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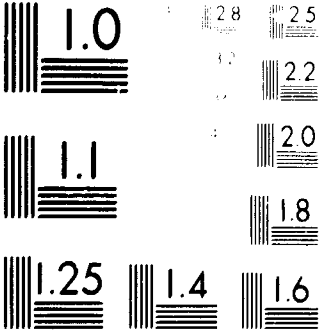

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10 December 1982

ENGLISH

Ethiopia.

RESEARCH AND DEVELOPMENT IN WATER PUMPING TECHNOLOGY FOR RURAL AREAS

DP/ETH/77/013

ETHIOPIA

Terminal report

Prepared for the Government of Ethiopia
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Karl Jensen, mechanical engineer

United Nations Industrial Development Organization
Vienna

1276

V.82-34848

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in Ethiopia is the birr (Br). During the period covered by the report, the value of the birr in relation to the United States dollar was $US 1 = Br 2.08.

The following abbreviations are used in this report:

EWWCA	Ethiopian Water Works Construction Authority (Formerly Ethiopian Water Resources Authority (EWRA)
IDRC	International Development Research Centre, Canada
ITDG	Intermediate Technology Development Group, London

Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

ABSTRACT

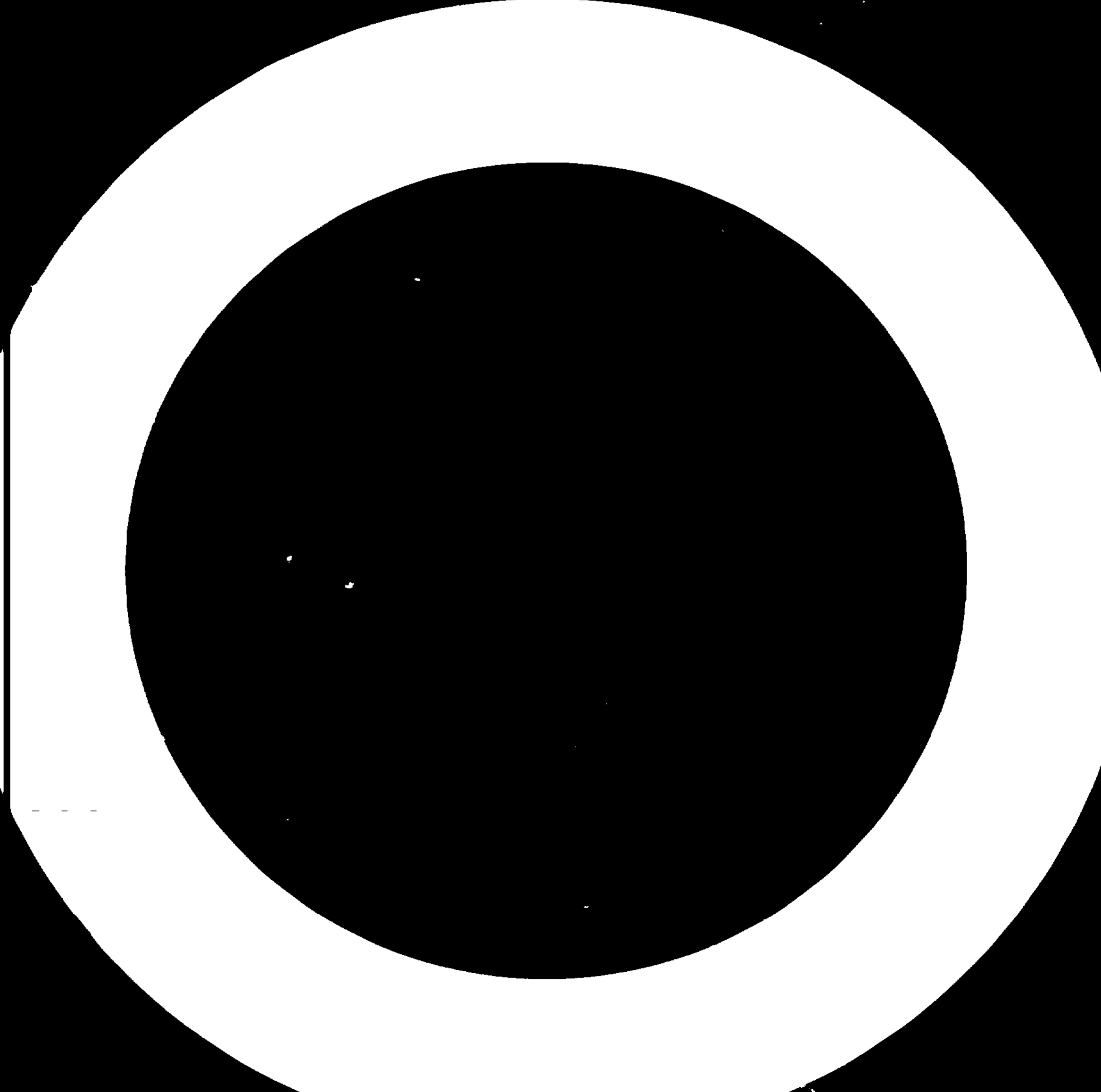
The project "Research and Development in Water Pumping Technology for Rural Areas" (DP/ETH/77/013) was implemented by the Ethiopian Water Works Construction Authority at the Faculty of Technology, Addis Ababa University from 27 January to 15 July 1982.

Within the framework of the project, which dealt with the development of water lifting devices for local manufacture, six types of hand pumps were studied and 140 hand pumps were made in the process. Small-scale manufacture of one simple hand pump type has already begun. Manufacture of three hand pump types is recommended.

Five wind turbine prototypes were designed and manufactured, the largest having a 10-m rotor diameter. Three turbines are already used in irrigation pumping, one supplying a rural community with domestic water from a borehole. The largest turbine, designed for pumping at a 100-m lift, was to be installed in May 1982. Manufacture of two wind turbine types is recommended.

A beam-type pump powered by a diesel engine was also made locally. This pump, while under test, supplied water from a 100-m borehole to a village with a population of 2,300.

Recommendations were made for further assistance to follow up activities as well as for a continuation of activities without UNDP/UNIDO assistance.



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Annexes

INTRODUCTION

A. Background

As a result of the Ethiopian Development-through-Co-operation campaign, which began in 1974, the need for the development of rural areas was recognized and emphasized. Within the framework of the campaign, a study of the rural water supply situation was made.

The study concluded that about 90 per cent of the population outside the larger communities, or more than 20 million people, were without access to water acceptably safe for human consumption. Available sources were limited to rivers, ponds, unimproved springs and uncovered wells.

During the period 1974 to 1976 experimental work geared towards the development of simple technologies for rural areas was initiated by the Faculty of Technology of the Addis Ababa University. The work included experimentation with simple water lifting devices and wind turbine models. Support to the activities was given by the Ethiopian Water Resources Authority (EWRA).1/

The Government is giving high priority to rural development in general and to the improvement of rural water supply in particular. Considerable technical and financial assistance has been received for this purpose from international and bilateral sources.

The desirability of a widespread use of hand pumps making it possible for water to be drawn from properly covered wells was recognized.

It was suggested that rural community water supply in some areas might be more economical if wind powered rather than engine powered pumps were used.

It was also suggested that costs of imported pumping equipment as well as difficulties in spare parts supply and maintenance associated with such equipment could seriously restrict development work planned in connection with rural water supply. The future use of water lifting equipment, which can be locally manufactured and consequently perhaps more easily maintained, was considered essential.

