the first year. This type of training program would greatly accelerate well drilling capacity. As shown in Table 2[19], below, the potential impact of the training program is significant: as the number of trained drillers increases, the total number of wells drilled for smallholder farmers increases rapidly. It is estimated that 966,000 wells could be drilled after 15 years of conducting the training program.

Table 2: Potential Impact of an Intensive Four-Month Well Driller Training

Year	Nuber of Drillers Certified Each Year	Number of New Drilling Enterprises Each Year	Cumulative Drilling Enterprises	Cumulative Number of Wells Drilled
1	80	40	training only	0
2	200	100	40	4,000
3	200	100	140	18,000
4	200	100	240	42,000
5	200	100	340	76,000
6	200	100	440	120,000
7	200	100	540	174,000
8	200	100	640	238,000
9	200	100	740	312,000
10	200	100	840	396,000
11	200	100	940	490,000
12	200	100	1040	594,000
13	200	100	1140	708,000
14	200	100	1240	832,000
15	200	100	1340	966,000

19 Table 2 assumes 25 trainees per group in the first year, with 4 groups in the first year, 10 groups per year in the second and each subsequent year. The table assumes that 80% of trainees become certified as drillers, that 50% of certified drillers establish their own business, that demand for wells will fully employ the new drilling enterprises and that each enterprise will be able to drill 90-100 wells/year (5 wells every 2 weeks for 9 months of each year).

The proposed training program would have a classroom and practice field located at an existing Agricultural Technical Vocational Educational Training (ATVET) center. The first 3 weeks trainees would be at the ATVET and learn the basic manual well drilling techniques. They would then spend 2 months with field-based instructors drilling wells in farmers' fields. Each trainee would participate in drilling about 15 wells in the field, including being lead driller for 5 wells. The final 5 weeks of training would be back at the training center where hydrogeological, pump selection, installation and maintenance issues would be discussed. In addition, there would be a training unit on enterprise development and business practice. The training program would have 25 trainees in a course and after the first year be able to conduct 10 courses per year. Table 2 of this document demonstrates the potential impact of such a training program. It assumes that 80% of the trainees become certified drillers with half of the certified drillers establishing their own drilling business. It further assumes that demand for wells will fully employ the new drilling enterprises and that each enterprise will be able to drill about 100 wells per year. As illustrated in Table 2, a formal training program will greatly accelerate well drilling capacity.

Important aspects to consider for training include:

- ✓ Training needs to include both classroom instruction and experiential learning to master handling of tools, directing the drilling activity, and to resolve problems resulting from different hydro-geological conditions.
- ✓ Manual drilling is physically very demanding—as many as 50% of potential trainees drop out of training within a week. A screening process enabling interested trainees to see and experience the working conditions before applying for in-depth training is important to improve retention of trainees.
- ✓ The number of wells drilled is less important than the number of different geological conditions experienced to determine if the trainee has sufficient experience for certification.

Most manual drillers have learned the trade by working with experienced drillers. While hands-on experience is essential, the field-based training period can be shortened if classroom instructionuses examples and illustrations to explain different techniques required for different geological conditions. Classroom instruction is more effective if trainees have at least an 8th-grade education perform better in the classroom than those with no education.