Manual Well Drilling Investment Opportunity in Ethiopia

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Executive Summary

Approximately 83 percent of Ethiopia's population of 82.8 million lives in rural areas and 52 percent of the rural population live in poverty (IFAD). Therefore, interventions that benefit the rural poor in Ethiopia could potentially improve the lives of almost 36 million rural poor people in the country. Improving smallholder farmers' agricultural productivity and access to water can increase their incomes, improve food security, and provide water for livestock and domestic needs. One solution for reliable and affordable access to shallow groundwater resources is manually-drilled wells. Once a well is drilled and farmers are able to access water, farmers have a variety of pump options (e.g. treadle pumps, motorized pumps) available to lift water from the well; a variety of water storage technologies; and a variety of water applications methods (e.g. drip or sprinkler) available to apply water to crops.

While manual well drilling is prevalent and highly developed in many Asian countries, it is not widely available in Ethiopia. Pilot efforts by International Development Enterprises (IDE) to establish private-sector well drilling demonstrated high demand among farmers for manually-drilled wells and high potential for manual drilling in the hydro-geological settings of the pilot areas.

Manual drilling is viable only in specific hydro-geologic settings. With careful selection of areas, IDE has 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 specific locations that are suitable for manual drilling. Therefore, investments in field-level data collection and mapping are necessary to determine areas suitable for manual drilling and then to estimate the number of smallholder farmers who could potentially benefit from manually-drilled wells. Estimated costs for this data collection and mapping are summarized here and detailed later in this document:

1. Initial nationwide mapping to select areas with higher potential for manual drilling: US$60,000
2. Groundtruthing and validation of areas with highest potential for manual drilling: US$250,000 for the first phase and an additional US$1.3 million for the second phase.
3. Physical testing of well drilling potential at 200 locations: US$3.42 million.

In addition to the above, developing an industry of private sector manual well drillers requires simultaneous investments in driller training and certification; creating supply chains for manual drilling supplies; creating demand from farmers for manually-drilled wells; supporting improved and sustainable smallholder agronomic production; and linking farmers to processing, storage and/or market opportunities for irrigated farm production.

As demonstrated through the pilot work led by IDE, manual well drilling could improve the livelihoods of a significant number of smallholder farm households in Ethiopia. This document details a model for private sector manual drilling and the investments required to catalyze the sector in Ethiopia.

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.

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.

Affordable Manual Well Drilling

In many Asian countries, including Bangladesh, India, Nepal, Myanmar, and Cambodia, manual well drilling - whereby village craftsmen use manual labor and charge for drilling services to access shallow groundwater resources - is prevalent and is highly developed in the private sector. Using manually-drilled wells, smallholder farmers have installed millions of pumps mounted on shallow tube-wells (drilled wells with pipe casing) to access shallow groundwater resources for utilization in irrigated farming. 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.

Private sector manual drilling is also utilized in some African countries, e.g. Sudan, Chad, Nigeria and Niger. For example, in Nigeria, more than 100,000 wells have been manually drilled; and in Niger, 42 private sector drilling teams operate and have drilled more than 18,000 wells[1]. In Asia and in Sudan, manual drillers operate as private enterprises without government or other support. Drillers charge for their expertise and service at negotiated rates dictated by competition. The cost of these manually drilled wells is approximately US $18 to US $200, which is significantly less expensive than motorized drilling, which costs approximately US $1,200 – US

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

$1,600 for 6-12 meters depth[2]. 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. Drilling deeper depths requires additional time and labor, which adds to the cost of the manually-drilled well.

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 initiated a shallow manual drilling pilot in Ethiopia to determine the technical and financial feasibility of private sector manual drilling and to assess farmer demand for wells. Following the pilot, IDE and partner organizations, with financial support from USAID and the Bill and Melinda Gates Foundation-supported Agricultural Water Management Landscape Analysis Project, initiated larger-scale efforts to create an industry of private well drillers. The goals were to catalyze widespread private-sector, low-cost manual drilling by creating an industry of private well drillers skilled in a variety of drilling techniques suitable for Ethiopia's challenging geologic conditions; mapping new areas with potential for manual drilling using GIS; and improving the effectiveness and reducing the cost of equipment through technical development.