The project, which began in early 1978, was designed to revive activities that had been initiated in the Faculty of Technology and thereby to develop and test wind turbine and pump prototypes in an attempt to locate units suitable for future local manufacture and application. (See also the job description of the UNIDO expert, annex I.)

The International Development Reserach Institute (IDRC), Canada, was a main contributor to the discussions leading to the project and further supplied a major part of the government inputs. (See Inputs.)

1/ In 1981 became Ethiopian Water Works Construction Authority (EWWCA).

B. Project arrangements

Project authorization

The project document and its major revisions were signed as follows:

	Government	UNDP	UNIDO
Original document	June 1977	July 1977	July 1977
Revision C	Feb. 1979	Feb. 1979	Dec. 1978
Revision E	May 1980	May 1980	March 1980

With revision C, UNDP inputs were increased from $US 127,412 to $US 160,062 to reflect increased costs and provision for employment of a United Nations Volunteer.

Revision E constitutes a considerable extension of the project duration, from two years to four years and five months. UNDP inputs were increased from $US 160,465 to $US 388,954.

The extension of the project was considered essential because of the late effective start up and an overestimation in the project design of the rate at which inputs, particularly manpower, could be delivered and outputs achieved.

Other revisions were the yearly mandatory ones reflecting actual expenditures and minor budget amendments.

The latest project revision at hand at the time of writing is revision G, specifying a UNDP input of $US 408,000.

Project location

The project was implemented by the Ethiopian Water Works Construction Authority (EWWCA). EWWCA is a government agency in charge of the planning and implementation of works concerned with rural water supply. It is an autonomous institution, in charge of which is a commissioner. Prior to mid-1981 the institution, then called Ethiopian Water Resources Authority (EWRA), was under the Ministry of Mining, Energy and Water Resources.

EWWCA provided the local project staff and equipment as well as the field sites, i.e. wells and boreholes, for the testing of the project prototypes.

Prototype manufacturing was undertaken in the workshops of the Mechanical Engineering Department, Faculty of Technology, Addis Ababa University.

The Faculty of Technology also provided project office facilities.

Inputs

Inputs as stipulated in the latest project revision are given in the following paragraphs.

The total government input in kind was 840,150 birrs. Most of the government inputs were provided through two agreements between EWRA and IDRC (International Development Research Centre, Canada).

The agreements were in the form of individual projects: (a) Pumping Technology Research, Ethiopia (Centre File No.: 3-P-77-0022). IDRC input: $Can 166,380; and (b) Wind Power, Ethiopia (Centre File No.: 3-P-77-0029). IDRC input: $Can 128,200.

The IDRC inputs included essential workshop equipment, a vehicle and the payment of local project staff salaries and per diems during most of the project period.

The local staff during most of the period consisted of 3 engineers and 2 technicians (see annex II).

The total UNDP input was $US 408,000, including 53.3 man-months of technical assistance, 24 man-months delivered through a UN volunteer, support staff payments, materials for prototype manufacture and non-expendable equipment (see annex III).

Project period

The project began on 27 January 1978 and ended on 15 July 1982. Short-period duties outside of Ethiopia were assigned to the UNIDO engineer (see annex IV). Taking this into account, the effective duration of technical assistance was 53.3 months.

C. Project objectives

The immediate objectives of the project were to:

(a) Develop further and field test specific hand pumps already under consideration in Ethiopia, and undertake the required prototype design, manufacture and follow-up;

(b) Assist in the initiation of the manufacture of hand pump type or types selected as a result of the testing;

(c) Construct, on the basis of wind turbine experiments carried out earlier in Ethiopia, at least three horizontal-axis wind turbine prototypes, as well as one vertical-axis wind turbine developed in Ethiopia;

(d) Field test the wind turbine prototypes with relevant pump adaptations;

(e) Participate in the intended programme concerned with the field testing of a wind turbine developed by Intermediate Technology Development Group (ITDG), London.

Long-term objectives are to:

(a) Further the socio-economic development of rural areas through increased and more economical water supply and irrigation;

(b) Promote national industrial activities by encouraging the use of locally made water lifting equipment.

Five wind turbine prototypes, one engine-powered deep well pump and approximately 140 hand pump prototypes were made. Testing and modifications will continue until the end of the project by which time immediate objectives will have been met satisfactorily.

I. ACTIVITIES

A. General

Before the implementation of the project began, candidates for the local staffing of the project were sought, interviewed and selected for employment by EWRA. A UNIDO expert was assigned, on EWRA request, to a two-week mission in December 1977. During the mission, tenders for IDRC donated equipment were perused, basic workshop equipment was selected for the project, and initial discussions on project location and participation of government institutions were undertaken.

Since it became apparent in the early stages of the project that manpower could not be provided as planned through the University of Addis Ababa because of shortage of staff and disputes on technicians' working conditions, other workshops were considered.

As other government and private workshops were unsuitable for the work considered, renegotiations were made with EWRA, the University of Addis Ababa and UNDP resulting in an agreement on the participation of the technicians of the Faculty of Technology in prototype manufacturing work against payment from UNDP funds for actual work delivery to the project. So, the Faculty of Technology with its adequate facilities was chosen as the location of the project.

Re-advertisements were made and permanent project staff, whose salaries were funded by IDRC for most of the project period, was selected again. The reasons for this were late finalizing of the EWRA/IDRC agreements and a general shortage of mechanical engineers and skilled technicians (see annex II).

On-the-job-training of the local project staff was emphasized. The project engineers participated in IDRC-sponsored seminars on hand pumps and wind power. A fellowship leading to a post-graduate degree was obtained for the project team leader. The funds were made available through UNDP project, "Strengthening of the Executive Organ of the Ethiopian Water Resources Authority" (ETH/75/005). The team leader is expected to resume the work for which he was trained in September 1982.

The project took part in senior mechanical engineering student education. In particular, senior student design projects were and are still being supervised. These projects were as far as possible geared towards training the students in work related to project activities, such as wind turbine and pump design.

Limited technical assistance was given to national and international organizations on problems associated with water pumping, wind turbines, mini hydro-power stations, solar energy, bio-gas production and workshop installation.

B. Technical

Sources of detailed information on project prototypes and activities are given in annex V.

Hand pumps

Six types of hand pumps, designed on the basis of initial experiments made in the Faculty of Technology and on the basis of a design originated by IDRC and the Waterloo University, were made and tested. In addition, three commercial pumps were considered.

A total of 140 hand pumps were made within the framework of the project. Eighty-five pumps were subjected to tests lasting from one to three years. Twenty pumps were subjected to short-period and single tests. The remaining project-made pumps were delivered to users on request.

The bulk manufacture of shallow well pumps has been started on a small scale in the EWWCA workshops.

Pumps with pumping elements, i.e. cylinder, foot-value and piston, submerged in the well water only were considered.

At the beginning of the project it was decided that "suction" pumps with their priming problems or greater requirements to piston and valve seals were not suitable for rural community use.

As costs were to be kept as low as possible and as adequate foundry facilities were lacking, it was further decided that the pumps suggested for local manufacture should require neither casting nor sophisticated machining operations.

The type-A pump has a valveless, wooden piston operating in a standard steel water pipe. The piston rod handle is operated directly, i.e. without above-ground leverage.

A follow-up on this pump, a number of which were installed prior to the project implementation, showed that service life due to piston wear and tear was too short. In rigorous community use service life was only one week.

