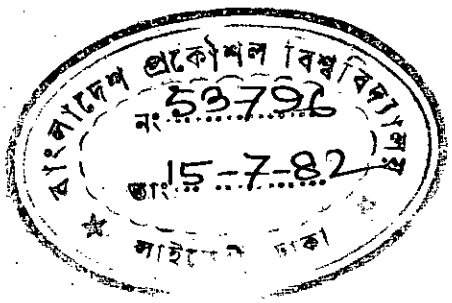
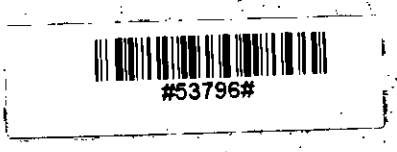
THESIS

STUDY OF PERFORMANCE CHARACTERISTICS OF SOME MANUAL METHODS OF IRRIGATION



KAMAL UDDIN AHMAD

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE IN ENGINEERING
(WATER RESOURCES)



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ENTITLED STUDY OF PERFORMANCE CHARACTERISTICS OF SOME MANUAL METHODS OF IRRIGATION BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING (WATER RESOURCES).

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ABSTRACT

(13)

Manual irrigation devices are providing irrigation to about 38 percent of irrigated area with minimum Government investment. In Bangladesh there is immense scope for expanding its utilization, though modern pumping equipment has supplimented or replaced traditional devices in many other countries.

Manual water lifting devices have some important advantages in this country. Some of these advantages are - (i) the human energy requirement for lifting water can be provided by the user in rural areas, (ii) the devices are labour intensive and require elementary technologies, both of which are locally available, (iii) the capital costs of manual water lifting units are low and (iv) compared to alternative forms of water lifting divices which are dependent on imported fuel, the manual devices are little sensitive to inflation.

The objective of this study was to identify the manual water lifting devices in operation in Bangladesh, to estimate the potential contributions which manual devices can make in irrigation; their performance characteristics and scope of future development of these implements.

From field data it was found that the maximum discharge obtained by 'dhone' at 30 inches lift height was about 0.25 cusec and the rate of loss was low, the irrigation cost per acre by this device

was only Tk. 553 (1981 costs) and it came down to only Tk. 88 when family labours where utilized(considering about 10% hired labour). It can be operated in khals, borrowpits, and depressions where monsoon rain is stored and water surface is within 10 feet. from the field to be irrigated.

The maximum capacity of swing basket was found to be about 0.090 cusec at 30 inches lift height but the rate of loss was found to be very high ranging from 9 to 34 percent. The use of swing basket may be discouraged due to its low discharge, low volumetric efficiency and high man power requirement. This is perhaps the most laborious method in which full weight of water is borne by the operators.

Manually operated Shallow Tubewell for Irrigation (MOSTI) has been found popular with users. The maximum area that was found to be irrigated was 0.6 acre. It required a capital cost of about Tk. 1600. Hand Tubewell may be successfully utilized where depth of ground water table is low. By applying different operation techniques its discharge may be substantially increased.

The discharge of 'dhone' may be increased and its operation may be made easier by changing its design, utilizing plank or G.I. Sheet instead of tree trank and introducing 'one way valve' at the bottom of intake section.

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ABBREVIATIONS

BADC	Bangladesh Agricultural Development Corporation
BKB	Bangladesh Krishi Bank
BRRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water Development Board
Cusec	Cubic feet per second
DEM	Directorate of Extension and Management
dia	diameter
DPHE	Directorate of Public Health Engineering
DTW	Deep Tubewell
ft.	foot
'	foot
"	inch
GDP	Gross Domestic Production
gpm	(US) gallon per minute
hp	horse power
hr	hour
HTW	Hand Tubewell
HYV	High Yielding Variety
IDA	International Development Agency
IECO	International Engineering Company
IRDP	Integrated Rural Development Programme
KSS	Krishi Samabay Somity
lb	pound
LLP	Low Lift Pump
m	million
MCC	Mennonite Central Committee
m^3/hr	cubic meter per hour
MOSTI	Manually Operated Shallow Tubewell for Irrigation
MTFPP	Medium Term Food Production Plan
No.	number
Nos.	numbers
O&M	Operation and Maintenance
STW	Shallow Tubewell
TCCA	Thana Central Co-operative Agency

TIP	Thana Irrigation Programme
TTDC	Thana Training and Development Centre
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development.

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয়
নং.....
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লাইব্রেরী, ঢাকা

CHAPTER - I

INTRODUCTION

1.1 General

Bangladesh has an area of 35.3 million acres of which at present 22.50 million acres or almost all of the arable lands are cultivated, but only 1.61 million acres are tripple cropped, 7.83 million acres are double cropped and remaining 13.06 million acres are single cropped (Bangladesh Bureau of Statistics,1980). Irrigation presently covers about 16.5% of the cultivated area (Planning Commission, 1981). Thus there is immense scope of expanding irrigation facilities to cover more areas of the country and increasing cropping intensity and food production.

The mean annual rainfall in Bangladesh varies from about 50 inches in the western part of the country to almost 200 inches in the northeast and is characterised by wide seasonal fluctuations with about 90 percent of the rainfall occurring in the five months period of the monsoon (May to September). In spite of an overall abundance of rain, serious droughts do occur. There are instances of inadequate rainfall even during the monsoon season and the minimum rainfall duringmost of the dry season is almost 'nil'.

Bangladesh has a predominant rural economy with agriculture accounting for 55 percent of Gross Domestic Production (GDP), 80 percent of employment and 90 percent of export. Of the total population of 90 million, about 81 million live in villages of which 59 percent are farmers and 25 percent are agricultural labours (the defination of agricultural work force includes those who are available to work in agriculture and, therefore, must not be confused with the rural work force which also consist of workers in non agricultural activities in rural area) (Hamid, 1979). The rural work force has been growing by at least 2 percent per annum. The agricultural labour for hire has been growing rapidly and has gone upto 3.7 percent (Biggs, 1978). The growing tide of landlessness and low production in below subsistance holding sizes are forcing a greater proportion of the population into rural labour market.

In Bangladesh disappointing performance has characterised agriculture during the last three decades. Though food grain production, the key domain of food supply and nutrition, has increased by about 1.5 percent a year in the 1970's this growth rate has been exceeded by population growth rate of about 2.7 percent per annum, and the percapita availability of food from domestic sources has declined. Food selfsufficiency was the primary objective of First-Five-Year-Plan (1973-78) but the objective failed and foodgrain imports averaged around 2 million tons per year since the early seventies (Medium Term Food Production Plan, 1980).

1.2 Present Position of Irrigation in Bangladesh

Out of possible 22.5 million acres of arable lands in Bangladesh only 3.725 million acres are supplied with irrigation water in some form (Planning Commission,1981) . The acrage coverages by various methods are: 0.254 million by gravity supply, 1.071 million by tubewells, 1.400 million by low lift pumps and approximately 1.00 million by traditional methods. Some characteristics of various methods of irrigation in Bangladesh are shown in Table 1.

1.2.1 Surface Water Irrigation

Bangladesh Water Development Board (BWDB) provides irrigation facilities through large projects by gravity/ primary pumping system. BWDB followed the Master Plan prepared in 1964 by International Engineering Company (IECO) (IECO Master Plan, 1964). The plan divided the country into some 50 major projects of large areas which would have jointly provided flood control and drainage for about 12.1 million acres and would have supplied irrigation to 7.9 million acres.

BWDB has completed some of the small irrigation schemes of the plan but is yet to complete any of the major schemes.Under this type of irrigation projects, mainly river water is diverted and pumped to obtain head for gravity distribution within the project area. In some projects, flood protection is provided by enclosing the area with flood embankments.

These projects are very expensive. These schemes take long period of gestation before results can be obtained. Even after the schemes are completed, there are serious technical and institutional problems due to which irrigation facilities benefit a much smaller area than originally intended. The area irrigated by BWDB upto June 1981 is about 2,54,000 acres.

1.2.2 Low Lift Pump (LLP)

In Bangladesh Low Lift Pump irrigation programme was started in early fifties. Constant efforts are being made for its intensification and expansion of irrigation coverage per cusec. Untill 1979 almost all LLPs in Bangladesh were owned by Bangladesh Agricultural Development Corporation (BADC). LLPs were rented out to a farmers' group for a winter period and a fixed subsidised amount was charged for spares and repair services. Often it was found that the coverage by the LLPs were very low (approximately 19 acres/cusec in 1978).

There were two main reasons for poor utilization. There was lack of financial incentive to spread costs over larger area as the hire charges were heavly subsidised. The other reason was low hour of total operation which resulted mainly from the tendency to avoid risk of failure due to over loading.

Poor operation and maintenance was due to a number of factors. Equipments were rented, not owned; thus these were misused; the lack of incentive to care for equipments was compounded by the fact that there was no guarantee that renters would get back the same equipment in succeeding years.

For the purpose of increasing farmers' incentive and attention to the equipment, BADC decided to gradualy reduce the rental procedure and started to sell new pumps to the farmers' at subsidised cost. Old pumps were rented out but the charges were enhanced. The charge levied by BADC in 1980-81 season were Tk. 900 as rent and Tk. 450 for spares and repair services. The farmers had to bear the fuel cost. BADC at present is planning to sell out the old pumps also.

The rated capacity of the pumps already fielded are two cusec and one cusec. Out of 36,348 Nos. of LLPs fielded in 1981 about 8000 Nos were of one cusec capacity and the remaining were of two cusec capacity. Actual discharge under field condition has been observed to be less than the rated capacity. A co-efficient of 0.8 is used by BADC engineers to estimate the discharge at field condition. On this basis of calculation the present coverage of LLPs are about 27 acres per cusec. This can further be increased by providing adequate repair and maintenance services and supplying spares at proper time.

1.2.3 Deep Tubewells (DTW)

Exploitation of ground water for irrigation in Bangladesh was probably introduced by Mr. Akhter Hamid Khan at the then Pakistan Academy for Rural Development, Kotbari, Comilla. Upto 1965 the major effort to exploit ground water was tho sinking of 380 DTWs by BWDB in Thakurgaon area of north-west Bangladesh. Following that BADC tookup project for DTW sinking and started works for construction of 5000 tubewells in 1970 which however suffered during the war of liberation. International Development Agency (IDA) assisted BADC to install another 3,000 DTW in the north-west region of Bangladesh. This was completed in 1980.

The typical DTW in Bangladesh has a total depth of 200-400 feet and turbine pump set at about 60 feet, driven by a surface mounted 20 hp diesel engine. Nominal capacity is two cusec. Till June 1981 DTW contributed 0.62 million acres of land irrigated by 10,132 Nos. of equipment. Average per cusec coverage is 30.6 acres. If it is assumed that actual discharge is less than the rated capacity and if like LLP a co-efficient of 0.8 is used to take care of field condition, then the coverage per cusec increases to 38 acres.

The DTW programme had suffered from much the same shortcomings as the LLP programme. Renters paid only Tk. 1,200/- per year plus spares at cost upto a miximum of Tk. 1,000/- while the service is free. The present cost of a DTW is about Tk. 2,81,500/-. BADC is now making out right sale of DTW to

the farmers' group at the rate of Tk. 70,000/- on credit and Tk. 60,000/- on cash. The subsidy is about 79%.

The rate of DTW development is constrained by installation capacity. Currently drilling rigs are in short supply. Drilling can only take place during the dry season and good rig output requires skilled operators.

1.2.4 Shallow Tubewell (STW)

In Bangladesh STW programme was started in about 1970-71. This programme was accelarated after a ground water study was undertaken by BADC which revealed that, in many areas, aquifer conditions were such that they could be satisfactorily exploited by shallow tubewells using surface mounted centrifugal pumps. The proposed design was a 80-90 ft. 4 inch diameter well equipped with a centrifugal pump capable of delivering 0.5-0.75 cusec when coupled to a 5-6 hp diesel engine (World Bank Report on Review of Minor Irrigation, 1981).

Such an installation has many advantages over the DTW design . It is relatively cheaper (currently one nineth of the DTW cost) and irrigate about 10 to 15 acres. It can therefore be sold to invividuals or small groups, overcoming a major drawback of the two cusec capacity of LLP and DTW, which needs larger group to be formed and managed. It is also easier to install a shallow tubewell.

The STW has always been sold at or near full cost less duties and taxes, and spares also have been sold at cost price, only service has been provided free of charge, thus the programme has placed little financial burden on Government as compared with the LLP and DTW programmes.

Because the equipment has been fully owned by a small group, there has been an incentive to use it well. A further benefit of the STW programme has been the growth of a limited private sector business making and selling spares and providing services.

From 1974-75 STW development programme has been executed both by BADC and the Bangladesh Krishi Bank (BKB). The pace of development has been considerable and upto June 1981, 36,622 Nos. of STW were fielded. The area irrigated by STW upto June 1981 is 0.41 million acres.

1.2.5 Hand Tubewells (HTW)

In the mid 1960s UNICEF launched a programme to install small hand tubewells to provide clean drinking water in rural areas. Farmers quickly recongnized the potential of these hand tubewells for irrigation, as HTWs are inexpensive (Tk.1,380) and labour intensive and can irrigated between 1/3 to 1/2 acres.

Recognising the potential of hand tubewells UNICEF started an irrigation project namely MOSTI (Manually Operated Shallow Tubewell for Irrigation) project in 1975-76 for 10,000 wells. This was so successfull that the project was extended to July 1979 and by the time almost 90,000 wells were supplied.

Following the pattern established for drinking water, the MOSTI project was executed by the Department of Public Health Engineering (DPHE) with UNICEF assistance. Raw materials were imported and pumps were fabricated locally. Sales were made through the Integrated Rural Development Programme and the Thana Central Co-operative Association (TCCA)/Krishak Samabaya Samity (KSS) farmers co-operative society at the village level.

USAID supported a second project in 1977-78, which was executed by BADC and provided 150,000 wells. IDA is currently appraising a third project for 180,000 wells. It is proposed that the later is to be executed by DPHE and IRDP. 1,53,000 Nos. of HTW were fielded covering an area of 46,000 acres by June 1981.

1.3 Institutions for irrigation development in Bangladesh.

The major Government agencies involved in irrigation development are:

i. Bangladesh Water Development Board (BWDB);

ii. Bangladesh Agricultural Development Corporation(BADC);

iii. Integrated Rural Development Programme (IRDP);

iv. Bangladesh Krishi Bank (BKB).

In addition to those Government agencies many relief and voluntary agencies in the private sector are active for development of irrigation in Bangladesh.

1.3.1 Bangladesh Water Development Board (BWDB)

BWDB, founded in 1959, is a semi-autonomous government organization. BWDB is responsible for major surface water irrigation schemes, drainage and flood control schemes erosion control, town protection and river training works throughout Bangladesh. It also operates small number of LLP and DTW Programme. BWDB has the statutery responsibility for surface and ground water resources management of Bangladesh.

The functions and responsibilities assigned to the Bangladesh Water Development Board may be outlined as follows: (World Bank Report No. 2327-BD,1979).

1. To prepare for approval of the Government achemes for flood control,development and utilization of water resources of Bangladesh.

2. To Farme schemes in the following areas:

   a. construction of dams, barrages, reservoirs and other original works; irrigation, embankments and drainage;

   b. flood control including watershed management;

   c. prevention of salinity, water congestion and reclamation of land;

   d. maintenance, improvement and extension of channels including dredging of channels but excluding all such operations as may be assigned by the Government to any other agency;

   e. regulation of channels to concentrate river flows for more efficient movement of water, silt and sand, etc.

1.3.2 Bangladesh Agricultural Development Corporation(BADC)

BADC, established in 1961, is a semi-autonomous agency under the Ministry of Agriculture. BADC's present role in irrigation sector may be summarised as: (World Bank Report on Review of Minor Irrigation, 1981).

   i. To procure and supply irrigation equipment to farmers, mainly on rental basis (LLP,DTW) and also by outright sale;

   ii. To procure parts and, through the operation of workshops and stores, provide spares and maintenance services for both rental and sold equipment;

iii. To train and equip machanics to enable them to establish private business;

iv. To procure and supply diesel and lubricating oil for irrigation equipment particularly in remote areas inadequately served by the private sector;

v. To provide technical inputs to Thana Irrigation Programme (TIP), procedures to ensure appropriate sitting of LLP and, acting directly, to approve sittings of DTW and STW;

vi. To collaborate with Directorate of Extension and Management (DEM) and IRDP to advise equipment users how to improve command area development;

vii. To gather groundwater resource data and determine groundwater availability using modelling techniques;

viii. To gather surface water resources data to enable an expansion and reliability of LLP fieldings.

1.3.3 Integrated Rural Development Programme(IRDP)

For the purpose of group action to solve farmers' problems which are interrelated and indivisible, some institution is required. Such an integrated approach for Rural Development was experimented in Comilla Kotwali Thana under the auspices of the then Pakistan Academy for Rural Development in the early sixties (IRDP, 1978). There are four major components of the programme:

i. Two-tier cooperative structure under which farmers are organized into cohesive groups of village based multipurpose cooperatives and then federated at thana level which is the supporting organization for the supply of credit, inputs and coordination of activities;

ii. Thana Training and Development Centre(TTDC)located at thana level to serve as a transmission centre for diffusion of technologies through training of chairmen, managers and model farmers of primary cooperative societies by the local experts of the nation building departments.

iii. Thana Irrigation Programme for the improvement of drainage and irrigation and organizing small groups to use indivisible inputs such as deep tubewells and low-lift pumps. These organized groups are gradually converted into cooperative societies. Technical services were to be provided by all government agencies.

iv. Rural Works Programme is designed to build physical infra-structure in the rural areas and provide additional employment oppertunities to the rural poor.

IRDP, an agency of the Ministry of Local Government, Rural Development and Co-operatives, was formed for promoting the Comilla type, two tier, TCC/KSS co-operatives system.This now covers 350 thanas and is planned to expand country wide.

1.3.4 Bangladesh Krishi Bank(BKB)

BKB was established in 1973 to provide credit facilities to all persons and corporate bodies enagaged in agriculture and cottage industries. An Engineering Department has been added to provide technical support to its tubewell programme. By the end of 1980, BKB has sold about 14,500 STW. BKB contracts private contractor for driling and installation of shallow tubewells.

1.3.5 Private Sector

Until recently the private sector has played a very limited role in the irrigation sector. The main contribution has been the manufacture of centrifugal pumps by private agencies.Many relief and rehabilitation agencies are also working to increase the command area of LLP, DTW and STW etc. Some of these organizations also devoted energy for development of appropriate water lifting divices viz the Rower pump. Though their combined efforts have not been quantified, their role is substansial and is increasing.

1.4 Potentials for Irrigation Development

Bangladesh is situated in the delta of the three mighty rivers, Ganges, Brahmaputra and Meghna and entirely laced by their numerous distributories and tributories. In major parts of Bangladesh, depth of ground water level during dry season varies from a few feet to about 30 feet. So both the surface and ground water resources bear potentiality for irrigation development in Bangladesh.

1.4.1 Surface Water Potential

The country has abundant supply of surface water brought by the rivers and received from rainfall in the wet months. During the monsoon, concentration of rainfall often creates hazardoues flood condition, but due to terrain formation of Bangladesh possibilities of storing this excess water is minimum. More than 80 percent of the supply comes in July through October when the country's demand of water is less and the remaining months are dry having little water in some areas for irrigation purpose. The maximum requirement for crop is during the months of least rainfall period and minimum river flow which occures between the months of November and March. Over and above, due to use and diversion of more and more surface water by neighbours in upper riparrian the supply of surface water to Bangladesh during periods of actual need is becoming less and less. For improvement of this condition measures like storge of water through canal digging has been taken up.

1.4.2 Ground Water Potential

A large quantity of data have so far been collected, through the project namely "Ground Water Survey in Bangladesh" of BWDB which was concluded in June, 1981. Results and findings of the survey works conducted for general appraisal of ground water condition of Bangladesh have indicated that most part of

the country is underlain by a storage of ground water at varying depths, depending on locations and season. The data are to be further analysed and processed to achieve the specific results. (Karim,M.A., 1980).

Deep perculation of rain water constitutes the principal recharge mechanism in Bangladesh. Average annual recharge values have been estimated to vary between 0.46 feet in Kushtia district and 5.64 feet in Sylhet district. On this basis, the average yearly, ground water recharge in the country is 46.5 MAF (S.I.Bhuiyan,1977).

1.5 Objectives of the Study

Proper development of irrigation is essential for increasing food production in Bangladesh. In the preceding sections it has been shown that good potentials for development of both surface water and ground water exists in the country and there are several Government and Semi-Government Organizations who are working for this purpose. But their current coverage of irrigable land is yet to achieve desired proportions. Traditional methods using surface water, or hand tubewells and dug wells using ground water contineus to contribute significant areas under irrigation coverage. Planning Commission in 1981 estimated a coverage of 1.0 m acres whereas Bureau of Statistics in 1979 estimated the coverage to be as high as 1.6 m acres. The various agencies mentioned earlier has no efforts in increasing the capacity or efficiency of traditional methods.

Though some of these organizations provide inputs for HTW, no systematic studies have been made to find out there effectiveness. Recently the government has intensified efforts for expansion of irrigation facility, though mechanical irrigation devices (LLP,DTW and STW etc) and gravity irrigation having some attention, the tremendous potentialities of traditional methods are being completely ignored. No efforts are required to introduce them to the farmers but effort to increase their efficiencies and performance is essential. Further, inview of shortage and rising cost of energy, these traditional means of lifting water may play an important role in development of irrigation.

In the light of the above discussion a study was undertaken regarding performance characteristics of some manual methods and the objectives were as follows:

1. To identify the various types of manual irrigation devices used in Bangladesh;
2. To develop the performance characteristics for these devices;

and 3. To compare the performances of the various mannual irrigation devices.

CHAPTER - II

THE MANUAL METHODS OF IRRIGATION IN BANGLADESH

2.1 Introduction

Three or four manual methods in irrigation are widely used in Bangladesh. They are 'dhone', swing basket and tubewell (HTW) or 'MOSTI' (manually operated shallow tube-well for irrigation), 'dab' or pitcher method using dug wells. Scoop is also utilized where lift height is short and small quantity of water is required,

Some efforts have been made to introduce new appropriat technology in water lifting devices. A "see-saw" pump was designed by Mahtab in 1976 (Gerit vander, 1978). The use of chinese chain and washer pump was tried in the Savar area by researchers from the UNICEF in June, 1978 (Willy and Jim Byrne, 1979). The Agricultural Engineering Division of Bangladesh Rice Research Institute (BRRI) designed and introduced manually operated Diaphram type pump in 1978 (BRRI,1979). Rower pump was developed by Mennonite Central Committee (MCC) in 1978 and tested in Noakhali area (G.Kalssen,1979).

2.1.1 The 'dhone'

The 'dhone' is a hollowed out log with one end closed (figure 1). It is slightly curved near the closed end and is operated by one man with the help of a lever. The lever is

pivoted eccentrically from the centre and hanged on longer end of the lever in such a way that there exists sufficient slopping in the 'dhone' for quick discharge of the lifted water. The operator puts his weight on the closed end of the 'dhone' to fill it with water from river or pond using his leg. He stands on a bamboo platform usually six inches above the water surface. When the 'dhone' is filled, the operator removes his weight and it is automatically lifted up owing to the counter weight on the other end of the lever.

The discharge of a 'dhone' varies with the lift height, geometry of the implement, skill and efficiency of the operation and strength of the lever. With the increase of the lift height, the farmers increase the number of stages of 'dhone'. Generally when the lift height exceeds five feet, the farmers arrange for next stage. It has been observed that the usual practices of farmers is to go for 2-3 stages; however in some cases upto 4 stages may be found.

2.1.2 Swing Basket

The swing basket is made from tin sheet or closely woven mat of bamboo of about 20 inches square with one of its sides doubled up and swen together (figure 2). One rope is fastened to each corner of the scoop. The water lifting operation is done by two operators standing at some distance apart and each holding the ropes. They plunge the swing basket into the water,

draw it out and throw the water with a quick pull on the back ropes to raise the back of the basket. Some times it is operated by one operator holding the ropes of the same ~~si~~ side and fastening the ropes of the other end with a pole. In that case both frequency of stroke and thus the discharge is reduced. The discharge varies with the lift height, size of the basket, operation duration and skill and efficiency of the operator.