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[3]. The map in Appendix 1 shows the locations of these drilled wells. These efforts established the following:

- 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.
- There is huge demand among smallholder and larger-scale farmers to access groundwater and the pilot created significant demand from farmers for drilled wells. For every well drilled, an additional three farmers were interested in investing in a well. Smallholder farmers' key constraint was lack of available investment capital at the time of year when farmers required wells for crop production.

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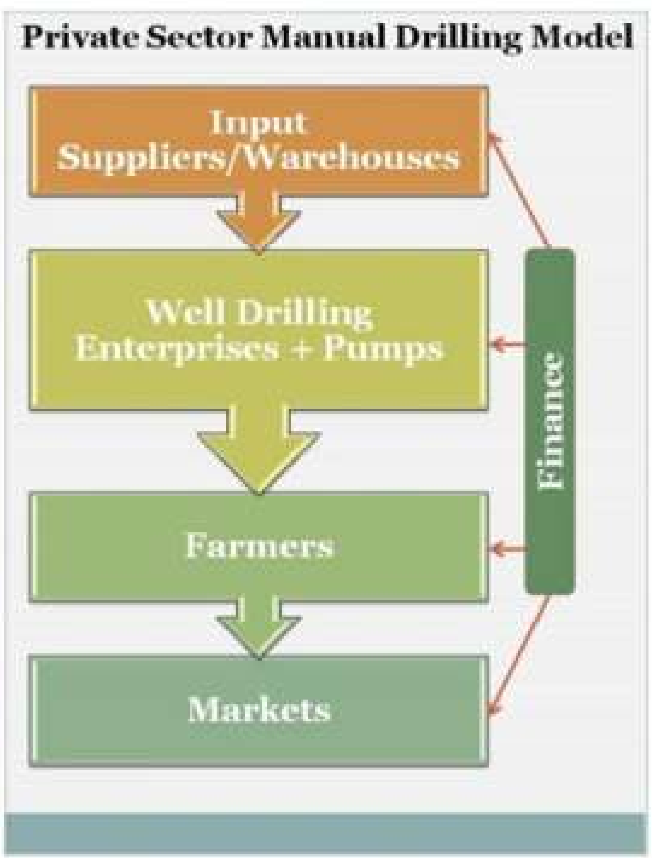
[2] "Best Practices in the Development of Small Scale Private Irrigation in West Africa". Onimus, Francois; Stephan Abric, Moise Sonou, Benedicte Augeard, 2010.

[3] 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.

- The International Water Management Institute (IWMI) analyzed the manual well drilling activities in Ethiopia and concluded that there is no substitute for manual drilling. The cost of a hand dug well is similar to the cost of a manually-drilled well, but the depth of a hand dug well is limited. Machine-drilled wells can drill deeper than manually-drilled wells, but machine drilling costs approximately 7 times the amount of manual drilling.
- The pilot confirmed the financial viability of creating a private-sector industry of affordable manual well drilling services.
- Female farmers benefited from improved access to water, which decreased the time and labor previously required to secure water from significant distances for domestic use and crop production.
- Due to Ethiopia's landforms and soils, the geology for drilling is more challenging than the river deltas and outwash plains in many countries in Asia and other African countries where manual well drilling proliferates. In Ethiopia, there are pocket areas with high potential for manual drilling due to shallow water and permeable soil layers. These pocket areas are smaller than in the Gangetic Plain of Asia; however, with careful selection of areas, the success rate for manual drilling is approximately 80%.

Private Sector Manual Well Drilling Model for Ethiopia

A private sector manual well drilling model is depicted in the diagram below. This model is based on the principle that building a self-sustaining and self-expanding local industry of manual well drilling enterprises will improve smallholder farmers' affordable access to shallow groundwater. 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 enterprises. The well drilling enterprises 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 wells at an affordable cost to the farmer. Farmers pay the well drilling enterprise to drill a well and install a pump on their property. Farmers then have improved access to water, which can improve their crop productivity and increase the



number of crops grown per year. Yield increases combined with market access increase farmers' incomes. Financial products and services are available and tailored to the needs of farmers and other enterprises in this model.