Three prototypes were made of the type-B pump with above-ground leverage, a buoyant wooden pump rod and wooden piston with valve flap. Tests were made using a steel cylinder as well as a plastic cylinder and with and without an air vessel incorporated above the pump cylinder. At the same time work on the type-BP pump began. A comparison of cost, performance and local circumstances greatly favoured the type-BP pump. The type-B pump was consequently not considered any more.

The type-BP pump was designed on the basis of IDRC initiated work on a pump often referred to as the Waterloo pump.2/

The original version of the IDRC/Waterloo pump used PVC piston with polyethylene seal rings, a foot valve identical to the piston and a PVC riser pipe, which also constituted the cylinder.

The project design for shallow well pumps is a simplified version of the above pump.

2/ Tests on this pump were made in the Waterloo Research Institute, University of Waterloo, Canada.

Two versions were made using 2-inch and 1.5-inch PVC pipes made locally. Pistons and foot valves were made from solid stock polyethylene. No piston seals were used since experience with the type-A pumps showed that pistons without seals could perform adequately at low pumping heads when operated directly by a handle bar attached to the pump rod. This mode of operation allows for higher piston speeds, reduces pump cost and the number of elements subject to wear and tear.

A total of 120 type-BP pumps were made, most of which were subjected to extensive field tests.

Because of difficulties in well allocations, field installation and testing were delayed. Pumps had to be installed far afield and in small groups, making installation and follow-up difficult. Distances from Addis Ababa to the nearest and farthest installed type-BP pump are 130 km and 800 km respectively. Failures were experienced and numerous modifications had to be made.

The 2-inch version (type-BP-50 pump) is now considered suitable for extensive use at pumping heads up to 10 m. Wells of this depth constitute a large percentage of all hand dug wells in Ethiopia.

The 1.5-inch version (type-BP-40 pump) was tested at heads from 10 to 22 m. The results of tests led to the conclusion that hand pumps without above-ground leverage should not as a rule be used for heads in excess of 20 m because operation then becomes too heavy even though a very small diameter piston is used in the pump.

Furthermore, frequent breakage due to fatigue failure of the PVC riser pipe was experienced at heads above 15 m.

The type-BP-40 pump can therefore be considered suitable for heads from 10 to 15 m only. Below 10 m a larger piston is preferable.

The manufacture of the type-BP-50 pump began on a small scale at the EWWCA workshop. Only 150 pumps have been made so far, the production being halted by the lack of locally produced PVC pipes. The plastic factory is under expansion and has not as yet resumed manufacture of the required pipes. At present there are delays in the import of pipes, which would enable pump manufacture and installation.

The type-BP-50 pump is undergoing tests carried out by the Consumers' Association, Harpenden Rice Laboratories, England. The tests are made on request by the International Bank for Reconstruction and Development (IBRD) in co-operation with the United Nations Children's Fund (UNICEF). Information useful for the assessment of limits of application of this type of pump should result.

Observations made by studying and questioning about 60 different users, including children, confirmed a disadvantage of this pump. The major force to be applied is a lift force. The human operator finds work primarily involving downwards directed forces preferable.

Widespread application is nevertheless considered justifiable by virtue of the low cost and ease of installation and maintenance. The pump can be installed and withdrawn without the use of tripod and hoisting gear.

A design for a type-BPL pump for use in deeper wells (above 20-m lifts) was made. Ten prototypes were manufactured. Initially the design was merely a version of the type-BP pump, incorporating a welded-steel pump stand with a lever and a heavier PVC pump rod.

Among early modifications necessitated by the result of field tests were re-design of the pump stand for greater strength and the use of ring seals on the piston. Testing during longer periods further resulted in failures of PVC riser pipe and pump rod.

In the latest version, now being tested, steel riser pipe and solid steel pump rod are used. The type-BPL pump now resembles a classical hand pump except that no castings are used and that cylinder, piston and foot-valve are made from plastic.

A pump conforming to the latest modification has been used by a rural community for about a year. The type-BPL pump can be recommended for manufacture and extensive use at heads from 10 to 30 m and possibly also larger heads at the end of the project period.

Six prototypes of the type-C pump were made and tested. The pump is merely a pipe with a foot-valve at its lower end and a discharge spout at its upper end. It is suspended on a spring clamped to a base plate on the well cover. The user brings the pipe to oscillate vertically at a frequency determined by the spring and the mass of pipe and water column. The pumping effect is caused by the water becoming "weightless" at correctly selected combinations of pumping speed and stroke.

Encouraging results were available from some initial tests made in the Faculty of Technology prior to project implementation.

Field tests of short duration were also encouraging. The pump is well accepted by users. Of the pumps tested by the project, including commercial pumps, the type-C pump is undoubtedly the easiest one to operate.

In community use of longer duration, however, spring failures and pipe joint failures were experienced. On the basis of this, dimensions required for satisfactory service life were established. It was estimated that these dimensions would bring the pump to a cost level comparable to that of the imported, commercial pumps. Recommendations for the manufacture and extensive use of the type-C pump cannot therefore be made.

The type-D pump is stipulated in the project document as part of the activities, and it is mentioned here for that reason only. Three prototypes only were made. The pumping action relies on the oscillation of a water column suspended on an air cushion. Brief early tests showed some promise. But project experience confirmed criticism directed at this type of pump from elsewhere. None of the rural users trying the pump could operate it. Project consensus of opinion is that this type, unless drastic changes in the design can be conceived of, has no place as a rural community pump, if indeed in any other application.

Commercial hand pump types installed in areas in which the project is operating were studied and briefly tested in order to make use of possible desirable design features.

A trial manufacture of a pump stand similar to that used on the British Consallen pump was made. With the available technology, however, the resulting unit was more expensive than the type-BPL pump stand. It was concluded that advantages, primarily a neater design, did not justify the extra cost.

In the experience of the project staff, the most favourable pump of the ones observed in respect of convenience of operation and service life is the Mono pump.

The Mono pump is a rotary screw type pump, the manufacture of which cannot be undertaken with technology available at present.

The study of a possible future manufacture of screw type pumps for hand-, wind- and engine-powered applications i- considered highly desirable.

Hand dug wells

A considerable number of the wells in which project pumps were installed dried out during the project period. The EWWCA teams are now using de-watering pumps during the last stage of the well digging process in order to provide wells of sufficient depths. A de-watering pump based on the type-BP design was made by the project. The piston of this pump is operated by a rope led over a pulley attached to the tripod used during well digging. This allows the use of very long strokes and operation by two or more persons.

In some areas, 4-inch PVC casings were used in hand dug wells. The well was dug, the casing inserted and the well filled up around the casing.

Many of the wells prepared in this fashion proved to have insufficient yield for continuous pumping.

Wind turbines

Five wind turbine prototypes were designed and manufactured. Four of the turbines are horizontal-axis rotors designed for high to moderate speeds. The rotor diameters range from 6 to 10 m. Methods of speed control used range from blade-tip spoilers through classical tail-vane control and negative blade-angle control to control by fully feathering blades.

Experiments on smaller models, as well as general considerations and discussions undertaken in the Faculty of Technology prior to the beginning of the project, led to the conclusion that the trend should be towards the development of high-speed turbines. Low-speed rotors are in principle heavier, i.e. they require more material for their construction.

It was felt that some sophistication in design and manufacturing technology and consequently a larger man-hour input could be justified if this could result in savings in weight and thereby in the use of imported materials.