2.1.3 Hand Tubewell (HTW)

Hand tubewells (HTW) are manually operated reciprocating pumps. It utilises groundwater at shallow depth. It is also named as the 'MOSTI' (manually operated shallow tubewells for irrigation) (figure 4). For irrigation purpose generally one or two 20 feet long 1.5 inch diameter blind pipes are commonly used with strainer being of same diameter and six/seven feet long. The inside diameter of the pump is four inches and the piston called 'bucket' is fitted with connecting rod having strocke length of about 12 inches.

The discharge of HTW varies with the depth of groundwater table, characteristics of the aquifer, quality and age of the pump, condition of the bucket, quality of maintenance and repair works, strength of the operator and techniques of operation etc.

2.1.4 Dug Well

Pitchers are sometimes used to lift water for irrigation from the dug well. The device consists of a lever which swings around pivot having counter weight on one side and pitcher fastened by rope on the other side. The operator pushes the pitcher into the water and the pitcher is lifted up by the counter weight of the lever. Sometimes instead of counter weight one end of a bamboo is kept fixed on the ground and the elastic action of the bamboo is used to lift up the pitcher from the dug well. This device is called 'dab' or 'rati' in some locality. The frequency of stroke depends on the depth of water, size of the pitcher and counter weight to lift up water.

For small plots the farmer or house-wife sometimes carry water from some surface source in a pitcher or bucket and spray over the field. This method is only adopted for the crops like tobacco which requires very shallow depth of water for irrigation and the source of water is nearer to the field. It is also adopted for small plots of vegetable near the home steads.

2.1.5 Scoop

Some times shovel or scoop is used to lift water through a short height. Its operation is a combination of 'dhone' and swing basket. The scoop or shovel is suspended from a mast rested on a tripot and operated by single man holding the handle of the scoop (figure 6). Two of the suspended ropes are fastened to the

blade and one is tied to the handle by means of a loop so as to permit adjustment of the position of the blade. The scoop is pushed forward to lift water and discharge the water on the field. The blade of the scoop pushes about 5 litres (1.32 US gallon) of water in each swing and is worked at a high speed with a frequency of about 30 swings/minute. However the loss of water from source to field is very high.

2.1.6 "See-saw" Pump

The "See-saw" pump is designed (figure 5) to over-come the difficulty of lift height in the operation of hand pump. The system consists of two alternatively operated reciprocating pumps, sucking water from common tubewell and placed at the ends of a axil or bar hinged at the centre, a vacuum reservoir, three one way check valves and pedeling arrangements at the ends of the bar (figure 5).

The machine is operated by two operators pressing the ends by leg alternatively. When one side of the bar is prossed the piston of that side moves down and the check valve is closed preventing the backward flow of the water and the piston valve is opened permitting water to enter the space above the piston. At the same time the other end of the bar rises up, drawing up the piston of that side and consequently suction stroke is achieved. During suction stroke the check valve is opened, allowing water to flow in one direction and

the piston valve is closed and the water above the piston is delivered to the spout. The vacuum reservoir ensures even flow of water into the pump. Without the vacuum reservoir water flows in surges into piston pumps, resulting in a higher peak flow velocity. A constant flow reduces friction loss as friction loss is proportional to the square of velocity. Therefore, the addition of the vacuum chamber improves the over all pumping efficiency. Also the efficiency of the device increases as the amount of water which leaks between the piston and the cylinder walls decreases during a stroke. Though this pump was developed several years earlier it is not yet adopted by farmers in Bangladesh.

2.1.7 Chinese Chain and Washer Pump

The Chinese chain and washer pump is made of a 2 inch diameter rising pipe through which closely fitted washers, arranged in a chain is pulled (figure 7) (Willey & Jim Byrne, 1979). The pulling action of the chain and washer lifts water through the pipe which is discharged into a collecting tray at the top of the pipe. The entire structure is supported on a wooden frame placed in a vertical plan to operate manually. The washers are made of wood or steel and rubber. The links support both the weight of the loop that hangs from a wooden wheel having a radius of one and a half to two feet and the weight of water in the pipe. Oil soaked wood block-bearings with a grease point

are used on a mild steel axle. The washers are cut from locally available ¼ inch thick rubber matting. One support disc of mild steel plate (One and half inch diameter and 1/16 inch thick with one inch drilled whole) is welded to a straight section of a chain link. The rubber washer is sand-wiched by another disc of mild steel. These discs are then bolted together. The drive handle is made of mild steel flat bar (One inch wide by ⅛ inch thick), and is fitted with bamboo grips. The delivery tray is made of welded tin plates. As stated by developers, the maximum head for this type of pump is about 45 feet, with a discharge of 500 US gallons per hour. The cost of material is approximately Tk. 600 (1979 estimates). However this device has not as yet reached the users level.

2.1.8 BRRI Pump

BRRI pump is a diaphram type twin positive displacement pump. Two pumps are installed over one platform and act as a single unit. Both the pumps have one common suction pipe but separate discharge pipes. In the suction chamber of each pump there is a one way valve allowing the water to enter into the suction chamber. The extended lift arms of pumps are connected with the long operation handle by bolts. The operation handle is fitted on a stand and actuates over a fulcrum.

The construction of the pump is not complicated and it is not expensive as it can be made from locally available materials by local technitians. This pump can lift water

easily from a depth of 15 feet and can deliver about 80 gallons (US) of water per minute. This pump is being introduced in the Joydebpur area of Dacca District..

2.1.9 Rower Pump

The Mennonite Central Committee (MCC) has developed a simple pump, called the Rower Pump, that promise to be cheaper, easier to operate and easier to maintain than the conventional hand pump (G.Kalssen, 1979).

The Rower Pump is a resiprocating piston pump with 2 inch (50 mm) PVC pipe as the pump cylinder. This cylinder is inclined at 30° from horizontal and the operator pushes and pulls directly on a 'T' handle at the end of the piston rod. The pump is operated with a rowing action, hence the name 'Rower' .(figure 8).

The pump contains a suction surge chamber, which provides a steadier upward flow of water in the ground pipe and enable the operator to make easier and quicker strokes. The improvement in operating comfort is remarkable.

Simplified maintenance is an important feature of this pump. Access to both piston and foot valve is quick and simple and they can be removed without dismantling the pump. The piston, with a leather cup, has a loose fit in the cylinder and can be slid out easily after the piston rod guide is removed. The foot

valve, held in place by a rubber disc fitting lightly between the cylinder wall and the edge of a steel disc, can be withdrawn for repair by sliding it out through the cylinder. A rod with a hook at one end and a ring at the other is used both to withdraw the foot valve and to slide it back in again.

At 19 feet depth of ground water table the average discharge without surge chamber was about 7.7 gallon per minute and with surge chamber it was about 12.3 US gallon per minute. This pump is being used in Noakhali district.

2.1.10 Archimedean Screw

This device belongs to Egypt where it was invented two thousand years ago. This device consists of a drum with a concentric screw augur of appropriate pitch in order to enable the conveyance of water along the spindle to which the augur is fastened. The pitch is about 1.5 times the diameter of the drum and the inclination of the unit is 30° to horizontal. The unit can lift 15-30 m^3/hr (65-130 gpm) if the water table is 0.15-0.75m (6"-30"). There are many advantages of this device compared with other. The power application is based on a rotation rather than to and fro or up and down.

As the screw is nailed to the drum, water does not leak between these two parts, although some return water exits,

The archimedean screw can be made entirely of local materials except for the iron rod which follows the centre line. The handle is offen made of iron plate, but planks can also be used.

The screw is made of about 80 propeller, put together over an iron rod whose upper end is shaped to a crank handle. A post is placed in the water and serves as support for the lower end; while the upper end is supported by a beam. The archimedean screw is constructed in relation to the power of a man. The gear ratio is constructed in relation to a car. However, this principle is yet to be tried in Bangladesh.

2 2 Discussion on Manual Methods of Irrigation

The various advantages and difficulties in manual methods of irrigation are discussed below:

2.2.1 Advantages

i. Low investment: Capital cost required for manual methods are very low in comparison to mechanical systems. A swing basket costs only Tk. 30/- the cost of a 'dhone' is about Tk. 400/- and the cost of a hand tubewell is around Tk. 1600/- (1981 estimates).

ii. Employment: Manual methods of irrigation are highly labour intensive. Bangladesh has abundant resources in man-power and these methods of irrigation thus provide an opportunity for their utilization.

iii. Management: The most critcal constraint of optimum utilization of the already created facilities by mechanized irrigation system is the organizing of large number of members into viable, self-supporting and continuing groups. Manual methods of irrigation are small , and simple in nature and requires no or small organizational structures.

iv. Reliability: There are several instances of crop failure due to trouble of the mechanised irrigation equipment. Since manual methods depend on human energy alone their possibility of failure is minimum on account of energy supply.

v. Simple engineering: The devices for manual methods of irrigation are locally manufactured from locally available meterials by village black smiths and artisanes and some times even by the farmers themselves.

2.2.2 Disadvantages

i. Laborious: Most of the manual methods are laborious. Particularly in operation of swing basket full weight of water is to be borne by the operators.

ii. Low lift height: The maximum lift height for 'dhone' and swing basket is only 5 feet. Farmers increase stages for higher hights but loss in each stage reduces the total efficiency of the system. With increase of stage, number of labour requirement increases and hence the

operation cost increases. It is seen that several farmers start irrigation from the same source but when the lift height increases some of them discontinue irrigation to minimise the expenditure.

HTW can lift water from 25 feet depth well. Discharge decreases and cost increases with depth.

iii. Limited coverage: As the discharge from manual water lifting devices is very low it is generally applied in the fields which are in the vicinity of the water body and thus extensive coverage is not possible.

iv. Time consuming: Due to its low discharge, time taken to irrigate the field is more. An operator can apply only about 0.5 inch over 0.5 acre of land in a day with a new HTW. Since the rate of evaporation is generally high at that period of the year, effective water application to the root zone is much reduced.

CHAPTER - III

ESTIMATION OF COST FOR IRRIGATION

3.1 Introduction

The cost of operation of various manually operated irrigation methods and the other standard mechanical methods has been compared in terms of cost per acre-inch of water. The comparision of cost on the basis of per acre coverage is also made.

The total cost of an irrigation system may be divided into:

a. Capital cost

b. Direct Operation and Maintenance (O&M) cost

c. Indirect O&M cost

3.1.1 Capital Cost

The capital cost includes the cost of the water lifting device , its accessories and their installation. A DTW, for example, consists of an engine, pump, pipes, fittings and pump house. A LLP set consists of an engine, a pump and a trolly on which these two are mounted, fittings to join the pump on the trolly and the suction and delivery pipes. The 'dhone' consists of the 'dhone' it self, one lever of about 25-30 feet long, two hinging poles on which the lever rests, one counter weight and a connecting bamboo.

Capital cost structures of different water lifting devices are shown in Appendix B.

3.1.2 Direct Operation and Maintenance Cost

Expenditure incurred by the farmer for operation of the devices consists of:

i. Pay of manager;
ii. Pay of Operator;
iii. Cost of Diesel;
iv. Cost of Oil;
v. Cost of Spare Parts;
vi. Channel Maintenance Cost.

3.1.3 Indirect Operation and Maintenance Cost

For calculation of indirect O&M cost the following items were considered:

i. Salaries and Allowances for Staff
ii. Depriciation of Buildings and Structures
iii. Maintenance of Structures
iv. Depriciation of workshop equipments
v. Interests (Govt. and Foreign)
vi. Miscellaneous.

3.2 Calculation of Total Cost of Water

The above mentioned items of costs were estimated for different types of Irrigation. Total cost of water was calculated considering 800 hours of operation in a season. Different cost

of STW, DTW, LLP and HTW of June 1981 were collected from BADC. The total costs of irrigation by 'dhone' and swing basket consist of capital cost and operation cost only. In 1979 the capital costs of 'dhone' and swing basket were Tk. 300/- and Tk.20/- respectively, wage of labour per day was Tk. 10/-. During June, 1981 the capital costs for these two items and wage per day per labour were collected from the study area. The capital costs are Tk. 400/- and Tk. 30/- for 'dhone' and swing basket respectively and wage is Tk. 16/-. These figures were added with the data collected from BADC and shown in Table II. Assumptions made and sources of various components is also given in the table.

From the table it is evident that the 'dhone' method of irrigation has the lowest cost of water per acre-inch and also intermes of per acre coverage. The cost efficiencies of swing basket is not much favourable.

The deep tubewell has the added advantage of collection of water from deep aquifer and thus ensured water supply. However if surface water source is available within reasonable height the dhone may prove to be much more economic over the LLP. Thus the 'dhone' should receive much attention from researcher to increase its efficiency and use.

CHAPTER - IV

RESEARCH METHODOLOGY

4.1 Site Selection

To study the manual methods of irrigation in Bangladesh a suitable site where large number of such devices are used in closed area was located. In 'Dangar Beel' area in the village Malancha, P.S. Melandah, District Jamalpur about 30 'dhone's and 7 swing baskets were used throughout the Rabi season (January to May) of 1979, to irrigate High Yielding Variety (HYV) Boro and wheat from water of the beel . On the bank of the beel there were many hand tubewell irrigation block. There was one deep tubewell in that village; a number of shallow tubewells and several low lift pumps were also in the sur-rounding area.

As the area had same micro-climate, similar soil and social patterns and identical agricultural practices, the Danger Beel area was conveniently selected to study the performance of different irrigation devices.

4.2 Data Collection

Following methods were adopted to collect data for further analysis as stated below:

a. 'Dhone': The length, corss-section at the intake, outlet, and the curvature of the 'dhones' were recorded with the help of a measuring tape. The

operator was requested to fill the 'dhone' and held it in steady position without discharging water. At that position the perpendicular height of bottom of the 'dhone' from the water surface was measured and was termed as lift height. After measuring the lift height the operator was requested to continue his work as before. Then the discharge of the 'dhone' was collected and measured by collecting the discharged water into a container (9" x 9" x 13"). After a few minutes, when the operator devoted himself in the work his performance (number of strokes in five minutes) was counted secrately.

The operation was repeated for 16 locations from 5 blocks randomely selected in the Danger Beel area (figure 9). Constant observation was made over the operators to determine the period through which an operator could work at a stretch at that particular lift height.

When the lift height exceeded four feet the discharge per strock reduced significantly. Farmers were very reluctant to introduce second stage. They only go for stages if it can not be avoided otherwise. The discharges of multistage 'dhone' system vary with time, position, lift hight and the efficiency of the operator.

b. Swing basket: For studying the characteristics of swing baskets, a straight bamboo was placed prallel to the water surface on the bundh. On both the sides of the bamboo the perpendicular distances of the water surface and field were measured. The distence of the water surface of the source was the actual height through which water was lifted. Analysis of data and plotting of curves were based on this distance. The defference of these two distances gave the actual height through which water was lifted and was taken as the effective height.

The discharge of the swing basket was collected in a large polythine bag and was measured with measuring container (9" x 9" x 13"). The volume of water contained in the swing basket when it was just filled was also measured. The difference between these two volumes gave the loss per stroke. The loss increased with the increase of lift height. When the operators continued to work, their performances for five minutes duration were recorded. The total time period over which an operatorworked continuously was also recorded.

c. Hand Tubewell(HTW): The hand tubewells are operated by man of various ages. Generally the farmers engaged all of their children over ten years old to operate

the HTW coninuously by turns. Some land owners engaged one or two wage labours to operate the HTW continuously.

The discharge of the HTW were measured by placing the measuring container under the discharge end of the pump. The number of strokes and time taken to fill the container were also recorded. The performances of the operators were recorded by counting the number of strokes in five minutes. Caution was taken to avoid the conscious of the operator.

Duration of pumping at a stretch and discharge obtained from a tubewell operated under different techniques, were recorded. It was operated by hand and also by leg, both in standing and sitting position. The performance of a ten years old boy was compared to that of an adult operator. In a tubewell block two boys sitting on a bench combindly operating a pump by legs were noticed.

The ground water table was recorded by measuring the depth of water table from a fixed point parallel to the ground in a well close to the HTW irrigation block.

CHAPTER - V

PERFORMANCE CHARACTERISTICS OF MANUAL WATER LIFTING DEVICES

5.1 Introduction

To study the performance characteristics of the 'dhone', swing basket and HTW, data collected from field were analysed. Curves had been plotted to see the effect of different parameters such as lift height of swing basket; lift height, shape and size of 'dhone'; age of hand tubewell and its technique of operation on discharge of each device. Curves and tables had also been prepared to show how time taken per stroke by each device varied with lift height. Water distribution system in HTW irrigation block was also observed.

In the following sections the performance characteristics of the devices are discussed in details:

5.2 Characteristics of 'dhone' Irrigation

The length of 'dhone' was found to vary from 150 inches to 210 inches. Longer 'dhones' were found suitable for higher lift height. The discharge end of the device was rectangular in shape with open top. The depth and width of the discharge end varied from 5 to 6 inches and 5 to 8 inches respectively and those of the intake end varied from 7 to 9 inches and 7 to 10 inches respectively. The bottom of the intake end was made

conical in shape to minimize the boyant force and both side walls were made concave to increasé the inside volume. The intake part was about 50 percent of the total length and slightly raised upward to increase ease of operation and to facilitate quick filling of the 'dhone'.

To study the effect of 'dhone' geometry on its performance discharges of seven different 'dhones' were plotted against lift height in figures 10-16. The intake and outlet sections and shape of 'dhone' were also shown in the figures. Seven curves thus obtained were superimposed in figure 17. Figure 10 shows discharge versus lift height curve of 'dhone' D-411. The 'dhone' was 195 inches long, the intake and outlet sections were 9" x 10" and 8" x 6" respectively. The side walls of the intake part was made concave to increase the intake volume. The first 100 inches from the discharge end was straight and the rest-portion was curved up. The total raise was 35 inches at the intake end with respect to the straight portion. As the intake part was curved upward, the effective intake arc length was reduced which increased the frequency and ease of operation.

The 'dhone' D-205 was similar to 'dhone' D-411, but it was straight. Its length was 195 inches, intake and outlet sections were 8" x 9.5" and 6" x 6" respectively. Shape and size of the 'dhone' was shown in figure 11. The discharges of those two 'dhones' (D-411 and D-205) at 36,38,40,44,48,52 inches lift heights were 91,93,85,72,74,50 gpm and 82,76,66,53,45,39 gpm

respectively. Thus the discharges of the curved 'dhone' D-411 compared to the discharge of straight 'dhone' D-205 at the above lift heights were 11%, 22%, 29%, 36%,42% and 28% higher. It may therefore be stated that curved 'dhone' had advantage over straight ones and the efficiency increased significantly with increase of lift heights even though there was an optimum height beyond which this tendency started falling. At higher lift haght the intake sections of both types of 'dhones' could not be filled up fully, consequently the discharges were less. At lower lift height initially curved 'dhone' contained more water than the straight one but during the upward movement of the intake section tne upper end of the curvature came out of water earlier and excess water spilled over the curved surface. As a result the discharges obtained from curved and straight 'dhone's at low lift height were closer.

The 'dhone' D-515 was also slightly curved. Its length was 176 inches, intake and outlet sections were 8" x 7" and 6" x 5" respectively (figure 12). It was shorter and total volume was less, but due to curvature its discharge was significantly higher. The performance of D-515 can be compared to that of D-104 whose length was 193 inches, intake and outlet sections were 7" x 7" and 5.5" x 5" respectively (figure 13). The former was slightly curved and intake part was larger. Comparing these data it might be concluded that curvature and volume of intake section were two important parameters for increasing the efficiency of 'dhone' irrigation system.

The performance characteristic of the smallest 'dhone' (D-516) used in study area was plotted in figure 14. The length of the 'dhone' was 140 inches, intake and outlet sections were 7" x 7" and 5" x 4" respectively. The curve obtained by plotting the discharge against lift height for the 'dhone' was steeper. Though at lower lift height its discharge was higher, with the increase of lift height discharge decreased very rapidly. Since it was short and weight of water lifted in each stroke was less, a higher frequency of operation was obtained at lower lift height. At 20 inches lift height its frequency was 12 strokes per minute whereas at 30 inches lift height frequency was 8 strokes per minute. In case of longer 'dhone' the number of strokes was between 6 to 7. Comparison of frequency of operation of longer and shorter 'dhones' at various lift heights shows that range of suitable lift height increases with length of 'dhone'.

D-104, D-102, D-206 and D-516 all were straight 'dhones'. The intake end of straight 'dhone' was required to be lifted higher for complete discharge of the lifted water. Similarly the intake end was required to be pushed deeper into the water to fill the 'dhone'. Ultimately effective arc length of swing was increased. For such type of operation the operator had to sit on the platform and extend his leg to push the 'dhone' into water. Then he had to rise-up to operate the 'dhone'. This consumed much time and decreased the frequency. Thus the operation became trouble some. This was the reason for the low

discharge of the longer 'dhone' D-104 compared to the shorter 'dhone' D-516 at relatively low lift height (with in 30 inches). Discharge - lift height characteristics of 'dhones' D-102,D-104, D-206 and D-516 thus shows that for low lift height shorter 'dhones' are suitable.

To have a comparative idea about discharge lift height characteristics of 'dhones' of different sizes and shapes figure 17 was plotted. Figure 17 clearly shows that at constant lift height discharge of a 'dhone' is a function of both intake section and curvature of the 'dhone'.

Total number of strokes achieved by the operator in a specified time period directly controls the discharge. Thus to study the effect of 'dhone' size on discharge and time taken per stroke at a constant lift figure 18 was plotted. Figure 18 shows that while discharge increased with 'dhone' size, the time per stroke remained constant in contrary to the expected trend. This may however be explained as follows.

Due to the greater self load of bigger 'dhone' the operator of the bigger 'dhone' had to apply more energy per stroke than the operator of the smaller 'dhone', and as a result the operator of the bigger 'dhone' became tired within a very short period. To avoid this trouble the farmers used to employ strong labours to operate the bigger 'dhone' and thus labours were distributed according to their ability. For this reason for the

same lift height the observed values of time taken per stroke in operating 'dhones' of different sizes were found more or less constant (figure 18). Had the same labour been asked to operate the 'dhone' of different cross-section, it might have been found that the time taken per stroke was directly proportional to size of the 'dhone'. The curvature at the intake part of the 'dhone' also had a significant role on the discharge.

Figure 19 shows discharge lift height characteristics of single, double abd tripple stage 'dhones'. It may be mentioned here that multistage i.e., more than one stage curves were the summation of single stage systems operated in different stages of lift height. Average time taken per stroke versus lift height curve for 'dhones' was also included in figure 19. Curve for single stage lifting shows that for 54" lift height discharge was about 32.6 gpm. Under this condition two units side by side would give a discharge of 65.2 gpm. The curve for double stage lifting shows that for 54" lift height discharge was more than 110 gpm. Careful analysis of the curves of figure 19 thus shows that for better efficiency one should go from single stage to multistage system when certain maximum lift height is exceeded.

In the 'dhone' irrigation system studied, lift height varied from 20 inches in single stage to 140 inches in four stages. Generally the farmers went for next stage of lifting when the lift height exceeded 50 inches. Though with longer 'dhone' water could be lifted from lower level but discharge and frequency

would have decreased significantly. The range of lift height for 'dhone' of length 200 inch and 150-200 inches were 40-48 inches, and 36-40 inches respectively. The maximum lift height for single stage was found to be 54 inchees at which average discharge was 35-40 US gallons per minute (about 0.08 cusec). The time taken per stroke was increased with the increase of lift height (fig.19). Lift height of the upper stages fluctuated with the discharge of the preceding one. The farmers made an artificial ditch to reserve the water delivered from the preceding one by digging a trench of about 5' x 2' x 4' size and encircling the same by a bundh of about 3 feet height.

