WATER AND SANITATION FOR HEALTH PROJECT

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PHILIPPINE HAND PUMP PROGRAM (BARANGAY WATER PROGRAM)

WASH FIELD REPORT NO. 54

AUGUST 1982

Prepared for:
USAID Mission to the Philippines
Order of Technical Direction No. 40

WATER AND SANITATION FOR HEALTH PROJECT

WASH

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18 August 1982

Mr. Anthony Schwarzwalder
Mission Director
USAID
Manila

Attn: Mr. Carlos Crowe

Dear Mr. Schwarzwalder:

On behalf of the WASH Project I am pleased to provide you with 10 copies of a report on Philippines Hand Pump Program.

This is the final report by Mssrs. Alan Pashkevich and Tyler E. Gass and is based on their four trips to the Philippines. Mr. Pashkevich was in the Philippines from 5 July to 23 December 1981, and from 1 March to 30 March 1982; trips by Mr. Gass were from 23 January to 23 March 1982, and from 13 April to 28 April 1982.

This assistance is the result of a request by the Mission on 22 January 1981 in Cable Manila 1775. The work was undertaken by the WASH Project on 14 May 1981 by means of Order of Technical Direction No. 40, authorized by the USAID Office of Health in Washington.

If you have any questions or comments regarding the findings or recommendations contained in this report we will be happy to discuss them.

Sincerely,

Dennis B. Warner

Dennis B. Warner, Ph.D., P.E.
Director
WASH Project

cc: Mr. Victor W.R. Wehman, Jr.
S&T/H/WS

DBW:MSC:nmc

WASH FIELD REPORT NO. 54

PHILIPPINES

PHILIPPINE HAND PUMP PROGRAM (BARANGAY WATER PROGRAM)

Prepared for the USAID Mission to the Philippines
Under Order of Technical Direction No. 40

Prepared by:

P. Alan Pashkevich
and
Tyler E. Gass

August 1982

Water and Sanitation for Health Project
Contract No. AID/DSPE-C-0080, Project No. 931-1176
is sponsored by the Office of Health, Bureau for Science and Technology
U.S. Agency for International Development
Washington, DC 20523

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ACKNOWLEDGEMENTS

The consultants, Mr. Gass and Mr. Pashkevich, wish to express their gratitude on behalf of Georgia Tech to the many people who have given of their time and energy during the undertaking of the Philippine Hand Pump Program. The authors would like to express special thanks to Mr. Charles Brady and Mr. Carlos Crowe, USAID project directors for the Barangay Water Program (BWP), Mr. Gaspar Nepomoceno, BWP Project Director, Engineer Oscar Basa, USAID, and Engineer Rene Galera, Tri-Star Metal Industries, for their contributions to a very successful program.

The following BWP personnel who served as trainers during the hand pump and water well technologies seminar are also deserving of special mention:

Noel Viaje	Romeo Calumpad
Lex Nesas	Henry Berango
Ruth Reyes	Danilo Santos
Joel Valdescona	Rudy Soriao
Menrado Sabuya	Frisco Perez
Larry Cabrera	

The authors also wish to express their appreciation to the BWP training personnel who assisted in the preparation and delivery of the seminar, the secretaries (Glo and Vangi) who spent long hours typing the manuals, the staff and management of Tri-Star Metal Industries and the staff and management of Batulao Club where the seminar was held.

While it is impossible to list all the individuals who rendered assistance, it is hoped that those mentioned will pass along the gratitude of the Georgia Tech personnel to all associated with the program.

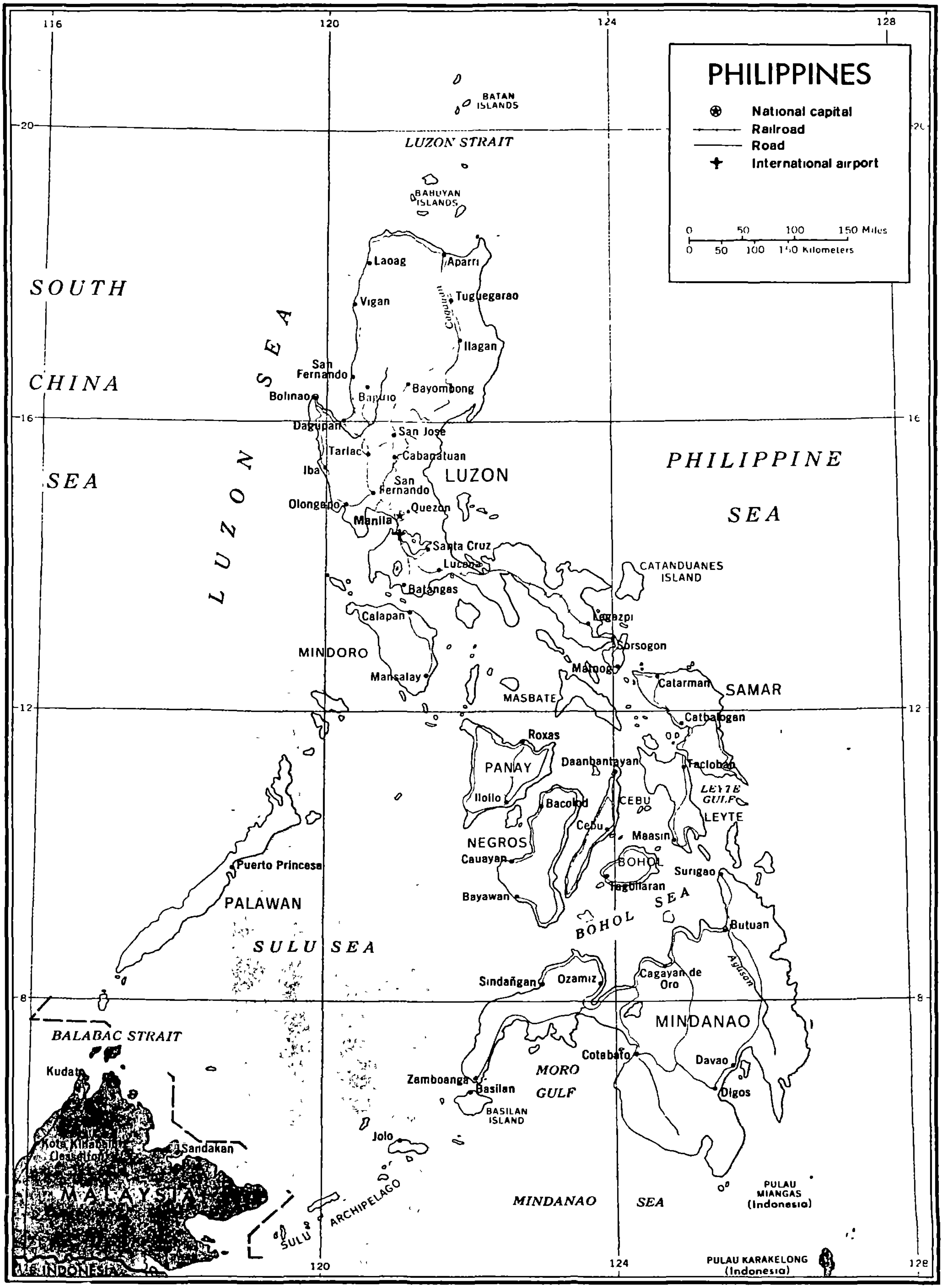
EXECUTIVE SUMMARY

Georgia Institute of Technology (Georgia Tech) was contracted in June, 1981, by CDM Five, principal consultants of the Water and Sanitation for Health (WASH) Project sponsored by the Agency for International Development (AID), to provide technical assistance to the AID Mission to the Philippines (USAID/Manila) and to the Government of the Philippines through the Barangay Water Program (BWP). Technical assistance was provided for hand pump manufacture and installation, water well technology, the development of hand pump and water well technology manuals, and the delivery of a training seminar based on the manuals. The primary consultants for Georgia Tech were Mr. P. Alan Pashkevich, Research Engineer, Georgia Tech and Mr. Tyler E. Gass, Hydrogeologist, Bennett and Gass, Inc. Mr. Pashkevich was responsible for the hand pump component while Mr. Gass carried out the water well component.

Work on the hand pump component began in early July 1981. Two hundred fifty hand pumps and 400 two-inch deep well cylinders were produced, tested and accepted on behalf of AID by Georgia Tech over the following ten months. The consultant was satisfied with the competency and product quality of the manufacturer. Ten hand pump units were installed in the field beginning in the latter half of November 1981, and monitored by Georgia Tech and USAID/Manila personnel. Monitoring is continuing under USAID/Manila supervision. The hand pump technology manual addresses pump operation, sanitary site selection, well disinfection, monitoring, and pump installation, maintenance and repair. The manual was reviewed and found applicable and readable by AID/Washington, USAID/Manila, and BWP personnel, by a WASH consultant, and by the seminar participants.

The water well technology component began in January 1981 with surveys of local well drillers' capacity, existing hand pump installations of the Barangay Water Program (BWP) (a project jointly sponsored by USAID and the Philippine Ministry of Local Government) and a local manufacturer of PVC well casing and screen. Following the initiation of these surveys, work began on the development of the water well technology manual addressing basic hydrogeology, well site selection, water well design, well construction, installation of plastic well casing, casing seal, well development, testing, maintenance, rehabilitation and abandonment, well records, and water well construction standards. The manual was also reviewed and found to be applicable and readable by AID/Washington, USAID/Manila, and BWP personnel, by a WASH consultant, and by the seminar participants.

In March of 1982, Mr. Gass and Mr. Pashkevich began preparations for the training seminar. Ten trainers assisted the consultants in the training of the ninety engineers and technicians who participated in the seminar. The trainers helped design the seminar, led groups of up to 10 people, and provided valuable feedback during the seminar and ensuing evaluation. Evaluations by the participants and trainers indicated that the seminar successfully imparted the desired information and skills to the participants. The evaluations also revealed that it was the first BWP seminar to make use of small groups and workshops. However, it was strongly recommended that the scope and detail of the water well technology training segment be broadened and deepened to more fully meet the needs of the waterworks engineers who design and supervise the construction of the wells.



Source: Background Notes, U.S. Department of State, Publication 7750, 1981.

Chapter 1

BACKGROUND

1.1 Introduction

There is an obvious need for effective rural water supply programs in the Philippines. The country's population has been growing at an annual rate of approximately three percent over the last decade and in 1976 was about 43.7 million (12.7 million or 29 percent in urban areas and 31 million or 71 percent in rural communities). During the next several years, the population is expected to increase by an average of 1.3 million per year with the urban sector increasing by 0.5 million and the rural sector by 0.8 million annually. Water and sanitation related diseases remain a significant health problem (of the ten leading causes of morbidity between 1970 and 1975, gastroenteritis was third with a rate of 545 cases per 100,000 population and dysentery was eighth with a rate of about 48 per 100,000). At the present time, some 23.8 million people (55% of the total population) utilize water often of doubtful quality from various sources such as open wells, rain water cisterns, lakes and streams.[1/]

In response to the need in countries like the Philippines for a reliable and improved supply of safe water and the worldwide need for a long-lasting, easily maintained and repaired, economical, locally manufactured hand pump, the Agency for International Development (AID) contracted the Battelle Memorial Institute to design, develop and laboratory test a reciprocating pump for shallow and deep well application. After completion of a final design, Georgia Institute of Technology (Georgia Tech) was contracted by AID in late 1976 to manufacture and field test the pump in Nicaragua and Costa Rica. The scope of work included the provision of technical assistance to foundries and machine shops in the manufacturing operations and the evaluation of the performance and acceptability of the hand pump when heavily used in field situations. The hand pump was subsequently determined to be reliable, sturdy, easily maintained, low in cost compared to imports, and capable of being manufactured in developing countries.

After the completion of a local feasibility survey of existing manufacturing capabilities, AID hand pump programs have been initiated in Nicaragua, Costa Rica, the Dominican Republic, Indonesia, Tunisia, Sri Lanka, Honduras, Ecuador and the Philippines. In undertaking projects in these countries, Georgia Tech has established a proven methodology for coordinating the efforts of private sector manufacturers and government organizations in implementing comprehensive hand pump programs that address a wide range of technical needs. The needs include quality control in pump production, site selection, pump installation, pump performance monitoring and evaluation, preparation of hand pump training manuals, water quality analysis, and training in installation, maintenance and repair. Most recently, Georgia Tech has rendered technical assistance in the fields of hydrogeology and water well design, construction, development, and

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1/ Phillip W. Potts, Robert Knight and Dr. Yaron M. Sternberg, Feasibility of Local Manufacture of the AID Hand-Operated Water Pump and Other Technology Appropriate for Rural Water Supply Programs in the Philippines (Atlanta: Georgia Institute of Technology, 1979), pp. 3-4.

maintenance. Included in this assistance have been surveys of well drillers' capacities (equipment, techniques, personnel, training, etc.), evaluation of plastic well screen and casing, preparation of a water well training manual, training in water well technology and advisement on proposed and completed water well installations.

The Philippine Hand Pump Program is one segment of an integrated water supply scheme called the Barangay Water Program (BWP). BWP is jointly sponsored, funded and administered by USAID and the Philippine Ministry of Local Government. The following are excerpts from the introduction to the Barangay Water Program Operations Manual.[2/]

> The Barangay Water Program (BWP) is a domestic water program to provide potable water for household purposes to small rural farming and fishing communities. As the communities are small, the water systems are also small, generally consisting of the development of springs or wells, storage facilities, and transmission lines and laterals. Water is delivered to the consumers through strategically placed public faucets or individual house connections. The type and size of the projects will vary from community to community, but one characteristic is central to all systems: they will be owned, maintained, and managed by the users themselves through rural waterworks associations.
>
> With 42,000 small rural communities, representing 20 million Filipinos largely outside the jurisdiction of water systems in the Philippines, there is no central agency with sufficient resources or organizational outreach to satisfactorily diminish the magnitude of the water problem. Therefore, the Barangay Water Program works through local officials, provincial or city governments, in an effort to develop their capabilities to plan and install village-owned water systems. A small national level project management staff sets the policies, standards, and guidelines and trains the local government planning and engineering offices to develop and implement the water systems.
>
> The immediate goal of the Barangay Water Program is to develop national and local government capacity to plan, design, and implement small scale domestic water systems. Local BWP Rural Water Associations will manage, maintain and operate the systems. The local associations will also repay a portion of the systems' capital costs.... A longer range goal is the proliferation of water systems and facilities in small rural communities across the country.
>
> [The beneficiaries] are small rural farming and fishing communities ranging in size up to [10,000] people.... The beneficiaries will fall largely in the lowest 60% of the nation's income group.
>
> The basic project offerings under the Barangay Water Program are water systems rather than handpumps due to the greater health, economic and social benefits associated with the former, and

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[2/] Barangay Water Program Operations Manual, Ministry of Local Government and Community Development, Philippines, p. 1-1.

because of the obvious convenience factors made possible through complete systems.... Nevertheless, handpump projects are also undertaken on a limited basis in order to accommodate locations where electricity does not exist or where full-fledged systems are not technically advisable or financially feasible.

1.2 Survey of Existing Pumps

A survey of existing hand pump technology was conducted by Georgia Tech during August of 1981. Surveyed were fourteen Local Government Units (LGU's) from Northern Luzon to Central Mindanao including southern Tagalog and the Visayas.

The currently used hand pumps are of two basic types: the jetmatic and the traditional hand pumps. The jetmatic (also trade named Fuji, Jetmatic, Dragon, Lucky and Wilson) is widely available throughout the Philippines and spare parts can be purchased at most hardware stores. This is the only pump available through the Rural Waterworks Development Corporation water program and the primary pump used in BWP's Level I projects.[3] The pump is only for use in wells where the water table is 25 feet or less. The pump is priced and designed for single-family use. The cost of the jetmatic pump varies from $25 to $50, depending on the quality of materials and the country where it was produced. The cast components have thin cross sections and the bearing surfaces are small. Mating surfaces are often poorly machined and casting defects are sometimes epoxied over. The pump uses a four-inch rubber cup. The rubber cup will not form a seal with the cylinder walls when it has worn down a little. This, coupled with a leaky foot valve, requires that the pump be primed daily or even more frequently. The local engineers who install jetmatic pumps say that the expected lifetime of the pump being used by an average of ten households (sixty people) is about three years. The most common causes of failure are broken cast parts and worn out bearing surfaces.

The jetmatic has a lower-cost version called the "pitcher pump." It utilizes the same cups but is smaller overall (in height, handle length, and bearing surface area) and sells for about $12. Its expected life is two years at best when used for community water supply (multi-family use).

The traditional pump (also called Magsaysay, after the late Filipino president, Ramon Magsaysay, who implemented a widespread water program) utilizes locally available materials for the superstructure (cement, pipe fittings, wooden beam, etc.) and a down-the-casing cylinder. Many pumps that were installed during the Magsaysay Administration in the mid-1950's are still operating. The long wooden handle gives good mechanical advantage for pumping at the lower water tables (100-200 feet). However, leaky foot valves and a long, bulky handle have caused the users to label the pump cumbersome. Often, regardless of the feasibility, the prospective users will request that the traditional pump be replaced with a jetmatic pump because of its relative ease of operation. There is no standard design for the traditional hand pump. This leads to the use of low quality materials (including the pivot shaft and bearings) and excessive time being

[3] BWP provides three levels of service to its beneficiaries: Level I service consists of hand pumps; Level II provides piped water systems with stand pipe connections; and Level III service provides piped water-systems with in-house connections.

spent on the design and construction of each project. A governmental unit is usually required to make repairs because 1) the tripod and necessary tools are not usually available in the village and 2) the users do not think of it as their pump. The cost of materials for the superstructure and cylinder varies from $75 to $150.

The survey of existing hand pump installations revealed that sanitary well protection has not been emphasized by recent water programs during well site selection or well-head construction. The largest factors in the selection of a hand pump site were donated land and access to the population. However, this led to siting the pumps near sources of contamination such as toilets, creeks, animal pens, etc. In most installations, the concrete apron was four feet by four feet square or less with little or no drainage provided. Well casings were seldom sealed at the top by grouting or by a water tight joint at the apron. However, the best protected wells with the largest aprons and best drainage were those with a traditional hand pump.

The inadequacies of the existing pumps and installations can be summarized as follows: (1) there is a general lack of quality control resulting in accelerated wear and premature failure, 2) the traditional pumps are less favored than the jetmatic because of their "heavy" operation and difficulties encountered in repair, 3) the jetmatic pumps are underdesigned for use in community water supply, and 4) little attention is paid to sanitary well site selection and construction techniques. It was the opinion of USAID/Manila, the BWP Project Director and the consultant that these inadequacies could be resolved or lessened by: 1) the in-country production of a high quality hand pump for use in all pitcher and jetmatic hand pump applications and many traditional hand pump applications, 2) the in-country production of a deep well cylinder for use with the traditional hand pump superstructure, 3) the writing of a hand pump installation, maintenance, and repair manual to: a) establish sanitary well head construction techniques, b) standardize traditional hand pump design, and c) be used as an instruction manual for hand pump installation, maintenance and repair, and 4) the presentation of a seminar based on the manual to train technicians and engineers in hand pump technologies.

1.3 Scope of Work

The scope of work of WASH Order of Technical Direction (OTD) 40, the Philippine Hand Pump Program, was divided into two components: the first concerned hand pumps and the second dealt with water wells. Following are the tasks outlined in the scope of work for each component. OTD 40 and supporting documents appear in Appendix A.

Component #1 - Hand Pump Development and Reproduction[4/]

A. Selection of a suitable manufacturer for reproduction of two hundred fifty (250) AID hand pumps.
B. Selection of suitable manufacturers and suppliers for the reproduction of four hundred (400) improved 2-inch diameter cylinders for deep-well hand pumps.

[4/] Component #1 as it appears here is taken from the Telex: MANILA 1775, 22 Jan 81, as amended by OTD 40.

C. Provision of technical assistance to both of the above suppliers on the various aspects of hand pump and cylinder reproduction, including the provision of drawings and patterns, replication of prototype hand pumps, and the provision of continuous technical assistance through final acceptance by the WASH contractor of the 250 AID hand pumps and the 400 cylinders.
D. Installation and training of locals in installation of up to 20 of the hand pump systems in sites agreeable to and with the approval of AID mission liaison officer (Mr. Charles Brady).
E. Preparation of a section in the BWP Operations Manual entitled "Hand Pump" covering hand pump installation, maintenance and repair.
F. Participation as a principal resource speaker in a four-day training seminar for Local Government waterworks engineers and technicians, the BWP architectural and engineering (A&E) firm and the USAID engineering personnel. The seminar will utilize the materials prepared in item "D" of the scope of work as the basis for the curriculum and will cover hand pump installation, maintenance, and repair.

Component #2 - Well Design and Construction [5/]

1. Familiarization of Barangay Water Program (BWP) well requirements based on a survey of existing BWP projects. Subcontractor shall prepare a comprehensive survey of Level 1 (hand pump activities) programs in the Philippines which are currently being implemented unsatisfactorily by a number of both centrally located and local Government of Philippines (GOP) agencies. Thus, the review should include an investigation of the procedures, approaches and outputs of each program.
2. Survey of Philippine well driller's capacity (equipment, techniques, personnel, training, etc.). Subcontractor shall prepare a survey which will include a thorough look at both the public and private sectors, and will require coordination with various GOP agencies and private companies, field visitation trips, data collection, and data analysis.
3. Provision of technical assistance to various Manila and/or Cebu based suppliers and manufacturers of plastic well casing and well screen. This technical assistance should focus on one particular supplier, Neltex, to evaluate its present production of both casing and screen in comparison with potential quantity and quality of competitors.
4. Preparation of a section for the BWP water operation manual entitled "Well Design and Construction." This will include preparation of criteria for site selection and well development standards and specifications based on knowledge gained while doing items 1, 2, and 3, and in consultation with BWP hydrogeologists. A step-by-step manual will be prepared by Subcontractor for site selection and source development taking into account existing data bases as well as driller capabilities, agency financial capacities, local support industries, and will provide procedures for such items as well perforation, casing, screening, disinfecting, well recharging and rehabilitation, water quality testing, and water quality control.

[5/] "Scope of Work" from Subcontract for Consulting Services Under GIT Project No. A2957-002 Between Georgia Institute of Technology and Bennett and Gass, Inc., Jan. 21, 1982, Exhibit A.

5. Preparation for classroom and field practicum presentations of a seminar for local government waterworks technicians and engineers, to include printing of well development manuals and guides, curriculum and training materials.

6. Participation as a principal resource speaker in a seminar for waterworks technicians, local A&E engineers, and USAID technical personnel on well design and construction. This aspect will include training in well site selection, materials, design standards, drilling, casing, gravel packing, grouting, testing and disinfecting wells. The seminar will be one week in duration and will be held jointly with a member of the research faculty of the Georgia Institute of Technology who will cover hand pump nomenclature, installation, maintenance and repair.

1.4 Modification of the Original Scope of Work

Component #1 Paragraph B. Due to the unexpectedly large amount of research and design that went into producing the improved two-inch cylinders and to the fact that the manufacturer was heavily involved in the design process, it was expedient to produce the deep-well cylinders at the same factory as the pumps.

Component #1 Paragraph B and C. The number of cylinders to be produced was changed from "300 two-inch deep well cylinders and... 100 three-inch deep well cylinders" to 400 two-inch deep well cylinders at the request of USAID/Manila because the majority of existing well casings are less than the four-inch diameter required for three-inch cylinders.

Component #1, Paragraph F. The five-day seminar was reduced to four based on the anticipated amount of time required to effectively present the seminar material.

Component #1, Paragraph F. The seminar participants included Waterworks Engineers because they site, design, and supervise the construction of the wells. It would not have been necessary to invite the engineers had the seminar concerned hand pumps only.

1.5 Report Organization

Mr. P. Alan Pashkevich, Research Engineer, and Mr. Tyler E. Gass, Hydrogeologist, undertook the tasks of Component #1 and Component #2, respectively. Tasks A through E of Component #1 and 1 through 4 of Component #2 were completed independently by the consultants. The other tasks (preparation and delivery of the Level I seminar) were interrelated and were undertaken jointly. For this reason, the remainder of the report follows in a similar order with the consultants' itineraries included as Appendix B. Appendix C provides a listing of officials interviewed by project consultants.

Chapter 2

MANUFACTURING
(Component #1, Tasks A,B,C)

2.1 Foundry Selection

Before OTD 40 was issued, a survey of existing manufacturing capabilities for the production of the AID pump was conducted by Mr. Phillip W. Potts (Georgia Tech), Mr. Robert Knight (U. of Maryland), Dr. Yaron M. Sternberg (U. of Maryland) and Mr. Victor W. R. Wehman (AID/Washington) during a visit to the Philippines from March 3 to March 24, 1979. Eight foundries throughout the Philippines were visited to investigate the feasibility of manufacturing the AID pump. Of the eight foundries, four were located in Manila, two in Cebu and two in Iloilo. The survey concluded that based on equipment, quality of current work, capacity, and management interest, Tri-Star Metal Industries in Manila, Metaphil, Inc., in Cebu, and New Commonwealth Foundry Shop in Iloilo would be suitable foundries for the manufacture of the pumps.

The following profiles of the three recommended foundries are summarized from the report issued by the survey team at the conclusion of the survey:[6/]

1. Tri-Star Metal Industries, 210 Jaboneros Street, Binondo, Manila--This was a young and dynamic company that has been in operation since early 1977. The average management age was 30-32 years. The foundry was orderly and clean with good working conditions for its employees. The plant was complete with laboratory and testing equipment. The pattern shop appeared to be excellent and the machine shop was well-equipped with some twenty-four lathes, five drilling machines, two milling machines, a large planing machine and an eight-foot vertical lathe. At the time of the survey, the firm was awaiting the delivery of new equipment, including centrifugal molding machines from the United States. The management (Mr. Herman Laurel, Mr. Leong Lam and Mr. Crisanto Lomuntad) showed a definite interest in manufacturing the AID pump and a visual inspection of their castings suggested that the AID pump was well within the company's capabilities. The estimated price for an initial order of 50 AID pumps was \$60-\$65 and this unit price was projected to drop below \$50 with larger quantities (100 or more pumps per order) after initial development costs were recovered.

2. Metaphil, Inc., M. J. Cuenco Avenue, Corner Manalili Street, P.O. Box 722, Cebu City--Metaphil Inc., was more than adequate for the manufacture of the AID hand pump. Personal observations of the plant facilities and management of the company revealed competence and quality consciousness that led to the conclusion that Metaphil would be a suitable AID pump manufacturer. However, the estimated price for the AID pump, if manufactured by Metaphil, would have been \$80.

3. New Commonwealth Foundry Shop, 108 Arsenal Street, Iloilo City--The manager of this foundry, Mr. Limneo Ang, appeared extremely interested

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6/ Potts, Knight and Sternberg, _op_. _cit_., p. 13-16.

in manufacturing the AID pump and knowledgeable of the requirements for producing a quality pump. The facilities observed were admirable with modern equipment, skilled labor and finished products that denoted quality castings and machining. The foundry was also expanding and had the capacity for increased volumes of production.

An estimate of the price for manufacturing the AID pump at New Commonwealth was \$60-\$65 on the initial order. Mr. Ang believed that subsequent orders would have enabled lower prices as his employees became more efficient in the production of the pump and as larger orders (greater than 100 units) brought about economies of scale.

In July 1981, under OTD 40, Mr. Phillip W. Potts, Mr. William C. Larson, and Mr. P. Alan Pashkevich arrived in the Philippines to make the final selection of the pump manufacturer. Mr. Charles C. Brady, then the USAID Project Officer for BWP, concurred with the recommendation of the Georgia Tech team that Tri-Star Metal Industries be selected to manufacture the pumps. During the intervening 28 months, increased material and labor costs raised the price of the pump to \$95.60. On July 15, 1981, a contract was signed with Tri-Star for the production of 125 shallow-set pumps. This was followed by an order for 125 medium-set pumps on July 22, 1981 and an order for 400 deep well cylinders on December 17, 1981.

2.2 Manufacturing Operations

The manufacturing process began in July 1981, and consisted basically of the following subprocesses:

1. Pattern Making
   Using an AID hand pump made in Indonesia and working drawings supplied by Georgia Tech, a set of wooden patterns was prepared. The one exception was the handle pattern which was a modified cast iron (C.I.) handle from the sample pump because the pattern makers found it too difficult to copy. The smaller patterns were set on a match plate and the larger patterns were split. The match plate and split patterns could both be used on the pneumatic self-stripping molding machines which decreased mold preparation time and improved casting quality.

2. Mold Making
   Green sand molds were used to cast the various pump components. Molding boxes were made of metal which allowed accurate matching of the cope and drag. The molds were made on a bank of molding machines designed by the foundry engineer, Rene Galera. These machines facilitated the tamping of the sand and the stripping of the patterns from the mold while increasing the mold production rate. The cores were made of a clay/sand mixture and were hardened using a heat-activated CO_2 stabilized process.

3. Casting
   Scrap metal of select quality was melted down in Tri-Star's two 5-ton cupolas. The melt was transported to the molds from the cupolas either by hand or overhead crane. All pouring was done by hand.

4. Machining
The castings were prepared for machining by sand blasting. Most of the machining and threading operations were performed by lathe. Other major processes employed were shaping (cap) and grinding (cap, handle, fulcrum, and body).

5. Miscellaneous Components
The PVC deep well cylinder body components and the PVC sleeve were purchased from local manufacturers and were machined and assembled by Tri-Star. American-made leather cups were procured through an importer at the request of USAID/Manila to assemble the pumps with the highest grade materials available on the local market. However, locally manufactured cups in the correct sizes are widely available on the local market, too. The rubber seal used in the valve assembly was punched out by a subcontractor and assembled by Tri-Star. Pins and bushings were machined by Tri-Star and hardened by a subcontractor. Random sampling at Tri-Star's laboratory showed the pins and bushings to be within the specified hardness ranges.

6. Assembly
Tri-Star designated one crew to work full time on the assembly of the pumps. The subcomponents such as the plunger assemblies, foot valves, and deep well cylinder bodies were assembled first. All the subcomponents were then organized in specific locations of the factory to facilitate assembly. Tri-Star systemmatically checked each component for quality in the casting, machining and assembly subprocesses. Most of the rejected parts were culled in the casting stage, usually for excess porosity. Excess porosity was also easily spotted in the machining subprocess. During assembly, each foot valve was tested for leaks. If the valve could hold a column of water overnight, Tri-Star would pass the valve. The major cause of valve leaks was the sealant that was used around the valve seat being smeared on the valve seat itself. These and other defects noted during the acceptance testing are detailed in Section 2.4. The shallow-set and medium-set pumps appear in Figures 1 and 2.

2.3 Design of the Deep Well Cylinder

Georgia Tech was requested to render technical assistance in the design and reproduction of 525 improved two-inch cylinders for deep well hand pumps (125 for the medium-set well pumps and 400 additional). The design constraints established by USAID/Manila and Georgia Tech were that the cylinder 1) fit inside a 3" well casing, 2) perform satisfactorily (without foot valve leaks, rapid cup wear, cylinder failure, etc.) over a long period of time under heavy usage, and 3) require infrequent maintenance and repair which could be easily undertaken by an LGU. In addition, it was decided that whenever a choice between quality and cost was required, quality should be selected.

Georgia Tech's design was not the first attempt to produce a 2-inch polyvinyl chloride (PVC) cylinder in the Philippines. The Water Resources Center of the University of San Carlos in Cebu City had been developing a 2" deep well cylinder over the previous year under a USAID grant and had installed several prototypes in the field. Their design utilized a PVC pipe as the cylinder with internal threads machined into either end to attach the brass cylinder ends.

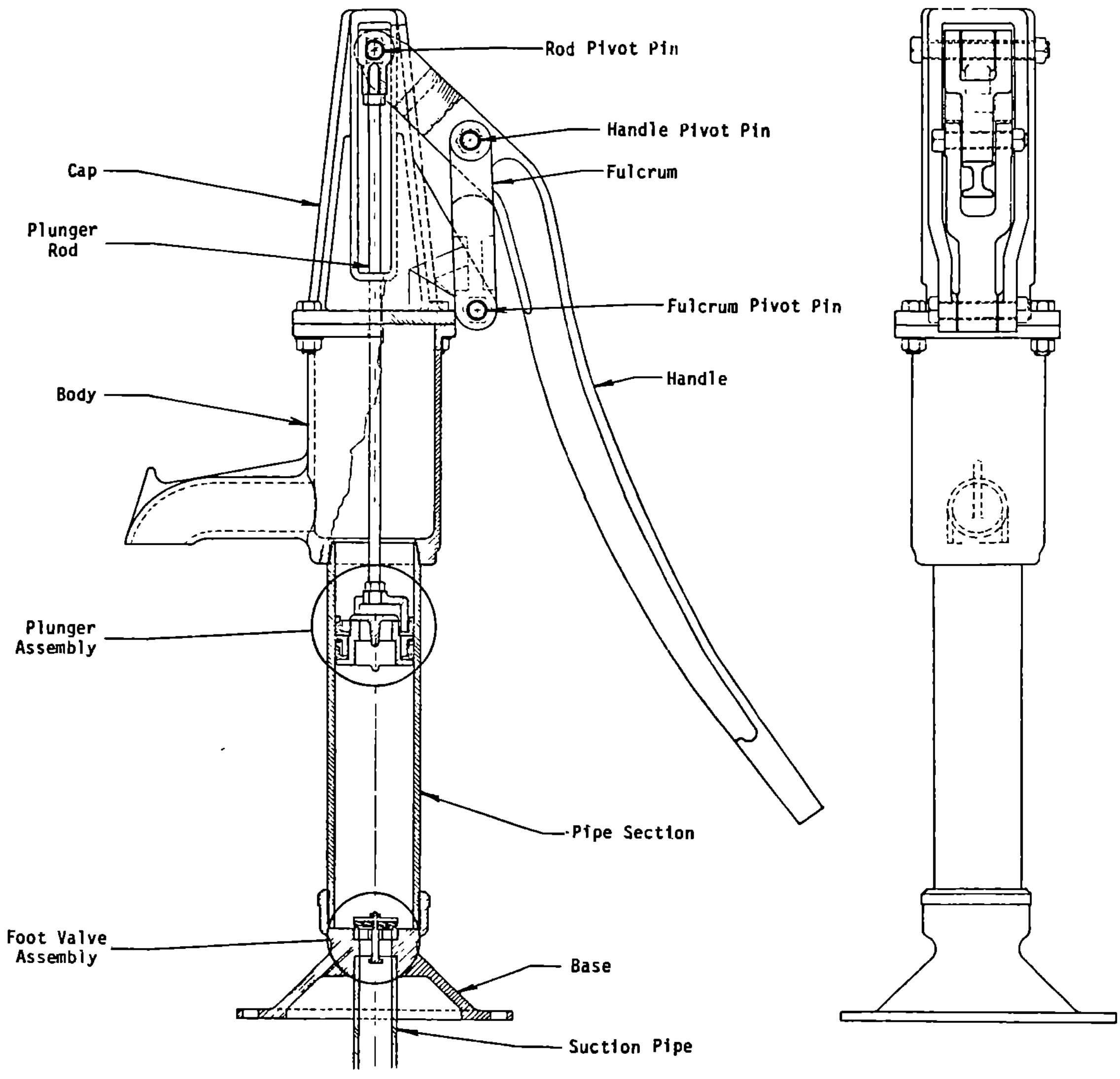

Figure 1 Shallow-Set Pump

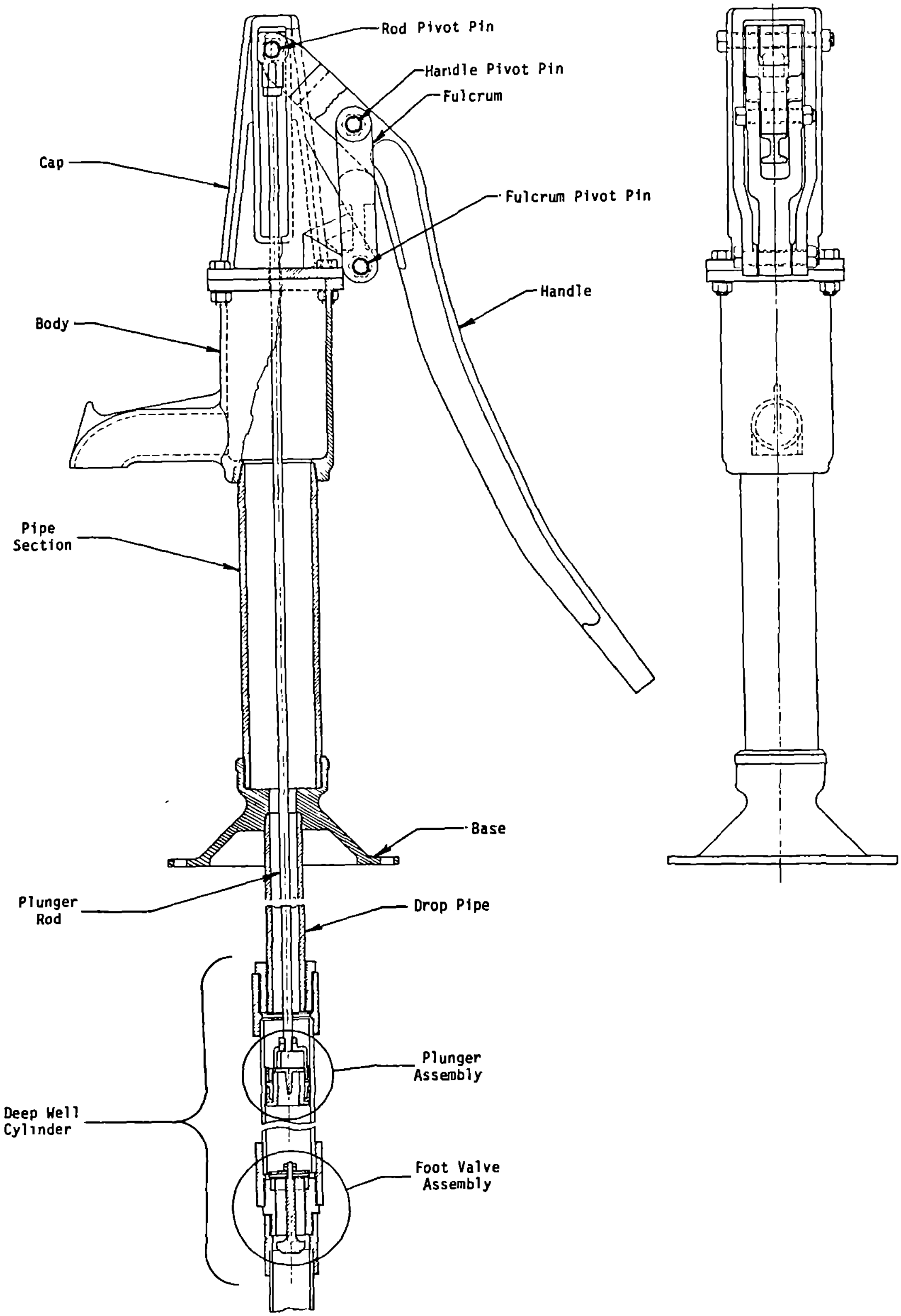

Figure 2 Medium-Set Pump

The foot valve was a brass poppet seating on an "O" ring and the plunger assembly was similar to that used in the AID pump. The University's engineers were finding that the cylinder wall would fail at the first thread of the lower (foot valve) end of the cylinder. A PVC coupling was glued around either end to thicken the walls. However, the glue used did not solvent weld the coupling to the pipe and the cylinder continued to fail at the same place. Georgia Tech personnel examined several of the failed cylinders and suggested that the failure was caused by stress concentrations resulting from the impacting forces of normal pumping. The "V" notches (threads) in the cylinder wall reduced the cross-sectional area and provided a point for crack propagation to begin. Additionally, PVC has low notch resistance. Georgia Tech recommended that 1) molded threads be used to reduce stress buildup caused by machining, and 2) the glue being used to join the coupling to the pipe be changed to a solvent.

After determination, on a cost basis, that PVC pipe would be used as the cylinder body, these recommendations were incorporated into the Georgia Tech design. A commercially available PVC female threaded adapter was specified for use. Also, a weld quality test was performed at Neltex's Pomplona extrusion plant on various solvents and, to the delight of Neltex personnel, Neltex solvent was found to be the only solvent of those tested; the others did not form a welded bond between the joined pieces (See Appendix F, Section 8C.6.3.1).

The design as originally conceived called for the plunger assembly and foot valve to be withdrawn through the pump base without having to remove the drop pipe. Clayton-Mark currently uses a design similar to this. However, this "through the pump" arrangement was prevented by 1) the uncertainty of making a long lasting connection between PVC drop pipe and the pump base (according to constraint #2 above) without significantly altering the pump base design, and 2) the unavailability of GI pipe whose couplings would fit in a 3" casing while allowing 2-inch diameter cups to pass through the pipe (the next smaller PVC pipe was 1 1/2" diameter and was considered too small for community water supply use).

Two-inch diameter (63mm) ISO[7/] PVC pipe was used for the cylinder because ASTM[8/] standard PVC pipe was being phased out of production in the Philippines. Clayton-Mark leather cups of 2 1/8" diameter were specified for their quality and fit. One and one-half inch (1 1/2") galvanized iron (GI) drop pipe was chosen because of its availability and three-eighths inch diameter (3/8") GI pipe was selected as the plunger rod because of its lightness, rigidity, corrosion resistance, and price. The deep well cylinder was designed to accept these sizes of drop pipe and plunger rod and appears in Figure 3.

The poppet-type foot valve design was selected because of its long life as demonstrated by its wide usage in high quality commercial hand pumps. The foot-valve has traditionally been one of the higher maintenance items on the AID pump. When discussing this aspect with Charles Brady of USAID/Manila, he recommended that, since pump repairs would be undertaken by the Waterworks Repair Shop of the various LGU's who would have responsibility for the repair of tens or hundreds of pumps, the maintenance requirements be reduced as much as feasi-

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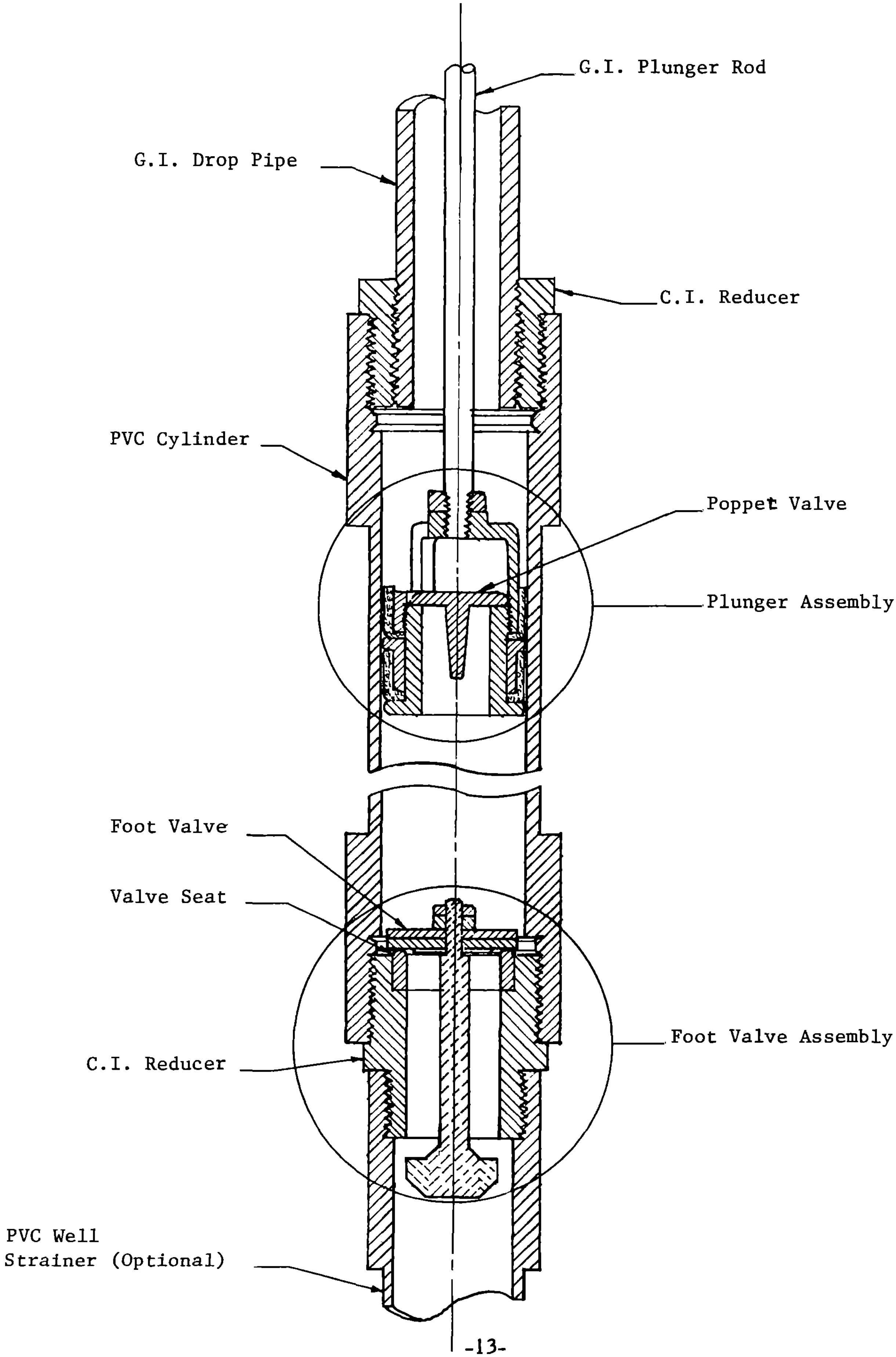
7/ International Standards Organization

8/ American Society for Testing Materials

FIGURE 3 DEEP WELL CYLINDER



ble even if it meant increased initial costs. This logic was applied to the shallow-set foot valve as well as the deep well cylinder foot valve although the designs differ somewhat to provide proper poppet guidance and adequate flow area.

The medium-set pumps were the first test pumps to be installed in the field (see Chapter 3) so that problem areas in the cylinder could be identified and corrected by the manufacturer before the order for 400 deep well cylinders was placed. No major problem has been encountered with the five test cylinders in the field to date. When the consultant inspected the pumps in March 1982, all cylinders were delivering the design water flow and exhibited no leakage through the foot valve.

2.4 Pump Acceptance Testing

2.4.1 General Inspection

Each pump unit was individually operated before acceptance to discern any major problems. The shallow-set pumps and deep well cylinders were tested by pumping water with them. The medium-set pumps were operated to demonstrate freedom of motion. All pump units were examined for binding, tightness and rubbing. The shallow-set pumps and deep well cylinder units were also examined for leakage.

Below is a summary of the acceptance testing:

	Shallow-Set	Medium-set Superstructure	Deep Well Cylinder
Total tested	125	125	525[1]
Leak around base[2]	8	NA	NA
Leak around body[3]	2	NA	0
Leak through base[4]	2	NA	NA
Leak through foot valve[5]	0	NA	8
Binding - pins overtightened[6]	7	26	NA
Slider blocks binding in tracks[7]	8	14	NA
Would not pump water	0	NA	0
Too difficult to pump[8]	0	NA	15
Cups unavailable[9]	0	NA	159
Loose valve seat[10]	0	NA	1
Cups slipped up on plunger assembly[11]	0	NA	2

NOTES:

1. This number includes 125 cylinders for the medium-set pumps in addition to the order of 400 units.
2. In six cases, leaks in the base could be directly attributed to casting voids in the threaded area that joins the pipe section. The other two showed no obvious defect. The six bases were replaced and the other two reassembled. No further leaks were noted.
3. Leaks through the threads joining the pipe section to the body were allowed by voids in the sealant. Sealant was reapplied and the components rejoined with no subsequent leakage.
4. In 2 cases, water leaked through the bases due to casting defects and high porosity. Both bases were replaced.

5. It was noted that 8 cylinders leaked excessively. When disassembled and examined, it was found that the valve rubber had separated from the weight. After calling this to the manufacturer's attention early in the inspection process, no more separations were found.
6. The overtightening of pins was related to the manufacturer who reinstructed his laborers. The use of a lock washer was also dissallowed. Pins were loosened whenever this situation was encountered.
7. Most binding was minor and would lessen with usage. One set of oversized blocks was replaced. These were the only non-standard sized blocks noted.
8. Ragged edges on the cups caused the difficulty in pumping. The upper edge of the bottom cup would overlap the top cup, making the lower cup's effective diameter approximately 1/16" larger. The manufacturer trimmed off the ragged edges on these cups and those used subsequently.
9. Cups for these cylinders were not available before the consultant departed. A visual inspection of each tenth cylinder body and foot valve assembly was made by the consultant. No defects were noted. However, cups have since been obtained and the deep well cylinders assembled.
10. One cylinder was found to have a loose valve seat. The valve seat was replaced.
11. In both cases the edges of the cups were found to be ragged. It was assumed that the increased friction with the cylinder wall caused the lower cup to slip up on the plunger assembly. The increased friction was caused by the ragged edges of the lower cup overlapping the upper cup.

2.4.2 Detailed Inspection

Ten percent of the pumps were disassembled and the foot valves and cups examined in detail for defects and irregularities. Nothing of consequence was noted for the foot valves or shallow-set pump cups. However, it was during this inspection that the two deep well cylinder cups were found to have slipped up on the plunger assembly. These were replaced by the manufacturer. No other defects were noted.

2.5 Current Manufacturing Status

Having completed the scope of work for the manufacture of the pumps and cylinders, the pumps were turned over to the Project Director of Barangay Water Program, Mr. Gaspar Nepomoceno. The disposition of the pumps at the time of turnover was as follows:

Installed in field:
- 5 shallow-set pumps
- 5 medium-set pumps

Warehoused at Tri-Star Metal Industries (Las Pinas):
- 120 shallow-set pumps
- 118 medium-set pumps
- 398 deep-well cylinders (159 lacking cups - out of stock in Manila)

Other:

1 medium-set superstructure with two (2) cylinders given to University of San Carlos (Cebu) Water Resource Center
1 medium-set superstructure in Merryland/USAID Office
2 deep well cylinders retained by residents of Barangay San Miguel, Batangas City, as spare parts

Mr. Nepomoceno, Oscar Basa, and the consultant prepared a distribution list for the disbursement of the hand pumps to the various LGU's. The distribution list is included in Appendix D. The LGU's were selected and the number of pumps specified according to past performance, proposed projects, and water level depths.

Due to a number of factors including the reorganization of top management and a dissatisfaction with a major client, Tri-Star has decided to shut down its foundry and machine shop for the near future. Mr. Leong Lam, the Executive Vice President and General Manager of Tri-Star, has said that they would like to continue assembling the pump to guarantee a quality product but would subcontract the casting and machining. Engineer Rene Galera, Tri-Star's very competent Foundry Division Manager, is beginning an aluminum and brass foundry but has said he would consult on any additional pump orders or return to Tri-Star if there is a need for his services.

BWP is not ready to commit itself to a second pump order although the demand from the LGU's would seem to justify it. Carlos Crowe, the project officer who has administered the BWP project since Charles Brady was reassigned, feels that it may be good for the pump units to be in the field for a while before placing a second order to further prove the durability of and the demand for the pump. However, at the end of April 1982 the use of some undesignated funds for purchasing additional pumps (the LGU's cannot advance money but only pay on delivery) was being considered by Mr. Crowe.

It is also believed by USAID/Manila and BWP that additional manufacturers will help guarantee quality control and reduce unit costs. Georgia Tech has prepared a brief on foundry selection and quality control for use by BWP staff in selecting additional foundries (see Appendix E).

Various aspects of the maintenance structure remain unclear and, although not directly related to manufacturing, these aspects have a direct bearing on the life of the pump. To date, no provision has been made for the procurement of spare parts. Most manufacturers (Tri-Star is no exception) will not accept orders without a down payment and the LGU's are prohibited from prepaying on materials, supplied and services. Until this situation is changed, spare parts cannot be procured. Also, BWP is recommending that all Level I projects be monitored once every three months. Currently, many LGU's do not conduct any monitoring of Level I systems. While this is highly advisable from a pump maintenance and repair standpoint, sources of funding have not been identified. Conversations with engineers and technicians from several LGU's indicated that additional funds will need to be budgeted for manpower, per diem, and gasoline if every pump is to be monitored once in a three-month period. This need will increase as the number of Level I systems grows.

2.6 Conclusions

1. Tri-Star Metal Industries, Inc., was found to be more than adequate to produce a high quality hand pump. Tri-Star's quality control permitted acceptance by the consultant of 88% of the pump and cylinder units produced with the remainder being accepted after the defects were remedied. Only 4% of the units tested required replacement of parts.

2. From all field testing and quality acceptance testing to date, it appears that the deep well cylinder could equal or surpass the durability of the current three-inch diameter AID cylinder used in other countries. To the best knowledge of the Georgia Tech consultant, it is currently the lowest cost deep well cylinder in the Philippines.

3. The poppet-type foot valve has performed without fault in all the test installations. No foot valve leaks have been noted in the field from either the shallow-set or medium-set pumps. The poppet-type foot valve is expected to outlast the flapper-type since the seal material is subject only to wear and impact from the opening and closing of the valve and not to flexure from being used like a hinge.

4. Demand for the hand pump is high. Mr. Pashkevich has been approached on several instances by LGU personnel for pumps in lots of 20 to 30. The recipients of the test pumps have also requested additional pumps from their LGU's.

5. In spite of the demand, the plans for the next production run are unclear. A second order will probably have to be funded initially by USAID. The LGU's are restricted to paying on delivery and therefore cannot advance money to a manufacturer. BWP claims not to have enough internal funds to make a down payment. Also, BWP is still in the process of deciding how to determine demand for the pumps. It is expected that once the remaining pumps are distributed BWP will be able to better estimate demand.

6. Gaspar Nepomoceno, BWP Project Director, has stated that any subsequent orders must be let in competitive bidding. USAID/Manila supports this, believing that competition will prevent quality from deteriorating and cost from rising as may be the case with a sole source supplier. However, outside technical assistance to the foundry will be required to manufacture a quality pump because BWP does not have personnel qualified to render this assistance.

7. BWP has several engineers competent to conduct pump acceptance testing. Romy Calumpad and Noel Viaje showed superior dedication and conscientiousness during the testing. Both have mechanical engineering backgrounds.

8. Various aspects of the maintenance structure need to be addressed. These include the provision of a spare parts procurement system and funding for the increasing monitoring requirements.

Chapter 3

FIELD TESTING
(Component #1, Task D)

Porosity, inclusions, and other casting flaws may not be readily determined by the examination methods (usually either visual or destructive) available in developing countries. To uncover such flaws, ten pumps were installed in the provinces surrounding Manila. Past experience has shown that major casting flaws can be expected to cause component failure within the first two weeks of normal operation.

The pumps were installed over the period from November 13 to December 3, 1981. As of this writing, no cast parts are known to have failed. However, a retaining nut backed off the foot valve stem in a medium-set pump 30 minutes after installation and in a shallow-set pump 3 days after installation. The foot valves were repaired using lock nuts and this modification was made to all other foot valves. There have been no other design related problems with the test pumps. Some non-design related problems include sand in the water, insufficient well recharge, and leaky drop pipe joints. A summary of the pump installation and monitoring data is presented in Table 1. Further monitoring of the pumps to determine component lifetimes and maintenance costs is being conducted by Engineer Oscar Basa of USAID/Manila with Engineer Ricardo Cruz assisting him in Pampanga.

TABLE 1 TEST PUMP DATA

Date Installed	Type	Local Gov't Unit	Site	Well Depth (Feet)	SWL Depth[1] (Feet)	Intake Depth (Feet)	# of Users (Households)	Flow Rate (liters/ stroke)	Leak Rate
Nov. 13, 1981	Medium-Set	Batangas City	San Miguel I[2]	120	37	90[3]	10-15	.345	0
Nov. 19, 1981	Medium-Set	Lucena City	Ilayang Iyam	98	47	78	20 + 500 Students	.380	0
Nov. 23, 1981	Medium-Set	Lucena City	Ilayang Talim	90	32	62	10 + 200 Students	.380	0
Nov. 23, 1981	Medium-Set	Batangas City	San Miguel II	95	79	92	10	.380	-[4]
Nov. 24, 1981	Shallow-Set	Pampanga	Lubao/Santa Catalina	120	3	120	50	1.00	0
Nov. 26, 1981	Shallow-Set	Pampanga	San Carlos/San Luis	200	22	200	20-30	.613	0
Nov. 30, 1981	Shallow-Set	Pampanga	Cavalantian[5]	100	11	100	30 + 600 Students	.633	0
Dec. 1, 1981	Shallow-Set	Pampanga	Lanary/Candaba	180	11	180	30-50	.543	0
Dec. 3, 1981	Shallow-Set	Pampanga	Santa Monica/Santa Rita[6]	30	1	30	15 + 600 Students	1.06	0
Dec. 3, 1981	Medium-Set	Angeles City	Sapang Bato	130	93	102	15	.404	0

NOTES:

1. Static Water Level was measured at the time of installation which was at the transition period between the wet and dry seasons.
2. Site where footvalve nut backed off and pipe leaks occurred.
3. The well was being pumped dry daily. Remedied by adding a 30' suction pipe to the cylinder to increase the effective well reservoir.
4. Leaking excessively. Thought be be caused by poor quality sealant at pipe joints - the same problem as San Miguel I.
5. Site where footvalve nut backed off.
6. Sand originally present in well water. No more sand being pumped as of March 17, 1982.

Chapter 4

HAND PUMP INSTALLATION, MAINTENANCE AND REPAIR MANUAL
(Component #1, E)

The hand pump manual was written to address the subjects of hand pump installation, maintenance and repair for the AID hand pump. However, as BWP planned to continue implementing traditional hand pump projects, the USAID project officer, Mr. Charles Brady, requested that the manual address the above issues for the traditional pump also. Georgia Tech concurred as this would make the manual complete for all the Level I pump needs of BWP.

The manual is written in an easy-to-read, cookbook fashion. Most of the hand pump installation, maintenance, and repair work is handled by persons with a high school degree (United States equivalent of tenth grade) or less. The major topics addressed in the manual are: sources of possible well contamination, pump theory and operation, site selection, apron construction, pump installation, well disinfection, symptoms of pump wear, pump maintenance, pump repair and monitoring.

The manual was first outlined in September 1981. Initially, Georgia Tech personnel drew some of the illustrations for the manual but later hired a draftsman to do the bulk of the drawing. The draftsman also redrew the shop drawings, incorporating the deep well cylinder and foot valve changes. The first draft of the manual was released for review by BWP and USAID staff engineers during the first week of December, 1981. The consultant returned to the U.S. for Christmas and continued work on the manual after the holidays. This included having the manual put on a word processor, touching up or completing the illustrations, and adding appendices and a water disinfection section. The manual, in photocopy-ready form, was distributed to AID/Washington, USAID/Manila, BWP, and WASH Project personnel for critical review. The manual as it appears in Appendix F includes several revisions suggested in the course of the seminar as well as suggestions from the above sources.

The engineers and technicians who attended the training seminar found the manual readable and well illustrated. Some commented that it was not necessary to read the text to understand apron construction and pump repair. The manual was equally well received by the BWP engineers and management.

Chapter 5

FAMILIARIZATION OF BARANGAY WATER PROGRAM WELL REQUIREMENTS (Component #2, Task 1)

A number of Government of the Philippines (GOP) agencies, foreign assistance programs, and private voluntary organizations are involved in the construction or funding for construction of Level I water supplies throughout the country.

Since the late 1940's the Ministry of Public Works has been active in drilling wells and installing the Liberty or Magsaysay (traditional) hand pumps on their wells. This program has been very successful in reaching people in need of water. Although the well design can be improved for some of their installations, the construction typically provides a fair amount of sanitary protection and the pumps appear to be relatively reliable. The few major weaknesses of the pump are breakage of the long wooden handle (which can usually be replaced easily), the height of the handle which sometimes makes it difficult or impossible for children to use, and occasional difficulty in pumping the well.

The Rural Water Development Corporation (RWDC) is a program of the Ministry of Human Settlement. This program is aimed at communities with less than 13,000 persons. RWDC provides assistance by making funds available for labor, materials and overhead (up to 30 percent) for Level I systems.

The Local Government Units can obtain materials such as piping and hand pumps through the Ministry of Human Settlements for the construction of Level I systems. A few LGU's have their own drilling equipment and construct their own wells.

The National Water Resources Council (NWRC) and the Bureau of Mines are not directly involved in construction of water supply systems but they do provide administrative and technical support. The NWRC functions like a regulatory agency and as a source of technical data. NWRC administers the construction permits for water resource development projects. It also provides technical publications on water resource development, hydrogeology, ground water, etc., written for provincial and local engineers.

The Bureau of Mines is the primary source of geologic and hydrogeologic data for the country. It has an on-going program of hydrogeologic evaluations and is developing an inventory of well records for the country. Staff members will provide direct technical assistance whenever possible. However, there is a severe shortage of hydrogeologists in the country and there appears to be little in the way of a good university curriculum in this subject area.

USAID, the Peace Corps, private voluntary organizations such as church groups, and local and national businesses also provide funds and technical assistance for Level I water resource development projects. The Asian Development Bank provides some money for hand pump programs but the vast majority of their funding for water resource development is aimed at large piped water supply systems.

The major problems associated with most of the Level I programs supported by the agencies listed above relate to the lack of follow-up monitoring and maintenance. Jetmatic pumps, which are a very popular hand pump, are notoriously unreliable. Failure of the pump to operate properly can result in further damage to the pump or well itself as community residents try to find other ways of extracting water from the well. At times, the well is simply left unused until a person arrives to repair it. During the period of disrepair most people return to using their old wells or extracting water from rivers, streams or lakes.

Available information on specifications for BWP water wells was collected and evaluated. This information included examination of specifications in the BWP handbook, the National Water Resources Council's Rural Water Supply Manuals (Volumes I, II, and III), and actual field installations.

Specifications for water wells in the BWP Operations Handbook are inadequate. The specifications are, at best, vague--not comprehensive enough to be a guide for the water well contractor or the well owner. As they exist now, they should be removed from the BWP Operations Handbook.

The NWRC's Rural Water Supply Manuals (Volumes I, II and III) provide some very useful information on the design and construction of wells, but the material is not meant to be used as a specification, nor would it be adequate for that purpose.

Contract agreements vary from vague to very vague and usually address only the well's approximate depth, slot size of the screen, and whether or not the well is to be gravel packed. The engineers and hydrogeologist of Sheladia Associates are improving the specifications for Level II and III systems but nothing has really been done to improve specifications for Level I until now.

Another problem is the lack of good well construction standards for Level I wells. Although sophisticated design is unnecessary, specifications that optimize the use of time and material and ensure better sanitary protection for the well would be useful.

Chapter 6

SURVEY OF PHILIPPINE WELL DRILLERS' CAPACITY
(Component #2, Task 2)

6.1 Introduction

The objective of this task was to evaluate 1) the availability of equipment, 2) the techniques and methods used, and 3) the training and aptitude of drillers in the Philippines.

To accomplish this objective, the consultant interviewed persons at the Bureau of Mines, the President and the Executive Director of the Well Driller's Association of the Philippines, independent drilling contractors, hydrogeological consultants, and hydrogeologists employed by large drilling companies. In addition, a considerable amount of time was spent observing drilling operations in the provinces of Pampanga, Batangas, and Pangasinan.

6.2 Availability of Equipment

The Philippines is relatively fortunate in terms of appropriate drilling equipment. The American armed forces turned over a fair number of percussion drilling rigs following WW II. In addition, the various mineral exploration and development companies imported American and European percussion and rotary drilling equipment for mineral exploration. Much of this equipment was eventually purchased by Philippine nationals and is now used for water well construction.

The vast majority of water wells in the country are drilled using percussion drilling equipment (cable tool rigs). The cable tool rig is very appropriate in terms of its depth capacity, ability to drill in a wide varity of geologic environments, the ease with which it is transported, and its ease of operation and maintenance.

The second most popular method of well construction in the country is jetting. The jetting method is used to construct many private small diameter wells in rural areas and a fair percentage of BWP Level I wells. The method works very well for installing 2- to 4-inch wells in unconsolidated materials, especially where the water table is not too deep. It is also extremely practical in terms of manpower needs, equipment maintenance and ease of equipment transportation. The one drawback to the method is that it requires a good quality source of water for drilling. Too often the use of a polluted water source results in the contamination of the well and surrounding aquifer. In spite of jetting's popularity, it probably accounts for less than 30 percent of the wells drilled.

Rotary drilling equipment is available, and some firms such as Shamrock Drilling Co. (recently sold to Asian Drilling Corporation) exclusively use rotary drilling equipment. Most the rotary drilling equipment is used for large diameter municipal, irrigation and industrial wells. Rotary equipment has also been used to drill wells on Philippine and American Military bases. Information available implies that rotary drilling equipment has not been frequently used in the BWP programs. The small diameter wells needed for BWP water supplies and transportation costs involved with transporting rotary drilling and support equipment have probably discouraged its use. In addition, rotary drilling equipment requires more skilled workers and stricter maintenance. In terms of the relative number of drilling rigs, less than 10 percent of the rigs used for water well construction are rotary rigs. Approximately 20 percent of the water wells are drilled by rotary drilling equipment.

In many coastal areas, and along the alluvial plains of some of the larger river valleys, wells are driven into the ground to supply domestic water supplies. Driven wells are usually shallow and only penetrate a few meters into the water table. Their yields, however, are normally great enough to meet the demands of a hand pump. This method is rarely used to construct wells for BWP projects since it is preferable to avoid the use of shallow ground water because of its susceptibility to contamination. Driven wells have been used for a few BWP Level I wells although the exact number is not known.

Wells are still dug in many areas of the country. Excavation is usually done by hand and hand tools. Older dug wells were lined with stone or brick, but new wells have made use of cement caissons. Some BWP Level I projects have made use of existing dug wells; an apron was constructed over the top for sanitary protection and a hand pump installed. The water quality of these wells is questionable. In some coastal areas and on small islands, dug wells are used because after only penetrating a few meters into the water table, they are able to provide suitable storage to meet demand while avoiding going deeper where salt water may be encountered. A Level II project on the island of Anda will make use of four new dug wells to meet the community's water supply demand.

6.3 Supplies

There does not seem to be a problem getting well construction supplies such as casing, screen, cement or drilling fluid. Either the supplies are manufactured in the Philippines or they are readily available as imported products through well stocked supply warehouses.

Black steel, galvanized iron (G.I.) and polyvinyl chloride (PVC) pipe are available for use as well casing. In addition, other metal alloy casing is available through some of the major suppliers, but BWP does not seem to make use of these more exotic, and more expensive, materials. For BWP projects there seems to be a preference towards the use of G.I. pipe for casing. This choice is quite satisfactory for G.I. pipe holds up fairly well in most subsurface environments encountered in the country. The use of polyvinyl chloride pipe as well casing is growing in popularity and suitable PVC pipe is readily available from domestic manufacturers. Because PVC pipe cannot be driven, it's primary use has been associated with rotary drilled or jetted wells. It has also been used in cases where dug wells have been reconstructed to improve sanitary protection.

The most widely used type of screen for wells constructed in unconsolidated materials consists of steel pipe or galvanized iron pipe in which vertical or horizontal slots have been torch cut. Specifications usually call for 1/8" slot openings, but the torch cut slots are rough, uneven, and usually range up to 1/2" in width. Many wells pump sand throughout their entire service life as a result of the use of this type of screen.

The Roscoe Moss Company does have a supplier of louvered or shutter type screen in the Philippines. Screen sizes as small as 6 inches in diameter with excellent control of a wide range of slot size openings are available. Their supplier reports that a 4-inch diameter shutter screen will soon be available.

Slotted plastic casing in a limited range of slot sizes is available and Neltex produces a "Robo-type" continuous slot PVC screen. These screens can effectively keep out fine sand particles if the wells are properly developed. Their popularity is on the rise because more water well contractors are experimenting with their use and also because of BWP encouragement.

U.O.P. Johnson and Screen Products PTE, Ltd. supply continuous slot wire wound screen in a full range of slot sizes and materials. However, their high cost has discouraged their use in BWP projects.

6.4 Water Well Contractors

Most water wells are constructed by private contractors. Their capabilities range from fair to excellent. There are some marginal drillers, there are some very sophisticated drillers, and there is a full range in-between. In the field, the consultant observed drilling crews who spent six months drilling a well to 300 feet as a result of poor planning and failure to have necessary equipment at the drilling site. The consultant also observed some excellent, very conscientious drillers who were meticulous about their work.

At random, a half dozen drillers in the metro-Manila area were selected from the phone book for interviews. Two of the drilling firms were more or less part-time drillers who spent their spare time installing shallow domestic wells. Two other firms were visited that would be considered family-owned, full-time businesses. The professionalism of one of these firms was especially noteworthy. They maintained excellent business records, an excellent drilling shop, one of the best inventories of supplies ever seen by the consultant, and kept excellent well records. This particular company had already drilled wells for a number of BWP projects. The two remaining firms visited were large corporations. Both firms used rotary drilling equipment and both were involved not only in water well construction but in drilling for geothermal development and mineral and oil exploration. One of these firms was a national supplier for Johnson screen. The other manufactured rotary drilling equipment in addition to its drilling operation.

Some LGU's have drilling equipment and apparently construct some community water supplies. However, their role in terms of the total amount of water well construction is relatively minor.

6.5 Training

The Well Driller's Association of the Philippines (WDAP) holds training seminars for contractors every couple of years. They usually enroll about 50 to 70 participants. Unfortunately, those who attend (who also are members of WDAP) are the better, more professional drillers. The WDAP has weekly meetings at night at their headquarters. About a dozen persons usually attend the meeting that is more socially than business oriented.

6.6 Well Design

The biggest problem facing the water well industry in the Philippines is lack of suitable well design. Most drilling contracts are based on a given depth, and drillers will typically drill to that depth in spite of the fact that they may have encountered ample supplies of water at shallower depths. For example, a contract will call for a well five hundred feet deep with 200 feet of slotted casing. The well will be drilled to 500 feet and the 200 feet of slotted casing will be used even if it means emplacement in non-productive formations. The same well usually can be drilled to a considerably shallower depth. Five feet of louvered casing, or wire-wound screen, can then be set adjacent to the best aquifer or the best part of an aquifer and provide ample open area for production up to 25 GPM. The shallower depth would probably offset the extra cost of a wire-wound screen, Robo screen or louvered casing.

Another problem facing the industry is contamination of the new wells as a result of the drilling process. If water is needed during the drilling process, the water used is often contaminated.

Failure to properly locate a well in terms of sanitary protection is yet another problem facing the water well industry. Wells are placed near highways, in rice fields, in depressions, etc., with little consideration of the potential sources of ground water contamination located near the surface.

To improve well design, construction and the selection of a well site, it is strongly urged that consideration be given to a series of USAID/BWP sponsored training programs for water well contractors and their drilling crews. These programs should be designed to instruct the driller WHY certain considerations are valuable in terms of site selection, well design, etc. Georgia Tech personnel propose that attendance of such a training program be a prerequisite if a contractor is to be awarded a BWP contract.

Chapter 7

TECHNICAL ASSISTANCE TO SUPPLIERS AND MANUFACTURERS OF PLASTIC WELL CASING AND SCREEN
(Component #2, Task 3)

On February 9, 1982 the Neltex Development Company, Inc. plant was visited and a tour of the facility provided by the plant supervisor. The company is the nation's largest manufacturer of plastic pipe for use as water well casing and screen.

The PVC pipe to be used as well casing has Standard Dimension Ratio (SDR) numbers ranging from 11 to 28 for casing diameters ranging in size from 30 mm to 100 mm. The pipe meets ISO specifications for water supply systems; however, there is no present compliance with ASTM F-480 or National Sanitation Foundation (NSF) standards for plastic water well casing. The plastic pipe used for casing would comply with almost all aspects of ASTM F-480 with the exception of what is considered to be standard sizes (ASTM standard pipe sizes are in English units; Neltex casing is in metric sizes), and the dimension of the belled-end coupling. Mr. Gass, who served on the committee which prepared ASTM F-480, has full confidence in the quality and structural design characteristics of the casing being produced by Neltex.

Neltex produces two types of well screen. One consists of vertical or horizontal saw cut slots. The other screen is similar (probably identical) to Robo screen. It displays good structural strength and provides a small range of slot size variability. It is only available for diameters of 75 mm, 100 mm and 200 mm. The Robo-type screen being produced by Neltex represents an excellent alternative to torch cut slotted casing typically used for BWP wells.

Filipinas-Eslon Manufacturing Corp. produces PVC pipe acceptable for well casing and saw cut slotted casing for screen. Unfortunately, it was not possible to set up a visit to their plant.

The demand for plastic well casing and screen is still small enough to be met by the production capability of Neltex, Filipinas-Eslon and a number of small plastic pipe manufacturers. The existing industry can probably meet the demand for plastic well casing throughout the 1980's even with anticipated increases in the use of such materials.

Chapter 8

PREPARATION OF A WATER WELL TECHNOLOGY OPERATIONS AND TRAINING MANUAL FOR BWP LEVEL I PROJECTS (Component #2, Task 4)

The objective of this task was the preparation of an operations and training manual that addresses well site selection criteria, well design, methods of well construction, well development, etc. The first draft of the manual was completed in the Philippines during the first half of March, 1982.

Because the manual was several hundred pages in length, the consultant suggested that for the sake of time and appearance, consideration be given to having the manual placed on a word processing disk which would facilitate editorial and technical revisions in subsequent drafts. USAID/Manila agreed with the suggestion and requested that the consultant obtain clearance from WASH to return to the United States where there would be access to a word processing machine, and where persons were available to review the manual and provide technical input.

On March 23 the consultant returned to the United States for approximately three weeks. During this time the manual was reviewed by Mr. Truman Bennett (Principal Geologist, Bennett and Gass, Inc.), Mr. James Poehlman (Director of Technical Services, National Water Well Association), and Mr. George C. Taylor, Jr. (Hydrogeologist). Many of the comments made by Mr. Bennett and Mr. Poehlman were included in the last draft of the manual. Mr. Taylor's review arrived too late for his suggestions to be examined and adopted; however, consideration has been given to his critique and some suggestions were incorporated in the final draft of the manual.

The final draft of the manual is single spaced and in the same format as the accompanying manual addressing hand pump installation, maintenance and repair. The completed manual appears in Appendix G.

The manual is written in a style to make it understandable to persons with a high school education. There are almost no mathematical formulas, and where formulas are present they require only simple addition, substraction, multiplication and division.

Originally, it was intended that the manual be written in a cookbook fashion. The consultant found that addressing aspects of well site selection, well design, etc. requires a detailed knowledge as to why certain things are being done so that the user could make suitable adjustments to his methodology based on variables encountered in the field. This problem was discussed among project personnel and a decision was made to write the manual using a combination of reference text and step-by-step descriptions of the technical methodology.

Section 8B.12 of the manual contains the specifications for the construction of water wells for Level I projects. It is intended to be used as written, but BWP engineers should be aware that modifications of the specifications may be necessary under special circumstances.

Chapter 9

TRAINING SEMINAR
(Component #1, Task F; Component #2, Tasks 5 & 6)

The water well and hand pump technology seminar was held on April 19-22 at a country club south of Manila. It involved more than 90 Waterworks Technicians and Engineers from nearly 40 Local Government Units (LGU's), 15 BWP staff (10 of whom were engineers), 3 BWP architectural and engineering (A&E) consultants, and one USAID engineer.

During preparation for the seminar, it was agreed that the size of the audience was too large for only two trainers (Gass and Pashkevich). It was further determined that the participants could be effectively trained and evaluated in groups of 6 to 10. To break into small groups of this size, it was necessary to train ten trainers. Realizing the potential of the trainers to input into the training design, it was decided that the trainers should help design and implement the seminar. Therefore, performance objectives for the training of trainers were established and are presented below:

By the end of the project, the trainers will have:

1. Weighted the seminar tasks according to their applicability to the participants (skills assessment).

2. Provided or approved activities suitable to Filipino culture.

3. Implemented the seminar design by leading small groups of participants.

4. Authored a revised and improved installation, maintenance and repair seminar, based on analysis and evaluation of this seminar.

In meeting these objectives, four of the trainers (Noel Viaje, Romy Calumpad, Lex Nesas, and Larry Cabrera) and Oscar Basa of USAID assisted Mr. Pashkevich in the preliminary planning of the hand pump segment of the seminar. This resulted in a change in emphasis placed on different aspects of the seminar material but not in the overall content.

After the planning session, the consultants discussed how to best use the trainers to plan the water well technology segment of the seminar. After several conversations with the trainers, a consensus was reached that since the material was virtually new to all of them, Mr. Gass would be the best prepared to design the segment. The design used lectures, slide presentations, workshops, overheads and movies to convey the seminar material.

The designs of both segments were presented again to the trainers and several members of the BWP training division. Further refinements were made and possible training activities were suggested.

The training objectives of the seminar for the hand pump technologies segment are presented below:

By the end of the seminar, each participant will have:

1. Evaluated a well site from a sanitary standpoint using the site selection checklist.

2. Constructed an apron with emphasis on sanitary considerations.

3. Installed a shallow-set and medium-set pump on a mockup site. (Deep-set pumps are similar to medium-set for installation purposes.)