All project-designed horizontal-axis rotors employ untwisted airfoil-shaped blades made from wood. This is also a result of earlier tests, which showed that in local manufacture the use of twisted blades would involve considerable cost with little gain in efficiency.

Of the horizontal-axis turbines one, with a 9-m rotor, was extensively performance-tested, coupling a dynamometer to its vertical drive shaft.

Except for the final prototype, with a 10-m rotor, all horizontal-axis turbines are undergoing tests in practical applications, community water supply and irrigation.

The manufacture of the 10-m prototype has been completed only now. The remaining time should just permit erection and short period testing.

Under the sponsorship of IDRC, a small vertical-axis wind turbine was made and its performance was tested. This turbine is known as the "Filippini" rotor. The project design is identical with the original Filippini rotor, except that it incorporates speed control by using hinged vanes, and that the rotor bearings are located at the wind pressure centre in order to reduce bearing and mill post loads.

The Filippini rotor with pump adapted is now undergoing tests in practical irrigation application.

Technical details on the prototypes are given in the technical report: "Wind Turbines for Pumping Applications", which was to be issued in June 1982. A brief description is given below.

Type DW is a three-bladed, high-speed, 6-m turbine rated at 2 kW and designed for piston pump operation. The intended application was for community water supply at a 30-m pumping head.

The rotor is self-orienting (downwind of tower) and employs blade-tip spoilers.

Type BW is a six-bladed 7-m turbine of moderate speed designed for piston pumping and community water supply at a 30-m head. Orientation and speed control are by tail-vane. The turbine is rated at 2.8 kW.

Type EW is a high-speed 9-m turbine with three main blades and three relatively short and broad control blades. Self-orientation downwind of the tower is used. The control blades are set at comparatively large angles in order to facilitate starting. Centrifugal weights turn the control blades towards smaller angles during operation. At the maximum speed setting control blade angles become negative creating a braking effect. Through bevel gears and centrifugal clutch the turbine drives a Mono borehole pump. Turbine rating is 6 kW. The design is for community water supply at a 60-m pumping head.

Type FW is a 10-m turbine designed for moderate to high speeds employing six blades and blade-angle speed control. It is rated at 8 kW. Pinions at the blade roots engage with a bevel gear turned in relation to the rotor shaft by the action of centrifugal weights. The blades can be fully feathered. The rotor is self-orienting downwind of the tower.

The design is for community water supply at pumping heads to 120 m.

The vertical-axis Filippini rotor has a diameter of 3.2 m and is 2 m high. Automatic speed control is by hinged mainblades, the blades swinging out by the action of centrifugal forces thereby effectively preventing overspeed. Power rating is 0.4 kW.

As far as installation and testing go the idea was to begin the testing programme with smaller wind turbine units, including a prototype, which was expected to be delivered by ITDG. This was to permit the gaining of experience before the local manufacture of larger wind turbines had to be completed.

The delivery of the ITDG turbine, however, did not materialize. Locations accessible to the project for the intended application of the smaller project prototypes could not be found. Boreholes in the region require larger pumping heads, except for a single, windless location, and dug wells do not yield enough water.

Field work concerned with wind-powered pumping consequently suffered from delay and had to begin with the larger 9-m wind turbine for which the intended application (60-m pumping head) could be found. Subsequent to performance testing, this wind pump is supplying water to the community of about 2,000 people at Waig, a village located about 170 km south of Addis Ababa. Wind conditions in general are poor at this site. Nevertheless, this turbine could satisfy demands over the year except for December and January, when a stand-by engine had to be employed.

The Waig location should be considered a borderline case for wind pump operation. Wind conditions are far better in most other areas.

The 6-m and 7-m turbines, as well as the Filippiri rotor, are installed for irrigation pumping. Water is pumped from the Awash river irrigating farm land near Melkassa, about 120 km south-east of Addis Ababa.

Melkassa is an experimental farm and part of an FAO-sponsored Agricultural Research Institute. The work concerned with testing and modifications will continue till the end of the project period after which service and maintenance will be taken over by the staff of an FAO project concerned with the development of farm implements. This project is located at Nazareth, about 20 km from the irrigation site, but is expected to be transferred to Melkassa in the near future.

The wind turbines were not designed for this application. Because of the low head of 2 m only centrifugal pumps would be needed. All the units, however, employ piston pumps, so that outputs are modest in spite of the favourable wind conditions.

The modification of the existing units to centrifugal pump drive, however, is difficult. This modification is therefore being made on one unit only, i.e. the 6-m turbine.

In the meantime, while being tested the 7-m wind pump and the Filippini pump are continuously delivering water to irrigation channels. The farmers have begun planting in the irrigated area compelling the project to limit modification work to the least possible.

Testing is not complete as yet. The 7-m turbine/quadruple piston-pump unit delivers an average of 150 m^3/d. The farmers are satisfied, but it is really poor performance when one considers that 600 m^3/d could be delivered had this turbine been connected to a centrifugal pump. The wind speed varies from 2 to 10 m/s with a probable average of 5 m/s for 10 h/d.

Diesel powered beam pump

The beam pump was made to study the possibility of using locally manufactured pumping equipment in rural boreholes where electricity supply is not available and wind conditions do not permit wind powered pumping. In the experience of the project, many rural water points are required to deliver only 5 to 20 m^3 of water per day. Typical pumping heads in the EWWCA Central Region are from 60 to 120 m.

At this head range and the relatively low pump discharge required, the commonly used submersible centrifugal pumps with above-ground Diesel electric generators have a low efficiency rate and correspondingly high fuel consumption. The trend is now towards the installation of Diesel powered Mono pumps at new sites.

A piston pump was selected partly because local technology can cope with this type of pump. Screw type pumps, such as the Mono pump, cannot be made at present. Also, the pump offers an opportunity to test the use of plastic cylinders and piston seals at a relatively large pumping head.

The use of a beam with horse head, similar to the typical oil field pump, allows force balancing and, therefore, reduces peak drive torque.

In the project design, the pump cylinder consists of a 2-m length of 3-in. plastic (ABS) pipe cemented inside a 4-in. steel pipe. Roundness of the cylinder is ensured by the use of spacer rings between plastic pipe and steel pipe. The internal cylinder surface is left as is, i.e. without machining. The piston is made from mild steel and fitted with polyethylene cup seals.

Laboratory tests showed that this type of pump could well be made for pumping heads of 200 m or more.

The prototype is installed at Ejerssa, a village about 80 km south of Addis Ababa. The population of the village is about 2,300. The water is to a tank at the centre of the village. From there water is piped to t public water collection points, one at each end of the village. Twelve houses, including two small hotels, are supplied directly with piped wat

The total pumping head varies from 90 to 100 m, depending on engine rpm setting. The discharge of a low-speed pump (30 strokes/min) is 3 m^3/h. Daily consumption varies from 8 to 15 m^3/d. Here, and at the other rural water points, water is sold at the rate of Br 1.25 per m^3, a probable reason for the low average per capita consumption of approximately 5 l/d.

Continuous recordings are being made of fuel consumption and of the delivered water so that a realistic figure for fuel costs could be obtained at the end of the project. Fuel consumption per unit of water delivered is about 0.15 l/m^3.

Laboratory tests of the pump type showed volumetric efficiencies in the order of 90 per cent. In the actual field installation it is difficult to maintain volumetric efficiencies above 75 per cent.