To compute the average discharge over a complete working day under normal operating condition of an average sized 'dhone' the performance of a semi-skilled operator was considered. The maximum power could be maintained for a period of 15 minutes of quick and continuous operation and thus the discharge obtained was about four time higher than that obtained over a complete day under normal operating condition. The discharge obtained within 30 minutes of quick operation period was about double than the average discharge. So during data collection, precautions were taken to have the average normal valve. It was observed that generally the operators discontinued their work after half an hour and took rest for a period of 5-7 minutes. The ability to continue the work without any rest was about 5-6 hours. But in that case performance decreased significantly.

Discharge per stroke of 'dhone' varied inversly with the lift height. At 20 inches lift height discharge per stroke was found to be 12.30 US gallons and at 54 inches it was 6.30 US gallons. At different positions of multi-stage system discharge per stroke did not vary, in other words discharge per stroke was independent of position and dependent mainly on lift height and cross-section of the 'dhone'.

Performance of a 'dhone' also depends on various other factors such as volume of 'dhone', mechanical advantage of the lever, weight of the counter balance, height of the hinging point from the ground, energy applied and its technique of application.

In bringing down the 'dhone' for filling, the counter weight may be balanced by body weight of the operator. For this purpose heavier counter weight can be placed on the discharge side of the lever. The intake and out-let side ratio of length of the lever is generally 4:1. In other words the mechanical advantage of the system is about 4. During upward movement of the lever to lift the 'dhone' out of water the pull of the operator is aided by the downward force of the counter weight. If a counter weight of 200 lb is raised by 1 ft. then, during its downward motion 50 lbs (0.8 ft^3 or 6 US gallons) of water will be raised by 4 ft. above the water surface. The muscular energy of the operator helps even to lift more water.

The discharge of a 'dhone' can be appreciately improved by modifying its design. Till now the use of 'dhone' have not been affected significantly due to introduction of diesel operated low lift pumps.

5.3 Characteristics of Swing Basket Irrigation

The cross-section or shape of swing basket was a hollow cone. It's volume was a function of the length and width of the mat or G.I. Sheet by which it was made. Generally farmers used a 20-22 inches square mat or G.I.Sheet. If the volume was increased it would become difficult to operate and the operators would become exhausted within a short period. The average volume of a swing basket was found to be 1.55 U.S.gallon. The discharge per stroke varied from 1.41 to 1.02 US gallon at lift heights of 31 and 57 inches respectively. This implied that loss per stroke increased with the increase of lift height. At 31 inches lift height loss per stroke was about 9 percent of total volume of the swing basket and at 57 inches lift height it increased to 34 percent. When the lift height exceeded 60 inches the loss increased to more than 50 percent as was observed in case of a swing basket made of bamboo mat. At higher lift, lift, duration of operation also shortened.

The discharge of a swing basket varied from 41.31 US gallon per minute (0.092 cusec) to 19.76 US gallon per minute (0.044 cusec) at lift heights of 31 inches and 57 inches respectively (fig. 19). Optimum Lift height of the swing basket was also

similar to that of 'dhone' and the stage was changed at every 50 inches. But the loss in lifting water was comparatively higher compared to that of 'dhone'.

Time taken per stroke of swing basket varied from 2.04 seconds to 3.33 seconds. This variation of time was due to variation of lift height and strength of the men operating the device.

For swing basket average period of work done at a strech was 15-20 minutes. Since all the weight of water was supported by the operators they became fatigued within a short period. Perhaps this is the most laborious irrigation method practised in Bangladesh.

5.4 Characteristics of HTW Irrigation

In HTW all pumps were set with 1.5 inch diameter G.I.pipe. At larger diameter discharge might increase slightly but the initial cost would increase tremendously. Farmers generally use No.6 hand pump for irrigation. The bore and stroke of No.6 pump are 4 and 9 inches rospectively. The displaced volume is 113.14 cubic inch (0.49 US gallons). The plunger consisted of a one way valve and a bucket generally made from leather or plastic. The leather buckets are more durable but comparatively more expensive than plastic bucket. According to the information available for one cropping season generally two leather buckets or six plastic busket are required.

The discharge of HTW varied with different factors such as depth of groundwater table, condition of the pump, strength of the operator, condition of the aquifer, system of operation, age of the pump etc. In the study area, pumps, of various ages were located and their relative performance were studied (Table III). As can be seen from the table, discharge from a HTW decreased with aging and after five years of continuous operation the discharge at a given water table reduced to more than half. At 10' depth the discharge of a new HTW was 19.98 gpm. and that from a 5 years old one was 9.0 gpm. At higher depth similar trend was also observed.

Another notable feature of HTW discharge as evident from the table was the decrease of discharge with increase in water table depth. This decrease of discharge with depth of water table was more for new HTW than for old ones. This observation suggests that relatively new hand tubewells should be used for lifting water from relatively less depth.

Figure 21 shows that the discharge of HTW decreased proportionately with depth of ground water table. There was considerable difference in the elevation of ground water table between the begining and the end of the irrigation season. When the depth of ground water table became more than 18 feet, the pump with 20 feet suction pipe discharged fine sand with water due to partial suction on sand layer and consequently discharge decreased. At that stage pumps with long suction and single strainer (7 feet)

might be used. Consequently initial cost would increase and the discharge also would decrease. Decrease of discharge with the increased depth was comparatively greater in the new tubewells than the old ones. This was due to roughness of the inner surface of the new pipe which increased the frictional loss.

In case of a new HTW discharge per stroke varied from 0.253 US gallon to 0.198 US gallon for the range of depth of ground water table between 10 ft and 18.25 ft. In case of five years old HTW discharge per stroke varied from 0.217 US gallon to 0.114 US gallon for the same range of depth of ground water table. Thus the percentage decrease of discharge per stroke with lift height was found to be more in case of new HTW than old HTW.

Time taken per stroke in HTW varied from 0.60 second to 1.43 second. Number of strokes varied from 500 to 209 in five minutes. Time taken per stroke greatly depended upon stroke length. When the operator completed the stroke from top to bottom it required more time and the discharge per stroke was higher. The operators always tried to increase the number of strokes per unit time but in most cases the strokes were only a fraction of a complete stroke. It may be concluded here if that the strokes were completed fully instead of partial completion the discharge of the pump would increase and the operator would be able to continue the work at a stretch for a longer period.

Figure 22 shows the work done at a stretch in operating HTW under different conditions of operation at 15 feet depth of ground water table. It was found that the pump operation by hand, sitting on a bench, was suitable for quick operation having more discharge rate. Work done at a stretch was however minimum for this type of operation. On the other hand operation of the pump by leg, sitting on a bench, was more convenient and the operation period was 2.4 times more compared to the operation period of a hand operated tubewell. When two boys operated the pump by leg, sitting on a bench, the work done at a stretch was found to be the maximum.

The energy obtained for operation by leg is generally higher than hand. So a higher total discharge was obtained from the same tubewell when it was operated by leg and this higher total discharge was due to longer operation period.

Mechanical advantage of the lever used in hand tubewell is about 4 to 1. Improvement may be obtained by extending the handle for greater mechanical advantage but this can not be done out of certain limit. As distance from the fulcrum to the handle will increase the radius of arc swept by the end of the handle will also increase Too large an arc will make the operation difficult.

To minimize the conveyance loss the HTW was dug about at the middle of the field. Channel were made on the 'ail' and slope was maintained. Water distribution system in hand tubewell irrigation block was shown in figure 23.

5.5 Labour Requirement for Various Manual Irrigation Systems.

Optimum or standard labour requirement data is essential for considering the economy of the irrigation system for the particular cropping pattern. This data is also valuable for estimating employment effects of specific crop production strategy or alternatives and for determining employment targets. The individual farmers in the area were contacted to collect data for labour requirement per acre for each operation of various types. Average data for a smaple of 30-40 farmers were taken. This value were treated as the labour requirement per acre. It is very difficult to find the actual labour that was put up for a particular purpose.

Operation wise per acre labour requirements for different irrigation system were shown in table IV. The labour requirement for mechanised irrigation system was minimum. For 'dhone' irrigation system per acre labour requirement was about double and for HTW and swing basket irrigation systems it were four times than the mechanised irrigation. Part of the total labour required for each system of irrigation was hired (casually or seasonally). Since the coverage of mechanised LLP's were big a large number of labourers were required to prepare the field. It was observed that HTW operation required minimum hired labour because of the scale of operation and mostly family labour was used.

CHAPTER - VI

CONCLUSIONS AND RECOMMENDATIONS

Various manual water lifting devices used for irrigation in Bangladesh have been studied and their relative economy with mechanised divices have been compared. Based on the study the following conclusions and recommendations are made:

Irrigation by indigenous means like 'dhones', swing baskets etc., may be practised in logical way in order to utilize huge human resources available in the rural area for fruitful and productive purpose. Effective and improved local methods might lead to reduce dependence on imported technology.

The use of mechanised irrigation devices may be managed to extend irrigation coverage by practising manual methods of irrigation properly. LLPs may be restricted where lift height is less than 10 feet. 'Dhones' may be conveniently used for such lift height. The borrowpits may be developed and fed by mechanised devices of greater capacity so that farmers can irrigate their fields by 'dhone'.

From the performance characteristics of curved and straight 'dhones' it was observed that curved 'dhones' had advantage over straight ones and the efficiency increased significantly with increase of lift heights even though there was an optimum height beyond which this tendency started falling.

From an overall study of performance of different 'dhones' it was concluded that curvature and volume of intake section were two important parameters for increasing the efficiency of 'dhone' irrigation system. It was also observed that range of suitable lift height increased with length of 'dhone'. For low lift height shorter 'dhones' were suitable.

Performance characteristics of single and multistages 'dhones' showed that for better efficiency one should go from single stage to multistage system when certain maximum lift height is exceeded.

To reduce the time of filling the intake section of 'dhone' and to increase the case of operation it is suggested that a 'one way valve' be introduced at the bottom of the intake part. On introduction of such a valve, selection of suitable curvature for the intake section may not be required.

Very large sized 'dhone' may be avoided as the excess weight of water will require heavy counter weight on the other part of the lever and this may cause crack or vibration of the lever. Considering the energy obtained from human body for long term operation to be 75 watts., optimum volume of intake part is about 3 cubic feet.

'Dhones' should be operated in shorter lift height, preferably within 3 feet. It has been observed that farmers are generally reluctant to introduce additional stage to avoid the

extra labour cost associated with the stage. They continue until water is available at that stage regardless of quantity of water lifted. But the present study shows that the discharge can be increased by introducing a second stage instead of operating single stage at a lift height of more than 3 feet.

For lift height with in 3 feet a 'dhone' can irrigate about 5 acres. The total cost of labour for the operation of such a 'dhone' is estimated to be Tk. 1,600. The value of the increased grain production would be about Tk. 1,500 x 5 = Tk. 17,500. The comparison of operation cost and value of increased production suggests that if the lift height is even more than 3 feet, double or tripple stage 'dhone' may be suitably used for irrigation economically.

The use of swing basket may be discouraged for the fact that for a swing basket the loss is generally higher and it increases with lift height. It is also labourious method as the whole weight of water is borne by the operators directly.

HTW may be used in the area where maximum depth of ground water table remains within 15 feet. For better efficiency new HTW may be used for shorter depth of ground water table and old HTW may be used for deeper depths. Hand pumps in use for more than five years have very low efficiency (Table-III). The operators generally try to increase the number of strokes to have better

discharge but in such cases strokes are not complete. During the suction stroke if the piston is swept from bottom to top of the cylinder bore, discharge and ease of operation are increased. So in operation of hand tubewell precaution is to be taken to complete each stroke.

To minimise the conveyance loss HTW may be installed at the centre of the plot and slope is to be maintained in the channel. Bark of banana plant may be used in the channel near the HTW to minimise seepage and percolation losses.

For better efficiency HTW may be operated by leg as it has been evident from the study that the energy obtained for operation by leg is generally higher than hand.

From cost estimates (as shown in table - II) it is observed that 'dhone' method of irrigation has the lowest cost of water per acre-inch and also in terms of per acre coverage. The cost effectiveness of swing basket is not much favourable.

Based on the observation of present study it is recommended that the following studies may be made for development of manual methods of irrigation:

a. Effect of one way valve in the intake section of 'dhone.'

b. Performance of 'dhone' with change of volume of intake section, curvature and length of the 'dhone'.

c. Suitability of different materials for construction of 'dhone'.

d. Similar study may be taken up for other localities to study the use of 'dhone' in other places.

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TABLE - I

SOME CHARACTERISTICS OF VARIOUS METHODS OF IRRIGATION IN BANGLADESH

(SOURCE: PLANNING COMMISSION)

Water Source	Surface water				Ground water			
Methods	Gravity canal	Low Lift Pump	'Dhone'	Swing basket	DTW	STW	HTW	Dug well
1	2	3	4	5	6	7	8	9
1. No.in operation (upto June,1981)	-	36,348	-	-	10,132	36,622	1,53,000	-
2. Area irrigated in thousand acres	254	1,400	962[1]	171[1]	619	406	46	452[1]
- in percentage	5.89	32.48	22.32	3.97	14.36	9.42	1.08	10.49
3. Discharge in cusec	-	2.0	0.257[2]	0.092[2]	2.0	0.6	0.044	0.021
4. Pumping height in ft.	0-30	0-20	0-4.5[3]	0-5[3]	More than 30	0-20	0-20	0-15
5. Source of Energy Diesel/Electric/ Manual	D/E	D/E	M	M	D/E	D/E	M	M
6. Working life in years	-	10	5	2	10	10	5	3
7. Command Area in acres	-	40	4-5	1-2	40	10	0.60	0.30
8. Capital Cost in Taka	2,900	37,934	400	30	2,81,500	23,840	1,600	200
9. Direct O&M cost in Tk.	350	23,718	1,600	3,200	31,368	10,390	1,680	1,600
10. Indirect O&M cost in Tk.	220	4,800	-	-	5,510	2,300	200	-
11. Total Cost per acre in Tk.	2,970	1,124	553 (88)	2,064 (217)[4]	2,406	1,446	4,999[4] (1,318)	-

TABLE - I (Contd)

1	2	3	4	5	6	7	8	9
Public Sector allocation in Million Tk. in SFYP 5/	12,440	2,270	Nil	Nil	4,980	1,450	140	Nil
	54.09%	10.00%			21.65%	6.30%		
in FFYP	3,095	740	Nil	Nil	1,740	210	-	Nil

1/ Coverage by mechanical methods upto June 1981 were quoted from Planning Commission. Since systematic data for coverage by traditional methods are not maintained in Planning Commission, data quoted from 1980 statistical year Book of Bangladesh. Coverage by other traditional methods was placed under dug well.

2/ Maximum discharge

3/ Lift hight for single stage. Head can be increased by adapting multistage.

4/ Assuming 40 inches water requirement for dry season paddy. Figures in the parenthesis indicate the cost considering 10% (e.i. 80 hrs) hired labour and balance 720 hours of family labour at no financial cost.

5/ An amount of Tk. 400 million has been provided for command area development and Tk. 100 million for traditional methods.

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TABLE - II

ESTIMATED COST OF WATER USING DIFFERENT TYPES OF IRRIGATION EQUIPMENTS

Source: BADC, June 1981 (800 hours/year)

Item of Cost	STW(6 hp) 0.6 cusec 100 ft	DTW(22 hp) (2 cusec (210 ft)	LLP(12 hp) 2 cusec	HTW(2 pipe 10 US Gall/ min.	'Phone' 0.155 cusec	Swing basket 35 US Gall/ min.
1	2	3	4	5	6	7
1. Capital cost	23,840	2,81,500	37,934	1,600	400	30
2. Annualized cost[1]	4,658	40,133	7,445	347	114	18
3. Direct O&M cost						
a. Pay of Manager		3,000	3,000	-	-	-
b. Pay of Operator	2,400	2,400	2,400	1,600	1,600	3,200
c. Diesel[2]	6,072	18,400	13,800	-	-	-
d. Oil	950	2,880	2,160	-	-	-
e. Spareparts[3]	468	3,188	1,358	80	-	-
f. Channel maintenance	500	1,500	1,000	-	-	-
Sub-total:	10,390	31,368	23,718	1,680	1,600	3,200

1	2	3	4	5	6	7
4. Indirect O&M costs						
a. Salaries and allowances of BADC staff	1,000	2,500	2,000	100	-	-
b. Depreciation of Buildings and structures	200	200	250	30	-	-
c. Maintenance of strufture	50	50	50	10	-	-
d. Depreciation of workshop equipments	250	400	300	-	-	-
e. Interest(Govt. & Foreign)	500	1,560	1,700	50	-	-
f. Miscellaneous	300	800	500	10	-	-
Sub-total:	2,300	5,510	4,800	200	-	-
5. Total O&M cost	12,690	36,878	28,518	1,880	1,600	3,200
6. Total annual cost	17,348	77,011	35,963	2,227	1,714	3,218
7. Total cost per acre inch	36.14	60.16	28.10	124.97	13.82	52.60
8. Cost per acre 4/	1,446	2,406	1,124	4,999 (1318)	553 (88)	2,064 (217)
9. Pumping height in ft.	0-20	more than 30	0-20	0-20	0-4.5	0-5

1/ Taken from the equipment wise calculation in appendix B.
2/ Fuel consumption of DTW, LLP and STW were assumed to be 1 gall/hr, 0.75 gall/hr and 0.33 gall/hr respectively, oil consumption was assumed to be 3% of fuel consumption.
3/ Assuming 4% of engine value and 1% of pump value.
4/ Assuming 40 inches water requirement for HYV paddy. Figures in the parenthesis indicate the cost considering 10% i.e., 80 hours hired labour and balance 720 hours of family labour at no financial cost.

TABLE - III

REDUCTION IN DISCHARGE OF HTW WITH INCREASED DEPTH OF GROUND WATER TABLE

HTW No.	Usage (Year)	Discharge at 10' gwt gpm	Discharge at 18.25' gwt gpm	Depth of gwt. in%	Reduction in discharge due to increased Usage: for 10' depth in %	for 18.25 depth in %	Average in %
706	New	19.98	14.02	29.83	-	-	-
705	1	16.51	12.03	27.14	17.37	14.19	15.78
708	2	16.07	11.95	25.63	19.57	14.76	17.17
702	3	13.15	10.61	19.32	34.18	24.32	29.25
703	4	9.39	8.19	12.78	53.00	36.52	44.76
701	5	9.00	8.00	11.11	54.96	42.94	48.95

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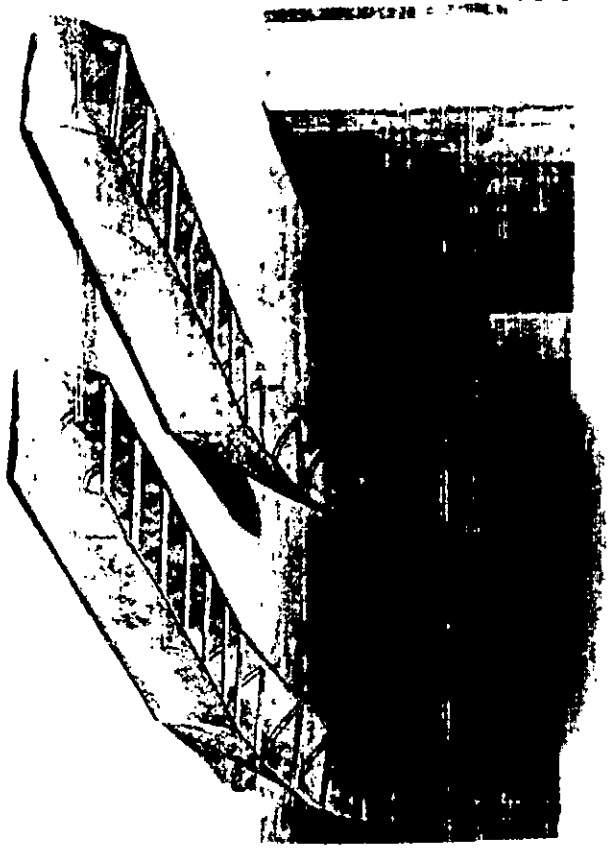
TABLE - IV

OPERATION WISE PER ACRE LABOUR REQUIREMENT FOR IR-8 UNDER DIFFERENT IRRIGATION SYSTEM.

Operations	Man days per acre			
	For Macha-nized irri-gation	For HTW irriga-tion	For 'dhone' irrigation	For Swing basket irri-gation
Land preparation	16	16	16	16
Ails & Drain making	5	4	4	4
Fertiler & Manure application etc.	4	4	4	4
Seedling uprooting & transplanting	14	14	14	14
Weeding	10	12	12	14
Irrigating	5	240	80	190
Spraying	1	1	1	1
Harvesting, carrying	14	14	14	14
Threshing	4	4	4	4
Drying, String etc.	5	5	5	5
Total:	78	314	354	306
% of hired labour required	60	25	40	50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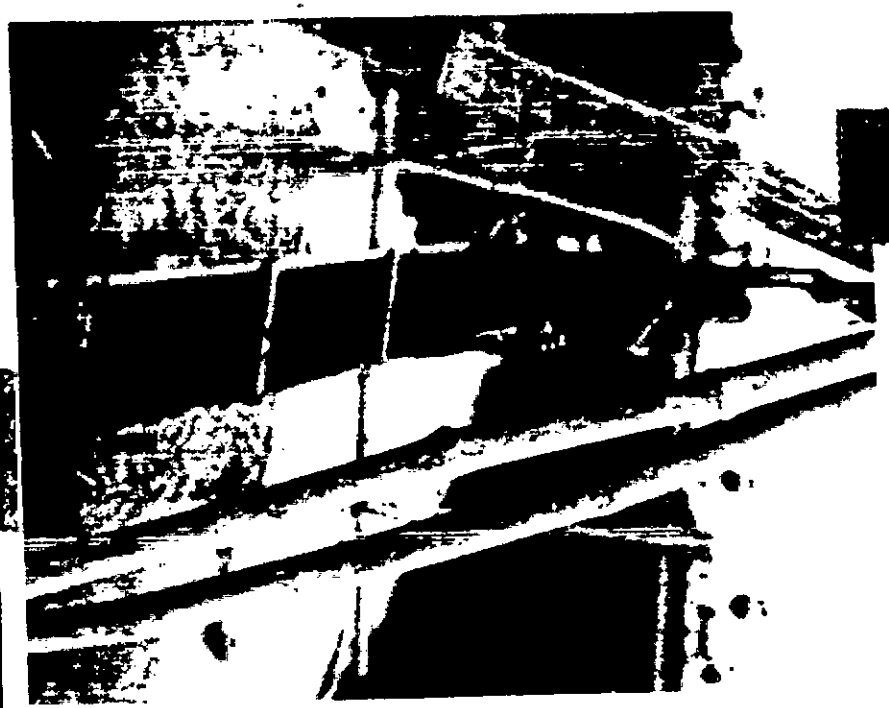