The key features of this model in Ethiopia are summarized in Table 1[4] and described below.

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

	Investment Cost	Additional Annual Income	Profit in Year 1
Farmer	$156	$490	$334
Well Driller	$1,247	$2,740	$1,493
Well Driller Apprentices[5]	$0	$667	$667

1. Farmers' Investment and Return. Farmers invest in a manually-drilled well, which provides affordable access to reliable irrigation water. During the well drilling, the farmer also provides drilling water and cow dung to make drilling mud and usually provides meals and lodging for the drillers. 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. Farmers also invest in improving their knowledge and skills to grow irrigated high-value crops to recover their investment in the well. While numerous variables affect estimated impact figures (e.g. depth of water; market access; agricultural risks, smallholder agronomic knowledge), estimated additional income for a farmer with a drilled well and a suction treadle pump and a 700 m^2 plot is approximately US $490[6]. This income pays for the well and the treadle pump within one year and provides an additional US $334 net income remaining. In comparison, a farmer could invest US $1,000 to have a larger bore well drilled and purchase an engine pump to irrigate 10,000 m^2 and earn US $3,000 additional income each year (US $2,000 net additional income in the first year after paying for the well and pump).

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 are knowledgeable regarding 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.

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

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

[6] 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.

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, transports, etc.

The estimated profit for a lead well driller from well drilling and pump installation is US$1,493/year[7]. Many manual drillers operate their business during part of the year and continue to farm or work in another trade, which provides multiple sources of income and is essential because drilling in the rainy season 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.[8] This income is competitive with alternative sources of income for unskilled labor: unskilled labor 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[9] in well drilling equipment each year, so supply chain actors profit as well drilling enterprises replace equipment and scale up.

[7] 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.

[8] 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.

[9] 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.

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.

Regarding competing products and/or services, 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).

An 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.

There are numerous synergistic products and services that leverage farmers' investments in water access and increase farmers' incomes. These products and services include irrigation application equipment, quality seeds, and support for high-value crop production, soil management, and market access. For example, once a well is drilled, a variety of pump choices is available to draw and distribute irrigation water. The choice of pump depends on several variables, including elevation, depth of water, water yield of the well, area to be irrigated, and use of water.

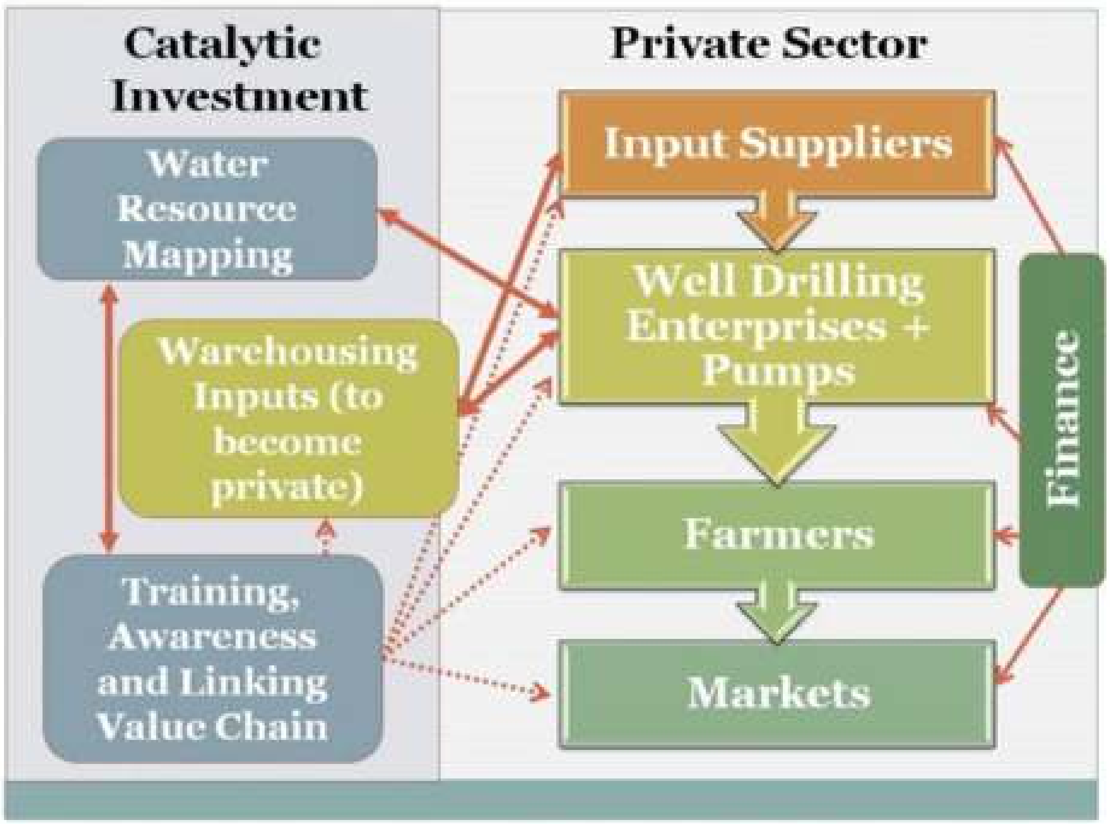
Catalyzing Private Sector Manual Drilling in Ethiopia