Service life will be estimated on the basis of the decrease in volumetric efficiency with time.

At the time of writing, the pump had been in operation for one year only, and with two differently shaped and dimensioned piston cup seals.

Sclar energy

On government request, a working paper, "Suggested Activities in the Field of Solar Energy" was prepared in November 1980 to serve as a basis for discussions on a development programme in the field of solar energy.

Further discussions resulted in a consensus that the Mechanical Engineering Department, Faculty of Technology, Addis Ababa University, should undertake initial experimental work on solar desalination.

A work programme for the period from April 1981 to April 1983 was prepared.

Training

On-the-job training only was foreseen for the local project staff.

A fellowship for post-graduate study undertaken at Belfast was obtained for one of the project research and development engineers, Ato Yohanis Yigzaw. Funding was made available through the EWWCA implemented UNDP project "Strengthening of the Executive Organ of the Ethiopian Water Resources Authority" (ETH/75/005). The candidate was expected to return to take up his duties as leader of the development team in September 1982.

The participation of the local project staff, research and development engineers, in seminars and workshops is as follows:

(a) Ato Yohanis Yigzaw. Workshop at Nairobi on Hand Pumps, held in August 1978. The workshop as well as the participation of the candidate was sponsored by IDRC;

(b) Ato Aseged Mammo. Seminar on Hand Pumps, held in Malawi in August 1980. The seminar as well as the participation of the candidate was sponsored by IDRC;

(c) Ato Teferi Taye. Seminar on Wind Energy and Bio-Gas, held in Botswana in November 1980. The seminar was arranged by the British Commonwealth Secretariat.

In order to involve engineering students in project activities, six students were assigned final year design projects in the field of wind turbines and pumps. The designs were supervised by the project staff.

The local project engineers now have the required knowledge in the field as well as the necessary skill enabling them to design and supervise independently the manufacture of wind turbines and pumping equipment of a technological level commensurate with the project activities.

Under an efficient administration, the staff can now carry on further development work in the field, including the development of new prototypes as well as the improvement of prototypes already selected as suitable for field applications.

II. FINDINGS

A. General

Difficulties were encountered in recruiting mechanical engineers and technicians because of the shortage of mechanical engineers and technicians - although an improvement is already apparent as a result of the country's emphasis on education in the professional technical fields - and because of the differences in salary levels of government institutions and semi-private sectors.

Too much emphasis has been, and still is, made on inputs from bilateral and multilateral sources. This has resulted in the employment of local staff on special fixed-term contracts. No provision exists as yet in the budget of the implementing agency for project staff salaries and per diem. Consequently, there were delays in finalizing a major project revision and EWWCA/IDRC agreements. The project could not be fully staffed, and delays in the payment of salaries and, in particular, per diems essential in the field work were frequent.

Failure to absorb firmly the project staff in the implementing government institution may deprive the country of the benefits inherent in the immediate utilization of the results of the project.

Difficulties arose from the fact that the project was implemented by one government institution and located in another. The project staff were considered outsiders to some extent and not closely enough attached to their employers.

The project implementation required the involvement of both EWWCA and the Faculty of Technology. The field work could not have been carried out without the close co-operation of EWWCA, and major prototype manufacturing work could not have been undertaken without the use of the Faculty of Technology facilities.

B. Technical

For sources of technical details see annex V.

Hand pumps

Of the pumps under study, three pumps are suitable for manufacture and extended field applications in view of manufacturing and maintenance costs, performance and service life expectancy.

The designs for these pumps were all made on the basis of a plastic pump design initiated by IDRC. The pumps, type BP-40 and BP-50, are described in chapter I, "Activities".

The Mono pump is in terms of performance and service life superior to project pumps as well as to other commercial pumps installed in the areas of project operation. Widespread use of this imported pump, however, is considered undesirable in view of the high cost. The pump should be considered only if it could be locally manufactured *in toto* or in part, thereby reducing the foreign currency expenditures.

Project observations indicate that hand pumping at lifts in excess of 30 m should not as a rule be considered in applications where a single user must be able to collect the daily water requirement without assistance.

The extensive use of hand pumps will be successful in the long run only if service and maintenance can be undertaken at the village level. To achieve this, however, will take long. Even in respect of the simple project pumps, attempts at involving community members, i.e. appointed by the community for the work, have not succeeded.

Wind pumps

A study of available wind data shows that wind conditions in Ethiopia are not ideal for the utilization of wind power. Wind-powered pumping, however, in domestic water supply as well as in irrigation has a large potential.

In many areas engine powered pumps could be economically replaced by wind powered pumps, provided that use is made of locally manufactured equipment.

An accurate assessment of the wind power potential in the various areas of the country is not possible with the available data.

Continuous recording is not made as a rule and in most weather stations the number of readings taken over the day are insufficient for the calculation of available useful wind power. An average wind speed is computed to be 3 m/s or lower over a longer period. This does not necessarily exclude the availability of useful winds during a shorter period.

An estimation of whether wind powered pumping would be economical at a particular water point is further complicated by the fact that wind conditions can vary considerably over short distances.

In one case a weather station (Awash Station) recorded annual mean wind speeds that would indicate wind power possibilities. Another station (Meta Hara), only 30 km from Awash, recorded annual mean wind speeds close to nil.

Wind conditions at Waig, in the Rift Valley, 170 km south of Addis Ababa, made it possible for the 9-m-diameter wind turbine to supply the population of about 2,000 with water during the past year, except for December and January, when a stand-by engine had to be used. One year is not sufficient to judge the potential with safety. Nevertheless, the result is not discouraging since wind conditions at the site were not sufficiently observed during the project.

At the site where three smaller project prototypes, 7-m diameter, 6-m diameter and a small vertical-axis Filippini rotor, are installed, wind conditions are good. This location, Melkassa, is also in the Rift Valley, 120 km south-east of Addis Ababa. Frequent observations have been made here during the past year and there is indication that wind speeds of 5 m/s or more can be expected for 10 h/d or more. The application here is irrigation.

Diesel powered pumps are used in the area. Some farmers employ hand pumps and some lift water from the river to irrigation channels by buckets.

At this location, wind powered pumping is undoubtedly economical. The largest of the project prototypes, with a 10-m diameter could, if fitted with a centrifugal pump, supply about 2,000 m^3/d of irrigation water.

Of the five project prototypes, three are considered too small for use in community water supply. In view of the relatively large pumping heads, from 60 to 120 m, of moderate wind conditions and of the population to be served from each borehole, the use of turbines smaller than 8-m diameter ones should not be considered.

After a year of testing and modifications, the 9-m diameter wind turbine prototype worked satisfactorily for about a year. Recent inspections have shown, however, that one further modification is required for satisfactory service life. The modification has already been introduced on the final project prototype and it makes head bevel gear alignment independent of positioning of mill head swivel bearings.

Mill head gear failure was observed earlier, but it was believed to be a result of overloading during dynamometer testing. Excessive wear persists, however, also under normal load conditions.

With the above modification, the 9-m-diameter pump is considered suitable for manufacture.

Of the smaller prototypes, the 7-m diameter prototype is the favourite one among the project staff as well as visitors to the site. It takes overspeeds (up to twice the design speed) without vibration. The 6-bladed rotor with tail-vane orientation and control is a standard one except for the use of untwisted blades.