Figure No.2 Photograph of swing basket

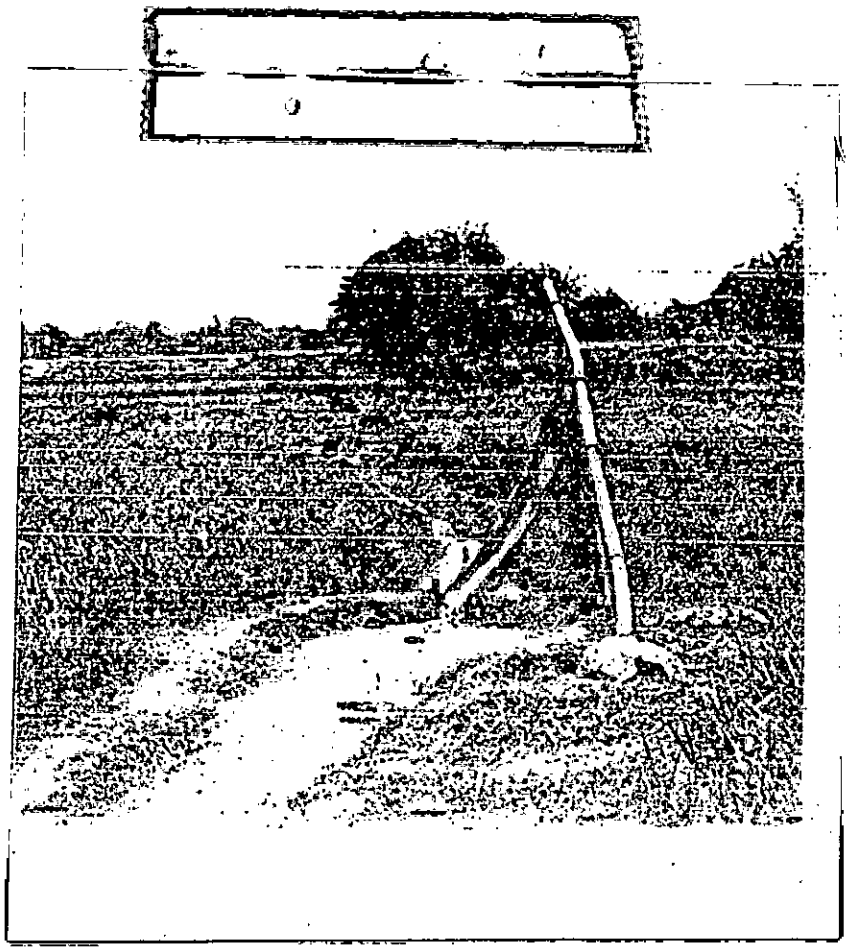


Figure No.3 Combined operation of 'dhone' and swing basket in stages

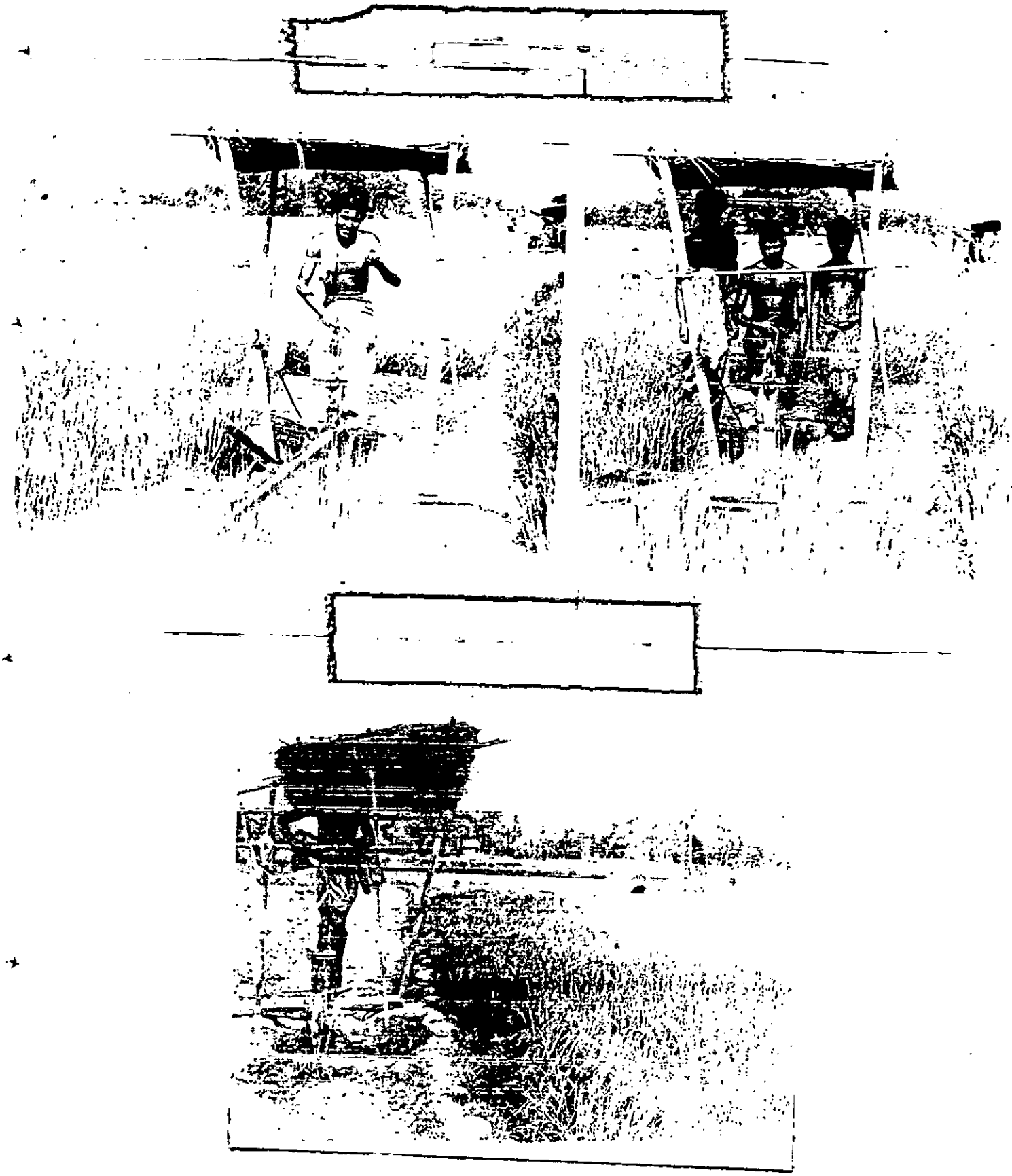


Figure No.4 Photograph of hand tubewell operation

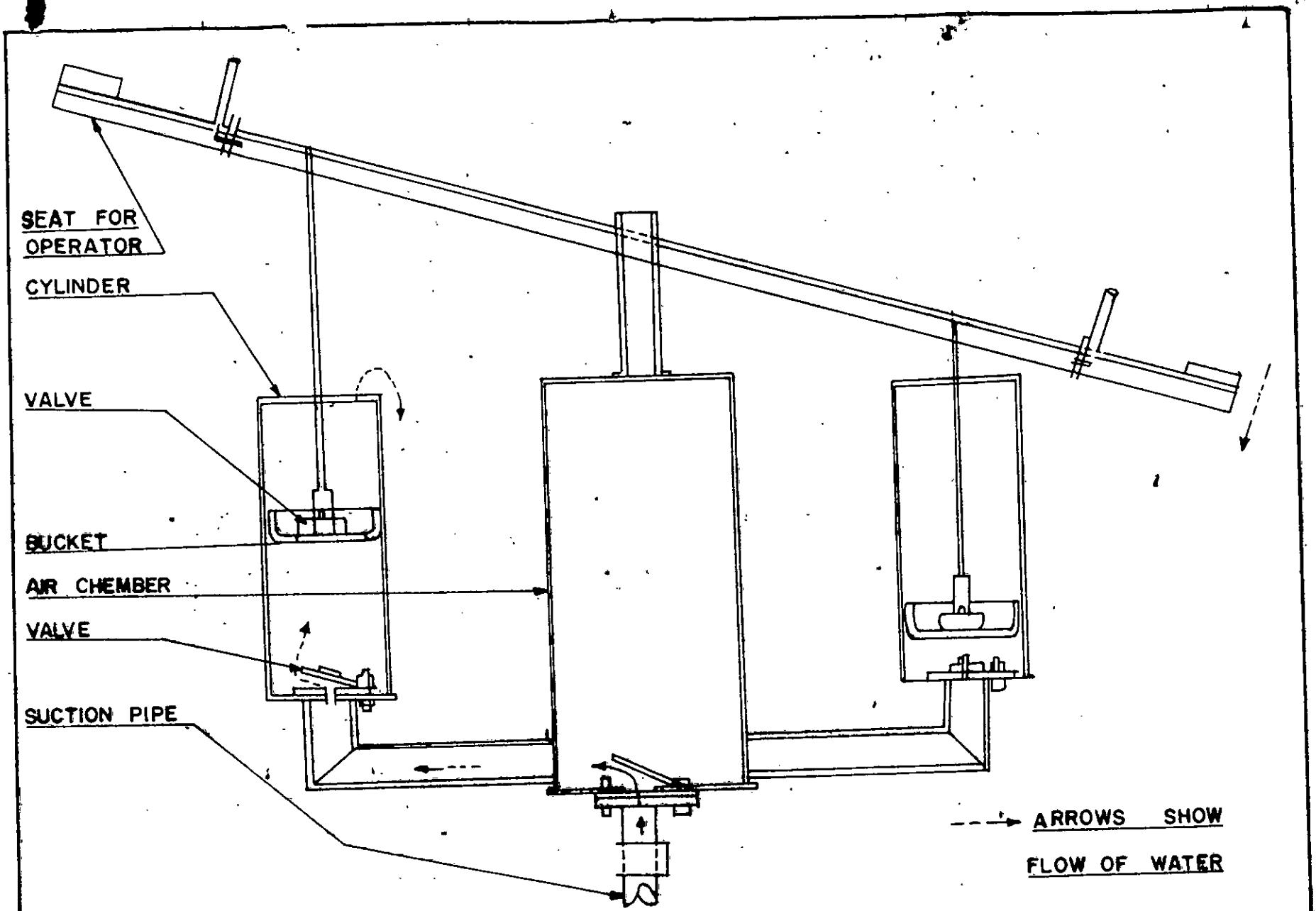


FIG. 5. SKETCH OF A 'SEE-SAW' PUMP

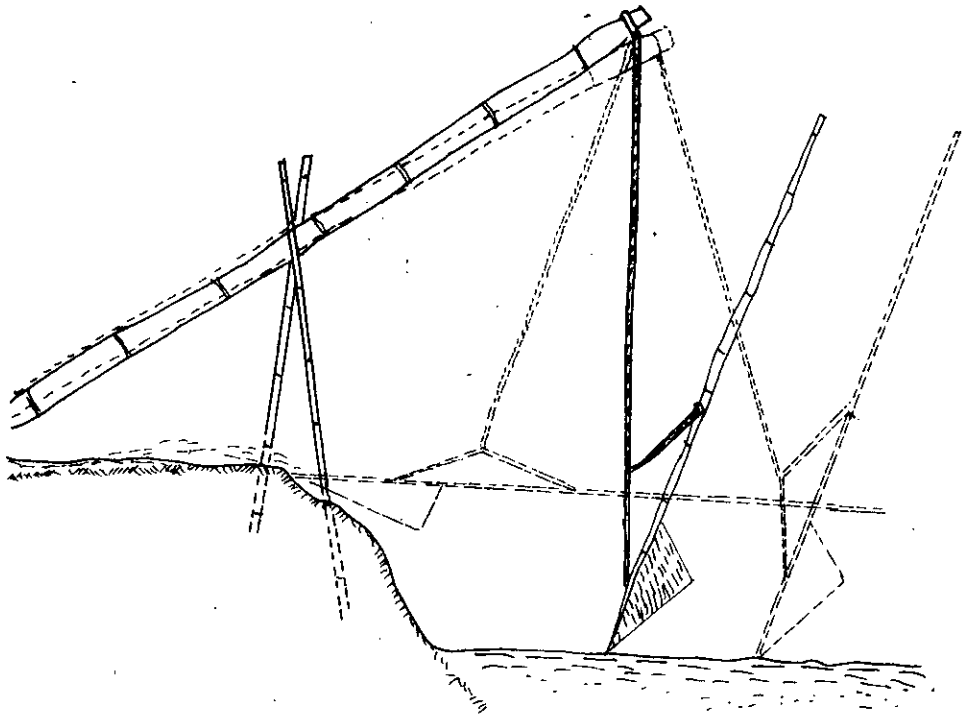


FIG. 6 SKETCH OF A SCOOP (SUSPENDED SHOVEL)

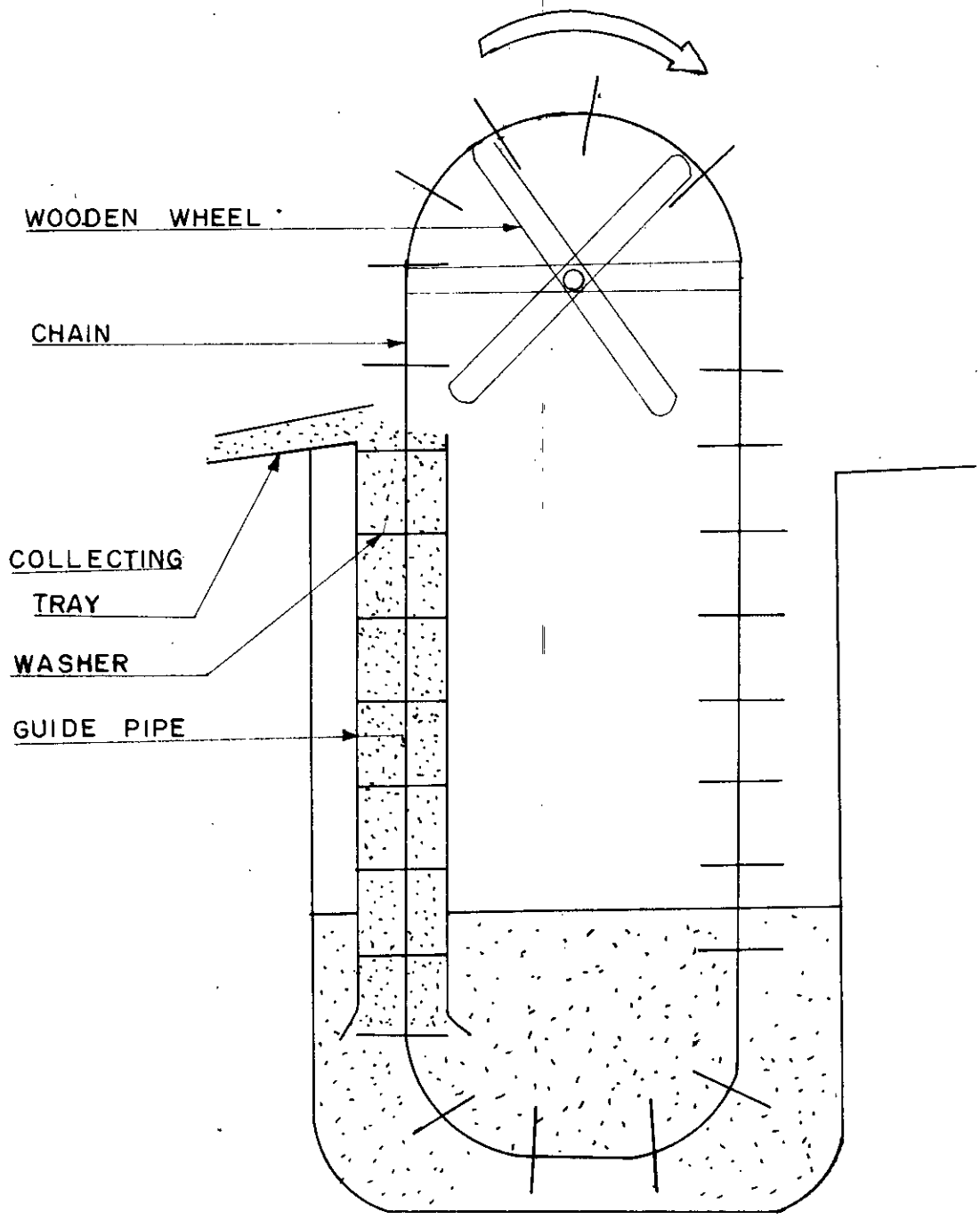


FIG. 7 SECTION OF A CHINESE CHAIN AND WASHER PUMP.

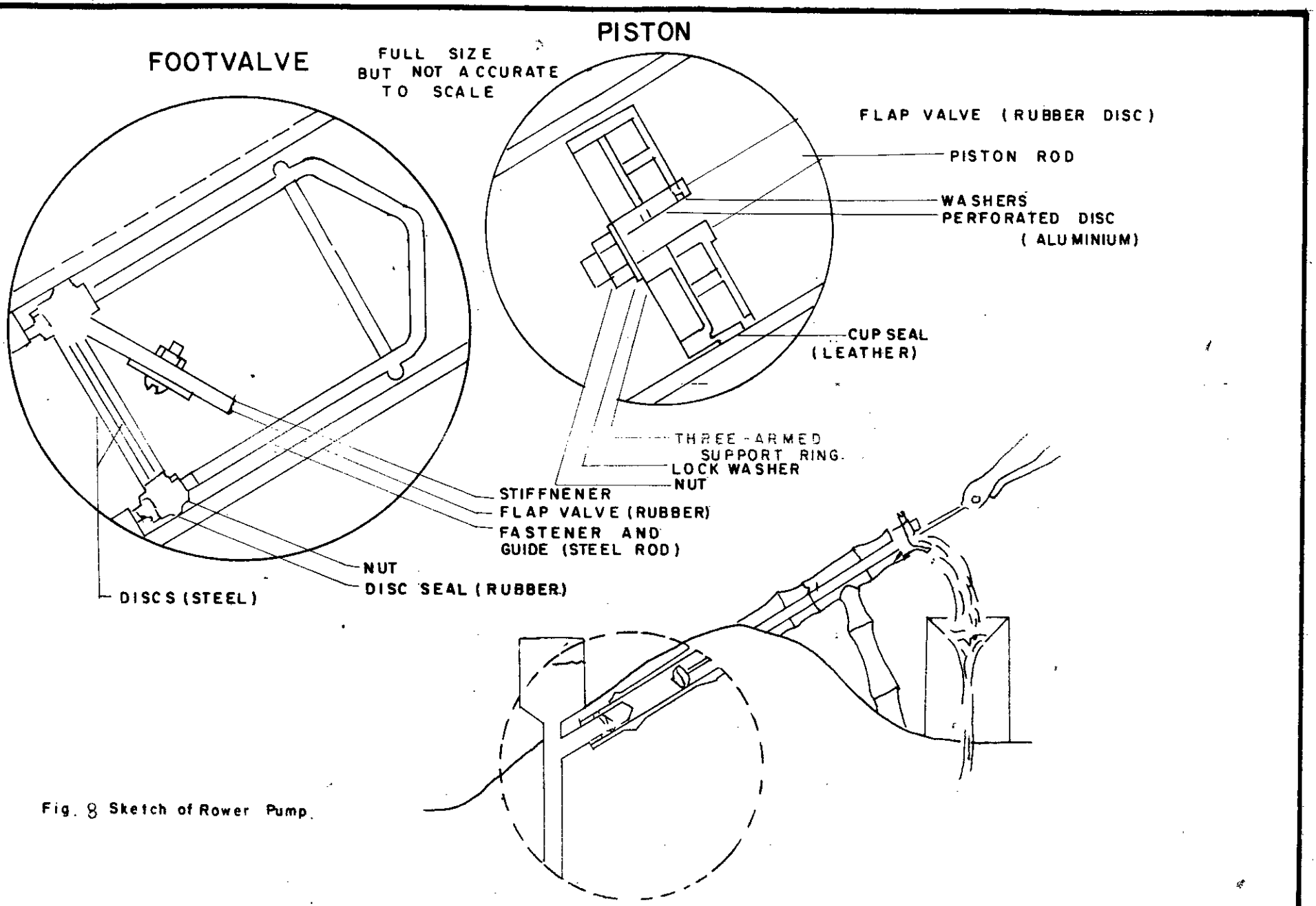


Fig. 8 Sketch of Rower Pump.