4. Disassembled and reassembled a shallow-set and medium-set pump, identifying the places and surfaces that need periodic lubrication.

5. Set up a monitoring circuit for his area of responsibility.

6. Selected the proper amounts of chlorine to disinfect various volumes of well water.

7. Chosen an appropriate method of well construction and development for a classroom problem.

8. Selected appropriate methods of well rehabilitation after determining causes of poor well performance.

The program of activities at the seminar is presented in Appendix H. This is a variation from the original program based on feedback from the participants and trainers and on observations by the consultants. Originally, the first two days were to have been devoted to Mr. Gass' presentation and the latter two to the presentation by Mr. Pashkevich. It was noted that the participants were being exposed to a lot of information in a short period of time and their attention span was diminishing. The days were then spent in morning classroom and workshop sessions and afternoon practicum sessions.

At the conclusion of the seminar the participants evaluated the content and the speakers. The results of that evaluation are included in Appendix I. From comments made by the participants, it appears that the manuals and training program were highly successful. Many said that it was the best training program they had ever attended and the first BWP program that had included practicums. The lectures, workshops and practicums were all well received by the participants. During the closing ceremony at which several participants spoke, the only negative comments concerned accommodations and food.

The participants also felt more time was needed to properly address the many aspects of water well technology and hydrogeology. The questions fielded during the open forum sessions and some of the post-training comments indicate that engineers are in desperate need of this type of information, and that the time scheduled for this training program permitted the presentation of only a general description of the technology.

The trainers also evaluated the seminar in a discussion led by Mr. Pashkevich. The following is a summary of that discussion.[9]

9/ From notes of that discussion taken by Mr. Pashkevich.

It was felt that the basic design and content was applicable and practical. However, the pump technology was more applicable to the technicians and the water well technology was more applicable to the engineers since this is their natural division due to educational background and job description. Even in the seminar situation, many engineers stood back as the technicians worked. Strong support was expressed for a suggestion to break the seminar into two parts, one for each target group.

It was mentioned that although the practicums were useful, they consumed a lot of time. More time should be devoted to the "critical processes" instead of pouring concrete, cutting out forms, etc. Also, more tools were needed which would have accelerated the work.

As trainers and leaders of small groups, the trainers felt a need for greater training in all areas of the seminar but particularly in water well technologies. They stressed their desire for in-depth training in water well technology and hydrogeology so that they would be prepared to work with the LGU's in a consulting capacity for well drilling.

The trainers also indicated that they had an insufficient background for the practicum where the participants tried to identify the problem in ten defective pumps without disassembling the pumps. Another complaint was the time constraint on each activity. As far as group size, the trainers felt that 6 to 10 was a manageable number, and that by having all technicians or all engineers in one group, the effectiveness of the groups would be increased.

After discussing the seminar and evaluations at length with three of the four trainers (Larry Cabrera was unavailable) who assisted in the preliminary planning and with Oscar Basa, it was decided that the hand pump technology segment of the seminar should be included in the annual Waterworks Technician's Training Seminar. They believed that they were sufficiently prepared to conduct their own seminar with the use of the hand pump manual and the experience they had gained in the seminar. They did not feel that it was necessary to plan out the proposed seminar on paper at this time, as had been stated in the consultant's objectives for the trainers.

No decision was made concerning a follow-on seminar for the water well technology segment because the trainers felt too ill-prepared to deliver the seminar without outside assistance. It is generally held by BWP staff that the two outstanding hydrogeologists retained by BWP, who are excellent in theory, subject matter, and field work, would not be appropriate choices to deliver a training seminar. This view was shared by the consultants. The consultants agreed to the request of the trainers to help seek sources of training assistance.

Chapter 10

RECOMMENDATIONS

1. The AID hand pump and improved 2" diameter deep well cylinder are recommended for use in the Barangay Water Program's Level I projects.

2. Monitoring of the test pumps should be continued so that life expectancies, maintenance costs and manpower requirements may be known. It would be helpful to monitor all the pumps and cylinders as this would allow the determination of life expectancies and maintenance costs over a broad range of variables.

3. Funding should be provided for improvements to be made to the Battelle design of the AID hand pump to reduce initial cost, improve manufacturability in developing countries and simplify maintenance procedures. Several improvements have already been made by Georgia Tech personnel in the course of past projects that have resulted in significant improvements in bearing and cup life. A concentrated, concerted effort would yield many needed improvements such as "through the pump" removal of the plunger cups and foot valve which would significantly simplify the repair procedure.

4. Future hand pump programs should include the mandatory provision of a local counterpart(s) for the manufacturing phase. More emphasis needs to be placed on developing a water program's ability to effect a hand pump manufacturing program instead of just on the manufacturing of a quality hand pump. Not having a counterpart(s) has caused a lack of continuity in the program turnover, an apparent feeling of non-involvement in the program by BWP, a sense of non-support by BWP on behalf of the consultant, and some unnecessary confusion and misunderstanding of policies, procedures, etc. during project implementation. This recommendation to emphasize the training of the water program staff or a local consultant can be and should be expanded to all phases of assistance projects such as this effort.

5. Various aspects of the maintenance structure remain unclear and should be addressed immediately. Because of the financial limitations of the LGU's, a system of obtaining spare parts from the manufacturer(s) without requiring prepayment by the LGU's needs to be implemented. Also, funding needs to be provided to the LGU's for monitoring, especially as the Level I program expands.

6. Provisions should be made by the LGU's and BWP for monitoring all the pumps and cylinders manufactured under this OTD. Regular monitoring will permit the gathering of more field data in order to make the pumps even more acceptable to the users and maintenance personnel.

7. Although the manuals appear to meet the needs of the engineers and technicians for hand pump and water well technologies, it is recommended that the procedures and standards set forth in them be reviewed annually for APPLICABILITY and UNDERSTANDABILITY. Attempts should be made to further tailor the manuals to the needs of the LGU's.

8. The hand pump training and the water well technology training should be two separate programs. The hand pump program should be aimed specifically at waterworks technicians. The water well technology program should be designed specifically for engineers. The division of the two programs would permit dissemination of information applicable to each group. It would also allow more time for field practicums and for specific training.

9. Based on seminar feedback, the engineers require a much more extensive training program. This does not mean they need more technical or sophisticated data, for this would be unnecessary for Level I wells and even some Level II and III wells. They do, however, require more training and practice in methods of well site selection, well design, preparation of water well specifications, evaluation of well problems and selection of well maintenance techniques. A new program designed for ten days duration can be prepared to address these needs (see Recommendation 10 below).

10. In the future, USAID/Manila or BWP personnel should be fully responsible for all aspects of Level I training. Therefore it is necessary that future trainers be selected and instructed in the technical subject matter and methods of training. They should also be given access to training materials.

    To accomplish this objective, extensive training for eight to ten individuals would be necessary. This training would last about one month. During this period, trainers would receive both technical and field training. One of the objectives of this program would be to enable the trainers to develop enough expertise to become resources for assisting LGU's with special hydrogeologic problems as well as well design, construction and operation problems. The trainers would also be taught methods of instruction and methods of developing instructional materials. A proposed schedule for training trainers is given in Appendix J.

11. USAID/Manila has two Filipino engineers directly assigned to BWP. They are both highly regarded by their BWP colleagues, and are often called upon to provide special assistance when solutions for technical problems cannot be determined by BWP engineers or LGU engineers. These individuals should be encouraged to continue to pursue appropriate education to improve their technical expertise and to expand upon their problem solving capabilities.

    At the present time, it is impossible to obtain training in the Philippines in the subject areas of hydrogeology and water well technology that would be of any value to the USAID engineers. However, this training is available in the U.S. and a recommendation is made in Appendix J.

APPENDIX A

Scope of Work

WATER AND SANITATION FOR HEALTH PROJECT
WASH
COORDINATION AND INFORMATION CENTER

Operated by CDM FIVE for the U S Agency for International Development

1611 N. Kent Street, Room 1002
Arlington, Virginia 22209 USA

Telephone: (703) 243-8200
Telex No. WUI 64552
Cable Address WASHAID

CDM FIVE is operated by Camp Dresser and McKee Incorporated; Principal Collaborators: Center for Educational Development in Health; Boston University; International Science and Technology Institute; Research Triangle Institute; University of North Carolina at Chapel Hill

June 24, 1981 File: P3-10-40

Mr. Phillip W. Potts
Senior Research Scientist
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, GA 30332

Dear Mr. Potts:

This is a letter of authorization for Georgia Tech to undertake work under OTD No. 40 (attached). The scope of work for this activity is described in the OTD and its attached cables. From time to time, additional guidelines and instructions will be given to you by the WASH office. It is understood that you will be responsible for overall management within Georgia Tech in carrying out this OTD, but that the direct technical manager of the activities under this OTD will be Mr. William Larson.

To carry out the above work, Georgia Tech is authorized up to 190 directly productive person days (DPPD) at a rate of 21.67 domestic DPPD's per month or 30 international DPPD's per month. This is equivalent to 8.77 person-months, if all work is domestic in nature, or 6.33 person-months, if all work is international in nature. The actual mix of domestic and international work will be determined by the needs of the OTD.

In addition, Georgia Tech is authorized to undertake up to six international round trips from the United States to the Philippines and return during the period of this OTD. The WASH office may require Georgia Tech personnel to pass through Washington, D.C. for briefing or de-briefing purposes in connection with these trips. Furthermore, Georgia Tech is authorized up to twenty round-trip internal Philippines airline trips from Manila to Ilo Ilo or Cebu Islands to work with local manufacturers if necessary.

The personnel to be involved in the technical aspects of this OTD are:

Mr. Phillip Potts
Mr. William Larson
Mr. Alan Pashkevich
Dr. Yaron Sternberg

Mr. Pashkevich is authorized to provide full-time service in the Philippines for up to six months. Mssrs. Potts, Larson, and Sternberg will provide short-term assistance in the Philippines as needed.

The Task Manager for this OTD will be Dr. Dennis Warner of the WASH staff, or his designated representative. You will be expected to keep him informed of all major activities in the course of the OTD and to obtain prior approval of any significant changes in the scope of work. All international travel under this OTD must have the prior written (or telexed) approval of the WASH Task Manager.

The final report for this OTD should be prepared in accordance with the WASH report guidelines. You are requested to provide a brief trip report after each international trip.

We look forward to working with you on this interesting and challenging task.

Sincerely yours,

Dennis B. Warner

Dennis B. Warner, Ph.D., P.E.
Acting Project Director

DBW/RS
Enslosures

May 14, 1981

Water and Sanitation for Health (WASH) Project
Order of Technical Direction (OTD) No. 40

TO: Mr. James Arbuthnot, P.E.
WASH Contract Project Director

FROM: Mr. Victor W.R. Wehman, Jr., P.E., R.S. VWW
AID WASH Project Manager

SUBJECT: Provision of Technical Assistance Under WASH Project Scope of Work for USAID/Philippines (Manila)

REFS: A) MANILA 1775, 22 Jan. 81
B) MANILA 6628, 23 Mar. 81

1. WASH contractor requested to provide technical assistance to USAID/ Philippines as per Ref. A (modified in this OTD). Contractor to provide technical assistance to accomplish para. 3 under Scope of Work Ref. A for component 1 and component 2. Component 3 is not authorized at this time under this OTD.

2. WASH contractor/subcontractor/consultants authorized to expend up to 215 person days of effort over a 6 month period to accomplish this technical assistance effort.

3. Contractor authorized up to 200 person days of international per diem to accomplish this effort.

4. Contractor to coordinate with ASIA/PD (Mr. Nussbaum), ASIA/TR/HN (Mr.Keller), AID/ASIA desk officer and should provide copies of OTD No. 40 along with periodic progress reports as requested by DS/HEA or ASIA Bureau.

5. Effort is to be an intensive one with technical assistance to 2 or 3 handpump manufacturers in the Philippines in 4 to 6 month period rather than normal 10 to 12 month period of past AID handpump program country activities. Expect it will be necessary to staff at least one full-time person to Philippines to work for 5 to 6 months continuously, supplemented by other specialty and management personnel as necessary. (See component 2 for example).

6. Contractor authorized to provide up to six (6) international round trips from consultants home-base through Washington to Philippines and return to home-base through Washington during life of OTD.

7. Contractor authorized up to 20 round-trip internal Philippines airline trips from Manila to ILO ILO or CEBU Islands to work with local manufacturers if necessary. Mission and DS/HEA may decide to work only with local manufacturers in Manila Metro Area as project proceeds.

8. Contractor authorized to obtain secretarial, graphics or reproduction services in Philippines as necessary to accomplish tasks. These services are in addition to the level of effort specified in para. 2 and para 3 above.

9. Contractor authorized to expend up to $4,500 for the training materials for the development or printing/support services associated with item 3, component 1, line item E.

10. Contractor authorized to provide for car rental if necessary to facilitate effort. Mission is encouraged to provide mission vehicles, if available.

11. Contractor will take portable (Manual) typewriter for consultants use in the field.

12. Item 3 component 1 line B of Ref. A changed from "1000" to "300" two inch and "100" three inch deep well cylinders.

13. Item 3 component 1 line C last sentence changed to read "This will include the provision of drawings, patterns, replication of prototype handpumps, and the provision of continuous technical assistance through final acceptance by the WASH contractor of the 250 AID handpumps, the 300 two inch deep well cylinders and the 100 three inch deep well cylinders."

14. Contractor authorized up to a total of $45,000 for the purchase of the patterns, molds and handpump and cylinder assemblies by subcontract from your subcontractor to local manufacturer(s) in the Philippines. No single purchase orders or sub-contracts with local manufacturers shall exceed $20,000 in value.

15. Contractor is authorized to install and train locals in installation of up to 20 of the handpump systems in sites agreeable to and with the approval of AID mission liaison officer (Mr. Brady).

16. WASH contractor will adhere to normal established administrative and financial controls as established for WASH mechanism in WASH contract. Mission liaison has requested that they initial field vouchers being sent back from field to mission. This has been agreed to by DS/HEA project manager. However, the contractor must understand that this is a participatory arrangement between USAID/Philippines and DS/HEA and does not represent an approval or disapproval by AID of the services vouchered in the particular voucher by the field consultant. All official approvals, disapprovals or decisions to ask for audits or revouchering continue to be made by the project manager in DS/HEA. DS/HEA however welcomes the mission's interest in validating that services were actually provided.

17. Items 5 para. A, B. and C. of Ref. A apply. Items 5 para. D and E of Ref. A do not apply to WASH contracting mechanism. WASH contractor should definitely be prepared to administratively or technically backstop field consultants and subcontractors.

18. Contractor report on overall progress of activity to be made in writing after each 40 person days of effort. Upon final acceptance of all locally manufactured equipment, the final report is due within 30 days to mission.

19. Mission should be contacted immediately and technical assistance initiated before the end of May 1981.

20. Appreciate your prompt attention to this matter. Good luck.

VWW:ja:5/14/81

ACTION AID-35

ACTION OFFICE DSHE-01
INFO AAAS-01 ASEM-01 ASPT-02 ASDP-02 ASPO-03 ASTR-01 AADS-01
DSPO-03 ENGR-02 CHB-01 RELO-01 MAST-01 /020 A4 722

INFO OCT-01 /036 W
------------------054511 220752Z /34
R 220606Z JAN 81
FM AMEMBASSY MANILA
TO SECSTATE WASHDC 1872

UNCLAS SECTION 01 OF 04 MANILA 01775

AIDAC

PASS TO MR. GENE MCJUNKIN, DS/HEA/COMMUNITY WATER SUPPLY

E.O. 12065: N/A
SUBJECT: TECHNICAL ASSISTANCE - BARANGAY WATER PROGRAM

REF: (A) 80 STATE 324366, (B) 80 MANILA 25419

1. SUMMARY:

THE MISSION HAS REQUESTED TECHNICAL ASSISTANCE FROM AID/W FOR THE LOCAL REPRODUCTION OF THE AID HANDPUMP.

WASHINGTON RECENTLY APPROVED SUCH ASSISTANCE. IT WILL BE FUNDED UNDER THE NEWLY AUTHORIZED WATER AND SANITATION FOR HEALTH PROJECT (WASH).

THIS CABLE OUTLINES A SCOPE OF WORK FOR SUCH ASSISTANCE, PROVIDES A BUDGET FOR SERVICES AND GOODS REQUIRED AND SUGGESTS OTHER PROGRAM AREAS FOR MUTUAL COOPERATION. END SUMMARY.

2. MISSION AGREES THAT THE AVAILABILITY OF A BETTER HANDPUMP FOR VILLAGE WELLS IS A NECESSITY AND ACCEPTS ASSISTANCE OFFERED IN REFTEL A. SURVEYS AND MISSION OBSERVATION, HOWEVER, DEMONSTRATE THAT THE PROVISION OF IMPROVED HANDPUMP WITHOUT EQUAL ATTENTION TO SOURCE DEVELOPMENT, MAINTENANCE AND REPAIR WILL YIELD ONLY MARGINAL BENEFITS. THUS, THIS CABLE PROPOSES A SCOPE OF WORK WHICH ADDRESSES ALL THREE AREAS. IT CONSTITUTES A COMPLETE HANDPUMP PROGRAM.

3. SCOPE OF WORK:

COMPONENT #1 - (HANDPUMP DEVELOPMENT AND REPRODUCTION)

THE SCOPE OF WORK HAS THREE BASIC COMPONENTS. THIS WORK COMPONENT CONSISTS OF THE FOLLOWING TASKS:

A. SELECTION OF A SUITABLE MANUFACTURER FOR REPRODUCTION OF TWO HUNDRED FIFTY (250) AID HANDPUMPS.

B. SELECTION OF SUITABLE MANUFACTURERS AND SUPPLIERS FOR THE REPRODUCTION OF ONE THOUSAND (1000) IMPROVED 2" CYLINDERS FOR DEEP WELL HANDPUMPS.

C. PROVISION OF TECHNICAL ASSISTANCE TO BOTH OF THE ABOVE SUPPLIERS ON THE VARIOUS ASPECTS OF HANDPUMP AND CYLINDER REPRODUCTION. THIS WILL INCLUDE THE PROVISION OF DRAWINGS, PATTERNS, REPLICATION OF PROTOTYPE HANDPUMPS, AND THE PROVISION OF CONTINUOUS TECHNICAL ASSISTANCE UP TO THE DELIVERY OF THE FIRST FIFTY HANDPUMPS AND ALL ONE THOUSAND CYLINDERS.

D. PREPARATION OF A SECTION IN THE BWP OPERATIONS MANUAL

ENTITLED, "HANDPUMP." IT WILL COVER A DISCUSSION OF HANDPUMP INSTALLATION, MAINTENANCE AND REPAIR.

E. PARTICIPATION AS PRINCIPAL RESOURCE SPEAKER IN A FIVE-DAY TRAINING SEMINAR FOR LOCAL GOVERNMENT WATERWORKS TECHNICIANS, THE BWP LOCAL ARCHITECTURAL AND ENGINEERING FIRM AND USAID ENGINEERING PERSONNEL. THE SEMINAR WILL UTILIZE THE MATERIALS PREPARED IN ITEM "D" OF THE SCOPE OF WORK AS THE BASIS FOR THE CURRICULUM AND WILL COVER HANDPUMP INSTALLATION, MAINTENANCE AND REPAIR.

- QUALIFICATIONS: THE QUALIFICATIONS FOR COMPONENT #1 OF THE SCOPE OF WORK ARE:

- CIVIL OR MECHANICAL ENGINEER WITH FIELD EXPERIENCE IN RURAL WATER PROGRAM HANDPUMP ACTIVITIES. IDEALLY, THE CANDIDATE FOR THIS ASPECT OF THE SCOPE OF WORK SHOULD ALSO HAVE EXPERIENCE WORKING WITH SUPPLIERS, MANUFACTURERS, AND FOUNDARIES IN THE REPRODUCTION OF HANDPUMPS.

- MANPOWER REQUIREMENTS:

- ONE (1) TECHNICIAN WILL BE REQUIRED FOR A FIVE-MONTH PERIOD OF CONTINUOUS SERVICE IN THE PHILIPPINES. THIS PERSON WILL INITIATE THE WORK TO IDENTIFY SUPPLIERS AND MANUFACTURERS AND REMAIN IN THE PHILIPPINES FOR THE DURATION OF PERIOD REQUIRED TO - 1) DEVELOP FIFTY COPIES OF THE PROTOTYPE AID HANDPUMP AND ONE THOUSAND IMPROVED TWO-INCH PLASTIC CYLINDERS, 2) PREPARE THE APPROPRIATE SECTION FOR THE BWP OPERATIONAL MANUAL, AND 3) CONDUCT THE THREE TO FIVE DAY TRAINING SEMINAR ON HANDPUMP INSTALLATION, MAINTENANCE, MONITORING AND REPAIR.

COMPONENT #2 - (WELL DESIGN AND CONSTRUCTION)

ACTION AID-35

ACTION OFFICE DSPE-01
INFO AAAS-01 ASEM-01 ASDP-02 ASPD-03 ASTR-01 AADS-01 ENGR-02
CH8-01 RELO-01 MAST-01 /015 A4 722

INFO OCT-01 /036 W
------------------054519 220755Z /34

R 220606Z JAN 81
FM AMEMBASSY MANILA
TO SECSTATE WASHDC 1873

UNCLAS SECTION 02 OF 04 MANILA 01775

AIDAC

THIS COMPONENT CONSISTS OF THE FOLLOWING TASKS:

A. FAMILIARIZATION OF BWP WELL REQUIREMENTS BASED ON SURVEY OF EXISTING BWP PROJECTS.

B. DEVELOPMENT OF A SECTION FOR THE BARANGAY WATER OPERATIONS MANUAL ENTITLED "WELL DESIGN AND CONSTRUCTION." THIS SECTION OF THE MANUAL WILL PROVIDE THE DESIGN STANDARDS AND SPECIFICATIONS FOR ALL BWP WATER PROJECTS, BOTH POINT-SOURCE DEVELOPMENT FACILITIES AND FULL-FLEDGED PRODUCTION WELLS FOR WATER SYSTEMS.

C. PROVISION OF TECHNICAL ASSISTANCE TO VARIOUS MANILA AND/OR CEBU BASED SUPPLIERS AND MANUFACTURERS FOR THE PROVISION OF PLASTIC WELL CASING AND WELL SCREENS.

D. PARTICIPATION AS A PRINCIPAL RESOURCE SPEAKER IN A SEMINAR FOR WATERWORKS TECHNICIANS, LOCAL A&E ENGINEERS, AND USAID TECHNICAL PERSONNEL ON WELL DESIGN AND CONSTRUCTION. THIS ASPECT OF TRAINING WILL INCLUDE WELL SITE SELECTION, MATERIALS, DESIGN STANDARDS, DRILLING, CASING, GRAVEL PACKING, GROUTING, TESTING AND DISINFECTI G WELLS.

- QUALIFICATIONS: HYDROGEOLOGIST/GEOHYDROLOGIST, CIVIL/ MECHANICAL OR SANITARY ENGINEER WITH EXTENSIVE EXPERIEGCE IN WELL DRILLING.

- MANPOWER REQUIREMENTS: ONE (1) PERSON FOR A FIVE-MONTH, CONTINUOUS PERIOD OF ASSIGNMENT IN THE PHILIPPINES.

COMPONENT #3 - (TRIAL PROJECT FOR TESTING WIND-POWERED COMMUNAL WATER SYSTEMS)

THIS COMPONENT OF THE SCOPE WILL CONSIST OF THE FOLLOWING:

A. IDENTIFICATION OF SITES FOR THE CONSTRUCTION OF SMALL, COMMUNAL WIND-POWERED WATER SYSTEMS AND FACILITIES.

B. IDENTIFICATION OF APPROPRIATE MATERIALS AND EQUIPMENT FOR WIND-DRIVEN SYSTEMS/FACILITIES.

C. PROCUREMENT OF MATERIALS AND EQUIPMENT.

D. PROVISION OF TECHNICAL ASSISTANCE IN THE DESIGN AND INSTALLATION OF THE SPECIFIED SYSTEMS AND FACILITIES.

E. PROVISION OF TECHNICAL ASSISTANCE DURING INITIAL OPERATING PERIOD OF SYSTEMS AND FACILITIES.

F. CONDUCT OF AN EVALUATION OF THE SYSTEMS AT THE END OF THE FIRST YEAR OF OPERATION AND PREPARATION OF RECOMMENDATIONS FOR REMEDIAL ACTION OR FURTHER EXPANSION OF WIND-POWERED WATER PUMPING PROJECTS. FURTHER MODIFICATION OR EXPANSION OF THE PROJECT WILL REQUIRE THE PREPARATION OF

A DETAILED MANUAL FOR INSTALLATION, REPAIR AND MAINTENANCE OF WIND-DRIVEN SYSTEMS AND FACILITIES.

- QUALIFICATIONS. CIVIL OR MECHANICAL ENGINEER WITH EXPERIENCE IN THE USE OF WINDMILLS FOR PUMPING WATER. INDIVIDUAL SHOULD BE KNOWLEDGEABLE ON THE ENTIRE RANGE OF WINDMILL DESIGNS AND CAPABILITIES.

- MANPOWER REQUIREMENTS: ONE (1) ENGINEER AS DESCRIBED ABOVE WILL BE REQUIRED FOR A PERIOD OF ONE YEAR DURING THE SELECTION, DESIGN AND CONSTRUCTION PHASES FOR SUBPROJECTS FOLLOWED BY THE SERVICES OF A SIMILARLY QUALIFIED TECHNICIAN FOR A TWO-MONTH EVALUATION AT THE CONCLUSION OF THE FIRST YEAR OF SUBPROJECT OPERATION.

THE MISSION RECOMMENDS AGAINST BROKEN ASSIGNMENTS OF PERSONNEL CONSISTING OF TWO TO THREE-MONTH STINTS ALTERNATELY SPENT HERE AND IN THE U.S. PAST EXPERIENCE WITH SUCH ASSIGNMENTS PROVE THEM TO BE EXPENSIVE AND ONLY MARGINALLY PRODUCTIVE. THUS, EMPHASIS SHOULD BE PLACED ON RECRUITING FIRMS WILLING TO ASSIGN PERSONNEL FOR THE DURATION OF THE RESPECTIVE ASSIGNMENTS.

4. BUDGET:
COMPONENT #1 - (HANDPUMP/CYLINDER - REPRODUCTION AND TRAINING)

- SALARIES AND WAGES (FIVE-MAN MONTHS - AT $3,000 PER MONTH)	$15,000
- OVERHEAD (100 PCT OF SALARIES & WAGES)	15,000
- DEFENSE BASE ACT INSURANCE	1,350
- IN-COUNTRY TRAVEL (15) ROUND TRIPS - MANILA/CEBU/MANILA	1,500

ACTION AID-35

ACTION OFFICE DSHE-01
INFO AAAS-01 AGEM-01 ASPT-02 ASDP-02 ASPD-03 ASTR-01 AADS-01
DSPO-03 ENGR-02 CHB-01 RELO-01 MAST-01 /020 A4 722

INFO OCT-01 /036 W
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FM AMEMBASSY MANILA
TO SECSTATE WASHDC 1874

UNCLAS SECTION 03 OF 04 MANILA 01775

AIDAC

- INTERNATIONAL TRAVEL (1 ROUND TRIP)	2,000
- PER DIEM (FIVE MONTHS AT $45 PER DAY)	6,975
- EQUIPMENT:	
- (HANDPUMPS - $125/UNIT X 250 UNITS)	31,250
- (CYLINDERS - $30/UNIT X 1000 UNITS)	30,000
- (REPLACEMENT PARTS FOR CYLINDERS)	5,000
- PRINTING/SECRETARIAL SERVICES	
- (MANUALS AND TRAINING MATERIALS)	5,000
- TRAINING (PARTICIPANT COSTS)	4,000
- TOTAL COST FOR COMPONENT #I	$117,075

COMPONENT #II - (WELL DEVELOPMENT/LOCAL PRODUCTION OF WELL SCREENS AND TRAINING)

- SALARIES AND WAGES (FIVE MAN-MONTHS	
- AT $3,000/MONTH	15,000
- OVERHEAD (100 PCT OF SALARIES & WAGES)	15,000
- IN-COUNTRY TRAVEL	2,000
- INTERNATIONAL TRAVEL (1 ROUND TRIP	
- USA/MANILA/USA)	2,000
- PER DIEM (5 MONTHS AT $45 PER DAY)	6,975
- MATERIALS (MANUFACTURING & PROCUREMENT	
- OF WELL CASING)	25,000
- PRINTING (MANUALS & TRAINING MATERIALS)	5,000
- TOTAL COST FOR COMPONENT #II	$72,325

COMPONENT #III - (PILOT FOR WIND-DRIVEN COMMUNAL WATER SYSTEMS AND EVALUATION)

- PHASE 1:	
- SALARIES & WAGES (12 MOS. X $3000/MO.)	36,000
- OVERHEAD (100 PCT OF SALARIES & WAGES)	36,000
- DEFENSE BASE ACT INSURANCE	3,240
- IN-COUNTRY TRAVEL	3,500
- INTERNATIONAL TRAVEL (1 ROUND TRIP	
- USA/MANILA/USA)	2,000
- PER DIEM (35 PCT OF WORK OUTSIDE MANILA)	4,000

- HOUSING AND UTILITIES	12,000
- EQUIPMENT (PURCHASE OF LOCALLY AVAILABLE	
- WINDMILLS)	24,000
- PRINTING/SECRETARIAL SERVICES	
- (REPORTS AND MANUALS)	5,000
- TOTAL PHASE 1 COMPONENT #III	$125,740

- PHASE 2 (EVALUATION OF PHASE 1 SUBPROJECTS):

AN EVALUATION IS PROPOSED TO TAKE PLACE AFTER WIND-DRIVEN COMMUNAL WATER SYSTEMS HAVE BEEN OPERATIONAL FOR ONE YEAR. ITS FINDINGS SHOULD SUGGEST A COURSE OF ACTION TO MODIFY OR EXPAND THE PROGRAM (OR BOTH) AND SIGNAL OPPORTUNITIES FOR THE USE OF OTHER NON-CONVEGTIONAL SOURCES OF ENERGY FOR PUMPING WATER, PARTICULARLY OF ADDITIONAL INTEREST ARE SMALL SOLOC ELECTRIC PUMPS UTILIZING SOLAR VOLTAIC CELLS.

- EVALUATION:	
- SALARIES AND WAGES (2 MONTHS AT $3500/MO)	7,000
- OVERHEAD (100 PCT OF SALARIES & WAGES)	7,000
- IN-COUNTRY TRAVEL (EACH OF THE PILOT	
- AREAS 1-1/2 TIMES)	1,000
- INTERNATIONAL TRAVEL (1 ROUND TRIP	
- USA/MANILA/USA)	2,500
- PER DIEM (60) DAYS AT $50/DAY	3,000
- PRINTING & SECRETARIAL SERVICES	
- (REPORTS, MANUALS)	2,000
- TOTAL PHASE 2 COMPONENT #III	$72,500

ACTION OFFICE DSHE-01
INFO AAAS-01 ASEM-01 ASPT-02 ASDP-02 ASPD-03 ASTR-01 AADS-01
DSPO-03 ENGR-02 CH8-01 RELO-01 MAST-01 /020 A4 722

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FM AMEMBASSY MANILA
TO SECSTATE WASHDC 1875

UNCLAS SECTION 04 OF 04 MANILA 01775

AIDAC

- TOTAL BUDGET:

COMPONENT I	$117,075
COMPONENT II	72,325
COMPONENT III	
PHASE 1	125,740
PHASE 2	22,500
GRAND TOTAL	$337,140

5. ADMINISTRATIVE AND SUPERVISORY ARRANGEMENTS:

A. THE CONTRACTORS WILL WORK CLOSELY WITH USAID AND PROVIDE TECHNICAL ADVICE TO LOCAL MANUFACTURERS, AND BOTH LOCAL AND NATIONAL GOVERNMENT OFFICIALS. THEY WILL WORK UNDER THE GENERAL SUPERVISION OF THE CHIEF OF THE MISSION'S OFFICE OF CAPITAL DEVELOPMENT AND ENGINEERING.

B. DAY-TO-DAY SUPERVISION WILL BE PROVIDED BY THE GOP'S PROJECT DIRECTOR FOR THE BARANGAY WATER PROJECT AND HIS USAID COUNTERPART.
OFFICE SPACE AND FURNITURE WILL BE PROVIDED BY THE BARANGAY WATER PROGRAM IN THE MINISTRY OF LOCAL GOVERNMENT AND COMMUNITY DEVELOPMENT.

C. ADMINISTRATIVE, SECRETARIAL SERVICES AND TRAVEL ARRANGEMENTS WITHIN COUNTRY WILL BE PROVIDED BY THE USAID/BWP STAFF AND OCCASIONAL PART-TIME SECRETARIES. SALARIES FOR THE LATTER ARE INCLUDED IN THE BUDGET PROVIDED.

D. TO ELIMINATE COSTLY MANAGEMENT SUPPORT EXPENSES, VOUCHERS CAN BE PREPARED AND PAID BY THE MISSION CHARGEABLE TO THE APPROPRIATE ALLOTMENT AND APPROPRIATION SYMBOLS. ALTERNATIVELY, VOUCHERS CAN BE PREPARED IN MANILA AND POUCHED TO AID/W OR THE DESIGNATED IQC.

E. ASSUMING THAT QUALIFIED INDIVIDUALS ARE IDENTIFIED TO PERFORM THE RESPECTIVE SCOPES OF WORK, NO ADMINISTRATIVE OR TECHNICAL BACKSTOPPING COSTS SHOULD BE NECESSANY BEYOND THOSE REFLECTED IN THE BUDGET.

6. INITIATION OF WORK

MISSION AND GOP DESIRE A START ANY TIME BEFORE MAY 1, 1981 FOR COMPONENTS #1 AND #2. START FOR COMPONENT #3 IS MORE FLEXIBLE, HOWEVER, A START BEFORE MAY 1 OR AFTER JULY 15 IS PREFERRED. MURPHY

UNCLASSIFIED

ACTION COPY

Department of State

INCOMING TELEGRAM

PAGE 01 MANILA 06628 231228Z 7000 026420 AID0231
ACTION AID-35

ACTION OFFICE DSHE-01
INFO AAAS-01 ASEM-01 ASPT-02 ASDP-02 STA-10 ASPD-03 ASTR-01
AADS-01 ENGR-02 CH8-01 RELO-01 MAST-01 /027 A4 823

INFO OCT-01 /036 W
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R 230656Z MAR 81
FM AMEMBASSY MANILA
TO SECSTATE WASHDC 4699

UNCLAS MANILA 06628

AIDAC

PASS TO GENE MCJUNKIN, DS/HEA/COMMUNITY WATER SUPPLY

E. O. 12065 N. A.
SUBJECT: TECHNICAL ASSISTANCE - BARANGAY WATER PROGRAM

REF: A. 80 STATE 324366 B. MANILA 01775

1. BASED ON LIKELIHOOD OF RECEIVING ASSISTANCE FROM THE WASH PROJECT FOR THE DEVELOPMENT OF IMPROVED HANDPUMPS AND CYLINDERS, MISSION SUSPENDED SIMILAR BUT MORE MODEST EFFORTS WITH LOCAL INSTITUTIONS.

2. MINISTRY OF LOCAL GOVERNMENT OFFICIALS AND PERSONNEL FROM THE UNIVERSITY OF SAN CARLOS ARE NOW REQUESTING INFORMATION ON THE STATUS OF PROPOSAL SUBMITTED IN REFTEL B.

3. THEREFORE MISSION WOULD APPRECIATE COMMENTS ON A) ACCEPTABILITY OF PROPOSAL BOTH IN TERMS OF MAGNITUDE OF FUNDING AND SCOPE OF WORK, AND B) AID/WASH PROGRESS TOWARD IMPLEMENTATION OF PROPOSAL.

4. IF PROPOSAL IS UNACCEPTABLE, MISSION IS OPEN TO RECOMMENDATIONS FOR REVISIONS.

5. PLEASE ADVISE C. C. BRADY AT EARLIEST OPPORTUNITY.
MURPHY

WATER AND SANITATION FOR HEALTH PROJECT

WASH

COORDINATION AND INFORMATION CENTER

Operated by CDM FIVE for the U.S. Agency for International Development

1611 N. Kent Street, Room 1002
Arlington, Virginia 22209 USA

Telephone: (703) 243-8200
Telex No. WUI 64552
Cable Address WASHAID

4 January 1982

Mr. Phillip W. Potts
Senior Research Scientist
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, GA 30332

Dear Mr. Potts:

This letter amends our June 24, 1981 letter of authorization for Georgia Tech to undertake work under Order of Technical Direction (OTD) No. 40. You are hereby authorized to send Mr. Tyler Gass to the Philippines between January 14, 1982 and April 22, 1982 to undertake the work described as "Component 2" of cable 1775 from AID/Manila dated January 1981, a copy of which is attached to this letter and a copy of which accompanied the original OTD. A copy of a December 11, 1981 amendment to the original OTD is also attached as well as a copy of cable 333583 from AID/S&T/HEA, dated December 1981, which responds to AID/Manila in its request for WASH assistance.

The terms of reference (scope of your work) as stated in cable 1775 are as follows:

A. Familiarization of BWP well requirements based on survey of existing BWP Projects.
B. Development of a section for the Barangay water operation manual entitled "well design and construction." This section of the manual will provide the design standards and specifications for all BWP water projects, both point-source development facilities and full-fledged production wells for water systems.
C. Provision of technical assistance to various Manila and/or CEBU based suppliers and manufacturers for the provision of plastic well casing and well screens.
D. Participation as a principal resource speaker in a seminar for waterworks technicians, local A&E engineers, and USAID technical personnel on well design and construction. This aspect of training will include well site selection, materials, design standards, drilling, casing, gravel packing, grouting, testing and

disinfecting wells.

The scope of work described above is further elaborated in section 3, paragraphs A, B, D, E and G of cable 27747 from AID/Manila dated November 1981, a copy of which is attached. Thus the scope of work also includes the following:

3A. Conducting a comprehensive field survey of level 1 (handpump activities) programs in the Philippines. These programs are currently being implemented unsatisfactorily by a number of both centrally located and local GOP agencies. Thus, the review should include an investigation of the procedures, approaches and outputs of each program.

3B. A survey of Philippine well drillers' capacity (equipment, techniques, personnel, training, etc.). This survey would include a thorough look at both the public and private sectors, and would require coordination with various GOP agencies and private companies, field visitation trips, data collection, and data analysis.

3D. Preparation of criteria for site selection and well development standards and specifications based on knowledge gained while doing items 3A and 3B, and in consultation with the Barangay Water Program hydrogeologists. The contractor will prepare a step-by-step manual for site selection and source development. The manual will take into account the existing data base as well as driller capabilities, agency financial capacities, local support industries, and will provide procedures for such items as well perforation, casing, screening, disinfecting, well recharging and rehabilitation, water quality testing, and water quality control.

3E. Preparation for classroom and field practicum presentations in a seminar for local government waterworks technicians and engineers, to include printing of well development manuals and guides, curriculum and training materials.

3G. Conducting a joint seminar which combines both Component #1 and Component #2 [cable 1775 AID/Manila] and covers handpump nomenclature, installation, maintenance and repair, site selection, source development and well monitoring procedures. The seminar will be of a 1-week duration.

The scope of work is strictly limited to the foregoing. Mr. Gass must meet with Mr. Charles Brady, AID/Manila, before doing any work in the Philippines in order to thoroughly define the details of the scope of work and mutually agree upon them. If the scope of work so agreed upon differs from that presented above, Mr. Gass and/or you are to immediately contact the WASH Project task manager and must not proceed until the task manager has explicitly approved the change in scope. All of your instructions must come only from the WASH Project task manager.

To carry out the above work, Georgia Tech is authorized up to a total of 90 directly productive person days. This includes four travel days, 80 days working in the Philippines (on the basis of 6 days per week), two days for briefing and debriefing, two days to revise the report after the debriefing and two days for Georgia Tech to administer the task. Any extension of the number of working days in the field must have the approval of the USAID Mission in Manila and of the WASH Project task manager. In addition, Georgia Tech is authorized to undertake up to two international round trips from the United States to the Philippines and return to accomplish this work. The WASH office may require Georgia Tech personnel to pass through Washington, DC for briefing or debriefing purposes in connection with these trips. All international travel under this OTD must have the prior written (or telexed) approval of the WASH task manager.

It is important to note that all travel should be by economy class on American flag carriers, and that if such travel is available, other travel will not be reimbursed.

A five-day work week is authorized. Payment can be made for working more than five days per week only if: (a) more than five days are worked; (b) it is necessary to work more than five days per week to get the work done; and (c) it is so certified on the time and expense reports. A working day is defined as a minimum 8-hour period of work or authorized travel in one day.

Neither time nor travel is authorized under this letter of authorization for Mr. Alan Pashkevich.

A draft final task report of this assignment should be presented to the AID Mission before returning to the United States and to the WASH Project upon return. A copy of any materials provided to the Mission should be given to WASH also. If there is disagreement with Mission staff on technical grounds, this should be made clear before leaving. The report should contain nothing which will surprise the AID Mission. It should be prepared in accordance with the WASH report guidelines, and its maximum length should be one double-spaced page for each day in the field.

In addition, an interim report of the progress of the work should be submitted in writing to the WASH office after each 40 person days of effort in the field.

In general, the AID Mission is not obligated to provide facilities such as transportation, office space, secretarial or interpretation assistance, etc., and it may not. If the Mission is unable or unwilling to provide such facilities or if the work is being handicapped for lack of such facilities, others may be arranged. Reasonable costs for this purpose will be reimbursed.

If for some reason it becomes impossible to progress with the assignment, a cable should be sent to Georgia Tech and WASH suggesting immediate return to the United States.

Following the submission of the report, there will be a debriefing in Washington, DC by representatives of the Office of Health and the Regional Bureau of AID and WASH Project staff. Arrangements for such a debriefing will be made at the appropriate time.

The task manager for this OTD will be Mr. Paul Howard of the WASH staff. You will be expected to keep him informed of all major activities in the course of the OTD and to obtain prior approval of any significant changes in the scope of work.

Mr. Phillip W. Potts
4 January 1982
Page 5

We look forward to working with you on this interesting and challenging task.

Sincerely yours,

Dennis B Warner

Dennis B. Warner, Ph.D., P.E.
WASH Project Director

DBW:PFH:mcl

enclosures

SUBCONTRACT FOR CONSULTING SERVICES UNDER GIT PROJECT NO. A-2957-002
BETWEEN GEORGIA INSTITUTE OF TECHNOLOGY AND BENNETT AND GASS, INC.

Exhibit A

SCOPE OF WORK

Mr. Tyler E. Gass of Subcontractor Bennett and Gass, Inc. will provide technical consulting services to the Institute in conjunction with the United States Agency for International Development (USAID) Barangay Water Program (BWP) in the Philippines. The services of Mr. Gass are unique and personal in nature and Subcontractor shall not substitute any other individual for Mr. Gass without prior approval in writing from the Institute.

Upon arrival in the Philippines and before the onset of the effort set forth herein, Mr. Gass shall meet with Mr. Charles Brady, USAID Mission to the Philippines, in order to thoroughly acquaint Subcontractor with the situation there and to discuss the details of the effort set forth in this Scope of Work. No modification shall be made to the Scope of Work without the prior written approval of Institute.

The effort to be performed by Subcontractor consists of the following:

1. Familiarization of Barangay Water Program (BWP) well requirements based on a survey of existing BWP projects. Subcontractor shall prepare a comprehensive survey of level 1 (hand pump activities) programs in the Philippines which are currently being implemented unsatisfactorily by a number of both centrally located and local Government of Philippines (GOP) agencies. Thus, the review should include an investigation of the procedures, approaches and outputs of each program.

2. Survey of Philippine well driller's capacity (equipment, techniques, personnel, training, etc.). Subcontractor shall prepare a survey which will include a thorough look at both the public and private sectors, and will require coordination with various GOP agencies and private companies, field visitation trips, data collection, and data analysis.

3. Provision of technical assistance to various Manila and/or Cebu based suppliers and manufacturers of plastic well casing and well screen. This technical assistance should focus on one particular supplier, Neltex, to evaluate its present production of both casing and screen in comparison with potential quantity and quality of competitors.

4. Preparation of a section for the BWP water operation manual entitled "Well Design and Construction." This will include preparation of criteria for site selection and well development standards and specifications based on knowledge gained while doing items 1, 2 and 3, and in consultation with BWP hydrogeologists. A step-by-step manual will be prepared by Subcontractor for site selection and source development taking into account existing data bases as well as driller capabilities, agency financial capacities, local support industries, and will provide procedures for such items as well perforation, casing, screening, disinfecting, well recharging and rehabilitation, water quality testing, and water quality control.

5. <u>Preparation for classroom and field practicum presentations of a seminar for local government waterworks technicians and engineers, to include printing of well development manuals and guides, curriculum and training materials.</u>

6. <u>Participation as a principal resource speaker in a seminar for waterworks technicians, local A&E engineers, and USAID technical personnel on well design and construction.</u> This aspect will include training in well site selection, materials, design standards, drilling, casing, gravel packing, grouting, testing and disinfecting wells. The seminar will be one week in duration and will be held jointly with a member of the research faculty of the Georgia Institute of Technology who will cover hand pump nomenclature, installation, maintenance and repair.

7. <u>A Draft Final Report shall be presented to the USAID Mission before the subcontractor returns to the United States and a copy to the Institute's project director upon his return.</u> A copy of any materials provided to the Mission should be given to the project director also. If there is disagreement with Mission staff on technical grounds, this should be made clear before leaving the Philippines. The report should contain nothing which is outside this Scope of Work or which has not been discussed previously with the Mission and should be prepared in accordance with Water and Sanitation for Health (WASH) report guidelines, and its maximum length should be one double-spaced page for each day in the field.

Following the submission of the report, there will be a debriefing in Washington, D.C. by represenatatives of the Office of Health and the Regional Bureau of AID, WASH Project staff, and representatives of the Georgia Institute of Technology.

In addition, an interim report of the progress of the work shall be submitted in writing to the ID project director after each 40 person days of effort in the field.

APPENDIX B

Consultants' Itinerary

APPENDIX B

CONSULTANTS' ITINERARY

P. Alan Pashkevich

Jul 5 - Jul 6, 1981	Traveled to Philippines with Phil Potts and Bill Larson.
Jul 19- Jul 18	Visited Indonesian pumps in Pangasinan. Signed shallow-set contract with Tri-Star. Visited U. of San Carlos.
Jul 19 - Aug 10	Conducted market survey on existing pumps. Met with University of San Carlos and PDC in Cebu. Signed medium-set contract with Tri-Star. Designed shallow-set foot valve. Began deep well cylinder design.
Aug 11 - Sep 3	Traveled to Pampanga, Pangasinan, La Union, Iloilo, Cebu, Butuan City, Agusan del Sur, Cagayan de Oro, Sorsogon, Albay, and Camarines Sur to review hand pump installations.
Sep 4 - Oct 8	Wrote field trip report. Began Level I manual. Finalized cylinder design. Began inspecting castings for dimensional accuracy and casting defects. Drew initial illustrations for manual. Completed apron construction section and circulated it for review.
Oct 9 - Oct 16	Inspected first shallow-set pumps to be assembled. Began site selection.
Oct 17 - Oct 21	Cebu Training Seminar - preparation and presentation.
Oct 22 - Oct 27	Off
Oct 28 - Nov 8	Identified the remainder of the test sites. Continued writing sections for manual. Hired draftsman to make illustrations for manual. Monitored progress on medium-set pumps at Tri-Star.
Nov 9 - Nov 27	Installed test pumps at majority of sites. Turned remainder of installations over to Oscar Basa.
Nov 28 - Dec 13	Completed draft of manual. Released it for review. Met twice with University of San Carlos personnel to coordinate the installation of a cylinder and medium-set pump.
Dec. 14 - Dec 18	Made monitoring trip, accompanied by Phil Potts, to review all test installations.
Dec 19 - Dec 21	Made final arrangements for departure to U.S.
Dec 22 - Dec 23	Traveled to U.S.
Dec 24 - Jan 10	Holiday

Jan 11 - Feb 20, 1982	Revised manual, added disinfection section, revised drawings, assembled draft of manual in photocopy-ready form.
Feb 21 - Feb 27	Attended training of trainers seminar sponsored by USAID in Airlie, VA. Conceived training of trainers segment of hand pump seminar during this week.
Mar 1 - Mar 2	Flew to Philippines.
Mar 3 - Mar 4	Met with Tyler Gass, Oscar Basa, Carlos Crowe and BWP staff.
Mar 5 - Mar 6	Inspected pumps in Batangas and Lucena Cities.
Mar 8 - Mar 16	Visited the Waterworks Technician Training Seminar in Bulacan. Outlined details of the hand pump seminar design with several BWP staff.
Mar 17 - Mar 18	Inspected test pumps in Pampanga and Angeles City.
Mar 19 - Mar 24	Continued work on seminar preparation including revisions to the manual. Read over Tyler's manual and commented on it. Prepared disbursement list for pumps.
Mar 25 - Mar 27	Began pump acceptance testing at Tri-Star.
Mar 29	Prepared letter format to LGU's for pump disbursement.
Mar 30	Visited Batulao, Nasugbu, Batangas, site of the seminar. Made logistical arrangements.
Mar 31 - Apr 1	Continued pump acceptance testing.
Apr 1 - Apr 11	Off
Apr 12 - Apr 17	Made final logistical arrangements for seminar (drum, bolts, pumps, shipment, etc.). Conducted training for trainers. Walked through seminar with trainers. Wrote pump manufacturing quality control brief for BWP engineers.
Apr 18 - Apr 24	Traveled to Batulao. Conducted seminar with Tyler Gass. Evaluated seminar, cleaned up practicum leftovers and returned to Manila.
Apr 26 - Apr 29	Briefed Carlos Crowe and Gaspar Nepomoceno, BWP project director, on results of seminar. Counted up the total number of accepted pumps one last time and turned them over to BWP using a USAID form. Briefed Tony Schwartzwalder, USAID/Manila Director, on total hand pump program including Tyler's component.
Apr 30	Returned to U.S.

Tyler E. Gass

Jan 23 - Jan 24, 1982	Traveled from Columbus, Ohio, to Manila, Philippines. Much of the time enroute was spent reviewing cables relating to the project, reading Alan Pashkevich's departure and travel reports, and reading the Area Handbook for the Philippines.
Jan 25	Met with Charles Brady, Oscar Basa and Jesse Cooper and received an orientation to BWP. Met with Mr. Brady to discuss the scope of work of my project and the level of assistance I could expect from USAID/Manila.
Jan 6	Met with Mr. Brady to discuss the nature of the training program and the audience which would receive the training. Traveled to BWP headquarters to set up desk and meet with personnel of the BWP project.
Jan 7	Traveled to Pampanga Province to begin orienting myself to the geology and to observe some BWP Level I and II water systems.
Jan 8-29	Field trip to Batangas Province to continue my familiarization with the geology, observe on-going BWP projects and examine some of the well construction techniques being used in the Philippines. Met and discussed the BWP program with the provincial engineer.
Jan 30	Worked in Manila and reviewed various BWP project reports, the BWP Operations Manual and some water well technology textbooks brought from the U.S.
Jan 31	Off
Feb 1	Worked at BWP headquarters. Met with Dr. Romeo M. Luis, Hydrogeologist, to discuss the general availability of geological and hydrogeological data pertaining to the Philippines.
Feb 2	Worked on Training Manual - geology section.
Feb 3	Worked at BWP. Attended a meeting of BWP's A&E's. Continued work on the geology section of the training manual.
Feb 4	Visited various drilling firms in the small metro-Manila area as part of a survey of drilling equipment, drillers' capabilities and problems associated with drilling in different parts of the Philippines.
Feb 5	Met with Dr. Luis at the Bureau of Mines. Obtained copies of geologic maps of the Philippines and geologic and hydrologic reports of different regions and localities throughout the country, familiarizing myself with geologic and hydrogeologic conditions.

Feb 6	Continued reading geologic and hydrogeologic reports. Finished the basic geology section of the training manual.
Feb 7	Off
Feb 8	Worked on training manual.
Feb 9	Met with Mr. Brady in the morning to review the progress of the project and discuss some additional aspects of the training program. In the afternoon Oscar Basa and I went to Neltex Plastic to take a look at their casing and screen. The pipe they are presently using for plastic well casing fits within the range of SDR values and tolerances in ASTM F-480. Therefore, their product should be acceptable for use as well casing. Neltex produces two types of well screen - saw cut slotted casing and continous slot "Robo-type" screen. The continous slot screen would be excellent for Level I wells. Two to three meters of this type of screen is all that would be necessary to permit 10 gpm to flow into the well from a moderately permeable aquifer.
Feb 10-11	Worked on well site selection section of the manual.
Feb 12	Met with the President of the Well Driller's Association of the Philippines, Mr. Luis Batao. Discussed the types of drilling rigs being used for construction of water wells, the availability of equipment and materials, and the attitude of the well drillers toward training programs.
Feb 13-14	Off
Feb 15	Worked on Well Site Selection section of the training manual.
Feb 16-17	Field trip to north central Luzon (main area of interest was Pangasinan) to examine BWP Level I and II projects and some of the geologic conditions in which ground water development must take place.
Feb 18	Field trip to La Union and Benquet Provinces to examine the geologic character of the more mountainous terrain.
Feb 19	Off
Feb 20-27	Worked on various sections of the manual and proofread some of the earlier sections that were typed. Completed some of the administrative responsibilities of the project.
Feb 28	Off
Mar 1	Met with Carlos Crowe who replaced Charles C. Brady as Project Director for BWP. Worked on well construction section of the manual.
Mar 2	Worked on well construction sections of the manual.

Mar 3	Met with Alan Pashkevich to discuss project progress and scheduling. At the BWP office Alan, Oscar Basa, and I discussed the training program in greater detail.
Mar 4	Alan and I met with Carlos Crowe to discuss our project and the schedule and objectives of our training program. Worked on the manual.
Mar 5-6	Based on Alan's critique of the first draft of the manual, the day was spent making certain revisions to the completed parts.
Mar 7	Off
Mar 8-10	Worked at BWP headquarters to complete all sections of the manual dealing with well construction. The well site selection and well construction sections of the manual are to be used as a handout for a BWP Waterworks Technician Training program on 3/11.
Mar 11	Presented a workshop on well site selection considerations and water well drilling methods to waterworks technicians. The program was part of a week-long session held in Bulacan.
Mar 12-13	Worked at the BWP office on the well development and well completion sections of the manual.
Mar 14	Off
Mar 15	Wrote the Water Well Construction Specifications for BWP Level I wells.
Mar 16-18	Preparation of Interim Report.
Mar 19-20	Reviewed draft of Operations and Training Manual.
Mar 22	Returned to United States.
Mar 24 - Apr 12	Revisions to earlier drafts. Typing of the Manual on a word processor and revisions to subsequent drafts. Collected materials for workshops.
Apr 13-14	Travel to Philippines. Worked on program curriculum.
Apr 15-17	Printing of manual. Preparation for training program.
Apr 18	Traveled to Batulao for training program.
Apr 19-22	Training Program.
Apr 24-27	Returned to Manila. Completed administrative responsibilities. Had conversations with associates to evaluate the training program.

Apr 28	Return to United States.
Apr 29 - May 4	Revision to Training Manual.
May 11-13	Completion of final report. Review final copy of Training Manual before duplication.

APPENDIX C

Officials Interviewed

APPENDIX C

OFFICIALS INTERVIEWED

Government Sector

Barangay Water Program, Mr. Gaspar Nepomoceno, Project Manager

Local Government Units
- Augusan del Sur, Arthur B. Madula, Assistant Provincial Engineer
- Albay, Bruno Navera, Provincial Development Coordinator
- Butuan City, Antonio C. Inchoco, City Development Coordinator
- Cagayan de Oro City, Ernesto B. Cascan, Assistant Mechanical Engineer of the Provincial Engineer's Office
- Camarines Sur, Romeo P. Papica, Supervising Project Development Analyst, and Alicia Y. Llorin, Engineering Analyst
- Iloilo, Freddie de Guzman, Provincial Waterworks Analyst
- La Union, Arnulfo Delizo, Water Resource Analyst
- Pampanga, Attorney Porfirio G. Punzalan, Provincial Development Coordinator
- Pangasinan, Roberto Ferrer, Provincial Development Coordinator, and Ernesto Mendoza, Provincial Waterworks Engineer

Ministry of Public Works, Jose H. Espiritu, Director, Bureau of Water Supply

USAID/Manila, Charles C. Brady, Project Officer, and Carlos E. Crowe, General Engineering Advisor

Private Sector

ADAMCO Well Drillers, Lucita D. Lugtu, Sales Manager, and Erie Puno, Operations Manager

Drilling Corporation of Asia, Alberto R. Sanchez, President, Simeon L. Soriano, Shop Superintendent, Cris Moro, Hydrogeologist

Makati Machinery, Reuben M. Valerio, President and General Manager

Miguel Well Drillers, Felicisimo G. Miguel, Manager, and Agaton M. Rentoria, Field Engineer

Neltex Plastics Corporation, Julianito C. Tantan, Operations Director, and Joe Austria, National Sales Manager

Shamrock Well Drilling Enterprises, Inc., Luis M. Baja, Vice President and General Manager, also president of the Well Drillers' Association of the Philippines

Sheladia Associates, Jesse Cooper, Hydrogeologist and Consultant (BWP), and Timothy McClellan, Water Supply Engineer (BWP)

Technics Consulting Engineers, Romeo M. Luis, Hydrogeologist (BWP)

University of San Carlos, Cebu City, Fr. Herman Van Engelen, Head, Water Resources Center

APPENDIX D

Hand Pump Distribution List

APPENDIX D

HAND PUMP DISTRIBUTION LIST

	Local Government Unit	Shallow-Set	Medium Set	Deep Well Cylinder
1.	Abra	5	5	15
2.	Agusan del Norte	3	3	10
3.	Agusan del Sur	5	5	10
4.	Albay	3	3	20
5.	Bataan	3	3	10
6.	Batangas City	3	3	10
7.	Batangas	5	5	10
8.	Butuan City	8	8	15
9.	Cagayan	3	3	10
10.	Camarines Sur	2	2	5
11.	Catanduanes	3	3	10
12.	Cavite	10	10	20
13.	Cebu	10	10	20
14.	Davao del Norte	5	5	15
15.	Iloilo	5	5	10
16	La Union	5	5	10
17.	Lucena City	3	3	10
18.	Misamis Oriental	2	2	5
19.	Palawan	5	5	15
20.	Pampanga	6	6	20
21.	Pangasinan	5	5	15
22.	Puerto Princesa City	8	8	15
23.	Roxas City	5	5	10
24.	Samar	3	3	10
25.	South Cotabato	2	2	5
26.	Zambales	3	3	10

APPENDIX E

Hand Pump Production Quality Control

APPENDIX E

HAND PUMP PRODUCTION QUALITY CONTROL

The following is an outline of hand pump quality control procedures for use by BWP personnel when evaluating additional manufacturers. Critical procedures are highlighted in the outline.

I. Selection of Manufacturers

Manufacturers should be selected on the following criteria:

1) Adequate facilities. A 3-ton cupola, several lathes and drill presses, and a shaper (or milling machine) are necessary to produce hand pumps in moderate quantities (25-100) in a reasonable period of time. Other recommended equipment and facilities include grinders, welders, hardness tester, ample casting and assembly floor space and heat treatment facilities.
2) Commitment to quality control. The commitment of the manufacturer to quality control can be determined by examining products on the market made by the manufacturer and by contacting his customers. No casting leaving the factory premises should have defects filled with putty or epoxies. Finished assemblies should not bind at joints nor should any pieces have to be hammered into place for a proper fit. Commitment to quality control can be gauged from the customers in two ways: first, the customer's level of satisfaction, and second, the customer's own reputation for quality products.
3) Difficulty of work undertaken to date. The manufacturer should have the ability to produce fairly complex shapes and parts such as valve housing, gear casings, etc. Round, symmetrical shapes with 1/4 to 1/2 inch thick sections are below the proficiency level needed to produce the hand pump which has a medium-difficulty casting (cap), a large casting (body), and a very long casting (handle). Each of these present special flow and shrinkage problems.
4) Personnel. Besides skilled foundrymen and machinists, the manufacturer should have at his disposal an experienced foundry supervisor who can revise the gating, runners, pattern and cores as needed to produce castings with minimal internal (porosity, inclusions, etc.) and external (imbedded sand, etc.) defects and to troubleshoot the flow and shrinkage problems mentioned above. The manufacturer should also designate one man to be responsible for the machining and assembly processes so that feedback can be constructively incorporated into the manufacturing program.
5) Pricing. Each prospective manufacturer should be shown a complete set of drawings and all special casting, machining and assembly procedures should be explained (this outline can be used) so that he can tender a competitive bid and so that BWP personnel can expect no surprises as the first prototype units are delivered. The contract should be let to the lowest bidder who meets the above criteria.

II. Casting

A. Adherence to drawings. The first prototype delivered to BWP for inspection should be measured at every dimension given on the drawings.

At no time it is tolerable for a cast section to be thinner than specified on the drawings. Likewise, thicker sections should be avoided as they only add more weight and increase the manufacturer's cost.

B. Internal defects. Blow holes and voids cause weak spots and increased breakage. The handle is most susceptible of all pump components to failure due to porosity and inclusions. The presence of blow holes and voids can be determined by exerting heavy pumping force on the handle of an assembled pump. Pressure should not be applied sharply as cast iron is brittle and not very impact resistant. The tester should apply his full weight against the handle in the "down" position.

C. External Defects. Most external defects can be eliminated by revising the gating and feed structures. Surface defects on the base and body threads and on the valve seats often result in leakage. Smoother external surfaces facilitate the cleaning of the pump.

D. Silicon Content. High silicon content makes the casting brittle and hard to machine. Typically, a good machinist will warn the foundryman of high silicon content because of the resistance of the casting to being machined.

E. Split or Misaligned Sections. These casting defects are caused by misalignment of the mold halves. Split sections can cause machining and assembly alignment problems and should be discarded.

III. Machining

Use of jigs and fixtures. The use of jigs and fixtures assures interchangeability of parts, increases productivity and decreases production of rejects. The major point of reference for the jigs is the pump centerline, e.g., the centerlines of the slider block tracks and the pipe section must be parallel to the pump centerline to prevent the slider blocks or cups from binding and wearing unevenly. The plunger rod hole in the pump cap must be on the centerline and the bolt holes on the cap and body must center on the plunger rod hole. The handle and fulcrum pin holes must always be perpendicular to the longitudinal axes of the handle and fulcrum so that no binding will occur in the assembled pump.

IV. Miscellaneous Procedures.

A. Heat treatment of pins and bushings. To increase life and facilitate repair, the pins and bushings are heat treated to different hardnesses. The pins are heat treated to Rockwell (C-scale) 40-45 and the bushings hardened to Rockwell (C-scale) 60-65. Both hardnesses should be confirmed independently of the manufacturer by BWP personnel.

B. Pump Leather. Imported Clayton-Mark leathers have been previously specified because of their consistently high quality. Other brands may perform satisfactorily but should be adequately tested first.

C. Valve rubber. The valve rubber should be soft enough to conform to irregularities in the valve seat but hard enough to wear well. The rubber surface must be smooth.

V. Assembly

A. Deep well cylinder. The deep well cylinder consists of a PVC section and two female connectors. To assemble, clean all surfaces to be joined with acetone. Spread solvent liberally on the joining surfaces.

Insert the pipe section fully into the connectors, turn each connector 90° to distribute solvent and hold for 30 seconds until set. Before accepting any solvent for this critical use, perform the solvent quality test as presented in the hand pump manual.

B. Shallow-set PVC insert. The PVC insert for shallow-set pumps is a PVC pipe section with the outer diameter machined down for a press fit into the G.I. pipe section.

C. Plunger assembly. Tighten the plunger assembly firmly but not so much as to make disassembly with a screwdriver and wrench difficult. The plunger rod should not protrude into the plunger cage which would reduce poppet travel. The plunger rod lock nut should be tightened firmly.

D. Pipe Section. The threads of the pipe section that join to the base should be coated with grease to prevent rusting. The upper threads connecting the pump body should be coated with gasket sealant. This provides a semi-permanent connection which enables the pump section to be unscrewed from the base using the handle as a lever.

E. Valve Seat. Gasket sealant should be placed around the valve seat to prevent leakage between the base and valve seat.

Test every pump of the initial production run of a new manufacturer, looking for the following items:

1. The pump pumps water. (With no pumping head shallow-set pumps and medium-set pumps will deliver .20 to .25 and .09 to .10 gallons per stroke, respectively.)
2. Handle movement is free and unrestricted; no dragging or rubbing on adjacent parts; handle falls by its own weight from raised position.
3. No leaks or streaks from previous leaks on pump base or pipe section.
4. Plunger rod not rubbing on sides of hole in pump cap.
5. Cups fit snugly - not too loose or too tight.

Every tenth pump should be set aside and disassembled. The following items should be examined:

1. Cups: tears, ragged edges, punched hole off center.
2. Looseness or tightness of plunger cage and lock nuts; the cage should only be tight enough to prevent loosening by hand so that repairs can be easily effected in the field.
3. Any irregularities: blowholes, rough valve seat, rubbing surfaces, internally scratched cylinders, etc.

If one pump from the ten percent sample fails, an additional twenty-five percent of the production run should be tested for the same default. If more pumps with the same defect(s) are found, the entire production run should be tested and all defects corrected.

For continued quality control testing of an accepted manufacturer, ten percent (10%) of the pumps should be randomly tested as detailed above. Every tenth pump that is tested should be disassembled and examined in detail. The same procedure as above should be followed when a defect is found.

APPENDIX F

Hand Pump Installation, Maintenance and Repair Manual

Project No. A-2957-002

Philippine Hand Pump Project
INSTALLATION, MAINTENANCE, AND REPAIR MANUAL

Prepared for

The United States Agency for International Development
Under Order of Technical Direction No. 40

by
P. Alan Pashkevich, Research Engineer

International Division
Technology Applications Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia
August 1982

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8C.1 Introduction

There are numerous small rural communities in the Philippines that lie outside the current or near future service areas of piped water systems. Moreover, they are unable to acquire such a system in the near future due to the financial limitations of the community or the absence of electrical service.

It is believed that in order to further accelerate the development of the rural areas in the Philippines, it is necessary to undertake small water facilities at the subsystem level (such as well development and pump installation projects) thereby laying the organizational groundwork on the part of the community for the development of more complete water systems. These systems will follow when these areas have gained electricity and when the water demand is sufficiently high to make feasible the provision of full-fledged and more complete systems.

During the initiation of the BWP Level I Program, the well development methods and the available hand pumps were examined and found to be below acceptable standards for community water supply. The Barangay Water Program undertook to establish recommended standards and procedures for Level I facilities. That effort resulted in the establishment of well development standards and procedures presented in Section 8B, the establishment of hand pump installation, maintenance and repair standards and procedures as follows in this section, and the production in the Philippines of a high quality hand pump designed for community water supply usage. An outline comparing the various pumps used previously appears in Appendix 8C.A.

It has been the longstanding policy of the Barangay Water Program to use only deep (up to 200 feet) and medium depth wells for BWP Level I installations. This is because water from deeper aquifers is less likely to be contaminated by fertilizers, insecticides, human and animal wastes, and other surface contaminants. However, in some areas deep drilled wells are artesian to less than seven to eight meters (20-25 feet) below the ground surface. For this reason and others enumerated below, three types of pumps are recommended for usage in BWP Level I activities. The shallow-set pump, which is easiest to install, maintain, and repair, is able to pump water from a depth of seven to eight meters to the surface. The medium-set pump, which requires less time and care to install than the deep-set pump, is currently limited by handle length to water depths of less than thirty-one meters (100 feet). The deep-set pump of the sturdy and reliable traditional, or "Magsaysay," design can be used in installations where the water table is over thirty-one meters.

8C.2 Sources of Possible Well Contamination

A well can become contaminated with organisms and substances harmful to humans from many different sources. The likelihood of contamination can be reduced greatly by 1) careful site selection, 2) good well protection and apron construction, and 3) the selection and timely maintenance and repair of a quality pump. The shallower the source of water, the greater the chances are for contamination. For this reason, BWP has adopted the policy of using deeper sources of water for level I installations.

8C.2.1 Site Selection

The likelihood of well contamination can be reduced by selecting a site at least fifteen (15) meters (50 feet) from:

1. Any sanitary facilities (toilets, septic pits, etc.).
2. Bathing, washing, or any open well.
3. Agricultural fields using pesticides and fertilizers.
4. Drainage canals, fish ponds, creeks, and other bodies of water.

Contaminated water from these sources can seep through the soil and contaminate the ground water or the aquifer from which the well is receiving water.

NOTE: The recommended distance of 15 meters does not guarantee freedom from contamination since the distance contaminants can travel through the ground formation is a function of material, flow rate, and elevation. The recommended distance is suggested by WHO (World Health Organization) experts as a rule of thumb for site selection.

8C.2.2 Well Protection and Apron Construction

Contaminated surface and ground water can follow the casing down to the aquifer formation unless means are provided to prevent water movement. The well can be protected by grouting the space between the casing and the well walls especially at the surface and through any formation suspected of being contaminated. Well protection is discussed in more detail in the level I well drilling section of the BWP manual.

The apron around the well further protects the well by draining away surface water that would normally be absorbed into the soil around the well and by providing a water-tight seal around the casing. Recommended apron construction is further discussed in Section 8C.5. Contaminated water can also be introduced into the well through the casing. The section on apron construction discusses the use of the casing pipe (Section 8C.5.3) or a PVC pipe section (Section 8C.5.5) as a water barrier for the top of the casing.

8C.2.3 Quality Pump, Timely Maintenance and Repair

Priming can introduce contaminated water to the well. The selection of a quality pump in conjunction with timely maintenance and repair will prevent the need for priming.

The shallow-set and medium-set pumps selected for BWP are of superior quality being manufactured with high quality materials by experienced machinists and foundrymen. The deep-set pump is described and detailed in Section 8C.6.5 so that the LGU responsible for the project will have in-depth instructions on how to construct a high quality above-ground structure.

Maintenance and repair are discussed in detail in Sections 8C.9 and 8C.10. Even the best made pumps require periodic maintenance and repair. It is for this reason that BWP strongly stresses the aspects of maintenance and repair in their water projects. These aspects are joint efforts of the LGU and the recipient barangays since the LGUs are better equipped and manned for major repair work while the barangay population can better maintain the pump and perform the less difficult repairs on short notice.

8C.3 Pump Theory and Operation

8C.3.1 Shallow-Set Pumps

Figure 8C-1 shows the components of a shallow-set pump. The body of the pump contains a valved plunger assembly which moves up and down during operation. The principle of its operation may be followed by examination of Figure 8C-2.

Its operation is as follows:[1]

1. With the pump primed, as shown at A, the plunger is raised. As air cannot pass the plunger owing to the water seal, a partial vacuum is created in the cylinder thereby reducing the air pressure on the surface of the water in the suction pipe. The atmospheric pressure on the water in the well is now greater than the air pressure on the water in the pipe, thereby forcing the air and water in the pipe upward. The space in the cylinder below the plunger fills with air from the pipe.

2. At the top of the cylinder the plunger stops, and the foot valve closes by its own weight, thus trapping air in the cylinder.

3. On the next downstroke the entrapped air is compressed between the plunger and the bottom of the cylinder. When the pressure becomes greater than the atmospheric pressure above the plunger plus the weight of the valve and of the priming water, the air will lift the plunger valve and escape through the priming water as shown at B.

4. On the next upstroke more air will be drawn out of the pipe and the water will rise higher, eventually flowing into the cylinder under the plunger as shown at C.

5. With the cylinder and pipe full of water as at C, the foot valve closes by gravity, trapping water in the cylinder.

6. On the next downstroke the plunger and valve pass through the water as shown at D.

7. When the plunger reaches the bottom of the cylinder and stops, the plunger valve closes, thus trapping the water above the plunger as shown at E.

8. On the next upstroke the water above the plunger is lifted out of the pump as shown at F. At the same time more water is forced into the cylinder through the foot valve.

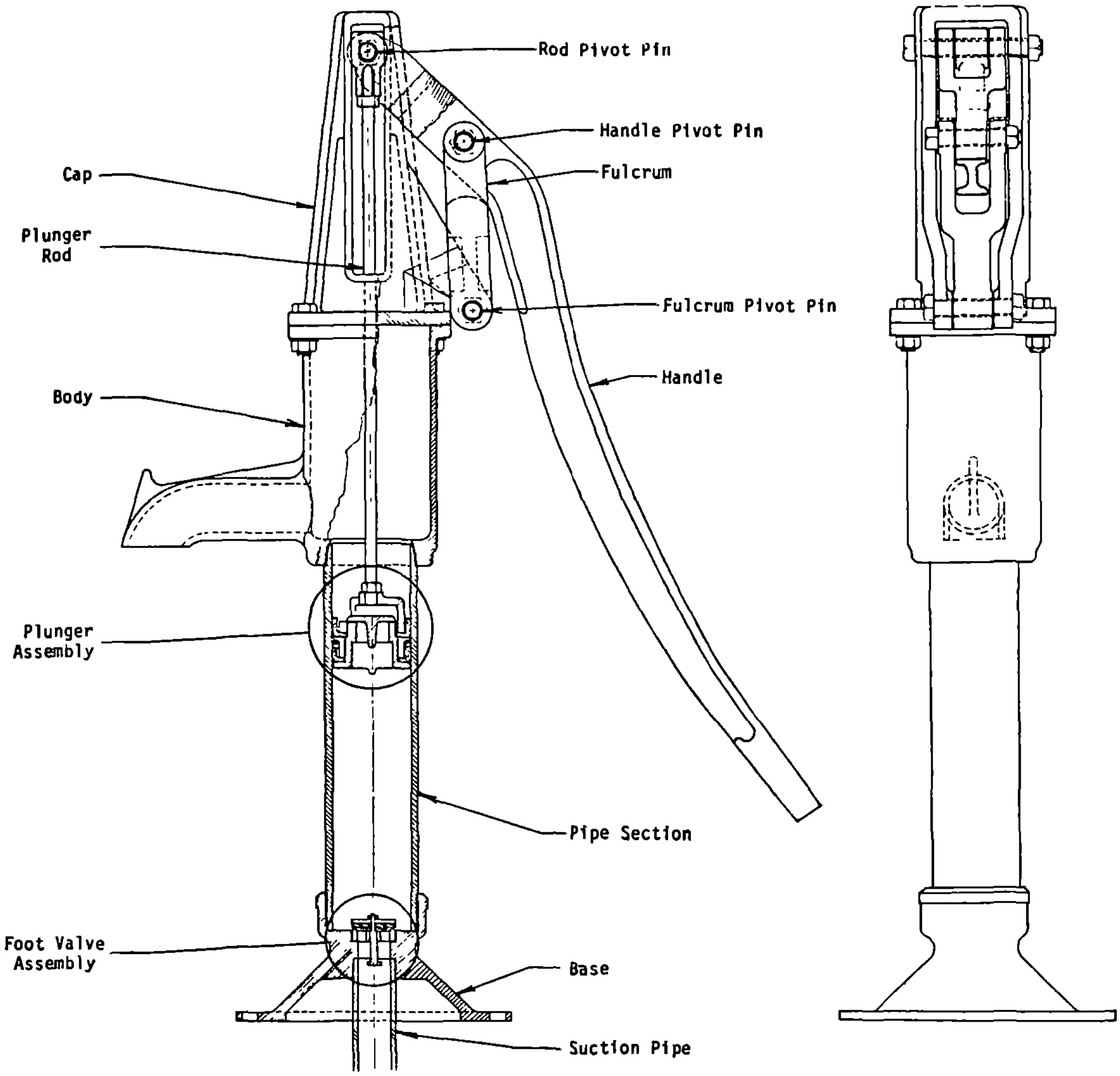


Figure 8C-1. Shallow-Set Pump

9. On each successive downstroke step D is repeated, and on each successive upstroke step F is repeated. Thus the pump delivers water on each upstroke.

Shallow set pumps do not "pull" or "draw" water from the source. Rather the pump reduces the atmospheric pressure on the water in the suction pipe. The atmospheric pressure on the water outside of the suction pipe pushes the water up and into the pump. Because of vacuum leaks around the plunger cups and through the plunger valve, the use of shallow- set pumps is limited to conditions where the water table during pumping is within 8 meters of the cylinder even though "standard atmospheric pressure" is about 10.3 meters (34 feet).