The turbine could be recommended for immediate bulk manufacture and extensive use in irrigation schemes. It was, however, adapted for piston pumping (as part of a well operation) but the full benefit of wind energy cannot be obtained with this type of pump.

The use of an automatically varying stroke has been suggested, but even if satisfactory mechanisms for this purpose were developed, the result would not be entirely satisfactory. If pumping in low winds is required as is the case here, the utilization of the energy in high winds is poor. Crankshaft speed and strokes are impeded by shock and dynamic load. Observations of the hinged tail vane control, also with the relatively light 6-blade rotor, lead to the conclusion that this form of control can be accepted. If, however, furling, i.e. rotor turning away from the wind, is set to begin at a given wind speed or rotor speed, a sudden wind speed increase will invariably result in some overspeeding.

Consequently, when using light rotors, the design has to permit the beginning of furling at speeds lower than maximum acceptable rotor rpm, which can result in a loss in output in variable winds.

Tail vane control is better suited for heavy rotors on which wind pressures are less dependent on output load and which require longer for speed changes.

For the 7-m turbine, the tail vane control can be considered acceptable. It should not, however, be recommended for larger wind turbines. Apart from undesirable speed characteristics, the need for an unavailable "sky hook" for work on the tail vane increases with size as does the cost of the construction as a whole.

The design can be recommended for rotor diameters up to 7 m, except that metal sheet should be used for tail vane. The plywood sheet used already shows minor signs of deterioration.

The 6-m turbine is probably the most economical of the project designs in terms of power output per dollar invested. With the dual piston pump adapted, however, serious vibrations are experienced within the design speed range. Conclusions cannot be drawn until tests with a centrifugal pump adaption, which is expected to be done during the project, have been made.

The small vertical-axis Filippini rotor designed during the project to incorporate speed control by hinging the main vanes has been performing well. Performance testing using a dynamometer yielded an acceptable power factor conforming approximately to tests sponsored earlier by IDRC. No problems in overspeeding and vibrations have been experienced with this rotor.

The amount of material used in the construction of the rotor is, however, larger than the requirements for the manufacture of traditional horizontal-axis rotors. Due to the large rotating mass it is unlikely that this rotor can be economically built in larger sizes. Manufacture is unsophisticated, however, so that the rotor could be a suitable item for manufacture in rural workshops for application in small irrigation schemes and as a substitute for hand pumps.

The final prototype considered by the project, the 10-m diameter wind turbine, was designed and manufactured on the basis of experience made during the manufacture and testing of the smaller units.

Findings on the basis of which the decision for this design was made can be summarized as follows:

(a) Local technology would permit the manufacture of larger wind turbines employing speed control by varying blade angles automatically;

(b) The difference in wind speeds at the lower and upper points of the plane of rotation was a greater factor in setting up vibrations in wind mills with relatively low tower heights than slight variations in blade angles, blade to blade;

(c) A period of experimentation in the manufacture of bevel gears considered essential for blade angle control of coned windmill rotors had acceptable results. A universal milling machine only was used;

(d) A two-blade windmill design was found undesirable due to low starting torque and gyroscopic characteristics. A three-bladed design also provides insufficient starting torques under prevailing conditions;

(e) A four-blade design may be satisfactory in certain conditions but it gives fluctuation in gyroscopic moment and is therefore undesirable in areas with rapidly changing wind directions unless rate of change of orientation is controlled;

(f) A six-blade rotor of moderate speed will change its orientation with the wind without imposing vibrations and has acceptable starting torque.

The 10-m prototype has been manufactured, but final finishing and painting are still to be done. Erection was to take place in May 1982, leaving one and a half months only for testing and observations within the project period.

The design has been dimensioned so that it can accept rotor diameters of up to 12 m. In view of design and field experience gained, small-scale manufacture of the project design in sizes of 8-m and 10-m rotor diameters is recommended.

Since the blade angle synchronization gear (one large bevel gear and 6 smaller ones) of the 10 m prototype with the available technology would be too expensive for use in production units, the use of the much simpler synchronization gear of the 9 m prototype is recommended. The cost of this gear is 20 per cent of the bevel gear arrangement only, and it is immediately adaptable to the 10 m design. Also, observations over a two-year period of operation have shown the satisfactory function of the cheaper type of synchronization gear.

Diesel powered pumps

The project designed beam pump, with a pumping head of 90 to 100 m, which had operated in a water supply application for a community of 2,300 for one year, was found satisfactory.

Service life expectancy will be determined at the end of the project. The pump is expensive to manufacture. (See below, Cost of project designs.) For this reason it should be observed for a further period of at least two years before any decisions are made.

Furthermore, in view of the expensive drive gear, a future application of the pump would probably be in very deep wells, of 150 m or more, where other pump types with comparable fuel economy are not available.

Cost of project designs

Manufacturing costs given below are estimated under the assumption that batches of 5 to 10 units are made in a small-scale production with a minimum use of jigs.

Item	Material (Birrs)	Total cost (Birrs)
Wind turbine, including tower		
10-m diameter	6,400	10,000
9-m diameter	4,500	8,000
7-m diameter	3,700	7,000
6-m diameter	2,400	5,000
Filippini rotor	1,300	2,500
Beam pump	5,300	8,300
Hand pump, BPL with 25-m riser	154	225
pipe and pump rod	567	638
Hand pump, BP-50	45	85
with 8-m riser pipe and pump rod	132	172
Hand pump, BP-40	35	75
with 13-m riser pipe and pump rod	156	196

The above costs do not include installation. (See also annex V.)

It should be noted that material costs in Addis Ababa are relatively high. In the figures given for the wind turbines, for example, an average of Br 3.00 per kg of raw material used is considered. The extra costs of more expensive elements, such as rolling contact bearings and gears should be added.

Labour costs are considered at Br 5.00 and Br 2.00 per man-hour for skilled and unskilled labour, respectively.

As the hand pumps had already been manufactured in batches, man-hours involved were established by time studies. For all other units, labour costs are estimated only.

In evaluating costs, it should be emphasized that the foreign currency component involved is estimated to be about 30 per cent of the material costs for the BP hand pumps and 50 per cent of material costs for the other units.

Notes on pumps

Although piston pumps have been widely used in classical wind pump installations, future trend should be towards the adaption of rotary pumps to wind turbines of moderate to high speeds. Even in low-speed, so-called fan mill installations, the piston pump should not be considered an ideal solution. A few commercial wind turbines of this type have been installed. The turbines are excellent, although very expensive, but their piston pumps are creating problems.

It is re-emphasized that the piston pump is a poor match for a wind turbine. The piston pump should be restricted to: (a) hand pumps; (b) engine or electric motor-driven pumps for very deep wells of low yield; and (c) small wind-pump installations where the cost of a better pump may constitute an unreasonable percentage of the total installation cost.

The positive displacement screw pump, of which the Mono pump is the most widely used in the country, is not a good load match for a wind turbine, either. It is, however, preferable to the piston pump because at average pumping heads a larger speed range can be tolerated due to the steady flow and, therefore, shockfree operation.

A kinetic pump should be used in connection with wind turbines.

Centrifugal or axial-flow turbine pumps for use in boreholes require high driving speeds. Costs must be taken into consideration as well as the desirability of using equipment with which installation and maintenance teams are familiar.

The use of Mono type pumps for wind powered community water supply from boreholes is recommended as well as the use of centrifugal pumps for low head wind powered irrigation.