Low-cost private-sector manual well drilling was recently initiated and is not widely available in Ethiopia. Currently, there are few skilled manual drillers and few farmers are aware of manual drilling, so there is little demand for manually-drilled wells. Also, the geographical extent of potential manual drilling is not known. Therefore, significant initial support to catalyze this private sector solution is needed in the following specific areas:

- Determine suitability domains for manual drilling, as well as the potential number of farmers who can benefit from manual drilling;
- Train manual drillers;
- Raise awareness and create demand from farmers for wells;
- Train smallholder high-value irrigated crop production and crop marketing;
- Stimulate private sector supply chains for spare parts and equipment for manual drilling;
- Engage financial products and services across the value chain;
- Monitor environmental risks (e.g. groundwater depletion and water quality impacts) associated with any drilling and maintain a nation-wide database of water resource availability and quality and manual well drilling conditions.

These recommended investments are depicted in the diagram and described in detail below. There are numerous entities (e.g. international organizations, government agencies, private businesses) who could be involved in a variety of approaches to spur private-sector manual drilling. It is recommended that external support to this sector be based on value chain analyses and careful consideration of how to strengthen rather than inhibit private sector growth.

It is estimated that this external support to manual drilling will catalyze the sector within 3 to 5 years. At that point in time, it is expected that private sector manual drilling enterprises and associated supply chain actors will be financially self-sustaining. Without this support, private sector manual drilling may advance independently, but it would take significantly longer than the projected 3 to 5 year timeframe.



1. <u>Map Water Resources and Assess the Potential Applicability of Manual Drilling</u>
   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; this creates geographical limitations for manual drilling and can lead to increased costs if drilling failure rates are high. Investments are needed to delineate the geographical limitations of manual drilling and to determine the potential number of farmers who can benefit from manual drilling. The suggested steps and estimated investments costs are below. Each step results in a finer level of detail regarding the potential applicability of manual drilling in Ethiopia, which improves the likelihood of drilling success and lowers the cost of investments in driller training.

- ✓ *Initial 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.
- ✓ *Selection of Potential Areas and Groundtruthing***.** 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. This groundtruthing process can be divided into two phases. In the first phase, a team of international experts train national experts in the groundtruthing 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 groundtruthing in 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.
- ✓ *Physical Testing/Validation of Well Drilling Potential***.** For areas where initial mapping and ground-truthing confirm that surface characteristics are favorable for manual drilling, test drilling is used to validate well drilling potential. Test drilling 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 2 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. First, machine drilling provides information rapidly, permitting faster determination of the periphery of areas suitable for manual drilling. In addition, machine drilling penetrates most geological formations to depths of at least 50 meters, including locations where manual drilling cannot proceed due to 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[10]. 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.

2. Raise Awareness and Create Demand. In Ethiopia, low cost drilling for irrigation is unknown; poor, risk-averse farmers are reluctant to invest in an unknown solution. To address this, it is important to create customer demand by investing in demonstrations of manual drilling using demonstration plots, model farmer demonstrations, farmer-to-farmer visits, extension services, etc. Through demonstrations, 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 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.