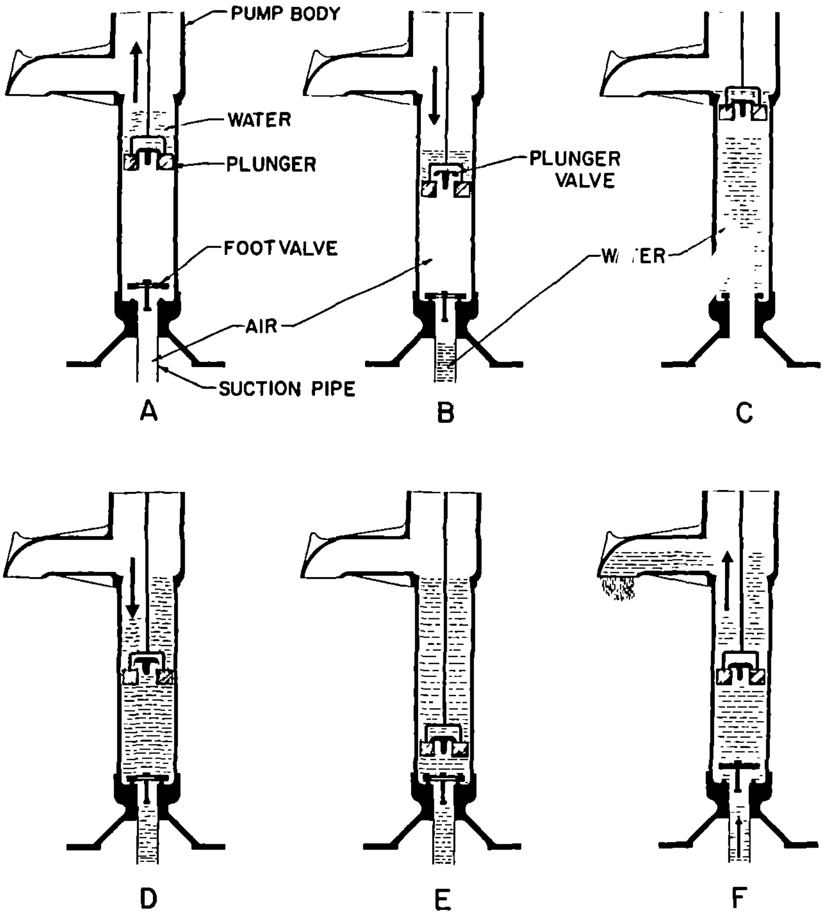


Figure 8C-2. Shallow-Set Pump Operation

8C.3.2 Medium-Set and Deep-Set Pumps

The cylinders of medium-set and deep-set pumps are usually located below the water level to prevent loss of priming. Water is lifted to the surface by the reciprocating action of the plunger assembly. The operation of a medium-set or deep-set pump is as follows:[2]

1. On the first upstroke, the water in the cylinder is raised and more water enters the cylinder through the foot valve as in Figure 8C-3A. Note that the cylinder is submerged.

2. Upon completion of the upstroke, the foot valve closes by gravity, trapping the water that has just entered the cylinder, as shown in B.

3. On the downstroke, the poppet valve in the plunger assembly opens, allowing water to pass as shown at C.

4. When the plunger assembly reaches the bottom of the cylinder and stops, the poppet valve closes, trapping the water above the plunger assembly as shown at D.

5. On the next upstroke, more water is lifted up the drop pipe and more is introduced into the cylinder. On each stroke the process is repeated until water comes out of the pump spout. Note: If the foot valve is holding water well, the drop pipe should usually remain full of water. Water should then be delivered within a few strokes if not on the first.

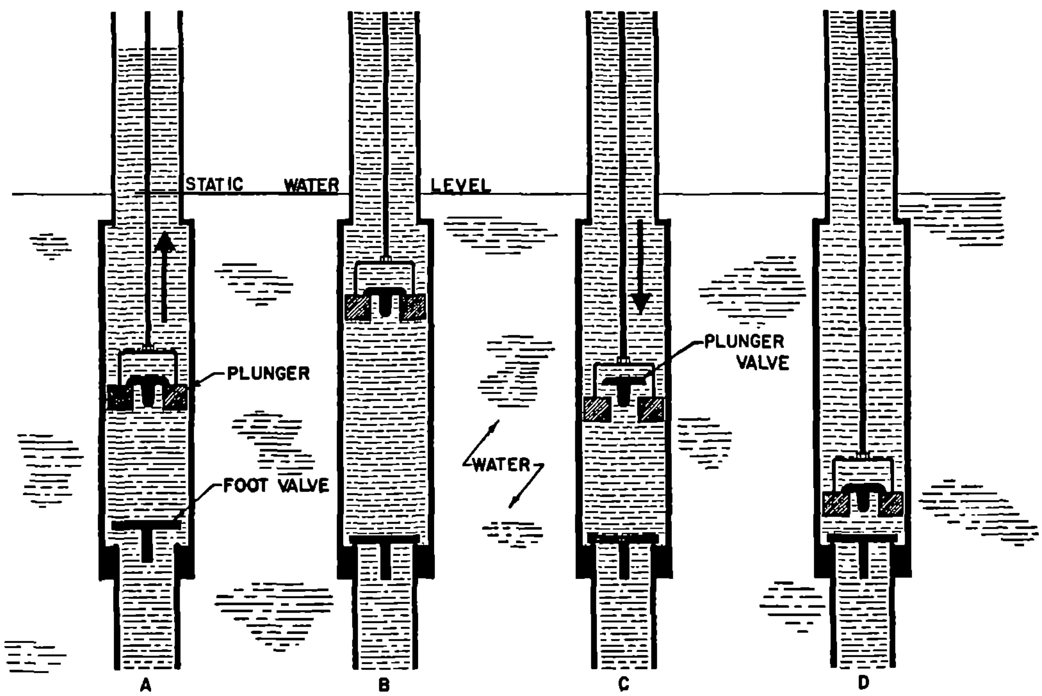


Figure 8C-3. Medium-Set and Deep-Set Pump Operation.

Sometimes it may be necessary to attach a length of suction pipe to the bottom of medium-set or deep-set pump cylinders. Some examples (Figure 8C-4) would be in the case of a lowered water table since the time of original installation due to overpumping of the source (irrigation, industry, etc.), and the use of undersized casing when drilling through difficult subsurface strata (small boulders, etc.). However, the water table during pumping cannot be more than about 8 meters below the pump cylinder.

The medium-set pump is shown in Figure 8C-5.

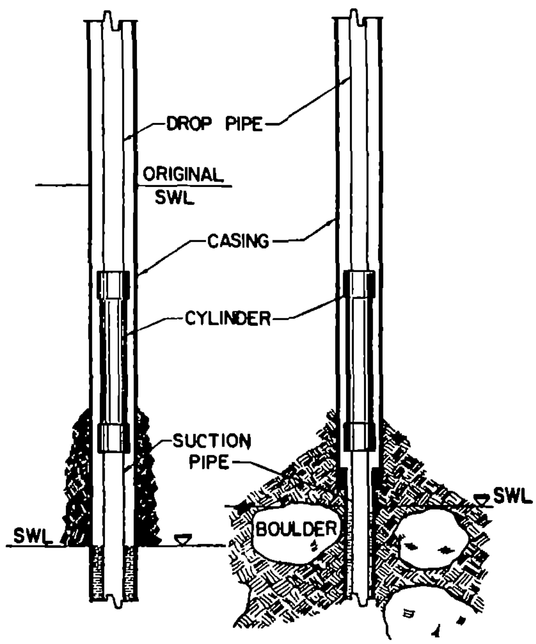


Figure 8C-4. Optional Installation for Pump Cylinder

8C.4 Site Selection Criteria

To assure safe, sufficient, and accessible water for the community, certain site selection criteria need to be followed in addition to the selection criteria specified in Section 8.3.1 of "Planning and Implementation of Level I Projects" in the BWP Operations Manual. The proposed site should:

1. Be acceptable to the local community.

2. Be located on public (or donated) land.

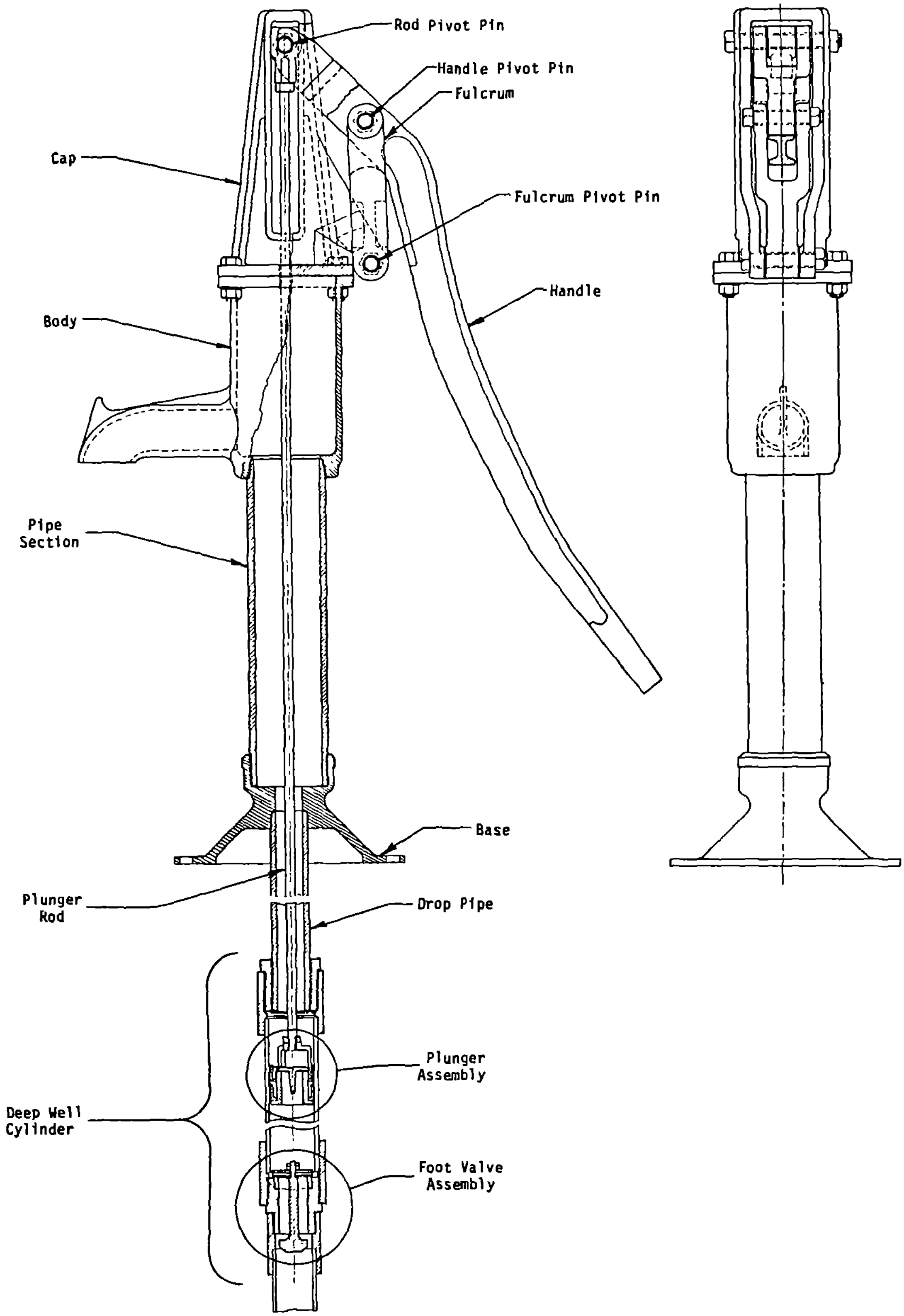


Figure 8C-5. Medium-Set Pump

3. Be located at least 15 meters and preferably uphill from all possible sources of ground water contamination such as:

    a. any sanitary facilities (comfort rooms, septic pits, etc.).
    b. bathing, washing, or other open wells.
    c. agricultural fields using insecticides and fertilizers.
    d. drainage canals, creeks, rivers, fish ponds, and other bodies of water.
    e. animal pens or feeding sites.

4. Provide sufficient water throughout the year (i.e., the well never dries up).

5. Provide water of quality acceptable to the community and within BWP water quality standards (negative results from the total coliform test).

6. Be located on ground conducive to good drainage and well above known flood conditions.

7. Be easily accessible for drilling, construction, use, repair, maintenance, testing, and monitoring.

8. Be on soil suitable to the sinking (drilling) methods available.

NOTE: The recommended distance of 15 meters does not guarantee freedom from contamination since the distance contaminants can travel through the ground formation is a function of material, flow rate, and elevation. The recommended distance is suggested by WHO (World Health Organization) experts as a rule of thumb for site selection.

8C.5 Apron Construction

The apron is a slab of concrete that surrounds the pump. Its purpose is to drain waste water away from the pump because standing water around the pump base may sometimes seep into the well and contaminate it. The apron also provides a firm, non-slip surface from which to operate the pump. It should not be less than three (3) meters by three (3) meters in size with a concrete drain of at least five (5) meters in length extending from it to a drainage ditch or sump.

Pools of waste water around the periphery of the apron will filter through the soil and may also contaminate the well. This standing water should be drained away by sloping the area around the apron using packed clay as the base and covering the clay with several centimeters of gravel.

8C.5.1 Materials and Tools

In the following lists, items marked with an asterisk will also be used in pump installation (Section 8C.6).

8C.5.1.1 Shallow-Set Pump Apron Construction and Installation - Tool Requirements

The following tools are required to construct the apron and to install a shallow-set pump:

1	Hammer
2	Trowel
2	Shovel
1	Wood saw
1	Square
1	Pick/maddock
1	Tape measure
1	Level/clear plastic hose
2	Pail/bucket
2	*Adjustable wrench
1	*Pipe wrench (2 inch grip)
1	*Pliers (to replace foot valve)
1	*Hacksaw
1	*Tape measure
	*Rags
	*Sandpaper

8C.5.1.2 Medium-Set and Deep-Set Pump Apron Construction and Installation - Tool Requirements

The following tools are required to construct the apron and to install medium- or deep-set pumps:

1	3/8" NPT pipe threader
1	1½" NPT pipe threader
1	Hammer
2	Trowel (Palitada)
2	Shovel
1	Wood saw
1	Pick/maddock
1	Level/clear plastic hose
2	Pail/bucket
1	*Tripod and pulley (or block and tackle)
1	*Heavy rope
2	*Pipe wrench (3 inch grip)
2	*Adjustable wrench
1	*Tape measure
1	*Pipe clamp
1	*Hacksaw
	*Rags
	*Stiff wire brush (to clean pipe threads)

8C.5.1.3 Shallow-Set Apron Construction and Installation -Material Requirements

Material	Quantity	Estimated Price 1981-1982 (₱)
Sand	2 m^3	50.00/m^3
Gravel	3 m^3	70.00/m^3
Cement	8 bags	34.00/bag
Anchor bolts	8	5.00 each
Wooden forms 2.5 x 15 cm (1 x 6 in)	16 m (1)	2.50/board foot
Wooden forms 5 x 5 cm (2 x 2 in)	14 m (1)	2.00/board foot
Concrete blocks	22	2.00 each
53 mm (1-1/2") PVC pipe*	determined by well depth	50.00/6 m
53 mm (1-1/2") male threaded adaptor*	1	8.00 each
53 mm (1-1/2") PVC connector*	1 per pipe length	5.00 each
PVC solvent cement*	-	8.00/4 oz can
Nails	-	
String	-	
Sandpaper		
(Reinforcing bars if applicable)	-	

Note (1). Lengths based on drilled well form requirements. Dug wells with an access hatch require more formwork. See text for lengths.

8C.5.1.4 Medium-Set Pump Apron Construction and Installation - Material Requirements

Material	Quantity	Estimated Price 1981-1982 (₱)
Sand	2 m^3	50.00/m^3
Gravel	3 m^3	70.00/m^3
Cement	8 bags	34.00/bag
Anchor bolts	8	5.00 each
Wooden forms 2.5 x 15 cm (1 x 6 in)	16 m	2.50/board foot
Wooden forms 5 x 5 cm (2 x 2 in)	14 m	2.00/board foot
Concrete blocks (4" x 8" x 16")	22	2.00 each
1-1/2 inch GI pipe*	determined from well depth	185.00/6 m
1-1/2 inch GI pipe connectors*	1 per pipe length	included above
Teflon tape*	-	6.00/10 m roll
3/8 inch GI pipe*	determined from well depth	80.00/6 m
3/8 inch GI pipe connectors*	1 per pipe length	included above
Nails	-	
String	-	
(Reinforcing bars if applicable)	-	

8C.5.1.5 Deep-Set Pump Apron Construction and Installation - General Material Requirements

Material	Quantity	Estimated Price 1981-1982 (₱)
Sand	3 m^3	50.00/m^3
Gravel	4 m^3	70.00/m^3
Cement	10 bags	34.00/bag
Forms		
Marine plywood (4' x 8' x 1/2")	1 sheet	130.00/sheet
Angular bar (1/8" x 1" x 1" x long)	11 m (35 ft)	3.00/meter
Wood screws (3/4" long)	1/2 kilo	40.00/kilo
Reinforcing bars		
3/8" Ø deformed bars	2 lengths (30 feet)	2.25/meter
1/4" Ø round bars	2 lengths (15 feet)	1.25/meter
16 gage tying wire	1/4 kilo	8.00/kilo
1/2" Ø anchor bolt - 10" long	4	4.00 each
1/2" Ø anchor bolt - 6" long	4	3.00 each
1-1/2" Ø GI pipe*	determined from well depth	185.00/6 m
1-1/2" Ø GI pipe connectors*	1 per pipe length	included above
Teflon tape*	-	6.00/10 m roll
3/8" Ø GI pipe*	determined from well depth	80.00/6 m
3/8" Ø GI pipe connectors*	1 per pipe length	included above
Nails	-	
String	-	
(Reinforcing bars if applicable)	-	

8C.5.1.6 Deep-Set Pump Installation - Well Head Material Requirements

Material	Quantity	Estimated Price 1981-1982 (₱)
Head assembly		
1" ∅ PVC nipple	1	4.00
1" x 2" GI pipe reducer	1	28.00
2" ∅ x 6" long GI nipple	1	25.50
2" ∅ GI Tee	1	51.50
2" ∅ x 18" long GI pipe (sched 40)	1	60.00
2" GI elbow	1	36.00
1/2" x 8" x 8" steel plate	1	47.00
2" ∅ x 10" long GI pipe (sched 40)	1	46.50
2" x 1-1/2" GI reducer	1	31.50
3/8" GI tee	1	10.00
1/2" x 3 1/2" long machine bolt	1	6.40
1/2" ID washer	3	1.20 each
1/2" thick x 1-1/2" ∅ rubber washer	1	4.00
Handle assembly		
3/16" x 6" x 24" steel plate	2	40.00 each
3/16" x 1-1/2" wide steel stripping (yoke)	see Fig. 8C-44	40.00
Hardwood bearing	2	4.00 each
Yacal beam (handle)	1	3.20/foot
6" Nail	1	10.40/kilo
1-1/2" ID Washer	4	6.80 each
1-1/2" ∅ x 11" long GI pipe	1	38.40

8C.5.2 Site Preparation

Based on the site selection criteria detailed in Section 8C.4, the well should be located on a local high spot. The slight rise in elevation above the surrounding area is conducive to good drainage and the prevention of well contamination.

Remove the vegetation and loose top soil to ensure that the base for the apron slab will be well-compacted earth. As per Section 8B, the well casing should be exposed to a length of at least 35 cm above the ground. If 35 cm are not exposed, remove more top soil from the entire area.

If the pump is to be installed on a dug well, refer to Section 8C.5.5 ("Special Preparations") for steel work and access hatch instructions.

Place the apron form on the cleared area (see Section 8C.5.6 for the details of the apron form). Determine the apron orientation and select the location of the concrete drain. Construction is easier and drainage better if the concrete drain is located at a corner. Center the apron form around the well.

Drive stakes at the four corners of the apron form as shown in Figure 8C-6. The apron form is then tilted in the direction of the drain to facilitate drainage. Mark on the stake nearest the drain fifteen (15) cm above the ground. A mark is then placed on the opposite stake ten (10) cm above the first mark. Use a level or water-filled clear hose to obtain exact heights. The other two stakes are marked at points five (5) cm above the first mark. Line up the top of the apron form with the marks and nail the form to the stakes. Gravel and sand are used as fill to build up to the bottom of the raised apron form.

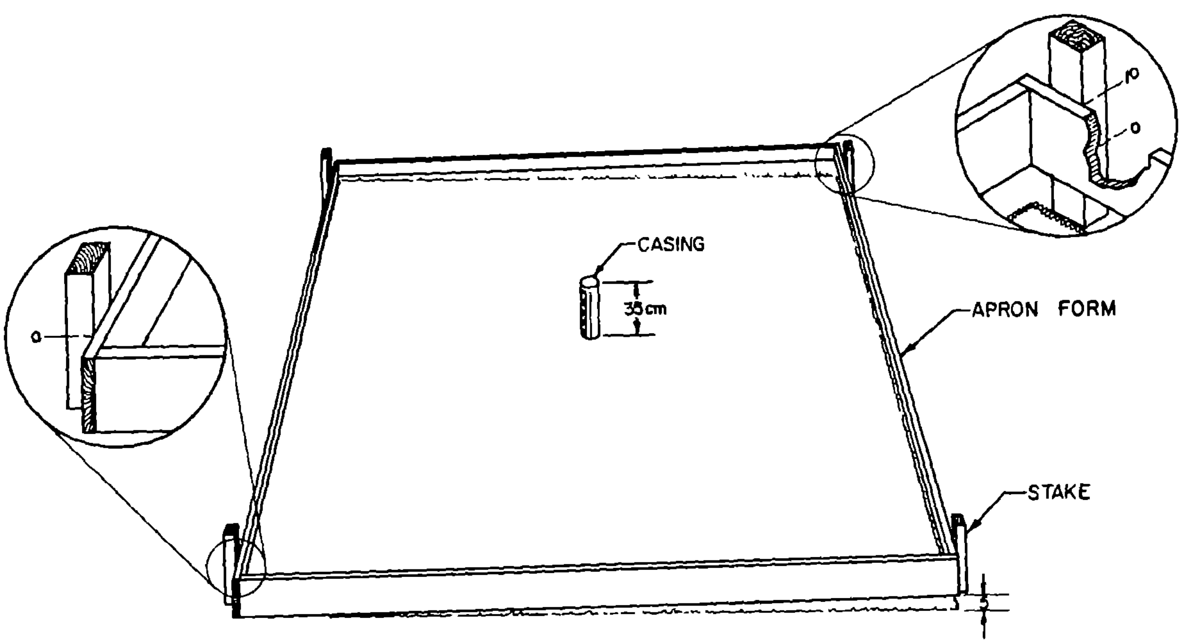


Figure 8C-6. Sloping The Apron Form

8C.5.3 Concreting the Apron

8C.5.3.1 Shallow-Set and Medium-Set Pumps

Measure ten (10) cm up from the bottom of the apron form and place a mark on the form. Repeat this in several places around the form. Prepare a 1:2:4 concrete mixture and fill the apron form to the height of the marks. Level the concrete with a long board (Fig. 8C-7) and fill any low spots that will prevent water from draining off the apron. Smooth the concrete because cement rendering will not be applied to the apron.

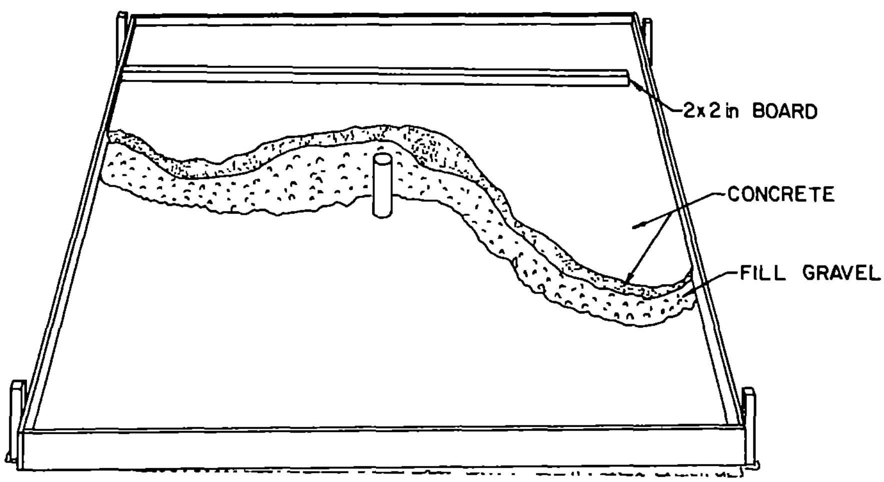


Figure 8C-7. Pouring the Apron Slab

Prepare the anchor bolts for placement by bolting them onto the pump base. The use of the base positions the bolts both vertically and in relation to one another. The anchor bolts should be toed out as in Figure 8C-8.

Measure up 25 cm on the casing from the apron slab. Cut off the casing at this point. Place the pedestal form (see Section 8C.5.6) around the casing. Center it carefully so that a bucket can be placed on the pedestal beneath the pump spout (Figure 8C-9).

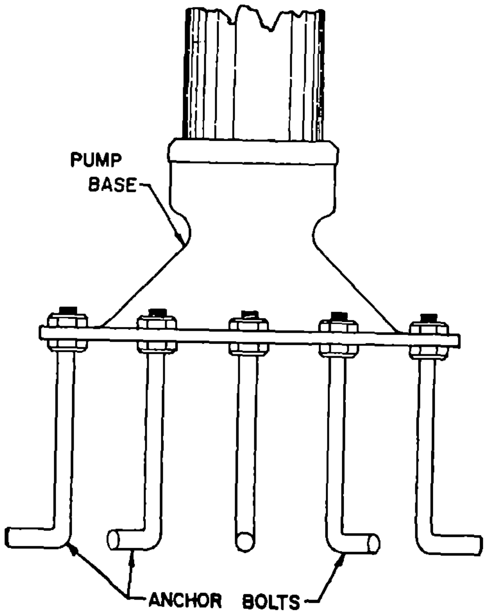


Figure 8C-8. Preparation of Anchor Bolts for Installation

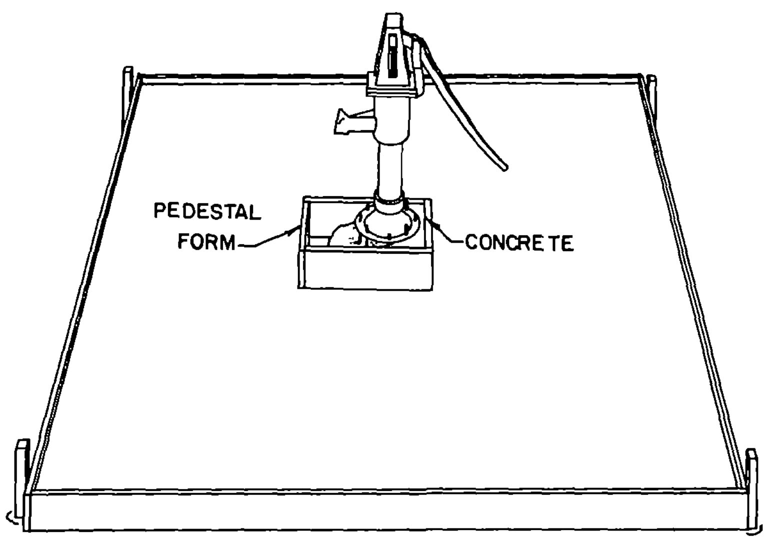


Figure 8C-9. Pouring The Pedestal

Place the pump on the well casing. Ensure that the base is level so that the installed pump will not be tilted.

Placing the pump base on the casing before concreting the anchor bolts in place creates a water barrier to prevent rain or pumped water from entering the well (Figure 8C-10). However, this is not a water seal and the well could become contaminated if flood waters cover the base.

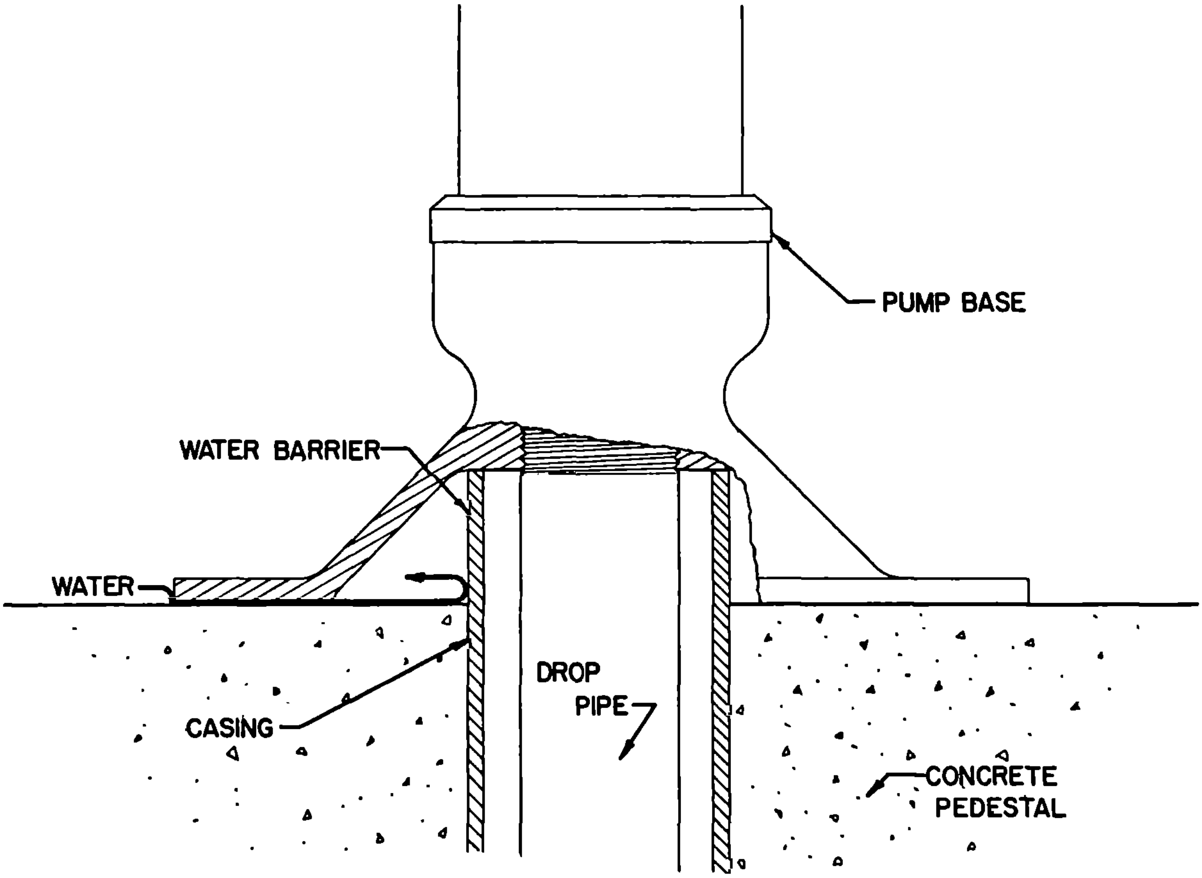


Figure 8C-10. Casing as Water Barrier

Slowly fill the pedestal form with concrete to the bottom of the pump base, packing the concrete firmly between the anchor bolts. It is not necessary to fill the form to the top but only to the bottom of the pump base. Any cement that is splashed onto the bolt threads should be wiped off before it hardens. After the concrete has set, remove the pump base and the pedestal forms and plaster the pedestal with a one (1) cm thick 1:3 cement/fine sand rendering. Fill any voids left around the well casing as waste water may enter the well at this point.

Leaving space for the drain, construct a five (5) cm high by ten (10) cm wide water curb around the perimeter of the apron. Use the curb form (Section 8C.5.6) as shown in Figure 8C-11. After removing the apron and curb forms, plaster the curb with a 1:3 cement/fine sand rendering.

Allow the apron and pedestal to cure for at least one week before installing the pump so that the concrete can harden sufficiently (refer to Appendix 8C.B, "Concrete Primer," for curing procedures).

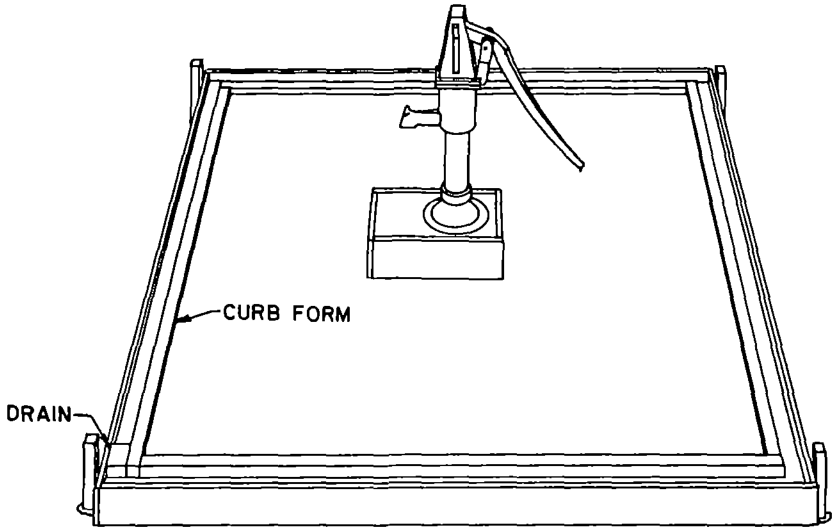


Figure 8C-11. Constructing The Apron Curb

8C.5.3.2 Deep-Set Pumps

Measure ten (10) cm up from the bottom of the apron form and place a mark on the form. Repeat this in several places around the form. Prepare a 1:2:4 concrete mixture and fill the apron form to the height of the marks, except where the column will be located. The column reinforcements tie into the apron slab. Level the concrete with a long board and fill any low spots that will prevent water from draining off of the apron. Smooth the concrete because cement rendering will not be applied to the apron.

Assemble the column forms as explained in Section 8C.5.6.2. Apply oil or lubricant to the inside faces of the column forms.

Center the bearing plate pattern around the well casing (Figure 8C-12) and locate the column form in the desired orientation. Place the pre-assembled reinforcements inside the column form.

Prepare a 1:1½:3 concrete mixture and fill the column form to the height of the bearing plate. Pack the concrete firmly around the casing and bearing plate anchor bolts. Allow the concrete to set before continuing the pouring.

Fill the remainder of the column form with concrete, packing the concrete firmly around the bearing block anchor bolts.

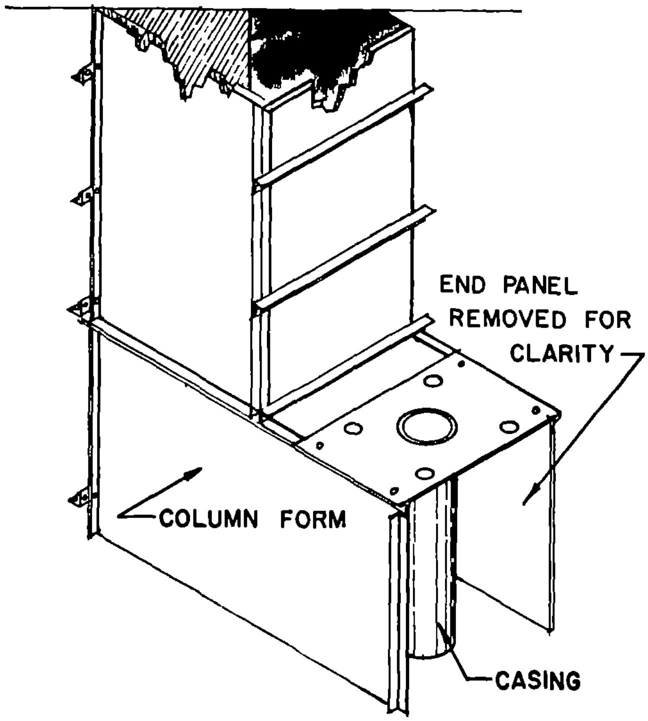


Figure 8C-12. Centering The Column Form

Leaving space for the drain, construct a five (5) cm high by ten (10) cm wide water curb around the perimeter of the apron. Use the curb form (Section 8C.5.6) as shown in Figure 8C-13. After removing the apron and curb forms, plaster the curb with a one (1) cm thick 1:3 cement/fine sand rendering.

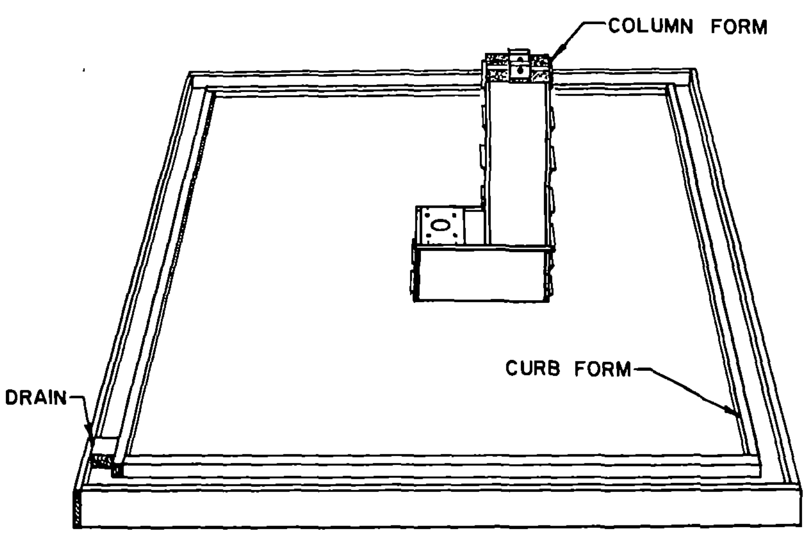


Figure 8C-13. Constructing The Apron Curb

When the apron form has been removed, construct and level the operator's platform form as shown in Figure 8C-14. The top of the form should be even with the top of the apron curb. Fill the form with five (5) cm of gravel. Prepare a 1:2:4 concrete mixture and pour the form to the top. Locate the low spots using a long board and fill with concrete.

Remove the form after 2 or 3 days. Plaster the column with a 1:3 cement/fine sand rendering of one (1) cm thickness. Inscribe the BWP logo on the side of the column. The proportions of the logo can be found in Appendix 8C.C.

Allow the apron, column, and platform to cure for at least one week before installing the pump to allow the concrete to harden sufficiently (refer to Appendix 8C.B., "Concrete Primer," for curing procedures).

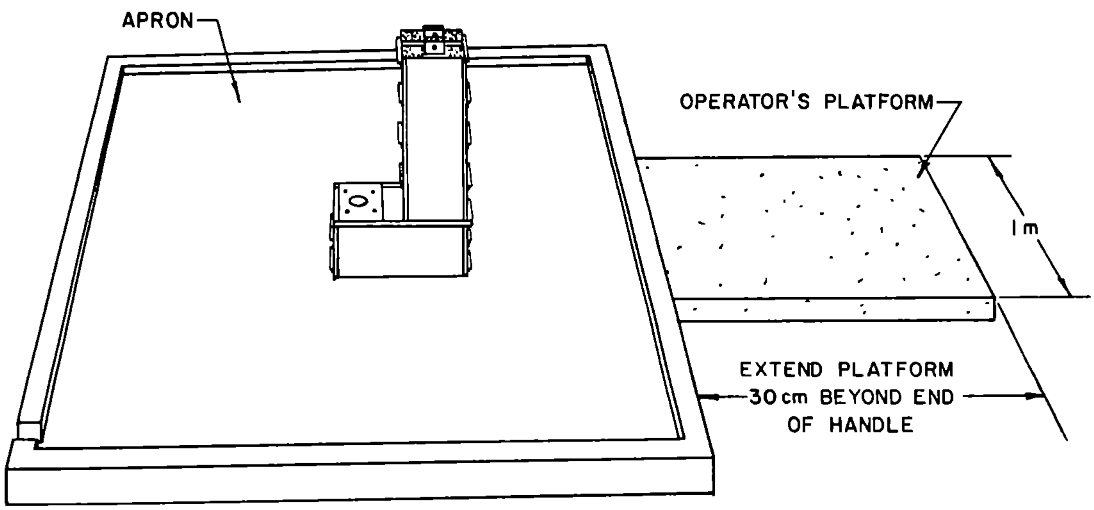


Figure 8C-14. Operator's Platform

8C.5.4 Concrete Drain and Area Around the Apron

Excavate a drainage trench from the drain space in the apron to a sump or an existing drainage ditch. Slope the bottom of the trench so water from around the apron will drain into it as shown in Figure 8C-15. Fill the trench with at least five (5) cm of small gravel. Using hollow blocks, construct a concrete drain over the gravel in the trench for a distance of at least five (5) meters. The floor of the drain should be five (5) cm thick and ten (10) cm wide. The concrete drain removes water from the apron while the sublayer of gravel allows water from around the apron to be drained away.

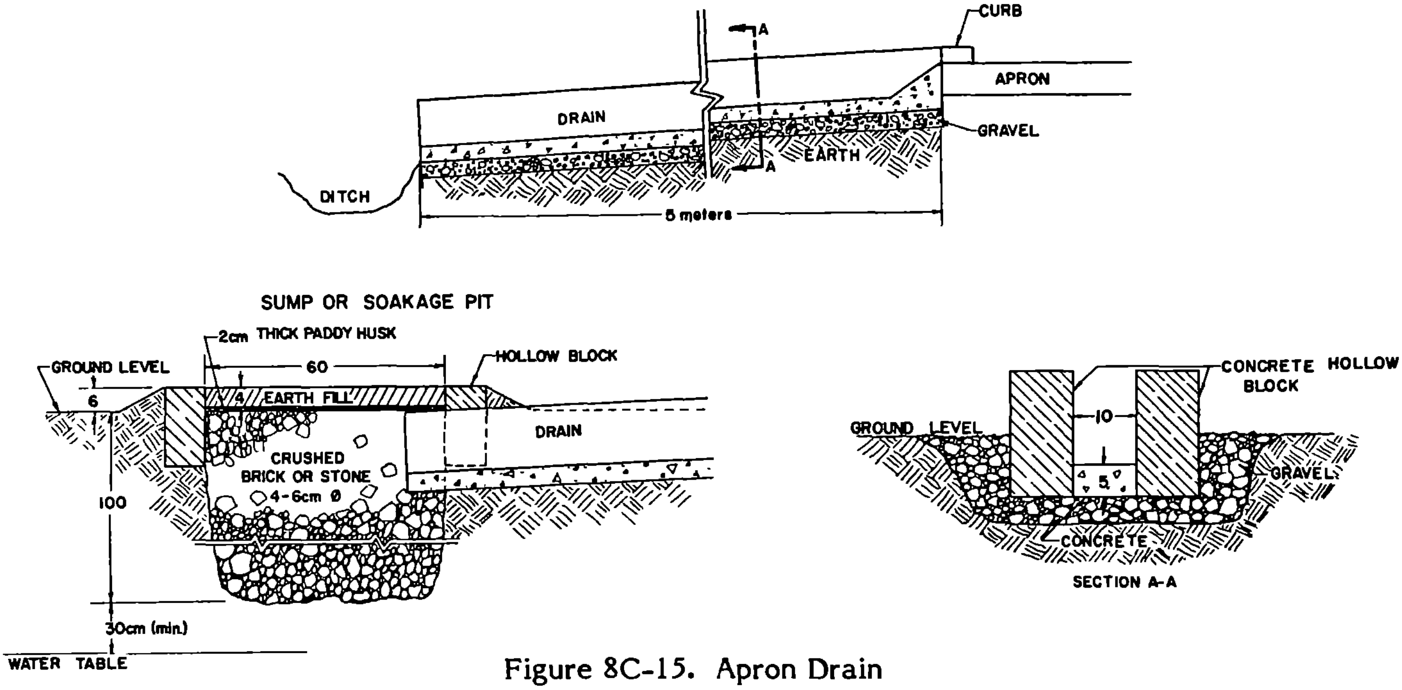


Figure 8C-15. Apron Drain

Clear a one and one-half (1½) meter area around the apron. The area should be sloped so that waste water is drained away from the apron and toward the drain. This procedure is recommended because standing water may contaminate the well. Splash water on the cleared area to locate low spots as in Figure 8C-16. When the low spots have been drained, cover the area with 10 to 15 centimeters of small gravel. The gravel provides a non-slip and neat surface especially during the rainy season. Sites on soft soil will require more gravel than those on hard soil.

The completed wells are depicted in Figure 8C-17 and 8C-18.

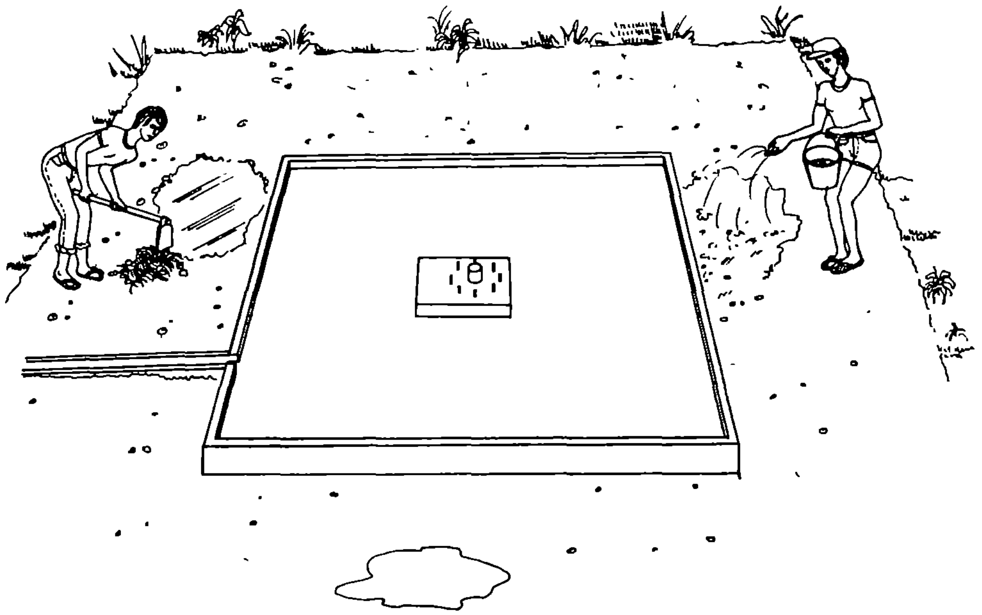


Figure 8C-16. Drainage of Area Around Apron

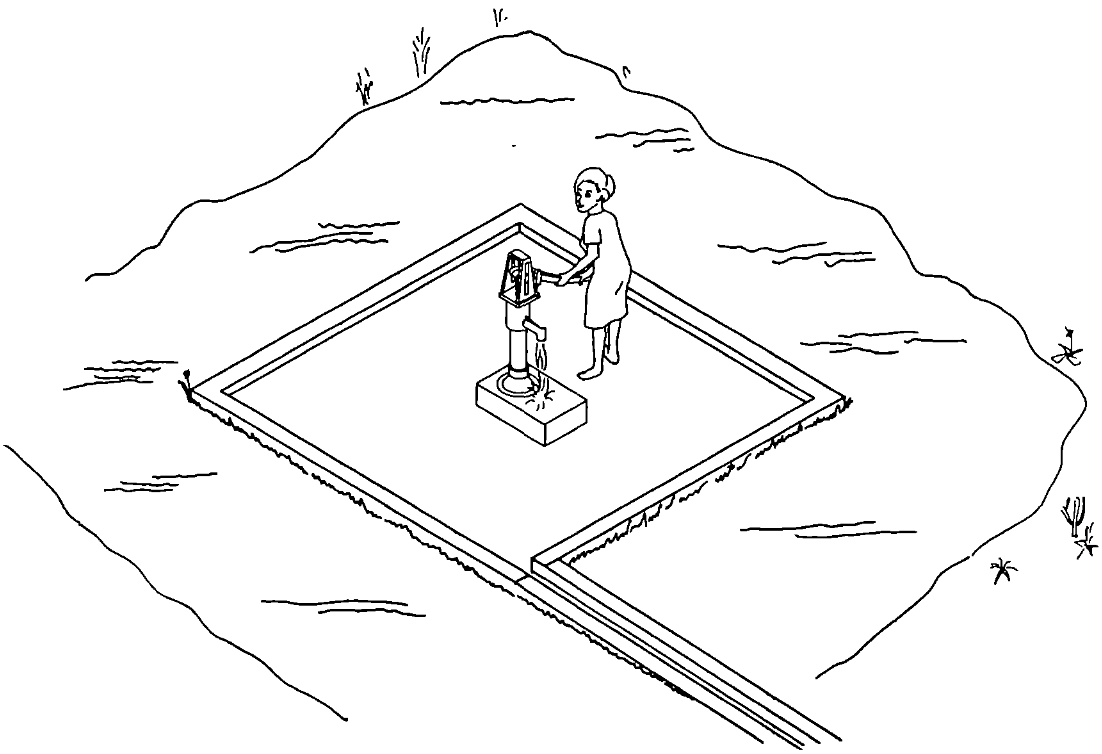


Figure 8C-17. USAID Pump for Shallow-Set and Medium-Set Installations

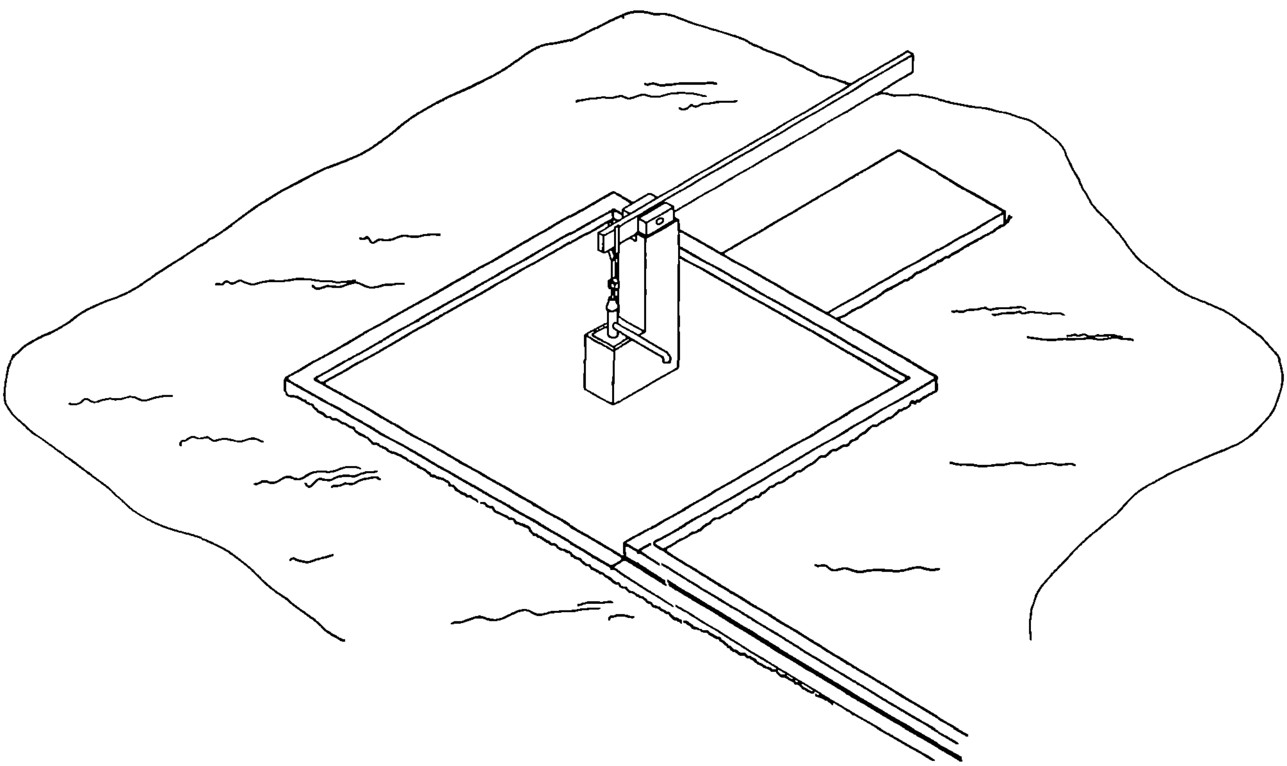


Figure 8C-18. Traditional Pump for Deep-Set Installations

8C.5.5 Special Preparations

8C.5.5.1 Steel Reinforcing - Reconditioned Dug Wells

Cover the well opening with wooden planks as shown in Figure 8C-19. If the well is over one (1) meter in diameter, supporting joints should be placed under the wooden platform. The top of the platform should be level with the surface of the surrounding earth.

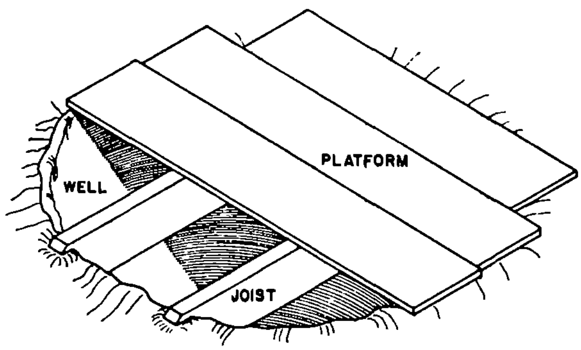


Figure 8C-19. Platform Construction for Dug Wells

Sometimes it is desirable to have an access hatch for reconditioned wells, especially if the site is remote and the well is the only source of water in the vicinity of the community. The hatch also allows access for periodic reconditioning. See Section 8C.5.5.3 entitled "Access Hatch" for details of construction.

If an access hatch is not required, mark the location of the pump on the wooden platform. Two items should be considered in locating the pump: a) the drop pipe or suction pipe should be in the deepest part of the well and b) the drop pipe of the medium-set and deep-set pumps should be straight even if the well is crooked to minimize wear by the plunger rod on the drop pipe. Cut a fifty-five (55) millimeter (mm) hole in the platform for shallow-set pumps or an eighty-five (85) mm hole if a medium-set or deep-set pump cylinder is to pass through.

Cut a section of ninety (90) mm (3 inch) PVC pipe and place it over the hole in the platform as in Figure 8C-20. For shallow-set and medium-set pumps, the pipe section is thirty-five (35) cm long and for deep-set pumps it is fifty (50) cm long. The pipe section serves as a concrete form during construction and a water barrier during operation. If well casing is used, the PVC pipe section is unnecessary.

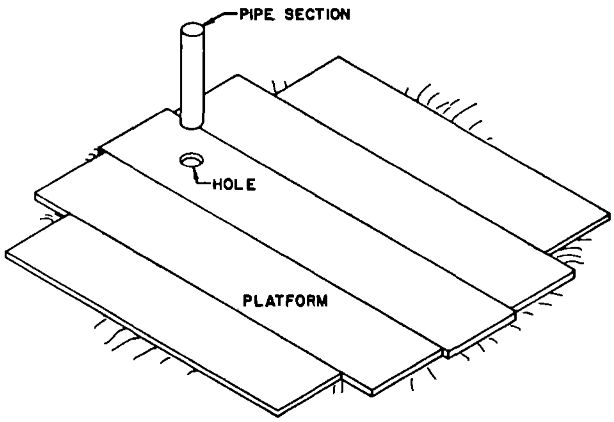


Figure 8C-20. Locating Pipe Section

Lay out ten (10) mm diameter reinforcing bars on twenty (20) cm centers. The bars should extend fifty (50) cm beyond the edge of the well on either side. After the bars have been cut to length and placed on center, tie them together with 16-gauge tying wire. The bars are then raised 1-1/2 to 2 cm above the planking by placing small rocks under the reinforcing bar framework. The well should now look like Figure 8C-21.

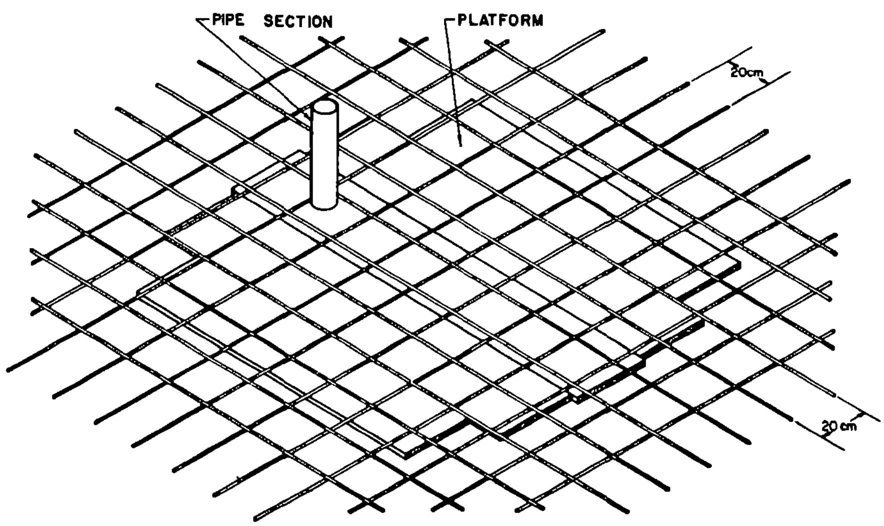


Figure 8C-21. Reinforcement for Dug Wells

8C.5.5.2 Steel Reinforcing - Filled Dug Wells

In some instances, it is advisable or more cost effective to refill a dug well. Some examples would be a very old dug well whose sides require extensive and prohibitively costly repair or a new dug well where casing the well with 90 mm (3 inch) pipe is less expensive than with concrete rings or bricks. However, an unfilled dug well has the advantage of providing a larger containment area or reservoir.

After installing the casing and gravel packing, fill and pack the well until it is level with the surrounding area cleared for the apron. As the fill may settle causing the apron to crack, it is necessary to use steel reinforcment in the apron slab.

Lay out ten (10) mm diameter reinforcing bars on twenty (20) cm centers. The bars should extend fifty (50) cm beyond the edge of the well on either side. After the bars have been cut to length and placed on center, tie the bars together with 16-gauge tying wire. The bars are then raised 1-½ to 2 centimeters above the ground by placing small rocks under the reinforcing bar framework. The well should now resemble Figure 8C-22.

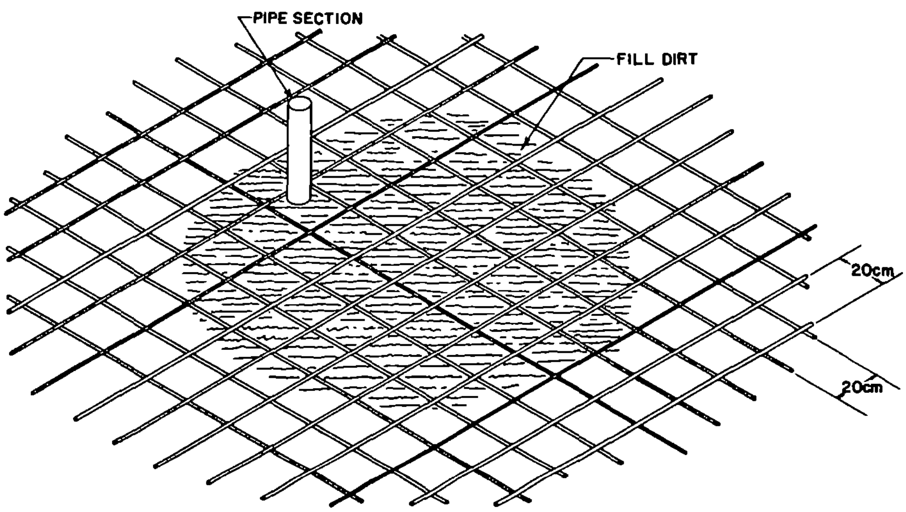


Figure 8C-22. Reinforcement for Filled Dug Wells

8C.5.5.3 Access Hatch

The location of the access hatch needs to be carefully selected. It should be on the opposite side of the pump from the drain and the pump spout should point away from it so that waste water will not be running around or on the hatch cover.

The hatch must be at least fifty (50) cm by fifty (50) cm in size to allow a man or bucket to pass inside. Having selected the hatch location, mark the location of the suction or drop pipe thirty (30) cm from the edge of the hatch opening. Be sure that the hatch and drop pipe will both be over the well opening.

Cut a hole for the suction or drop pipe in the wooden platform as described in the two preceding sections.

Construct the hatch opening form as described in Section 8C.5.6. Place the opening form and the 90 mm pipe section in their respective locations on the wooden platform as shown in Figure 8C-23. There should at least be twenty-five (25) cm between the pipe section and the opening form so that the hatch cover will later fit properly.

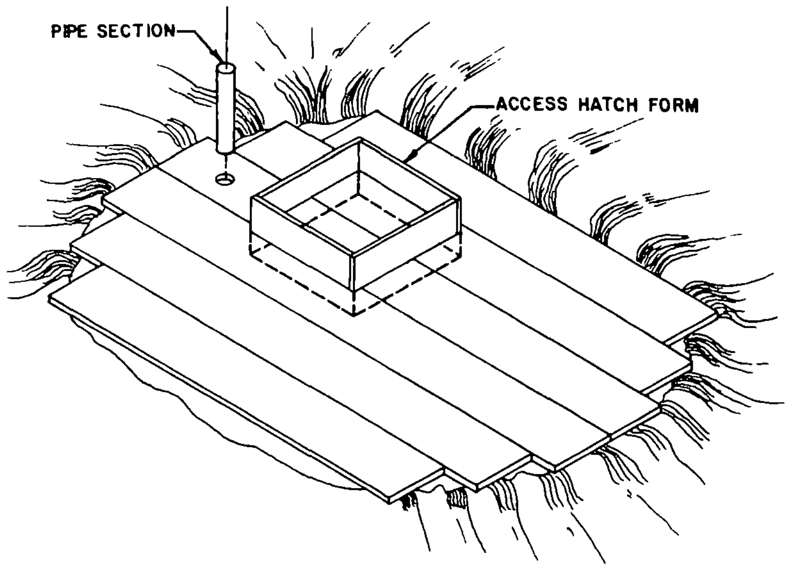


Figure 8C-23. Locating Pipe Section and Access Hatch

Next, lay out ten (10) mm reinforcing bars on twenty (20) cm centers. The bars should extend fifty (50) cm beyond the edge of the well on either side. As shown in Figure 8C-24, four bars should be laid out in a diamond shape around the hatch opening for additional strength. Tie the bars together with 16-gauge tying wire. Raise the bars 1½ to 2 cm above the platform by placing small rocks under the reinforcing bar framework.

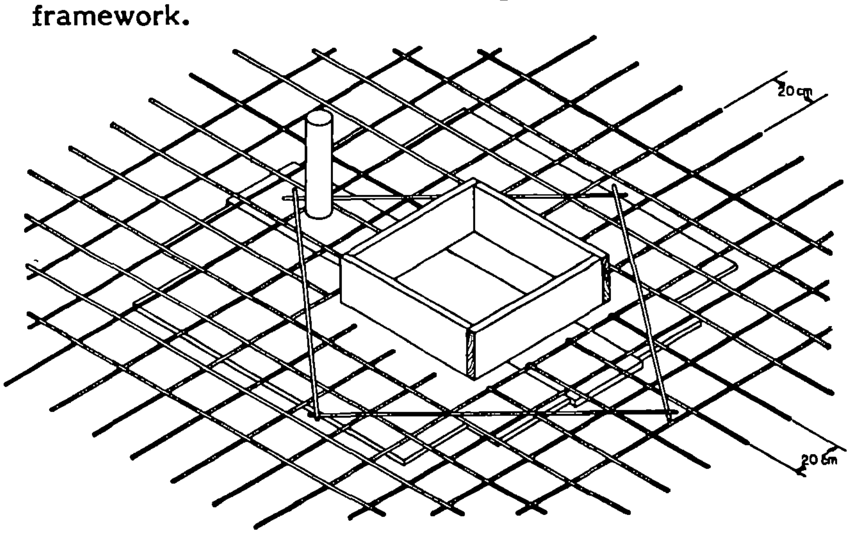


Figure 8C-24. Reinforcement Around Access Hatch

Level a one (1) meter by one (1) meter area near the well site. Construct the hatch cover forms as described in section 8C.5.6. Lay the small cover form in the center of the leveled area. Fill the inside of the form with dirt and pack it firmly. Cover the form with wet cement bags or damp newspaper. Shape them until they conform to the contour of the small cover form (Figure 8C-25).

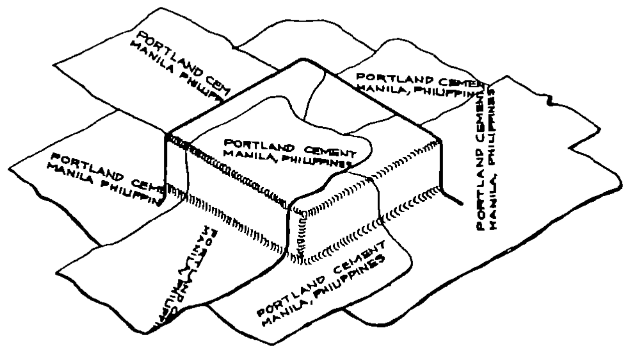


Figure 8C-25. Inside Form for Hatch Cover

Center the large cover form around the small cover form. Place and tie 10 mm (3/8 inch) reinforcing bars on fifteen (15) cm centers. Bend one piece of bar as shown to make a handle. Pour the hatch cover when pouring the concrete for the apron. The completed cover should resemble Figure 8C-26.

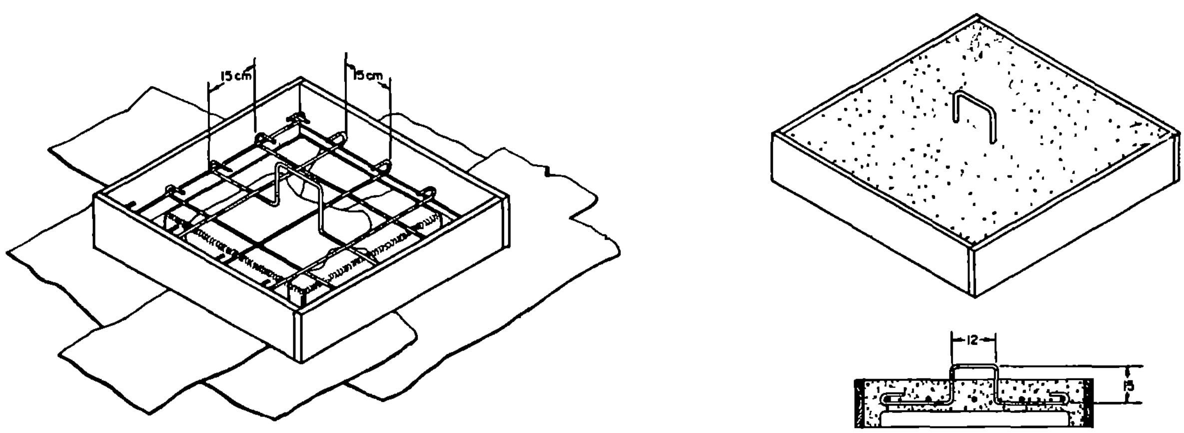


Figure 8C-26. Hatch Cover Handle Detail

Construct a curb around the hatch opening as shown in Figure 8C-27 using the hatch curb form described in Section 8C.5.6. The curb should be five (5) cm in height and width. Plaster over the curb with a one (1) cm thick 1:3 cement/fine sand rendering.

After the concrete has set and cured for at least ten (10) days, cut out the hatch opening in the platform with a keyhole saw or similar tool.

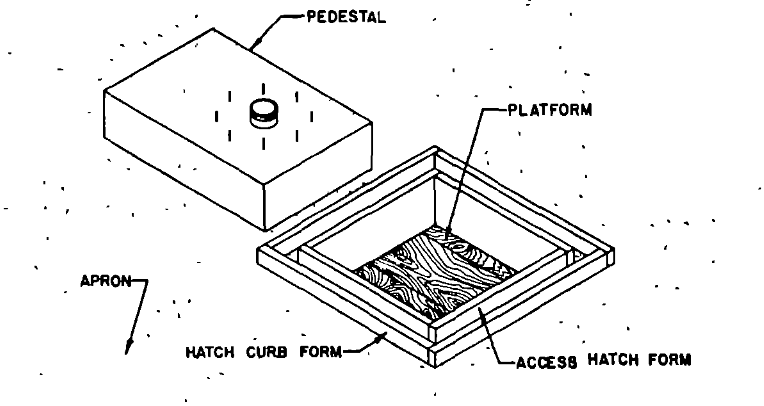


Figure 8C-27. Constructing Hatch Curb

8C.5.6 Form Work and Reinforcement

It has been found that the use of removable, reusable forms is more convenient and economical than other methods of concrete construction. This is particularly true of the deep-set pump column. The following section assumes the use of reusable forms. Form material is Tangili wood unless otherwise noted.

8C.5.6.1 Apron Forms

Apron Form
Size: 2.5 x 15 cm (1 x 6 inch)
Req'd length:303 cm
No. of pieces:4

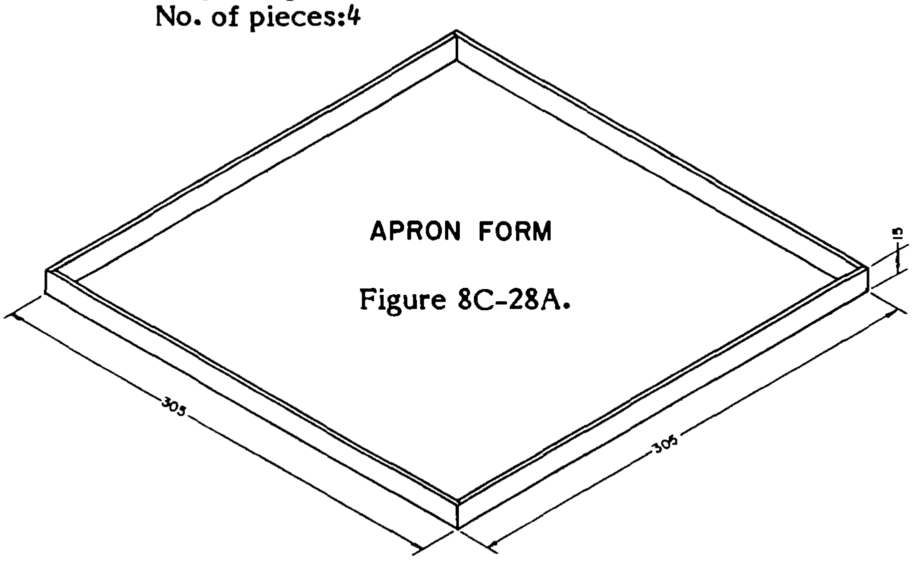
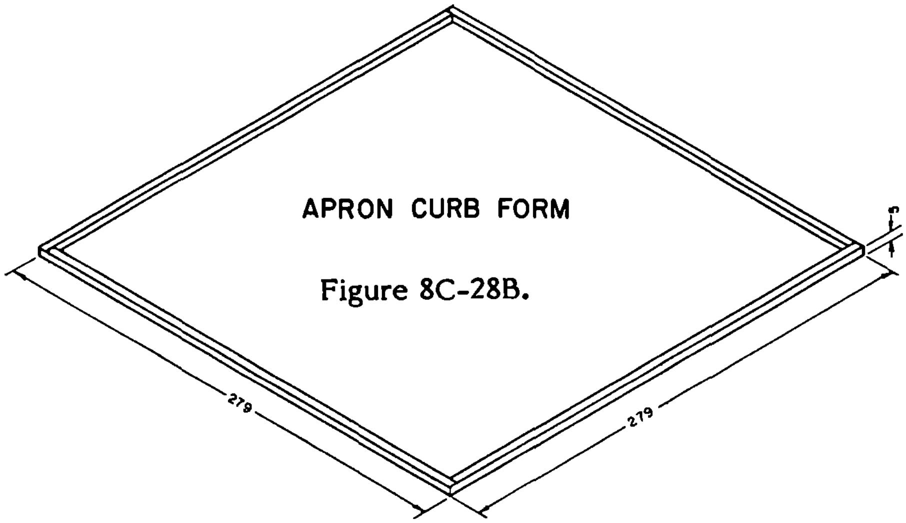


Figure 8C-28A.

Apron Curb Form

Size: 5 x 5 cm (2 x 2 inch)
Req'd length: 277 cm
No. of pieces: 4

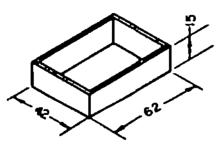


APRON CURB FORM

Figure 8C-28B.

Pedestal Form

Size: 2.5 x 15 cm (1 x 6 inch)
Req'd length: 60 cm No. of pieces: 2
Req'd length 40 cm No. of pieces: 2



PEDESTAL FORM

Figure 8C-28C.

8C.5.6.2 Access Hatch Forms

Opening form

Size: 2.5 x 15 cm (1 x 6 inch)
Req'd length: 48 cm
No. of pieces: 4

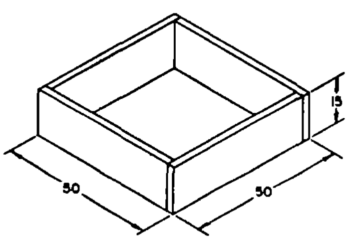


Figure 8C-29A. Opening Form

Opening curb form
Size: 5 x 5 cm (2 x 2 inch)
Req'd length: 62 cm
No. of pieces: 4

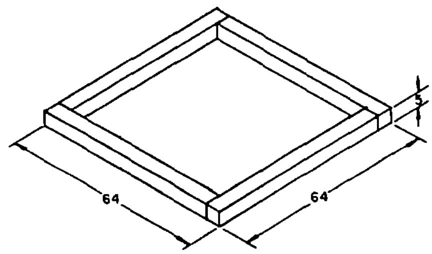


Figure 8C-29B. Opening Curb Form

Small Cover Form
Size: 5 x 5 cm (2 x 2 inch)
Req'd length: 58 cm
No. of pieces: 4

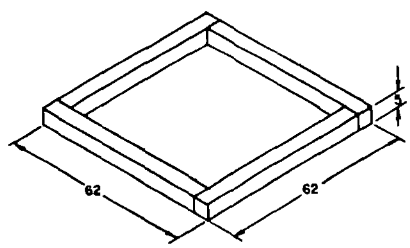


Figure 8C-29C. Small Cover Form

Large Cover Form
Size: 2.5 x 15 cm (1 x 6 inch)
Req'd length: 74 cm
No. of pieces: 4

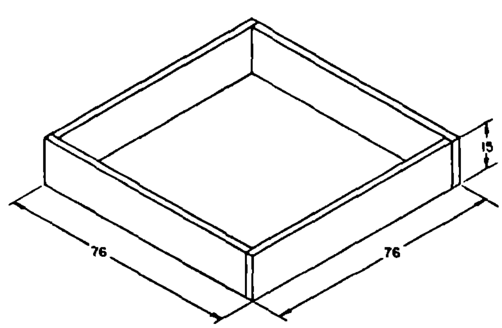


Figure 8C-29D. Large Cover Form

Assembly for above forms:

1. Cut the lumber to the required lengths as specified above.
2. Nail the boards together as shown in Figure 8C-30. The dimensions given above are for this method of assembly. Assemble the forms on a flat area so that they won't have a warp.

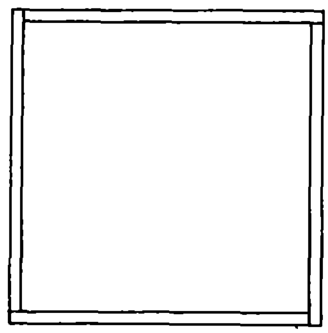


Figure 8C-30. Recommended Assembly of Forms

8C.5.6.3 Concrete Column Form[3]

Materials:

a. One sheet 1/2" x 4' x 8" marine (waterproof) plywood
b. 1" x 1" x 1/8" angle bar - 11 m (35 ft)
c. 3/4" long wood screws
d. Two bearing blocks (see text)
e. Four 5 x 25 cm (2 x 10) anchor bolts
f. Four 5 x 15 cm (2 x 6) anchor bolts

Assembly:

Sketch the forms on the plywood according to the dimensions given in Figure 8C-31.

Cut the plywood carefully and accurately. Try not to splinter the cut edge.

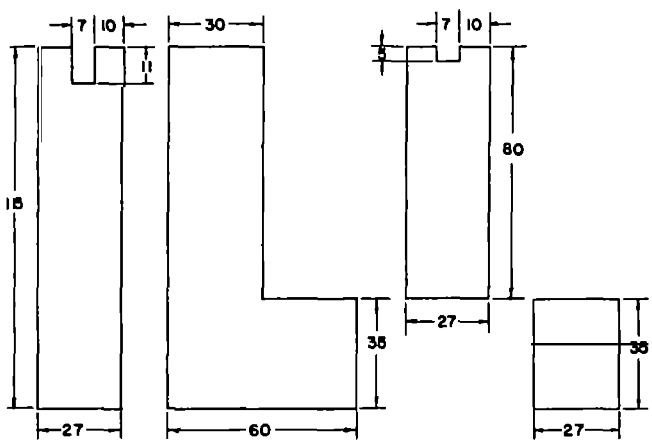


Figure 8C-31. Column Form Dimensions

Cut the following lengths and pieces of 1" x 1" angle bar:

Length	No. of Pieces
32 cm	17
60 cm	2
80 cm	4

Drill holes in the angle bar as per Figure 8C-32.