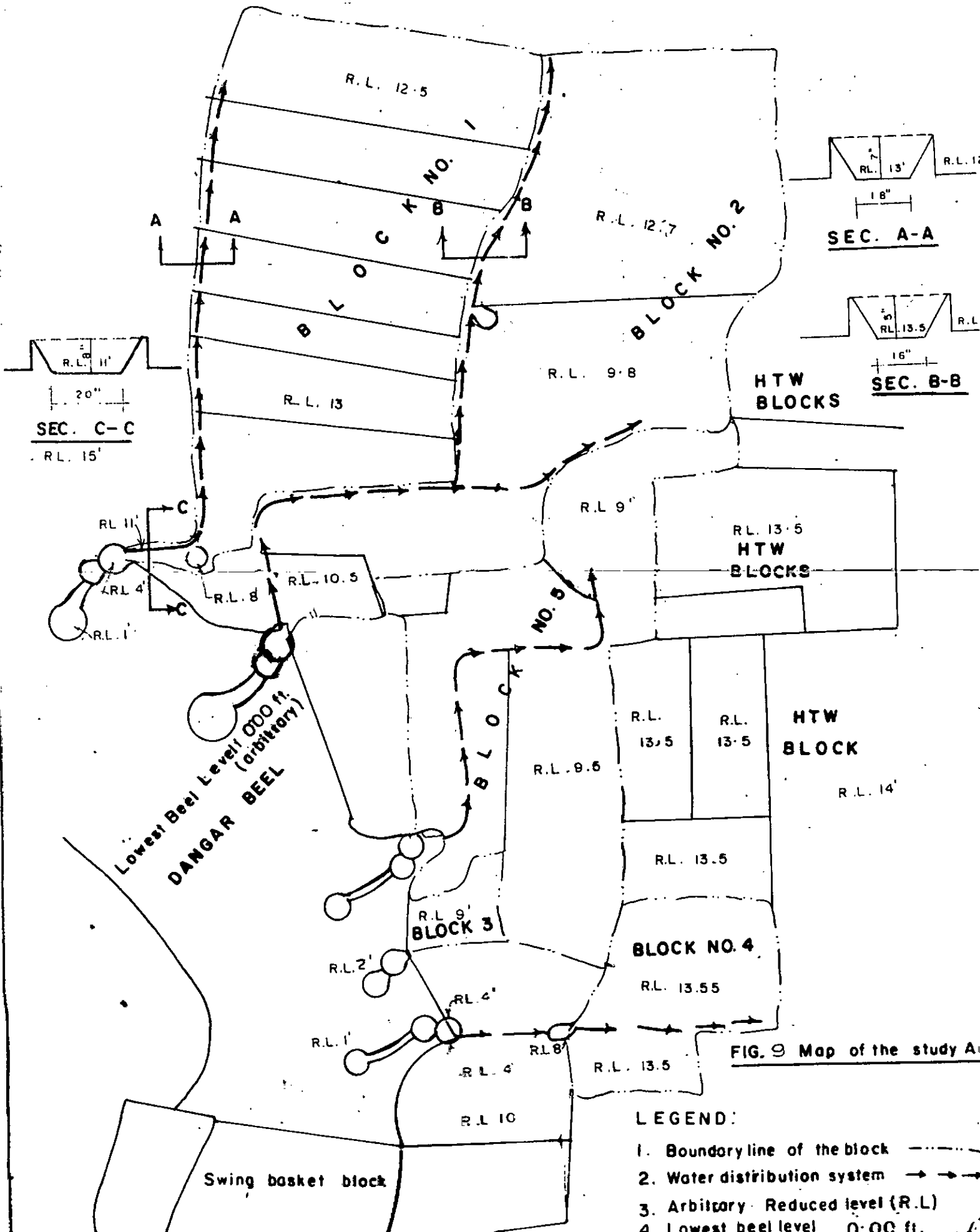


FIG. 9 Map of the study A

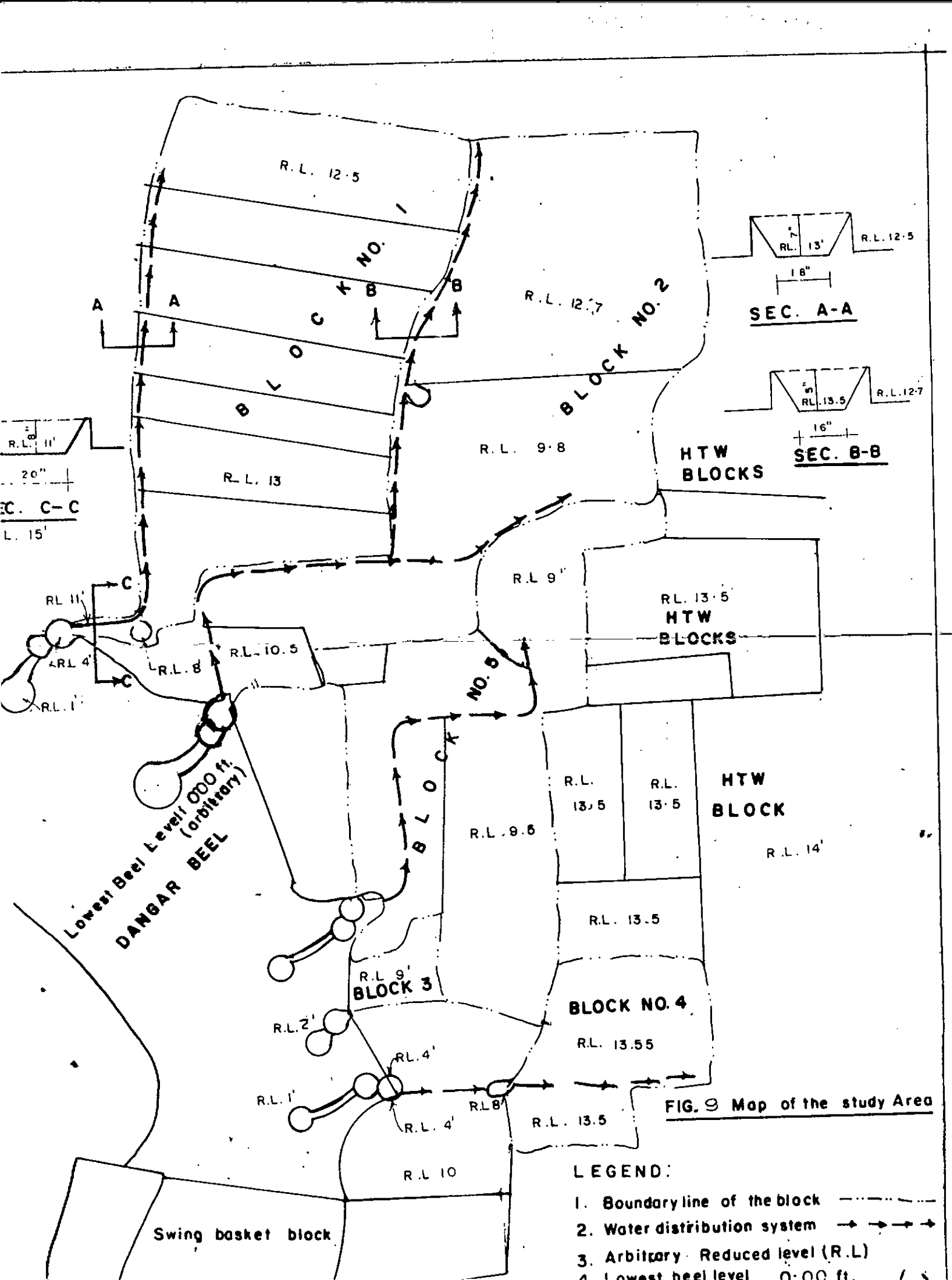


FIG. 9 Map of the study Area

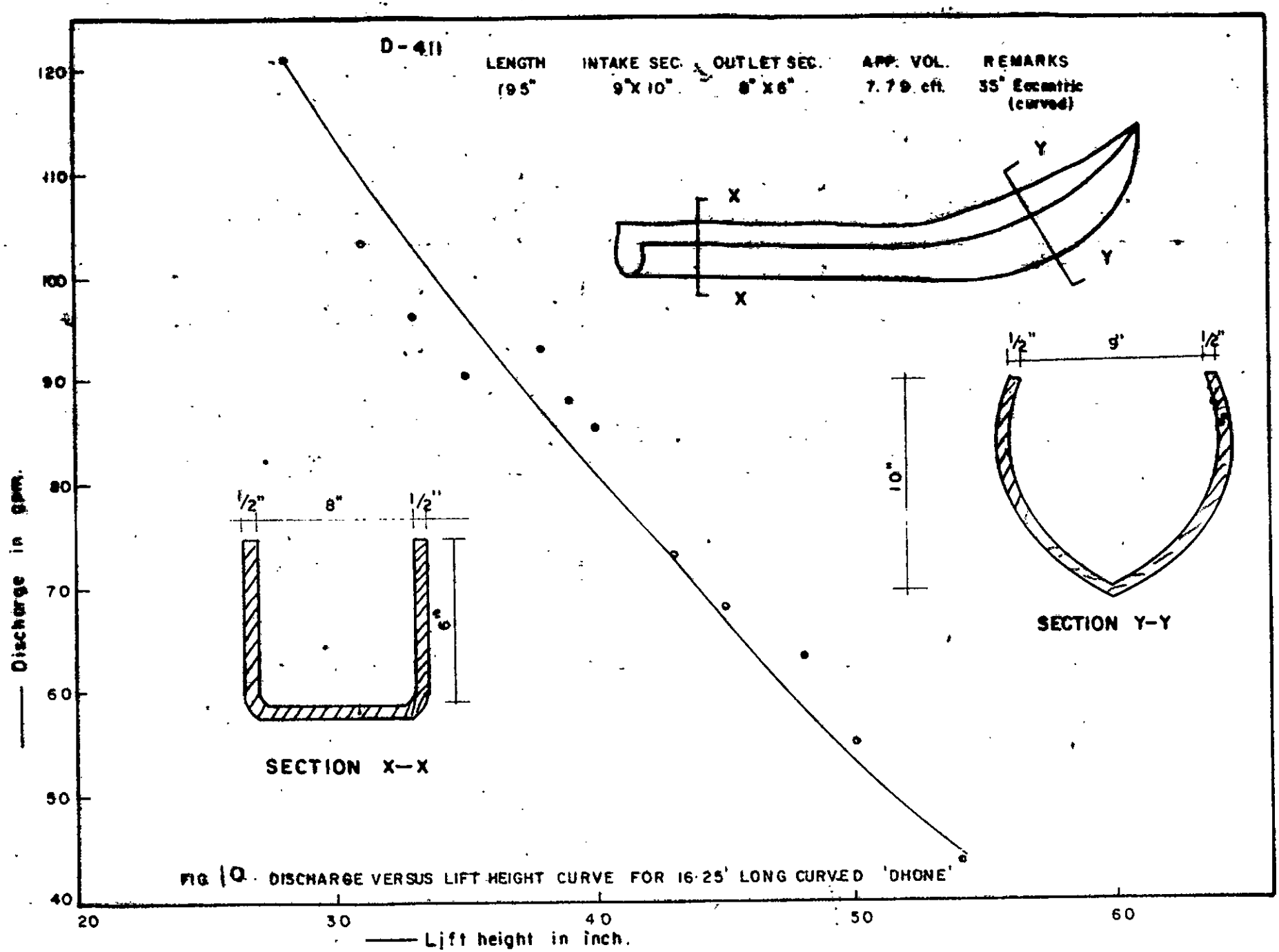


FIG 10. DISCHARGE VERSUS LIFT HEIGHT CURVE FOR 16·25' LONG CURVED 'DHONE'

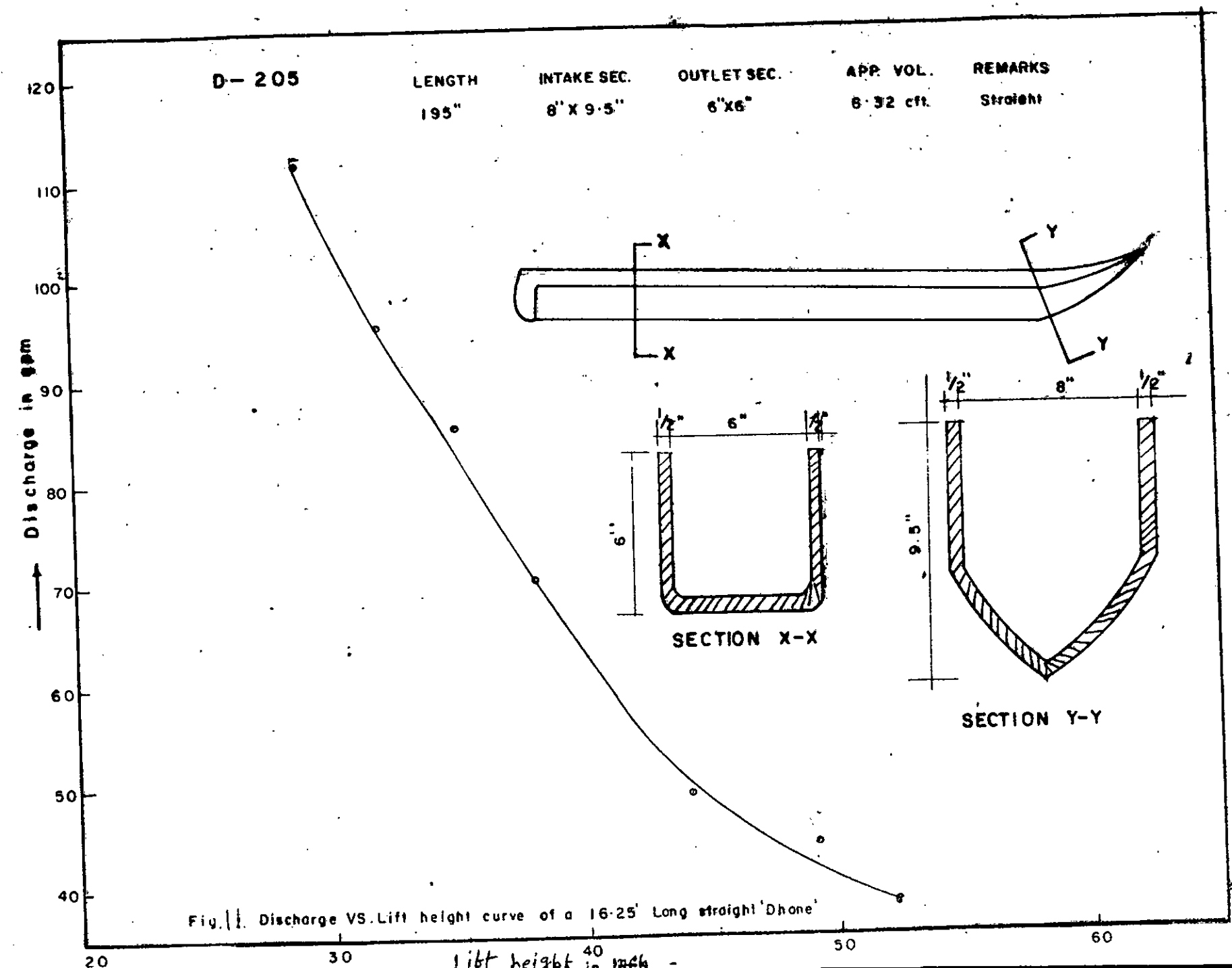


Fig. 11. Discharge VS. Lift height curve of a 16·25' Long straight 'Dhone'

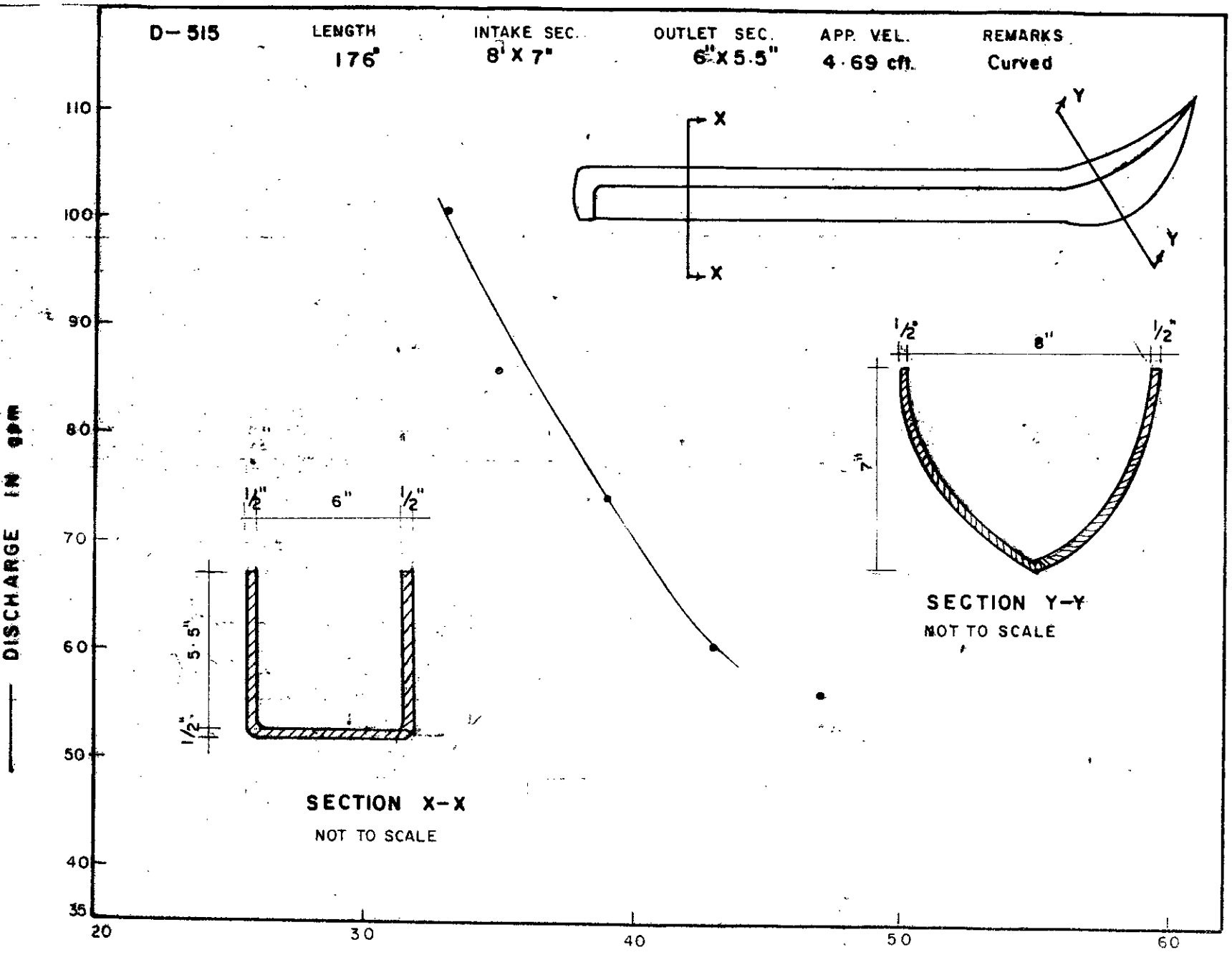


Fig. 12. Discharge VS. lift height Curve for 14·66' slightly curved 'Dhone'

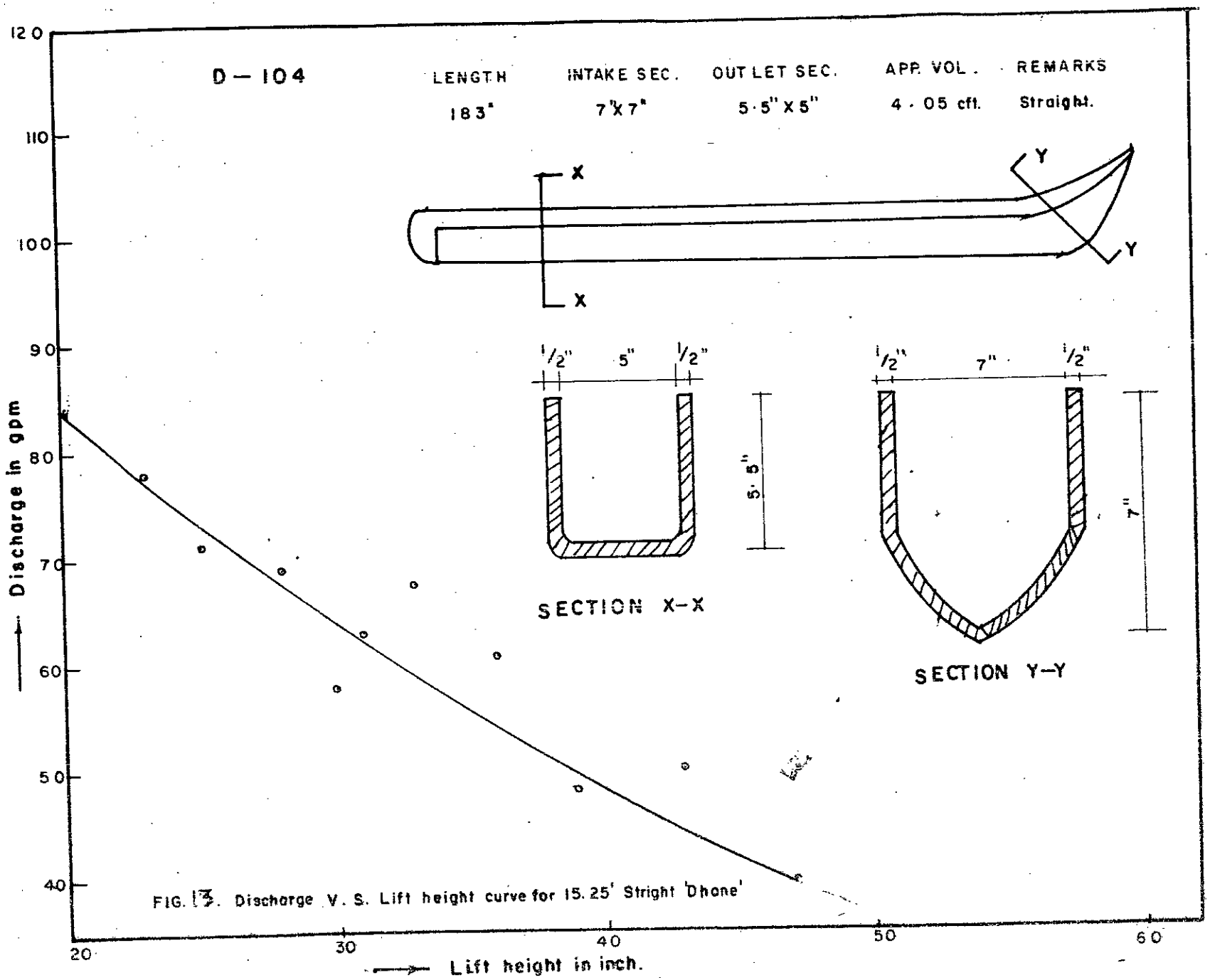


FIG. 13. Discharge V. S. Lift height curve for 15.25' Stright 'Dhone'

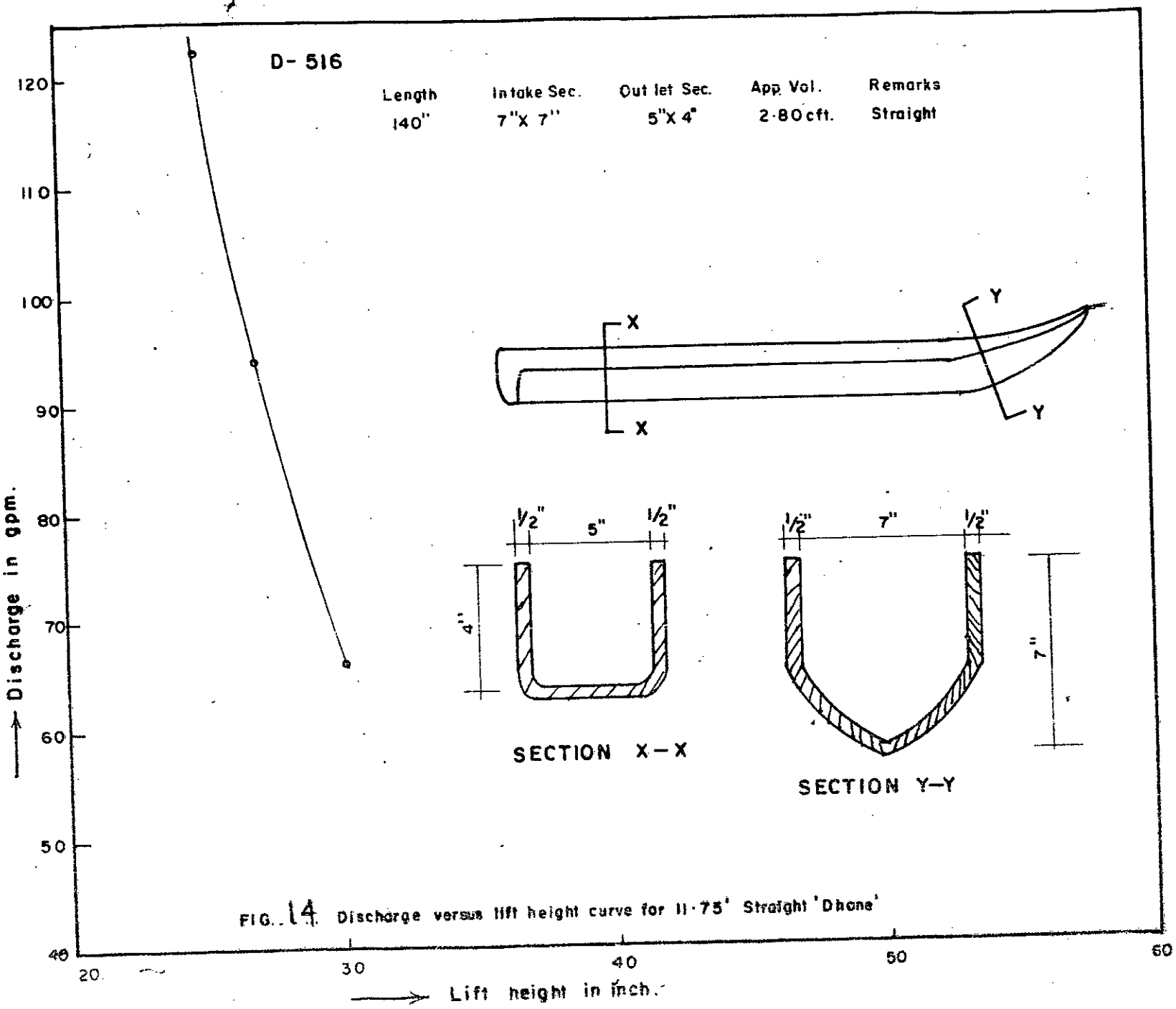


FIG. 14 Discharge versus lift height curve for 11·75' Straight 'Dhone'