   After test well drilling confirms the viability of manual drilling in a specific location, a manual well drilling team will drill wells in 3-6 locations in farmers' fields. This activity demonstrates manual drilling techniques, well development, and pump installation; and confirms acceptable water yield and quality for irrigation. In addition, the manual well drilling testing also functions as a recruiting mechanism for potential well drillers.

   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 a key aspect of creating demand for manually-drilled wells is providing training and support to farmers to grow and market irrigated high-value crops to increase their incomes. Training is often required for irrigated agricultural production (e.g. timing of

[10] 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.

market-oriented crop production, seedbed preparation, selection of quality seeds, crop water requirements, soil fertility management, integrated pest management, etc.) and production output services (e.g. post harvest processing, storage, and aggregation and marketing). This type of training ensures that farmers capitalize on their investment in a well and makes access to groundwater a driver in improving rural livelihoods and food security. The costs to train smallholder farmers to integrate irrigated cropping into their livelihood strategies are not included in this paper.

3. Train and Certify Drillers. It is important to ensure that private-sector well drilling enterprises emerge to meet customer demand. These enterprises need to be skilled in both the technical aspects of manual drilling as well as business management. In addition, a sufficient number of skilled manual well drillers are necessary to create competition, lower the price of drilling wells, maintain competitive quality, etc. Investments in training are essential to both increase the number of drillers and to improve the skills of drillers. Further, training develops the capacity of drillers, enabling them to establish private sector businesses that operate without external support. 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 designed to recruit, train and certify manual drillers. This experience demonstrated that 4 or more 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 an industry of quality, skilled and competitive drillers. Details regarding IDE's driller training program, including the content of the training, timeframe for training, skills required, and lessons learned are provided in Appendix 3.

   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[11], 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 will be drilled after 15 years of conducting the training program.

[11] 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).

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

4. Develop Supply Chains. Ideally, all manual well drilling and irrigation technologies are produced locally using locally available metal pipes, wood, chains, clamps, etc. provided 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 is testing various supply chain models. For example, IDE introduced warehousing, whereby IDE purchases and stocks supplies and accessories (e.g. PVC pipe and glue, pipe connectors) in bulk and stocks these in warehouses in project areas. Manufacturers and dealers then purchase these goods at cost from the warehouse. The warehouse plan makes it easier for manufacturers to access quality materials in a timely fashion at lower prices. Challenges with this warehousing model remain to be addressed, including responsibilities for transport from the warehouse, quality control, etc.

   Additional supply chain considerations include linking farmers to manufacturers for direct sales, linking farmers 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). General considerations to address in establishing an effective supply chain include: technical feasibility, demand projection, raw material supply, appropriate tools/machines, quality control systems, branding, managing a distribution network, marketing, finance and credit flows, and competition. Investments are required to test a variety of supply chain models to determine the most cost-effective model for Ethiopia.

5. Finance. Financial products and services are critical 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.

6. Develop Partnerships. Creating a partnership of government entities, NGOs, and other relevant partners is an important means to share knowledge and extend capacity for replication and rapid scale up. For example, the Ministry of Agriculture and Rural Development in Ethiopia hired experienced drillers from Sudan to drill a series of test wells designed for engine pumpsets in IDE's project area. The Ministry officials, IDE, and the Sudanese well drillers also shared their experience and compared manual drilling techniques. This association benefits all involved and helps to catalyze manual drilling.

7. Monitor/Evaluate. Regular visits to previously drilled wells and installed pumps are important to evaluate performance. Regular customer feedback from female and male farmers is also critical to ensure that products and services address the priority needs of farmers. Environmental issues also require continual monitoring. Since the manual drilling program taps the uppermost aquifer, which also 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 and enforced for each location. There is also a danger of agricultural chemical pollution. Since the aquifer is also used by local populations for domestic needs, it is important to ensure that drillers are trained in proper well development that guards against point-source contamination. In addition, agricultural 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.