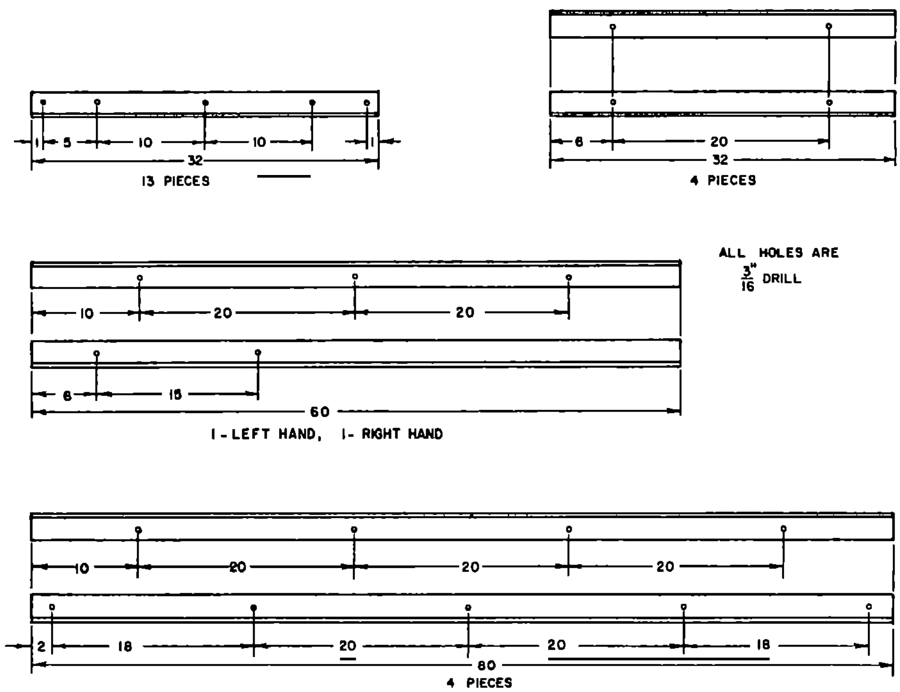


Figure 8C-32. Angle Bars

Attach the angle bars to the plywood forms with wood screws as shown in Figure 8C-33.

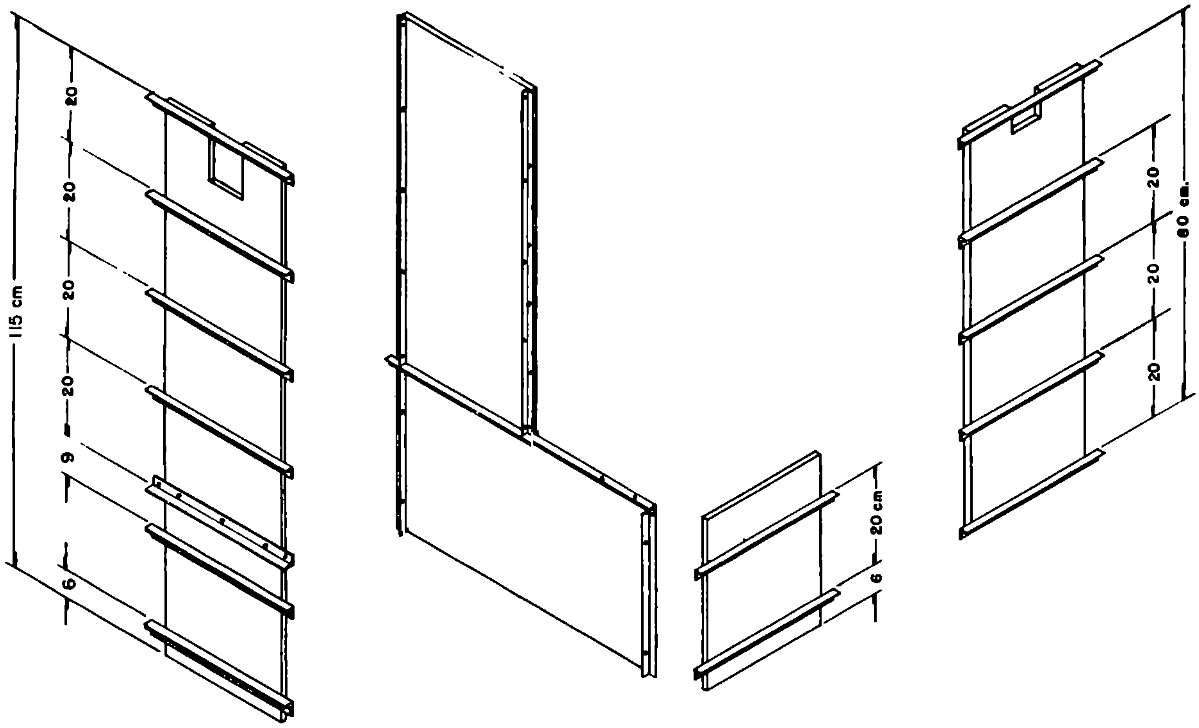


Figure 8C-33. Locations of Angle Bars on Column Form

Assemble the column form by tying the ends of the angle bars together with 16 gage tying wire. Refer to Figure 8C-34.

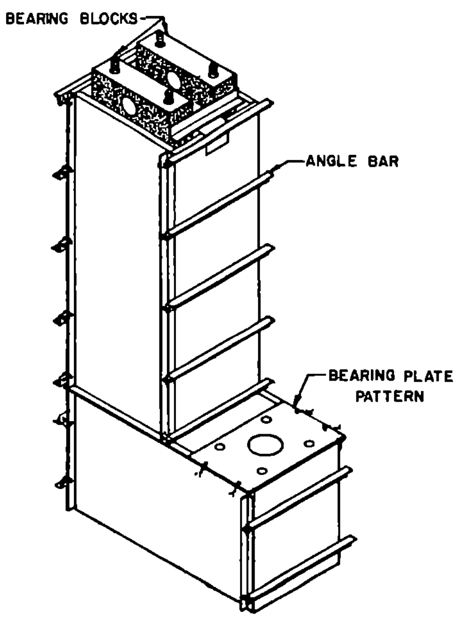


Figure 8C-34. Column Form Assembly

Cut a bearing plate pattern using a 20 x 32 cm piece of 1/2" thick marine plywood. Drill holes as illustrated in Figure 8C-35. Secure the anchor bolts to the pattern so that they will not move when concrete is packed around them.

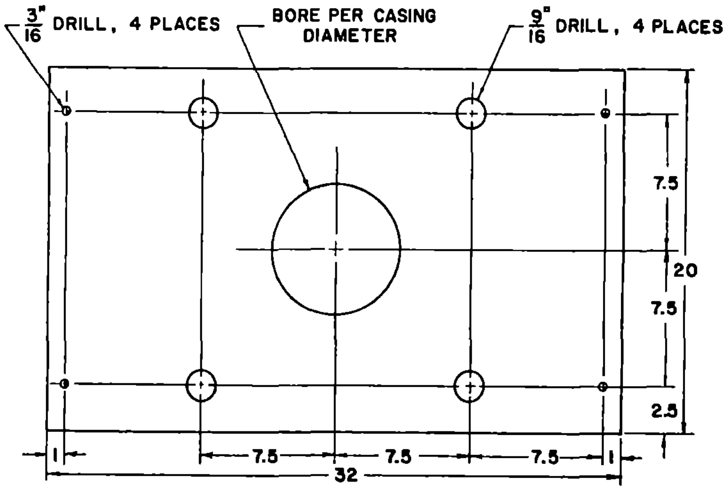


Figure 8C-35. Bearing Plate Pattern

Secure the bearing plate pattern to the main column form with tying wire. Refer to Figure 8C-34.

Prepare two bearing blocks as per Figure 8C-36. Impregnating the blocks with oil as outlined in Appendix 8C.C is recommended.

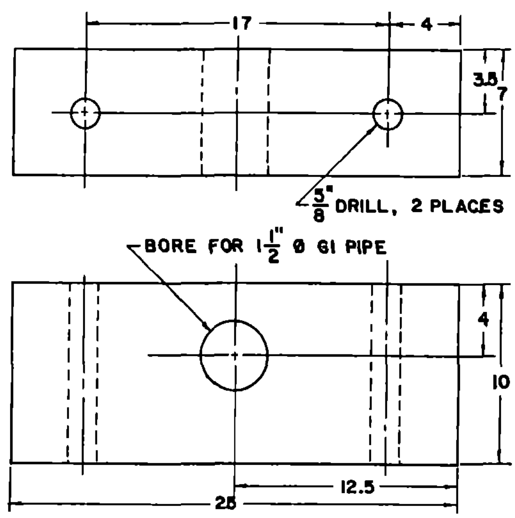


Figure 8C-36. Bearing Blocks

Fabricate the handle trough form from scrap lumber as illustrated in Figure 8C-37.

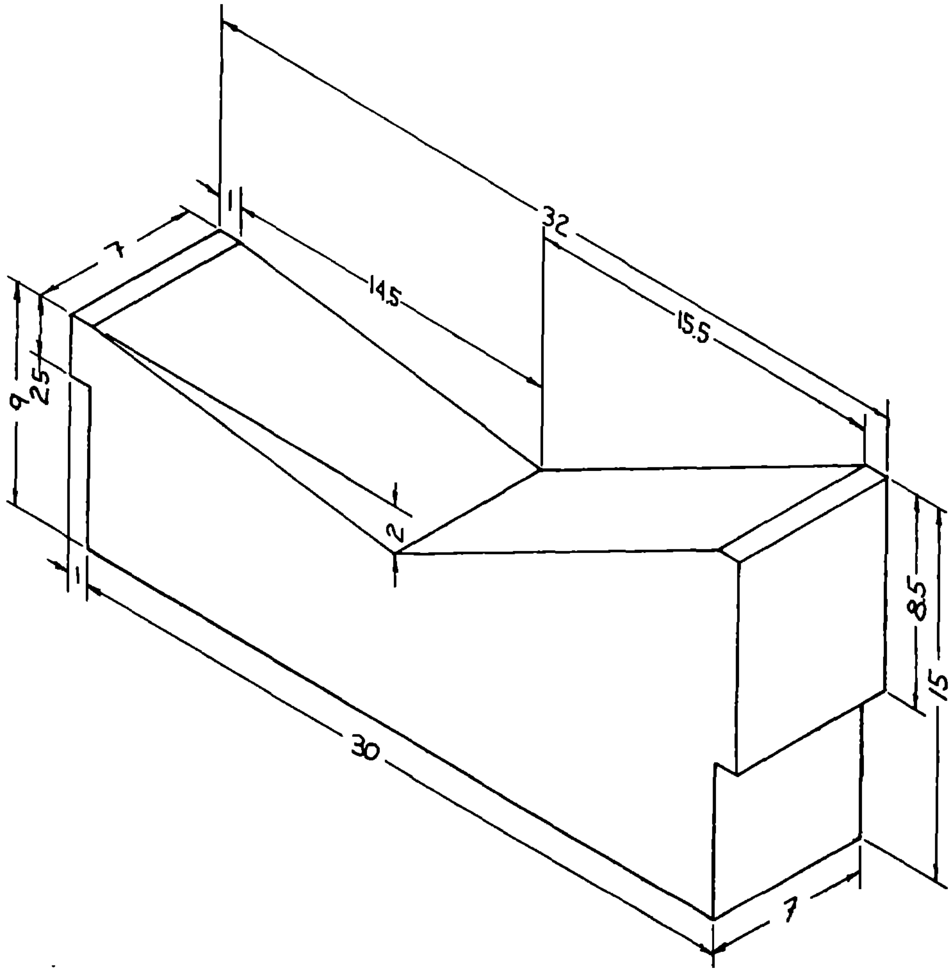


Figure 8C-37. Handle Trough Form

Secure the bearing blocks to the handle trough form with 1" x 1" angle bar as shown in Figure 8C-38.

Push 5 x 25 cm anchor bolts through the bolt holes in the bearing blocks and secure them in place with tying wire.

Insert the ends of the handle trough form into the slots in the main column form. Refer to Figure 8C-34. The concrete work is less tedious if the majority of the column form has been filled with concrete before performing this step.

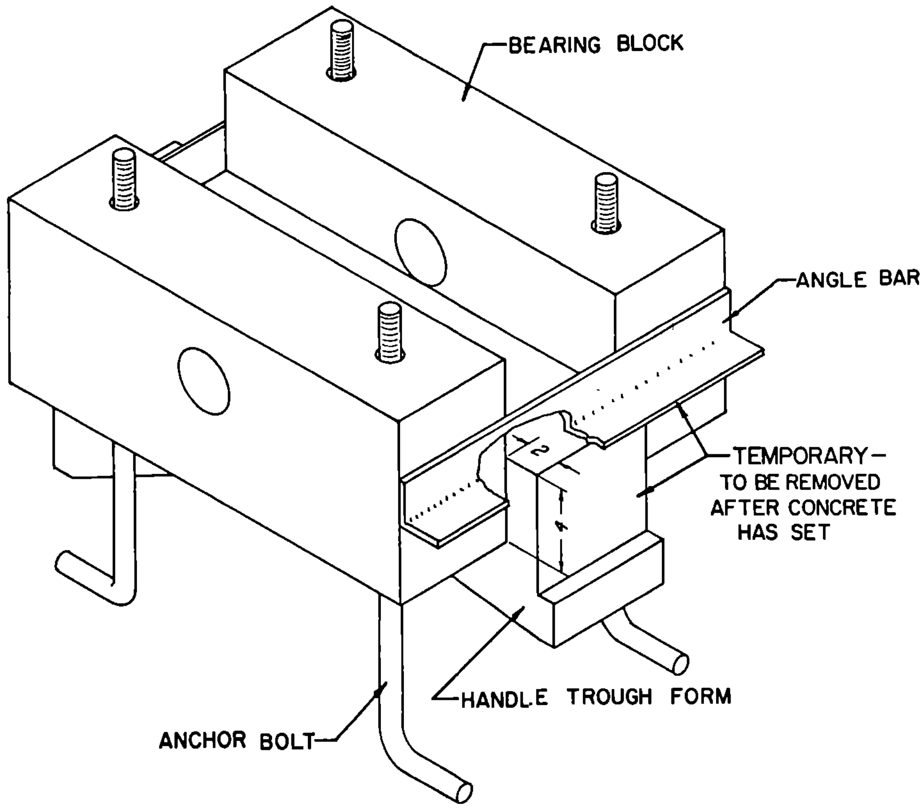


Figure 8C-38. Bearing Block/Trough Form Assembly

8C.5.6.4 Reinforcing Bars

Materials:

a. Two (2) lengths of 10 mm (3/8") Ø deformed bars
b. Two (2) lengths of 6 mm (1/4") Ø round bars
c. 1/4 kilo 16 gage tying wire

Cut and form the main reinforcing bars and the rectangular ties to the sizes and shapes given in Figure 8C-39a.

Assemble the bars and ties as illustrated in Figure 8C-39b.

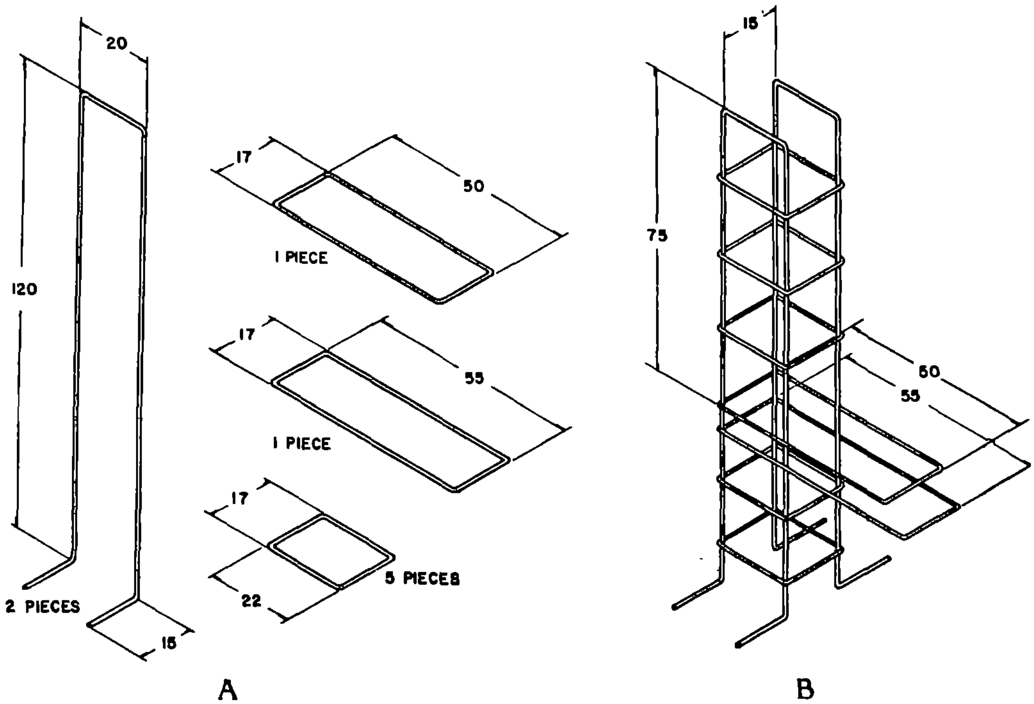


Figure 8C-39. Column Reinforcing Bars

8C.5.6.5 Anchor Bolts

Eight of the shorter anchor bolts depicted in Figure 8C-40 are required for each shallow-set or medium-set installation. Four of the shorter and four of the longer anchor bolts are required for each deep-set installation.

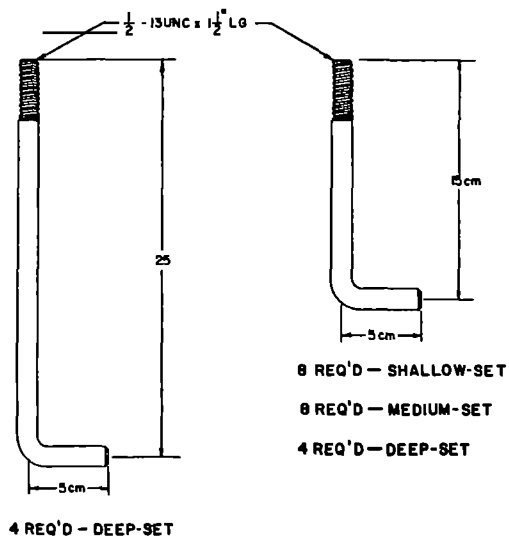


Figure 8C-40. Anchor Bolts

8C.6 **Pump Installation**

8C.6.1 Materials and Tools

The materials and tools required to install the shallow-set, medium-set and deep-set pumps are given in Section 8C.5.1 and are denoted with an asterisk.

8C.6.2 Pre-Installation Instructions

The night before installation, the plunger assembly should be removed from the pump and soaked in water. The leather cups absorb water and will expand in size to fit snugly inside the pump cylinder. This snug, moist fit makes the pump self-priming.

Remove the plunger rod/handle pin, the handle/fulcrum pin, and the fulcrum/pump cap pin and lubricate them over their entire length before reinsertion into the bushings. The slider block tracks should also be well lubricated before commencing with pump operation. See Section 8C.9.1 for more information on lubrication.

NOTE: Each pin is secured by two nuts. Tighten the nuts against one another and not the pump as this will result in binding or breakage of pump components.

Before installing the pump every connection should be double checked for tightness. The following should be given special attention:

- The nuts on the foot valve
- The plunger assembly
- All lock nuts on the plunger rod assembly
- All pipe thread connections, especially the medium-and deep-set models.

For deep-set pumps, fabricate and assemble the spout assembly, yoke, beam and bearing blocks before proceeding to the well site.

8C.6.3 Shallow-Set Pump Installation

1. Measure the depth a) to the bottom of the well, and b) to the static water level. This can be done using a weighted measuring tape or string. The depth to the bottom can also be found by determining the total number of installed casing pipes.

2. The 53 mm (1-1/2 inch) PVC suction pipe should be sized to extend below the dry season pumping water level by at least one (1) meter. The dry season pumping water level may be determined from the driller or from nearby wells. If this information is unavailable the pump should be temporarily installed and the well pump tested as per Section 8B. When in doubt, it is better that the drop pipe be sized too long than too short.

Well strainers are not considered in calculating the drop pipe length. Neither the bottom of the strainer nor the end of the suction pipe should be nearer than thirty (30) centimeters from the bottom of the casing assembly (casing, screen, well point, etc.) to prevent the intake of sand and other particles.

3. Solvent weld the 53 mm PVC suction pipe sections together. Weld a male threaded coupling on the upper end. Attach the well strainer, if used. Allow several minutes for the solvent weld to set.

4. Lower the suction pipe assembly into the well.

5. Screw the male threaded coupling into the pump. This task is much easier if the pump base was previously unscrewed from the pump body.

6. Lower the pump base onto the anchor bolts and fasten it in place. The pump spout and handle may be turned to any desired orientation.

7. The pump may require priming if the cups were not soaked overnight as per the pre-installation instructions. Pour a bucket of clean drinking water into the plunger rod hole in the pump cap. Repeat while pumping if water cannot be raised after the first priming.

8C.6.3.1 Joining PVC Pipe

The PVC pipe sections of the shallow-set pump must be joined with a vacuum-tight connection. The following method is recommended to obtain such a connection.

1. Wipe both surfaces to be joined with a clean dry rag.

2. Roughen both surfaces with sandpaper.

3. Thoroughly smear solvent over both surfaces to be joined.

4. Join the pieces together and turn the coupling or adapter 1/4 revolution (90 degrees) to assure good distribution of the solvent.

5. Hold the two pieces together for 30 seconds to ensure a good bond.

A proper PVC solvent weld will join the two pieces together as if they are one piece. They will also be as strong as one piece. Not all "solvents" form durable solvent bonds. A good test of solvent (or joint) quality, is to join a connector to a short pipe section following the above procedure. Cut the joined connector and pipe in half with respect to the center line as in Figure 8C-41A. Put the half-section in a vise (Figure 8C-41B) and crush it. If the pipe separates from the connector, the joint was not solvent welded. If the joined pieces do not separate, a solvent weld was formed.

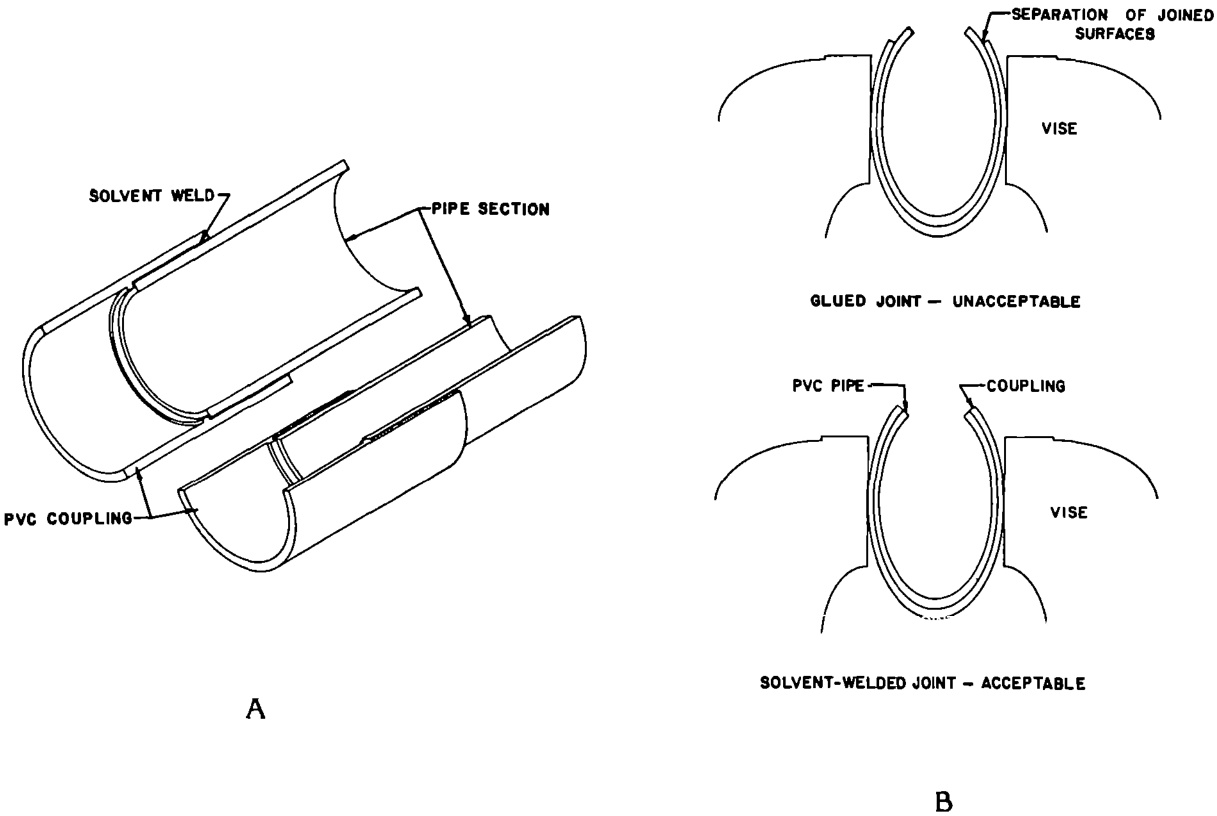


Figure 8C-41. Solvent Quality Test

8C.6.4 Medium-Set Installation

1. Measure the depth a) to the bottom of the well and b) to the static water level. This can be done using a weighted measuring tape or string. The depth to the bottom can also be found by determining the total number of installed casing pipes. Measurement should be done prior to purchasing materials.

2. The pump cylinder should be placed at least one (1) meter below the dry season pumping water level . The dry season pumping water level may be determined from the driller or from nearby wells. If this information is unavailable the pump should be temporarily installed and the well pump tested as per Section 8B. When in doubt, it is better to place the cylinder too deep rather than two shallow. The cylinder is placed underwater so that priming will not be required. However, the pump cylinder will work in suction as presented in Section 8C.3.2.

3. The drop pipe should be of 1-1/2 inch diameter schedule 40 galvanized pipe. The plunger rod should be of 3/8 inch diameter schedule 40 galvanized pipe although solid rod or different sized pipe may be used. Schedule 20 pipe is too thin for use in hand pump installations. Both pipes are purchased in corresponding equal lengths.

4. Thoroughly brush the pipe and rod threads with a stiff wire brush to remove dirt and rust. Wipe the threads clean with a rag. After applying Teflon tape to the threads, attach a length of plunger rod to the cylinder plunger rod section. Tighten firmly. Next, attach an equal length section of drop pipe to the cylinder. Use Teflon tape and tighten firmly. If used, attach a strainer to the bottom of the cylinder.

5. Lower this portion of the drop pipe assembly into the well casing (see Section 8C.10.3, "Medium-Set Pump Repair," for illustrations).

6. Put a section of plunger rod inside an equal length section of drop pipe. Raise these sections over the already lowered portion of drop pipe assembly and connect first the plunger rod, then the drop pipe. After applying Teflon tape to the threads, tighten each connection firmly. A pipe clamp and tripod will be required to perform this step and those following. Again, always wipe the threads clean before applying Teflon tape and joining.

7. Continue adding sections of plunger rod and drop pipe as per steps 5 and 6 until the desired cylinder depth is reached.

8. Unbolt the pump cap from the pump body. Attach the pump body and base to the drop pipe. (See Section 8C.10.2.) Bolt the base onto the anchor bolts.

9. Raise the plunger rod to the highest position (until it cannot be raised any more). See Fiqure 8C-42. Mark the rod 1-1/4 inches above the top of the pump body. Cut and thread the plunger rod. This step ensures that the plunger assembly will be well centered within the cylinder.

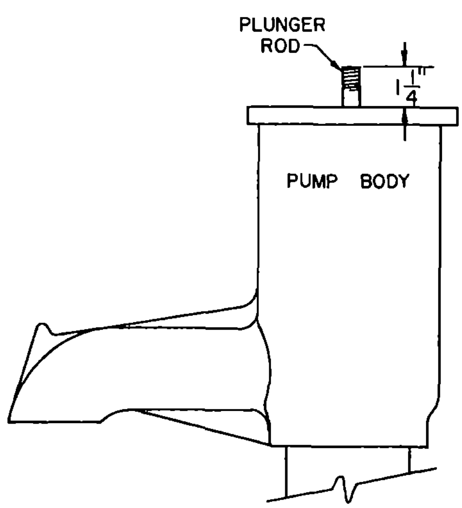


Figure 8C-42. Marking Plunger Rod

10. Attach the halves of the plunger rod union to the plunger rod (3/8" pipe) assembly and the upper plunger rod (1/2" rod). Holding the pump cap over the pump body, join the plunger rod sections.

11. Rebolt the pump cap to the pump body. Check all exposed nuts and bolts for tightness.

12. Test pump the pump. Each stroke of the handle should be stopped by the handle striking the fulcrum. If the motion of the handle is being restricted by the plunger rod, the reason (too long or too short) should be determined and the appropriate steps taken. If the rod is too long, the plunger assembly will strike the bottom of the cylinder. If it is too short, the plunger assembly will strike the top of the cylinder. Both instances will result in the premature failure of the plunger assembly. The pump should not be used until corrected. In the case where the rod is too long, the rod can be remeasured and cut. When the rod is too short, the proper length is determined and this amount is cut off the drop pipe.

8C.6.5 Deep-Set Installation

NOTE: Prior to installation, the material listed in Section 8C.5.1.6 ("Deep-Set Well Head Materials") should be procured and the fabrication and asssembly of these components undertaken as necessary.

1. Measure the depth a) to the bottom of the well, and b) to the static water level. This can be done using a weighted measuring tape or string. The depth to the bottom can also be found by determining the total number of installed casing pipes. Measurement should be done prior to purchasing materials.

2. The pump cylinder should be placed at least one (1) meter below the dry season static water level (SWL). If the dry season SWL is not known, place the cylinder two (2) to three (3) meters below the current SWL. The cylinder is placed under water so that priming should not be required.

3. The drop pipe should be of 1-1/2 inch diameter schedule 40 galvanized pipe. The plunger rod should be of 3/8 inch diameter schedule 40 galvanized pipe. Schedule 20 pipe is too thin for use in hand pump installations. Both pipes are purchased in corresponding equal lengths.

4. Thoroughly brush the pipe and rod threads with a stiff wire brush to remove dirt and rust. Wipe clean with a rag. After applying Teflon tape to the threads, attach a length of plunger rod to the cylinder plunger rod section. Tighten firmly. Next, attach an equal length section of drop pipe to the cylinder. Use Teflon tape and tighten firmly. If used, attach a strainer to the bottom of the cylinder.

5. Lower this portion of the drop pipe assembly into the well casing (see Section 8C.10, "Medium-Set Pump Repair," for illustrations).

6. Put a section of plunger rod inside an equal length section of drop pipe. Raise these sections over the already lowered portion of drop pipe assembly and connect first the plunger rod then the drop pipe. After wrapping Teflon tape around the threads, tighten each connection firmly. A pipe clamp and a tripod will be required to perform this step and those following. Again, always wipe the threads clean before applying Teflon Tape and joining.

7. Continue adding sections of plunger rod and drop pipe as per steps 5 and 6 until the desired cylinder depth is reached.

8. Attach the spout assembly (Figure 8C-43) to the last length of drop pipe.

9. Push the plunger rod down until the plunger assembly rests against the bottom of the cylinder. Put a mark on the plunger rod where it extends beyond the spout assembly. If no plunger rod is showing, another piece of rod can be added or several inches can be cut off the drop pipe.

10. Raise the plunger rod several inches. Measure 2.5 cm down from the mark and cut the rod. This prevents the plunger rod from hitting the bottom of the cylinder.

11. Connect the yoke assembly to the plunger rod as shown in Figure 8C-44.

12. Assemble the handle with 3/8" bolts from the pieces shown in Figure 8C-45. Refer to Table 8C-1 to determine the length of the beam. Insert the GI pipe "shaft" into the pivot hole in the assembled beam. Slip the bearing blocks over the ends of the shaft. Place the washers on the shaft and pin them in place as in Figure 8C-46.

TABLE 8C-1

DEEP-SET PUMP HANDLE LENGTH

Well Depth		Total Length of Beam	
meters	feet	centimeters	feet
7.5 - 12.0	25 - 40	230	7.5
12.5 - 17.0	41 - 55	260	8.5
17.5 - 21.0	56 - 70	290	9.5
21.5 - 29.0	71 - 95	320	10.5
29.5 - 33.5	96 - 110	350	11.5
34.0 - 38.0	111 - 125	380	12.5
38.5 - above	126 - above	410	13.5

13. Bolt the beam and bearing blocks to the column. Before tightening, center the beam so that it does not rub against the column or the blocks. Secure the beam to the shaft by driving a 6" nail

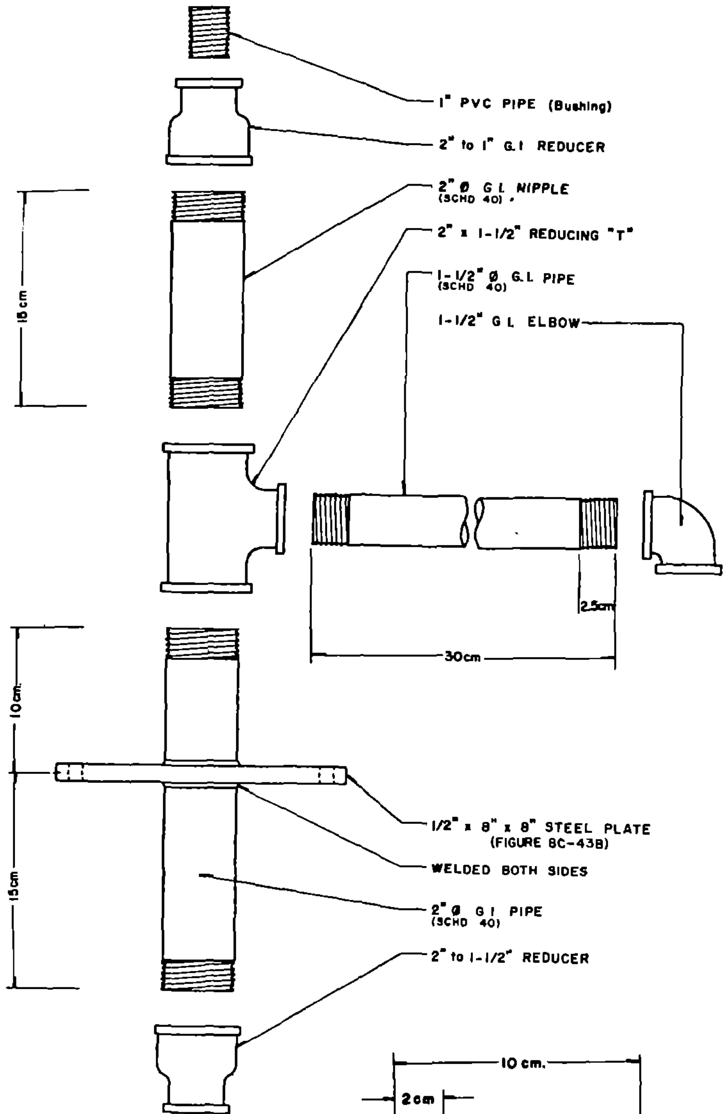


Figure 8C-43A
Spout Assembly

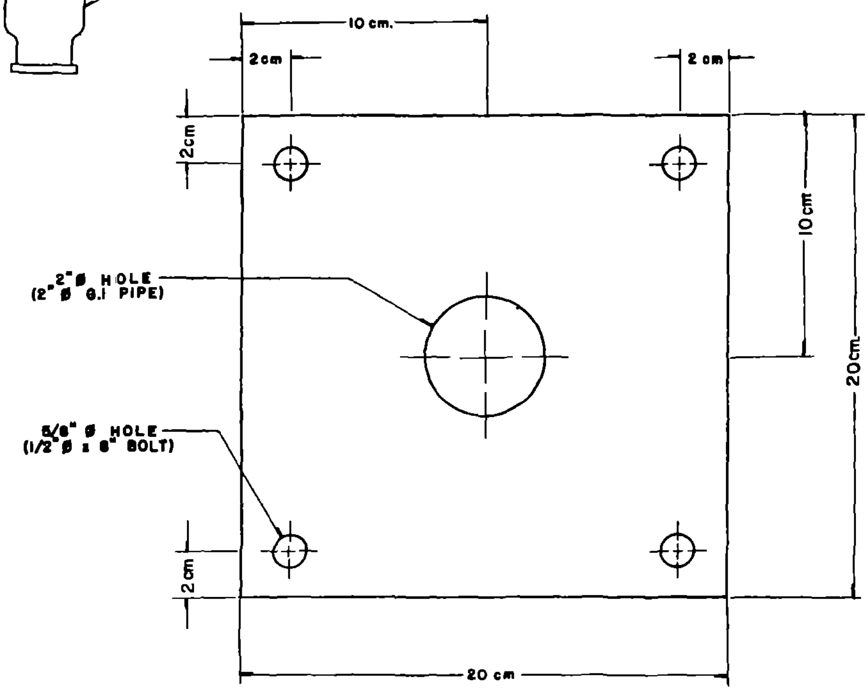


Figure 8C-43B
Bearing Plate Detail

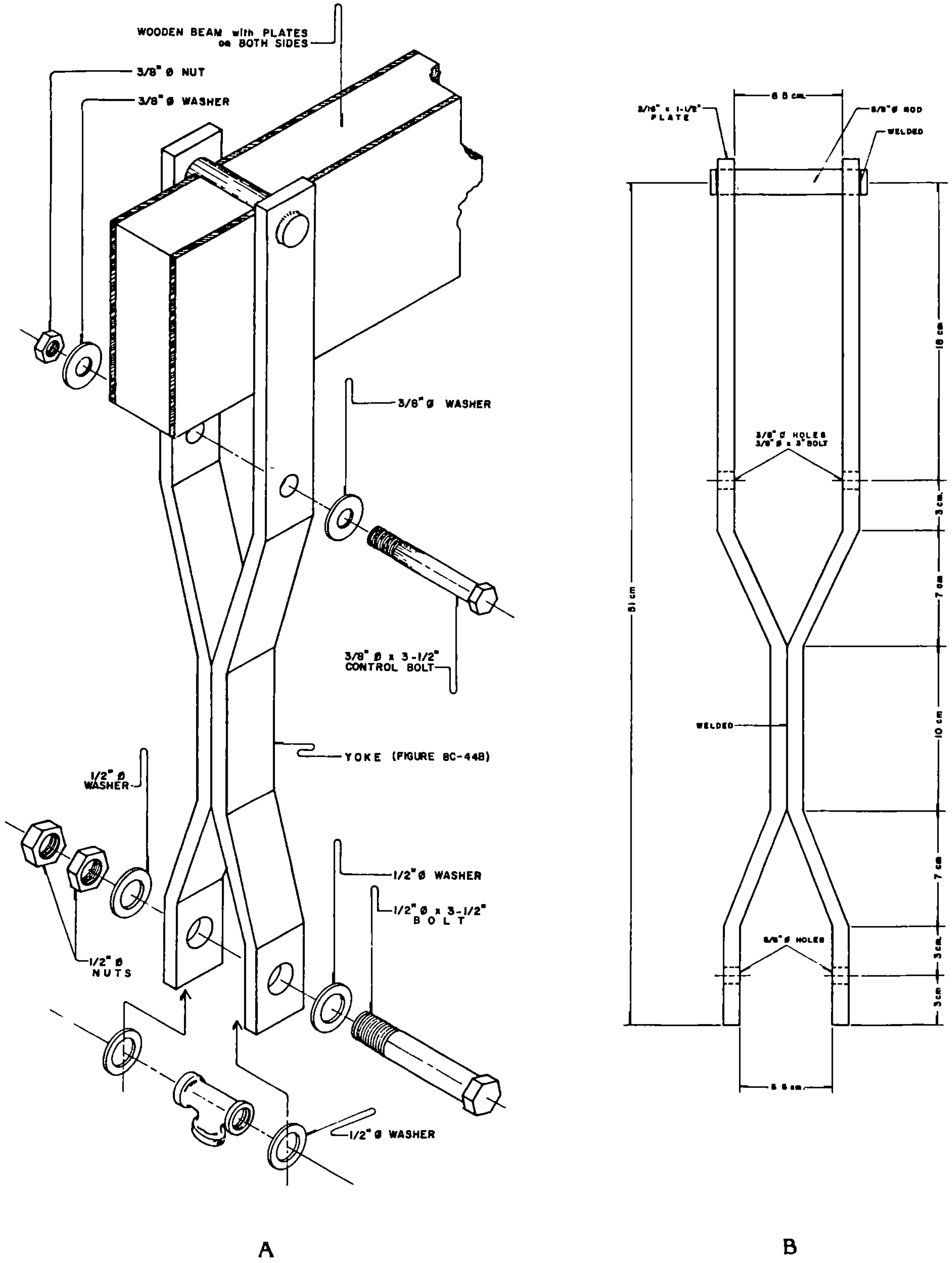


Figure 8C-44. Yoke Assembly

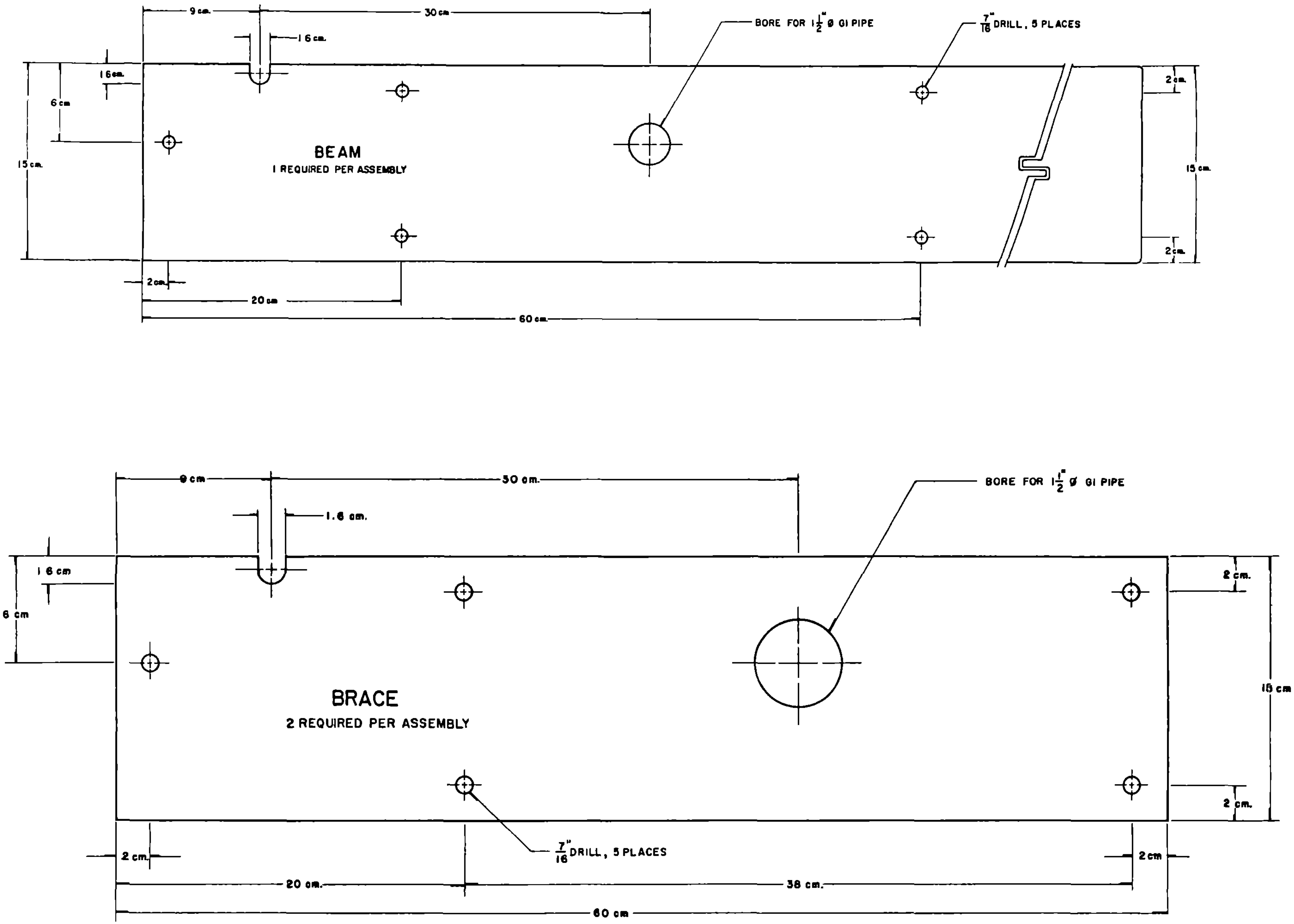


Figure 8C-45. Details of Handle Assembly

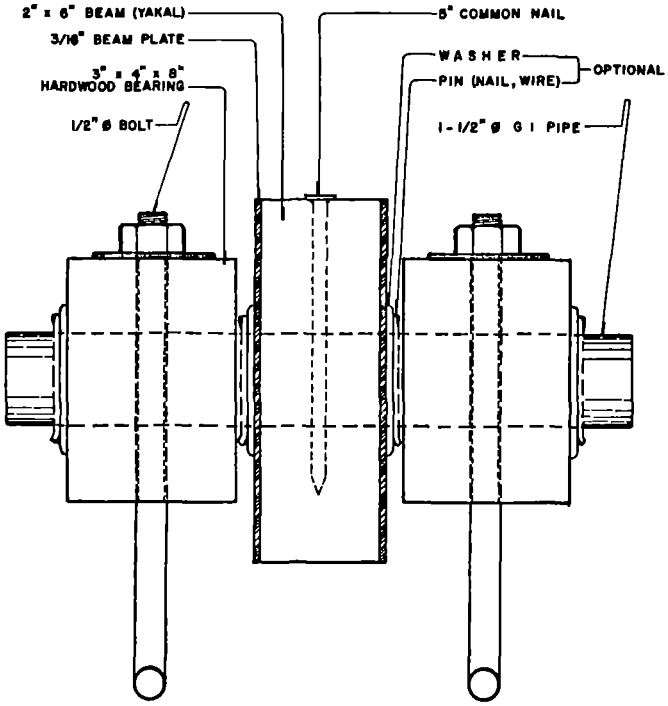


Figure 8C-46. Handle Pivot Assembly

through the beam and shaft. This prevents the shaft from turning in the beam. The bearing blocks are designed to wear longer than the beam. Also, blocks are much easier and cheaper to replace.

14. Test pump the pump. If the motion of the handle is being restricted by the plunger rod, the reason (too long or too short) should be determined and the appropriate steps taken. If the rod is too long, the plunger assembly will strike the bottom of the cylinder. If it is too short, the plunger assembly will strike the top of the cylinder. Both instances will result in the premature failure of the plunger assembly. The pump should not be used until corrected. In the case where the rod is too long, the rod can be remeasured and cut. When the rod is too short, the proper length is determined and this amount is cut off the drop pipe.

8C.6.6 Installation Evaluation

After an installation has been completed, pump performance should be evaluated. If performance is below standard, the problem should be identified and corrected immediately while the tools for installation are still at the site.

Flow Rate: Measure the pump flow rate with a container of known size using full strokes. As a reference, a properly operating pump will fill a 19 liter cooking oil can in the following number of strokes:

Shallow-set	18-22	(or 1 liter/stroke)
Medium-set and Deep-set	55-65	(or .3 liter/stroke)

Causes of reduced flow rate include debris in drop or suction pipe, plunger valve seating poorly, damage to the cups and/or cylinder wall, and suction leaks.

Pump Leak Rate: Allow the pump to stand idle for 15 minutes before pumping again. Count the number of strokes required for water to flow out of the pump. Ideally, water should flow out on the first or second stroke. Greater delays are caused by a leaky foot valve or leaky joints. This situation is intolerable in shallow-set installations since the pump may require regular priming which can introduce contaminants into the well. In medium-set and deep-set installations, this situation is inconvenient at best to the users. In both cases, the pump should be removed and the cause of the leak determined and corrected.

The flow rate and leak rate should be recorded on the Installation Data Sheet. Any remedial action needed to increase flow rate or decrease leak rate should be noted under "Additional Information and Comments."

8C.7 Disinfecting Wells[4]

Bacteria and parasites which cause illness can be introduced into a well by dirty and contaminated well casing, drop pipe, tools, etc., and by contaminated water seeping into the well. The likelihood of the latter can be greatly reduced by careful site selection and construction as outlined in Section 8C.4 and 8C.5.

The bacteria and parasites must be destroyed before the well is used for the first time and each subsequent time the well is reopened for repairs. Chlorine is the most widely used chemical for disinfection of water wells and has no harmful side effects on the users of the well. Chlorine is added to the well water in a quantity sufficient to produce a strong chlorine solution of about 30 ppm (30 mg/l). This solution can then be used to rinse off the rest of the well and the pump components. Iodine and potassium permanganate may also be used as disinfectants but their use is not discussed in this manual.

8C.7.1 Useful Definitions

Aquifer: An underground layer of rock, sand, or gravel that will provide water to wells and springs.

Available Chlorine: The amount of chlorine present in a compound or solution that is usable for disinfecting water.

Chlorine Demand: The amount of chlorine required in the disinfection process to combine with certain organic and inorganic materials in the water and destroy bacteria and parasites.

Chlorine Dosage: The amount of chlorine added to the water to produce a chlorine concentration expressed as milligrams per liter (mg/l).

Disinfection: A process which purifies water through addition of a chemical (disinfectant) that destroys bacteria and parasites.

Milligrams Per Liter (mg/l): A standard unit for describing the concentration of a chemical in water, expressed as the number of milligrams of a chemical in one liter of water. Another standard unit is concentration in parts per million:

1 mg/l = 1 part per million (ppm).

Static Water Table: The final level to which water will rise in a well.

8C.7.2 Determining the Required Amount

1. Determine the volume of the water in the well. For a circular well, measure the depth of water (H) and the well diameter (D). The volume (V) is found by the following equation:

$$V = \text{Area} \times \text{Depth}$$

$$V = \frac{\pi}{4} D^2 \times H \quad \text{Where: } \pi = 3.1416$$

or

$$V = .7854\, D^2 \times H$$

All dimensions should be either in feet or in meters.

2. From Table 8C-2, find the amount of chlorine that should be added to the volume of water calculated above to produce a strong chlorine solution.
3. Dissolve the powdered chlorine compound in a bucket before adding it to the well. It is important that the solution be prepared in a clean container and mixed with clean utensils. Dirt, grease, oil, and organic matter will reduce the strength of the chlorine solution. Avoid the use of metal containers because the strong chlorine solution will cause them to rust. Instead use plastic, ceramic, glass, or rubber-lined containers.

   CAUTION: The chlorine compounds and solutions used to disinfect wells can cause irritation to skin and eyes. If possible, wear gloves, protective clothing and glasses when handling chlorine. However, if you get chlorine on your skin or in your eyes, wash it off with water immediately. Do not rub your eyes until you have washed the chlorine off your hands. Work with chlorine only in areas with good air flow. Never use chlorine when persons are working inside the well.

8C.7.3 Steps in Disinfecting a Drilled Well

1. Wash the exterior surface of the pump cylinder and drop pipe as they are lowered into the well. Do not bolt the pump to the concrete pedestal or column.

2. Pump the well until the water is relatively clear and as free from cloudiness (turbidity) as possible.

3. Slowly pour the required amount of chlorine solution as determined above into the well. Allow the solution to wash down the sides of the casing.

4. Mix the chlorine solution with the water in the well. This can be done by tying a rope around a large, clean rock and moving it up and down in the water in the well.

5. Add 25 to 40 liters (5 to 10 gallons) of clean, chlorinated water to the well to force the solution into the aquifer.

6. Operate the pump until you can smell chlorine.

7. Stop pumping and allow the chlorine solution to remain in the well for at least 12 hours, but preferably 24 hours.

8. After disinfection, pump the well until the residual chlorine level is below 0.7 mg/l or until the odor and taste of chlorine in the water is no longer objectionable. If there is no chlorine residual or odor after the disinfection period, disinfection should be repeated until a residual is obtained.

In the case of deep wells with a high water table, special steps should be taken to ensure that the chlorine is thoroughly mixed with the well water. The following procedure must be performed before the pump is installed:

1. Take a length of pipe which is 60 to 100 cm (2-3 feet) long and 50 mm (2 inches) in diameter. Plug one end of the pipe with a block of wood or with a threaded or welded cap. On the other end, fit a threaded cap with an eye loop for a rope or cable.

2. Drill a large number of 2 or 3 mm (1/16-1/8 inch) holes at 4 cm (1½-inch) spacing over the entire surface area of the pipe.

3. Remove the threaded cap and fill the pipe with calcium hypochlorite (HTH) tablets. Replace the cap and attach a rope to the eye loop.

   NOTE: When a length of a pipe is not available, this disinfection procedure can be accomplished by placing HTH tablets in a burlap bag with a rock in it. Then tie a rope tightly around the top of the burlap bag and proceed with step 4.

4. Alternately raise and lower the pipe section in the water to distribute the disinfection agent.

8C.7.4 Chlorine Residual

The chlorine residual is the amount of chlorine that is left in treated water. Chlorine is used up as it disinfects. Add enough chlorine to the water so that there is a residual after the chlorine has had at least 12 hours to react with and kill all the living organisms in the water. This assures that all the disease-causing bacteria have been destroyed and that there is still some chlorine available to kill other contaminants which might enter the water at a later time.

The recommended chlorine residual is 0.5 mg/l. A higher residual will cause an obvious chlorine taste in the water. Above 3.0 mg/l chlorine concentration can cause diarrhea.

Chlorine residual is easily checked with any of the commercially available color comparators. Most of these use an "orthotolidine solution," which turns progressively more yellow at higher chlorine residuals.

Table 8C-2

AMOUNTS OF CHEMICALS REQUIRED FOR A STRONG CHLORINE SOLUTION CAPABLE OF DISINFECTING WELLS AFTER THEIR CONSTRUCTION*

Water		High Strength Calcium Hypochlorite (70%)			Bleaching Powder (25-35%)			Liquid Bleach (5% Sodium Hypochlorite)		
m^3	ft^3	g	tbs	cups	g	tbs	cups	ml	cups	gal
0.10	3.5	4.3	1/4		10	3/4		60	.25	
0.12	4.2	5.2	1/3		12	3/4		72	.30	
0.15	5.3	6.5	1/2		15	1		90	.40	
0.20	7.1	8.6	2/3		20	1 1/4		120	.50	
0.25	8.8	11	3/4		25	1 3/4		150	.70	
0.30	10.6	13	1		30	2		180	.80	
0.40	14.1	17	1 1/4		40	2 3/4		240	1.0	
0.50	17.6	22	1 1/2		50	3 1/2		300	1.4	
0.60	21.2	26	1 3/4		60	4		360	1.6	
0.70	24.7	30	2		70	4 3/4		420	1.9	
0.80	28.2	34	2 1/4		80	5 1/2		480	2.1	
1.0	35.3	43	3		100	6 3/4		600	2.7	
1.2	42.4	52	3 1/2		120	8		720	3.2	
1.5	53.0	65	4 1/2		150	10		900	4.0	
2.0	70.6	86	6		200	14		1,200	5.4	
2.5	88.3	110	7 1/2		250	17	1.00	1,500	6.7	
3.0	106	130	9		300	20	1.25	1,800	8	
4.0	141	170	11 1/2		400	27	1.70	2,400	11	
5.0	176	220	15		500		2.10	3,000	13	
6.0	212	260	17 1/2	1	600		2.50	3,600	16	1.0
7.0	247	300	20	1.25	700		2.90	4,200	19	1.2
8.0	282	340	23	1.5	800		3.40	4,800	21	1.4
10	353	430		1.8	1,000		4.20	6,000	27	1.7
12	424	520		2.2	1,200		5.0	7,200	32	2.0
15	530	650		2.7	1,500		6.3	9,000		2.5
20	706	860		3.6	2,000		8.4	12,000		3.4
30	1,060	1,300		5.5	3,000		12.6	18,000		5.0
40	1,410	1,700		7.2	4,000		16.8	24,000		6.7
50	1,760	2,200		9.2	5,000		20.5	30,000		8.4
60	2,120	2,600		11.0	6,000		25			
70	2,470	3,000		13	7,000		29			
80	2,820	3,400		14	8,000		34			
100	3,530	4,300		18	10,000		42			
120	4,240	5,200		22	12,000		50			
150	5,300	6,500		27	15,000		63			
200	7,060	8,600		36	20,000		84			
250	8,830	11,000		46	25,000		105			
300	10,600	13,000		55	30,000		126			
400	14,100	17,000		71	40,000		168			
500	17,600	22,000		92	50,000		210			

*This produces a chlorine concentration of approximately 30 mg/l (ppm). This water should not be drunk by people or animals.

8C.8 Trouble-shooting Pump Problems

A. The pump must be pumped several times before water comes out (particularly in the morning).

Cause:
1. The foot valve is excessively worn or dirt is allowing water to leak past.
2. A leak has developed in the drop pipe (loss of water) or suction pipe (loss of vacuum).

Remedy:
1. Examine foot valve. Clean or replace as necessary.
2. Examine drop pipe or suction pipe. Correct leak.

B. The amount of water pumped per stroke is significantly less than when the pump was new.

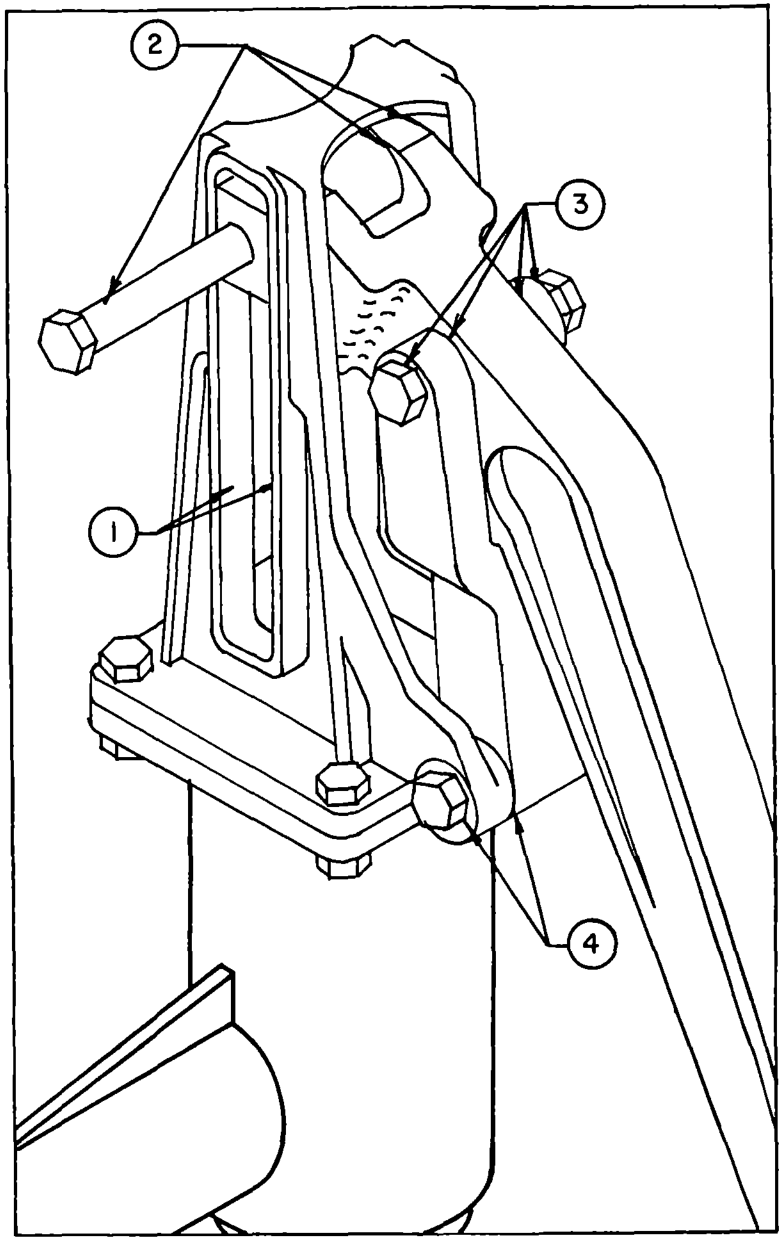
Cause:
1. The plunger cups are worn and not sealing against the cylinder walls.
2. The foot valve is excessively worn or dirty.
3. A leak has developed in the drop pipe (loss of water) or suction pipe (loss of vacuum).
4. Dirt and debris are obstructing the flow or water.

Remedy:
1. Examine the plunger cups for excessive wear or a tear. Replace as necessary.
2. Examine the foot valve. Clean or replace as necessary.
3. Examine drop pipe or suction pipe. Correct leak.
4. Examine drop pipe, suction pipe, foot valve, and plunger valve for dirt and debris. Remove the dirt and debris.

C. No water can be pumped.

Cause:
1. Foot valve is broken or is stuck in the open position.
2. The plunger cage is broken.
3. The plunger assembly or a section of plunger rod has become unscrewed from the rest of the plunger rod.

Remedy:
1. Examine foot valve. If broken, replace. If stuck, clean it or remove the blockage. If the valve still sticks, replace it.
2. Examine plunger assembly. A broken plunger cage is usually the result of an improperly sized plunger rod and will occur only in the medium-set and deep-set models. To prevent the plunger cage from being broken again after it has been replaced, it is necessary to determine how much too short or long the plunger rod is and make the needed adjustment in length.
3. Examine the plunger assembly and plunger rod. Reconnect the joint tightly. In the case of an unscrewed plunger assembly, be sure that the lock nut on the plunger rod is tightened securely.



8C.9.1 LUBRICATION

Lubricate the following places weekly:

1. Slider block tracks
2. Plunger rod/handle pin
3. Handle/fulcrum pin
4. Fulcrum/pump cap pin

Every month the pins and slider blocks should be removed and the old grease and dirt wiped off of the pump components. Be sure to clean the metal powder and dust out of the bushings and holes in the slider blocks. Regrease the above four places and all contacting surfaces with new grease before reassembly.

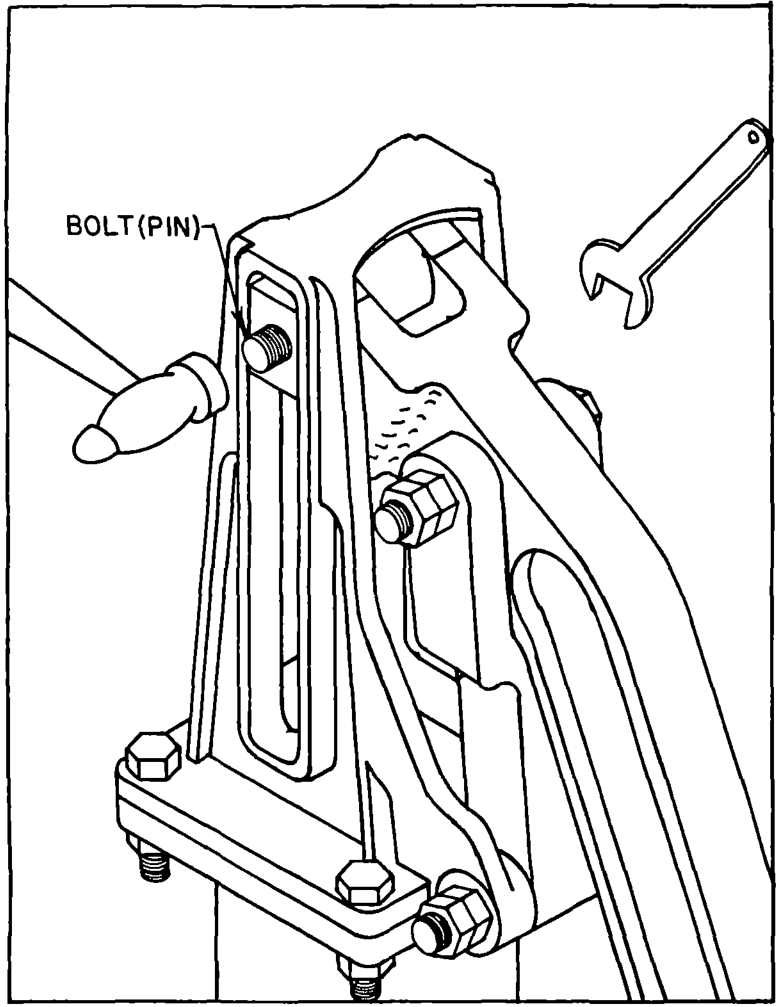
Whenever the pins are removed for any reason, they should be lubricated before reinsertion. The pins on a new pump should be removed and lubricated before the pump is installed

No parts inside the pump require lubrication.

8C.9.2 Site Maintenance

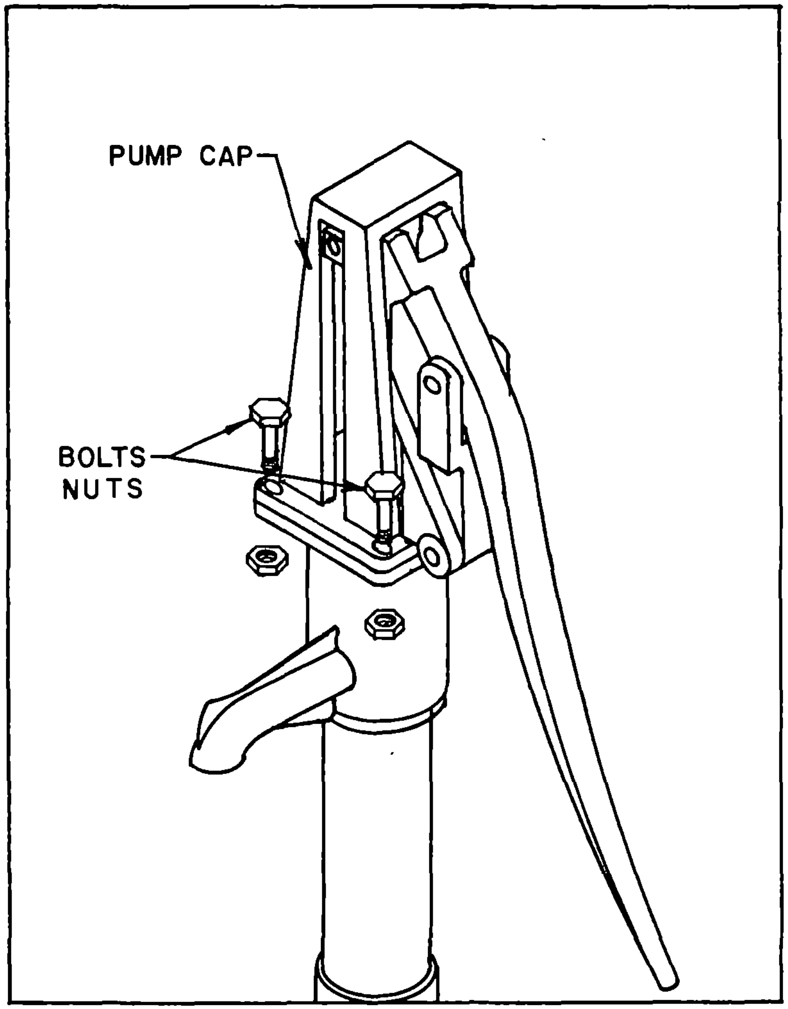
The concrete apron and the area surrounding the pump should be swept and any debris removed at least once a week. Over a period of time, the apron slab may become slimy and slippery due to the growth of mold and other organic matter. When this happens, the apron should be scrubbed with soapy water, rinsed, scrubbed again with a bleach solution (5 tablespoons of liquid bleach to 1 gallon of water or 1/2 teaspoon of bleaching powder to 1 gallon of water), and rinsed a final time.

Animals and pets should not be allowed near the pump. Animal manure and other feces near the pump site (especially on the apron or graveled area around the apron) should be removed immediately.



8C.10.1 PIN REPLACEMENT AND REMOVAL

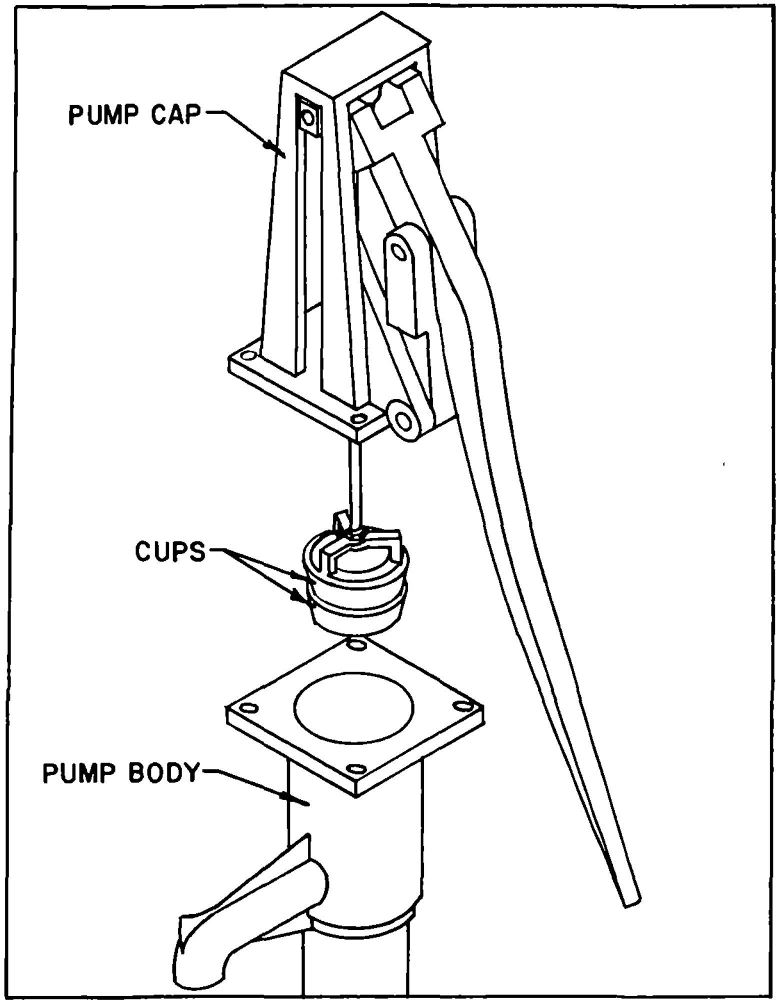
Remove the nuts from the bolts and drive the bolts out as shown.



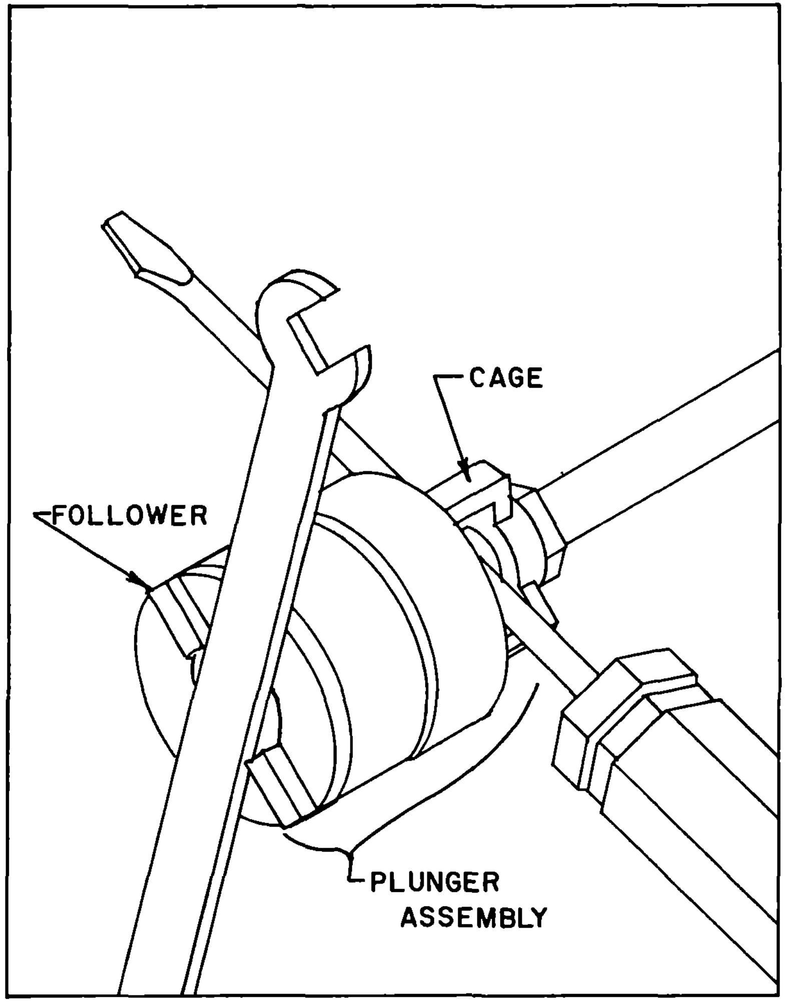
8C.10.2 SHALLOW-SET PUMP REPAIR

8C.10.2.1 CUP RELACEMENT

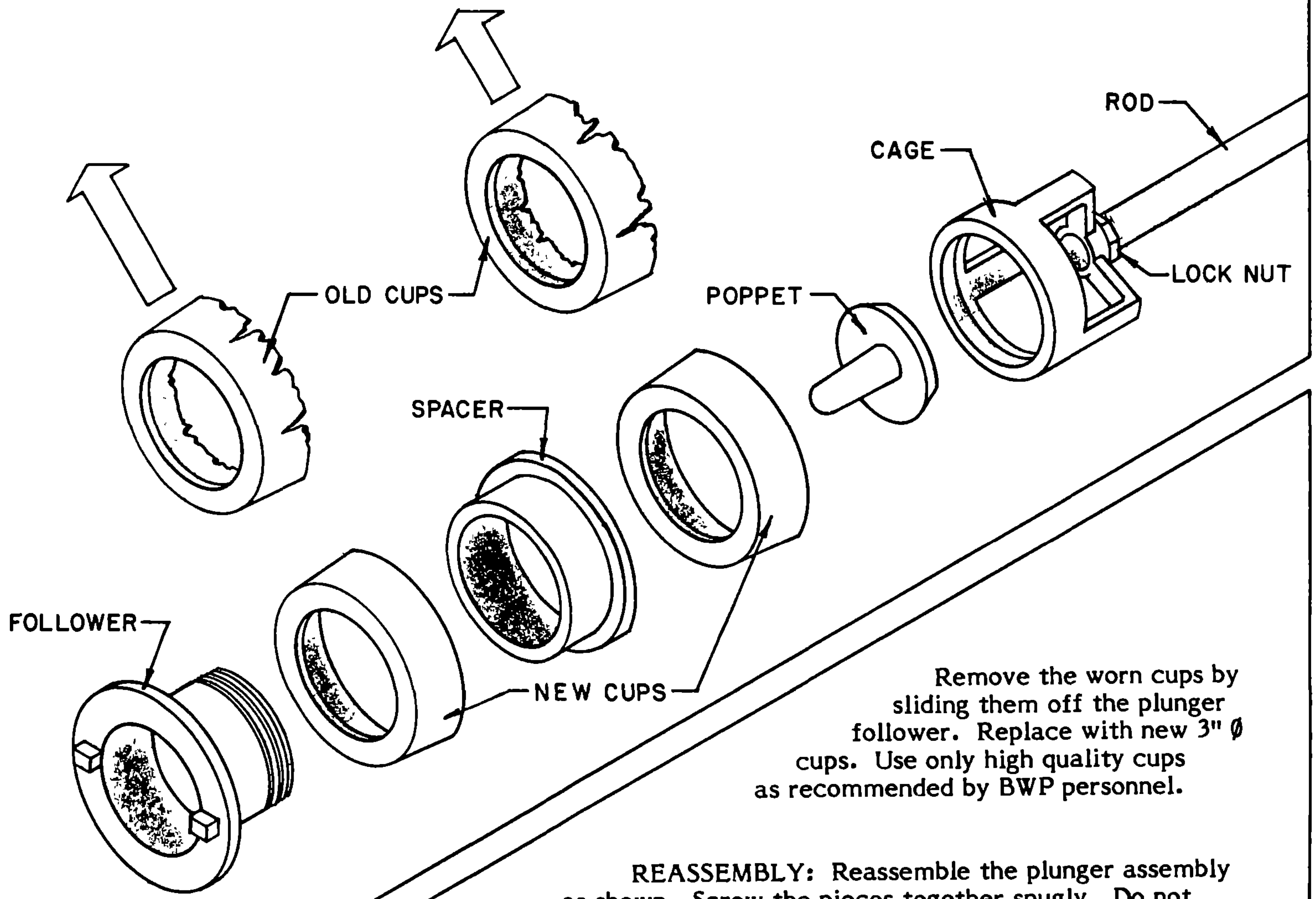
Remove the bolts holding down the pump cap.



Lift the pump cap off the pump body.