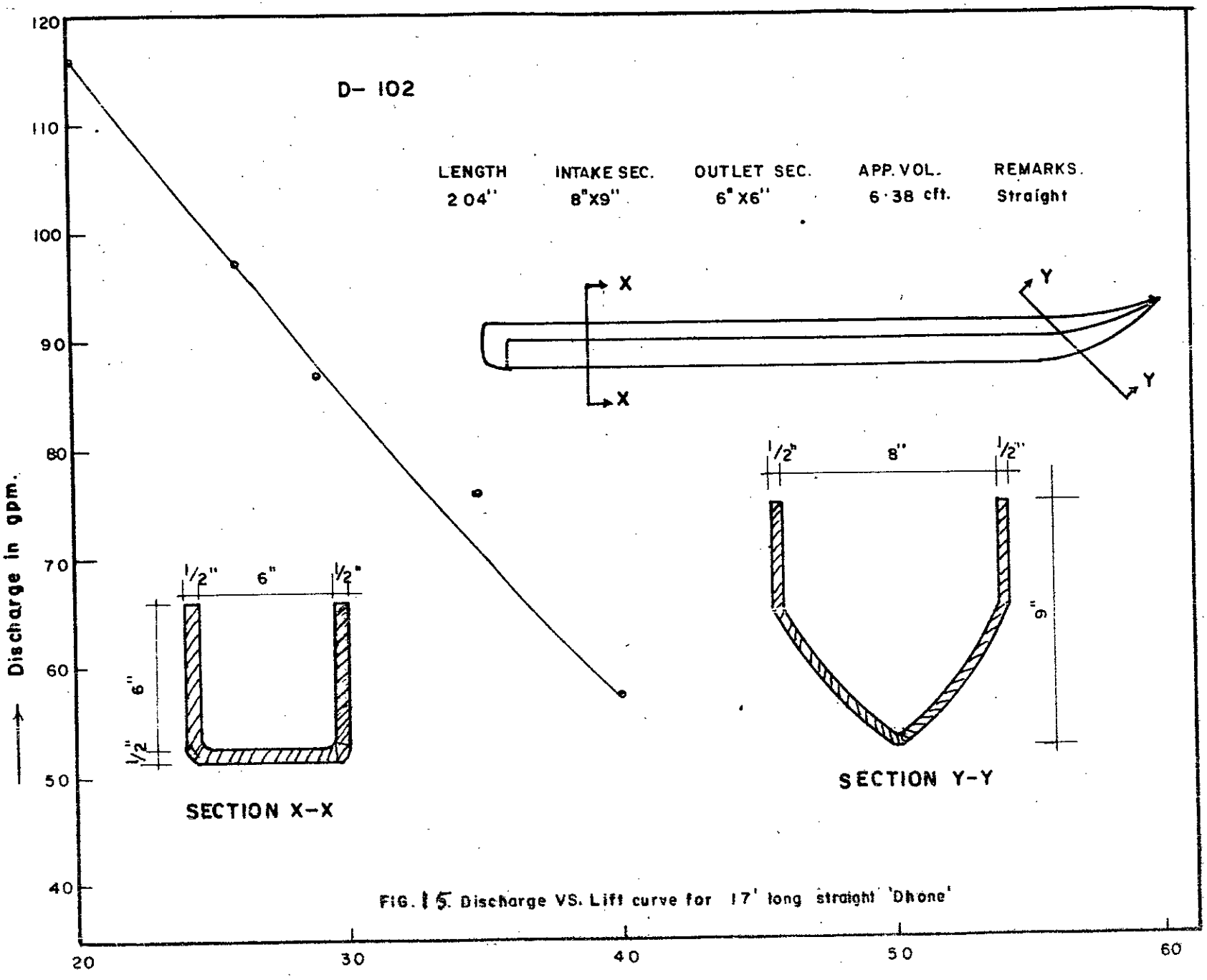


FIG. 15 Discharge VS. Lift curve for 17' long straight 'Dhone'

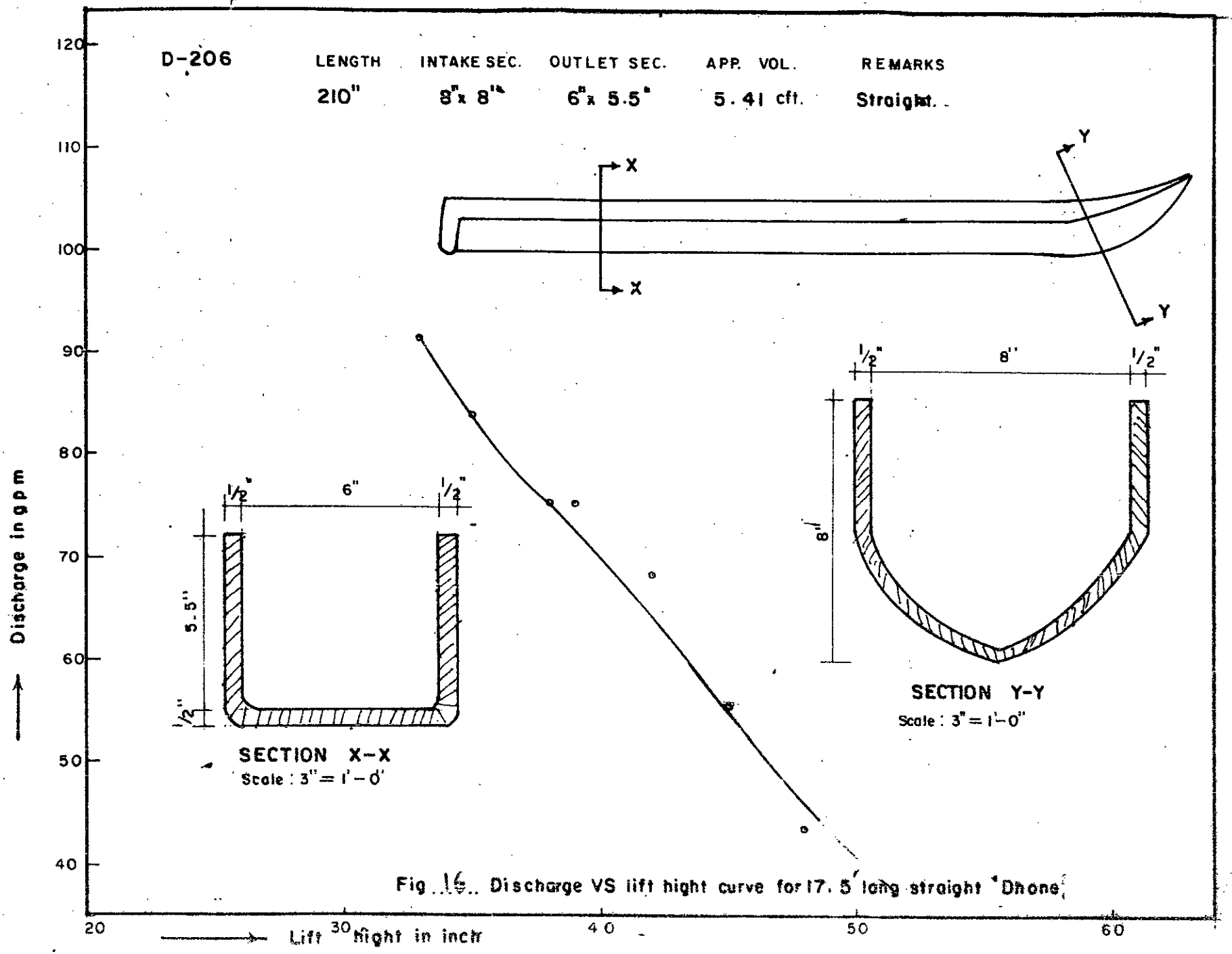
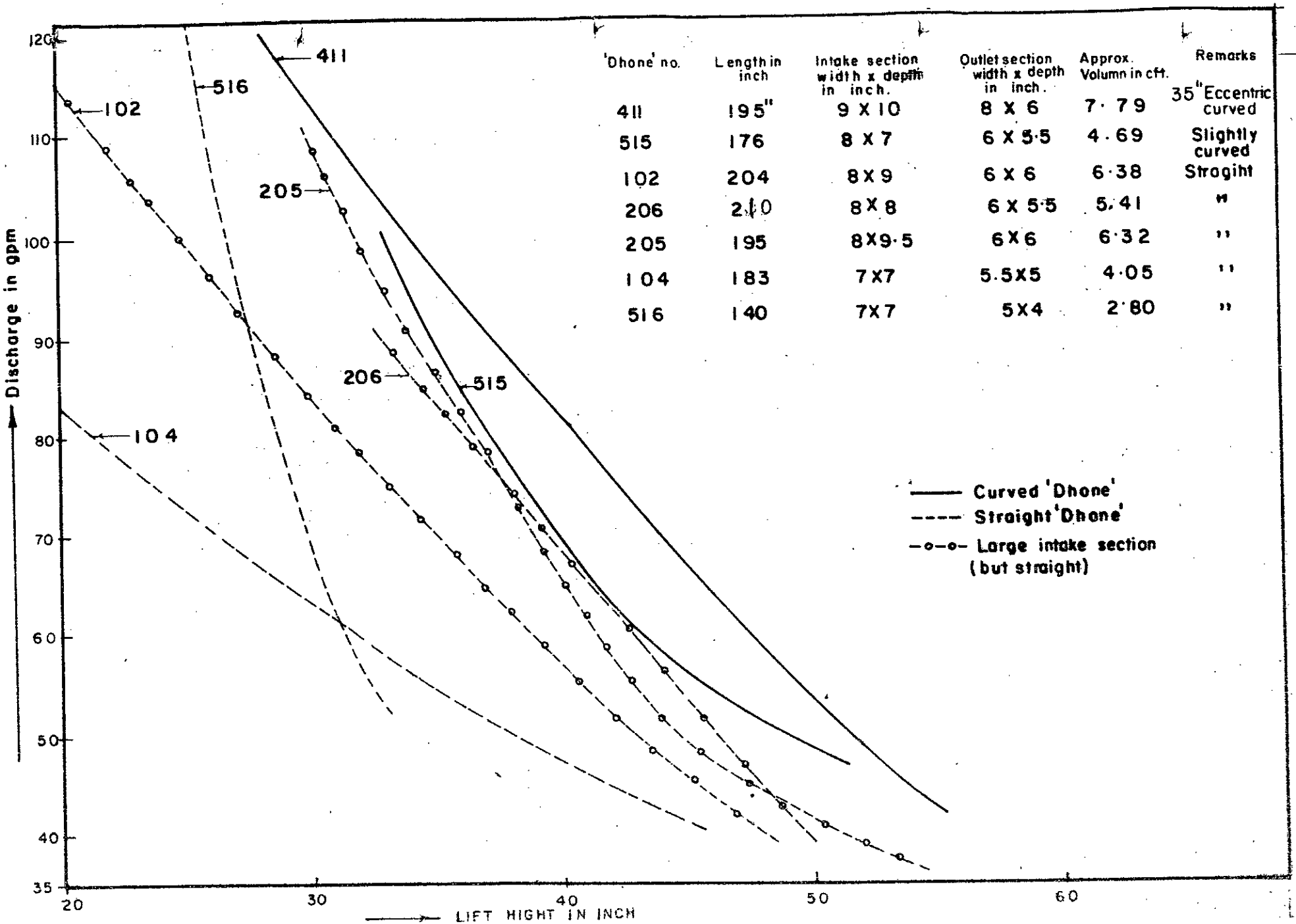


Fig 16. Discharge VS lift hight curve for 17.5' long straight 'Dhone'



'Dhone' no.	Length in inch	Intake section width x depth in inch.	Outlet section width x depth in inch.	Approx. Volumn in cft.	Remarks
411	195"	9 X 10	8 X 6	7·79	35" Eccentric curved
515	176	8 X 7	6 X 5·5	4·69	Slightly curved
102	204	8X9	6 X 6	6·38	Straight
206	210	8X8	6 X 5·5	5·41	"
205	195	8X9·5	6X6	6·32	"
104	183	7X7	5.5X5	4·05	"
516	140	7X7	5X4	2·80	"

FIG. 17. Difference in performance of straight and curved 'Dhone'

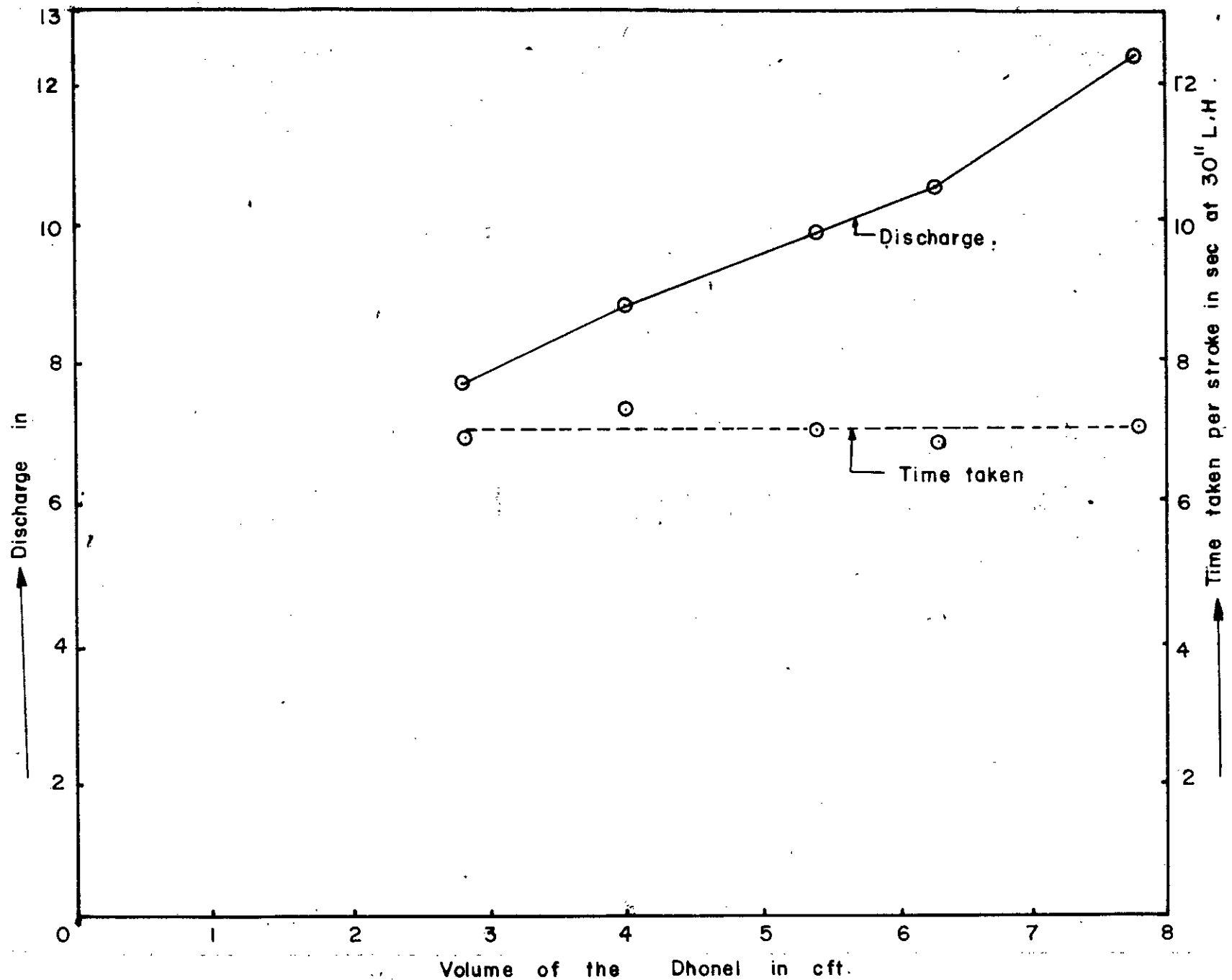


FIG. 18 Effect of geometry of the Dhonel on discharge per stroke. (Lift height constant.)

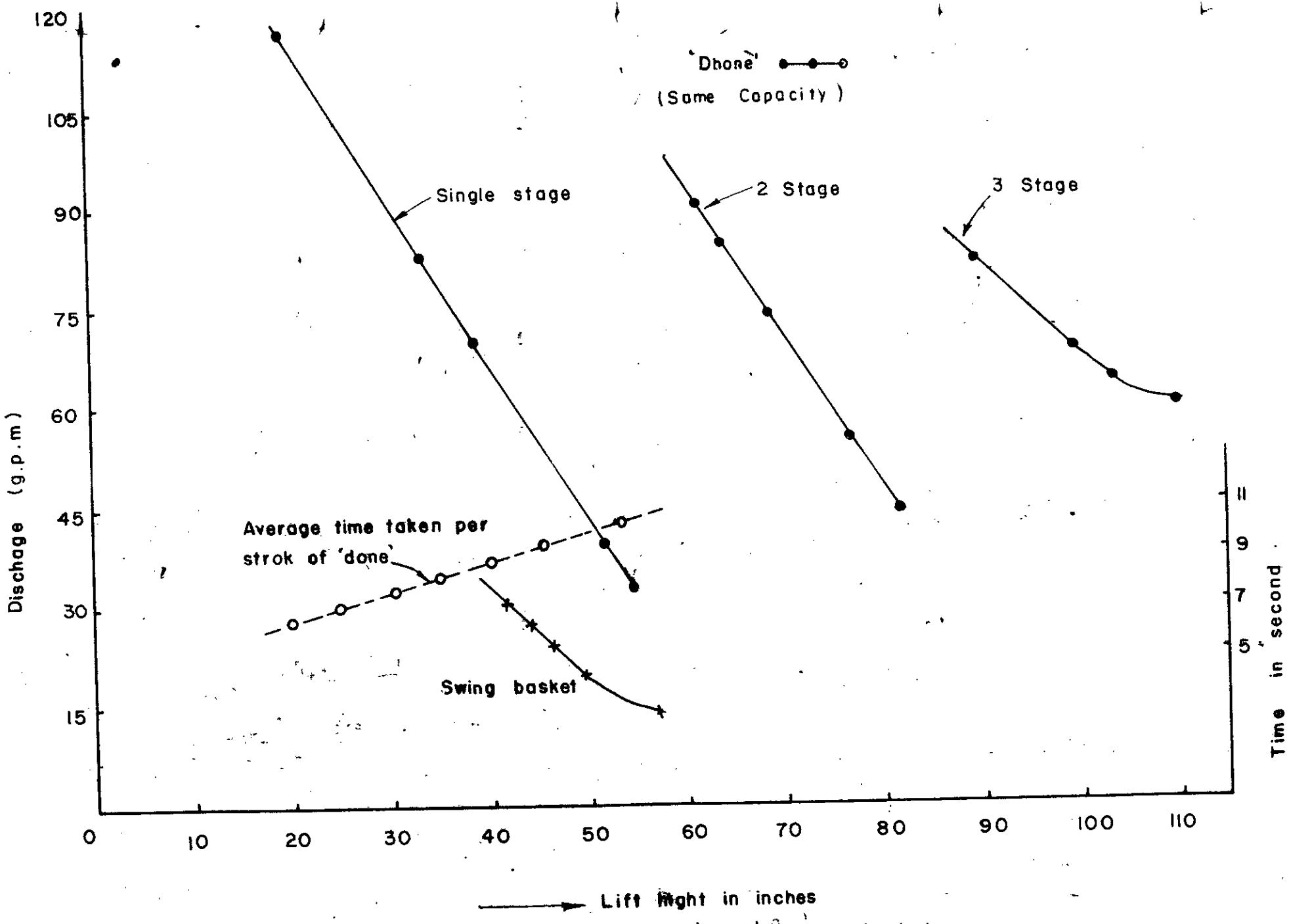


FIG. 19 Discharge versus lift curves for 'dhone', swing basket

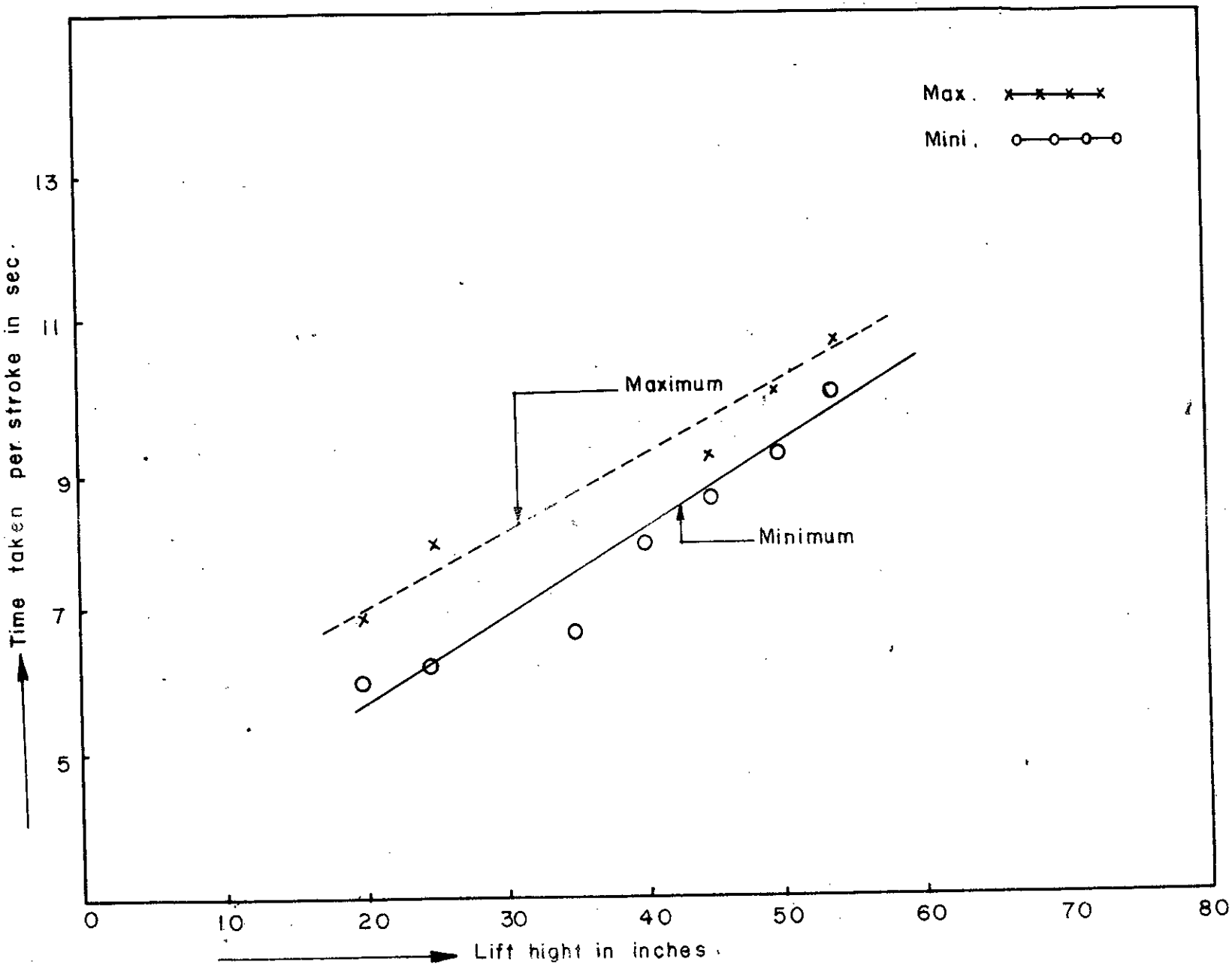


FIG. 20 Maximum and Minimum time taken per stroke of 'dhone' at different lift hight.