III. RECOMMENDATIONS

In order to make use of the results of the project activities, a project concerned with the establishment of a pilot plant for small-scale manufacture of wind turbines and pumps was suggested by a visiting UNIDO commission.

As a result of discussions in the Tripartite Review Meeting held in October 1981, a project aimed at providing assistance to further development activities was suggested.

A draft project document, entitled "Development in technologies for rural areas", was prepared and discussed.

It seems at present that fund availability and considerations of country priorities will not permit the implementation of the projects.

A. Institutions

It is strongly recommended that immediate steps be taken by EWWCA to secure permanent employment of the local project staff. In this connection, contact should be made also with the project team leader, who is undertaking postgraduate studies at Belfast.

In order to secure a closer link between employer and employee, it is further recommended that the project staff be transferred from the Faculty of Technology to the EWWCA Central Workshop and that office space be provided for the engineers there. A gradual transfer over a period of one to two years might be preferable.

The employment of at least two additional technicians to join the development team is considered essential for the follow-up on project prototypes in operation in the field.

A desirable upgrading of the EWWCA Central Workshop should include the addition of a larger lathe capable of handling diameters up to 600 mm, a universal milling machine and an increase in the stock of cutting tools. A minimum investment would probably be Br 100,000.

This addition is considered necessary for the manufacture of wind turbine parts and highly desirable for the maintenance of general equipment.

It is felt that the project team should form a unit operating directly under the administration of a general manager, who would be responsible for all product development and manufacturing work undertaken by EWWCA.

Furthermore, greater efficiency and better co-operation with workshop personnel would be achieved if the workshop supervisor were made directly responsible to the team leader.

In spite of the relocation of project staff the importance of maintaining close co-operation with the Faculty of Technology is emphasized.

The facilities available at the Faculty of Technology are expected to remain superior to those of EWWCA and most other workshops for a considerable period of time. These facilities are not fully utilized for educational purposes. For the benefit of the Faculty and of the country, activities should be continued. Expensive equipment should not be left unused. In fact, it is justified only if used to the maximum possible extent. Care should be taken, but equipment should be utilized in its intended application.

It is suggested that sophisticated manufacturing work as well as difficult items of equipment repair work be carried out in the Mechanical Engineering Workshop of the Faculty. This could possibly include occasional manufacture of spare parts for, for example, the very expensive drilling equipment employed by EWWCA.

It is also suggested that the Faculty as well as EWWCA be consulted on general technical problems and in further development work.

This could be a starting point towards the greater involvement of the Faculty in industrial activities. A project concerned with this type of activity has already been prepared by the Faculty.

Design projects for senior students of mechanical engineering geared towards the development of rural technologies should be encouraged. Efforts made in this direction should be continued. It is recommended, therefore, that EWWCA makes the project engineers available to the Faculty of Technology to supervise projects to the extent their experience allows them.

It is hoped that the development work in the Faculty in the field of solar energy, small water turbines and experimental work on air turbine drive using a hollow-bladed wind turbine will continue and that the EWWCA development team will assist in the further work irrespective of future institutional framework.

The main reasons for the above recommendations are:

(a) No conclusions were reached in earlier discussions on future location of project activities;

(b) A considerable part of the development work, and in particular follow-up activities, consists of field work of extended duration;

(c) Field work in connection with rural water supply is administered by EWWCA, and close co-operation with EWWCA regional teams is essential;

(d) Location at the Faculty of Technology is desirable from the point of view of technological development. But major emphasis should now be on the implementation of project results, and the real utilization takes place at the rural water points;

(e) Presently the manufacture of project designs is unlikely to be undertaken at a scale warranting a location under the Ministry of Industry;

(f) And EWWCA is the implementing agency for the project and therefore the most appropriate institution to undertake follow-up activities.

B. Technical

Hand pumps

Prototypes recommended for manufacture are:

Type	Application
BP-50	Pumping heads to 10 m
BP-40	Pumping heads of 10 to 15 m
BPL	Pumping heads of 15 to 30 m

The first step towards the manufacture and installation of hand pumps is the manufacture of 2-in. and 1.5-in. PVC pipe.

It is suggested that the manufacture of 8,000 m of 2-in. pipe, 2,000 m of 1.5-in. pipe and 9,000 m of 0.75-in. pipe should be immediately requested for the use of the EWWCA hand pumps alone. This quantity should meet the requirements for 1983.

The standard PVC pipes used in the pumps also have application potential as water pipes in rural and urban installations.

It is strongly emphasized that the production of PVC pipes remain in the programme of the plastic factory in spite of the ongoing expansion and adaption of new products.

To meet the hand pump requirements, since the local plastic factory is not as yet producing suitable stock for the manufacture of pistons and foot valves, an order for such stock should be placed abroad. Because of delays in imports in the past, the stock maintained for pistons and foot valves (high density polyethylene) should conform to the demands for hand pumps for at least one year.

The demand is expected to be approximately for 500 BP-50 pumps, 100 BP-40 pumps and 100 BPL pumps.

It is recommended that the pump manufacture itself be geared towards maintaining a stock commensurate with three months' demand, i.e. 125 BP-50 pumps, 25 BP-40 pumps and 25 BPL pumps.

As very few type-BPL pumps have undergone extensive field tests, the development team should carefully monitor this pump type for at least one year.

It is suggested that 10 pumps selected within a radius of maximum 200 km from Addis Ababa, be tested and inspected every three months. Possible modifications should be introduced to all pumps if and when snags are observed.

Wind turbines

Recommendations for a one-to-two year period after the termination of the present project are given below.

1. The manufacture of three additional 10-m diameter turbines according to the final design agreed on for the larger turbines. This design is identical to the present 10-m diameter prototype, except that the blade angle synchronization gear of the 9-m diameter prototype is adapted.

2. Modification of the 9-m diameter prototype operating at Waig to conform to the final design.

3. Installation of two 10-m diameter turbines with Mono pumps for community water supply from 80 to 120 m deep boreholes. Sites should be selected with a view to promote interest for wind pumping. Easily accessible areas with reasonable winds should be preferred.

4. Installation of one 10-m diameter turbine at Melkassa Farm. The turbine should be fitted with a commercial centrifugal pump of the type already in use in Diesel powered irrigation units. The final drive should initially be arranged as a V-belt drive for ease of speed adjustments. This installation should be valuable also for demonstration purposes since the unit in the winds available here should compete favourably with the Diesel powered pumps presently used. The farm is frequently visited by government officials and representatives from other countries and international institutions.

5. Following a test period of 6 to 12 months, a centrifugal pump should be made locally and fitted to the Melkassa unit substituting a locally made gear box for the V-belt drive. Because of the lack of casting facilities the pump housing should be made in reinforced concrete.

6. Manufacture of three wind turbines to the 7-m diameter project design. The only modification being foreseen at this time is the use of a tail vane in steel sheet in lieu of the present plywood vane.

7. Installation of the three 7-m diameter turbines in the Jijigga area for use at cattle watering points. A request for such units has already been received by the project since the manual water lifting presently used does not seem to be able to meet the demands. The present multiple piston pump design may be used, the number of pumps being adapted to prevailing head and wind conditions.

8. The three smaller wind pumps installed near Melkassa should be visited and inspected monthly for one year for further possible snag correction. Service and maintenance of these units should be taken over by the Agricultural Implements Development team at Melkassa.

9. In view of the limited availability of wooden planks of the quality, length and width required for large blades, the use of plastic blades may be preferable. The assistance of a consultant in hand laid glassfibre reinforced plastic would be desirable for this item.