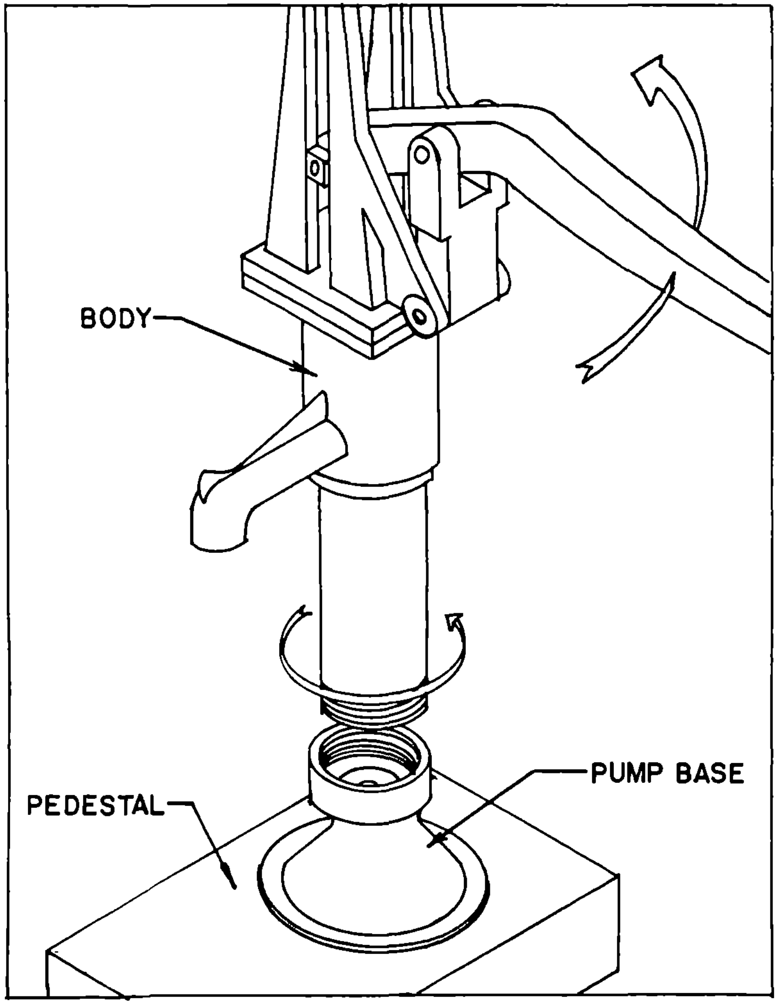


Unscrew the plunger assembly as shown using a wrench and screwdriver.



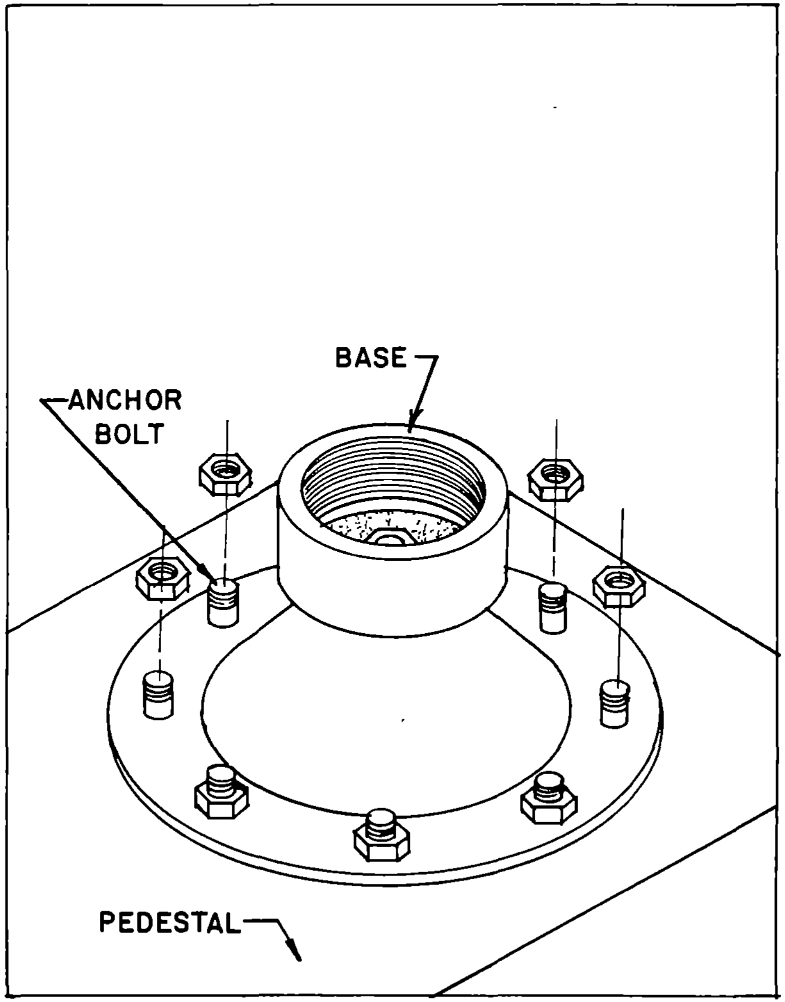
Remove the worn cups by sliding them off the plunger follower. Replace with new 3" Ø cups. Use only high quality cups as recommended by BWP personnel.

REASSEMBLY: Reassemble the plunger assembly as shown. Screw the pieces together snugly. Do not overtighten as this will make future disassembly more difficult. Ensure that the plunger rod does not protrude into the cage because it will reduce poppet travel. Tighten the plunger rod lock nut firmly.

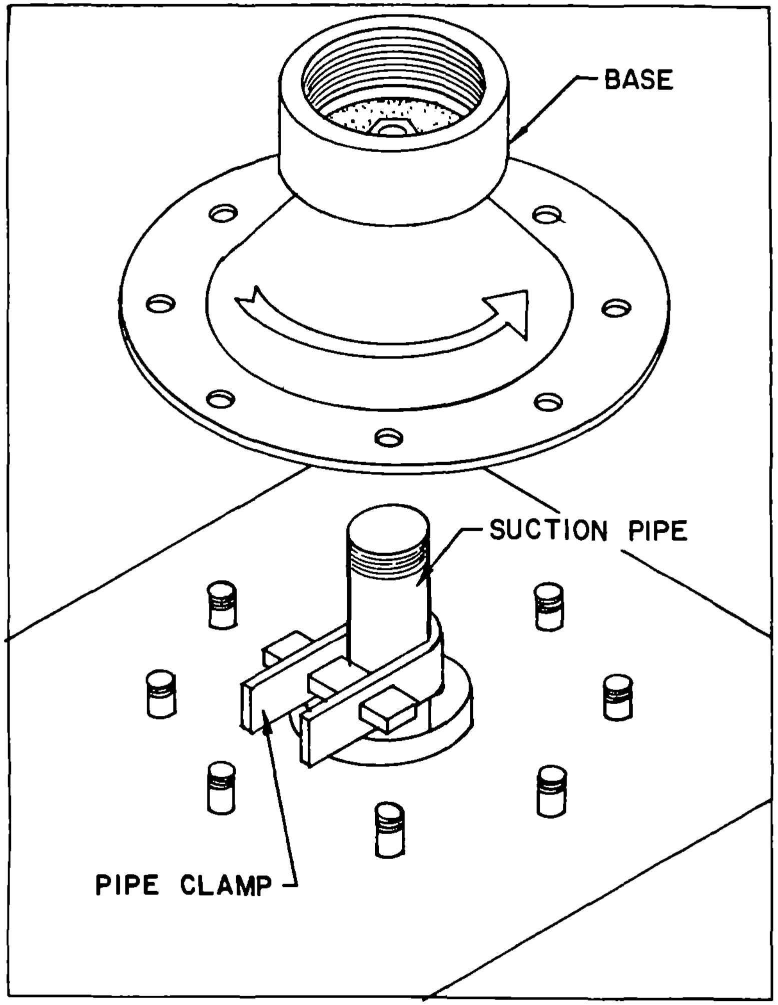


8C.10.2.2 FOOT VALVE REPLACEMENT

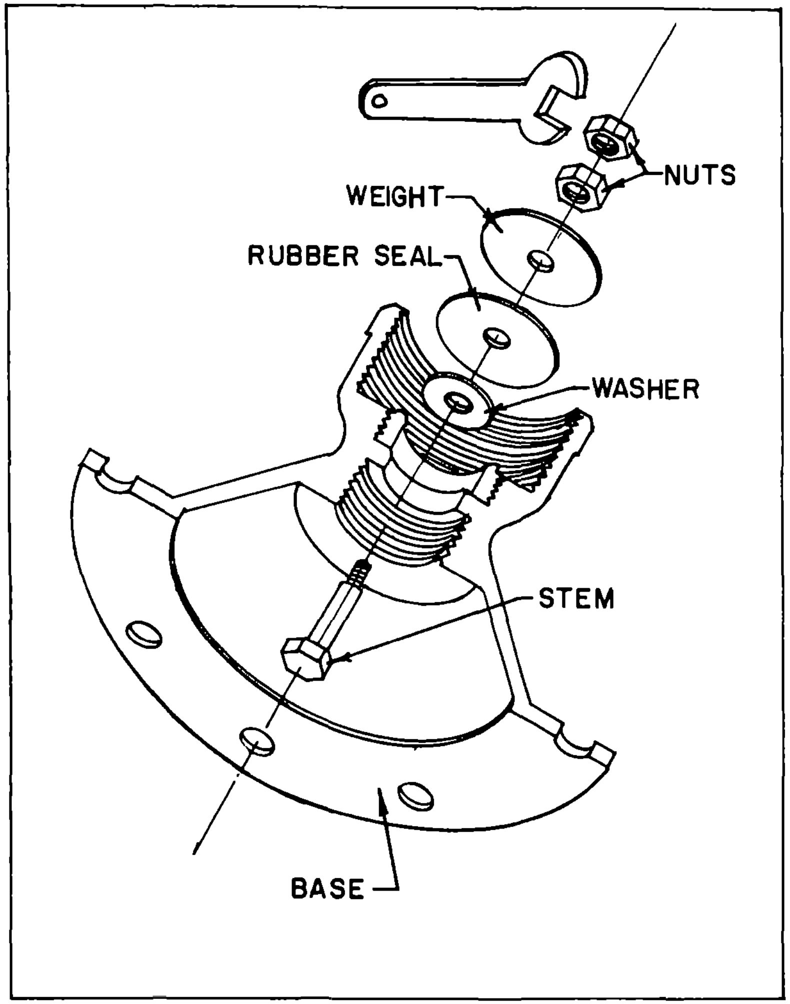
Unscrew the pump body from the pump base. The handle may be used as a lever.



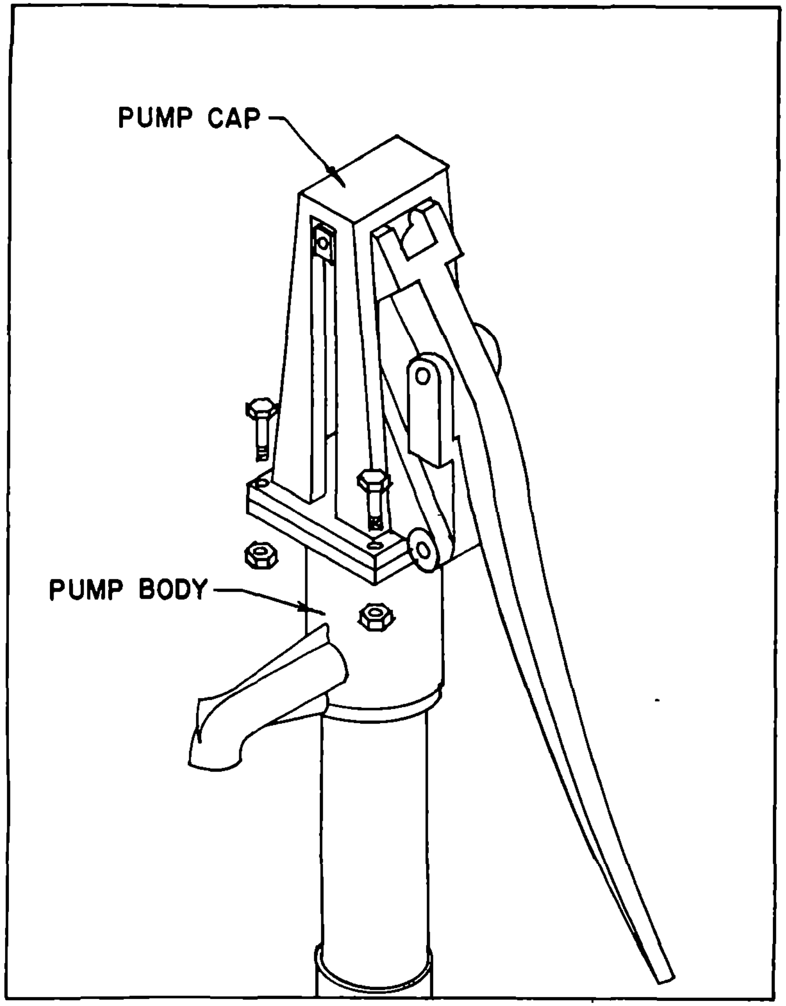
Unbolt the pump base from the pedestal.



Unscrew the pump base from the suction pipe.

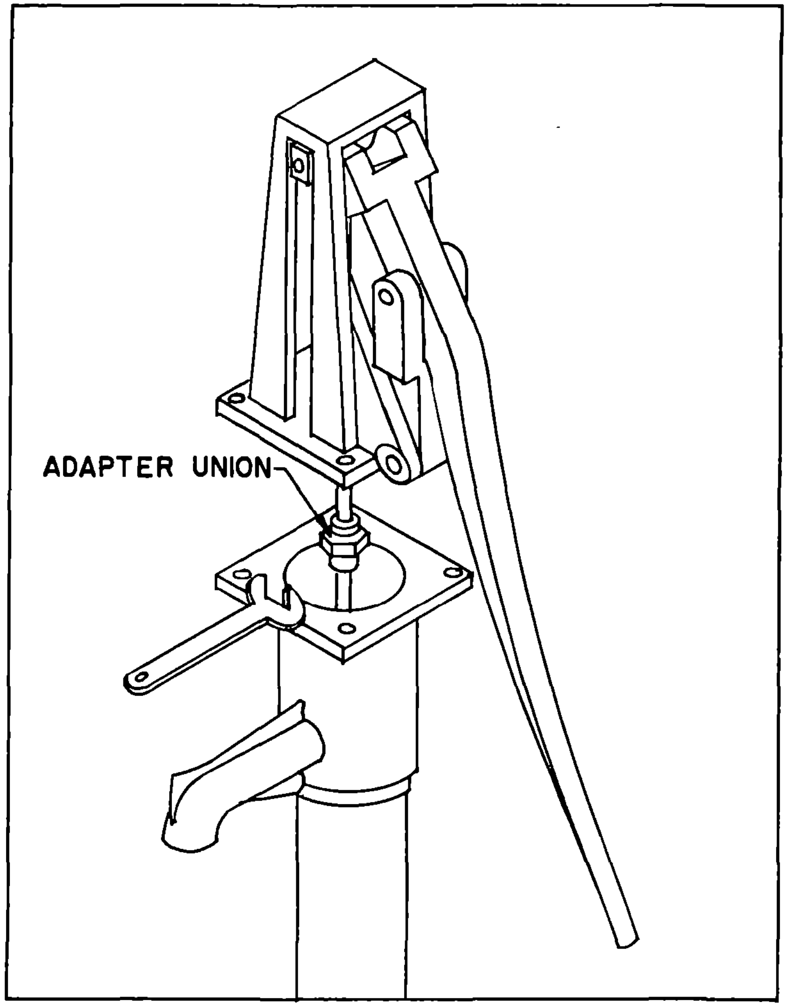


Remove the valve from the base by unscrewing the retaining nuts. Replace the worn rubber seal. Glue the new rubber seal in place with epoxy or rubber cement.

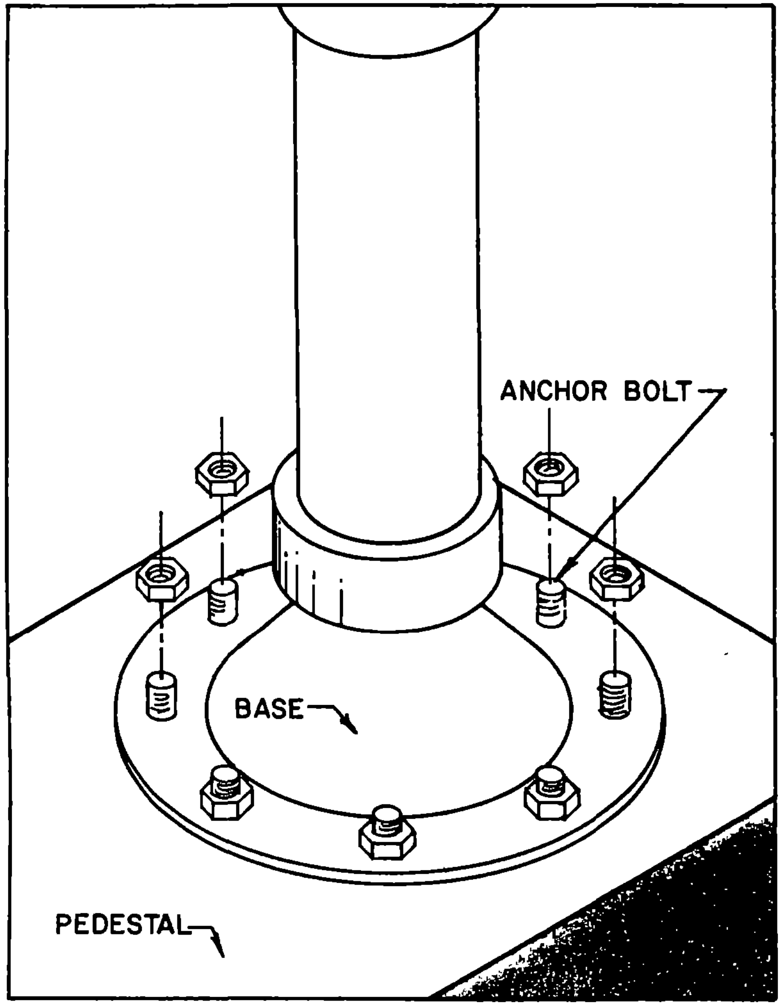


8C.10.3 MEDIUM-SET PUMP REPAIR

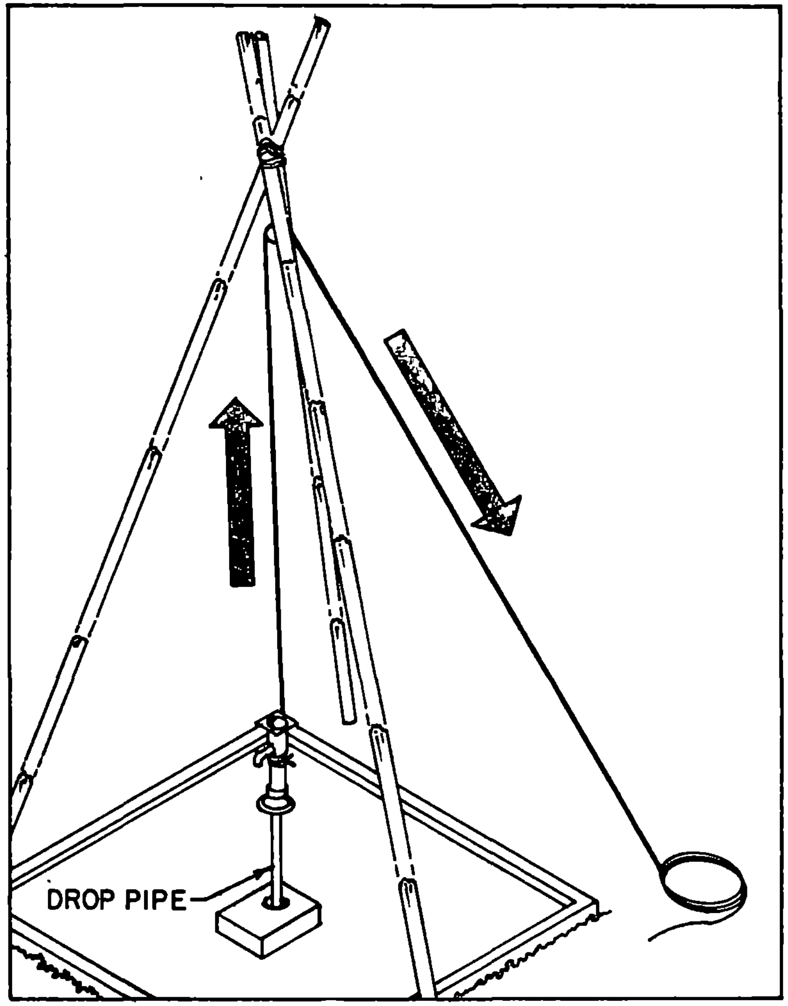
Unbolt the pump cap.



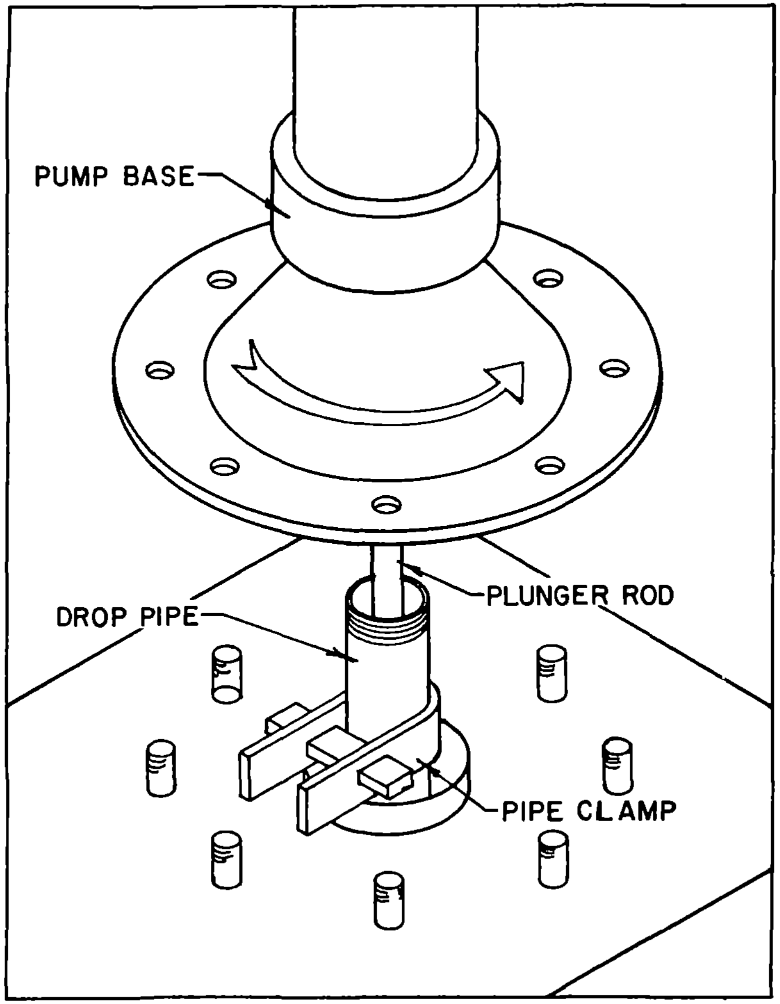
Disconnect the plunger rod assembly at the union.



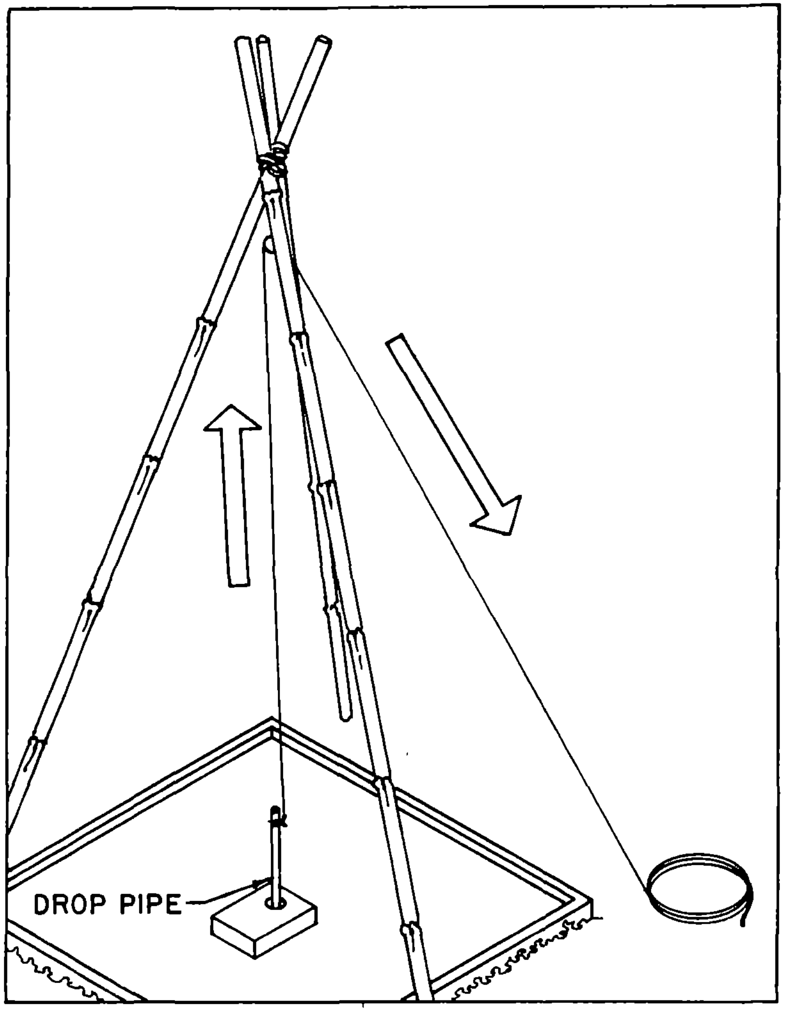
Unbolt the pump base from the pedestal.



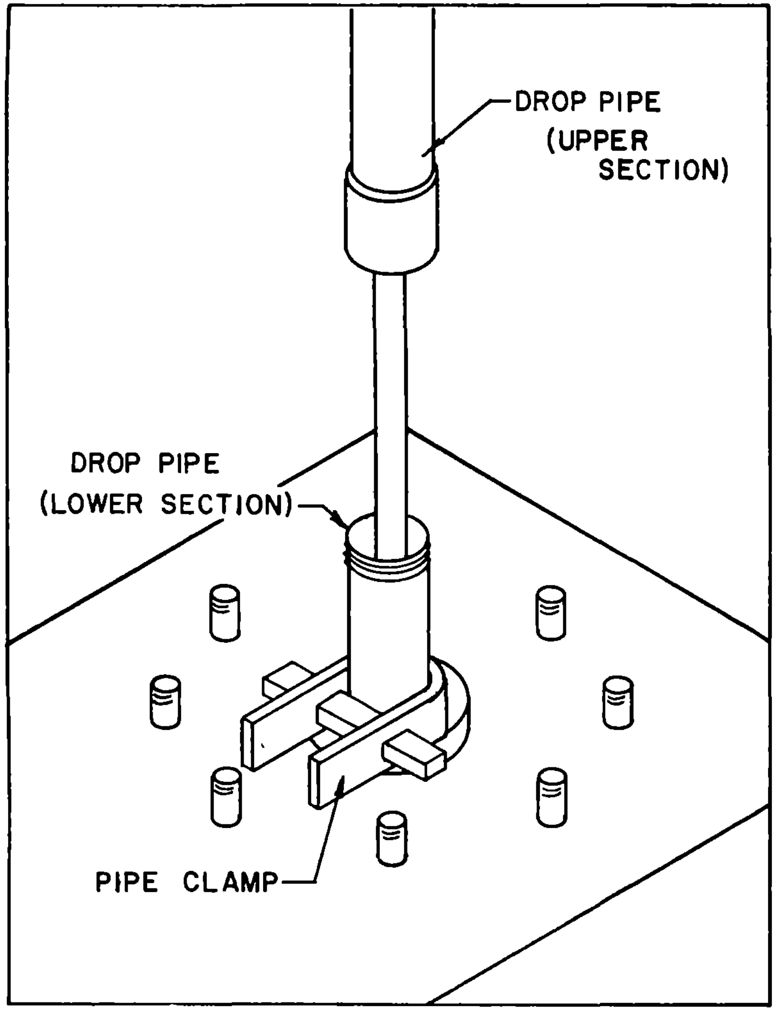
Raise the pump off the pedestal to allow access to the drop pipe.



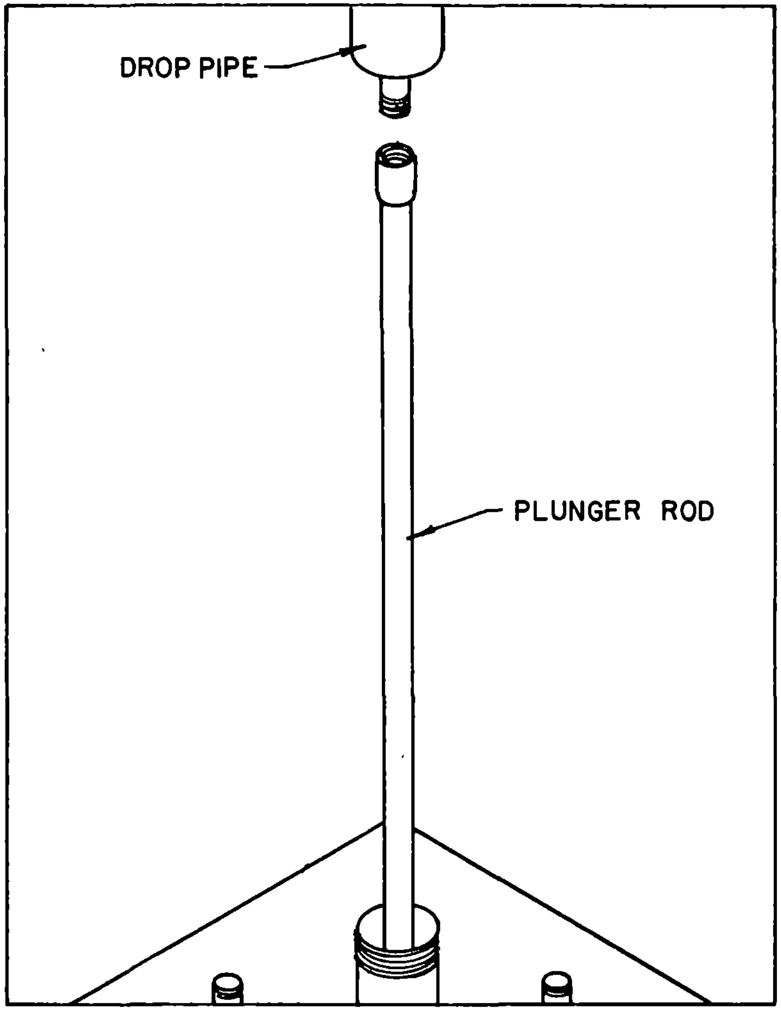
Unscrew the pump base from the drop pipe.



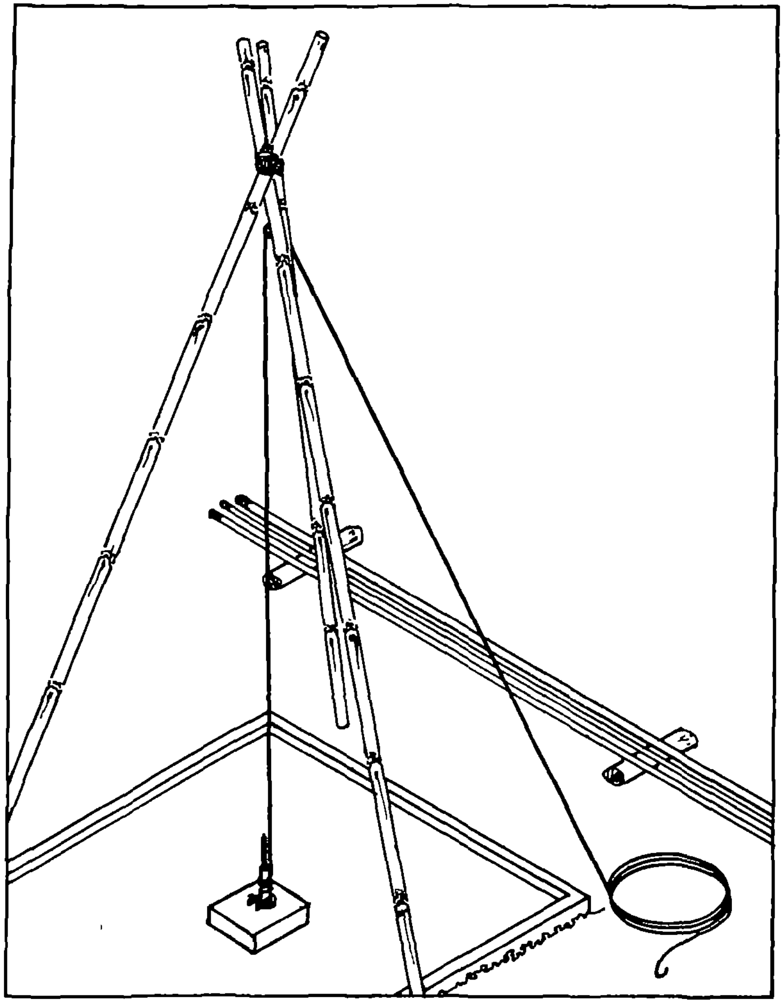
Raise the first length of drop pipe.



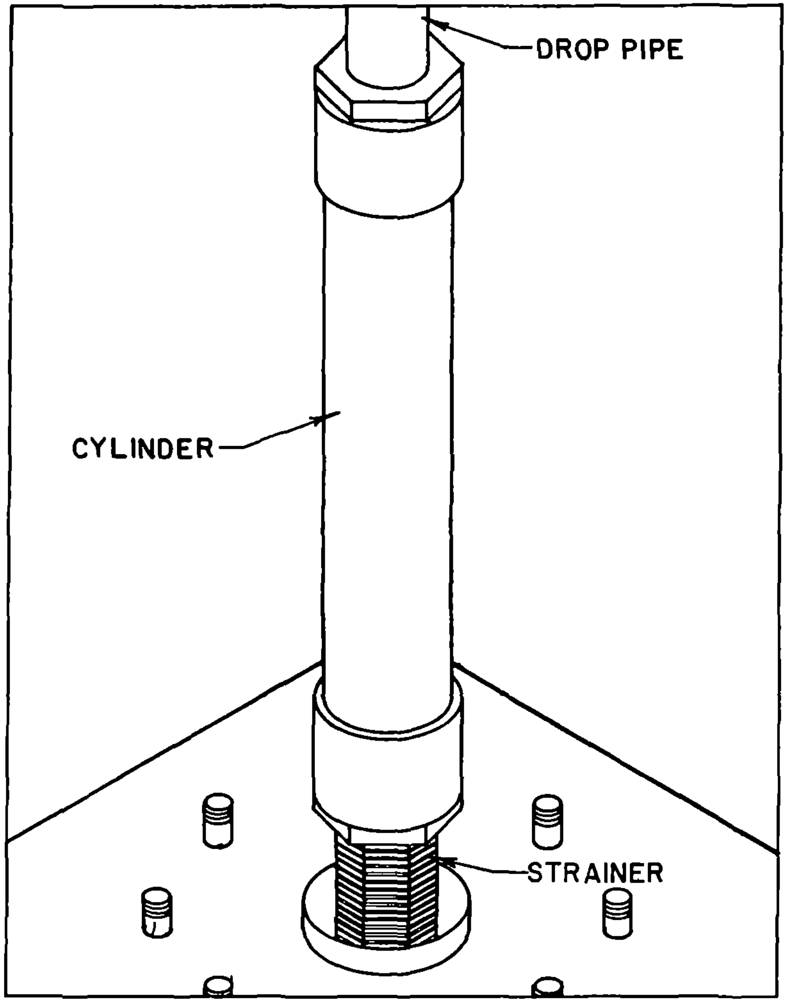
Disconnect the upper section of drop pipe from the lower.



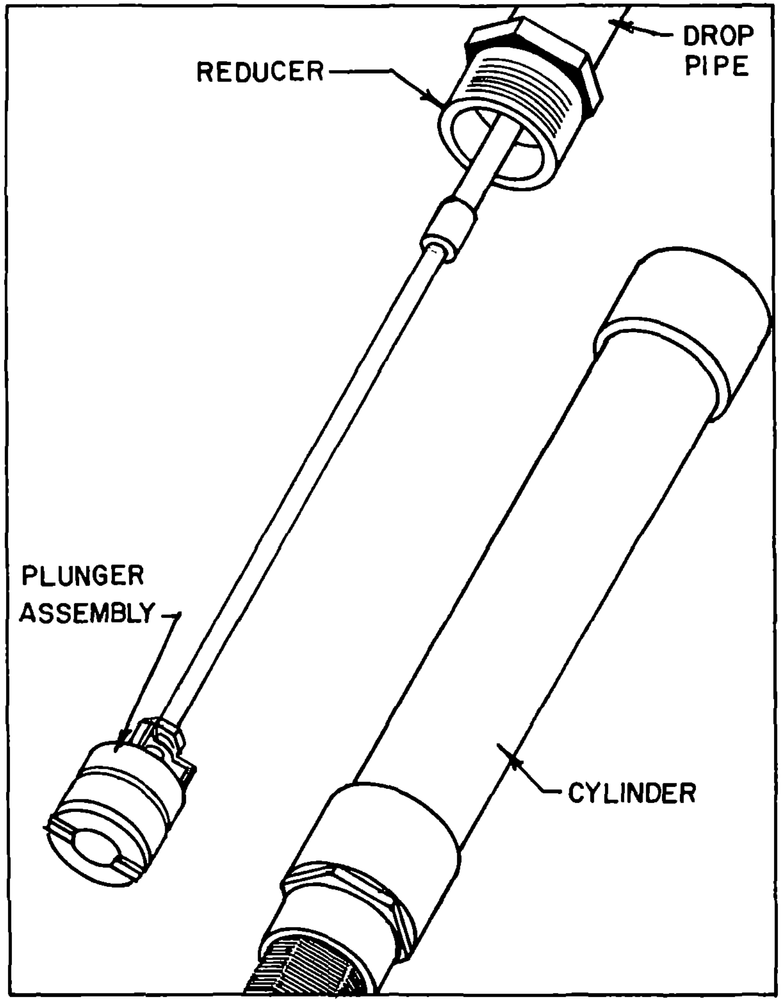
Raise the upper drop pipe section until the plunger rod connector is exposed. Unscrew the plunger rod sections.



Repeat the preceding two steps until all of the drop pipe and plunger rod have been removed from the well.

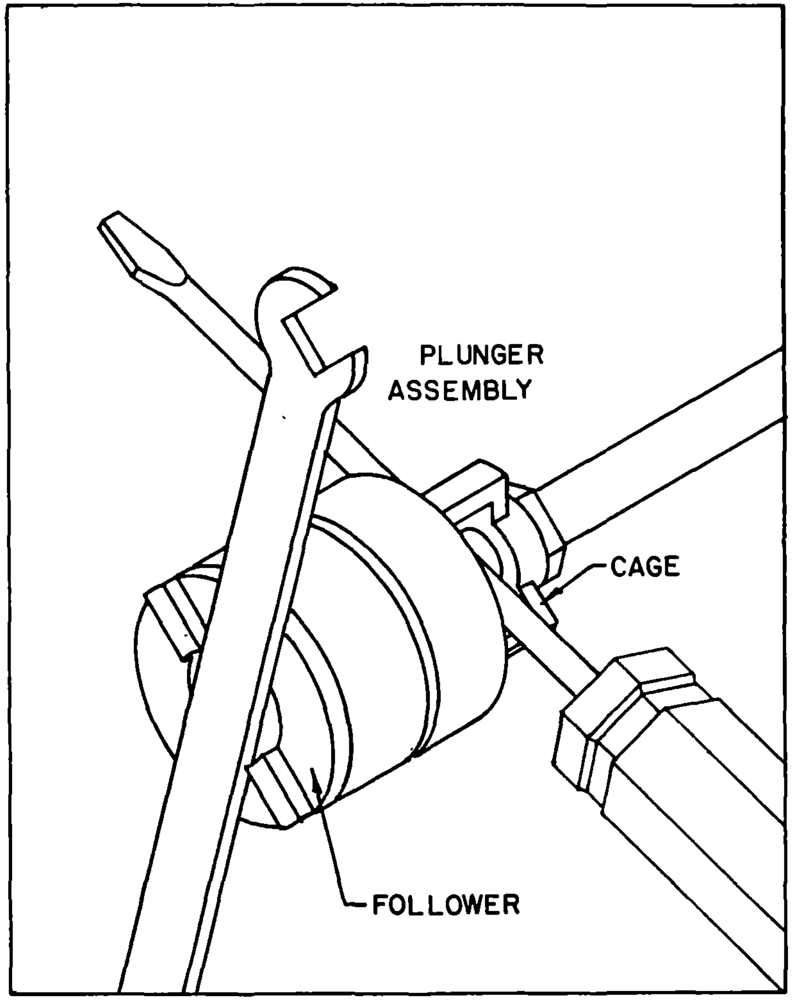


Remove the cylinder and strainer with the last section of drop pipe.

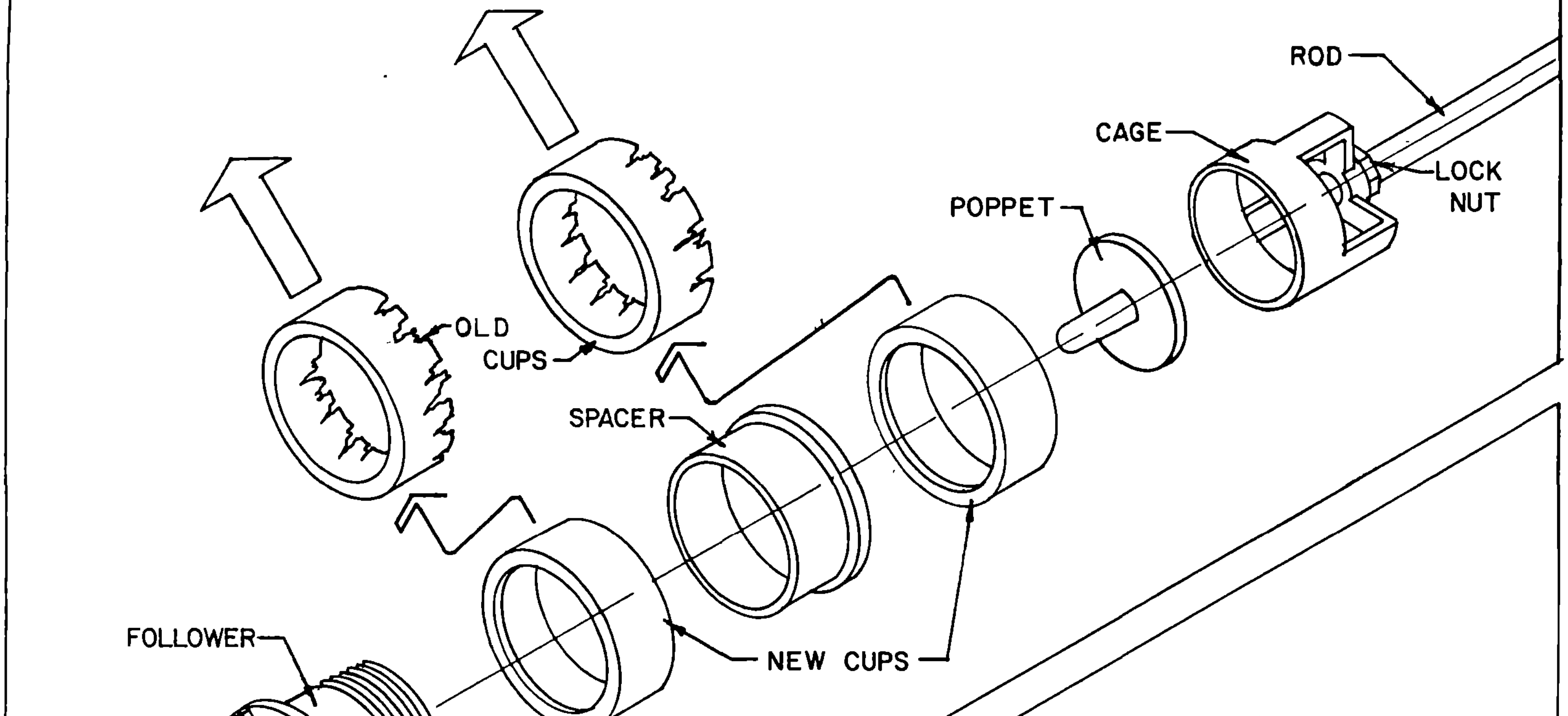


8C.10.3.1 CUP REPLACEMENT

Separate the cylinder from the drop pipe. Remove the plunger assembly from the cylinder.

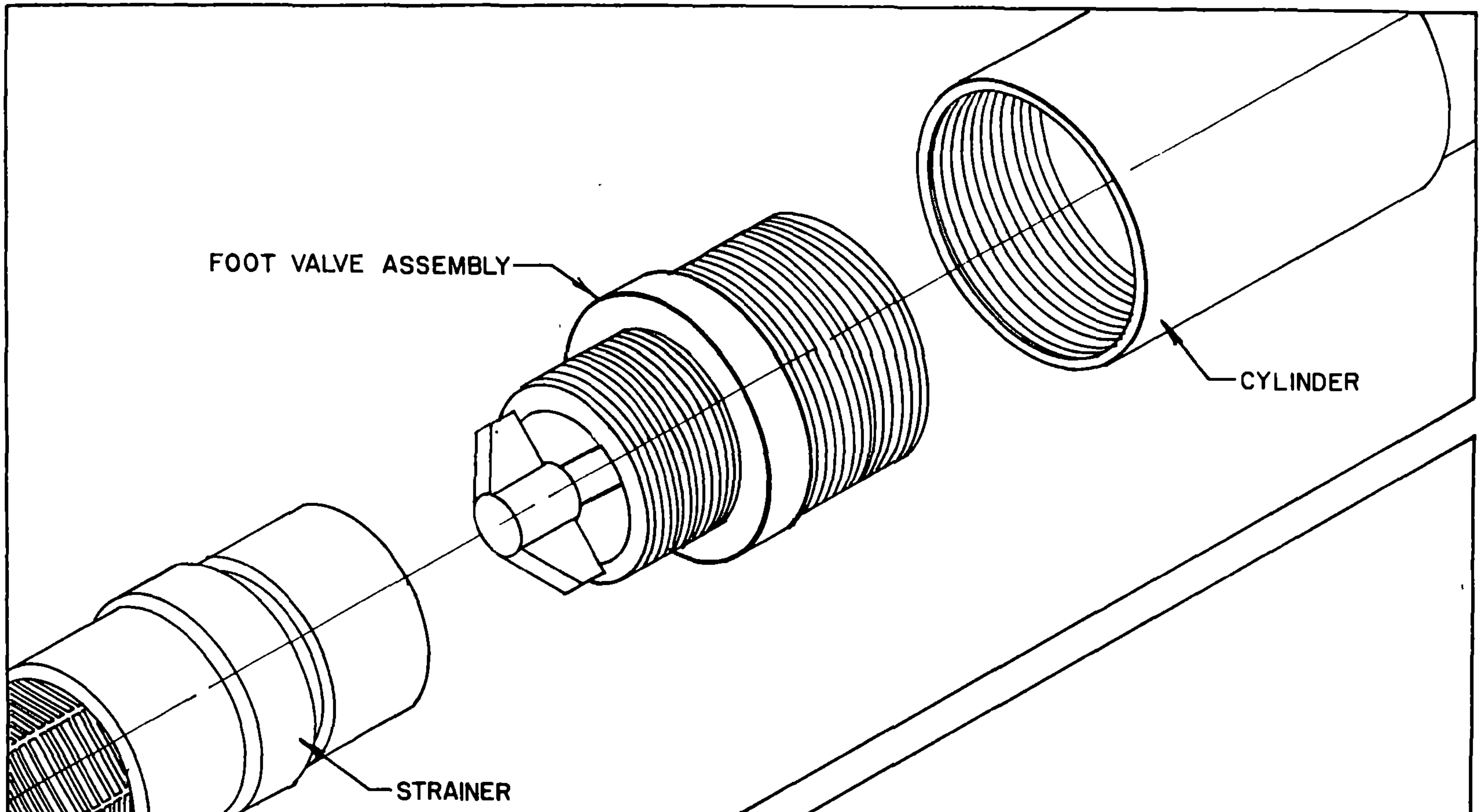


Unscrew the plunger assembly using a wrench and screwdriver as shown.



Remove the worn cups by sliding them off the plunger follower. Replace with new 2 1/8" Ø cups. Use only high quality cups as recommended by BWP personnel.

REASSEMBLY: Reassemble the plunger assembly as shown. Screw the pieces together firmly. Do not overtighten as this will make future disassembly more difficult. Ensure that the plunger rod does not protrude into the cage because it will reduce the poppet travel. Tighten the plunger rod lock nut firmly.

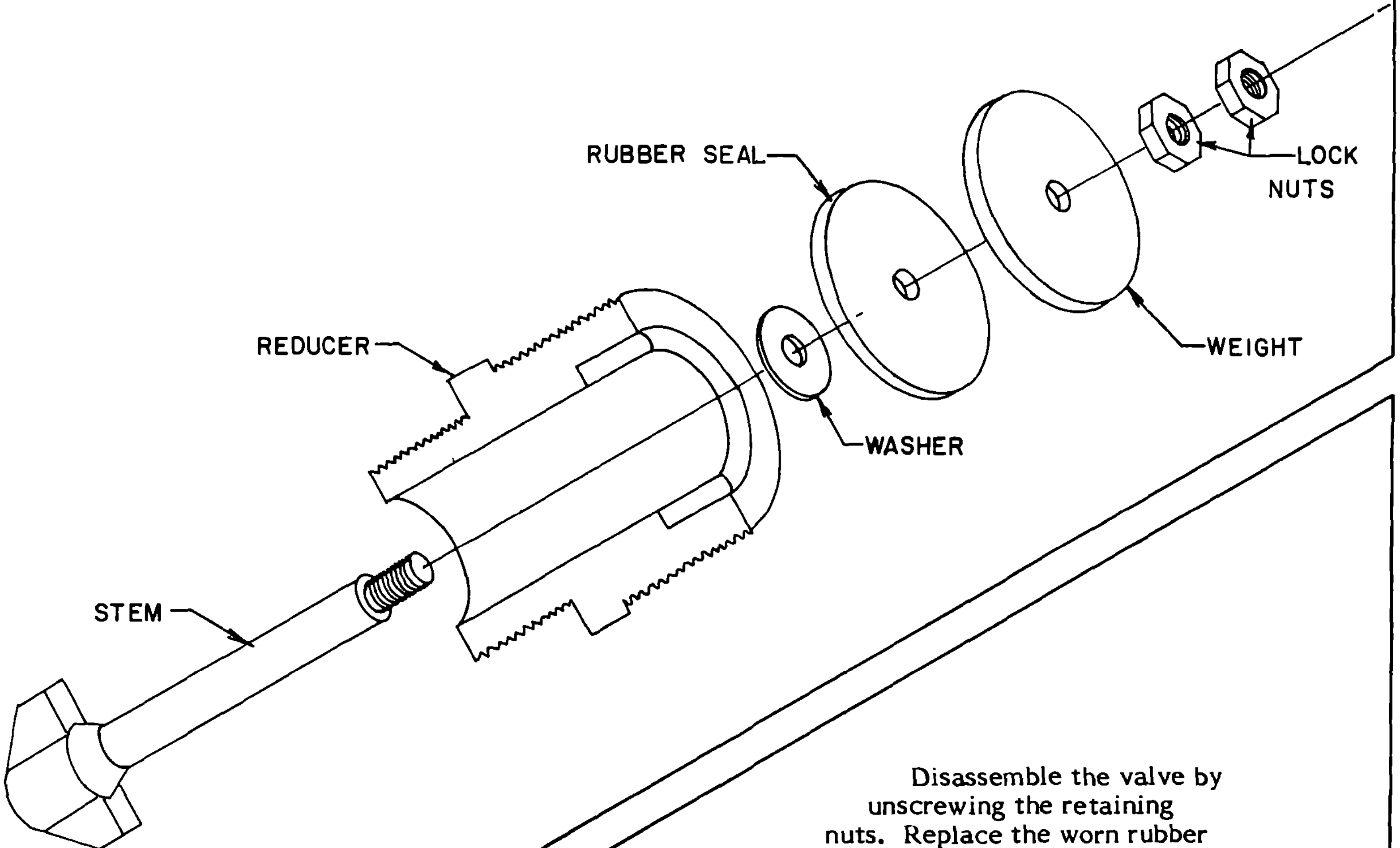


8C.10.3.2 FOOT VALVE REPLACEMENT

Disconnect the footvalve assembly from the cylinder and strainer.

MINISTRY OF LOCAL GOVERNMENT
BARANGAY WATER PROGRAM

PUMP REPAIR



Disassemble the valve by unscrewing the retaining nuts. Replace the worn rubber seal. Glue the new rubber seal to the weight with epoxy or rubber cement.

8C.10.4 Requesting Repairs

Repairs that are above the capabilities of the barangay shall be effected by the Water Works Repair Shop. WRS services for Level I shall be requested in the same manner as for the higher levels, as presented in Section 6.V.D. and 6.V.E.

8C.11 Spare Parts

8C.11.1 Barangay Level

Spare parts can be purchased by the water committee from a hardware store or through the WRS. Some pump components (especially deep-well components) are widely available while others (foot valves and plunger assemblies) are specialty products manufactured by a limited number of companies. The latter components will be held in inventory by the WRS of each LGU for purchase by the water committees.

The spare parts request to the WRS should be made in person with the desired parts already identified from the assembly drawing in the "Barangay Information Packet" or by presenting the part to be replaced. Positive identification facilitates repair and enhances health by reducing the time the pump is out of service because the wrong part was purchased.

8C.11.2 LGU Level

The WRS shall maintain a minimum number of spare parts in inventory depending on the number of installations being serviced. Orders for more spare parts should be placed the same day that the minimum inventory is reached.

The typical spare parts inventory of a WRS should include the following number of replacement components. The recommended inventory is given first and the minimum inventory second.

Component	Number of Installations		
	1-10	11-25	Every Additional 25
Shallow-Set Pumps			
Spare Pump	2 / 1	3 / 1	2 / 1
Plunger Cups	4 prs. / 2 prs.	5 prs. / 3 prs.	5 prs. / 3 prs.
Foot Valve Assembly	3 / 2	5 / 2	5 / 2
Medium-Set Pumps			
Spare Pump	2 / 1	3 / 1	2 / 1
Plunger Cups	4 prs. / 2 prs.	5 prs. / 3 prs.	5 prs. / 3 prs.
Foot Valve Assembly	3 / 2	5 / 2	5 / 2
Cylinder	2 / 1	3 / 2	3 / 2

Component	Number of Installations 1-10	11-25	Every Additional 25
Misc. Parts			
Long Pin	2 / 1	3 / 1	2 / 1
Short Pin	4 / 2	6 / 2	4 / 2
Long Bushing	6 / 3	6 / 3	6 / 3
Short Bushing	12 / 6	12 / 6	12 / 6
Deep-Set Pumps			
Cylinder	2 / 1	3 / 2	4 / 2
Foot Valve Assembly	3 / 2	5 / 2	4 / 2
Plunger Cups	4 prs. / 2 prs.	5 prs. / 3 prs.	5 prs. / 3 prs.
Spout Assembly	2 / 1	2 / 1	2 / 1
Yoke Assembly	2 / 1	2 / 1	2 / 1
Handle Assembly	2 / 1	2 / 1	2 / 1
Bearing Blocks	2 prs. / 1 pr.	2 prs. / 1 pr.	2 prs. / 1 pr.

8C.11.3 Reordering Spare Parts

The waterworks technicians shall be responsible for monitoring and maintaining inventory levels and shall initiate the reorder of pump components. Some pump components (especially deep-well components) are widely available and can be purchased in any provincial capital or city of similar size. Other components (e.g. foot valves, plunger assemblies, etc.) are manufactured by a limited number of companies. The lifetime and performance of a third category of components (plunger cups, bushings, and the medium-set and deep-set cylinder) are very dependent on component quality. These components should only be purchased from a supplier whose quality is known.

Below is a list of components available from Tri-Star Metal Industries, currently (1982) the only manufacturer of the shallow-set and medium-set hand pumps. Tri-Star's mailing address is: Tri-Star Metal Industries, Inc., 210 Jaboneros St., Binondo, Manila, Tel: 23-16-51 through 59.

Pump Parts Cost (1982 Est.)

	Shallow-Set	Medium-Set	Deep-Well Cylinder
Head	₱ 159.00	₱ 159.00	
Body	132.30	132.30	
Base	134.25	119.25	
Handle	134.25	74.40	
Fulcrum	27.75	27.75	
Slider Blocks (Set)	3.60	3.60	
Pins, Bushings (Set)	18.65	18.65	
Cylinder Body	73.95	45.65	
PVC Cylinder	-	74.35	74.35
Plunger Assy. Foot Valve Assy.	137.15	167.00	167.00
Pump, Complete	₱ 761.05	₱ 821.95	₱ 241.35

In addition to Tri-Star Metal Industries, Clayton-Mark leather plunger cups (made in USA) are imported by Rennnolds Co., Inc., P.O. Box 784, Manila; Plant: Km 21 South Super Highway, Montinglupa; Ph: 828-97-36 and also retailed by New Oregon Industrial in Manila. Clayton-Mark cups are of known high quality and are recommended for replacement of the original (Clayton Mark) plunger cups. A number of lower-cost, locally manufactured cups are available but they are not expected to wear as well as Clayton-Mark cups.

8C.12 Level I Monitoring

8C.12.1 Personnel

Level I monitoring shall be the responsibility of the Barangay Waterworks Repair Shop.

8C.12.2 Responsibilities

The Barangay Waterworks Technician shall perform the following functions as part of his monitoring responsibilities:

1. Arrange transportation suitable for the locations of the well sites.
2. Transport to the site the tools and spare parts listed below. Having suitable tools and spare parts to perform most repairs will reduce the amount to travel and field time required in monitoring.
3. Review the physical condition and operational status of the pump at each well site.
4. Complete the monitoring record sheet (Form No. 08C-4).
5. Maintain a current file on each well site.
6. Train persons in the recipient communities and barangays in hand pump maintenance and repair as set forth in this manual. To facilitate training, he shall distribute no less than two (2) copies of the "Barangay Information Packet" as described below to the barangay captain for each well site.
7. Coordinate and, later, effect any repair work that can not be undertaken on the monitoring visit.

8C.12.3 Tools

It is recommended that the waterworks technician take the following tools on monitoring trips to effect repairs as needed:

1 - pulley (or block and tackle)
1 - rope to make tripod from bamboos (if metal tripod unavailable)
1 - rope for pulley
1 - 18" pipe wrench
1 - 24" pipe wrench
2 - adjustable wrench
1 - pipe clamp
1 - steel brush
2 - shovel

The following items should also be taken:

Rags
Teflon tape
Grease

8C.12.4 Spare Parts

The following is a recommended supply of spare parts to have on hand for every five pumps to be visited when monitoring is conducted.

1 - deep well cylinder (for medium-set and deep-set pumps)
1 - deep well foot valve assembly
1 - shallow-set foot valve assembly
1 - set of deep well cups
1 - set of shallow-set cups

The actual ratios will vary depending on the total numbers of shallow-set, medium-set, and deep-set pumps.

8C.12.5 Monitoring Record Sheet

The monitoring record sheet (BW Form No. 08C-4) is found at the end of Section 8C. A line by line explanation of the sheet is as follows:

1. Date - Date of monitoring visit.

2. Pump Conditon - Condition as Good (G), Fair (F) or Poor (P). Good indicates that the pins are tight and operation is like new. Fair means the pins and cups are getting loose or that the pump has been repaired with substandard components. Poor indicates that pieces of the pump are broken or missing or the pump is inoperable.

3. Pump Maintenance - A rating of Good means the water committee is regularly lubricating the pump and initiating repair work as it is needed. Fair indicates occasional lubrication and delay in initiating repair work. A Poor ranking indicates that pump maintenance is being ignored.

4. Apron Condition - A Good rating indicates that there are no cracks or chips in the apron, pedestal, water curb or drain. Fair denotes cracks or chips that do not allow waste water into the soil through the apron or drain. Poor means that water can pass through the apron or the drain, possibly contaminating the well.

5. Apron Maintenance - Maintenance refers to the cleanliness of the well site. Good means the apron is clean and that there are no pools of waste water or animal manure within 15 meters of the site. Fair indicates that there are no pools of waste water nor animal manure within 15 meters of the site but that the site is not swept and neat. A rating of Poor means that site maintenance is neglected.

6.Flow Rate - Place a 19 liter square cooking oil bucket under the pump spout and count the number of strokes required to fill the bucket. A new shallow-set pump should take about 18 to 20 strokes and a new medium- or deep-set pump around 55 to 60 strokes.

7. Leak Rate - Allow the pump to stand idle for 15 minutes. Begin pumping and count the number of strokes before water is pumped. Record the number of strokes.

8. Pumping Difficulty - Pumping difficulty can be determined from the users but, of course, will vary from barangay to barangay. H -Hard, A - Average, E -Easy.

9. Water Availability - The times of the day and year when water is not available in sufficient quantities for the needs of the community should be recorded. If insufficient supplies persist over a long period of time or progressively worsen, deepening the well or drilling an additional well should be investigated.

10. Water Acceptability - The users find the water acceptable to drink (Good-G) or unacceptable (No Good - NG).

11. Water Quality - Results of the total coliform test, when performed, are recorded in parts-per-million (ppm).

12. Parts Replaced - Note all the parts replaced since the last monitoring visit. Elaborate if necessary under "Comments" at the bottom of the monitoring sheet.

13. Initials of person making the monitoring visit on that date.

Any line that is rated Poor or No Good should be explained under "Comments" and the plan of corrective action outlined. Be sure to date each comment as it is entered.

8C.12.6 Level I File

A section of the files holding the Barangay Water Program records for the LGU shall be designated the Level I File and marked as such. Each Level I activity shall be kept in a separate folder to facilitate locating well data for monitoring purposes. The folders can be sorted alphabetically or, preferably, in order of the monitoring circuit. It is the responsibility of the waterworks technician to maintain and update regularly the Level I File.

The following information shall be stored in the Level I File:

Letter of Authority	- Attachment 05A-3
Tech Description and Cost Estimate	- BW Form No. 06A
Plans and Specifications	- Attachment 06A-1
Map of Barangay	- Attachment 06A-2
Site Selection Checklist	- BW Form No. 08C-1
Installation Data Sheet	- BW Form No. 08C-2
Project Approval Checklist	- BW Form No. 08C-3
Final Inspection Report	- BW Form No. 14A
Monitoring Record Sheet	- BW Form No. 08C-4

8C.12.7 Monitoring Circuit

Each LGU shall establish a monitoring circuit by grouping a number of well sites within a reasonable proximity into one-day monitoring trips. The monitoring circuit shall be regularly updated to include new projects as they are completed. Manpower and financial resources shall be budgeted based on the requirements of the monitoring circuit.

The monitoring circuit shall be repeated every three (3) months.

The monitoring of a well site shall commence two weeks after initial installation. A second monitoring visit shall be made one month after the first. The well site shall then be incorporated into the monitoring circuit where monitoring shall be conducted tri-monthly.

8C.12.8 Training of Local Repairmen

Training shall be conducted informally, utilizing the learning-by-doing method as the waterworks technician effects repairs. The barangay captain shall select persons with mechanical aptitude and interest to assist the waterworks technician with repairs and eventually to undertake repairs of lesser difficulty.

8C.12.9 Barangay Information Packet

Two copies of the "Barangay Information Packet" shall be distributed to the barangay captain for each well site under his jurisdiction.

The "Barangay Information Packet" shall consists of the following:

Cover letter BW Form No. 08C-5 (completed by waterworks technician)
Assembly Drawing of Installed Pump (either Figure 8C-1 or 8C-5)
Trouble-shooting Guide (Section 8C.8)
Maintenance (Section 8C.9)

The "Barangay Information Packet" may be photocopied directly from this manual.

SITE SELECTION CHECKLIST

		DATE	INITIAL
1.	Located at least 15 meters (50 ft.) from:		
	a) Sanitary facilities (toilets, etc)	________	________
	b) Open wells	________	________
	c) Agricultural fields	________	________
	d) Bodies of water	________	________
	e) Livestock pens	________	________
2.	Located above known flood level	________	________
3.	Adequate drainage available	________	________
4.	Located on public or donated land	________	________

BW Form No. 08C-2

INSTALLATION DATA SHEET

Name of Site: ______________________________

Type of Pump: ______________________________

Date of Installation: ______________________________

Depth of Well: ______________________________

Depth to Static Water Level: ______________________________

Depth of Cylinder: ______________________________

Length of Suction Pipe: ______________________________

Casing Diameter: ______________________________

Suction or Drop Pipe Diameter: ______________________________

Plunger Rod Diameter: ______________________________

Strainer - Type, Diameter, Length: ______________________________

Pump Flow Rate (Liters/Stroke): ______________________________

Pump Leak Rate (# of strokes to get water, after waiting 15 minutes): __________

____

Additional Information/Comments: ______________________________

____

____

____

____

____

____

____

____

____

BW Form No. 08C-3

PROJECT APPROVAL CHECKLIST

Name of Site:______________________________

Depth of Well:______________________________

Depth to Water Level: ____________________

Depth of Cylinder:__________________________

Casing Diameter:____________________________

Suction or Drop Pipe Dia: ________________

Plunger Rod Diameter: ____________________

Strainer - Type, Diameter & Length:_____

____

Shallow-Set and Medium-Set Pumps	Date	Initial
1. Apron is at least 3 m by 3 m in area	______	______
2. Concrete drain extends 5 m from the apron	______	______
3. Water does not stand on apron but is drained off rapidly	______	______
4. The casing extends at least 2 cm above the top of the pedestal (water barrier)	______	______
5. Water curb around apron is at least 4 cm in height	______	______
6. Pump located at comfortable height for users	______	______
7. Gravel spread liberally around apron (about 1½ m on all sides) and all low spots drained	______	______
8. Concrete mixture of class C or better	______	______
Medium-Set and Deep-Set Pumps		
9. Drop pipe is schedule 40	______	______
10. Cylinder is located sufficiently deep to guarantee adequate water year-round	______	______
11. Teflon tape or equivalent used at all joints in cylinder, drop pipe and plunger rod	______	______
Deep-Set Pumps		
12. Design conforms to BWP Specifications	______	______
Length of Handle (__________cm long)		______
Pivot pin		______
Handle reinforcing plate		______
Plunger rod stirrup		______
Height of handle (__________cm to pivot)		______

Rev. 8/82

BW Form No. 08C-4

MONITORING RECORD SHEET

Well Location ____________________ Date of Installation ____________________

1. Date								
2. Pump Condition (G, F, P)								
3. Pump Maintenance (G, F, P)								
4. Apron Condition (G, F, P)								
5. Apron Maintenance (G, F, P)								
6. Flow Rate (# of strokes)								
7. Leak Rate (# of strokes)								
8. Pumping Difficulty (H, A, E)								
9. Water Availability								
10. Water Acceptability (G, NG)								
11. Water Quality (in ppm)								
12. Parts Replaced								
13. Monitoring Conducted By:								

Comments and Recommended Plan of Action ____

____

____

____

____

____

BW Form No. 08C-5

Date________________________

To: ________________________

Head of Water Committee

Address: ________________________

____

____

From: ________________________

____

Names of Waterworks Technicians

Address: ________________________

____

Name of site: ____________________

Type of pump: ____________________

Date of installation: ________________

Depth of well : ____________________

Depth to water: ____________________

Depth to cylinder or length of suction pipe:

____

Reference: BWP/MLG HAND PUMP PROJECT TURNOVER

This letter is to confirm the completion and turnover to the Water Committee of your hand pump by the Barangay Water Program and the Ministry of Local Government. The well and pump data are listed above. Attached is an assembly drawing of your pump, a trouble-shooting guide to diagnose pump problems, and a maintenance guide. Please use the first two attachments when reporting pump problems.

A waterworks technician will be making a monitoring visit about every three months to review the installation. Repairs can be made at this time. In addition, should a pump fail between monitoring visits, please notify one of the waterworks technicians at the above address. We will make the necessary repairs as soon as possible. Please make provisions for two men to assist us in the making of repairs.

Repairs will be charged to the water committee as set forth in the BWP Operations Manual, Sections 6.V.D and 6.V.E.

Thank you for your continued cooperation.

Signed________________________

____

Appendix 8C.A

USAID Hand Pump History

Appendix 8C.A
USAID Hand Pump History

USAID/BWP identified the need to provide Level I sub-systems in its service areas in the late 1970's but hesitated to proceed with such a program because of the observed poor performance of the existing hand pumps. A USAID consultant who conducted a study of hand pump installations in July and August 1981 summarized the situation as follows:[5]

> Almost all hand pumps in use in the Philippines are of one of two types: jet-matic (trade named Jet-matic, Fuji, Dragon, Wilson, etc.) or traditional (also called Liberty or Magsaysay). The majority of users prefer the jet-matic type because it is easier to pump and to maintain. However, the poor quality of the jet-matic pumps causes the need for frequent repairs and pump replacement. The traditional hand pumps are generally more durable but often are constructed with inferior workmanship and low quality materials. LGU's were finding that they also required a week or more to construct the pump superstructures.
>
> Below are characteristics of the jet-matic and traditional hand pumps:

JET-MATIC

- Designed for single family use
  - Thin cast parts
  - Small bearing surfaces
  - Inexpensive materials
- Poor quality control
  - Casting defects (sometimes epoxied over)
  - Poorly machined surfaces
- Limited to shallow wells
  - Limited applicability
  - Greater likelihood of surface contamination
- Low cost
- Easy to operate and maintain
- Wide availability of spare parts

TRADITIONAL

- Superstructure made from locally available materials
  - Easy to procure or fabricate
  - Repairable by users
- Requires field assembly
  - Minimal quality control
  - Time consuming, labor intensive

- Cylinder repairable with use of tripod
- Handle length adjustable to suit depth of well
- Cumbersome or "heavy" operation

In the mid-sixties, USAID conducted a similar study on a worldwide basis. The generalized inadequacies of existing pumps were identified as:

- Insides of cylinders too rough
- Plunger cups improperly sized (generally too large)
- Highly stressed fulcrums and handles, frequently made worse by poor alignment and tolerances
- Bearing surfaces too small
- Valve seats poorly cast and machined
- Fasteners (bolts and nuts) poorly made

Based on this information, a hand pump was designed and constructed for USAID with the following improvements:

- Use of smooth inside diameter PVC cylinders and sleeves
- Correctly sized cups
- Fulcrum and handle adequately sized and designed to minimize stress
- Large (5/8" Ø) and hardened bearing surfaces
- Technical assistance for quality control and dimensional accuracy rendered to foundry/machine shop.

Through field testing in twelve countries to date (1982), further design and production modifications and improvements have been made. The results of the field testing show the pump to be very sturdy with maintenance requirements of regular pump lubrication and periodic cup and foot valve replacement due to normal wear. A local example of pump durability is five USAID hand pumps produced in Indonesia and installed in Pangasinan in early 1980. Observed almost twenty months later, the superstructure showed little visual signs of wear (the deep-well cylinders were not of USAID design), although one pump had significantly more than the recommended 200 users (the barangay captain reported 1,500 users).

In mid-1981, a Metro-Manila foundry/machine shop was contracted to produce the USAID hand pump for use in the Barangay Water Program's Level I activities. Ten test pumps were installed during the last quarter of 1981. Feedback from the test pumps led to several minor design and assembly modifications before the quality and suitability of design for the Philippines was accepted by the USAID consultant and the pump recommended for use by the Barangay Water Program. In April 1982, the supervision of pump manufacturing was turned over to BWP/USAID personnel.

Appendix 8C.B

Concrete Primer

Appendix 8C.B

CONCRETE PRIMER[6]

A. Introduction to Cement

Cement is one of the most useful materials in well construction. It can easily be mixed with sand and water to make mortar or with gravel, sand and water to make concrete. Both mortar and concrete are among the strongest and most durable materials used for all types of construction around the world. Mortar is normally used as the bonding agent between bricks or rocks while concrete is normally reinforced with steel bars and molded to the desired size and shape.

For well work, mortar or concrete is usually the best material for the lining, headwall, platform and cover of dug wells, and the platform and seal around the top three meters of casing in drilled wells.

Cement is available in almost every country in the world. Sand and gravel are usually available locally. Occasionally it will be difficult to get cement for well construction either because there are other higher priority demands for the cement or because it is too expensive. It is impossible here to say how or even whether cement can be obtained in such a circumstance.

Of the two cement compounds, mortar and concrete, concrete is the stronger. This is because the rock that makes up the gravel itself is stronger than the concrete and so contributes to its strength. Sometimes the two can be used interchangeably where lack of materials or working conditions demand it. Remember that concrete is the stronger product and should be used where possible.

NOTE: The rest of the discussion in this appendix will deal specifically with concrete. The same procedures can and should be followed if mortar is used instead.

B. Ingredients of Concrete

Concrete is made from cement, sand, gravel and water. These ingredients are combined in certain proportions to achieve the desired strength. The amount of water used to mix these ingredients is by far the most important factor in determining the final strength of the concrete. Use the least amount of water that will still give you a workable mix. Sand and gravel, which are sometimes referred to as fine and coarse aggregate respectively, should be clean and properly graded. Cement and water form a paste which, when mixed, acts as a glue to bind the aggregates together in a strong hard mass.

1. Proportions:

- There are four major ingredients in concrete: cement, sand, gravel, and water.
- Dry ingredients are normally mixed in certain proportions and then water is added. Proportions are expressed as follows: 1:2:4, which means that

to one part cement you add two parts sand and four parts gravel. A "part" usually refers to a unit of volume. Example: A 1:2:4 concrete mix could be obtained by mixing 1 bucket full of cement with 2 buckets of sand and 4 buckets of gravel.

- Proportions are almost always expressed as cement: sand: gravel, and they are usually labelled that way.

- There are many minor variations in the proportions used for mixing concrete. The most commonly used are 1:2:4, 1:2:3, 1:2.5:5. For purposes of well construction, all work equally well.

  NOTE: A 1:2:4 mix will go a little farther than the 1:2:3 mix and allows a little more room for using less than the best grade of sand or gravel than a 1:2.5:5 mix.

- Normal range for amount of water used to mix each 50 kg bag of cement is between 20 liters and 30 liters (94 lb. bag of cement is between 4.5 gal. and 7 gal.)

- The water-tightness of concrete depends primarily on the water/cement ratio and the length of moist curing. This is similar to concrete strength in that less water and longer moist-curing promote water-tightness.

2. Choice of Ingredients

- Cement: The descriptions and properties given in this appendix are specifically of Portland cement. This is the type most commonly used and hereafter will be referred to only as cement.

  When used, it should be dry, powdery and free of lumps. When storing cement, try to avoid all possible contact with moisture. Store it away from exterior walls, off damp floors, and stacked close together to reduce air circulation. If it could be kept completely dry it could be stored indefinitely. Even exposed to air it will gradually draw moisture, thus limiting even the covered storage time to between 6 months and 1 year depending on conditions.

- Water: In general, water fit for drinking is suitable for mixing concrete. Impurities in the water may affect concrete setting time, strength, shrinkage or promote corrosion of reinforcement.

- Aggregates: Fine and coarse aggregates together occupy 60% to 80% of concrete volume.

  - Fine aggregate: Sand should range in size from less than .25 mm to 6.3 mm. Sand from sea shores, dunes or river banks is usually too fine for normal mixes. (You can sometimes scrape about 30 cm of fine surface sand off and find coarser, more suitable sand beneath it.)

  - Large Aggregate: Within the recommended size limits mentioned later, the larger the gravel you use the stronger and more economical the concrete will be.

- The larger the size of the gravel the less water and cement will be required to get the same strength concrete.

- The maximum gravel size should not exceed:

  - one-fifth the minimum dimension of the member;
  - three-fourths the clear space between reinforcing bars or between reinforcement and forms. (Optimum aggregate size in many situations is about 2.0 cm.)

The shape and surface texture of aggregates affect properties of freshly mixed concrete more than they affect hardened concrete. Rough textured or flat and elongated particles require more water to produce workable concrete than do rounded or cubical aggregates and more water reduces the final strength of the concrete.

It is extremely important to have the gravel and sand clean. Silt, clay, or bits of organic matter, even in low concentrations, will ruin concrete. A very simple test for cleanliness makes use of a clear widemouth jar. Fill the jar about half full of the sand and small aggregate to be tested, and cover with water. Shake the mixture vigorously, and then allow it to stand for three hours. In almost every case there will be a distinct line dividing the fine sand suitable for concrete and that which is too fine. If the very fine material amounts to more than 10% of the suitable material, then the concrete made from it will be weak.

This means that other fine material should be sought, or the available material should be washed to remove the material that is too fine. This can be done by putting the sand (and gravel if necessary) in some container such as a drum. Cover the aggregate with water, stir thoroughly, let stand for a minute, and pour off the liquid. One or two such treatments will remove most of the very fine material and organic matter.

Another point to consider in the selection of aggregate is its strength. About the only simple test is to break some of the stones with a hammer. If the effort required to break the majority of aggregate stones is greater than the effort required to break a similar sized piece of concrete, then the aggregate will make strong concrete. If the stones break easily, then you can expect that the concrete made of these stones will only be as strong as the stones themselves.

In very dry climates several precautions must be taken. If the sand is perfectly dry, it packs into a smaller space. If 20 buckets of dry sand are put in a pile and two buckets of water stirred in, you could carry away about 27 buckets of damp sand. If your sand is completely dry, add some water to it or else measure by weight instead of volume. The surface of the curing concrete should be kept damp. This is because water evaporating from the surface will remove some of the water needed to make concrete properly. Cover the concrete with building paper, burlap, straw, or anything that will hold moisture and keep the direct sun and wind from the concrete surface. Keep the concrete moist by sprinkling as often as necessary; this may be as often as three times per day. After the first week of curing, it is not necessary to keep the surface damp continuously (see "Curing Concrete" below).