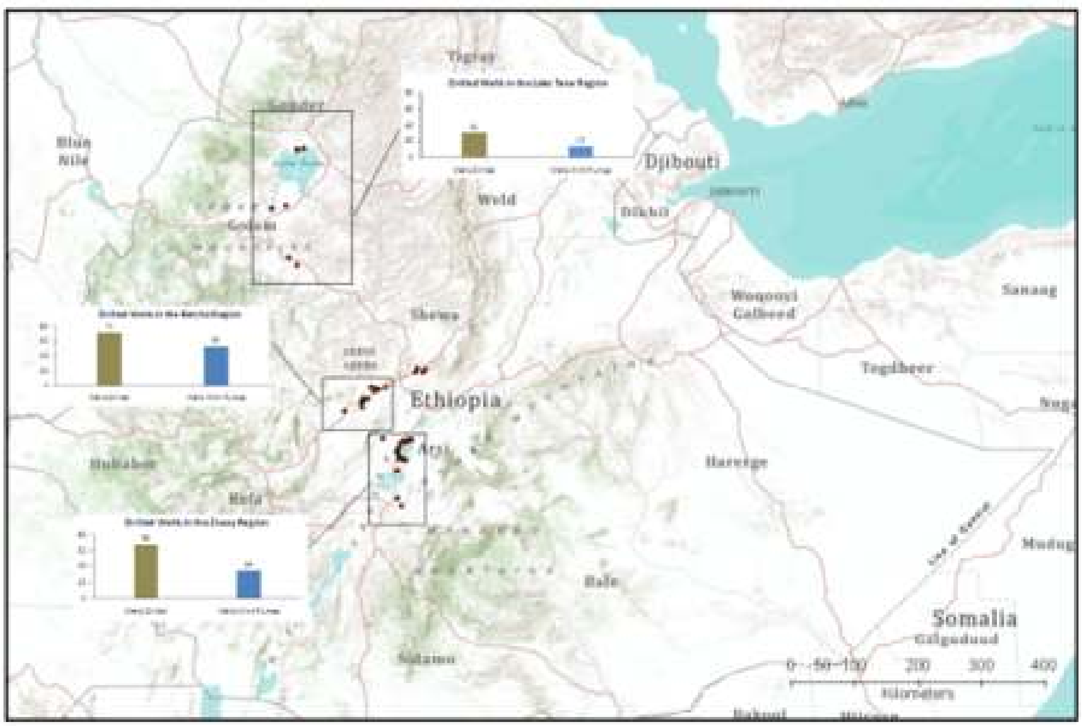
Potential Risks and Mitigation Measures of Manual Well Drilling in Ethiopia

As stated above, potential environmental risks include agricultural chemical pollution of the uppermost aquifer. Risk mitigation measures include training drillers in proper well development to guard against point source contamination. In addition, training and support to farmers for safe agricultural chemical use, together with regular monitoring of water quality is important.

In addition, as mentioned above, while there is limited risk of over-pumping from the upper-most aquifer, an area with a high density of wells could result in interference among wells and impact intra-annual water supply. For this reason, it is recommended that a minimum distance between wells and a maximum number of wells per hectare be established and enforced. Establishment of a groundwater monitoring system is also recommended. Ideally, this monitoring program would link information and data gathered by manual drilling businesses and support programs, including suitability mapping of manual drilling potential, information and data collected during groundtruthing, physical testing of well drilling potential, and regular reporting from drilling logs of manually drilled wells. Synthesizing information and data from these and other sources will ensure an accurate database of well drilling potential, risks and impacts.

Appendices

Appendix 1: Map of Areas for Piloting Manual Drilling in Ethiopia



Appendix 2: Drilling Log Report

Data Collect by	Berhanu	Serial #	A801031001	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)	6
Type of Pump Installed	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

Problems 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
		Medium	m	Semi-Compact	SC
		Course	c	Compact	C
Permeability		**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							
17.0							
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Additional Notes:

Photo	
Photo_Date	

Appendix 3: 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.

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 instruction uses 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.

A recently proposed manual well driller training program for the Government of Ethiopia estimated the cost to establish and operate an intensive 4-month manual well driller training program would be approximately US $950,000 the first year and US $680,000 per year operating costs after the first year. The 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.