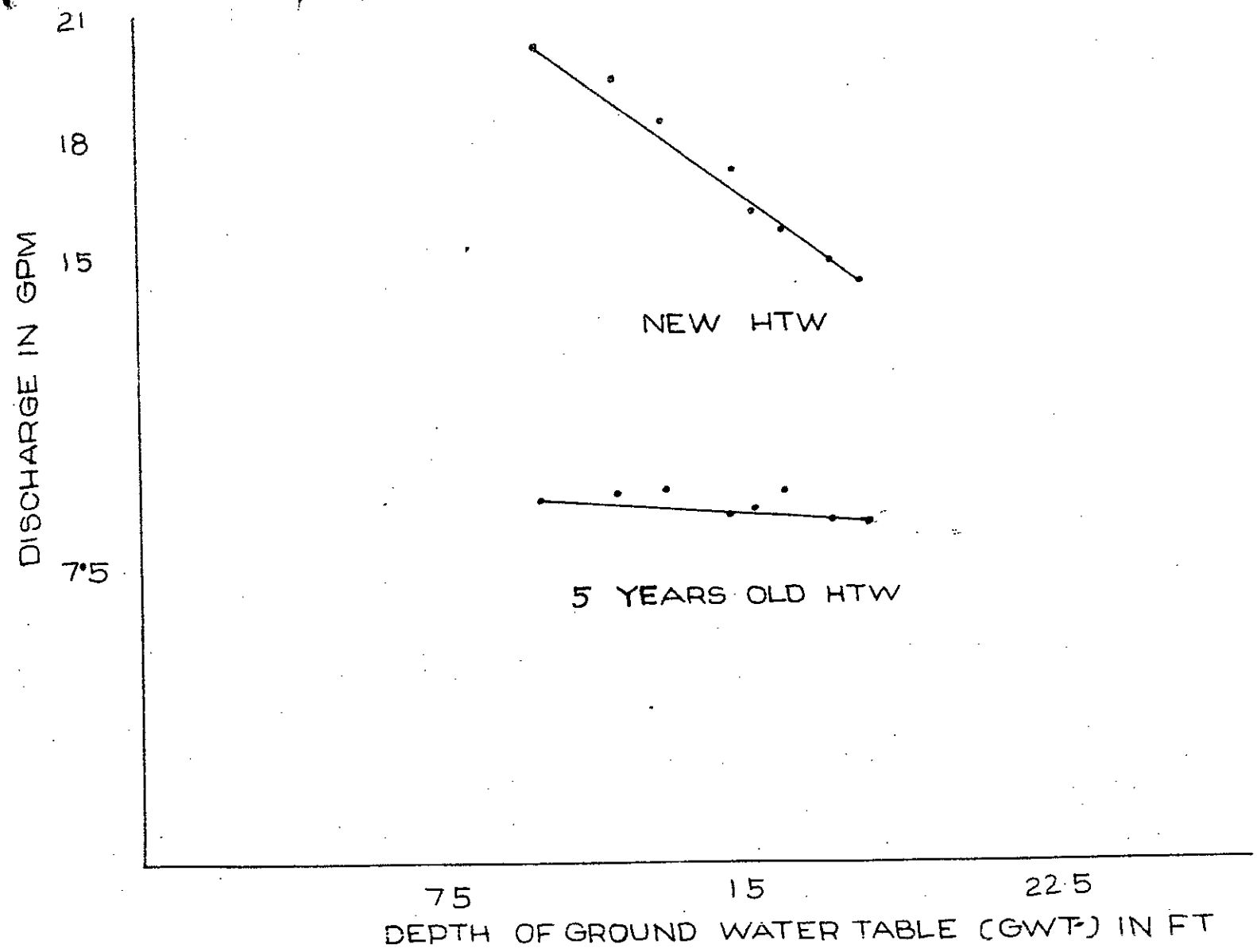


FIGURE 20 DISCHARGE VERSUS DEPTH OF GROUND WATER TABLE CURVES FOR NEW AND 5 YEARS OLD HTW

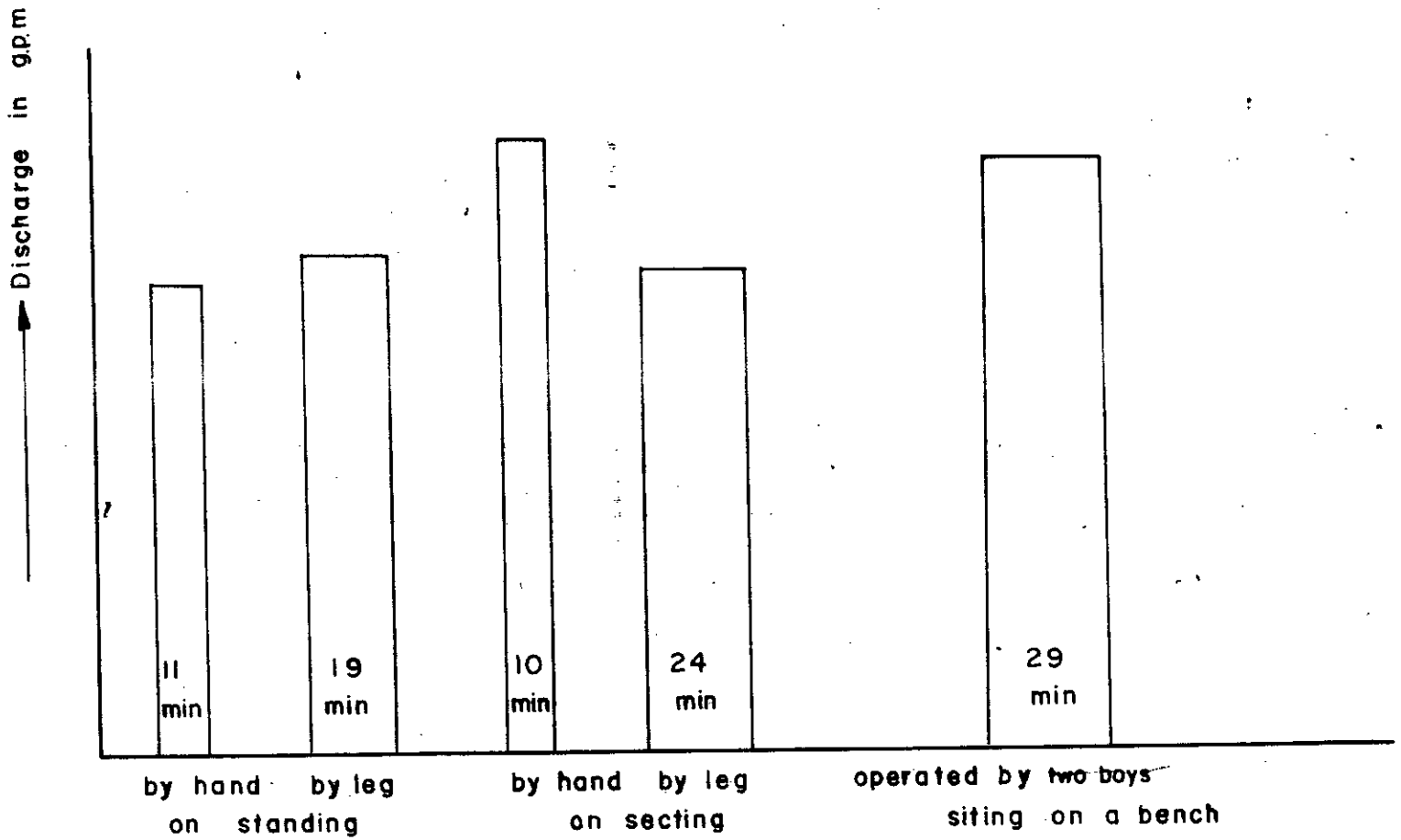


FIG. 22 Performance of HTW under different conditions of operation

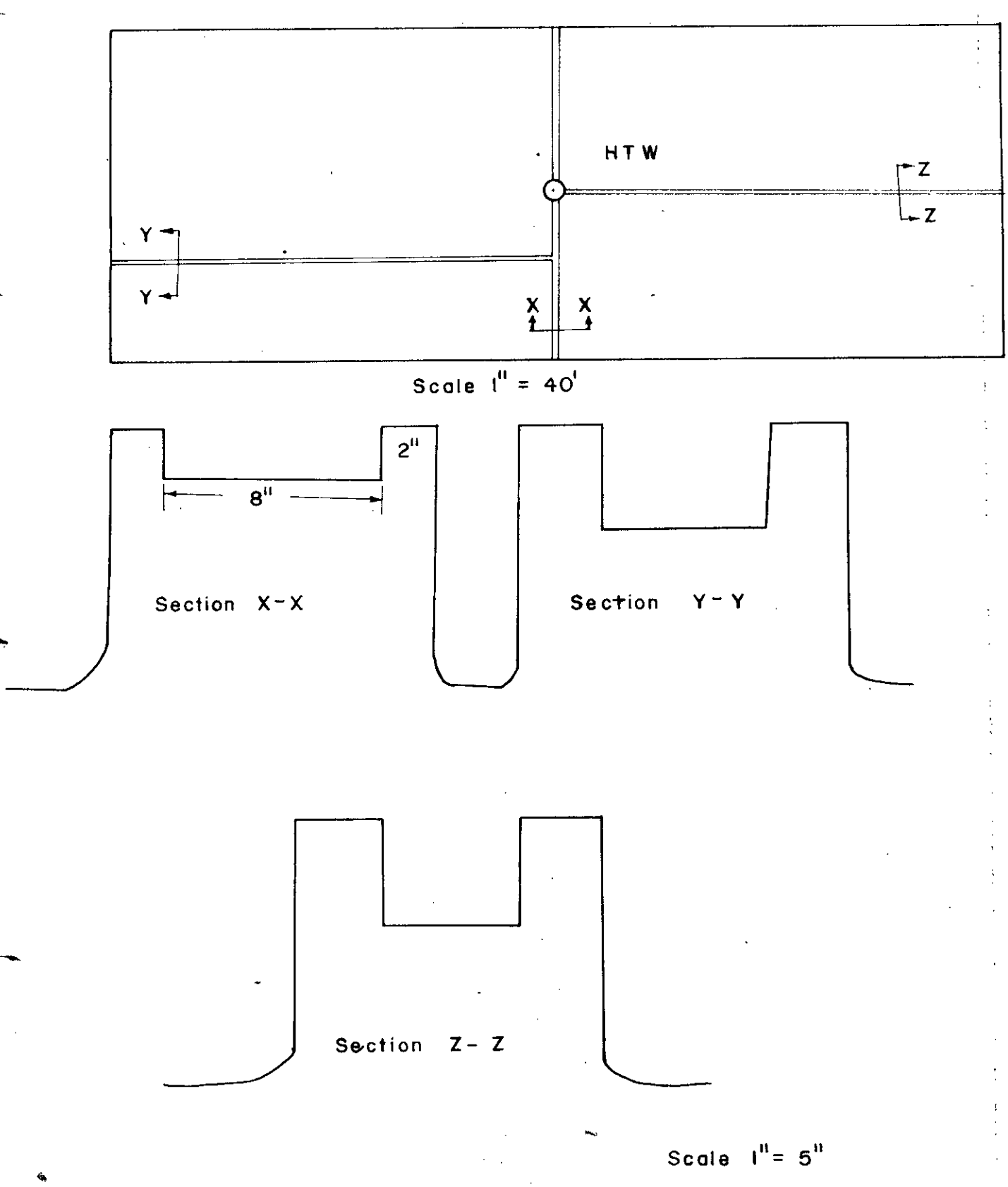


FIG. 23 Water distribution system in H T W Block.

APPENDIX - A

Data collected from five 'dhone' irrigation blocks, one swing basket block and nine hand tube-wells were tabulated in the following tables.

TABLE A_1

PERFORMANCE OF A D-101* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cusec	Average discharge in gpm
1	2	3	4	5	6	7	8	9
21.1.79	30	42	1.31	9.82	7.14	31	0.184	82.50
25.1.79	31	40	1.27	9.47	7.50	45	0.169	75.77
29.1.79	31	41	1.27	9.47	7.32	37	0.173	77.67
3.2. 79	30	38	1.22	9.12	7.89	48	0.141	63.31
6.2. 79	34	32	1.13	8.42	9.38	56	0.120	53.88
9.2. 79	32	34	1.22	9.12	8.82	36	0.138	62.02
11.2.79	31	39	1.31	9.82	7.69		0.171	76.60
13.2.79	30	40	1.27	9.47	7.50		0.169	75.77
15.2.79	31	41	1.27	9.47	7.32		0.172	77.67
17.2.79	31	39	1.31	9.82	7.69		0.166	74.64
20.2.79	30	41	1.22	9.12	7.32		0.167	74.78
22.2.79	29	37	1.22	9.12	8.11		0.150	67.49
3.3.79	30	38	1.36	10.17	7.89		0.172	77.31
6.3.79	31	39	1.27	9.47	7.69		0.165	73.87
10.3.79	30	38	1.31	9.82	7.89		0.166	74.64
12.3.79	32	37	1.36	10.17	8.11		0.168	75.28
15.3.79	30	41	1.27	9.47	7.32		0.173	77.67
18.3.79	30	38	1.31	9.82	7.89		0.166	74.64
21.3.79	31	36	1.27	9.47	8.33		0.152	68.18
24.3.79	32	35	1.27	9.47	8.57		0.148	66.30
26.3.79	30	35	1.36	10.17	8.57		0.159	71.21
29.3.79	31	39	1.31	9.82	7.69		0.171	76.61
31.3.79	31	35	1.36	10.17	8.57		0.159	71.21

* Length 210 Inches, intake end 8" x 7.5" out let end 6"x5", total volume 5.9 cft. Operated in the first position and was fed by preceeding dhone.

TABLE A_2

PERFORMANCE OF D-102* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHT

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
21.1.79	20	50	1.55	11.58	6.00	0.258	115.75
25.1.79	23	48	1.45	10.87	6.25	0.232	104.38
29.1.79	25	46	1.41	10.52	6.52	0.216	96.81
3.2.79	29	44	1.31	9.82	6.82	0.192	86.42
6.2.79	35	45	1.13	8.42	6.67	0.169	75.76
9.2.79	40	39	0.98	7.36	7.69	0.128	57.45
11.2.79	26**	42	1.41	10.52	7.14	0.197	88.39
13.2.79	23	41	1.36	10.17	7.32	0.186	83.41
15.2.79	25	46	1.41	10.52	6.52	0.216	96.81
17.2.79	27	44	1.31	9.82	6.82	0.192	86.42
20.2.79	24	45	1.36	10.17	6.67	0.204	91.55
22.2.79	25	43	1.36	10.17	6.98	0.195	87.48
3.3.79	26	45	1.36	10.17	6.67	0.204	91.55
6.3.79	27	42	1.31	9.82	7.14	0.184	82.50
10.3.79	26	43	1.31	9.82	6.98	0.188	84.47
12.3.79	27	41	1.27	9.41	7.32	0.173	77.67
15.3.79	26	42	1.31	9.82	7.14	0.184	82.50
18.3.79	28	41	1.27	9.47	7.32	0.173	77.66
21.3.79	26	46	1.27	9.47	6.30	0.194	87.13
24.3.79	25	48	1.27	9.47	6.25	0.202	90.91
26.3.79	27	42	1.22	9.12	7.14	0.171	76.61
29.3.79	26	41	1.31	9.82	7.32	0.179	80.56
31.3.79	25	43	1.31	9.82	6.98	0.188	84.47

* Length 204 inch, intake end 8"x9" out let end 6"x6", Total volume 6.38 cft.

** Next stage started.

TABLE A_3

PERFORMANCE OF D-103* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
11.2.79	22	42	1.41	10.52	7.14	0.197	88.39
13.2.79	25	38	1.49	10.17	7.89	0.172	77.31
15.2.79	28	36	1.31	9.82	8.33	0.158	70.72
17.2.79	33	35	1.27	9.47	8.57	0.148	66.30
20.2.79	38	34	1.23	9.12	8.88	0.138	62.02
22.2.79	43	34	1.08	8.07	8.88	0.122	54.86
3.3.79	30**	37	1.31	9.82	8.11	0.162	72.68
6.3.79	28	38	1.36	10.17	7.89	0.172	77.31
10.3.79	29	35	1.31	9.82	8.57	0.153	68.75
12.3.79	27	37	1.22	9.12	8.11	0.150	67.48
15.3.79	29	36	1.31	9.82	8.33	0.158	70.72
18.3.79	30	32	1.17	8.76	8.76	0.125	56.12
21.3.79	29	35	1.27	9.47	8.57	0.148	66.30
24.3.79	28	34	1.27	9.47	8.82	0.143	64.40
26.3.79	30	36	1.22	9.12	8.33	0.146	65.66
29.3.79	30	33	1.22	9.12	9.09	0.134	60.19
31.3.79	28	39	1.27	9.47	7.69	0.165	73.87

* Length 201 inch intake end 7"x8" out let end 6"x5", Total volume 5.00 cft.

** Next stage started.

TABLE A_4

PERFORMANCE OF D-104* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
3.3.79	20	43	1.31	9.82	6.98	0.188	84.47
6.3.79	23	41	1.27	9.47	7.32	0.173	77.66
10.3.79	25	39	1.22	9.12	7.69	0.159	71.13
12.3.79	28	38	1.22	9.12	7.89	0.154	69.31
15.3.79	30	33	1.17	8.76	9.09	0.129	57.87
18.3.79	31	36	1.17	8.76	8.33	0.141	63.13
21.3.79	33	40	1.13	8.42	7.50	0.150	67.35
24.3.79	36	38	1.08	8.07	7.89	0.137	61.31
26.3.79	39	33	0.98	7.36	9.09	0.108	48.62
29.3.79	43	36	0.93	7.02	8.33	0.113	50.59
31.3.79	47	30	0.89	6.66	10.00	0.089	39.99

*Length 183 inch intake end 7"x7" out let end 5.5"x5", Total volume 4.05 cft.

TABLE A_5

PERFORMANCE OF D-205* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
21.1.79	30	50	1.50	11.22	6.00	0.248	112.25
25.1.79	33	47	1.36	10.17	6.38	0.213	95.62
29.1.79	35	45	1.27	9.47	6.67	0.190	85.24
3.2.79	39	40	1.17	8.76	7.50	0.156	70.15
6.2.79	45	35	0.93	7.02	8.57	0.109	49.11
9.2.79	50	33	0.89	6.66	9.09	0.098	43.99
11.2.79	53	30	0.84	6.31	10.00	0.084	37.88
13.2.79	30**	48	1.45	10.87	6.25	0.232	104.39
15.2.79	29	46	1.45	10.87	6.52	0.223	100.03
17.2.79	31	41	1.41	10.52	7.32	0.192	86.28
20.2.79	32	45	1.41	10.52	6.67	0.211	94.71
22.2.79	33	38	1.36	10.17	7.89	0.172	77.31
3.3.79	33	35	1.36	10.17	8.57	0.159	71.21
6.3.79	32	36	1.36	10.17	8.33	0.163	73.24
10.3.79	31	38	1.41	10.52	7.89	0.177	79.38
12.3.79	32	33	1.36	10.17	9.09	0.150	67.14
15.3.79	33	30	1.36	10.17	10.00	0.136	61.03
18.3.79	31	36	1.41	10.52	8.53	0.169	75.77
21.3.79	30	34	1.41	10.52	8.82	0.159	71.56
24.3.79	32	35	1.36	10.17	8.57	0.159	71.21
26.3.79	33	36	1.36	10.17	8.33	0.163	73.24
29.3.77	31	37	1.41	10.52	8.11	0.173	77.87
31.3.79	33	31	1.36	10.17	9.68	0.140	63.07

* Length 195 inch intake end 8"x9.5" out let end 6"x6", Total volume 6.32 cft.

** Next stage started.

TABLE A_6

PERFORMANCE OF D-206* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm	Remarks
13.2.79	33	45	1.36	10.17	6.67	0.204	91.55	
15.2.79	35	43	1.31	9.82	6.98	0.188	84.47	
17.2.79	38	40	1.27	9.47	7.50	0.169	75.77	
20.2.79	39	40	1.27	9.47	7.50	0.169	75.77	
22.2.79	42	39	1.17	8.76	7.69	0.152	68.40	
3.3.79	45	33	1.13	8.42	9.09	0.124	55.56	
6.3.79	48	30	0.98	7.36	10.00	0.098	44.15	
12.3.79	33	48	1.27	9.47	6.25	0.202	90.91	next stage started
15.3.79	32	43	1.31	9.82	6.98	0.188	84.47	
18.3.79	31	40	1.31	9.82	7.50	0.175	78.57	
21.3.79	33	45	1.27	9.47	6.67	0.190	85.24	
24.3.79	31	43	1.31	9.82	6.98	0.188	84.47	
26.3.79	32	46	1.31	9.82	6.52	0.201	90.36	
29.3.79	33	46	1.27	9.47	6.52	0.194	87.13	
31.3.79	33	42	1.27	9.47	7.15	0.178	79.91	

* Length 210 inch intake end 8" x 8" out let end 6" x 5.5"; Total volume 5.41 cft.

TABLE 7A

PERFORMANCE OF D-207* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
12.3.79	25	48	1.50	11.22	6.25	0.240	107.70
18.3.79	27	40	1.50	11.22	7.50	0.200	89.80
21.3 79	29	41	1.45	10.87	7.32	0.199	89.17
24.3.79	30	38	1.41	10.52	7.89	0.178	79.98
26.3.79	35	37	1.27	9.47	8.11	0.156	70.08
29.3.79	39	35	1.22	9.12	8.57	0.142	63.84
31.3.79	43	30	1.13	8.42	10.00	0.112	50.51

*Length 185 inch, inlet end 8" x 8" out let end 6" x 6", Total volume 5.35 cft.

TABLE A_8

PERFORMANCE OF D-308* WHICH WAS LIFTING WATER UNDER DIFFERENT LEFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm	Remarks
21.1.79	28	47	1.64	12.28	6.38	0.257	115.40	
25.1.79	31	46	1.59	11.93	6.52	0.244	109.72	
29.1.79	33	46	1.50	11.22	6.52	0.230	103.27	
3.2.79	36	43	1.45	10.87	6.98	0.208	93.52	
6.2.79	38	45	1.41	10.52	6.67	0.211	94.74	
9.2.79	41	40	1.36	10.17	7.50	0.181	81.38	
11.2.79	44	39	1.31	9.82	7.69	0.171	76.61	
13.2.79	46	35	1.17	8.76	8.57	0.137	61.38	
15.2.79	49	30	1.03	7.72	10.00	0.103	46.30	
17.2.79	54	28	0.84	6.31	10.71	0.079	35.36	
20.2.79	37	46	1.41	10.52	6.52	0.216	96.81	next stage started
22.2.79	38	42	1.36	10.17	7.14	0.190	85.45	
3.3.79	37	41	1.41	10.52	7.32	0.192	86.29	
6.3.79	38	40	1.36	10.17	7.50	0.181	81.38	
10.3.79	38	39	1.36	10.17	7.69	0.177	79.34	
12.3.79	37	38	1.41	10.52	7.89	0.177	79.98	
18.3.79	37	43	1.41	10.52	6.98	0.178	90.50	
20.3.79	36	45	1.41	10.52	6.67	0.211	94.71	
22.3.79	37	41	1.41	10.52	7.32	0.192	86.29	
24.3.79	38	37	1.36	10.17	8.11	0.168	75.28	
26.3.79	36	36	1.45	10.87	8.33	0.174	78.28	

* Length 215 inch intake end 8" x 8" out let end 6" x 6", Total volume 6.22 cft.

TABLE A_9

PERFORMANCE OF D-309* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
20.2.79	30	47	1.50	11.22	6.38	0.235	105.51
22.2.79	32	42	1.45	10.87	7.14	0.203	91.34
3.3.79	33	40	1.45	10.87	7.50	0.194	86.99
6.3.79	35	41	1.41	10.52	7.32	0.192	86.29
10.3.79	38	40	1.31	9.02	7.50	0.175	78.57
12.3.79	41	43	1.27	9.47	6.98	0.181	81.45
18.3.79	44	41	1.22	9.12	7.32	0.167	74.78
20.3.79	48	38	1.08	8.07	7.89	0.137	61.31
22.3.79	50	33	0.93	7.02	9.09	0.104	46.30
24.3.79	53	30	0.80	5.96	10.00	0.080	35.78
26.3.79	54	29	0.75	5.61	10.34	0.072	32.55

* Length 200 inch, intake end 8" x 7.5" out let end 6" x 5.5", Total volume 5.38 cft

TABLE A_{10}

PERFORMANCE OF D-410* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm
21.1.79	33	50	1.36	10.17	6.00	0.227	101.72
25.1.79	31	48	1.41	10.52	6.25	0.225	101.02
29.1.79	32	45	1.41	10.52	6.67	0.211	94.71
3.2.79	33	46	1.31	9.82	6.52	0.201	90.36
6.2.79	31	42	1.36	10.17	7.14	0.190	85.45
9.2.79	30	43	1.45	10.87	6.98	0.208	93.52
11.2.79	34	38	1.31	9.82	7.89	0.166	74.64
13.2.79	31	40	1.41	10.52	7.50	0.187	84.18
15.2.79	32	36	1.41	10.52	8.33	0.169	75.77
17.2.79	35	39	1.27	9.47	7.69	0.165	73.87
20.2.79	31	43	1.36	10.17	6.98	0.195	87.48
22.2.79	34	42	1.27	9.47	7.14	0.177	79.55
3.3.79	32	40	1.31	9.82	7.50	0.175	78.57
6.3.79	35	41	1.22	9.12	7.32	0.167	74.78
10.3.79	33	42	1.27	9.47	7.14	0.177	79.55
12.3.79	30	44	1.36	10.17	6.82	0.199	89.52
18.3.79	31	42	1.36	10.17	7.14	0.190	85.45
20.3.79	34	36	1.27	9.47	8.33	0.152	68.19
22.3.79	31	35	1.31	9.82	8.57	0.153	68.75
24.3.79	30	38	1.41	10.52	7.89	0.178	79.98
26.3.79	34	39	1.22	9.12	7.69	0.158	71.14
29.3.79	35	40	1.17	8.76	7.50	0.156	70.15

*Length 175 inch, intake end 8" x 7" out let end 6" x 5", Total volume 4.36 cft.