3. Estimating Quantities of Materials Needed

   1. Calculate the volume of concrete needed.

   2. Multiply the volume of concrete needed by 3/2 (1.5) to get the total volume of dry loose material needed. The cement and sand do little to add to the volume of the concrete because they fill in the air spaces between the gravel.

   3. Add 10% (1/10) for losses due to handling.

   4. Add the numbers in the volumetric proportion that you will use to get a relative total. This will allow you later to compute fractions of the total needed for each ingredient (1:2:3 = 6).

   5. Determine the amount of cement needed by multiplying the volume of dry material needed (from step 2) by the proportional amount of the total mix (e.g., amount cement needed = 1/6 x volume dry materials).

   6. Divide by the unit volume per bag, 33.2 liters per 50 kg bag cement or 1 cubic foot per 94 lb. bag cement. When figuring the number of cement bags round up to nearest whole number.

      NOTE: This calculation, even with the 10% addition for handling losses, rarely leaves any extra concrete, particularly for small jobs requiring less than 5 hand-mixed bags of cement.

C. Construction with Concrete

1. Outline of Concrete Work:

   - Build form (8C.5.2)
   - Place rebar (8C.5.3)
   - Mix concrete (8C.5.4)
   - Pour concrete (8C.5.4)
   - Remove forms (8C.5.4)
   - Finish surface (8C.5.4)
   - Cure concrete (8C.5.4)

2. Materials for Forms

   The following materials are used to construct interior forms:

   - Steel: forms made of steel are durable and strong but are heavy, awkward, and expensive.

   - Sheet metal: with a simple triangular interior support, forms made of sheet metal have proved to be successful. They are lighter and more maneuverable than steel forms but are not as strong and durable.

   - Wood: this material is commonly used because it is lightweight and strong. It must be carefully bent, waterproofed, and reinforced.

By using boards as wide as possible, form construction is easier and quicker. It also reduces the number of lines on the concrete surface that form at the junction of two boards. Plywood is excellent, especially if it has a special high density overlay surface. This allows for a smoother concrete finish, easier form removal and less wear on the forms.

If unsurfaced wood is used for forms, oil or grease the inside surface to make removal of the forms easier and to prevent the wood from drawing too much water from the concrete. Do not oil or grease the wood if the concrete surface will be painted or stuccoed.

- Earth: Any earth that can be dug into and still hold its shape can also be used as a form. Carefully dig out the desired shape and fill it with concrete. Once the concrete has set and cured it can be dug up and used where needed. A new form will have to be dug out for each piece of concrete poured.

- Other materials: Plastics and fiberglass are also occasionally used and continue to be experimented with as form materials. Fiberglass is much lighter than steel and, if handled carefully, lasts for a long time. Its cost and availability in developing nations seem to be the only factors limiting more widespread trials.

3. Concrete Reinforcement

Reinforcing concrete will allow much greater loads to be carried. Design of reinforced concrete structures that are large or must carry high loads can become too complicated for a person without special training.

Concrete alone has great compression strength but little tensile strength. Concrete is very difficult to squeeze (compression), but breaks relatively easily when stretched (put in tension). Reinforcing steel has exactly the opposite properties; it is strong in tension and weak in compression. Combining the two results in a material (reinforced concrete) which is strong in both compression and tension and therefore useful in a large number of situations.

Concrete is best reinforced with specially made steel rods which can be imbedded in the concrete. Bamboo has also been used to reinforce concrete with some success although it is liable to deteriorate with time.

- Reinforced concrete sections should be at least 7.5 cm thick although 10 cm is preferable.

- The reinforcing bar (rebar) usually comes in long sections of a given diameter.

- Exactly how much rebar is needed in a particular pour will depend on the load it will have to support. For most concrete work, including everything discussed in this manual, rebar should take up 0.5% to 1% of the cross-sectional area.

- Reinforcing bars should also have clean surfaces free of loose scale and rust. Bars in poor condition should be brushed thoroughly with a stiff wire brush.

- When placing rebar in a form before the concrete is poured it should be located:

  - at least 2.5 cm from the form everywhere.
  - in a plane approximately one-third of the way into the thickness of the pour from the bottom of the structure or slab.
  - in a grid so that there is never more than three times the final concrete thickness between adjacent bars.
  - no closer than 3 cm to a parallel bar.

- Rebar strength is approximately additive according to cross-sectional area. Four 4 mm rebars will be about as strong as one 8 mm rebar. The cross-sectional area of four 4 mm rebars equals the cross-sectional area of one 8 mm rebar.

- The rebars should be arranged in an evenly spaced grid-type pattern with more and/or thicker rebar along the longest dimension of the pour.

- All intersections where rebars cross should be tied with thin wire.

- When one rebar is tied onto another to increase the length of the rebars, the overlap should be 20 times the diameter of the rebar and be tied twice with wire.

Rebar Size	Overlap
6 mm	12 cm
8 mm	16 cm
10 mm	20 cm
12 mm	24 cm

- Larger sizes of rebar often have raised patterns on them which are designed to allow them to be held firmly in place by the concrete. Smaller sizes of rebar are generally smooth. When using smooth rebar always make a small hook at the end of each piece that will be in the concrete. Without the hook, temperature changes may eventually loosen the concrete from the rebar thereby destroying much of its reinforcing effect.

- Rebar should be carefully prepared so that the rebar is straight and square. Sloppy rebar work will result in weaker concrete and waste rebar.

- For particularly strong pieces or where small irregular shapes are being formed, the rebar can be put together in a cage-like arrangement. Use small rebar for the cross-sections and larger rebar for the length. This system is used to reinforce pieces like a cutting ring, with its irregular shape, or perhaps a well cover, which may have many people standing on it at one time.

- Where possible, it is usually best to assemble rebar inside the form so that it will fit exactly.

- The proper distance from the bottom of the pour in a slab can be achieved by setting the rebar on a few small stones before the concrete is poured or simply pulling the rebar grid a couple of centimeters up into the concrete after some concrete has been spread over the whole pour.

4. Mixing Concrete by Machine or by Hand

a. Mixing by Machine

Concrete must be thoroughly mixed to yield the strongest product. For machine mix, allow 5 or 6 minutes after all the materials are in the drum. First, put about 10% of the mixing water in the drum. Then add water uniformly with the dry materials, leaving another 10% to be added after the dry materials are in the drum.

b. Mixing by Hand

On many self-help projects, the amount of concrete needed may be small or it may be difficult to get a mechanical mixer. If a few precautions are taken, hand-mixed concrete can be as strong as concrete mixed in a machine.

The first requirement for mixing by hand is a mixing area which is both clean and watertight. This can be a wood and metal mixing trough (Fig. 8C-45) or simple round concrete floor (Fig. 8C-46).

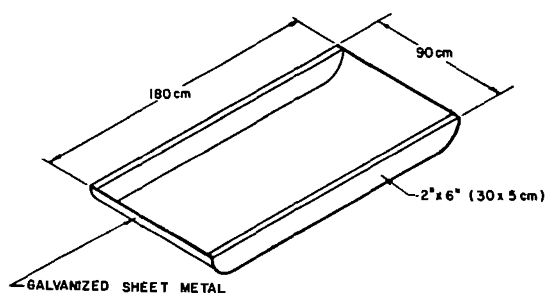


Figure 8C-47. Mixing Trough

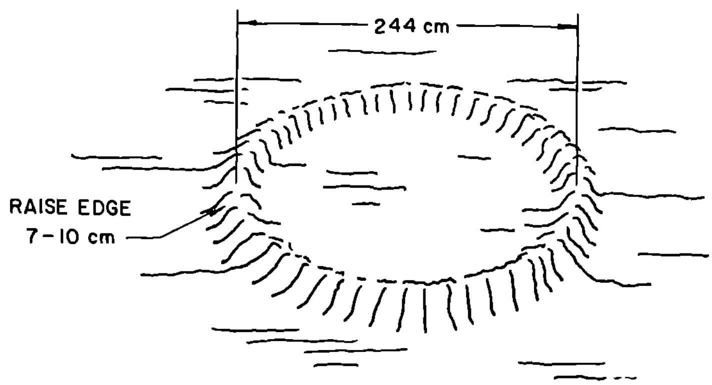


Figure 8C-48. Mixing Floor

Use the following procedure:

1. Spread the fine aggregate evenly over the mixing area.

2. Spread the cement evenly over the fine aggregate and mix these materials by turning them with a shovel until the color is uniform.

3. Spread this mixture out evenly, spread the coarse aggregate on it and mix thoroughly again. All dry materials should be thoroughly mixed before water is added.

A workable mix should be smooth and plastic -- neither so wet that it will run nor so stiff that it will crumble. If the mix is too wet, add small amounts of sand and gravel, <u>in the proper proportion</u>, until the mix is workable. If a concrete mix is too stiff, it will be difficult to place in the forms. If it is not stiff enough, the mix probably does not have enough aggregate, thus making it an uneconomical use of cement.

When work is finished for the day, be sure to rinse concrete from the mixing area and the tools to keep them from rusting and to prevent cement from caking on them. Smooth shiny tools and mixing boat surfaces make mixing surprisingly easier. The tools will also last much longer.

5. <u>Pouring Concrete Into Forms</u>

To make strong concrete structures, it is important to place fresh concrete in the forms correctly.

The wet concrete mix should not be handled roughly when it is being carried and put in the forms. It is very easy, through joggling or throwing, to separate the fine aggregate from the coarse aggregate. Do not let the concrete drop freely for a distance greater than 90 to 120 cm (3 to 4 feet). Concrete is strongest when the various sizes of aggregates and cement paste are well mixed.

Properly proportioned concrete will have to be worked into place in the form. Concrete that would on its own flow out to completely fill in a form would be too wet and therefore weak.

When pouring concrete structures that are over 120 cm high, leave holes in the forms at intervals of less than 120 cm through which concrete can be poured and which can later be covered to permit pouring above that level. Alternatively, a slide could be used through which concrete could flow down to the bottom of the form without separating. Any "U"-shaped trough wide enough to facilitate pouring concrete into it, narrow enough to fit inside the form, and long enough so that the concrete can slide down the chute without separating will work.

As the concrete is being placed it should be compacted so that no air holes, which would leave weak spots in the concrete, are left. This can be done by tamping the concrete with some long thin tools or vibrating the concrete. Tamping can be accomplished with a thin (2 cm) iron rod, a wooden pole or a shovel.

The concrete will be compacted to some extent as it is moved into its final position in the form. However, special attention must be paid to the edges of the pour to make sure that the concrete has completely filled in against the form. If the forms are strong enough they can be struck with a hammer on the outside to vibrate the concrete just enough to allow it to settle completely in against the forms. Too much vibration can force most of the large aggregate toward the bottom of the pour, thus reducing the overall strength of the concrete.

6. Finishing

Once the concrete is poured into the forms, its surface should be worked to an even finish. The smoothness of the finish will depend on what the surface will be used for. Where more concrete or mortar will later be placed on this pour, the area should be left relatively rough to facilitate bonding. Where the surface will later be walked on, as for example the cover of a well on which a pump will be mounted, it should be somewhat rough to prevent people from slipping on the concrete when its surface is wet. This somewhat rough texture can be achieved by finishing with a wooden float or by lightly brushing the surface to give it a texture. A very smooth finish can be made with a metal trowel. Over-finishing (repeated finishing) can lead to powdering and erosion of the surface.

7. Curing Concrete

After the forms are filled, the concrete must be cured until it reaches the required strength. Curing involves keeping the concrete damp so that the chemical reaction that causes the concrete to harden will continue for as long as is necessary to achieve the desired strength. Once the concrete is allowed to dry the chemical hardening action will gradually taper off and cease.

The early stage of curing is extremely critical. Special steps should be taken to keep the concrete wet. Once the concrete dries, it will stop hardening; after this happens it cannot be re-wetted in the field to re-start the hardening process.

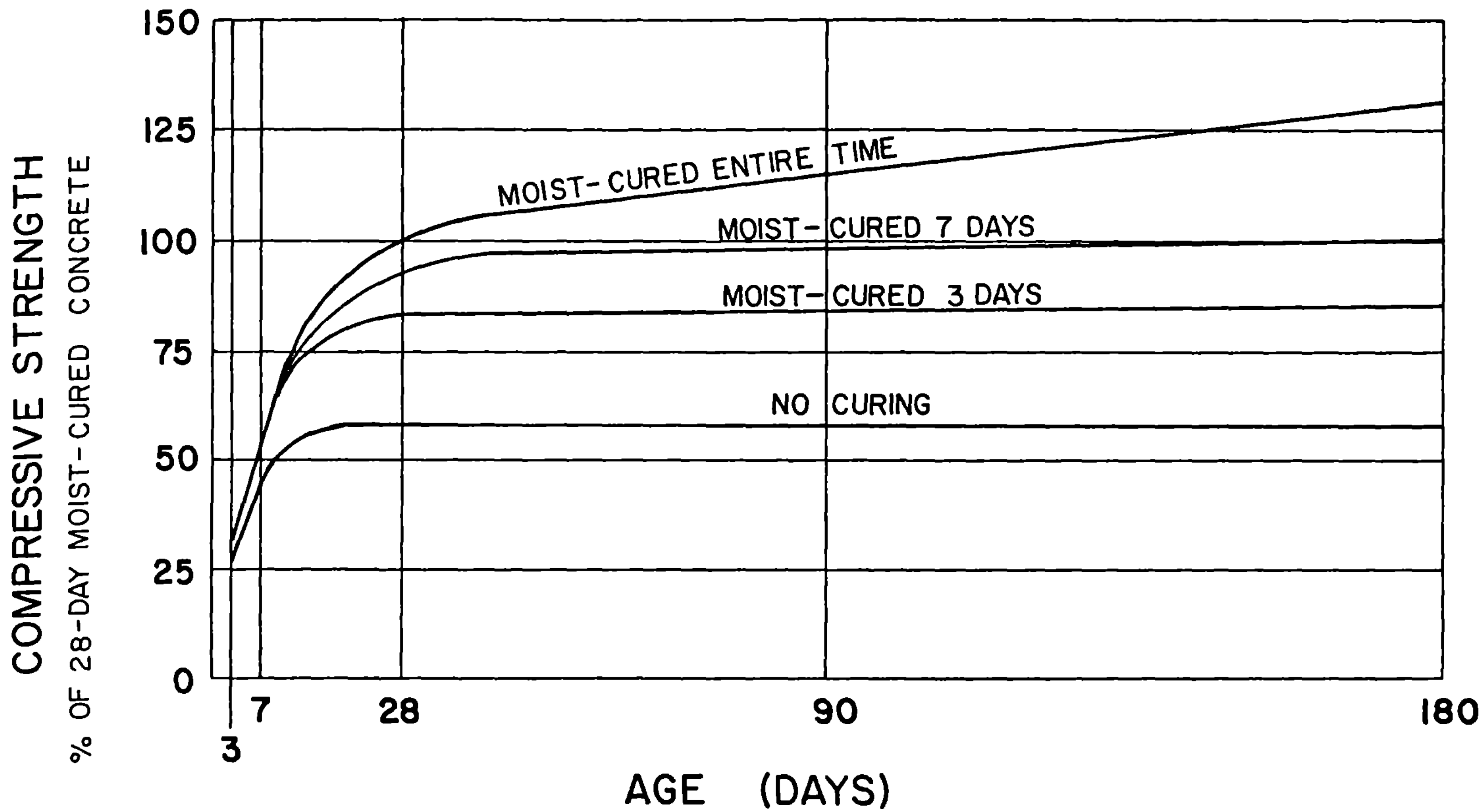
Covering the exposed concrete surfaces is usually easier than continuously sprinkling or frequently dousing the concrete with water which would otherwise be necessary to prevent the concrete surface from becoming dry. Protective covers often used include canvas, empty cement bags, burlap, plastic, palm leaves, straw and wet sand. The covering should also be kept wet so that it will not absorb water from the concrete.

Concrete is strong enough for light loads after 7 days. In most cases, forms can be removed from standing structures like bridges and walls after 4 or 5 days, but if they are left in place they will help to keep the concrete from drying out. Where concrete structures are being cast on the ground, the forms can be removed as soon as the concrete sets enough to hold its own shape (3 to 6 hours) if there is no load on the structure and measures are taken to ensure proper curing.

The concrete's final strength will result in part from how long it is moist cured. As can be seen from the Graph 8C-1, concrete will eventually reach about 60% of its design strength if not moist cured at all, 80% if moist cured for 3 days, and almost 100% if moist cured for 7 days. If concrete is kept moist, it will continue to harden indefinitely.

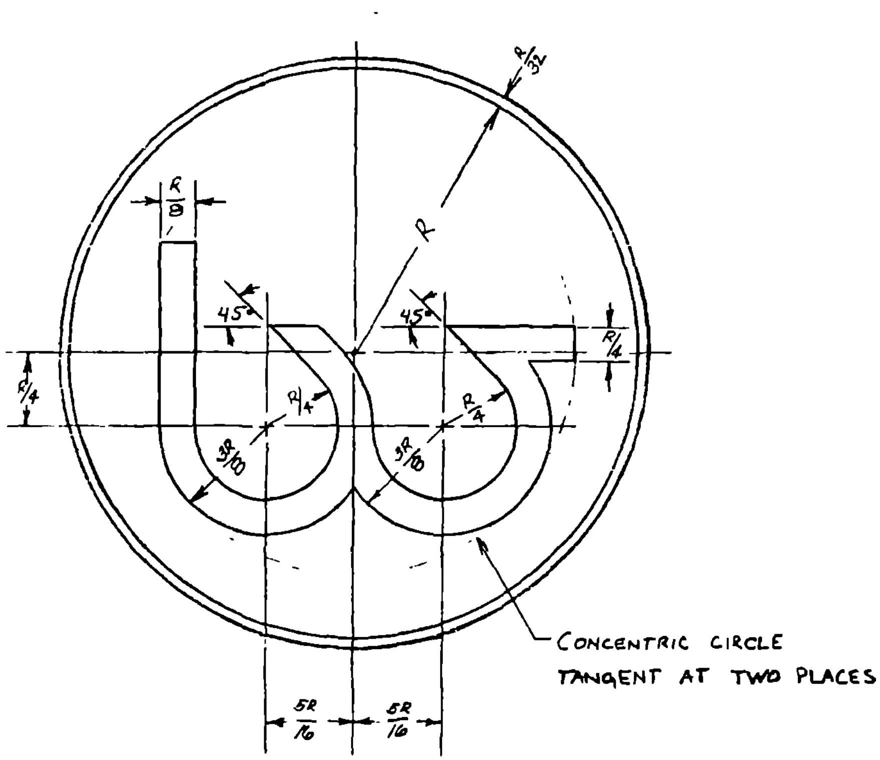
GRAPH 8C-1

Compressive Strength of Concrete



Appendix 8C.C

BWP LOGO



BARANGAY WATER PROGRAM LOGO

DRAWN BY: P.A. PASHKEVICH	DATE: 6 OCT 81
CHECKED BY: ANDY de OCAMPO	DATE: 9 OCT 81
APPR'D BY: Arturo R Rama	DATE: 9 OCT 8

Appendix 8C.D

OIL SOAKED BEARINGS: HOW TO MAKE THEM

Appendix 8C.D

OIL SOAKED BEARINGS: HOW TO MAKE THEM[7]

The purpose of this article is to provide some background information for both constructors and designers who wish to use wood bearings. The type of wood to use, its treatment, lubrication and expected performance are included.

Advantages

Some of the advantages of oil-soaked wood bearings are obvious. They can be made from available materials by local craftsmen with woodworking skills. They are easily assembled, do not require lubrication or maintenance, and operate under dirty conditions. They can be quickly repaired or replaced and provide a temporary means of repairing a more sophisticated production bearing. They also require low tolerance on both the shafts and the housings.

One of the essential characteristics to look for in the choice of wood is hardness. Because the harder the bearing surface, the less the deformation and the smaller the coefficient of friction and the lower the rate of wear. It is also unlikely to break down prematurely, singe or ultimately burn. It is also worth noting that, generally, the harder the wood, the greater its weight and the more difficult it is to work.

The oiliness of the wood is a particularly important consideration when the bearings are unlikely (or not intended) to receive lubrication during their service. Practical indicators that assist the identification of timbers which may have good self-lubricating properties are: they are easily polished, do not react with acids, are difficult to impregnate with preservatives and glue does not easily stick to them.

Other Considerations

High moisture content causes a reduction in hardness and results in greater wear. For most applications low moisture content is preferred and excess moisture must be removed to prevent subsequent shrinkage, especially if the bearing is to be used as a bush.

The hardest wood is to be found in the main trunk just below the first branch.

The piece of timber selected for the bearing should be free from cracks. Some suitable timbers are listed below:

"Greasy" woods	Lignum vitae	(Guaiacum officinale)
	Tallowood	(Eucaliptus microcorys)
	Teak	(Tectona grandis)
	Blackbutt	(Eucaliptus pilularis)
Other woods	Poon	(Calophylium tomentosum)
	Hornbeam	(Carpinus botulus)
	Degame	(Calycophyllum carididissimum)
	Boxwood	(Phyllostylon brasiliense)
	Pear	(Pyrrus communis)
	Oak	(Quercus robur)
	Camphorwood	(Dryobalanops aromatica)

If the timber is not of the self-lubricating variety (or of doubtful self-lubricating characteristics) it can be soaked in oil to minimize the need for subsequent lubrication. It is important to have dry wood to assist maximum absorption of oil.

Construction

The following notes relate to experience gained in the "field" manufacture and testing of three types of wood bearing - the bush bearing, the split-block bearing and the one-piece block bearing. All are of the oil-soaked variety. H.S. Pearson has suggested that as a general rule-of thumb guide to the size of timber needed for the bearing, the axial length of the bearing should be at least twice the shaft diameter. For example, for a 25 mm diameter axle, the bearing should be at least 50 mm long.

In the case of the block bearings, the thickness of bearing material at any point should not be less than the shaft diameter.

The drilling of radial holes for lubrication purposes is only recommended by Pearson for the bush type of bearing. He found that if lubricated holes were drilled in block bearings not only were the bearings weakened but also the holes acted as dirt traps.

Whenever possible the bearings should be located in a position where falling dirt will not directly enter the bearing. For example, if the axle is carried in bearings mounted under the floor of a cart instead of a fixed axle with bearings at the hub of the wheel, then dirt falling from the rim of the wheel will not fall directly onto the bearing.

If the bearing is expected to take side-thrust, large flat washers must be used, the one at the end of the bearing being free to rotate on the shaft.

The bearing surface of the shaft should be perfectly round and smooth and polished in appearance.

How to Make the Bearings

Available timber often has rather doubtful self-lubicating properties and high moisture content. In this instance, a simple procedure for making an oil-soaked bush bearing has been devised by the Industrial Development Centre, Zaria, Nigeria. Excess water is removed and subsequent shrinkage prevented.

First, reduce the timber to a square cross section and bore a hole through the centre the same diameter as the journal on which the bearing will be working.

Place the blocks into a metal container of commercial groundnut oil and keep them submerged by placing a brick on top. Raise the temperature of the oil until the water in the wood is turned into steam - this will give the oil the appearance of boiling vigorously. Maintain the temperature until only single streams of small pin-size bubbles are rising to the surface of the oil. This may take anything from 30 minutes to 2 hours depending on the moisture content of the wood.

Remove the heat source and leave the blocks in oil to cool overnight if possible. During this stage the wood will absorb oil. Be very careful if you need to handle the container whilst it is full of hot oil. If the temperature of the oil is allowed to get too high after the bubbles have ceased to appear, the wood will change to charcoal and the bearings will be ruined.

Rebore the centre hole to compensate for any shrinkage that might have taken place.

Place on a mandrel or lathe and turn the outside diameter to the required measurement that will give the bush a press fit into the hub.

Bore four equally spaced holes through the wall of the bush at its mid-point and fill with lubricant -- in general terms, the harder the lubricant the better, so animal fat, soap or tallow are preferable although grease is an excellent alternative. Finally press the bush into the hub.

The forty bush bearings made and tested at Zaria were 2½" long by 1.550" outside diameter with a 0.855" bore. They were pressed into 1½" seamless black iron Class C pipe, and turned on a ½" pipe journal. The wood used was mahogany (being the most readily available) and rig tests with a loading of 100 lbs and a speed of 100-200 rev/min indicated sufficient lubrication. These test conditions were chosen to simulate the working force on a 7" gauge wheel of an ox-drawn plough. Tests performed on bush bearings without the four radial lubrication holes again indicated sufficient lubrication.

On heavy equipment such as ox-carts or where it is not possible to push the axle through a bush-bearing, the split-block bearing provides a more practical solution.

It is simple to fit and replace, and if wear takes place the two halves can be changed around. After further wear, the life of the bearings can be extended by removing a small amount of material from the matching faces.

A simple procedure was devised by the GRZ/ITDG project at the Magoye Regional Research Station in Zambia for the production of such a bearing, again using an oil soaking technique. The timber in this case was teak, and used engine oil provided a satisfactory alternative to groundnut oil.

Reduce the timber to a square cross-section and cut lengthwise into two halves.

The two halves of the bearing must be clamped firmly together for the drilling operation. It is most important that the hole for the axle is bored exactly square through the blocks. For the best results an electric powered pillar-drill would be quite satisfactory. If neither of these is available, a jig would have to be made to keep the drill bit in line. After drilling, the two halves should be tied together to keep them in pairs.

For soaking in oil an old 20 litre (5 gal.) drum is needed. Fill it three-quarters full with used engine-oil and bring to the boil over an open fire. Great care is needed when handling the drum of hot oil. Lift the drum off the fire and carefully place the pairs of bearings into the hot oil. Put a brick on top of the last pair to stop them from floating, and leave the drum and contents to cool slowly overnight.

The split-block bearings measured 150 mm x 150 mm x 75 mm with a 38 mm diameter bore. They were field tested for reliability by installing them on ox-carts fitted with iron or pneumatic wheels and carrying loads of up to 2 tons.

A radial clearance on one of these assemblies of about 1 mm was found to be essential. If carefully run in at low speeds (ox draft) the clearance is increased to 1.5 to 2.0 mm and the bearing surface attained a highly polished glass-like appearance. Having reached this condition it was found capable of withstanding journeys of a few kilometers at higher speeds (Land Rover towing).

A soft pine-wood oil-soaked bearing was tested as an alternative to the hardwood bearing, and this also gave satisfactory performance but might have a shorter life.

For lower load, lower speed applications such as the seed-drive mechanism on a small planter, a smaller one-piece oil-soaked block bearing was used measuring 50 mm x 50 mm x 50 mm with a 16 mm diameter bore, and this gave satisfactory results although tests were not exensive.

The possibility of boring the axle hole using hot irons was not investigated but there should be no serious objection to this alternative.

Bibliography

"The Characteristics of Bearings When Employed in Slow Running Machinery," D. A. Atkinson. University of Manchester Institute of Science (UMIST), 1972.

Carts Intermediate Technology Publications, 1975.

"The Wood Bearing: How to Make It," Shambaugh, T. J., Pearson, H. S. & Jibril, Center, Zaria, Nigeria, December 1969.

FOOTNOTES

1. Adapted from McJunkin, F. Eugene, Hand Pumps for Use of Drinking Water Supplies in Developing Countries, The Hague, The Netherlands: WHO International Reference Centre for Community Water Supply, 1977, pp. 26-27.

2. Based on McJunkin, pp. 26-27.

3. This section and others concerning the construction of the deep-set pump are based on the Installation Manual for Cylinder Pumps by the Water Resources Center of the University of San Carlos, Cebu City, Philippines, sponsored by the Asia Foundation.

4. From Brush, Richard E., Wells Construction, Washington, D.C.: Peace Corps, pp. 261-264, and "Disinfecting Wells," from Water for the World, Technical Note No.RWS.2.C.3f, Washingtion, D.C.: USAID.

5. Taken from an unpublished trip report by P. Alan Pashkevich which was written during the undertaking of the project which produced this manual.

6. Adapted from Brush, Richard E., pp. 221-238.

7. Collett, John, Oil Soaked Bearings: How to Make Them, Silsoe, Beds, Great Britain: National College of Agricultural Engineering.

APPENDIX G

The Siting, Design, Construction & Maintenance of Water Wells for BWP Level I Projects

THE SITING, DESIGN, CONSTRUCTION AND MAINTENANCE OF WATER WELLS FOR BWP LEVEL I PROJECTS

Prepared for

The United States Agency for International Development
Under order of Technical Direction No. 40

by

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8B.0 THE SITING, DESIGN, CONSTRUCTION AND MAINTENANCE OF WATER WELLS FOR BWP LEVEL I PROJECTS

This section of the BWP Operations Manual has been written to provide information to waterworks technicians and engineers which will: assist the user to select appropriate locations for the placement of water wells; enable the user to design appropriate water wells; familiarize the user with the types of drilling techniques, equipment, and procedures to enable supervision of the construction of a water well; and provide direction so that the user can develop a maintenance program and perform maintenance for BWP level water wells.

The nature of the BWP level I program makes it unnecessary to address the sophisticated hydrogeologic techniques for well site evaluation, well design, and well construction. In most areas of the country, a well can be drilled almost anywhere with only modest design consideration and it can provide enough water to meet the capacity of a hand pump.

Section 8B describes methods of site selection with emphasis placed upon water source protection and accessbility to user, and well design and construction that meets the community's demand while again providing protection against contamination of the water source. This section also develops a foundation upon which more complex siting and design information can eventually be developed for BWP level II and level III systems.

8B.1 AN INTRODUCTION TO HYDROGEOLOGY

To understand ground water and the fundamentals of well siting and water well construction it it necessary to have some familiarity with geology and hydrogeology. The intent of this section is to introduce a few geologic and hydrologic concepts that will facilitate the presentation of material presented throughout Section 8B. After the user feels comfortable with the material in this section the user may elect to read Appendix 8B-A, which goes into this subject in more detail.

Upon completion of this section the manual user:

1. will understand the origin of the three major rock groups that make up the earth's crust;

2. will be able define porosity and permeability, and understand their relationship to well yield; and

3. will be familiar with certain common rock formations and their water producing capabilities.

8B.1.1 Rock Types

Geologists classify rocks into three major groups: a) igneous rocks, or those rock which have cooled and solidified from a molten mass; b) sedimentary rocks, or those rocks resulting from deposition of sediments by water, wind, or chemical precipitation, and later consolidation; and c) metamorphic rocks or those rocks of either of these first two groups which have been altered by heat, pressure, solution, or other means.

There are two types of igneous rocks: intrusive and extrusive. The intrusive igneous rocks were formed by the slow cooling of molten material, called magma, at great depths under the earth's surface. Intrusive igneous rocks are usually coarse-grained and form common types of rocks such as granite.

Water associated with intrusive igneous rock is usually found in joints or fractures of the rock and occasionally in the upper weathered surface of the rock. Normally only a very small amount of water can be obtained from wells drilled into such rock.

Extrusive igneous rocks are commonly fine grained rocks that have cooled rapidly at or near the surface. Basalt lava flows are perhaps one of the most common type of extrusive igneous rock. Under some circumstances modest amounts of water can be produced when wells penetrate porous zones near the tops or bottoms of lava flows and other extrusive igneous rock types. Basalt lava fractures upon cooling, or exposure at the earth's surface. If enough fractures are intersected the basalt can be a good source of water.

Sedimentary rocks include shale, sandstone, conglomerate, limestone, dolomite and gypsum. These rocks are the result of compaction and consolidation of loose sediments such as clay, sand, gravel, lime muds, fossil shells, and chemical precipitates.

The terms clay, silt, sand, and gravel properly refer only to the size of the particles that compose a sediment. When sediment consolidates to form sedimentary rock, the proper rock name is applied. Clay becomes shale, sand becomes sandstone, gravel becomes conglomerate, etc..

Water is often found in abundance in the openings between the particles of the medium- and coarse-grained sediments and sedimentary rocks, such as sand and sandstone. Fine-grained sediments and sedimentary rock such as clay and shale, may contain much moisture, but due to the small size of the particles and the pore spaces between the particles it is difficult to obtain much water from such sediments or rocks.

Limestone and dolomite are rocks composed chiefly of calcium carbonates, and both calcium and magnesium carbonate respectively. Some limestones are formed of calcium carbonate from animal shells and skeletons deposited in oceans and lakes. Carbonate rocks are somewhat soluble in water, and fracture surfaces are dissolved to form solution channels and cavities. Large amounts of ground water can frequently be obtained from wells which penetrate such solution openings.

Metamorphic rocks include slate, quartzite, marble, and schist. They are the result of the long action of heat, pressure, and solution upon igneous and sedimentary rocks. With the exception of marble, which may retain some solution openings, metamorphic rocks are generally poor producers of water. Most rocks in this group can only produce small amounts of water from cracks and factures.

Geologists group certain rock units which can be mapped or traced over considerable area into "formations". Each formation is given a name, usually referring to some geographical place where the formation is well exposed at the surface.

Waterworks technicians and engineers should become familiar with the types of rocks and the names of formations likely to occur in their areas in order to keep accurate logs of the wells drilled.

8B.1.2 Porosity and Permeability

The porosity of a rock or soil is a measure of the amount of void or space present in the material, such as the space between individual sand grains in a sandstone. Porosity is usually expressed as a percent. For example, in 2,830 liters (100 cubic feet) of a sandstone with 38 percent porosity there will be 1755 liters (62 cubic feet) of sand particles and 1075 liters (38 cubic feet) of open space. Porosity, therefore, is a relative measure of the amount of water that can be obtained in any given volume of rock or soil. The amount of water that can be extracted from a rock by means of a well penetrating it will not exactly equal the total amount of water in the rock. This is because a thin film of water will continue to cling to each rock particle even after the rock is dewatered by pumping.

The ability of rocks or soils to transmit water and yield it to wells is known as permeability. Permeability is related to the number and size of openings in a rock and the degree of interconnection of these openings.

Rocks or unconsolidated material with high permeabilities are called aquifers. Therefore, it is the responsibility of the driller, waterworks technician or engineer to identify the aquifers in the area in which they work and construct wells in those aquifers.

8B.1.3 Geology of the Philippines

It is impossible to do justice to the complexity of the geology or geologic history of the Philippines in a few pages. The data that exists on the geologic history of the Philippines is somewhat limited, and except for a new publication being prepared by the Bureau of Mines, preceeding reports failed to consider the islands in light of what is now known about crustal plate movements and continental drift. However, there are numerous publications describing the geology and mineral availability in different parts of the country. Also a hydrogeological map of the country is being prepared by the Bureau of Mines and will be available in mid-1982.

The Philippines are one of a great series of Pacific Island Arcs fringing the Asian Continent. The Philippine Archipelago contains eleven (11) major islands and approximately 7,000 small islands. The geology and physiography of most of the islands are strongly influenced by the volcanic origin of much of the country.

As far as its geologic age, the country is relatively young. There are few rocks bodies that are older than 100 million years, which is not old considering the earth is about 4,500,000,000 years old. In fact, most of the igneous, metamorphic and sedimentary rocks which make up the Philippines are less than 25 million years old. Also, it is obvious that the country is still geologically active in terms of recent volcanic and earthquake activity.

Igneous rocks dominate the landscape and consist of both extrusive rocks (volcanic in origin) and intrusive rocks (having formed below the surface). Mountains in the country are of two types, both consist predominantly of igneous rocks. The first type is the classical conical shaped mountain of volcanic origin such as Mt. Arayat. The other mountain type consists of intrusive igneous, and metamorphic rocks that have been thrust hundreds of meters upward by forces deep within the earth.

Flanking and sometimes topping the mountains are many types of sedimentary rocks including sandstone, shale, conglomerate and limestone. Coquina and coralline limestone, formed in shallow quiet seas, can often be found several hundred meters above sea level, again providing evidence that the land has risen relative to the sea. Interlayered with the sedimentary rocks, lava flows and volcanic ash can be found, attesting to the islands' continuing volcanic nature.

There are a few major valley areas filled with several hundred to several thousand meters of sedimentary rock and unconsolidated sediments. Examples of such valleys are the Cagayan River Valley and the valley of the Pampanga River in Luzon, and the Agusan River of Mindanao. These and other valley areas are fairly consistant in their geology and generally contain a number of excellent aquifers.

Conversely, the higher more rugged areas of the country consisting of igneous and metamorphic rocks are geologically very complex. They are highly faulted, with rock types changing dramatically in distances often measured in tens or hundreds of meters. These areas must rely on the limited presence of sedimentary rocks, or the fractured or highly jointed zones in the igneous or metamorphic rock sequences for ground water development.

The limestone found scattered throughout the islands also tend to be prolific aquifers, especially if they are composed of coral or coquina.

In spite of the complexity of the country's geology there are many similarities in terms of structure and rock type found throughout the entire archipelago. The geologic and hydrogeologic evaluation of landforms on one island or in one area will provide insight into many of the other areas. It is strongly recommended that all BWP personnel familiarize themselves with the literature and types of technical assistance available from the Bureau of Mines.

8B.2 CONSIDERATIONS FOR WELL SITE SELECTION

Ground water is generally available throughout the Philippines, however, there are many things that should be considered when selecting a location for ground water development. The ground water at the well site must be available in sufficient quantity, capable of providing sustained yield over a long period of time, and be of good quality for drinking and other hygienic purposes. In addition, the well must be located away from potential sources of ground water contamination that may effect the quality of the water from the well at some time in the future. To meet the above criteria, a program of exploration and evaluation is necessary. While scientific knowledge of hydrogeology is desirable, common sense and practical experience will prove of great assistance for selecting the appropriate well location.

The BWP level I projects require that the wells be capable of yielding 0.19-0.64 liters per second (3 to 10 gallons per minute). Although such yields are relatively easy to obtain, to minimize well construction costs and depth from which the water must be pumped, some easy step by step procedures have been developed to increase the likelihood of successfully selecting site for a well. Also, a person should not be bothered, if after following the advice contained in this manual they fail to select a good well location. Even the most experienced hydrogeologists often misinterpret the geologic evidence and select an inappropriate location.

This section has been written to inform the reader of the existing information that would be useful in selecting a site for a well, and provide some insight into how the information can be used. If past experience has shown that it is difficult to develop ground water in the area, then a BWP hydrogeologist should be consulted for assistance. By working with the hydrogeologist, an engineer or waterworks technician will gain further insight into the intrepretation of existing information.

Also addressed are factors that one must consider while performing the field survey for a well location. Types of ground water contamination sources are described, as well the means by which the contaminants migrate through the subsurface environment.

The manual user, upon completion of the section will:

1. be able to locate useful existing information that may be of assistance in locating a site for well construction;

2. understand how this existing information can be interpreted to provide data for well site selection. However, the manual user is not expected to be able to interpret the data without assistance from a hydrogeologist;

3. know what factors to consider during a field examination which may provide information which will ensure better well yields, increase the accessability of the well site to users in the barangay, and lessen the likelihood that the ground water will become contaminated.

8B.2.1 Collection of Existing Data

Once the general location for ground water development has been selected the project engineers or technicians should accumulate and evaluate pertinent information that may already be available on the area. This information includes, but is not limited to:

1. geologic and hydrogeologic reports;

2. geologic and hydrogeologic maps;

3. topographic maps;

4. aerial photographs;

5. well logs.

One primary source of this information is the Bureau of Mines. They have available a great number of reports describing the geologic and geographic characteristics of different areas of the country. Although hydrogeologic data is more limited, the Bureau of Mines is actively working on providing an assessment of the nation's ground water resources. A set of hydrogeologic maps and an accompanying report should be available from the Bureau of Mines by mid-1982.

Well logs are records of information pertaining to the drilling and construction of individual wells. These well logs are usually prepared by a well driller, but some of the larger companies make use of hydrogeologists to analyze samples from the well, prepare the well log, and design the well.

Well logs contain information relating to: 1) the location and depth of the well; 2) depth, thickness, and description of rock formations penetrated during drilling; 3) water level variations as successive formations are penetrated; 4) water yield of each potential aquifer; 5) the major construction features of the well; and 6) the description and the results of any tests that may have been performed on the wells.

These records are usually not available from a single source. However, the Bureau of Mines is once again a good starting point. After that, getting in touch with water well drillers that work in the area is very useful. Some drillers will keep good well logs, others will not, but you should be able to determine the types of rocks penetrated and the anticipated depth that the well would have to be drilled by simply talking to them.

8B.2.2 Using Exisiting Information

As you read geologic reports for the area in which you are working you will begin to develop an understanding of the types of rocks in the area, those rock types that are most likely to be good aquifers, and those which may form confining beds. Most sedimentary rocks or unconsolidated sediments usually can be developed into good aquifers. However, if ground water must be developed from igneous or metamorphic rocks, then much greater care must be taken to locate fractures and joints which may readily yield water to a well.

Most geologic reports will contain one or more geologic maps. These maps will prove to be extremely useful. First, they show the relationship of rock type at the surface with geographic features such as roads, villages, rivers, streams, and springs. Remember there is a relationship or hydraulic connection between surface water and ground water. If the map shows a river flowing through a wide valley filled with alluvial material (Figure 8B-1), then wells drilled into alluvium can be expected to induce recharge into the aquifer from the river, expecially if the pumps in the wells can be set deeper than the stream bed. If igneous and metamorphic rocks are present in the area where a well is to be located, then look for points where faults intersect (Figure 8B-2). The intersection of faults and fractures are frequently good locations for a well site because they are zones of high secondary porosity and permeability.

Minor faults and fractures are usually not shown on geologic maps but can be detected on aerial photographs and topographic maps by looking for straight or rectangular stream patterns (Figure 8B-3) or straight, parallel alignment of valleys.

Geologic maps also contain information related to the width of a rock outcrop, and the angle at which the rock dips beneath the earth's surface. Therefore, it is possible to estimate the depth at which the aquifer will be penetrated if the well is drilled at any given location. Knowledge of the geologic materials also will be useful in determining ground water recharge areas.

Geologic cross-sections (Figure 8B-4) are usually prepared from a geologic maps or well logs. These cross-sections can provide clues to the ground water conditions of the area. They depict the character, thickness, succession of underlying formations, and therefore, the depths and thickensses of existing aquifers.

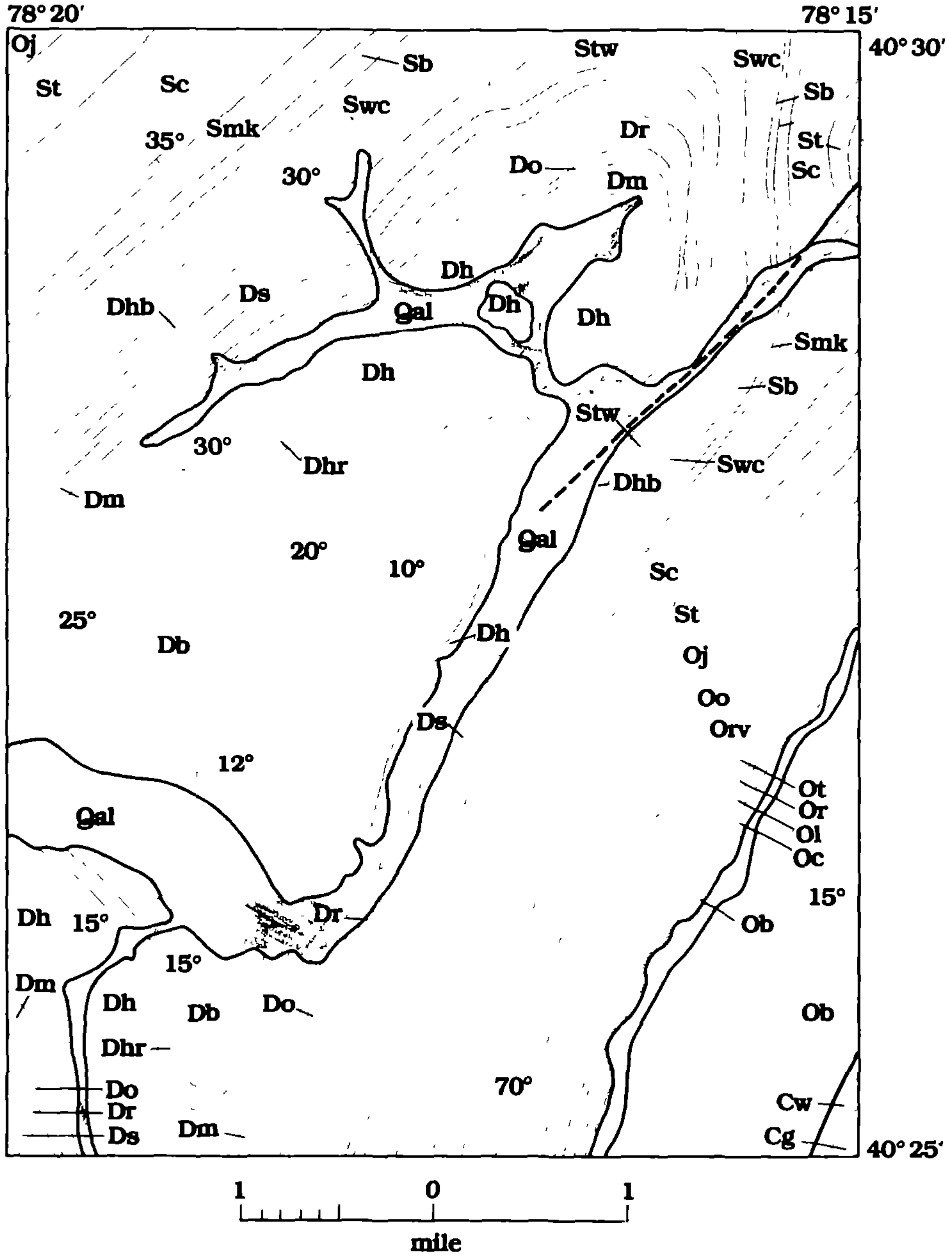


Figure 8B-1 Geologic map depicting an alluvial valley (Qal). The alluvial valley contains more permeable materials than the surrounding sedimentary rocks.

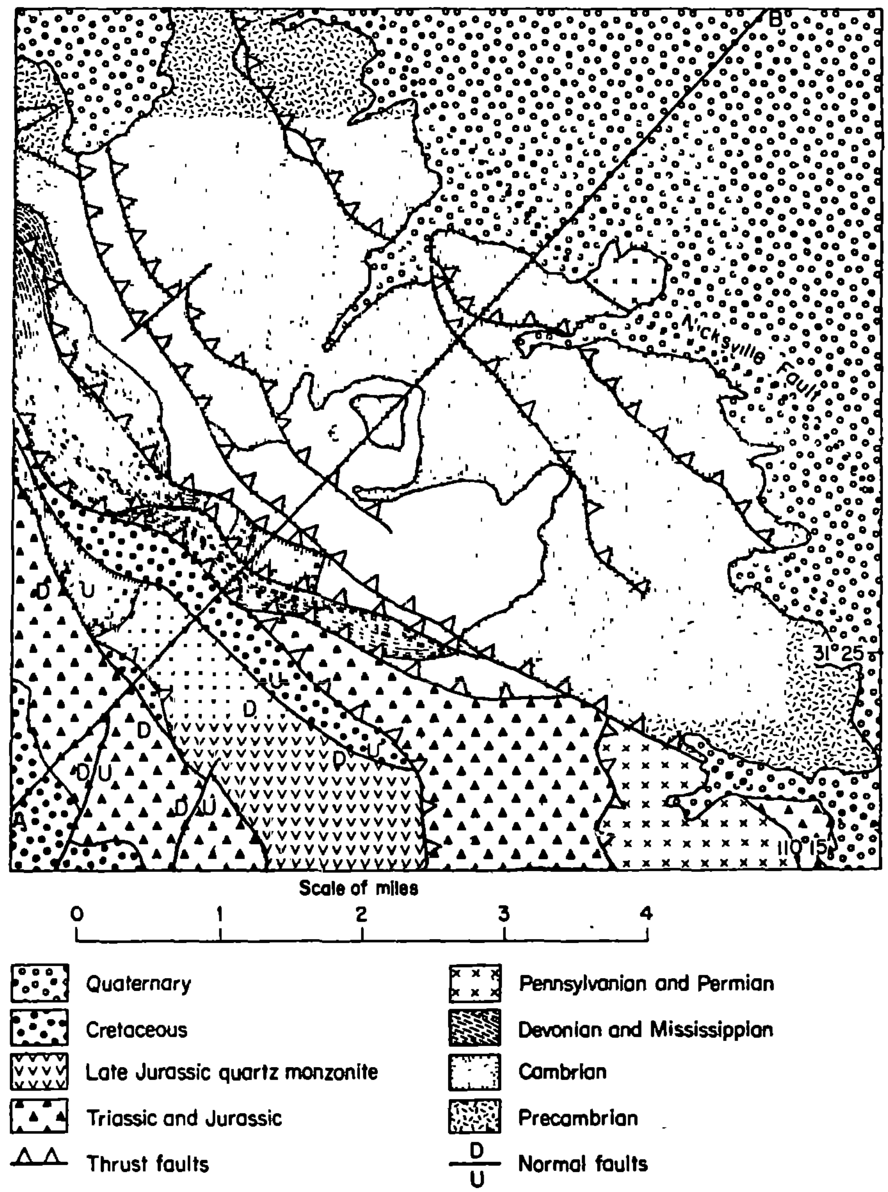


Figure 8B-2 Geologic map of an igneous rock area with numerous intersecting faults.

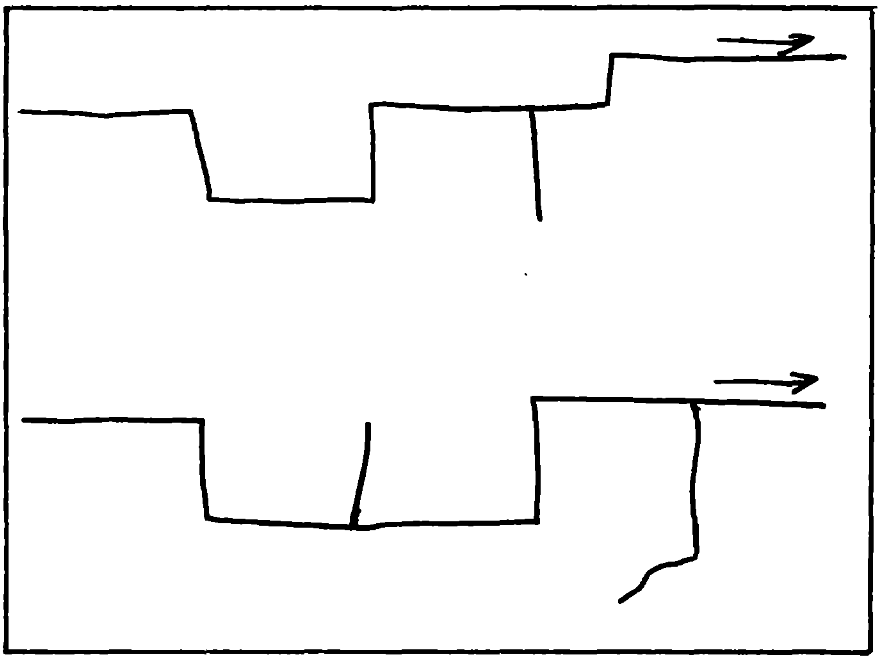


Figure 8B-3 Rectangular stream patterns.

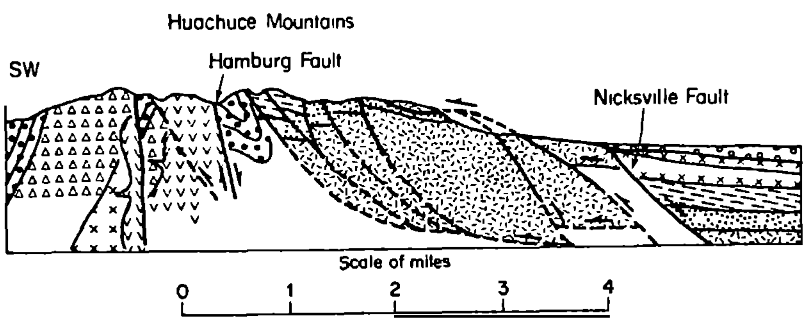


Figure 8B-4 Geologic cross-section of the geologic map in Figure 8B-2.

Preparation of a geologic cross-section usually involves considerable skill. However, if a four or more well logs are availablefor an area a cross-section can be prepared with a moderate amount of practice and common sense. The following steps should provide a reasonable guide for cross-section development.

Step 1. Select four or more wells located along a relatively straight line. The associated well logs should contain good rock description (Figure 8B-5).

Step 2. If not already done, change the written rock descriptions into symbols. Use Figure 8B-6 as a guide in this process. The symbols are then used to construct of geologic log as depicted in Figure 8B-5. Select a convenient vertical scale (i.e., 1 cm = 10 meters), and horizontal scale (1 cm = 100 meters). Notice that the vertical scale is usually larger than the horizontal scale.

Step 3. Place the geologic log on a sheet of paper or map approximating their relative positions both horizonally and vertically. Usually sea level or some elevation above sea level can used as a base line (Figure 8B-7).

Step 4. Draw lines between the tops and bottoms of similar formations or rock units. There is nothing wrong with using a little imagination. Keep in mind rock units may pinch out or grade into another type of rock (Figure 8B-6).

Step 5. If the elevation of the water table is known in each well, then draw a dashed line from log to log representing the water table.

If there is a lot of well data available, a number of cross-sections can be produced and joined together to form a fence diagram (Figure 8B-8). Here again, the well logs are placed on a base map or sheet of paper in such a manner as to represent the relative horizontal positions and elevations. Thess time lines are drawn connecting different cross-sections to develop a three dimensional perspective. Fence diagrams can be placed directly on the base map, or sometimes a special base map with distorted angles can be used to provide a different perspective.

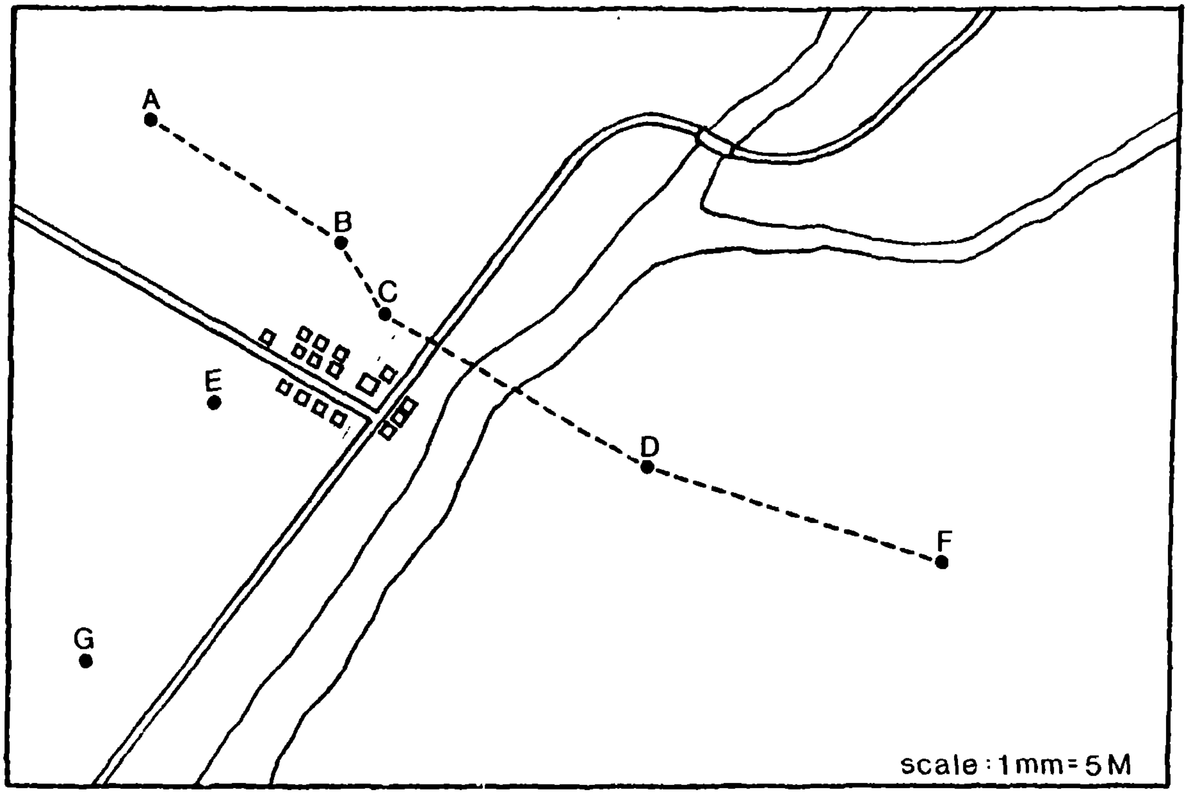


Figure 8B-5 Map showing location of wells and associated well logs.

Well A elev. 90m

0 - 4 sand and gravel
4 - 15 ash
15 - 35 silt
35 - 56 sand
56 - 74 volcanic flow (lava)
74 - 78 broken lava
78 - 100 limestone
SWL 20

Well B elev. 82m

0 - 14 sand and gravel
14 - 19 ash
19 - 34 silt
34 - 60 sand
60 - 70 lava
70 - 96 limestone
96 - 100 weathered igneous rock
100 - 110 fresh, hard igneous rock
SWL 14

Well C elev. 80m

0 - 17 alluvium
17 - 20 ash
20 - 29 silt
29 - 35 sand
35 - 68 sand and gravel
68 - 96 limestone
96 - 104 weathered igneous rock
104 - 110 fresh igneous rock
SWL 13

Well D elev. 70m

0 - 70 alluvium
70 - 78 silt with limestone fragments
78 - 102 limestone
SWL 11

Well F elev. 94m

0 - 15 alluvium
15 - 24 ash
24 - 33 pyroclastic material
33 - 50 volcanic rock
50 - 74 sand w/silt
74 - 78 granite
SWL 25

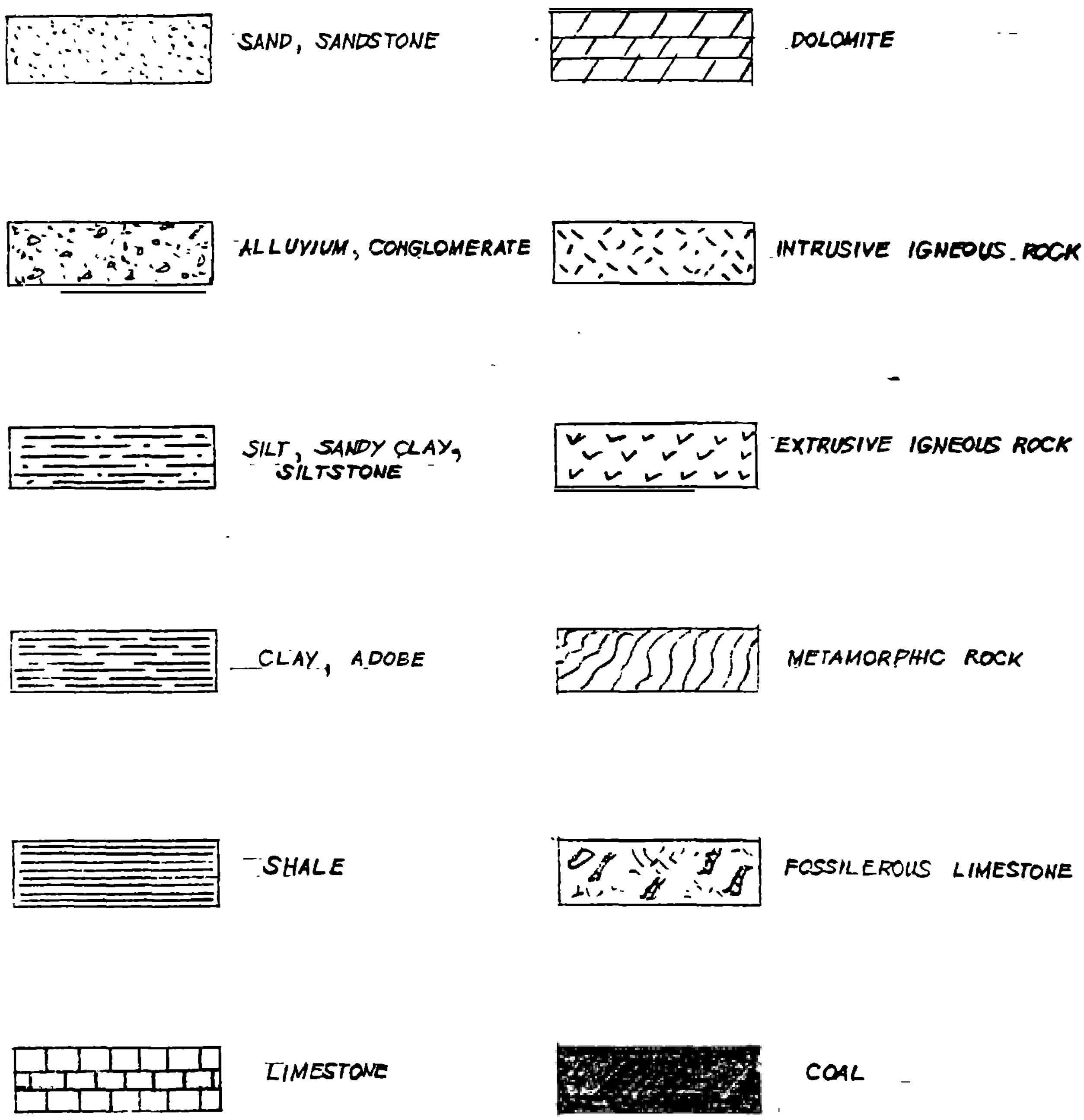


Figure 8B-6 Typical geologic symbols.

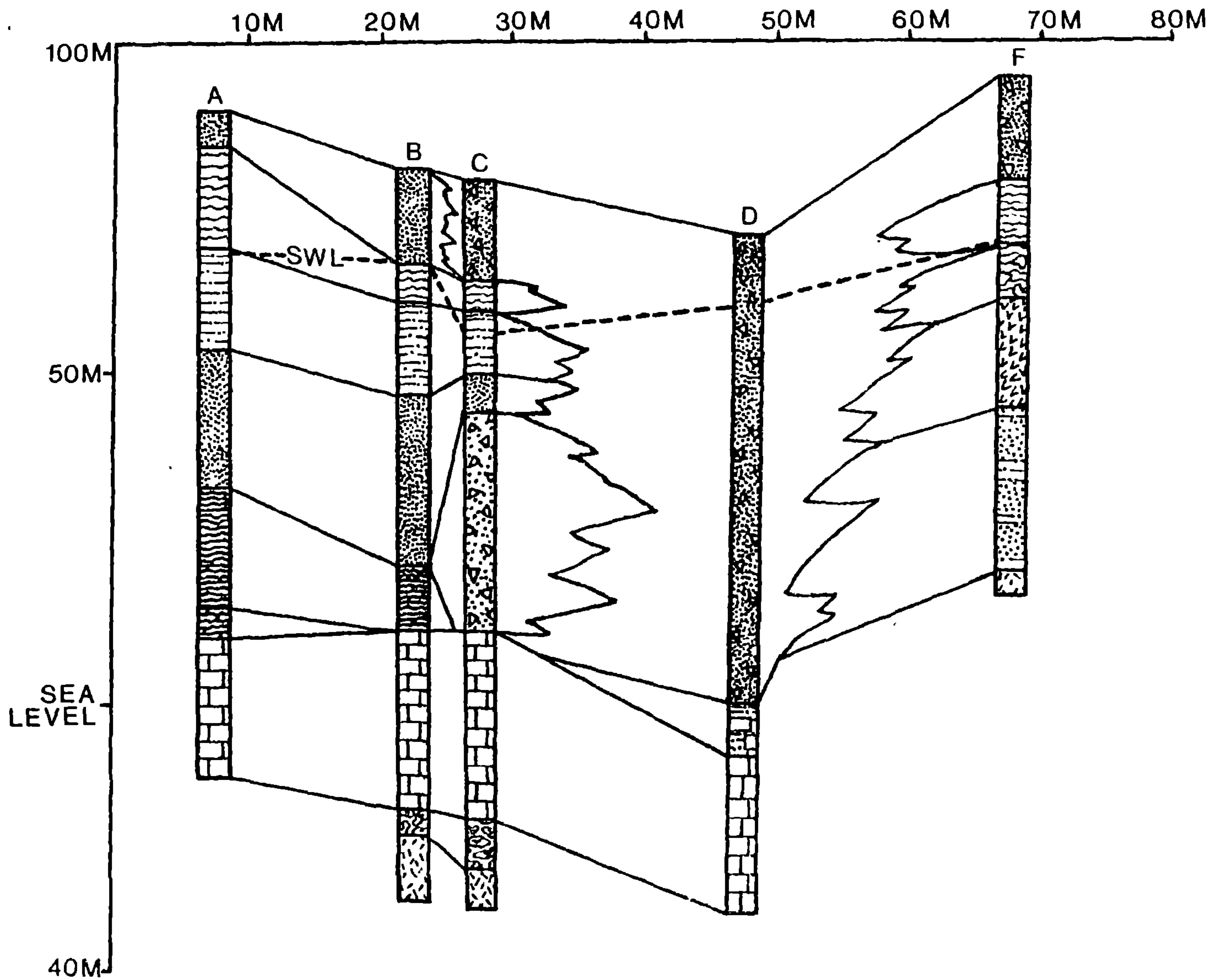


Figure 8B-7 Geologic cross-section drawn from well logs of wells A, B, C, D and F (Figure 8B-5).

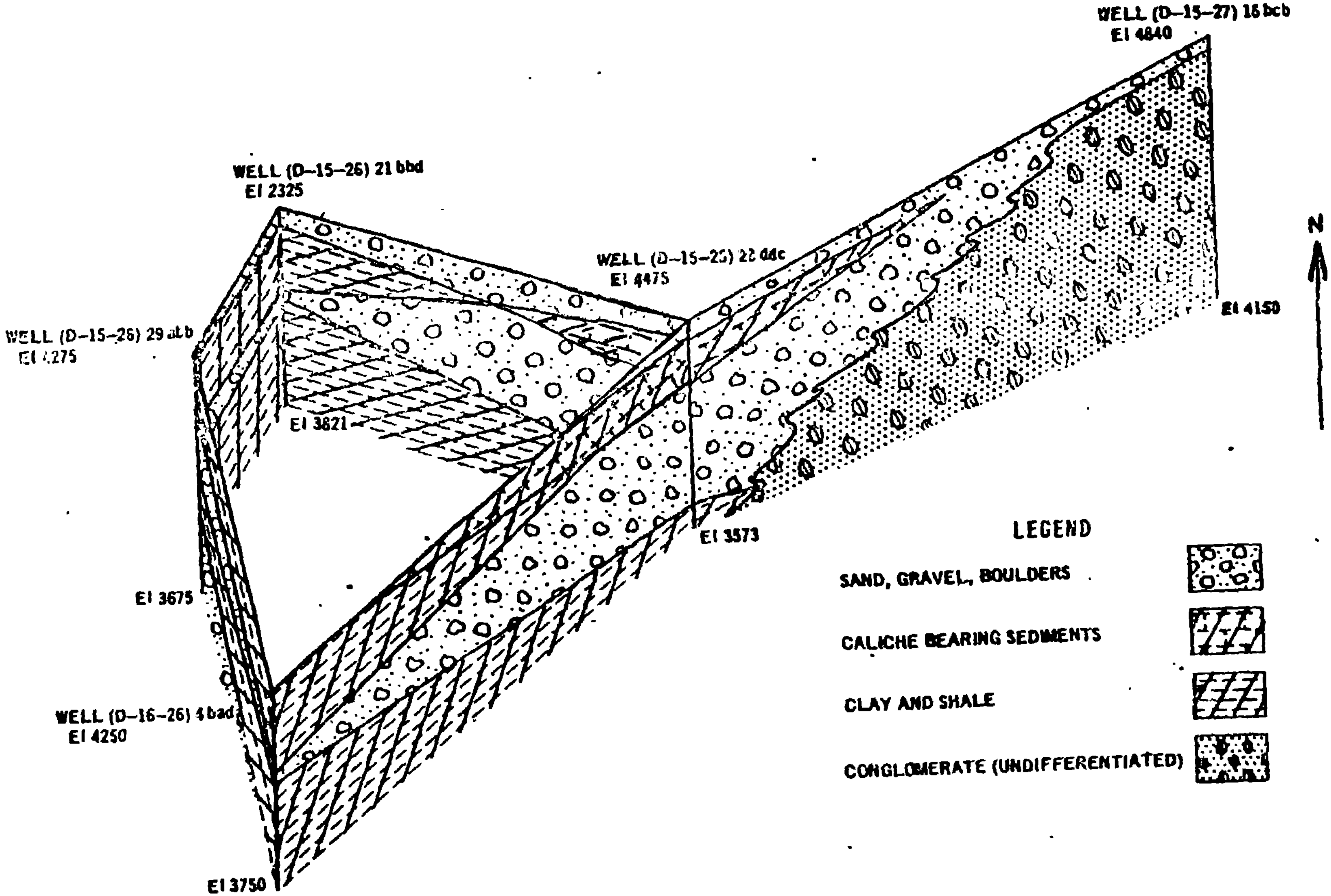


Figure 8B-8 Fence Diagram.

8B.2.2.1 Aerial Photographs

Aerial photographs, when interpreted accurately, provide valuable information relating to terrain characteristics which have considerable bearing on the occurrences of ground water. Geographic features which can be used to interpret subsurface conditions include: vegetation; landforms; land use; type of erosion processes; drainage patterns; and the presence of alluvial fans, gravel pits and quarries.

Frequent use of aerial photographs backed up with field checks will help enable the investigator to determine the most promising areas for ground water development.

Through recognition of landforms, information on lithologic and geologic structure may be interpreted. The amount of information obtainable depends primarily on the types of rocks exposed, climate, and stage of erosion. Areas of gently folded sedimentary rocks of contrasting hardness yield the most information, areas of igneous rocks next, and metamorphic rocks the least. Sedimentary terrains have marked differential erosion characteristics that stand out on aerial photographs while intrusive rocks are relatively homogenous over wide areas. A criss-cross pattern of joints or short lineations is distinctive in many areas. Many types of intrusive rocks display development of irregular and widely spaced joints. Extrusive rocks are marked by characteristic landforms such as volcanic cones, and lava flows. The process of metamorphism tends to destroy the erosional difference and the landform characteristics of the original sedimentary or igneous rocks and, as a consequence, aerial photographs of metamorphic terrains may reveal little information.

Although climate, vegetation, and the later stage of the erosion cycle introduce variables, the following list of photo images and commonly associated rock types will prove helpful in determining the lithology of many terrains.

Photo-Image	Photo-Interpretation
Terrain Features	
1. Flat to gently rolling	a. Flat-lying or nearly flat-lying sedimentary rocks underlying coastal plains, plateaus, mesas
	b. Peneplain or homogeneous, igneous or metamorphic rocks

2. Gently rolling to moderately rolling; smoothly rounded	a. Shale exposed in humid climate
	b. Old igneous or metamorphic rock with deep soil profile
3. Gently rolling to moderately rolling; hilltops are flat or rounded with similar elevations	a. Dissected horizontal sedimentary rocks in humid climate
	b. Dissected peneplain on homegeneous, igneous or metamorphic rocks
4. Moderately rolling, hilly, with variations in relief	a. Igneous or metamorphic terrains; variations in relief caused by non-homogeneous rock or structure
5. Low to high relief with parallel ridges and valleys	a. Folded and faulted sedimentary rocks

<u>Drainage Pattern (Figure 8B-9)</u>

1. Dendritic	a. Horizontal or gently dipping sedimentary rocks
	b. Homogeneous rocks with lack of structural control
2. Subdendritic	a. Homogeneous rock at surface underlain by non-homogeneous rock
3. Trellis	a. Steeply dipping sedimentary rocks, less commonly the result of faulting
4. Angulate	a. Strongly jointed or faulted igneous or metamorphic rocks
5. Annular or ring-like	a. Sedimentary rocks in structural domes or basin
	b. Ring dikes in regions of igneous activity
6. Rectangular	a. Limestone or Dolomite

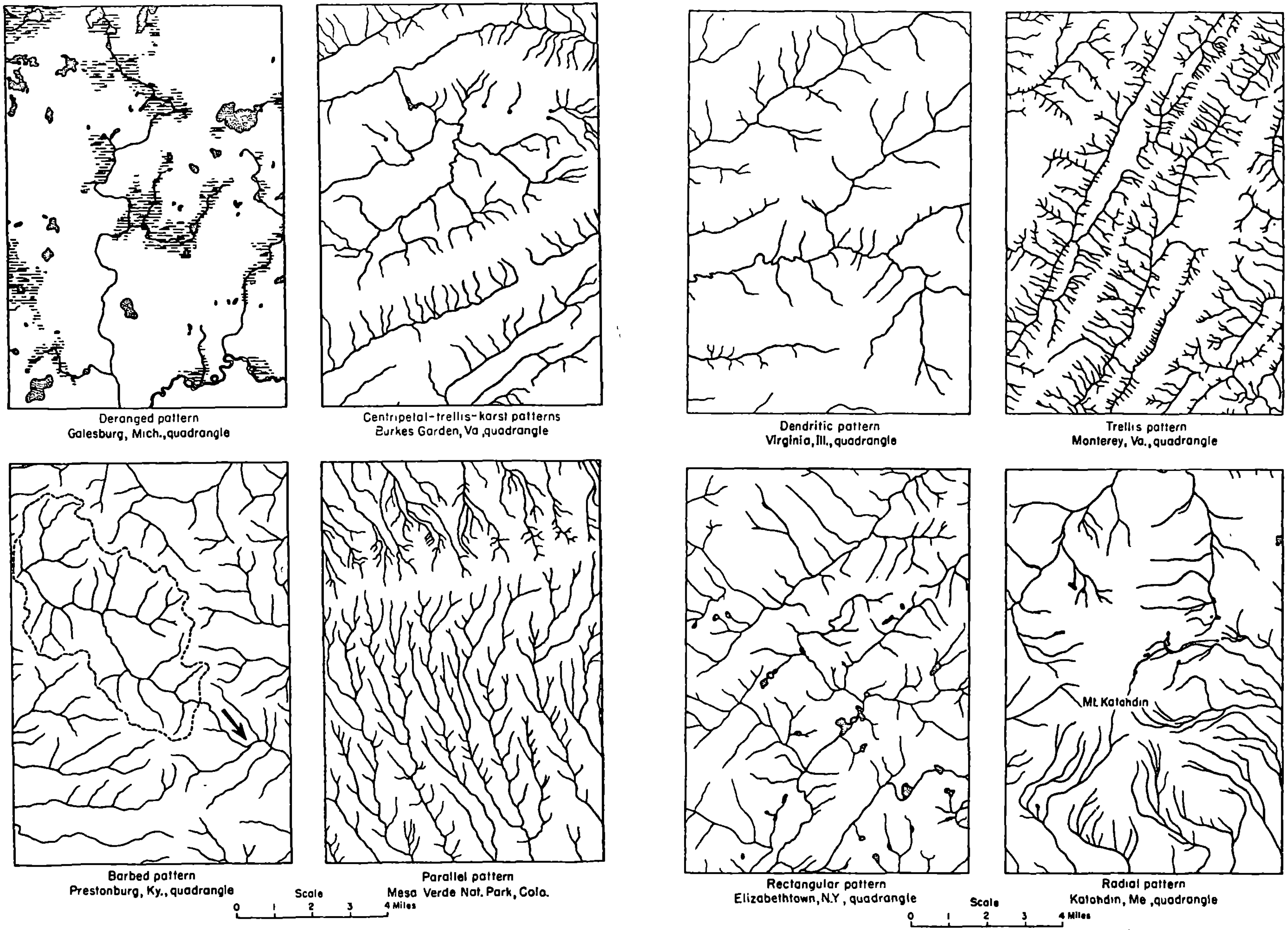


Figure 8B-9 Common drainage patterns.