10. As recommended by the last Tripartite Review Meeting, a specialist in meteorology should be consulted on wind data analysis and actions to be taken for future wind data collection in the country.

Other

The Diesel powered beam pump at Ejerssa should be inspected and tested at regular intervals over a two-year period. Life expectancy needs to be more firmly established.

It is felt that due to the cost involved, manufacture and further application of this pump type can be recommended only if life expectancy exceeds that of the Mono type pumps.

In view of the versatility of the screw type pump, it is felt that the possibility of manufacturing this pump locally should be studied.

The pump is reasonably suitable for a variety of head and discharge combinations, adaptable to Diesel-motor wind turbine and hand operation and has acceptable cost and service life.

If is felt, however, that the services of a consultant with experience in the manufacture of this pump should be used.

Annex I

JOB DESCRIPTION
DP/ETH/77/013/11-01/31.9.A

POST TITLE: Mechanical engineering expert in wind-powered and manual pumping equipment development.

DURATION: One year; with possibility of extension.

DATE REQUIRED: As soon as possible.

DUTY STATION: Addis Ababa.

PURPOSE OF PROJECT: To study, modify, manufacture and field test pumps and wind turbines developed or under development in the country. To establish design data and practical limitations for the pumping devices. To initiate the establishment of rural and urban workshops for production of selected designs.

DUTIES: The expert will be attached to the Ethiopian Water Resources Agency (EWRA) and work in co-operation with the Faculty of Technology of the Addis Ababa University, as well as with officials from the Ethiopian Science and Technology Commission and the International Development Research Centre, Canada. Specifically, the expert will be expected to:

1. Prepare an integrated work schedule on the basis of already existing hand pump and wind pump development proposals.

2. Prepare materials and equipment specifications for local purchase and imports.

3. Prepare working drawings and specifications for pumps deemed ready for field testing and supervise manufacture of same.

4. Prepare detailed field testing procedures and information system and assist in site allocation.

5. Design, manufacture, initially test and modify suggested wind rotor and pump types following established criteria. Select units for field testing.

6. Co-ordinate all laboratory and field tests. Collect and evaluate data, and on the basis of performance and cost evaluation recommend plants and items for full scale local production.

7. Suggest establishment of rural and urban workshops for production of selected designs.

8. Prepare final report, including recommendations for future action in the field of rural water supply development.

QUALIFICATIONS:	Degree or diploma in mechanical engineering combined with education or extensive experience in workshop technology with experience in wind turbine and pump design and manufacture in a developing country.
LANGUAGE	English:
BACKGROUND	
INFORMATION:	The above mentioned activity is designed to facilitate implementation of the approved large-scale project DP/ETH/77/013, which will develop design and manufacture of various hand and windpower operated pumps to be set up for water supply purposes in the rural areas of the country.

Annex II

LOCAL PROJECT STAFF

Project directors	Kefyalew Achamyeleh Ayele Habte Michael
R and D Engineers	Aseged Mammo Yohanis Yigzaw Teferi Taye Alemu Berhe
Technicians	Ayalew Mohamed Eassu Akale Wold Mulugetta Abebe Abebe Tadesse
Driver/Mechanic	Bayou Eshete
Administrative assistant	Yemane Deneke

Annex III

UNDP FINANCED EQUIPMENT[a/]

Item	Quantity	Dollars
Project vehicle, Landrover 109" Chassis No.: 91549089C Engine No.: 90210704 Reg. No.: UN 0142	1	10,002
Project vehicle, Toyota HI-LUX 1600 CC Chassis No.: 151406 Engine No.: 2324185 Reg. No.: UN 0896	1	3,931
IBM Selectric II C model 895 typewriter	1	1,375
Electronic calculator HP33E	1	106
Cup anemometer with electric transmission Cat. No.: 1442	2	1,824

a/ Total budget allocation for equipment was $US 54,000.

Annex IV

ASSIGNMENTS OUTSIDE OF ETHIOPIA

1. Travel to Kenya, 21 to 26 April 1978

The purpose was the review of the project, "Development and Manufacture of Low Cost Water Lifting Devices" (DP/KEN/75/010). (See travel report of 26 April 1978.)

2. Travel to Kenya, 6 to 18 June 1978

The purpose was consultancy on project, "Development and Manufacture of Low Cost Water Lifting Devices" (DP/KEN/75/010). (See travel report of 18 June 1978.)

3. Travel to Kenya, 19 to 29 August 1978

The purpose was participation in Hand Pump Meeting organized by IDRC from 21 to 24 August 1978, as well as the consultancy on project "Development and Manufacture of Low Cost Water Lifting Devices" (DP/KEN/75/010), from 25 to 28 August 1978. (See travel report of 2 September 1978.)

4. Travel to Kenya, 23 to 30 August 1979

The purpose was to review the status of the project "Development and Manufacture of Low Cost Water Lifting Devices" (DP/KEN/75/010). (See travel report of 5 September 1979.)

5. Travel to Thailand, 4 to 10 November 1981

The purpose was participation in meeting arranged and sponsored by the UNDP/WG Global Hand Pump Project (INT/81/026), held at the Asian Institute of Technology, Bangkok, from 5 to 7 November 1981.

The eight participants (Bangladesh, Ethiopia, Kenya, Malaysia, Sri Lanka, Thailand as well as the International Bank for Reconstruction and Development (IBRD)) discussed hand pump activities in the countries concerned and, in particular, limitations of pumps made from plastic.

Annex V

DOCUMENTARY OUTPUTS

Progress reports

Reports were prepared covering the following periods:
February-August 1978
September 1978-February 1979
March-September 1979
October 1979-March 1980
April-September 1980
October 1980-March 1981
April-September 1981

Major technical papers

1. EWRA Working Group on Pump Power Units: Engine derating proposal, April 1979. The paper proposes procedure for the calculation of combustion engine outputs at altitudes above sea level. A table is included listing calculated engine power in percentage of sea level rating, at altitudes of 250 to 3,000 m, at temperatures of 30^{o} and $50^{o}C$.

2. Polyethylene/PVC hand pump, September 1979. This interim technical report describes simple plastic pumps, their design and the result of initial field tests.

3. Items for consideration in assessing the feasibility of local hand pump manufacture, September 1979. The report recommends two simple plastic pumps for manufacture and estimates the costs involved.

4. Suggested activities in the field of solar energy, November 1980. The paper, prepared on government request, suggests activities in the field of solar powered desalination, pumping, refrigeration, heating, cooling and power generation.

5. Solar Desalination Project: initial activities, March 1981. The paper suggests activities in experimental work on solar desalination to be executed by the Mechanical Engineering Department, Faculty of Technology, Addis Ababa University. A work programme for the period April 1981 to April 1983 is recommended.

6. Hand pumps, June 1981. This technical report describes six different pumps considered by the project, their design, test results and observations.

7. Development in technologies for rural areas, December 1981. This is a draft of a project document geared towards the continuation of present project activities and the initiation of development work in other relevant areas.

8. Wind turbines for pumping applications, July 1982. The paper gives design procedures and criteria, describes five wind turbine designs and includes test results and observations.

9. A locally made deep well diesel powered beam pump, July 1982. The paper describes a beam operated pump using plastic cylinder and plastic piston seals. Performance data are given for the pump operating in an application of community water supply from a 100 m deep borehole.