TABLE A_{11}

PERFORMANCE OF D-411* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm	Remarks
21.1.79	28	43	1.78	14.05	6.98	0.269	120.66	
25.1.79	31	40	1.73	12.98	7.50	0.231	103.83	
29.1.79	33	38	1.69	12.63	7.89	0.213	95.97	
3.2.79	35	37	1.64	12.28	8.11	0.202	90.85	
6.2.79	38	39	1.59	11.93	7.69	0.207	93.02	
9.2.79	39	38	1.55	11.56	7.89	0.196	87.97	
11.2.79	40	37	1.55	11.56	8.11	0.191	85.66	
13.2.79	43	35	1.41	10.52	8.57	0.164	73.66	
15.2.79	46	35	1.31	9.82	8.57	0.153	68.75	
17.2.79	48	34	1.27	9.47	8.82	0.143	64.40	
20.2.79	50	33	1.13	8.42	9.09	0.124	55.56	
22.2.79	54	30	1.03	7.72	10.00	0.098	44.20	
3.3.79	30	41	1.64	12.28	7.32	0.224	100.67	next stage started
6.3.79	31	42	1.64	12.28	7.14	0.230	103.13	
10.3.79	32	39	1.59	11.93	7.69	0.207	93.02	
12.3.79	30	39	1.69	12.63	7.69	0.219	98.50	
18.3.79	35	41	1.55	11.56	7.32	0.211	94.92	
20.3.79	34	42	1.55	11.56	7.14	0.217	97.23	
22.3.79	33	42	1.59	11.93	7.14	0.210	94.29	
24.3.79	30	40	1.64	12.28	7.50	0.219	98.22	
26.3.79	31	43	1.59	11.93	6.98	0.228	102.56	
29.3.79	36	40	1.41	10.52	7.50	0.187	84.18	

*Length 195 inch intake end 9" x 10" out let end 8" x 6", Total volume 7.79 cft. Intake section is curved about 35" upward.

TABLE A_{12}

PERFORMANCE OF D-412* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per Stroke in Sec.	Average discharge in cusec	Average discharge in gpm
3.3.79	29	48	1.50	11.22	6.25	0.240	107.76
6.3.79	30	45	1.50	11.22	6.67	0.225	101.02
10.3.79	33	42	1.41	10.52	7.14	0.197	88.33
12.3.79	36	40	1.36	10.17	7.50	0.181	81.38
18.3.79	38	40	1.31	9.82	7.50	0.175	78.57
20.3.81	40	38	1.27	9.47	7.89	0.160	71.98
21.3.79	43	33	1.17	8.76	9.03	0.129	57.88
24.3.79	45	30	1.13	8.42	10.00	0.112	50.51
26.3.79	47	29	1.08	8.07	10.34	0.104	46.79
29.3.79	50	30	0.93	7.02	10.00	0.094	42.09

* Length 189 inch, intake end 7.5" x 7" out let end 6" x 5.5", Total volume 4.68 cft.

TABLE A_{13}

PERFORMANCE OF D-513* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch.	No.of Strokes in 5 min	Discharge per stroke in m^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm	Remarks
21.1.79	29	40	1.69	12.63	7.50	0.225	101.02	
25.1.79	32	38	1.64	12.28	7.89	0.208	93.37	
29.1.79	34	35	1.55	11.56	8.57	0.180	81.03	
3.2.79	38	35	1.50	11.22	8.57	0.175	78.57	
6.2.79	41	33	1.45	10.87	9.09	0.160	71.77	
9.2.79	43	34	1.41	10.52	8.82	0.159	71.56	
11.2.79	44	33	1.31	9.82	9.09	0.144	64.82	
13.2.79	48	30	1.17	8.76	10.00	0.117	52.61	
15.2.79	52	26	0.98	7.36	11.54	0.085	38.31	
20.2.79	31	35	1.59	11.93	8.57	0.186	83.48	next stage started
22.2.79	33	34	1.45	10.87	8.82	0.165	73.94	
28.2.79	32	38	1.50	11.22	7.89	0.190	85.31	
3.3.79	31	37	1.55	11.56	8.11	0.191	85.66	
6.3.79	30	38	1.59	11.93	7.89	0.201	90.63	
10.3.79	32	35	1.50	11.22	8.57	0.175	78.57	
12.3.79	31	36	1.50	11.22	8.33	0.180	80.81	
18.3.79	30	33	1.64	12.28	9.09	0.180	81.03	
21.3.79	31	30	1.55	11.56	10.00	0.155	69.45	
24.3.79	32	35	1.50	11.22	8.57	0.175	78.57	
26.3.79	31	36	1.59	11.93	8.33	0.191	85.87	
29.3.79	32	31	1.45	10.87	9.68	0.150	67.42	
31.3.79	30	38	1.59	11.93	7.89	0.202	90.64	
5.4.79	29	38	1.64	12.28	7.89	0.208	93.30	
7.4.79	31	36	1.55	11.56	8.33	0.186	83.34	
9.4.79	33	32	1.45	10.87	9.38	0.156	70.01	

* Length 185 inch, intake end 9" x 7" out let end 6" x 6", Total volume 5.30 cft.

TABLE A_{14}

PERFORMANCE OF D-514* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm	Remarks
20.2.79	25	45	1.64	12.28	6.67	0.246	110.44	
22.2.79	28	40	1.56	11.93	7.50	0.212	95.41	
28.2.79	31	39	1.45	10.87	7.69	0.189	84.82	
3.3.79	36	38	1.36	10.17	7.89	0.172	77.31	
6.3.79	41	35	1.31	9.82	8.57	0.157	68.75	
10.3.79	44	37	1.27	9.47	8.11	0.156	70.08	
12.3.79	48	33	1.13	8.42	9.09	0.124	55.56	
18.3.79	30	39	1.45	10.87	7.69	0.189	84.82	next stage started
21.3.79	28	38	1.55	11.56	7.89	0.196	87.97	
24.3.79	28	39	1.55	11.56	7.69	0.201	90.29	
26.3.79	29	37	1.50	11.22	8.11	0.185	83.06	
29.3.79	30	36	1.45	10.87	8.33	0.174	78.30	
31.3.79	31	35	1.45	10.87	8.57	0.170	76.12	
3.4.79	32	33	1.41	10.52	9.09	0.155	69.45	
7.4.79	32	34	1.41	10.52	8.82	0.160	71.76	
9.4.79	33	31	1.36	10.17	9.68	0.140	63.06	

*Length 180 inch, intake end 8.5" x 7" out let end 6" x 5", Total volumen 4.67 cft.

TABLE A_{15}

PERFORMANCE OF D-515* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No.of Stroke in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Average discharge in cusec	Average discharge in gpm	Remarks
18.3.79	33	45	1.50	11.22	6.67	0.225	101.02	
21.3.79	35	41	1.41	10.52	7.32	0.192	86.29	
24.3.79	39	38	1.31	9.82	7.89	0.166	74.64	
26.3.79	44	36	1.13	8.42	8.33	0.135	60.61	
29.3.79	47	38	0.98	7.36	7.89	0.125	55.98	
3.4.79	25	60	1.36	10.17	5.00	0.273	122.67	next stage started
7.4.79	27	50	1.27	9.47	6.00	0.211	94.71	
9.4.79	30	43	1.03	7.72	6.98	0.148	66.36	

* Length 176 inch, intake end 8" x 7" out let end 6" x 5.5", Total volume 4.69 cft.

TABLE A_{16}

PERFORMANCE OF D-516* WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No. of strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stoke in Sec.	Average discharge in cusec	Average discharge in gpm
3.4.79	25	60	1.36	10.17	5.00	0.273	122.67
7.4.79	27	50	1.27	9.47	6.00	0.211	94.71
9.4.79	30	43	1.03	7.72	6.98	0.148	66.36

* Length 140 inches, intake section 7" x 7", outlet section 5" x 4" operated in the 4th stage for a short period. After one week water was not available.

TABLE A_{17}

PERFORMANCE OF SWING BASKET WHICH WAS LIFTING WATER UNDER DIFFERENT LIFT HEIGHTS

Date	Lift Height in inch	No. of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cu-sec.	Average discharge in gpm
21.1.79	42	135	0.150	1.122	2.22	23	0.067	30.08
28.1.79	44	124	0.145	1.08	2.42	22	0.060	26.24
4.2.79	47	113	0.141	1.05	2.65	21	0.053	23.80
21.1.79	31	147	0.188	1.41	2.04	25	0.092	41.31
28.1.79	33	139	0.178	1.33	2.16	23	0.083	37.27
4.2.79	36	128	0.173	1.29	2.34	24	0.074	33.25
6.3.79	49	90	0.141	1.05	3.33	24	0.042	18.86
6.3.79	54	110	0.141	1.05	2.72	20	0.052	23.35
6.3.79	57	98	0.134	1.02	3.06	19	0.044	19.76

TABLE A_{18}

PERFORMANCE OF A NEW PUMP No.706) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUND WATER TABLE

Date	Depth of gwt in ft.	No.of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cu- sec	Average discharge in gpm	Remarks
28.1.79	10.00	395	.034	.253	.781	13	.0433	19.98	New Pump
6.3.79	12.08	384	.034	.253	.798	14	.0424	19.43	
23.3.79	13.25	382	.032	.240	.806	12	.0386	18.34	
3.4.79	15.00	377	.030	.228	.796	11	.0383	17.19	One siting by hand
5.4.79	15.50	370	.029	.217	.811	10	.0359	16.06	
7.4.79	16.17	361	.029	.217	.809	13	.0339	15.67	
10.4.79	17.42	359	.028	.207	.813	11	.0340	14.86	
12.4.79	18.25	354	.026	.198	.822	12	.0322	14.45	
20.4.79	18.25	373	.028	.207	.804	14	.0344	15.44	

TABLE A_{19}

PERFORMANCE OF A NEW HTW (No.704) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUNDWATER TABLE

Date	Ground water lable (gwt) in ft	No.of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cu-ft sec	Average discharge in gpm	Remarks
28.1	10.00	440	.028	.207	.682	25	.0406	18.22	
6.3	12.08	439	.023	.175	.683	30	.0342	15.37	Data taken at noon.
28.3	13.25	412	.026	.198	.728	28	.0363	16.32	
3.4	15.00	435	.025	.190	.690	29	.0368	16.53	
5.4	15.50	433	.025	.190	.693	26	.0366	16.45	
7.4	16.17	430	.024	.182	.698	26	.0340	15.65	
10.4	17.42	436	.023	.175	.688	23	.0340	15.26	
12.4	18.25	434	.023	.169	.691	24	.0327	14.67	
20.4	18.25	450	.023	.169	.666	25	.0339	15.21	

TABLE A_{20}

PERFORMANCE OF A ONE YEAR OLD HTW (No.705) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUND WATER TABLE (gwt)

Date	Depth of gwt in ft	No.of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cu-sec	Average discharge in gpm	Remarks
28.1.79	10.00	362	.030	.228	.829	12	.0368	16.51	One year old pump
6.3.79	12.08	388	.026	.198	.773	15	.0342	15.36	
28.3.79	13.25	340	.024	.182	.882	14	.0276	12.38	Data taken at noon
3.4.79	15.00	355	.024	.182	.845	10	.0288	12.92	
5.4.79	15.50	400	.023	.175	.750	19	.0312	14.00	By leg.
7.4.79	16.17	391	.023	.169	.767	18	.0294	13.22	
10.4.79	17.42	386	.022	.163	.777	11	.0280	12.58	
12.4.79	18.25	383	.021	.157	.783	12	.0268	12.03	
20.4.79	18.25	387	.021	.157	.775	14	.0271	12.15	

TABLE A_{21}

PERFORMANCE OF A TWO YEARS OLD HTW (No.708) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUND WATER TABLE (gwt)

Date	Depth of gwt in ft	No. of Strokes in 5 min	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cusec	Average discharge in gpm
28.1.79	10.00	423	.025	.190	.688	8	.0369	16.07
6.3.79	12.08	384	.028	.207	.781	15	.0354	15.90
28.3.79	13.25	408	.024	.182	.735	14	.0331	14.85
3.4.79	15.00	379	.023	.175	.791	13	.0296	13.27
5.4.79	15.50	375	.023	.169	.800	14	.0282	12.68
7.4.79	16.17	372	.22	.163	.806	11	.0280	12.57
10.4.79	17.42	374	.021	.162	.802	12	.0261	12.14
12.4.79	18.25	373	.021	.160	.811	11	.0259	11.95
20.4.79	18.25	376	.022	.163	.798	10	.0273	12.26

TABLE A_{22}

PERFORMANCE OF A THREE YEARS OLD HTW (No.702) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUND WATER TABLE (gwt)

Date	Depth of gwt in ft.	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cu-sec	Average discharge in gpm	Remarks
28.1.79	10.00	346	.025	.190	.867	14	.0293	13.15	
6.3.79	12.08	347	.024	.182	.865	13	.0281	12.63	
28.3.79	13.25	343	.025	.190	.875	12	.0290	13.03	
3.4.79	15.00	345	.023	.175	.870	15	.0269	12.08	
5.4.79	15.50	350	.023	.169	.857	13	.0263	11.83	
7.4.79	16.17	341	.023	.169	.880	14	.0257	11.53	
10.4.79	17.42	342	.022	.163	.877	15	.0248	11.15	
12.4.79	18.25	338	.021	.157	.888	16	.0236	10.61	
20.4.79	18.25	343	.021	.157	.875	13	.0240	10.77	

TABLE A_{23}

PERFORMANCE OF A FOUR YEARS OLD HTW (No. 703) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUND WATER TABLE (gwt)

Date	Depth of gwt in ft.	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cusec	Average discharge in gpm
28.1.79	10.00	361	.017	.130	.831	10	.0209	9.39
6.3.79	12.08	376	.016	.120	.798	12	.0201	9.02
23.3.79	13.25	500	.011	.083	.600	20	.0185	8.30
3.4.79	15.00	360	.017	.127	.833	13	.0204	9.14
5.4.79	15.50	358	.016	.123	.838	12	.0196	8.81
7.4.79	16.17	357	.016	.120	.840	15	.0191	8.57
10.4.79	17.42	355	.016	.120	.845	13	.0190	8.52
12.4.79	18.25	350	.016	.117	.857	11	.0182	8.19
20.4.79	18.25	350	.016	.123	.857	11	.0192	8.61

TABLE A_{24}

PERFORMANCE OF A FIVE YEARS OLD HTW (No. 701) WHICH WAS LIFTING WATER UNDER DIFFERENT DEPTH OF GROUND WATER TABLE (GWT)

Date	Depth of gwt in ft.	No. of Strokes in 5 min	Discharge per stroke		Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge	
			in ft^3	in US gall.			in cusec	in gpm
28.1.79	10.00	354	.017	.127	.847	8	.0200	8.99
6.3.79	12.08	385	.016	.117	.779	10	.0201	9.01
28.3.79	13.25	350	.017	.130	.857	8	.0203	9.10
3.4.79	15.00	352	.016	.120	.852	10	.0188	8.45
5.4.79	15.50	355	.016	.123	.845	10	.0194	8.73
7.4.79	16.17	359	.017	.127	.836	9	.0203	9.12
10.4.79	17.42	357	.016	.120	.840	8	.0191	8.57
12.4.79	18.25	351	.015	.114	.855	8	.0178	8.00
20.4.79	18.25	360	.016	.117	.833	8	.0188	8.42

TABLE A_{25}

PERFORMANCE OF A HTW DISTRIBUTED BY UNICEF (No. 707) WHICH WAS LIFTING WATER UNDER DEPTH OF GROUND WATER TABLE (gwt)

Date	Depth of gwt in ft.	No.of Strokes in 5 min.	Discharge per stroke in ft^3	Discharge per stroke in US gall.	Time taken per stroke in Sec.	Work done at a stretch in min.	Average discharge in cusec	Average discharge in gpm
28.1.79	10.00	239	.047	.351	1.255	26	.0374	16.78
6.3.79	12.08	220	.047	.351	1.363	25	.0344	15.44
28.3.79	13.25	225	.041	.304	1.333	21	.0305	13.68
3.4.79	15.00	221	.041	.304	1.357	23	.0297	13.44
5.4.79	15.50	218	.038	.285	1.376	20	.0277	12.43
7.4.79	16.17	216	.036	.268	1.388	15	.0258	11.58
10.4.79	17.42	209	.034	.253	1.435	18	.0236	10.58
12.4.79	18.25	210	.032	.240	1.428	22	.0224	10.08
20.4.79	18.25	215	.034	.253	1.395	24	.0242	10.88

APPENDIX - B

Capital cost in June 1981 of Deep Tubewell, Low Lift Pump and Shallow Tubewell were collected from Bangladesh Agricultural Development Corporation(BADC) and shown in the following tables.

TABLE - B_1

CAPITAL COST STRUCTURE OF DEEP TUBEWELL
(Source: BADC, June, 1981)

Item of Cost	Cost (Including duty and Taxes) in Tk.	Annualized cost 1/ (In Tk.)
a. Engine	68,750	10,401
b. Turbine pump	43,750	6,619
c. Tubewell material	81,000	11,352
d. Tubewell borring	75,000	10,650
e. Pump house and other construction	6,000	117
f. Miscellaneous	7,000	994
	2,81,500	40,133

1/ Assuming sales at full financial cost, 13% annual interest rate, 15 years life of engine, 15 years' life for pump, and 20 years for the remainder; salvage value is 15% of the capital value.

TABLE - B_2

CAPITAL COST STRUCTURE OF LOW LIFT PUMP

(Source: BADC, June, 1981)

Item of Cost	Cost (Including duty and taxes) In Tk.	Annualized cost 1/ In Tk.
a. Engine	22,800	4,475
b. Pump with	6,770	1,329
c. Pipes and accessories	8,364	1,641
d. Trolly and cupingries	[illegible]	[illegible]
	37,934	7,445

1/ Assuming sales at full financial cost, 13% annual interest rate, 8 years life and Salvage vlue is 15% of capital value.

TABLE - B_3

CAPITAL COST STRUCTURE OF 4" dia. SHALLOW TUBEWELL

(Source: BADC June, 1981)

Item of Cost	Cost (Including duty and taxes) in Tk.	Annualized cost[1/] in Tk.
a. Engine	9,600	1,884
b. Pump	4,000	785
c. Tubewell strainer 40'	3,600	707
d. Pipe 60'	3,240	636
e. Tubewell borring	1,600	333
f. Accessories	1,800	353
	23,840	4,658

1/ Assuming sales at full financial cost, 13% annual interest rate, 8 years life and salvage value is 15% of capital value.

TABLE - B_4

CAPITAL COST STRUCTURE OF HAND TUBEWELL

(Source: BADC, June, 1981)

Item of Cost	Cost (Including duty and taxes in Tk.		Annualized Cost in Tk. [1/]	
	2 Pipes	1 Pipe	2 Pipes	1 Pipe
a. Pump head	500	500	127	127
b. Pipe	800	400	138	72
c. Strainer	240	240	65	65
d. Installation	40	20	11	6
e. Transportation	20	20	6	6
	1,600	1,180	347	256

1/ Assuming sales at full financial cost, 13% annual interest rate, 5 years economic life for irrigation of the pump head, 10 years for pipe, 5 years for the strainer and saleave values of 20% for pump head and pipes, 10% for strainer of the capital value.

CONVERSION CHART

(Values are accurate only upto the number of figures shown)

Length

1 inch = 0.0833 ft. = 25.40 mm.
1 foot = 0.1667 fathom=30.48 cm.
1 meter= 39.37 inch=3.281 ft=1.094yd
1 chain=66 ft
1 furlong=10 chain=220 yds.
1 km = 1093.6 yds.=0.6214 mile
1 mile=1.609 km=0.869 naut.mile
1 nautical mile=6080ft.=1.152mile

Area

1 sq,m.=10.76 sft.=1.196 sq.yard
1 acre=4840 sq.yd.=0.4047 hect.
1 sq.mile=640 acre=2.59 sq. km.
1 sq.in.=6.452 sq.cm.
1 sft.=.0929 sq.m.
1 hectare=2.471 acre=10,000 sq.m.
1 bigha=0.33 acre=0.135 ha.

Volume

1 cft.=1728 cu.in.=7.481 US.gal=28.32 litre=6.228 Imp.gal.
1 U.S.gal=231.0 cu.in.=.1337 cft.=3.785 litre=8 pint(US)=.833 Imp.gal.
1 Imp.gal=277.42 cu.in.=1.2 US gal=4.545 Litre=8 pint(Imp.)=128 fl.oz.
1 Litre=61.03 cu.in.=1000.028 cc=0.264 US gal=0.220 Imp.gal.
1 acre ft.=43560 cft.=271300 Imp.gal.=1233.5 M^3 1 busshel =1.25 cft

V locity & Flow

1 fps =.6818 MPH=.592 knot=1.097 KPH
1 MPH=1.467 fps.=.863 knot=1.609 KPH
1 KPH =27.78 cm/sec.=0.6214MPH
1 knot=1.689 fps =1.152 MPH=1.853 KPH
1 Km/L=2.82 mile/gal.(Imp.)
1 Kg./ha.=.898 lb./acre
1 rdn/sec.=9.55 rpm
1 rpm=.1047 rdn/sec.
1 cusec=448.9 gpm(US)=373.7 gpm (Imp.)
1 cu.meter/min.=0.589 cusec
1 L/ha.=.09 gal./acre

Pressure

1 psi =0.0703 Kp/s.cm.=0.0681 at.=0.144 kip/sft,=2.036 inch Hg.
1 Kg/s.cm.=14.22 psi =.968 at.=2.048 kip/sft.=73.56 cm.Hg.=9.81 Newton/s.cm.
1 at.=14.70 psi=1.033 Kp/s.cm.=1.013 bar.=29.92 inch Hg.=76.0 cm.Hg
1 foot water=0.4331 psi=2.24 cm.Hg.=0.0299 bar.or megadyne/s.cm.

Mass

1 lb.=453.6 gram =7000 grain
1 Kg.=2.205 lb.=85.73 tola
1 seer=2.057 lb.=.933 Kg.
1 tola =180 grain =11.66 gram
1 cwt.=112 lb.=50.8 Kg.
1 short ton (U.S)=2000 lb=907 Kg.
1 long ton(U.K)=2240 lb=1016 kg.
1 metric ton = 2204.6 lb.=1000 Kg.
1 maund =82.29 lb.=37.32 Kg*.
1 quintal=100 Kg.=220.6 lb.=107.18 seer.

Energy & Power

1 ft-lb.=0.3228 cal=0.001285 BTU=0.1383 KP-M=1.356 joule or Newton-met.
1 KWH=1.341 HPH=1.360 psH=859.9 Kcal=3412 BTU=3.67x10^5Kp-m.
1 HPH=0.746 KWH=1.014 PsH=641.2 Kcal=2544 BTU=1.98 x 10^6 ft.-lb.
1 BTU = 778.2 ft.lb.=107.6 KP-M.=.252 Kcal=.2931 watt-H.
1 Kcal=3088 ft.-lb.=426.9 KP-cm.=3.968 BTU=4187 joules.=1.163 watt-H.
1 joule=10^7 erg=10^7 dyne-cm=0.2388 calorie=0.102 Kp-m.=.738 ft-lb.
1 HP =746 watts=1.014 Ps=550 ft-lb/sec=.1781 Kcal/sec.=.7068 BTU/sec.
1 K.W.=1.341 HP=1.36 Ps=.2388 Kcal/sec.=.9478 BTU/sec.
**1 Ps.=0.9863HP =75.0 Kp-m/sec =0.1757 Kcal/sec=542.5 ft.lb/sec.

* Calculated at 80 tolas per seer

** Ps = Pferde - Starke = Metric Horse Power
1 Kp = Kilopond force = 1 Kg x 1 'g' acceleration.=9.8067 Newton.