Drainage Texture (Figure 8B-10)

1. Fine	a. Shale, siltstone, impervious rock; loess is an exception, probably because of fine grain size
2. Coarse	a. Sandstone, conglomerate, pervious rocks
3. Absent	a. Well-drained materials-gravel terrace, sand dunes, river flood plains, terrace alluvium
4. Karst	a. Limestone, dolomite; possibly gypsum or halite

Photographic Tone

1. Light	a. Sandstone, silstone, weathered shale, limestone, dolomite, chalk, gypsum, acid igneous rock
2. Dark	a. Red sandstone, graywacks, shale gray limestone and dolomite, basic igneous rock

Outcrop Features (Figure 8B-11)

1. Massive	a. Conglomerate, limestone, dolomite, gypsum, chalk, quartzite, igneous plutons
2. Bedded	a. Sandstone, siltstone, shale, limestone, precipitates, tuff, series of successive lava flows
3. Banded	a. Sandstone, siltstone, limestone, dolomite, metamorphic rocks
4. Foliated (dominate lineation direction)	a. Schist, slate
5. Other linear features (may or may not be outlined by vegetation)	a. Faults, joints b. Igneous dikes

Other Features

1. Lobate pattern of vegetation in vicinity of volcanic cone	a. Areas of flow rock

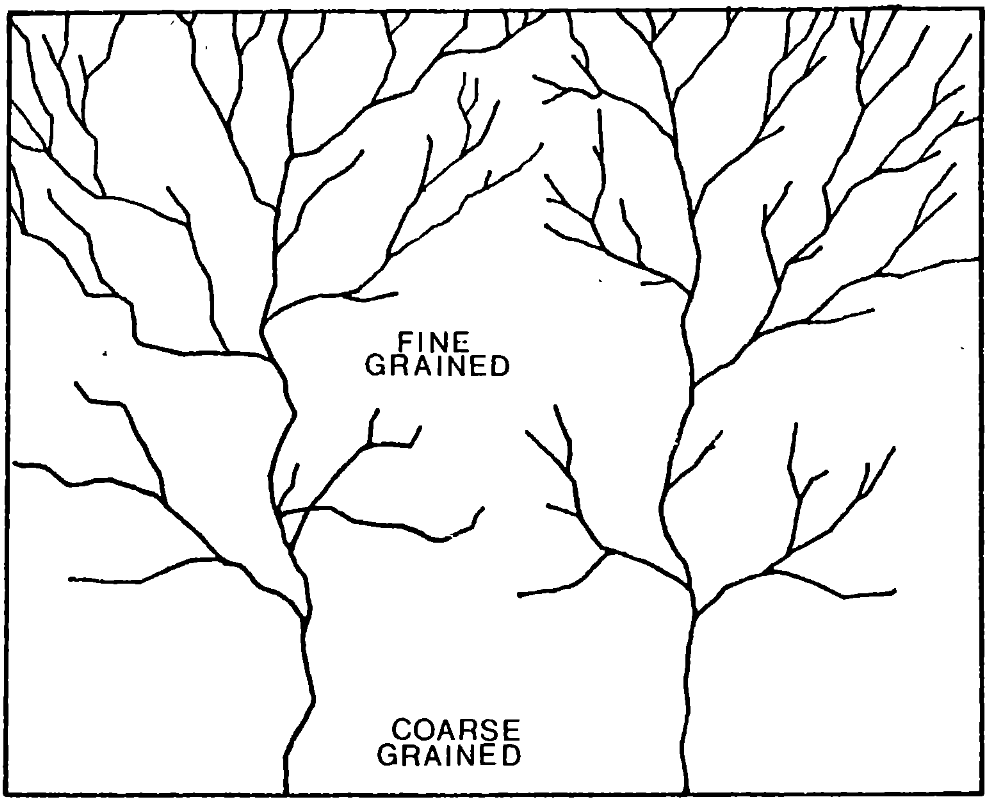


Figure 8B-10 Drainage texture.

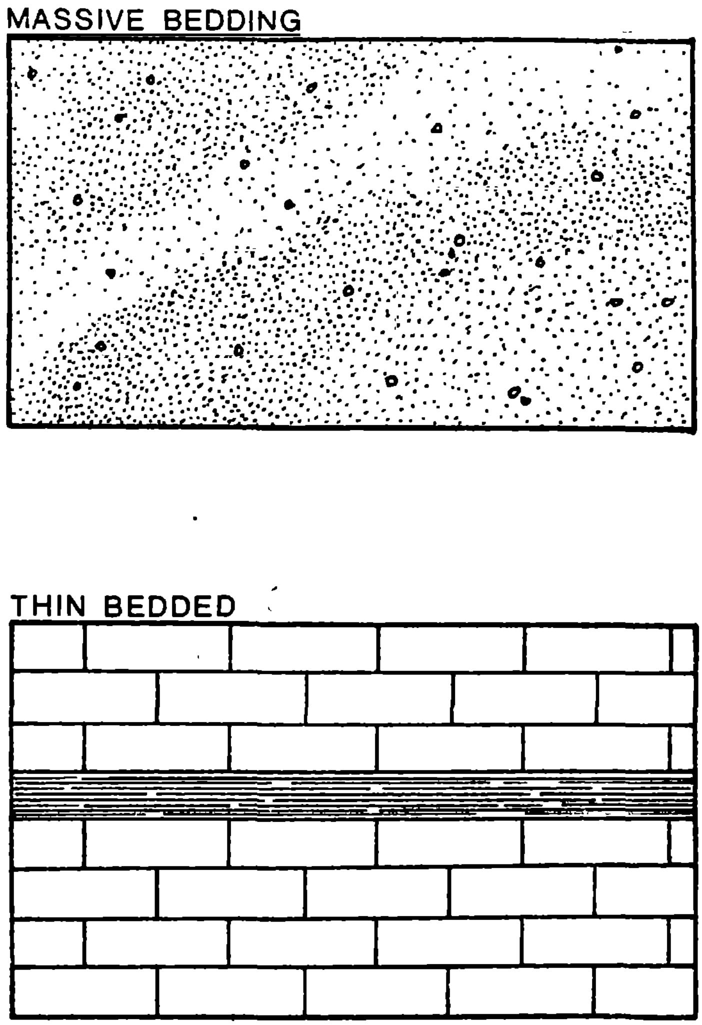


Figure 8B-11 Outcrop patterns.

2. Similar curvature of streams in areas of gently dipping sedimentary rocks	a. Indicates position of structural axis b. Convexity indicates direction of structural pluge
3. Modified dendritic drainage and scoop-shaped valley heads	a. Dissected loess
4. Valley shape	Near surface materials are:
a. Long, smoothly rounded b. "U" shaped c. "V" shaped	a. Clays b. Silts c. Sands and gravel
5. Mottled soils of flat fields	a. Light-toned areas generally slightly higher and better drained than darker areas in which clay materials and humus have accumulated.
6. Sharpness of tonal boundary	Soil properties:
a. Distinct b. Fuzzy, irregular	a. Coarse grained, well drained b. Fine textured, poorly drained
7. Rounded topography, intricate drainage channels and heavy vegetation	a. Probably deep soils
8. Sharp, steep, resistant ridges and rock controlled channels	a. Area of shallow soils
9. Scarp with hummocky topography below and local lobate outlines, undrained depressions	a. Landslide
10. Sinuous ridge, smoothly rounded surface, short steep gullies, very poor vegetative cover dull gray tones.	a. Serpentine outcrop area

In addition aerial photographs become a useful base map on which to plot well locations, major geographic features and geological characteristics. Locations of existing and proposed well sites can be easily plotted on aerial photographs once a few landmarks are identified.

8B.2.2.2 Topographic Maps

To a trained observer a topographic map provides a wealth of hydrologic and geologic information. First, it displays major landforms. Circular contours may be volcanoes, sudden changes in slope on a hillside may be related to the differential erosional characteristics of different sedimentary rocks. Joints and faults often show up as straight segments of streams or a linear alignment of a depressions in the topographic countour lines. Features like alluvial fans may be more outstanding on a topographic map than on an aerial photography especially because the landform-masking effect of vegetation is removed. In addition, springs and intermittent streams are usually plotted on topographic maps providing insight into ground water-surface water relationships.

Like aerial photographs, topographic maps can be used as base maps for plotting the location of wells and other key geographic features. And like aerial photographs interpretation of features on a topographic map are only as good as the skills of the interpreter and the amount of practice he has had.

When interpreting with topographic maps or aerial photographs it is very important to verify the interpretation with field observations.

8B.2.2.3 Inventory of Existing Wells

If possible, well logs (records of information pertaining to the drilling and construction wells) should be collected and evaluated. These logs may provide information pertaining to the location and depth of wells, well yield, type and thickness of rock formations penetrated, ground water level of various formations penetrated, and well design and construction characteristics. In addition to the well logs, some drilling companies may also keep samples of the rock material encountered during the drilling.

This information will provide a great deal of insight into the approximate depth to which the well will have to be drilled, the potential yield of the well, and the appropriate well design.

Collection of well logs is also necessary to develop subsurface geologic data, and the development of some types of geologic cross-sections and fence diagrams described earlier in the section.

8B.2.3 Field Evaluation

After existing data, such as geologic reports, aerial photographs and well logs, have been examined, it is necessary to visit the area being considered for ground water development and verify your interpretation of the data. Check the interpretation of some of the features you picked out on the aerial photographs.

Examine the vegetation. The presence of certain species of vegetation can be a useful indication that ground water or soil moisture lie relatively close to the land surface. Vegetative indicators are most obvious in arid parts of the world where green vegetation stands out. The principle of using plant species as an indicator to locate ground water near the surface is, however, also useful in humid regions. The best relationships are found between certain groups of plants which indicate depth to water, or water quality. In North Africa, for example, research has identified various plant species and their relationship to water depth and salt content. Salt cedar usually indicates saline ground water. Similarly in the arid western United States cottonwood trees, willows and mesquite are associated with shallow water tables. The Ministry of Agriculture may be able to provide insight into similar plant associations throughout the Philippines.

Examine the physiographic (landform) features. Now is the time to examine in greater detail the important surficial features picked out on the topographic maps and aerial photographs. Among the features that would provide valuable clues would be stream patterns, presence of springs and lakes and outcrops of any consolidated rock formations.

Keep in mind the following points: ground water is more likely to occur in larger quantities under valleys than under hills; valley fill containing rock debris washed down from the mountain sides are often found to be productive aquifer; look for wind blown sand deposits that may serve as aquifers or areas of ground water recharge; and along rivers and coastal areas, look for terraces which may make excellent aquifer material (Figure 8B-12).

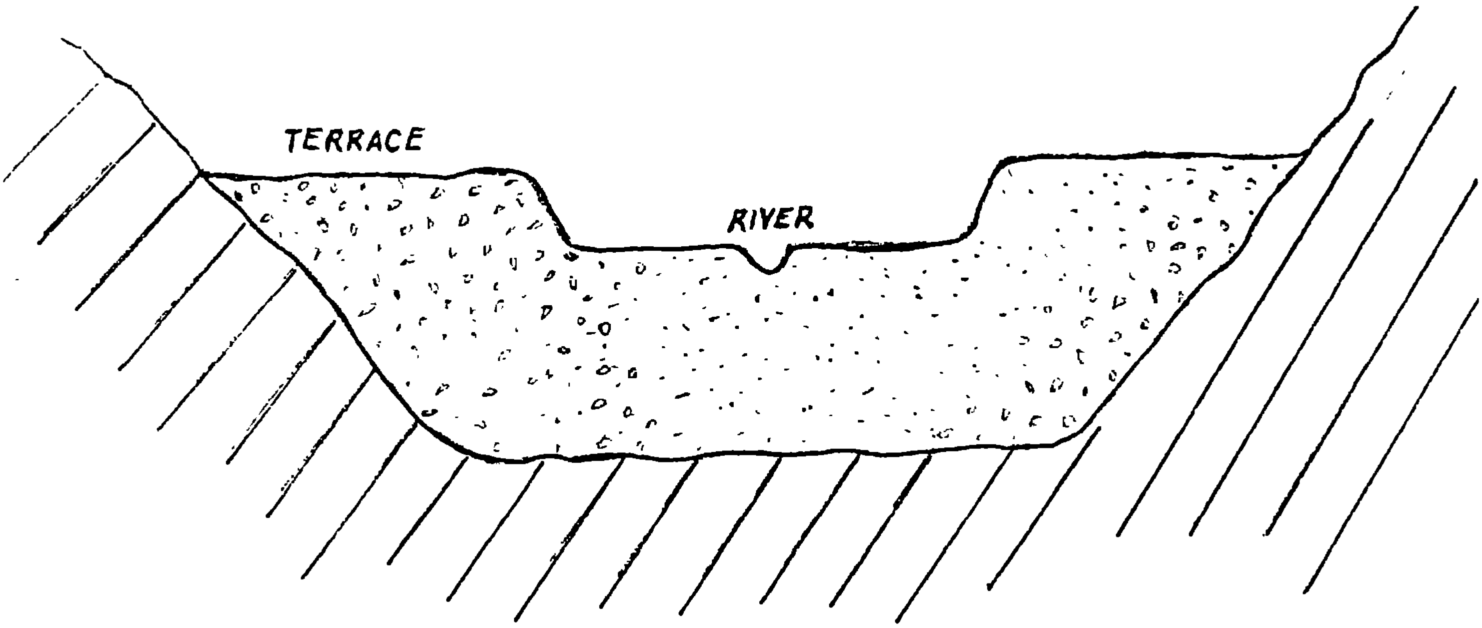


Figure 8B-12 Terraces along an alluvial valley.

Any evidence of surface water such as streams, springs, seeps, swamps or lakes is a good indication of the presence of some ground water, though not necessarily in usable quantities. Check the characteristics of surface water supplies. Ask barangay residents if springs or streams go dry, or if river flow radically decreases during the dry months. Such characteristics may indicate limited ground water, at least at shallow depths. If there are wells in the community, try to determine whether or not they periodically go dry or decrease in yield. Ask residents if there are any problems associated with the water such as turbidity, color, taste or odor, or if there are any wells in the community where the drinking water appears to cause illness

Now is the time to consider which sites appear most promising in terms of ground water availability and accessibility to the local community. The site should be close enough to the village to be used as a primary source of water. The well should be readily accessible. Placing a well half-way down a steep hill slope would discourage, rather than encourage its use, because of the difficulty of walking to or from the well carrying containers of water or doing laundry. Perferably the well should be located on a gentle slope within 250 meters of the proposed users. There should also be a path to or from the well. A gentle slope will permit drainage away from the well, but the slope should not exceed eight to ten degrees.

8B.2.4 Sanitary Survey

Assuming you have now selected a number of potential sites to place a well or wells in a barangay, you must now consider whether or not there are any environmental factors that are likely to result in ground water contamination, or threaten the quality of water derived at a given well location.

A brief description of how bacteria and chemicals move through the ground will be useful as an aid in understanding the factors that must be considered when checking to see if the well site is away from sources of contamination.

In many areas, ground water is encountered at very shallow depth. Trash, human and animal wastes, pesticides, herbicides and fertilizers placed on the ground contain bacteria or chemicals which can migrate from the earth's surface into the ground and down to the water table (Figure 8B-13). Contaminants (bacteria and chemicals), upon reaching the water table, then travel along with the general direction of ground water flow.

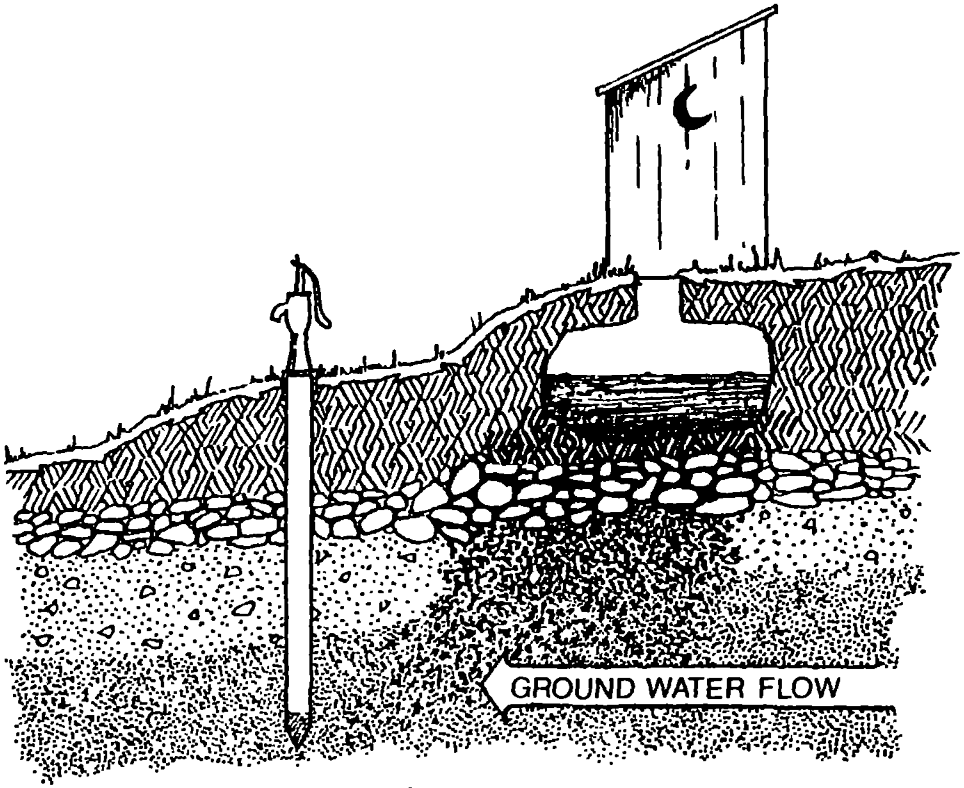


Figure 8B-13 Entry of contaminants into an aquifer.

Fortunately, there are a number of natural processes that occur beneath the surface which helps reduce or eliminate contaminants as they move through the earth. The first is filtration. Filtration is a function of the size of the pore spaces and fractures through which the contaminants and ground water must travel. The smaller the fractures and pores the better the filtration. The effect of filtration may be insignificant if soil moisture and ground water moves through large crevices, solution channels or coarse gravel.

The second factor is known as biodegradation. Biodegradation is a group of complex processes which reduce biological and chemical contaminants. In the soil, bacteria may help to break down harmful chemical substances into less threatening compounds. Harmful disease producing bacteria that can live only a short time outside of a natural host such as humans or animals, die off as they travel slowly through the ground. Some bacteria that enter the ground water soon die because of the lack of oxygen in most subsurface waters.

The third factor is called attenuation. Attenuation is a process by which soil and rock particles absorb chemical contaminants like a sponge would absorb water, or in which chemicals adhere to subsurface particles, as if the particles were covered with glue. Attenuation occurs primarily in fine grained soils, where the nature of the material ensures a lot of surface area on which attenuation can take place.

In many parts of the world, wells are constructed near the shoreline of contaminated rivers or lakes. The wells induce surface infiltration into the ground when they are pumped. As the water moves through the ground, contaminants are removed by filtration, biodegradation and attenuation. By the time the water enters the well it is usually safe to drink.

Wells located near saline bodies of water are subject to salt water intrusion. The pumping of the well may induce infiltration of salt water into the aquifer. The dissolved salts associated with saline water are not usually attenuated or filtered out of the water and represent a significant problem in low-lying areas near oceans, bays, or tidal estuaries. The problem is often very severe on offshore islands.

Where the potential for salt water intrusion exists special care must be used to select an appropriate site for a water well. It is useful to know that fresh water is less dense than salt water. Therefore, fresh water will float on a layer of salt water. A special rule of thumb is applied to siting wells where salt water underlies fresh water. For every meter that fresh water is encountered above sea-level the lens of fresh water will extend 40 meters below sea level.

Example: On a small island off the coast of Luzon water is encountered at an elevation of five meters above sea level. Therefore, it can be assumed that the fresh water layer or lens will extend to a depth of 200 meters below sea level. Providing for a decline in the water level because of drought, etc., the well should be no deeper than 120 meters.

Wells that must be located in coastal areas should be placed as far from the shoreline as practical, on the highest ground practical, or close to a source of fresh water recharge such as a river, lake, pond or fresh water lagoon. Special consideration should be given to monitoring chloride levels in coastal wells, especially during dry periods.

Where other sources of contamination exist such as refuse sites or privies, wells should be located up-gradient from the source. In other words, if the direction of ground water flow is known, the well should be placed "upstream" of the contaminant source (Figure 8B-14). Very often ground water flows in the same direction that surface water would runoff the land. Therefore, it is usually safer to place the well at a site topographically higher than the source of contamination. In addition to being located at a higher elevation, the well should be located some safe horizontal distance from the contaminant source. In fine to medium grained consolidated and unconsolidated materials the wells should be at least 15 meters away from privies, cesspools, septic tanks, livestock pens, refuse dumps, places where refuse is burned, bathing and laundry areas, and other sources of contamination. Because automobile and truck exhaust, and leaking oil represent sources of contamination, and because animals using the road deposit wastes, wells should be located at least 10 meters from the side of the road.

Other potential serious sources of contamination are agricultural lands where crops are fertilized or sprayed with pesticides and herbicides. Such compounds are usually designed to resist natural decomposition and are generally poisonous to humans. To ensure adequate protection for wells, sites selected for ground water development should be 20 to 25 meters away from such fields.

If ground water is encountered near the surface (at depth less than 5 meters), or wells are less than 10 meters deep, or if the well is drilled into coarse grained, fractured rock or solutioned limestone, then all the distances mentioned in the previous paragraphs should be doubled to promote sanitary well protection.

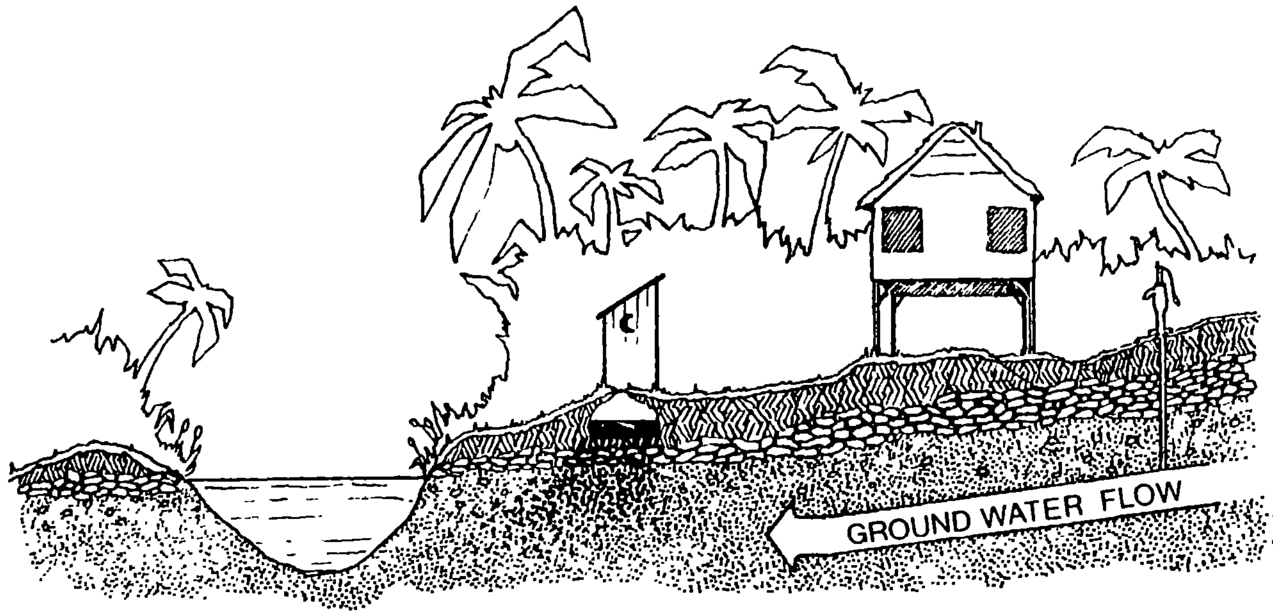


Figure 8B-14 Wells should be up-gradient of any sources of contamination.

WELL SITE SELECTION CHECK LIST

		Yes	No
1.	Has an effort been made to acquire existing information?		

a. geologic and hydrologic report and maps?
b. topographic maps?
c. aerial photographs?
d. well logs?

2. Have water well contractors been contacted who may provide information about ground water availability and quality in the area under consideration?

3. Has the interpretation of existing information proved useful in preliminary site selection? (If not, consider the assistance of a BWP Hydrogeologist)

4. During the field survey did you:

   a. look for vegetative indicators of ground water?
   b. examine physiographic features?
   c. consider accessibility of potential sites to barangay residents?
   d. locate all sources of potential ground water contamination?

5. Is the site selected appropriate in terms of protection from contamination and accessibility to users? (If the answer is no, provide an explanation as to the sites short comings and reasons why the site was chosen).

8B.3 WATER WELL DESIGN (for BWP Level I System Only)

The purpose of good water well design is to achieve the best possible combination of performance, sanitary protection, useful life and reasonable cost. Although some of the sophisticated engineering design considerations normally required for irrigation wells, municipal wells and even BWP level II wells can be overlooked, there are still many factors that should be considered in the design of level I water wells.

The well should be designed to allow the desired amount of water to flow freely into the well with a minimum of friction and loss of hydraulic head. At the same time, the well should be designed in a manner that prevents the entrance of sand or rock material through the screen and into the pump.

The well should also be designed in a manner that prohibits the migration of surface or near surface water into the well. If necessary, it should also be designed to prevent the entrance of poor quality water that may encountered in some formations.

Selection of materials to be used in well construction is also a function of well design. Materials used in the well must be able to resist the corrosive nature of some natural ground waters, or resist corrosive properties of some of the chemicals used during well disinfection and well maintenance for the removal of mechanical, biological and chemical incrustation. The casing and screen (when required) must be strong enough to withstand pressures encountered in deep wells, and forces exerted on the well during well development.

Finally, consideration must be given to the cost involved with well construction. Over-design of the level I well may be as bad as under-design. Because 0.19 - 0.64 liters per second (3-10 gpm) is all that is required for a level I well, over-design will do little to add to the well performance and would only serve to dramatically increase the cost of well construction.

When the manual user has completed this section he/she will be able:

1. to identify the components of a well;

2. understand the factors involved with the selection of well depth, well diameter, intake structure, gravel pack, and construction materials;

3. to delineate conditions which will determine well depth;

4. to select the appropriate well diameter;

5. to design or select the appropriate intake structure;

6. to determine where the intake structure should be placed;

7. to select the appropriate material for the casing and the intake structure;

8. to determine if gravel pack or formation stabilizer is necessary and the characteristics of its installation;

9. to determine if grouting is necessary and select an appropriate method of grouting.

8B.3.1 Parts of A Well

For design purposes, a well may be considered to have two main parts: The cased section and the intake section (Figure 8B-15). The upper part or cased section of the well serves as the housing for components of the pump, prevents the collapse of unconsolidated or weakly consolidated materials encountered near the surface, and serves as a vertical conduit through which water flows from the aquifer to the pump, or to the surface if the well is a flowing artesian well. The casing used must be water-tight and extend down from the surface to the aquifer or until consolidated material is encountered that will neither collapse nor slough into well. The casing should extend to a depth which ensures that water entering the well intake has traveled far enough through the ground to permit reasonable filtration.

The bottom or intake section of the well is that part of the well structure which permits water from the aquifer to enter the well. In unconsolidated formations and some weakly consolidated formations (i.e. friable sandstones and some ash beds), a screening device is used to permit water to enter the well while keeping out aquifer materials. When completed in consolidated materials, such as well-cemented sandstones, limestones, and fractured igneous and metamorphic rocks, screen is usually not necessary because of the nature of the aquifer to resist collapse and sloughing.

8B.3.2 Well Design and Well Construction Techniques

Well design is dependent on the well construction technique that has either been selected, or is typically available in an area. For example, there are design considerations associated with dug well construction that would be inappropriate for a well drilled using cable tool (percussion drilling) equipment. Likewise, a well installed by the percussion drilling method will have different design characteristics than a well drilled using rotary drilling equipment.

Special design characteristics related to particular methods of well construction are covered in greater detail in Section 8B.4. However, the basic elements of well design such as casing diameter, selection of materials, sanitary protection, and well sealing will be discussed in Section 8B.3.4 to 8B.3.8.

8B.3.3 Information to be Considered Before Designing a Well

The following information must be considered before designing a well:

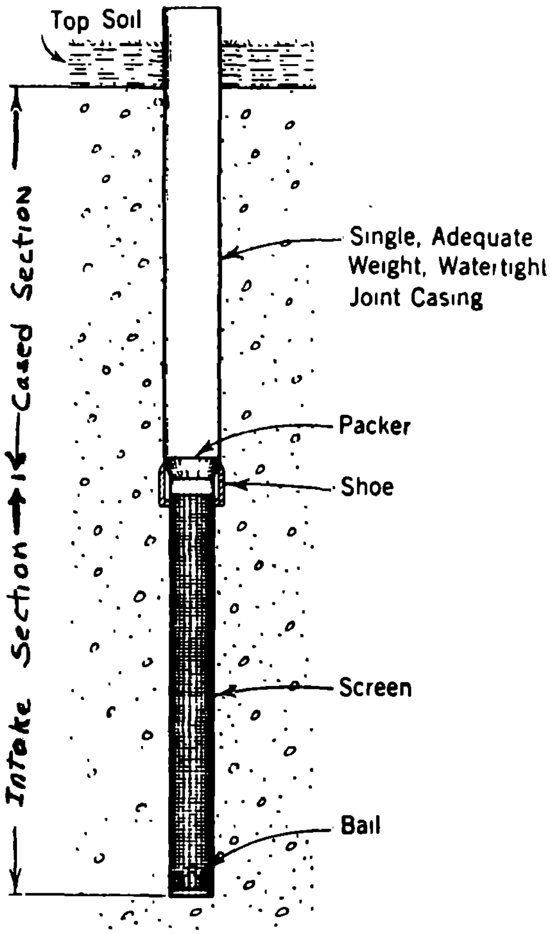


Figure 8B-15 Two main parts of a well:

1) the bottom section (intake structure)
2) the top section (casing)

(1) the thickness, character, and sequence of materials above the water table, or at the top of a confined aquifer;

(2) the thickness, character, and sequence of the aquifer(s), nature of the permeability (intergranular or secondary porosity), and the degree of confinement of the aquifer;

(3) the size and uniformity of aquifer materials;

(4) water level and seasonal water level fluctuations;

(5) water quality;

(6) design and construction features of wells previously constructed in the area;

(7) the operation and maintenance history of wells previously constructed in the area; and

(8) the desired yield of the proposed well;

It is unlikely that all of this information is available, but some or most of it can be acquired from sources such as the Bureau of Mines, or water well contractors who have worked in the area (Section 8B.2.1).

8B.3.4 Well Diameter

Well diameter will be affected by the method of well construction. For example, it is unlikely that a dug well can be constructed with a diameter much less than one meter. Likewise, a driven well is unlikely to have a diameter much larger than 75 mm.

Regardless of construction technique the well diameter must be chosen to satisfy two requirements:

(1) The well casing must be large enough to accomodate the pump, or pump components, with proper clearance for installation and efficient operation. Shallow-set pumps (pumping levels less than 8 meters) require that the well casing have a minimum diameter of 50 mm (2 inches). When pumping levels exceed 8 meters then the minimum diameter should be 100 mm (4 inches). Although the pump component will fit within a 75 mm (3 inch) diameter casing, installation and operation may be restricted if the casing is bent or not plumb.

(2) The diameter of the intake section of the well must be large enough to ensure good hydraulic efficiency of the well.

In deep wells, it is sometimes advantageous, for economic and other reasons, to reduce the casing diameter below the lowest anticipated pump setting (Figure 8B-16). This is done by telescoping one or more smaller size casing sections through the upper casing. The same consideration holds true for the well intake structure. If the pump setting is above the intake structure then the diameter of the screen can be reduced to lower costs or permit installation of a formation stabilizer.

8B.3.5 Well Depth

The anticipated depth of the well is usually determined by the experience of drillers in the area or the information contained in well logs of nearby wells.

Generally, a well is completed to the bottom of the aquifer. This is desirable for two reasons:

(1) more drawdown is available, ensuring optimum well performance; and

(2) there is a built-in safety factor should the pumping level drop.

There are some exceptions to this rule. In a uniform artesian aquifer it may be more desirable to center the screen between the top and bottom of the aquifer. If the aquifer varies in permeability it would be advantageous to place the intake structure adjacent to the most permeable portion of the aquifer. Still another exception is the situation where water of poor quality is found in the lower part of the aquifer. In this case, the well should be completed to a depth which will avoid undesirable water and obtain the best quality water that is available. If the lowest part of the drilled hole penetrates an aquifer with undesirable water, then the section should be carefully backfilled so that this water will not migrate upward when the well is pumped. The backfill material must be relatively impermeable and should be well compacted after it is emplaced in the well. Cement or concrete frequently is the best material for backfilling in this type of situation (Figure 8B-17).

8B.3.6 Intake Structure

The intake structure is that portion of the well which permits the entrance of water into the well. In consolidated rock, the casing extends down into an overlying impermeable stratum (the minimum depth setting of the casing should be 10 meters). An open hole is drilled into the aquifer. The length

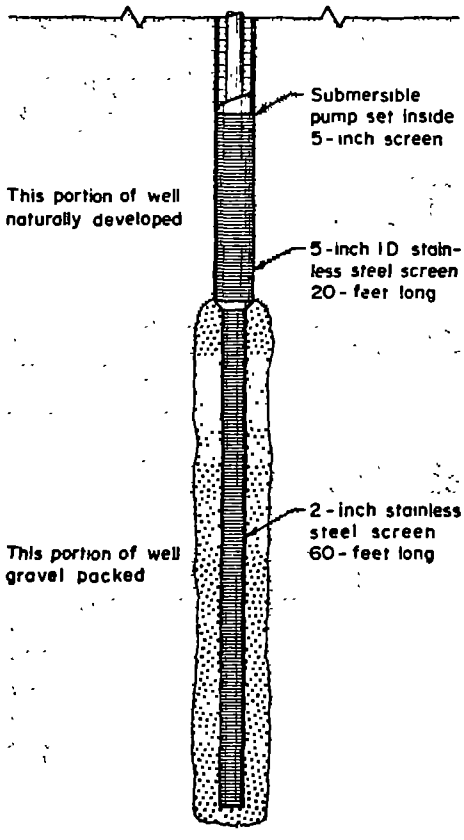


Figure 8B-16 Well designed with a reduced screen diameter.

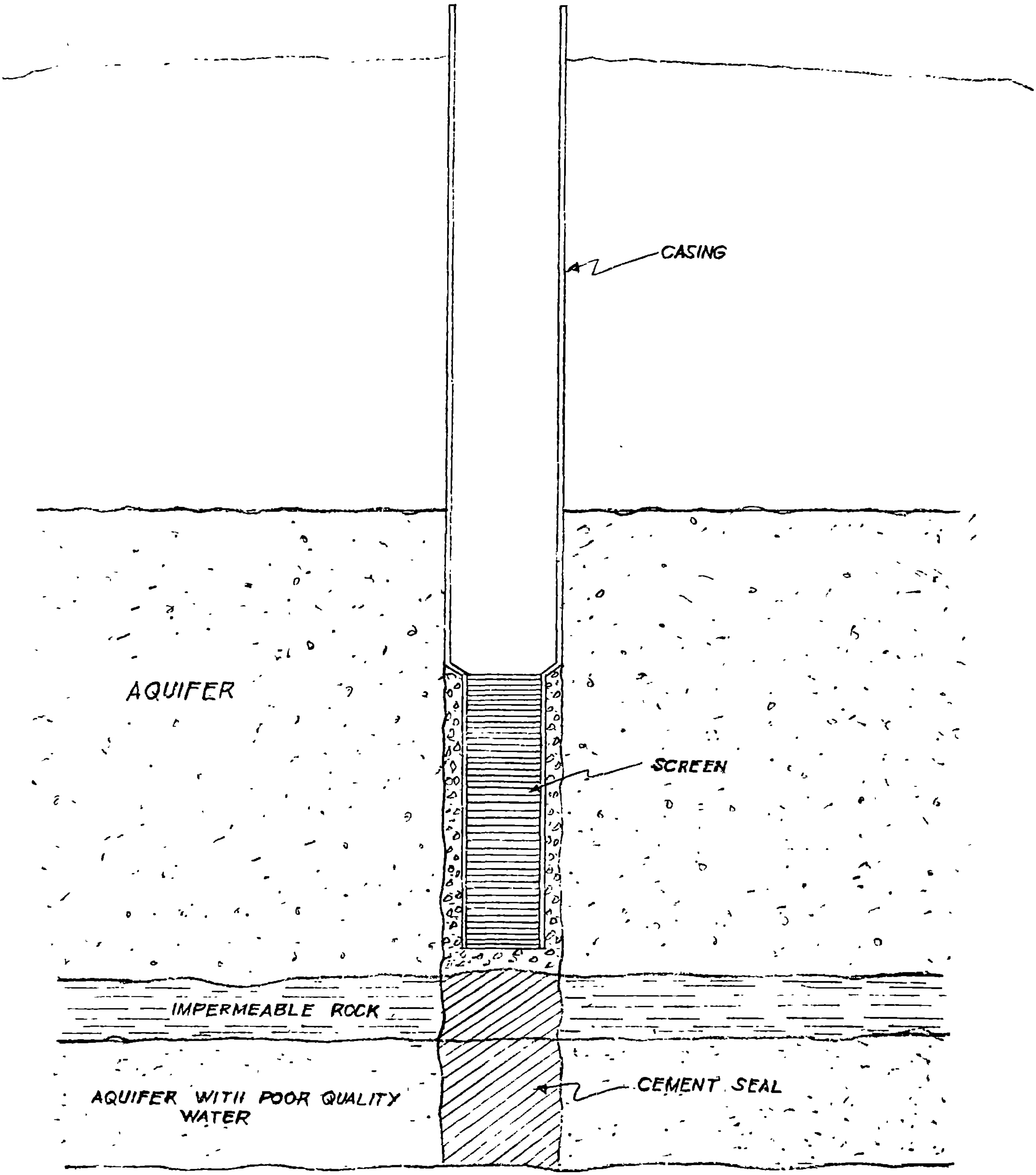


Figure 8B-17 Bottom seal in a well to prevent the entrance of poor quality ground water.

The length of the open hole is determined on basis of the desired yield of the well. Under some circumstances an open hole will penetrate a series of aquifers and impermeable formations until the well yields the desired quantity of water, or until a depth is reached where the water quality becomes undesirable (Figure 8B-18).

In unconsolidated material, the most important aspect of well design is the selection of an intake structure. The purpose of this component is not only to permit water to enter the well but also prohibit the entry of aquifer material. It is also very important that this structure permit the desired amount of water to enter the well with a minimum loss of hydraulic held.

There are several types of intake structures available in the Philippines. The most common type is made of casing with torch-cut slots (Fugire 8B-19A). Slot openings vary from .48 cm, to 1.0 cm., (1/4 to 3/8 inch). It is important to realize the disadvantages associated with this type of intake device. First, the openings cannot be closely spaced, therefore the amount of area open to permit the entrance of water is very limited. Second, the openings are uneven and vary in size. Third, the jagged nature of the slots makes them highly susceptible to corrosion. And finally, the openings are not small enough to control the entrance of fine, medium or even coarse sand. In most cases, such wells will experience the continuing entrance of sand. The sand may damage the pump and after a period of time will clog the intake structure.

Casing in which holes have been drilled (Figure 8B-19B) to permit the entrance of water is similar to torch-cut casing. Most of the disadvantages associated with torch-cut slots hold true for steel pipe with drilled holes.

The limited open area of slotted pipe or drilled pipe makes it necessary to use tens of meters of pipe. Sometimes as much as a hundred meters of slotted pipe have been used to acquire the desired yield.

Plastic casing with saw cut slots is an improvement over the metal torch-cut or drilled-hole devices. With saw-cut slots, slot openings are usually uniform and there is much better control of the slot width. Slot widths can be cut that are as small as 0.05 cm (0.2 inch). Therefore, the influx of very fine sand can be controlled. Since plastic is resistant to corrosion the slotted plastic casing can theoretically last indefinitely. The chief disadvantages of using saw cut slotted casing is the fact the casing has limited open area and the slots, especially the fine slots, can easily become clogged. Plastic casing is also more likely to collapse under pressure if installed improperly or

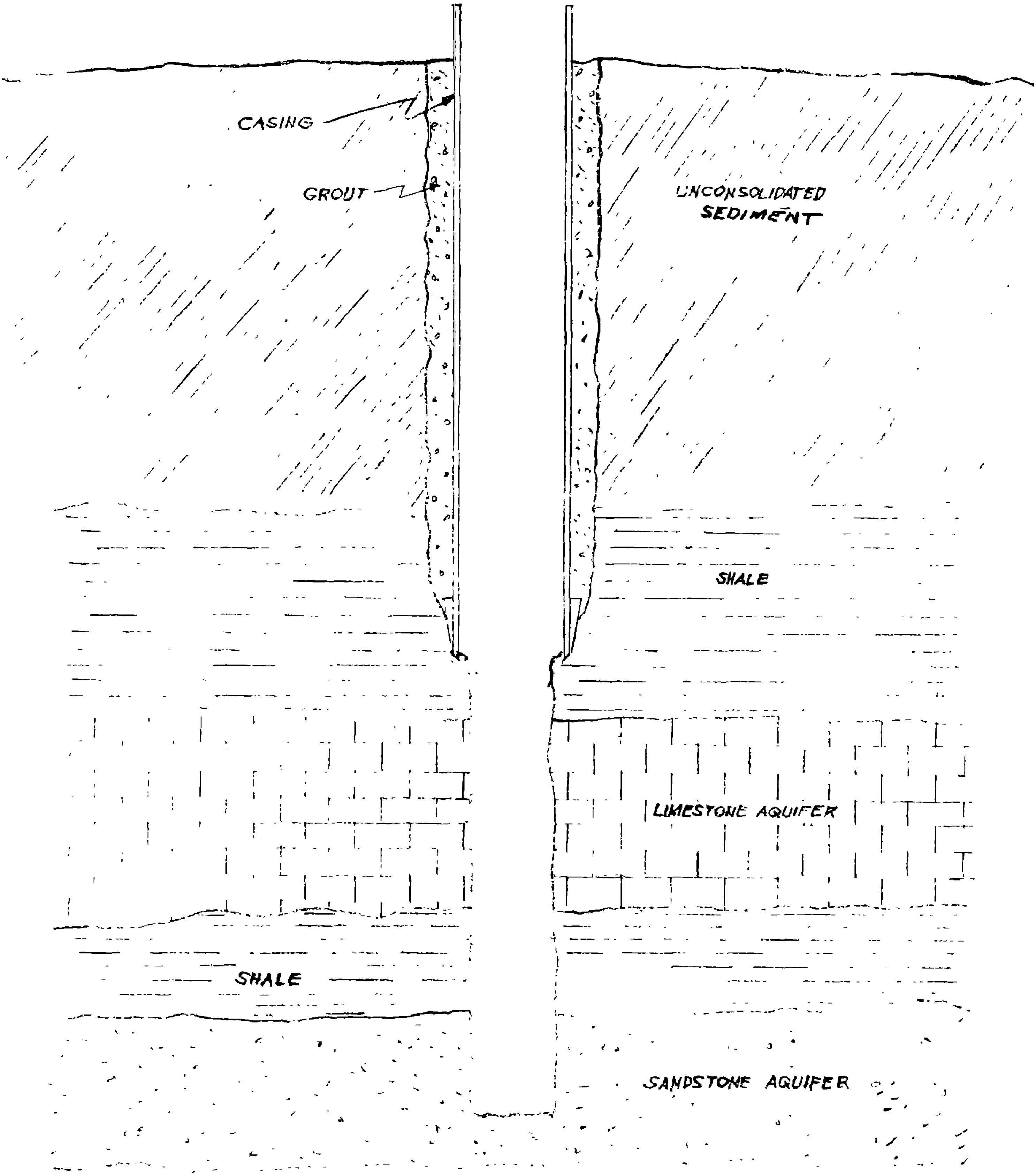


Figure 8B-18 Multiple aquifer rock well.

developed improperly. Proper installation and development is described in Section 8B.6.

Four inch diameter louvered casing (Figure 8B-19C) is also available as an intake structure. This type of screen offers greater open area and excellent slot size control. A wide variety of slot sizes are offered from the manufacturer. The screen has good strength characteristics and can be constructed from any one of a number of metal alloys to provide good corrosion resistance.

Wire-wound screen with ribbed supports is considered the best type of intake structure (Figure 8B-19D). It has the following advantages:

(1) openings in the form of slots are continuous and not interrupted around the circumference of the screen:

(2) closely spaced slot openings provide maximum open area per meter of pipe;

(3) V-shaped slot openings that widen inward improve well development and prevent clogging of slot (Figure 8B-20); and

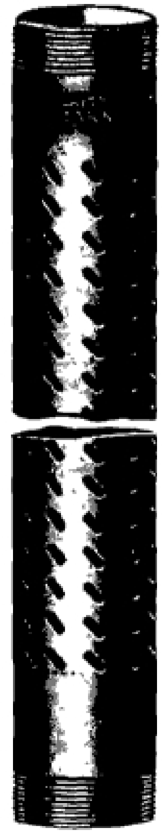
(4) less than 2 meters (5 feet), even with a 0.025 cm slot opening, is all that is necessary to provide enough open area to permit water to enter at a rate acceptable for level I well.

Galvanized iron, bronze alloy, or stainless wire-wound screens are availble.

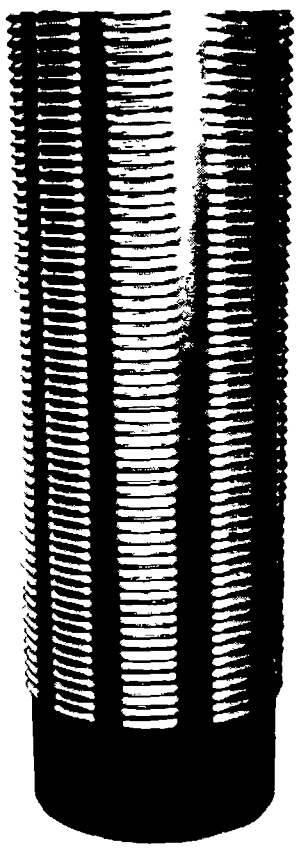
The only drawback to this type of screen is its high cost. However, in most circumstances 2 meters of 50 mm diameter screen can replace, tens of meters of slotted pipe. The saving resulting from using a shorter screen and having to drill to a shallower depth may offset the extra cost of the screen. In most cases, the use of wire-wound screen is more cost effective and provides longer service life than other types of intake structures.

Continuous-slot plastic well screen is also available in the Philippines. Although it has a lower collapse strength this type of screen has many of the advantages of the wire-wound continuous slot metal screen. If installed as described in Section 8B.5, then plastic screen and casing will have enough strength for construction of level I and level II wells. The only disadvantage to the continuous-slot plastic well screen is that it is not yet manufactured in the Philippines with the same keystone shape the wire-wound metal screen has, therefore, it is slightly more susceptible to clogging, especiallly when it has fine slot sizes.

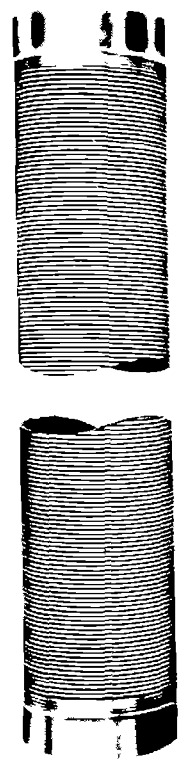
A. Torch cut.



B. Drilled perforations.



C. Louvered



D. Wire wound

Figure 8B-19 Common types of well intakes.

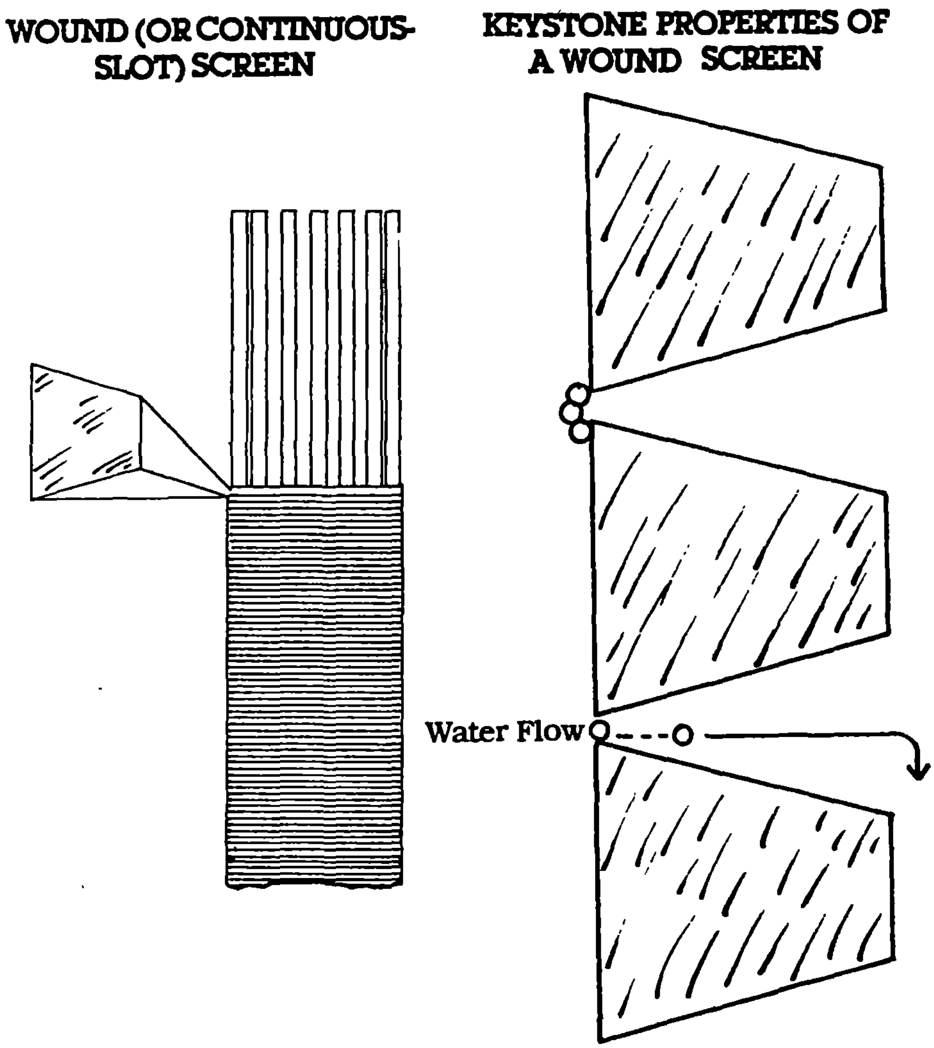


Figure 8B-20 Construction details of a wire-wound screen.

Intake structures of all types are available with standard pipe diameters (pipe size) for direct attachment to casing, or available with a slightly smaller outside diameter (telescope-size) to permit the screen to be lowered through the casing into place adjacent to the aquifer.

With level II and other types of community wells, unconsolidated aquifer materials should be placed through a series of sieves, and the percentage of material retained on each sieve should be plotted on a graph to determine a value for the optimum screen slot opening. This is probably not practical for level I wells. However, as a rule of thumb the following slot sizes can be used for different formations.

Sand Size	Slot Openings	
	cm	inches
fine sand	0.025-0.05	0.01-0.02
medium sand	0.05 -0.10	0.02-0.04
coarse sand & gravel	0.10-0.15	0.04-0.06

In a moderately well sorted aquifer these slot sizes should provide ample open area to enable good well development and ensure well performance. In most circumstances, a water well constractor will select a slot size based on his past experience in the area, and select a screen for a well even before the well is drilled. When in doubt about aquifer grain size the next smallest screen slot size should be selected. This practice is only acceptable because well efficiency for a level I well is not as critical a factor as in higher yield wells.

In cable tool and rotary drilled wells, and percussion-jetted wells, 2 to 3 meters of blank casing (tail pipe) can be attached below the screen to permit the accumulation of very fine sand or ash that may come through the intake structure when the well is pumped. Periodically (i.e., twice a year), a suction line should be extended down to the tail pipe to pump out the accumulation of sand.

8B.3.6.1 Placement of the Intake Structure

Where geologic formations are stratified, having layers of varying particle size distribution. Ordinarily the screen or slotted casing should be placed adjacent to the coarsest part of the aquifer. The following are a few rules which will simplify the placement of intake structures in unconsolidated formations:

(1) place the well screen in the lowest part of the coarsest part of the aquifer (Figure 8B-21A);

(2) if fine sand underlies a coarse grained aquifer, then the screen bottom should be about 30 cm (one foot) above the top of the fine material (Figure 8B-21B); and

(3) if fine sand overlies the coarse grained aquifer, then the top of the screen should be set at least 60 cm (2 feet) beneath the bottom of the finer formation (Figure 8B-21C).

8B.3.6.2 Selection of Casing and Screen Materials

The choice of materials that go into the construction of a well is a very important aspect of water well design. A well constructed of materials with little or no resistance to corrosion can be destroyed beyond usefulness by highly corrosive water within a few months of completion. Improper selection of materials can also result in collapse of the well due to inadequate strength. The above factors have considerable influence on what is called the useful life of the well. In addition to these influences, the selection of materials also has considerable bearing on the cost of well. Therefore, well material selection takes into consideration three factors: water quality; strength requirements, and cost.

Water Quality - Water quality refers primarily to the chemical or biological quality of the water. Water as it exists in nature will either cause metals to corrode, or cause incrustation in the aquifer or the well. In some rare situations, corrosion and incrustation can occur simultaneously. Whether corrosion or incrustation will occur, can usually be determined by chemical analysis of the water. However, most well drillers who have worked for a while in a area will generally know by experience whether a well will have problems with corrosion and/or incrustation.

Besides water quality other factors such as velocity of flow and dissimilarity of metals will contribute to the corrosion process. The greater the velocity of flow, the greater is the removal of the protective corrosion end-products from the surface of the metal, and hence the exposure of that surface to further corrosion. The use of two or more different types of metals such as bronze screen and galvanized iron casing can create a galvanic cell which induces corrosion of the less corrosion-resistant metal.

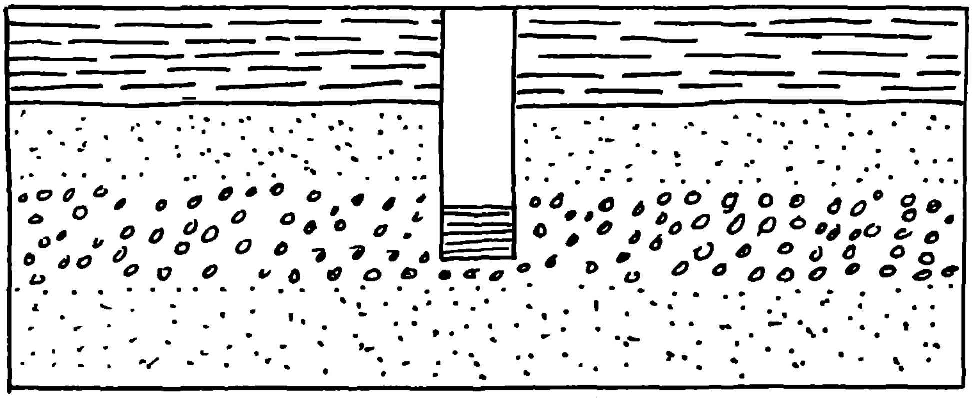


Figure 8B-21A Placement of screen in the coarsest part of aquifer.

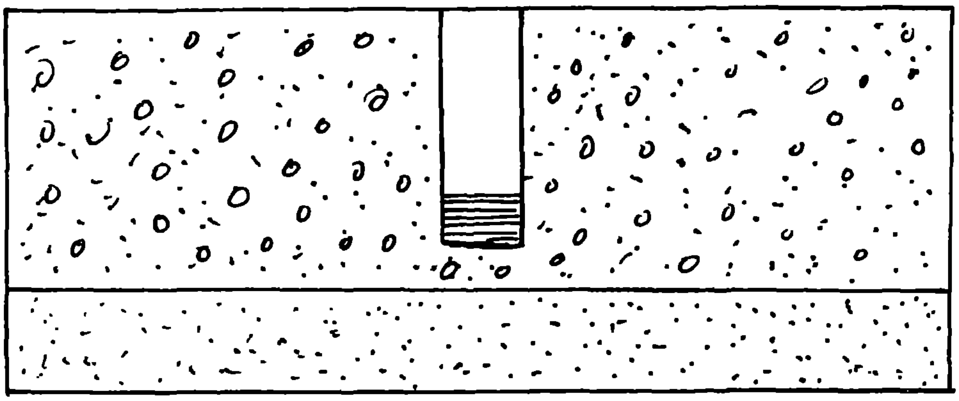


Figure 8B-21B Bottom of screen 30 cm above finer material.

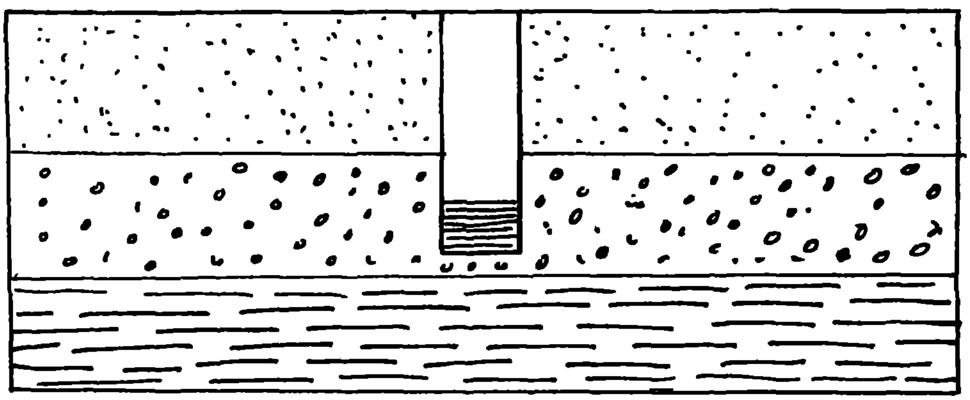


Figure 8B-21C Placement of screen at lease 60 cm below fine formation.

Ordinary steel and iron are not corrosion resistant. There are, however, a number of metal alloys available with varying degrees of corrosion resistance. Among these are the stainless steels, which combine nickel and chromium with steel, and also the copper-based alloys such as brass and bronze which combine traces of silicon, zinc and manganese with copper. In areas where corrosion is severe, stainless steel, or less expensive polyvinyl chloride (PVC) casing and screen can provide corrosion resistance and adequate strength.

Incrustation, unlike corrosion, results not in the destruction of metal, but in the deposition of minerals on the casing and screen, and in the aquifer immediately adjacent to the well. These deposits can cause the blocking of the screen openings and pore spaces of the surrounding rock formation. Incrustation can also be a result of bacteriological growth, or the migration of fine silt or clay into the aquifer and the well.

Incrustation problems are frequently treated with chemicals that may be corrosive to metal. Therefore, if incrustation is anticipated, then corrosion-resistant material should be used, especially for the intake area of the well.

Strength Requirements - Strength requirements are important in both casing and screen selection but are generally of more concern in screen selection. Screens must be strong enough to withstand the external radial pressures that could cause their collapse, as well as the vertical loading due to the weight of the casing above them.

Some metals have greater strength characteristics than others. Stainless steel, for example, can be twice as strong as some copper alloys. Manufacturers of casings and screens will often have available product information regarding collapse strength, tensile strength, compressive strength and resistance to corrosion. It is often helpful to consult with them on the selection of suitable materials.

Cost - Cost considerations may often be the deciding factor in the selection of the construction materials used in small wells. The situation may arise, for instance, where stainless steel would be the most suitable material for use, combining corrosion-resistance with excellent strength and a long, useful life. However, after weighing the benefits of extra useful life against lower initial cost, the cost of replacement at a later date, and the owner's financial resources, it's cost may necessitate the use of some other less suitable material.

8B.3.6.3 Gravel Packing and Formation Stabilization

Where aquifer materials are very fine or the aquifer contains thin layers of fine materials, selection of a well screen with very fine openings (.025 - .05 mm) would be necessary. The use of such fine slots reduces open area of the intake structure, and increases the susceptibility of the screen to clogging. To eliminate this situation, material coarser than the fines in the aquifer, such as sand or fine gravel can be placed between the well screen and the borehole wall. This gravel pack material serves to prevent fine sand from flowing into the well while making it possible to select slot sizes to hold out the gravel pack rather than the formation material. Thus, more open area is available, improving well performance.

There are many ways to determine the diameter of the particles to be used in a gravel pack and the degree of sorting that would provide the best pack material. For level I wells, such calculation is usually not necessary. The material used for the gravel pack should have a diameter no greater than five times larger than the fine material it is designed to filter out. For example, if the sand grains have a diameter of .02 mm then the gravel pack grains should have a diameter no larger than 0.10 mm. If the gravel pack materials is too coarse, then fine sand will find its way through the pore spaces of the gravel pack and migrate into the well. The gravel pack selected should also be well sorted. Poorly sorted gravel pack material will lower the permeability around the well screen and result in a loss of well efficiency and perhaps well yield.

The gravel pack thickness is usually 5-10 cm (2-4 inches). Thus it is necessary that the borehole be somewhat larger than the outside diameter of the screen (Figure 8B-22). Generally if a well is to be gravel packed it will be drilled using the rotary method or percussion-jetting method (Section 8B.4.) because a larger hole is drilled to permit installation of the casing and screen in the hole without interference. Gravel pack can also be installed using the cable tool method, if casing is driven to the bottom of the hole, then the screen is telescoped through the casing to the bottom of the hole. Gravel pack is added between the screen and the casing. Then the casing is jacked back exposing the gravel pack and screen to the aquifer (Figure 8B-23). The gravel pack should extend at least 3 meters (10 feet) above the top of the screen to allow for settlement or removal of some gravel pack material during well development.

The installation and the design of a <u>formation stabilizer</u> is similar to that of the gravel pack. However

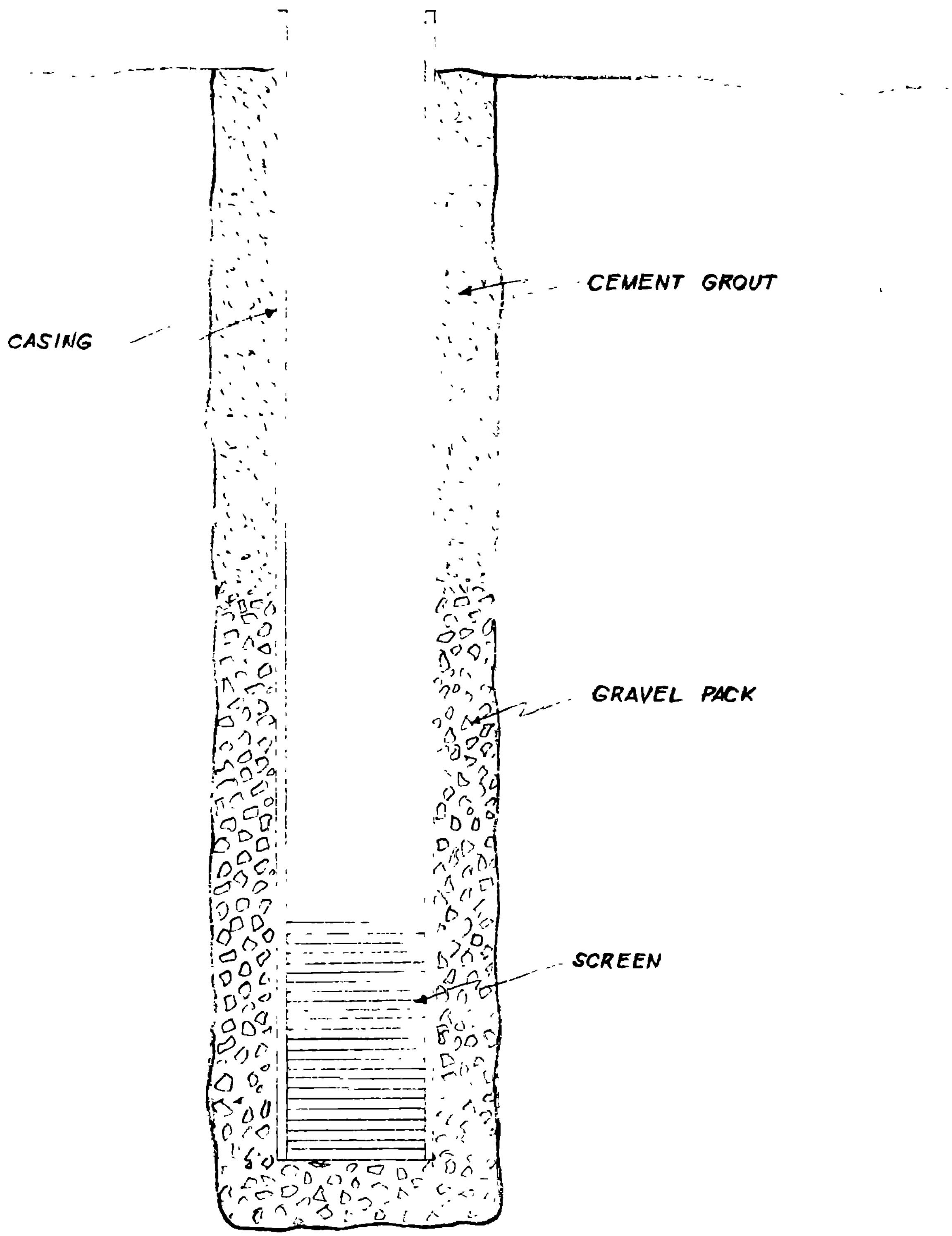


Figure 8B-22 Design of a gravel pack well.

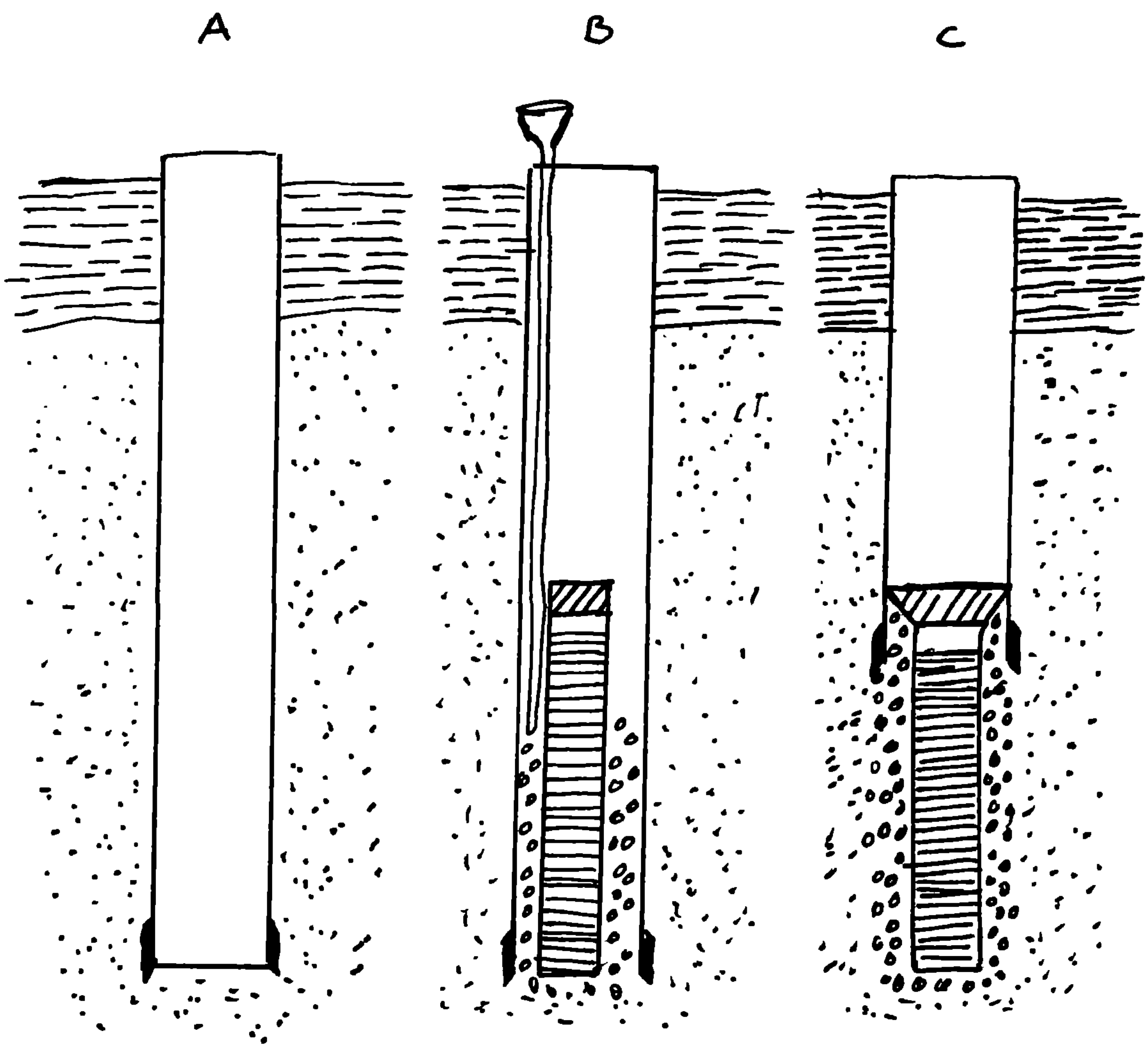


Figure 8B-23 Basic steps for gravel packing a cable tool drilled well.

A. install casing
B. telescope screen and place gravel pack
C. pull back casing exposing screen and gravel pack

the objective of the formation stabilizer is different. The formation stabilizer is used to prevent silt and clay materials above the aquifer from caving or slumping during the well development process. By avoiding such caving, proper development of the well can be carried out with less time and effort.

The quantity of formation stabilizer should be sufficient to fill the annular space around the screen and casing to the level of 3 meters (10 feet) above the top of the screen. This would allow for settlement and losses of material through the screen during development. If necessary, more material should be added as development proceeds to prevent the top of the formation stabilizer from falling below the top of the screen.

Size sorting is not as critical for a formation stabilizer as it is for a gravel pack. Usually materials with diameters ranging from 0.5 to 1.25 mm will be adequate.

8B.3.7 Sanitary Protection

The penetration of an aquifer by a well provides two main routes for possible contamination of ground water. These are the open or top end of the casing and the annular space between the casing and the borehole. The well must be designed to prevent contamination along these two routes.

8B.3.7.1 Upper Well Protection

The casing should extend at least 35 cm above the ground, or 35 cm above the highest anticipated flood level if the well is located in a flood plain. It should then be surrounded by a concrete apron as described in Section 8C.

8B.3.7.2 Lower Well Protection

For artesian wells, water-tight casing should extend downwards into the impermeable formation which directly overlies the aquifer. The purpose of this construction is to retain the artesian pressure of the aquifer by providing a seal against upward leakage from the aquifer up the outside of the casing. The borehole should not be extended into the artesian aquifer until the casing has been set and grouted.

In water table aquifers the casing should be extended at least 1.5 meters below the lowest expected pumping level. Under no circumstances should the casing be less than 10 meters long (Figure 8B-24).

The above are general rules which should be applied with some flexibility where geologic conditions so require.

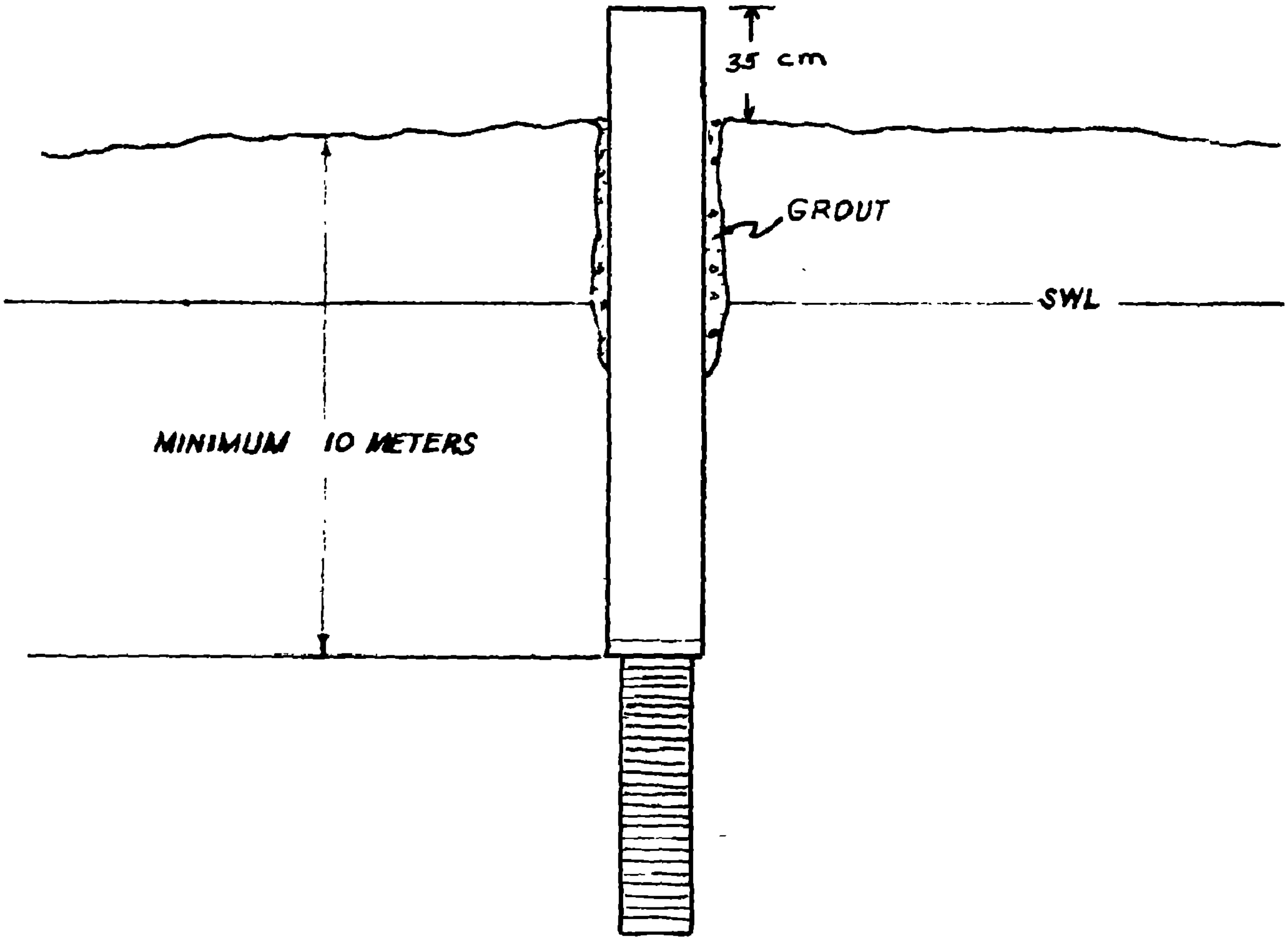


Figure 8B-24 The well casing should extend at least 10 meters beneath the ground surface.

WELL DESIGN CHECKLIST

1. How deep are wells in the area? ________________
2. Will the pumping level be within the suction limit for a shallow well pump? ________________
3. Has corrosion or incrustation been reported in other wells in the barangay? ________________
4. What method of well construction is most appropriate? ________________

Well Design Characteristics

1. Method of Construction ________________
2. Anticipated Well Depth ________________
3. Desired Well Yield ________________
4. Well Diameter ________________
5. Intake Structure ________________
6. Casing Material ________________
7. Screen Material ________________
8. Length of Intake Structure ________________
9. Gravel Pack or Formation Stabilizer (yes or no) ______________
10. Gravel Pack or Formation Stabilizer Grain Size ______________
11. Method of Upper Well Sealing ________________

8B.4 METHODS OF WELL CONSTRUCTION

There are many methods of well construction being practiced in the Philippines. Selection of any particular method is usually based on factors which include:

1. availability of equipment;

2. availability of skilled and unskilled laborers;

3. subsurface geology;

4. availability of an existing source of water;

5. depth to the water table; and

6. depth of the well.

For example, percussion (cable tool) drilling equipment is readily available throughout the country and most wells are drilled by this method. Percussion drilling is also popular because it is readily adaptable for drilling in many different types of geologic materials. However, in some coastal areas and on small islands, dug wells are usually constructed because the depth to water is shallow, and salt water may be encountered if the well is too deep. The large diameter of the dug well provides extra storage capacity to meet the desired yield of the well without having to extend to a greater depth which may have a poorer quality water.

In many parts of the country where fine or medium grained unconsolidated materials are encountered at moderate depths, the wells may be constructed by jetting or driving.

The methods of well construction examined in the manual, and most typically used in the Philippines are:

1. hand dug

2. driven

3. jetted

4. percussion

5. hydraulic rotary

Each particular method of well construction method has particular advantages and disavantages related to the required materials, equipment, labor skills, and the susceptibility of the well to contamination after it has been constructed. Dug, driven and jetted wells all share one common advantage: the equipment is light-weight, portable and easily maintaned. Further, skilled personnel requirements for these types of wells are very small. In the case of percussion and hydraulic rotary drilled wells the advantages are: ease of penetration, ease of construction, and better protection against contamination. The latter advantages are also true for driven and jetted wells.

In spite of the advantages listed above, each type of well has certain limitions. Dug wells and many driven wells have limited yield, although the yield usually meets the requirements of a level I system. Construction is slow and laborious when tightly compacted soil is encountered. And it is difficult to penetrate formations of hardpan and rock with tools and equipment provided.

Jetted wells are limited to shallow depth and there must be a source of good quality water nearby to use this drilling process. In addition, the jetting method is useless or difficult in consolidated soils and formations of hardpan, caliche, adobe and clay.

Drilled wells require more sophisticated equipment. The equipment may be hard to transport and set up in rugged terrain. And the equipment requires more maintenance and skilled operators. Rotary drilling equipment also requires a supply of good quality water that is readily available.

Section 8B.4 will familiarize the manual user with the well construction methodologies most appropriate for level I systems in the Philippines. Upon completion of this section the user will be able:

1. to select the most appropriate method of well construction for a given location;

2. to supervise the well construction operation;

3. to recognize the tools and equipment used during well construction, and understand their proper use;

4. to make changes in well design during the construction of a well to fit the geologic conditions encountered;

8B.4.1 Dug Wells

The practice of constructing hand-dug wells in the Philippines is declining. This is probably good in the sense that dug wells are highly susceptable to contamination and may represent a physical hazard to persons, especially young children who may haphazardly fall into the well. Nonetheless, dug wells still have a place in rural water supply development. A few level I projects have made use of existing dug wells for water supplies, and have upgraded those wells by installing an apron and a pump at the ground surface to improve sanitary protection of the water source. In some areas, where ground water yield is limited a dug well may prove more advantageous than other types of wells because its large diameter provides a reservoir for storage of water to make up for the low permeability of the aquifer.

Other advantages of hand dug wells include:

(1) easy fabrication of tools and equipment;

(2) a village supply of labor, and therefore the community feel more involved in the development of the program; and

(3) with the exceptions of cement and reinforcing rods, the necessary materials are usually locally available, making it one of the cheapest methods of well construction.

On the other, hand dug wells present certain limitations:

(1) sixty meters is usually the practical limit to the depth that can be reached, although most dug wells are less than 20 meters deep;

(2) construction is very slow, sometimes several months are necessary to construct the well;

(3) well yields are usually limited to 0.32-0.64 liters per second (5-10 gpm);

(4) consolidated rock is very difficult to penetrate;

(5) because it is difficult to dig below the water table, slight fluctuations in the water table often make dug wells unreliable. It is best to dig wells near the end of the dry season when the water is likely to be at or near its lowest point. Thus the well can be sunk deeper with less interference from the in flowing of water. The greater depth should ensure a more reliable supply. If the well cannot be dug during the dry season, plan to go back to it at the end of the dry season to deepen it; and

(6) because dug wells are usually shallow, subsurface water may not have traveled an adequate distance to be filtered in the subsurface environment, therefore they are more likely to be contaminated than deeper wells. In addition, it is very difficult to get a good seal between the borehole and the concrete caissons, often used as well lining, and it is difficult to get a good well seal at the surface. Thus, contaminated runoff and bacteria in the soil can easily migrate into the well.

8B.4.1.1 Planning

Outlined below is the preliminary planning that should be done by the drilling contractor and/or the project supervisor.

(1) Select a well site based on geologic factors, site accessibility, and sanitary conditions (Section 8B.2).

(2) Determine the availability of useful skills that residents of the barangay may have that would facilitate well construction.

(3) Assess the availability of construction materials and tools.

(4) Select a design and method of construction most appropriate to geologic conditions and availability of materials.

(5) Before construction begins, develop a written workplan for the entire project.

(6) All equipment and materials needed for well construction should be collected. Arrange the materials and equipment at the well site to facilitiate the construction phase.

(7) If concrete lining rings are to be used, begin constructing them in advance. Each ring should be cured for at least four days before it is installed.

(8) Layout the perimeter of the hole with provisions for checking diameter and plumbness.

(9) Arrange for people and materials to get in and out of the well.

8B.4.1.2 Dug Well Design and Construction

The design of the well will be a function of the digging and lining method selected, the quantity of water desired, and the anticipated depth of the well.

Well Shape - In nearly all situations dug wells are constructed with a cylindrical shape. This well shape produces the greatest amount of water with the least amount of work. Also, a round lining is the strongest that can be built with a given amount of material.

Well Diameter - The diameter of the well is the longest measure across the hole (Figure 8B-25). Selection of the diameter is usually based on the distance necessary to allow people to work within the well and the size of the forms or precast lining sections that are available for well construction. Dug well diameters may range from 1 meter to 10 meters, although 1-3 meter diameters are most common. Keep in mind that the smaller the diameter of the well, the less soil and rock has to be removed. If you double the diameter of the well you increase the amount of soil and rock that must be removed by four times.

During various stages of construction, a well may have two or sometimes three different diameters (Figure 8B-26).

(1) The borehole diameter

(2) The diameter when the lining is installed

(3) the diameter of the inner liner, especially if the well is relatively deep.

Lining - Designing the lining is largely a matter of assessing the ground conditions, availability of materials, and determination of the construction method most appropriate for the situation.

There are three basic types of ground condition:

(1) Very loose soil (i.e. dry sand) - the hole is as wide as the hole is deep, because it sides continually collapse and cave (Figure 8B- 27A).

(2) Loose soil (i.e. damp sand) - a relatively shallow (1 to 5 meter) hole can be dug before its sides may cave in (Figure 8B-27B).

(3) Firm soil (i.e. compacted clay) - a hole can be dug to the water table with minimal danger of collapse and cave-in (Figure 8B-27C). Unless the driller or engineer is very familiar with the soils in the area an unlined hole should never exceed 5 meters

Bottom Section Design - The design of the bottom section of the well will be determined by the method of construction selected.

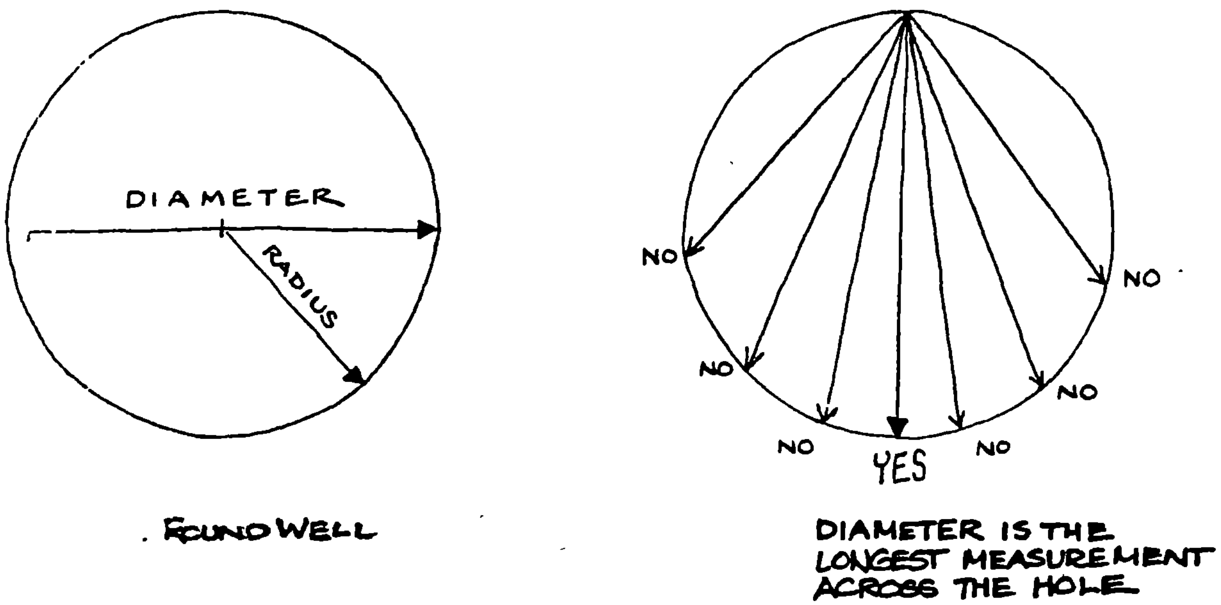


Figure 8B-25 Measurement of dug well diameter.

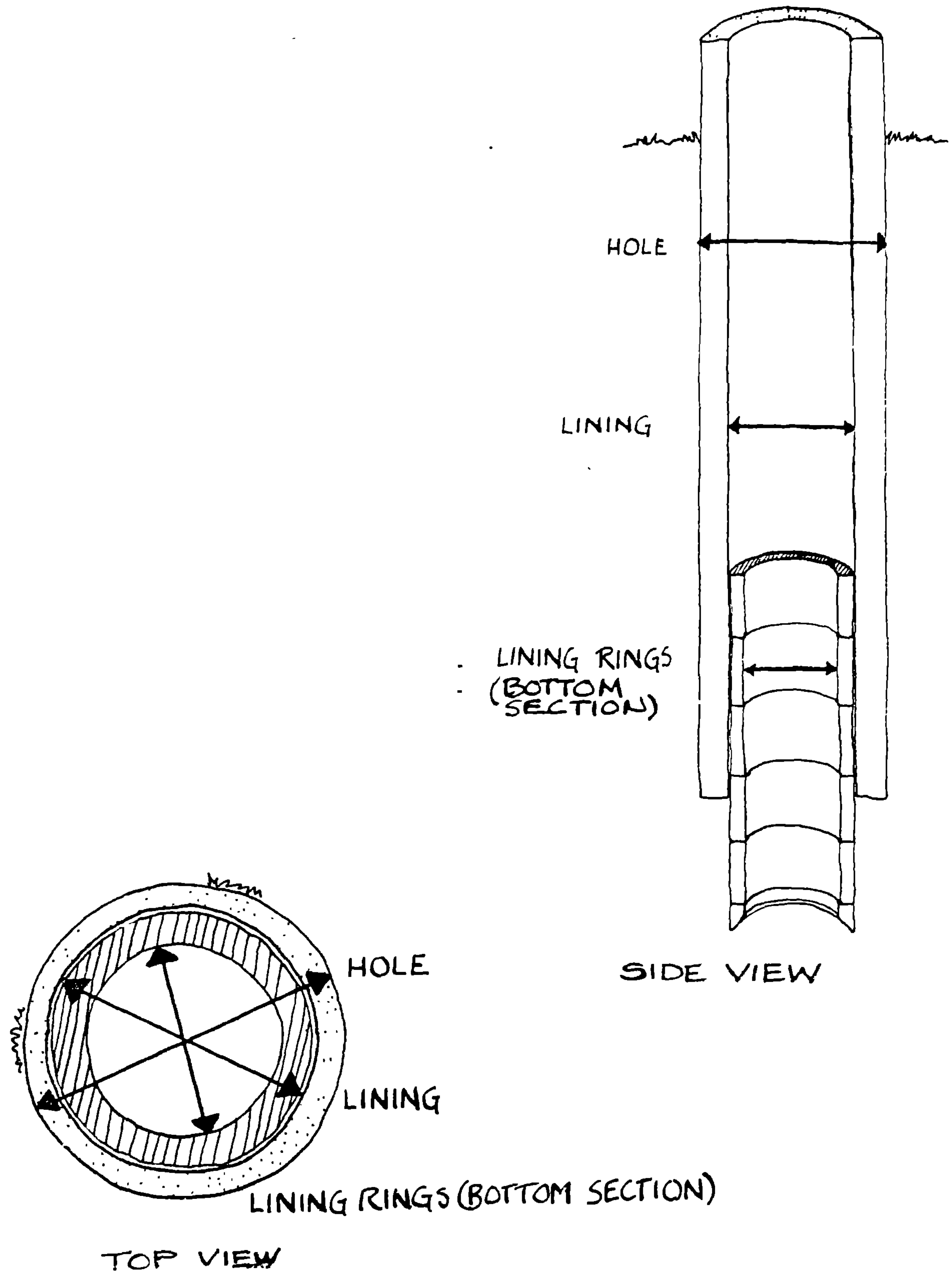


Figure 8B-26 Three different well diameters used during construction.

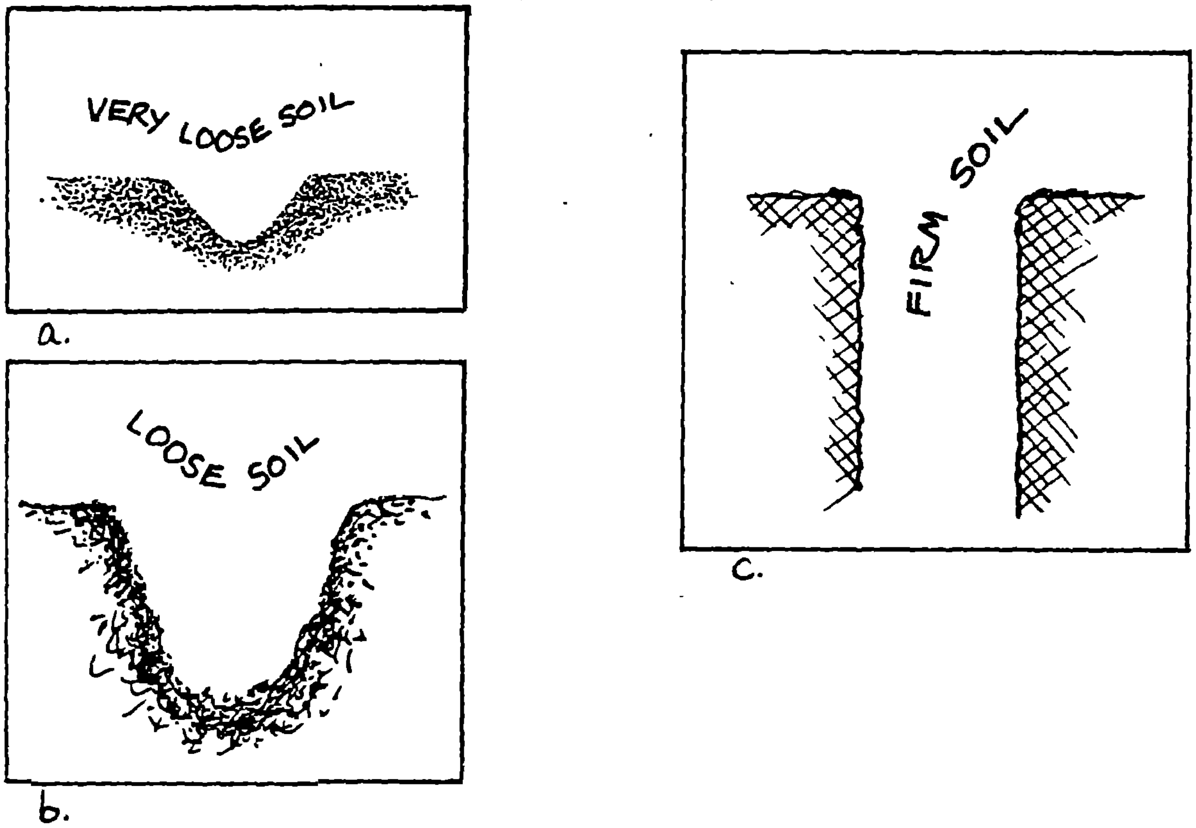


Figure 8B-27 Varieties of dug well ground conditions.

The purpose of the bottom section is to allow as much water as possible to enter the well without permitting any of the fine soil particles from the surrounding aquifer to enter the well.

There are three commonly used methods of allowing water to enter the well (Figure 8B-28 A, B, C,).

(a) through porous concrete lining

(b) through angled holes in the lining

(c) through the bottom

The lower edge of the bottom caisson may have a sharp edge sloping upward into the center of the well. This edge is called a cutting ring (Figure 8B-29). A cutting ring may not be a necessity in loose sandy aquifers, but it is useful. A flat edge would tend to be caught more easily, preventing further sinking, as opposed to a cutting edge which will tend to cut through loose material and funnel it toward the center of the well for easy removal.

The bottom section can be directly attached to the lining or it may be installed as an inner lining surrounded by, or extending into the main section of the well (Figure 8B-30). In such cases gravel should be placed between the main lining and the bottom section as a convenient filter and as a guide for the sinking rings.

There should be a gravel filter or plug at the bottom of the well to ensure that only water enters the well, and not particles of rock from the aquifer. There are two different materials that can be used separately or together: a gravel filter or a porous concrete plug (Figure 8B-30).

The gravel filter should have a minimum depth of 20 cm. The filter can be made more effective by using two or more different sizes of gravel in separate layers with the smallest size gravel on the bottom and the largest size gravel on top.

If a porous concrete plug is used it should fit closely into the inside diamenter of the bottom lining. The slab can be cast at the surface and later lowered into place. It should be placed on a layer of gravel 10-15 cm. thick. The slab could be made porous either by making holes in a regular concrete slab or using a concrete mixture with very little sand.

A. Through porous concrete lining - Lining rings sunk into the bottom section can be made of porous concrete which acts as a filter to prevent soil particles from entering the well.

B. Through angled holes in the lining - Holes can be punched in a freshly poured concrete ring which, when cured, can be sunk into the bottom section. These holes are more effective at preventing soil entry if they are slanted up toward the middle of the well.

C. Through the bottom - The bottom of the well should always be constructed to allow water to come up through it. Often the bottom is simply left open and uncovered but it is preferable to prevent soil entry and the gradual filling up of the well.

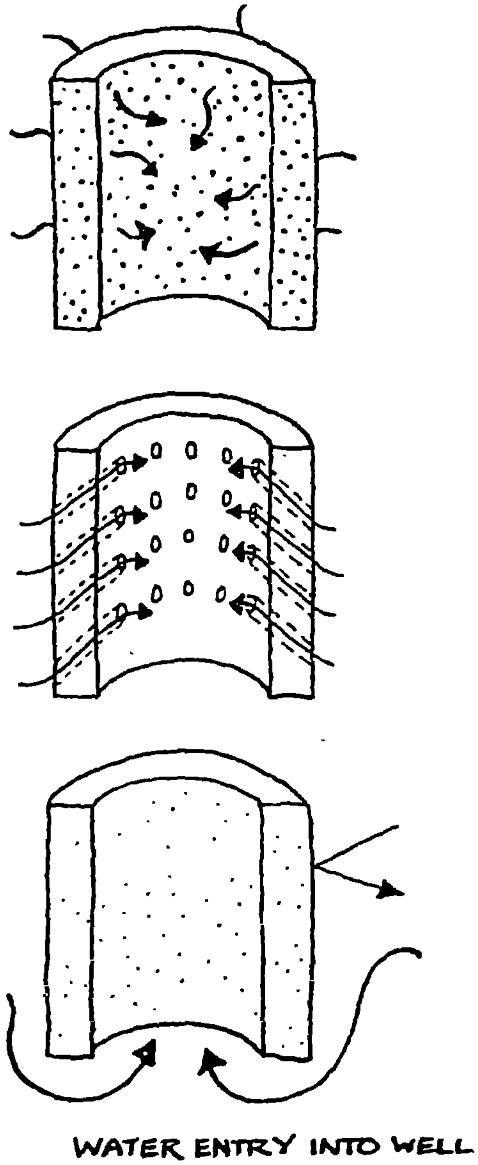


Figure 8B-28 Method of allowing water to enter a dug well.

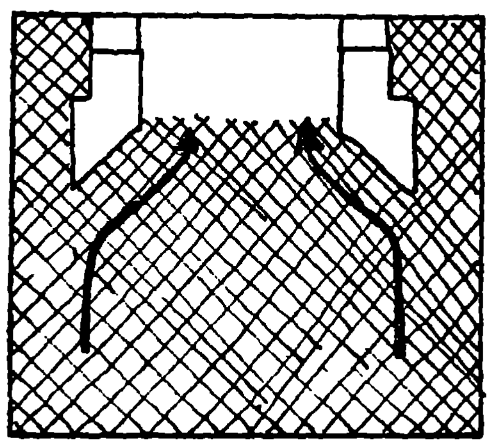
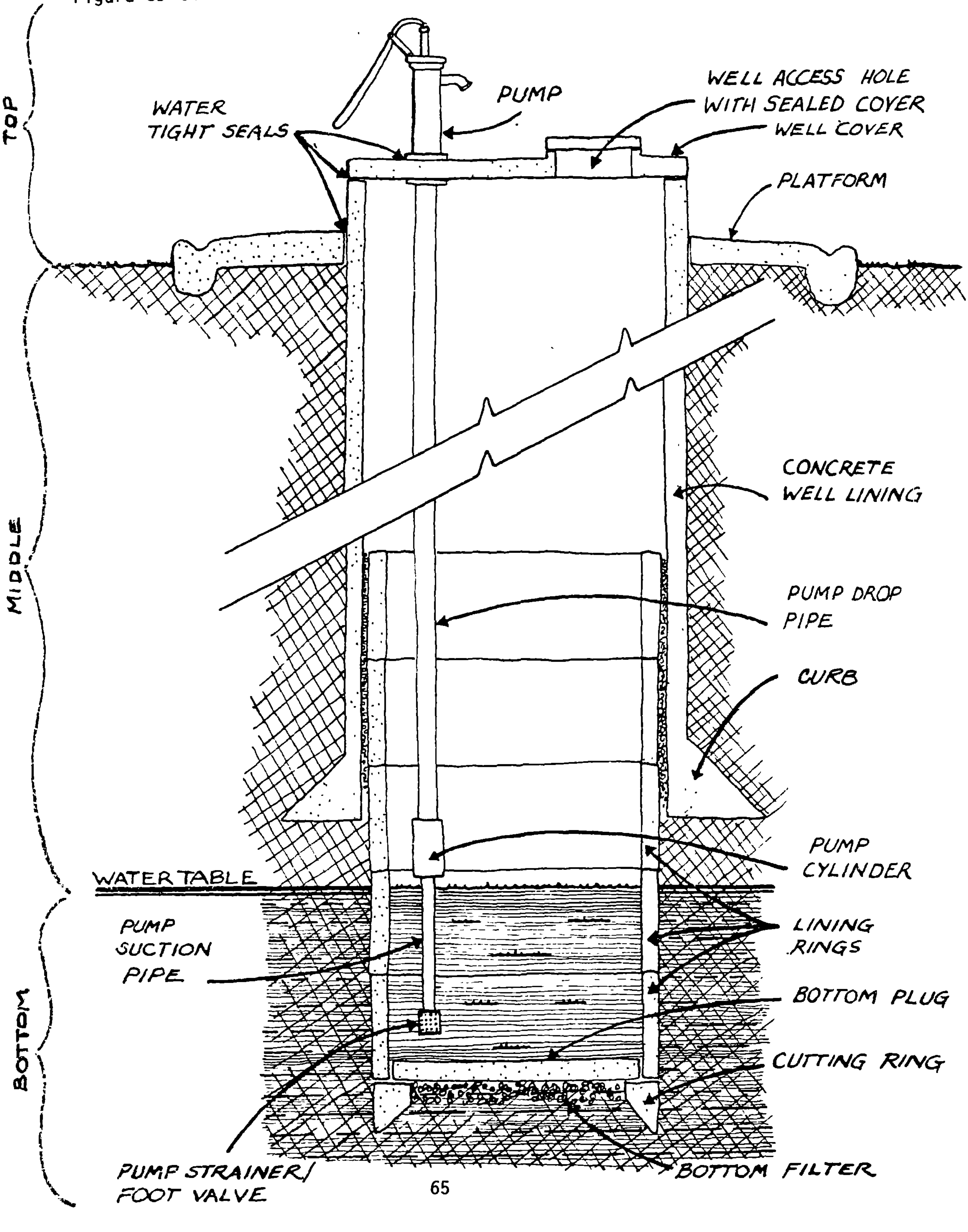


Figure 8B-29 Cutting ring effect

Figure 8B-30 Cross section of hand dug well with an inner liner.



In addition to precast concrete liners, the well may be constructed in a manner that requires the installation of a steel mold. Concrete is then poured between the mold and the wall of the borehole. Reinforcing rods may be emplaced before the concrete is poured to produce reinforced concrete.

In addition to concrete, a dug well can be lined with stone (Figure 8B-31) or brick (Figure 8B-32). If dug into solid rock there are times when a lining would not even be necessary.

Whether using precast concrete caisson, or pouring cement for lining directly in place, or using brick or stone there are four basic methods of dug well construction.

(1) dig-a-meter, pour-a-meter;

(2) dig-sink;

(3) dig-and-line-in short-sections; and

(4) dig to the water table and line.

In very loose materials the hole will start to collapse if digging exceeds one meter. Therefore, in this type of material the dig-a, meter-pour a meter is one of the methods that can be used. In this method, a one meter deep hole is dug and a circular mold is emplaced. If reinforced concrete is to be used, vertical and horizontal reinforcing rods are placed around the outside of the mold (Figure 8B-33). Then concrete is poured between the mold and the borehole wall. The vertical rods should be allowed to extend above and below the mold and concrete. If re-rod is not used the concrete is simply poured in between the mold and the borehole wall. Reinforced concrete is better able to withstand shifts of earth material and manipulations of the rings that may be necessary to keep the well straight and plumb.

Next, digging takes place below the first ring. Digging is done to a depth 10 cm greater than the depth of the mold. The first mold is disassembled and reassembled at the second level, and the entire procedure is repeated. There must be a 10 cm gap between the bottom of the top mold and the top of the next pour. This gap permits pouring of the concrete behind the lower mold. Cement or mortar can be used to fill the gap between the sections of line.

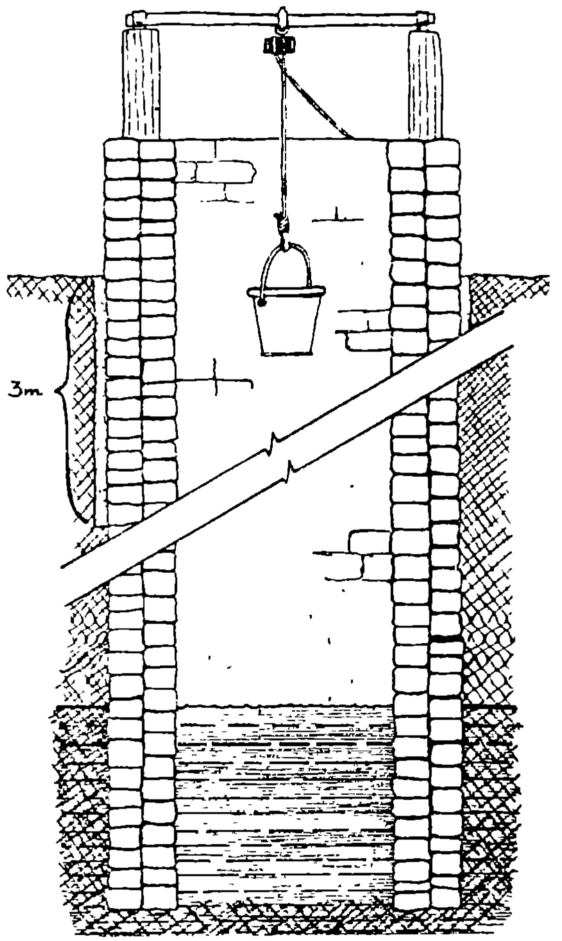


Figure 8B-31 Rock lined well.

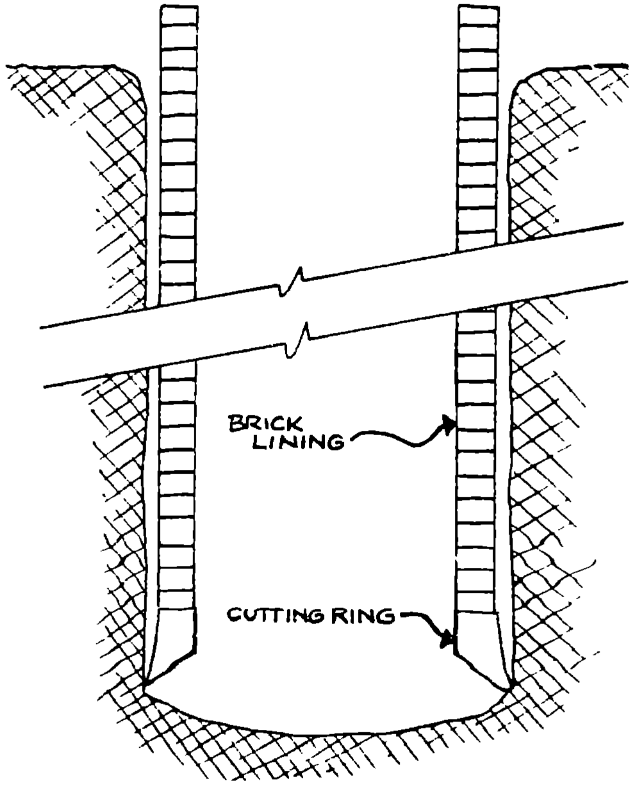
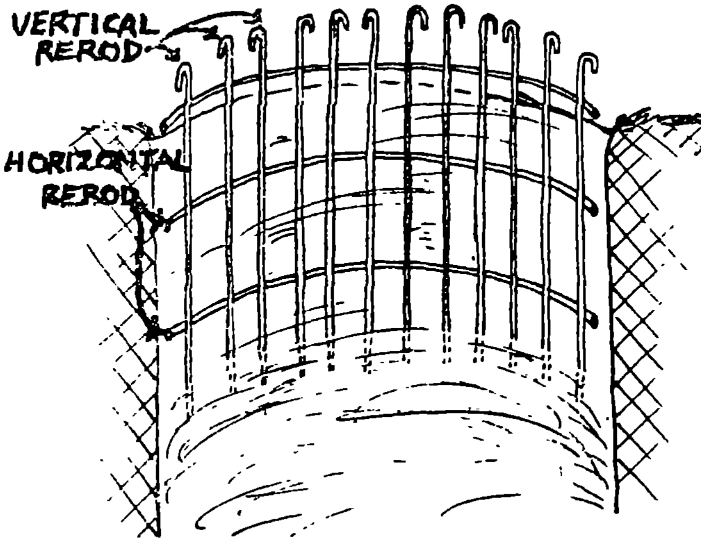
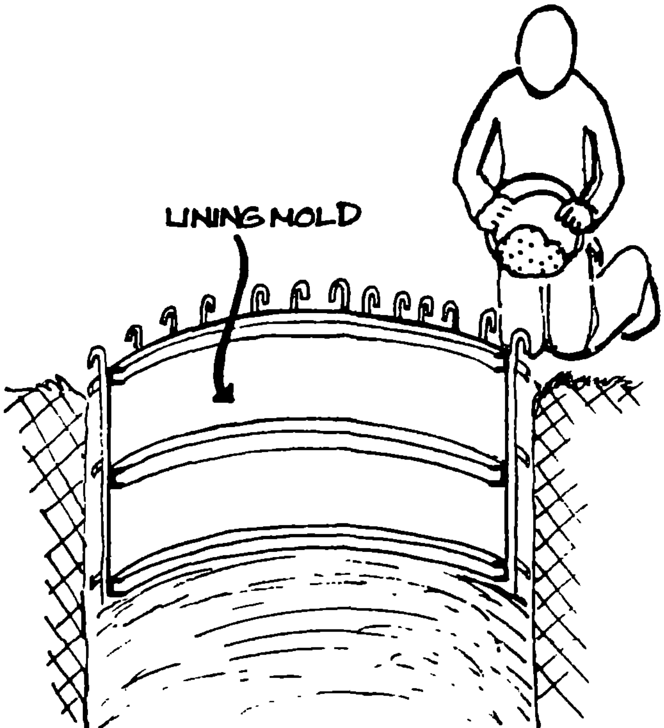


Figure 8B-32 Brick lined well.



a. The hole has been dug to the required depth and rerod verticals stuck into the ground. The rerod horizontals are then tied to the verticals.



b. The inside lining mold has been centered and leveled. Concrete can now be poured around the rerod between the lining mold and the side of the hole.

Figure 8B-33 Reinforced concrete lining built in place.

Another method that can be used in loosely consolidated materials is the dig-sink method. In this method a precast concrete mold is installed in a shallow hole. Digging proceeds beneath the mold, and as material is removed the caisson sinks. As soon as the top of the caisson is a few centimeters below the ground surface another ring is placed on top of it. The process keeps repeating itself until the well reaches the desired depth. One of the other advantages of this method is that construction below the water table is easier than if concrete had to be poured into a mold. In fact, with the dig-a-meter, pour-a-meter method, construction below the water table is difficult.

If the soil materials are moderately cohesive then a "dig-and-line-in-short-sections" method can be used. With this method, the hole is dug until it reaches a depth where it might be unsafe to continue, or until the 5 meters of hole are exposed. Re-rod is then emplaced. If possible, the length of the vertical re-rods should be equal to the full depth of the hole. The mold is then placed in the lowest part of the hole. Concrete is poured and allowed to set. The mold is then raised to the next level and concrete is poured again. The process continues until the top of the hole is reached or the overlying set of rings are reached. The procedure is repeated until the water table is reached. Just above the water table a curb is constructed to stabilize the support the structure.

If the digging occurs in consolidated materials, laterite, loess, or dry clay, the walls of the well may not collapse. Under these circumstances digging can progress to the water table. The well is then lined and digging can continue below the water table using a dig-and-sink method, or in crystalline rock by just digging out the rock.

Remember, regardless of the digging method that is used, after the water table has been penetrated the water should be pumped from the well to permit the digging to progress to the desired depth.

B.4.1.3 Modification to Improve Sanitary Protection of Dug Wells

There are two problems associated with dug wells. The first is the fact that it is extremely difficult to maintain sanitary protection, especially because they are relatively shallow and basically penetrate only the top of the aquifer. Secondly, their yields are low, and susceptible to fluctuations of the water table.

Dug wells usually can be made much safer and more productive by driving well points into the water-bearing formation (Figure 8B-34) and thus converting them to tube wells. A well point and several meters of casing can be driven from the bottom of a dug well further into the water bearing formation. The annular space between the casing of the driven well and the wall of the existing well should be back-filled with puddled clay, concrete or some other type of relatively impermeable material. The well depicted in Figure 8B-34 is better protected from near surface sources of contamination, and it's extra depth reduces the likelihood of the well going dry.

The method for driving a well point and pipe is discussed in the Section 8B.4.3.

8B.4.2 Planning for Driven, Jetted, and Drilled Wells

Outlined below is the preliminary planning that should be done by the drilling contractor and/or the project supervisor.

(1) Select a well site based on geologic factors, site accessibility, and sanitary conditions (Section 8B.2).

(2) Determine the availability of useful skills that residents of the barangay may have that would facilitate well construction.

(3) Assess the availability of construction materials and tools.

(4) Select a design and method of construction most appropriate to geologic conditions and availability of equipment.

(5) If the well construction process requires water, then locate a nearby "safe water supply". If the water that you plan to use may be contaminated, plan to add chlorine to it before its use.

(6) Before construction begins, develop a written workplan for the entire project.

(7) All equipment and materials needed for well construction should be collected and washed. Arrange the materials at the well site to facilitate the construction phase.

(8) Mark the exact location of the well and lay out how the drilling equipment is going to be situated in relationship to the well.

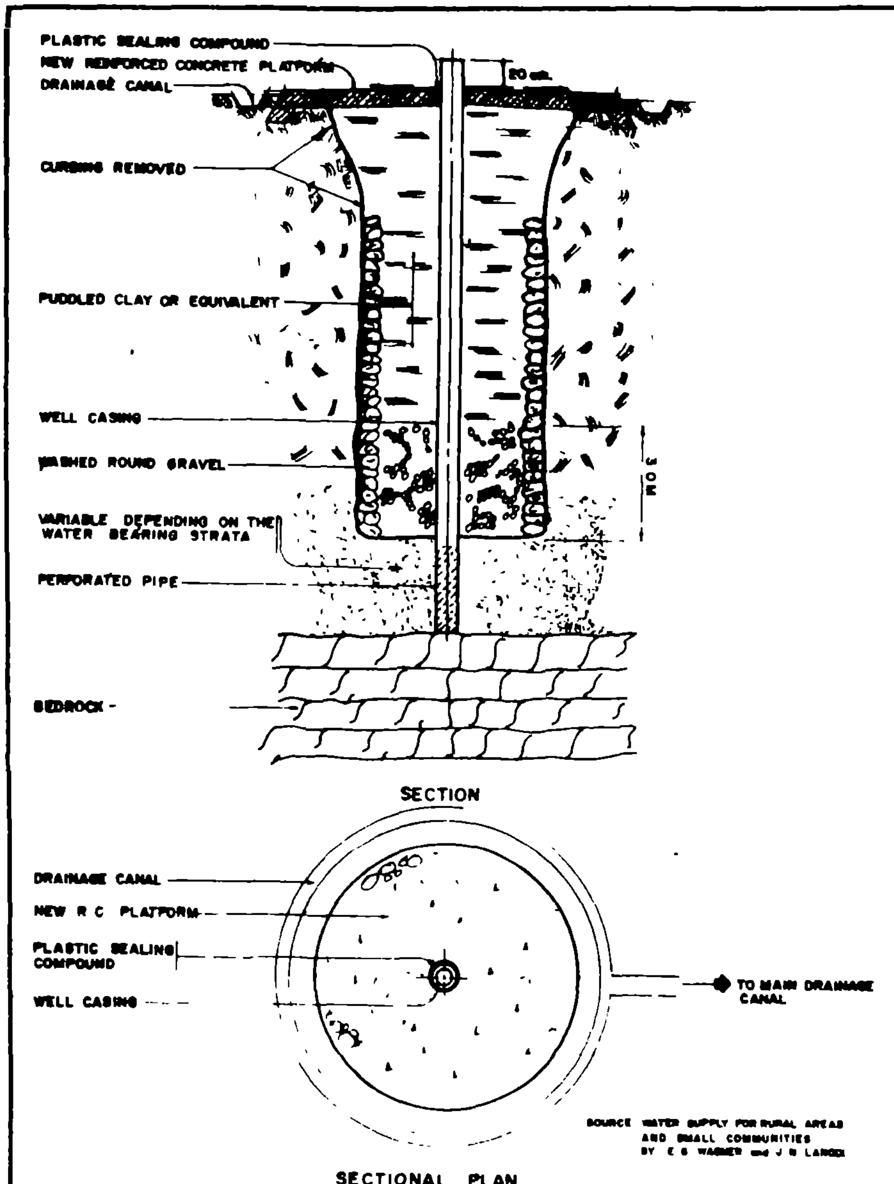


Figure 8B-34 Improvement of an existing dug well.

8B.4.3 Driven Wells

The driven well consists of a pointed perforated pipe, or a pipe with a pointed well screen attached, which can be driven into an aquifer (Figure 8B-35). Normally special pipe with thick walls and specially designed couplings are used to resist damage that may result from the driving forces.

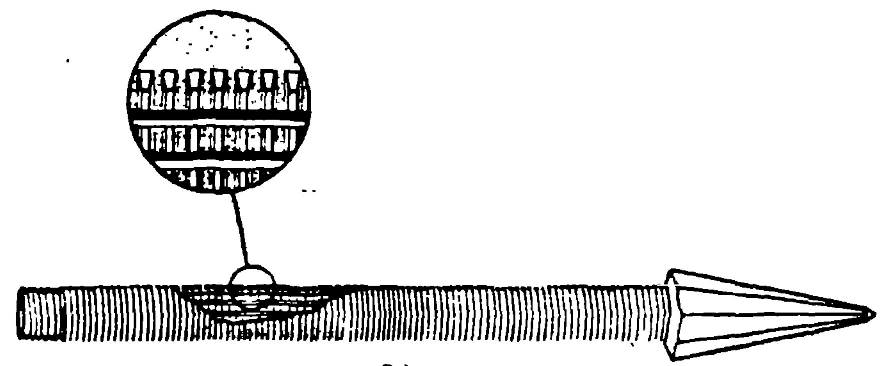
Driven wells are easy and quick to install. They are very well suited for areas of sandy unconsolidated formations, and where water tables are close to the surface. Unlike many other types of wells, if the well is dry, then the casing and screen can be pulled out of the ground and installed elsewhere.

Driven wells can be driven to 25 to 30 meters (80-100 feet) under favorable conditions, but most driven wells are approximately 15 meters deep. Well diameters range from 32 mm (1 1/4 inch) to 75 mm (3 inches). The limited diameter of the casing and the limited depth restricts driven wells in terms of their yield. However, they should easily be able to provide adequate capacity for the hand pump equipped well if installed and developed properly.

Another disadvantage of a driven well is that subsurface materials are merely forced aside, and not excavated during the driving process. As a result there are no subsurface samples. The depth to which the well will be driven will have to be based on information gathered during the drilling of other wells in the area or by the driller's experience and capability to "feel" an aquifer based on the rate of penetration for each blow of the drive hammer (Table 8B-1).

8B.4.3.1 Methods, Tools and Equipment for Constructing Driven Wells

Driving is normally accomplished by altnernately raising and dropping a weight used as a driver (Figure 8B-36). The driver is guided on either the inside of the pipe or the outside of the pipe causing it to strike squarely and accurately. If the driver is designed to strike the upper end of the pipe then a driving cap is screwed onto the threads to protect them (Figure 8B-36 A and B). As an alternative the driver may be designed to strike a clamp made for the purpose which is bolted around the outside of the casing (Figure 8B-36C). A long, thin driver which fits inside the pipe and which strikes a flat surface on the inside of the well screen point can also be used (Figure 8B-36D). The later technique eliminates



(a)

(b)

Figure 8B-35. Drive points and screens. (a) perforated pipe with screen; (b) spiral trapezoidal wire

TABLE 8B-1 - Identification of Formations Being Penetrated By a Drive Point

Type of Formation	Driving Conditions	Rate of Descent	Sound of Blow	Rebound	Resistance to Rotation
Soft moist clay	Easy driving	Rapid	Dull	None	Slight but continuous
Tough hardened clay	Difficult driving	Slow but steady	None	Frequent re-bounding	Considerable
Fine Sand	Difficult driving	Varied	None	Frequent re-bounding	Slight
Coarse Sand	Easy driving (especially when saturated with water)	Unsteady irregular penetration for successive blows	Dull	None	Rotation is easy and accompanied by a gritty sound
Gravel	Easy driving	Unsteady irregular penetration for successive blows	Dull	None	Rotation is irregular and accompanied by a gritty sound
Boulder and rock	Almost impossible	Little or none	Loud	Sometimes of both hammer and pipe	Dependent on type of formation previously passed through by pipe

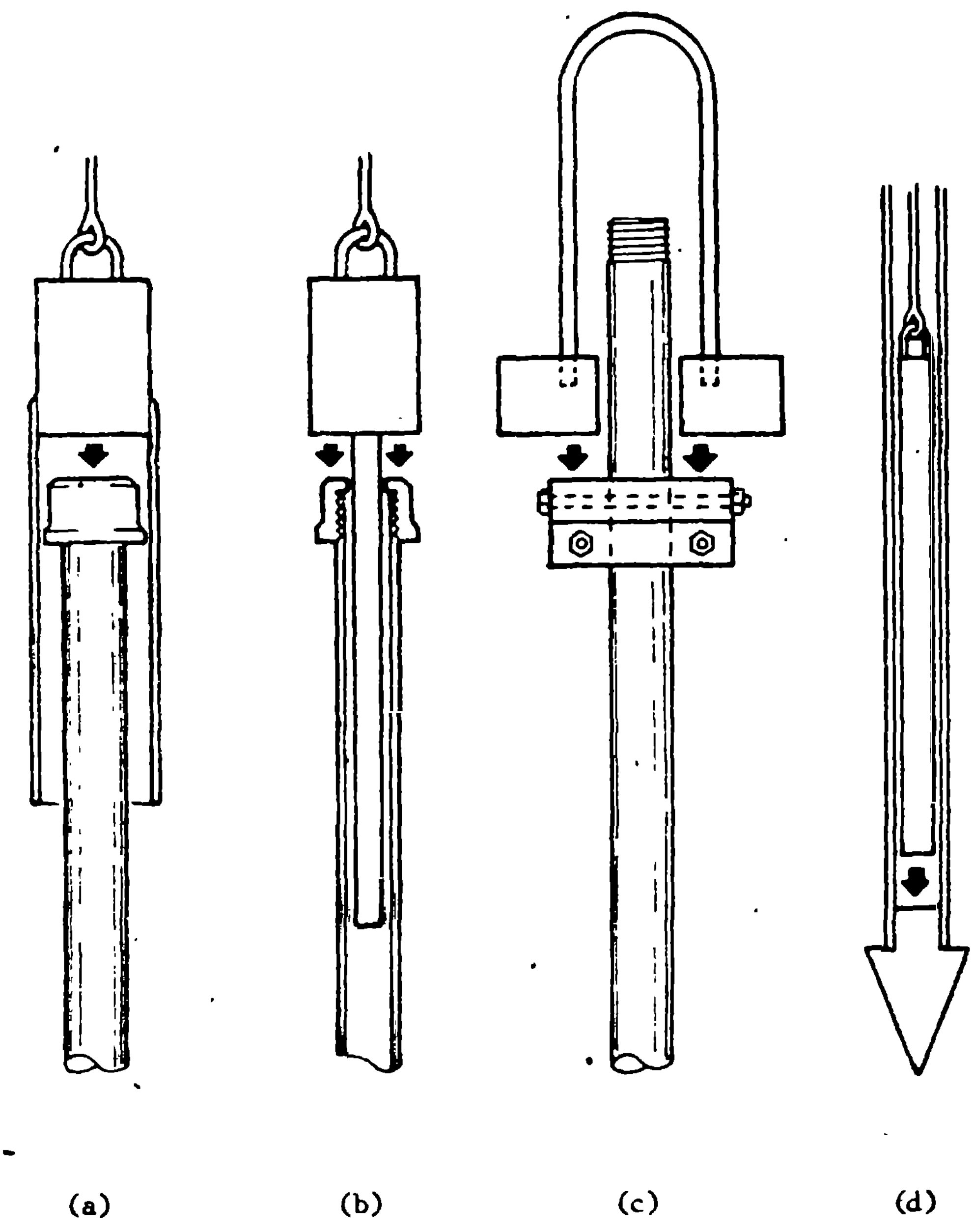


Figure 8B-36 Devices for well driving. (a) guided on outside of pipe; (b) guided on inside of pipe; (c) driving on clamp; (d) driving on inside of point compressive loading on the pipe normally caused by driving and reduces the need for heavy walled drive pipe.

Well screens for driving must have sufficient strength to withstand the forces caused by the driver and the abrasion of the material through which they pass. One common type (Figure 8B-35A) consists of a perforated drive pipe fitted with a point. The perforated section of the pipe is wrapped with a layer of brass screen of the desired mesh size, and the screen is protected from damage by wrapping it with a layer of perforated brass sheet. Both layers are soldered to the pipe. To prevent galvanic corrosion the pipe, screen, and protective wrapping should be constructed of the same material. Another type of well screen (Figure 8B-35B) is manufactured by wrapping trapezoidal or keystone shaped rods around a set of round longitudinal rods placed in a circular pattern with all intersections welded (exactly the same as a wire wound screen). This type of screen has the advantage of having a high percentage of open area and a slot shape which cannot become wedged full of fine sand particles.

A drive point can be fabricated locally from steel pipe (Figure 8B-37). The point is made by:

(1) flattening the end of the pipe to a gradual taper similar to the working end of a screwdriver or cold chisel;

(2) cutting out a "V" notch from the corners of the flattened end to a point at the middle of the pipe near where the taper starts;

(3) bringing the two resulting points together to a single point;

(4) welding the two sides of the point together; and

(5) filing or grinding away any irregularities to yield a smooth point. If welding equipment is not available the point can be forge-brazed. A collar should be welded or riveted above the point to increase the size of the hole to a diameter slightly greater than that of the pipe coupling used. As an alternative the point may be forged from solid steel and welded or riveted to the end of the pipe. In this case, care should be taken to make a shoulder on the back of the point which builds against the end of the pipe quite accurately and makes the largest diameter of

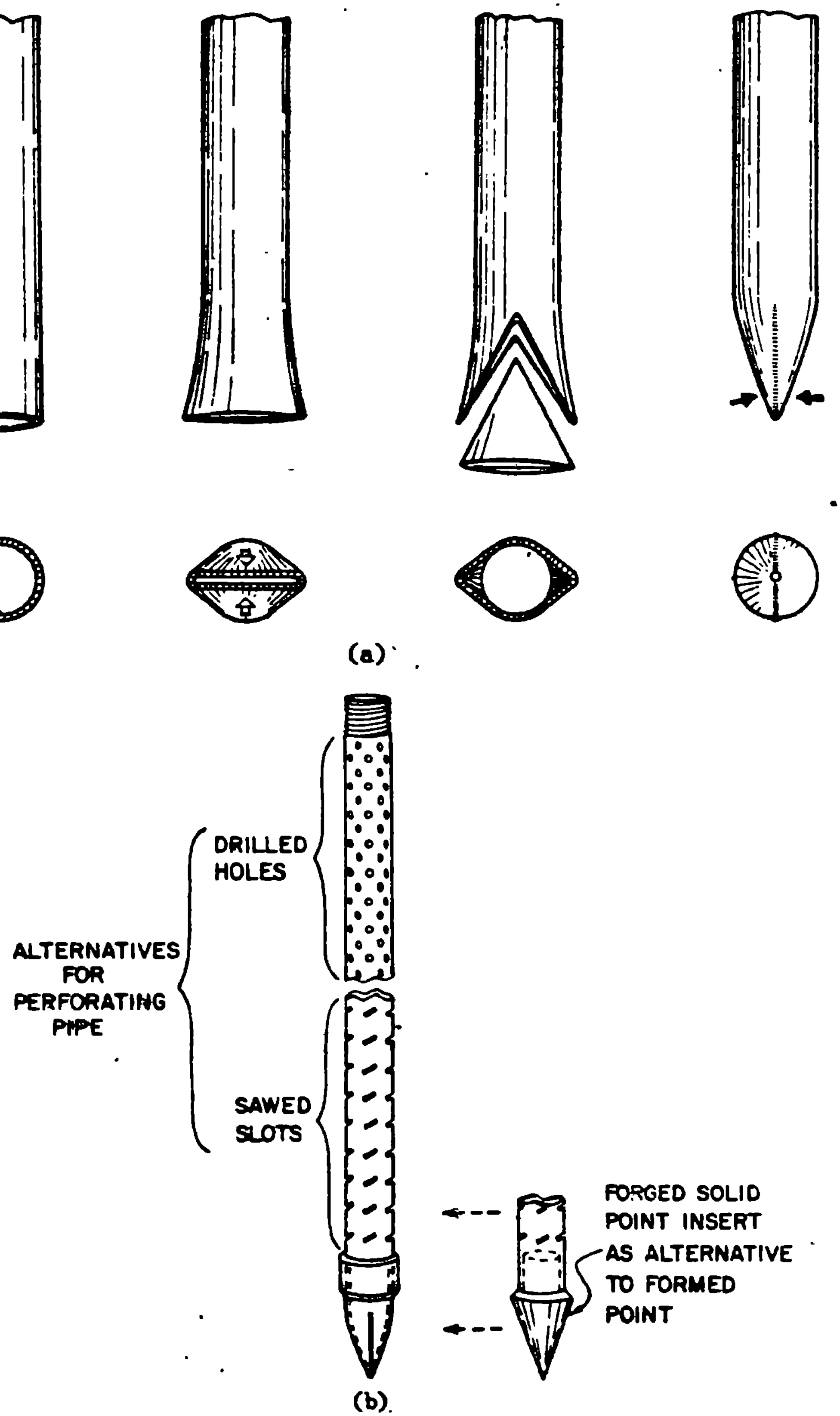


Figure 8B-37 **Drive point fabricated from pipe. (a) forming point on end of pipe; (b) alternative perforations and points** the point greater than that of the pipe coupling to provide clearance.

Perforations may be made by drilling holes of the desired screen size or by making a series of short diagonal hacksaw cuts (Figure 8B-37B). In either case enough strength must be retained in the pipe to permit driving. This can best be assured, in the case of the saw cuts, by leaving several longitudinal strips unperforated.

If driving is attempted using ordinary pipe and couplings, shearing or stripping of the pipe threads or breaking of the pipe at the threads may occur. It should be noted that threads, on standard weight pipe cut through more than half the wall thickness, greatly reducing the strength of the pipe where it is threaded. Drive pipe and couplings, in addition to being heavier than standard pipe are designed so that the pipe ends butt together inside the coupling (Figure 8B-38). This results in most of the driving force being transmitted by the ends of the pipe rather than by the threads. In addition, the couplings are frequently longer than normal couplings with a bore at each end which extends back over the nonthreaded portions of the pipe to give lateral reinforcement to weaker threaded ends.

Like any process of installation the actual first step for installation involves arrangement and set up of tools, equipment and supplies. The area immediately around the well site should be cleared of all debris and unnecessary equipment. If a tripod is to be used, set it up and locate it so that the weight will be centered directly over the hole. It will be easier to keep the pipe perfectly plumb if the weight is properly centered.

The next step is to dig or auger a shallow hole (50-80 cm) in which to start the well point. Periodically check the plumbness of the well point and drive pipe. After several lengths of pipe have been driven into the ground, plumbness can be checked less frequently. A support for the upper end of the pipe will initially help to hold the pipe plumb and may later assist in aligning new sections of pipe so they can be screwed into couplings.

Drive the pipe and add more pipe as needed. When the pipe has been driven so far that driving can no longer be accomplished, add another section of pipe. This is accomplished by removing the drive cap, installing the new

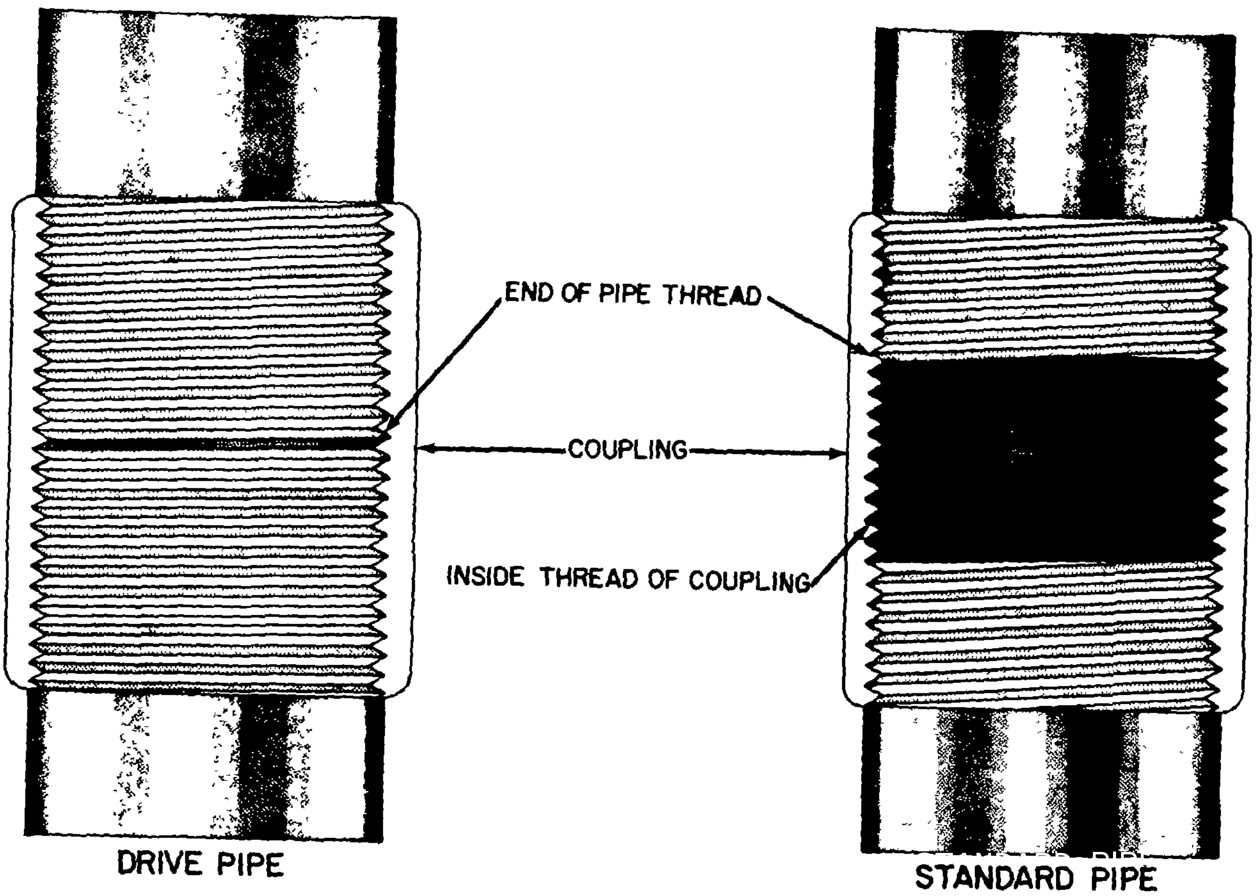


Figure 8B-38 A comparison of drive pipe and standard pipe.

section of pipe, and placing the drive cap on the top of the new pipe. Where drive clamps are used instead of a drive cap the procedures is slightly different. To begin driving, place the clamps on the pipe about 50 cm above the ground. It is easier to keep the pipes plumb if the point of impact is closer to the ground surface. When the clamp and pipe are driven to the ground move the clamps up about 50 cm. Firmly attach them to the pipe and continue driving.

To determine whether water had been reached, the plumbline can be lowered into the pipe. If the line comes up wet, you have hit water. The type of soil or formations you are driving through can be determined by the reactions of the pipe and the driving weight when the pipe is struck by the weight.

If you do not reach water or have for some reason driven beyond the water bearing formation you may want to lift the pipe string or remove it completely from the hole. This can be accomplished by placing a crowbar under the clamps and over a pipe that acts as a fulcrum of a lever (Figure 8B-39A), or two jacks can be placed under the pipe clamps to jack it out (Figure 8B-39B).

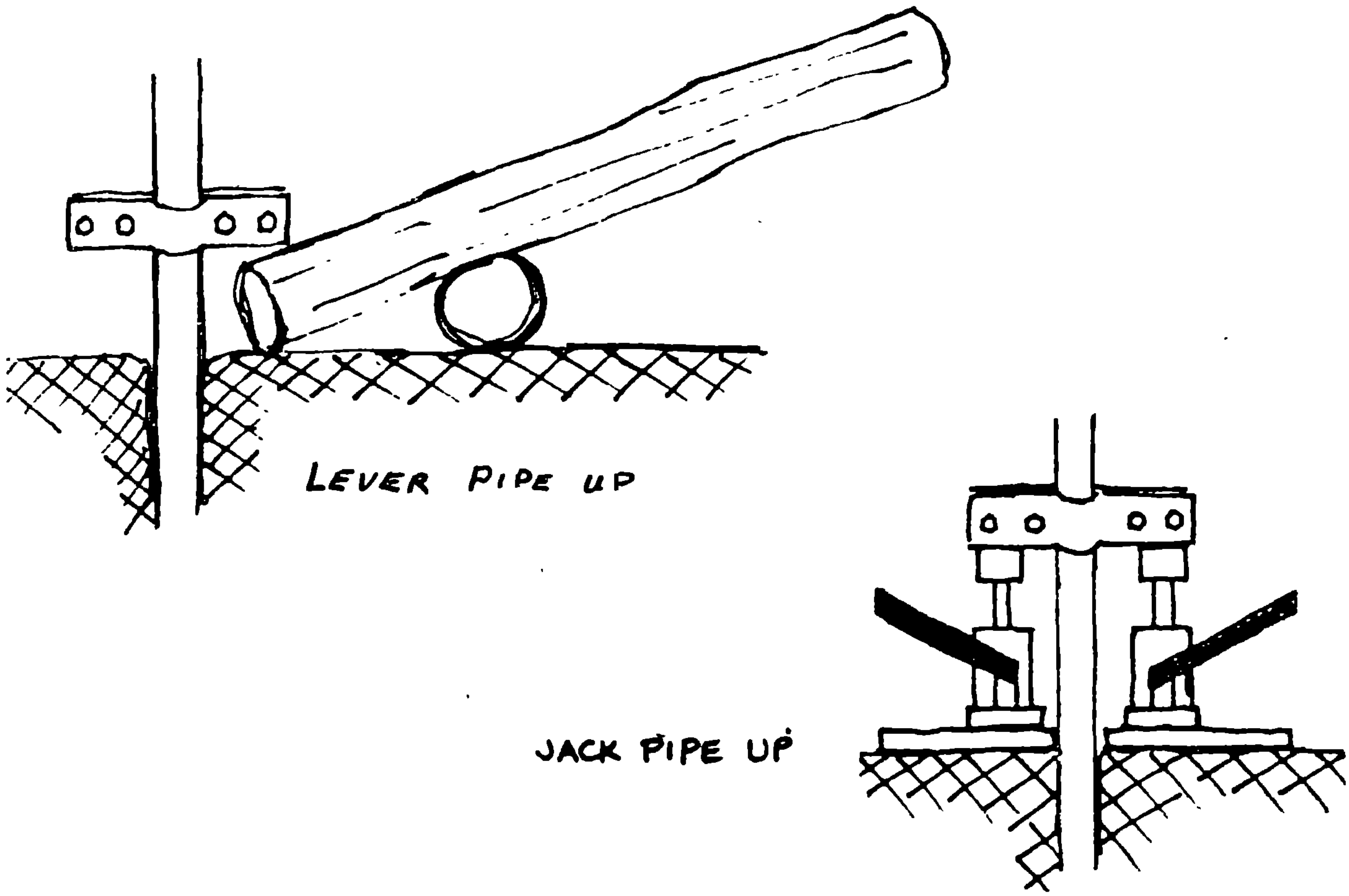


Figure 8B-39 Methods of jacking-up casing.

Entry of the well point into water-bearing sand usually is indicated by an increase in the rate of decent. Sometimes, this increase is as much as 7.5 cm (6 inches) per blow, although in fine sands the penetration per blow may change little or none at all. When it is suspected that the well point is in a water-bearing sand, driving is stopped and a weighted line is lowered into the well to check the depth to the water table. If water stands above the well point and within 5 to 7 m (15 to 25 feet) of the surface, a shallow well pump may be attached to the top of the well pipe and the well tested for yield.

Another simple method of testing well yield is to pour water into the well. If the well point is in dry sand, all the water added will drain into the sand. If the well point is in water-bearing sand, the quantity of water that can be poured into the well continuously is a rough measure of the rate at which the well can be pumped, since the saturated sand yields water about as freely as it absorbs it. Sometimes raising or lowering the well point a foot or more brings a greater length of the screen into contact with the water-bearing sand and a greater yield results.

Although a well site may have been properly selected, the strata correctly interpreted, and the presence of water accurately judged, a well may fail to yield water at first because the sand around the well point is clogged with fine particles that need to be removed by well development. The silt and fine sand may also have washed through the screen openings, partially filling the well point. This difficulty may be overcome with a shallow well hand pump. The common shallow well pump has a plunger and a check valve so arranged that the check valve can be tripped when the pump handle is raised as high as possible. It is, therefore, possible to pump for a while and then trip the check the valve to allow water to run back down the well pipe. By alternately applying a heavy suction on the well and tripping the valve to let the water run back, surging action is produced through the screen openings. Even if there is only a small flow of water at first, the reversal of flow due to the surging tends to loosen the fine material plugging the screen openings and to bring the fine sand and silt into the well point. This fine material may be pumped from the well if continuous hard pumping is done for a few minutes. The well is ready for use once it has been pumped enough to clear up the flow. The pump should be checked to see that there is no sand on the valves or on the plunger.

If all the sediment cannot be cleared from the well point by pumping, one of the following methods can be used.

(1) Lower into the well a series of connected lengths of 20 cm (3/4-inch) pipe, with the lower end resting on the sediment in the well point. Clamp the pipe in position and attach a hand pump to the upper end. Run water into the well pipe (not through 20 mm (3/4-inch) while operating the hand pump. By steadily pumping, the sediment will be lifted through the 20 mm (3/4-inch) pipe. Continue to lower the 20 mm (3/4 inch) pipe to the sediment level until the well is cleared.

(2) Insert a string of 20 mm (3/4-inch) pipe into the well and fill the well with water. Repeatedly raise and lower the pipe sharply by hand. By holding the thumb over the top of the 20 mm (3/4-inch) pipe during the upward movement and removing thumb during downward movements, a jet of muddy water is expelled on each downward stroke. When the material has been loosened and put into suspension the muddy water can be pumped out.

(3) Water pumped into a string of 20 mm (3/4-inch) pipe resting on the sediment will remove the fine material by jetting action. This procedure requires a large supply of water and a motor-driven or hand-force pump.

It may be impossible to develop a successful well if too fine a screen is used. The openings must be large enough to permit the finer particles of water-bearing soil to enter the well point while retaining the coarser particles. With properly sized screen openings, development expels the finer material adjacent to the well point and retains the coarser particles to form an envelop of highly porous and permeable material around the screen.

8B.4.4 Jetted Well Construction

Using the jetting method of well construction, a hole is drilled into the earth by the force of a high velocity stream of water. This stream loosens the material it strikes and washes the fine particles upward out of the hole. The jetting method of well construction is particularly successful in sandy soils where the water table lies close to the ground surface. It is a simple and dependable method that can be carried out entirely with handtools. Success does not depend upon bulky drilling equipment which is difficult to transport. Generally, two techniques of construction may be used: washing in a casing, or sinking a self-jetting well point. In addition, jetting may be used to sample the general character of a formation. Well cuttings are extracted from the return flow at the surface.

8B.4.4.1 Jetting Equipment

The essential jetting equipment includes a hoist, a jetting pump with hose, a water swivel, an adequate supply of jetting fluid, a drive weight, and a set of heavy pipe tools.

(1) Hoist. A hoist is needed to handle the drill pipe and casing. Hand-operated equipment such as a tripod with tackle may be used (Figure 8B-40). If available, it is desirable to use a percussion type drilling rig with a power hoist.

(2) Pump. A pump with suitable hose connection and capable of delivering 3 to 6 l/s (50 to 100 gallons per minute) at a pressure of 3/5 kg. per sq. cm (50 psi) is adequate. The quality of water needed to jet a well varies with the type of sediment being penetrated. Sandy soils require the most water, but high pressure is not necessary. 2.8 kg/sq.cm. (40 psi) nozzle pressure at the bit is adequate in most cases. Clay and hardpan require less water but they are not readily displaced expect by a small cutting stream delivered at high pressure. Pressure as high as 19 kg/sq. cm (200 psi) can be obtained from small nozzles in the drill bit.

(3) Swivel. The water swivel (Figure 8B-41) must be able to carry the weight of the drill pipe and to sustain the maximum pressure delivered by the pump. Figure 8B-42 shows a connection that may be used at the top of small diameter jetting pipe in place of a swivel.

(4) Jetting fluid. Plain water is commonly used in jetting wells, but a jetting fluid of greater viscosity and weight may be prepared by mixing clay or a commercial bentonite with water. This heavy fluid tends to seal the wall of the hole and to prevent loss of water into the formation being penetrated. Jetting fluid is channeled from the hole to a settling pit where cuttings (material washed from the hole) settle to the bottom. The fluid can be picked up again by the jetting pump and recirculated.

(5) Drive weight. A small weight may be added near the top of the drive pipe to help it penetrate clayey or semi-firm soil.

(6) Jetting bits. Different types of self-jetting well

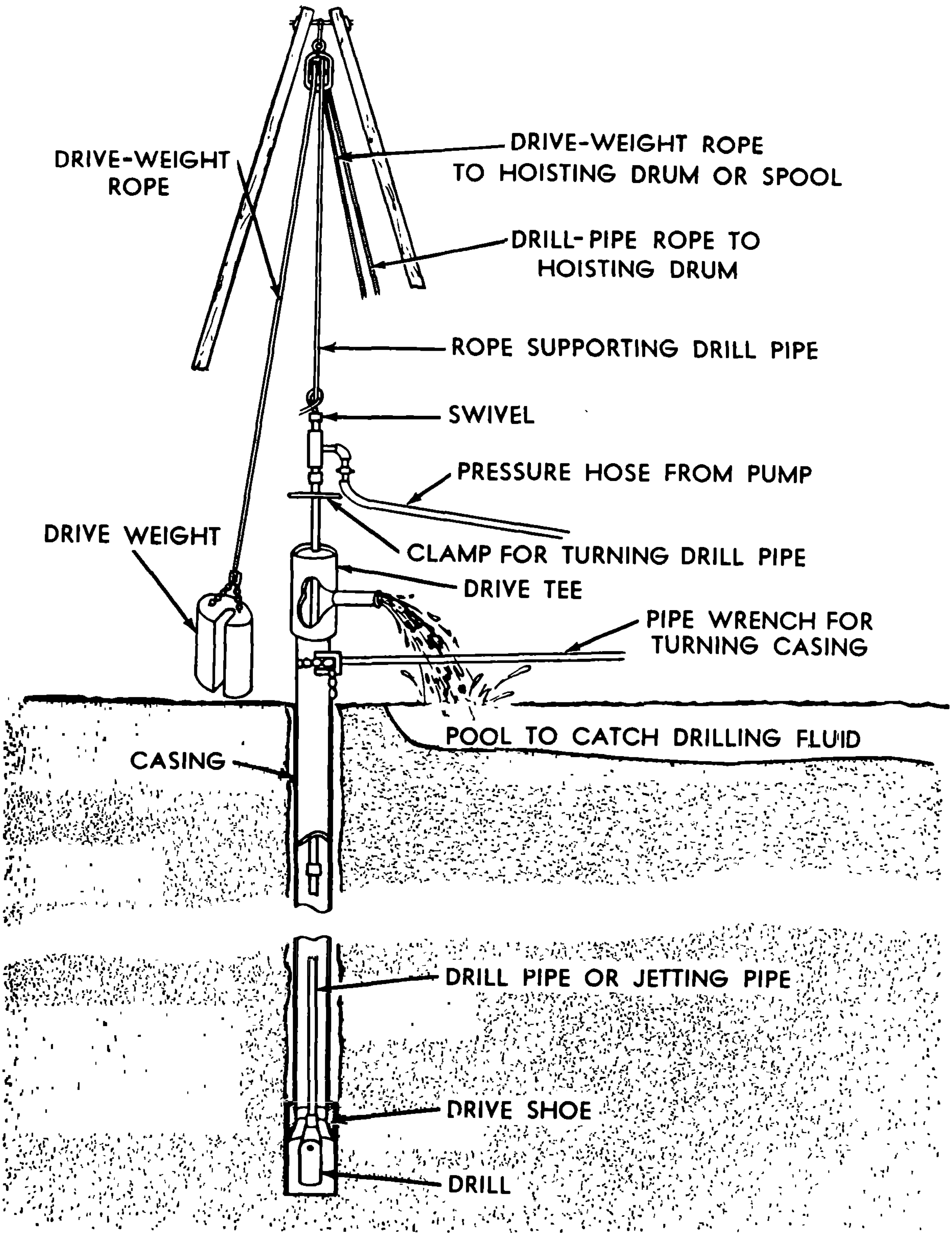


Figure 8B-40 Simple jetting rig.

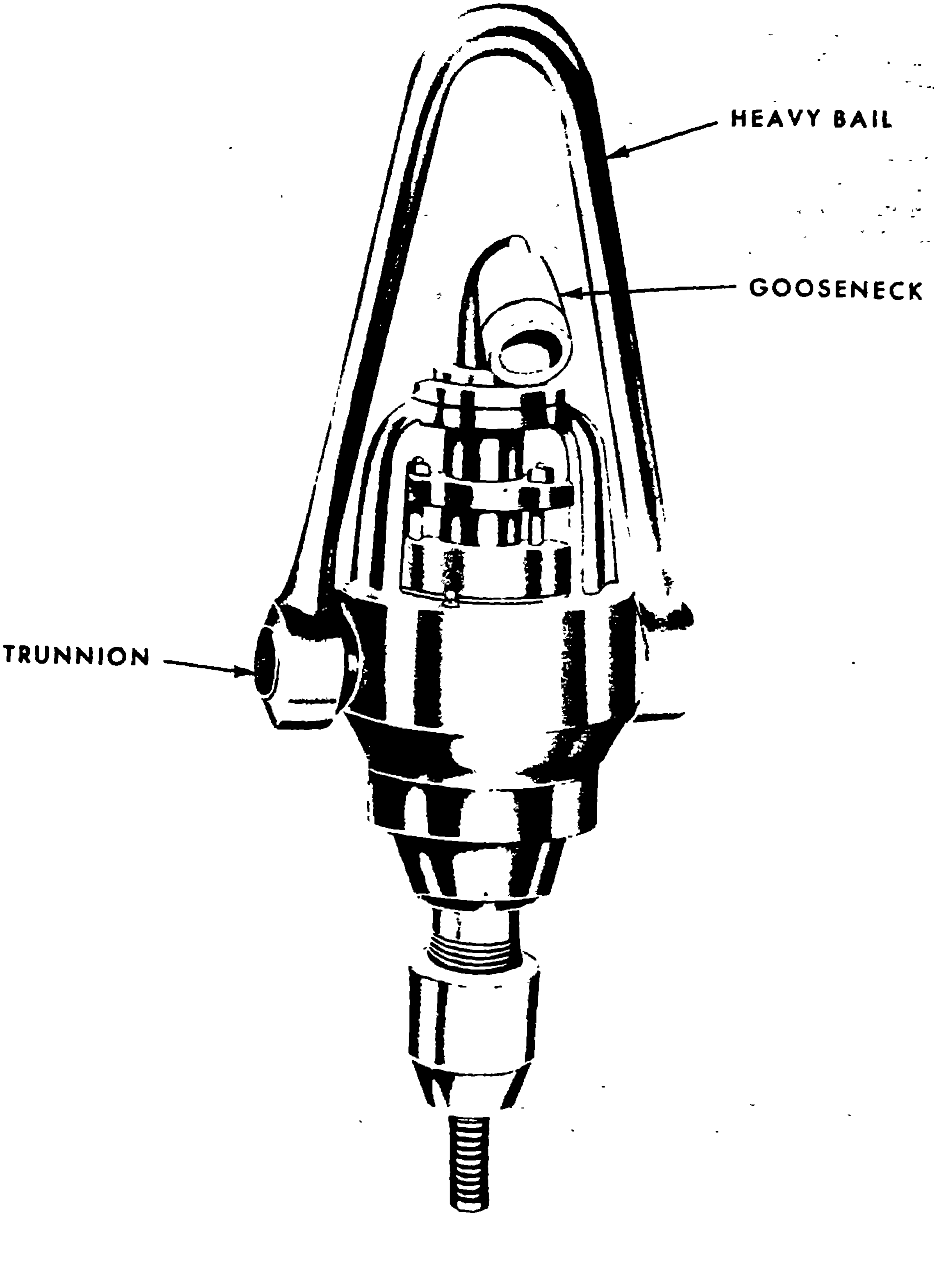


Figure 8B-41 Water swivel.

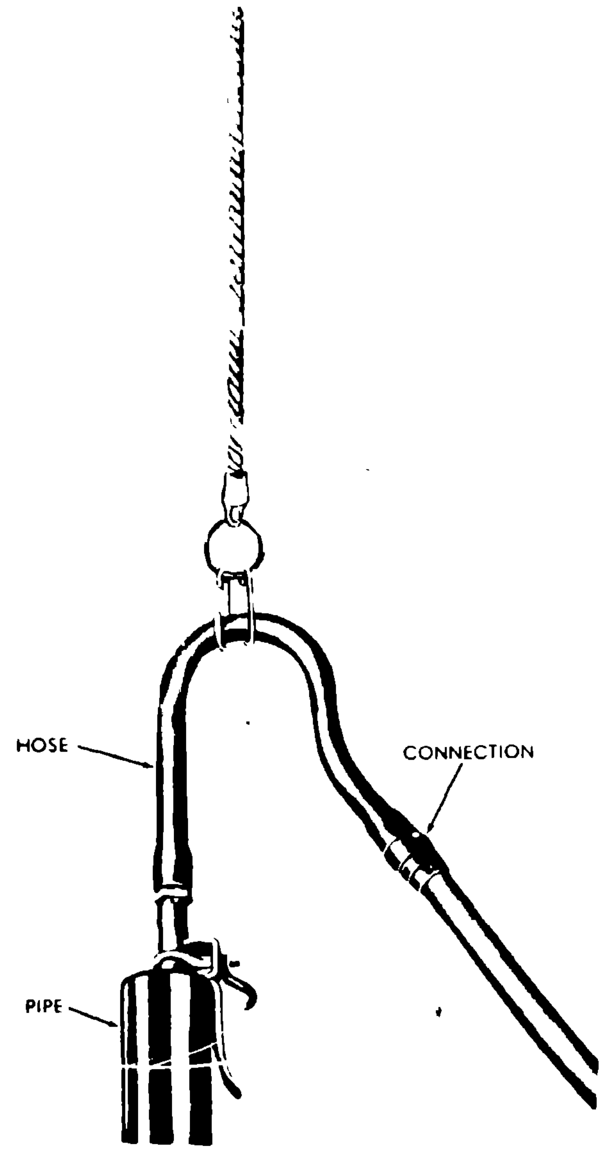


Figure 8B-42 Connection used in place of water swivel.

points and bits are illustrated in Figure 8B-43 A and B are used and are described as follows:

(1) Self-jetting well points. The continuous-slot self-jetting point has a screen constructed of a narrow ribbon of metal wound spirally around a skeleton of longitudinal rods. Each point of contact between the metal ribbon and the rod is electricly welded. The brass jacket-type self-jetting point consists of a woven wire gauze wrapped around a perforated pipe. For protection, a perforated brass sheet covers the gauze.

    The jetting head has a self-closing bottom. It contains a spring-loaded disk or ball type valve which opens when water is forced through it druing the jetting operation. The spring-loaded disk valve closes when the well is completed and pumping begins.

(2) Bit. The various types of bits used in jetting are illustrated in Figure 8B-43. In soft materials, a paddy or expansion bit may be used to make a hole slightly larger than the casing. When a hand rig is used, hard layers of formation are penetrated by the percussion-jetting method using one of the straight bits. With heavier rigs, one of the drill-like bits can be used to penetrate hard layers that do not yield to the water jet.

8B.4.4.2 Jetted Well Design and Construction

Setting casing and well screen can be accomplished by the following method. When the jetting fluid effectively prevents caving or collapse of the drilled hole, the casing can be inserted in a single string after the jetting has been carried to the full depth. Otherwise the casing is sunk as fast as jetting proceeds. If too much resistance is encountered, a certain amount of driving is required to force the casing down. One size of casing, such as 100 mm (4 inches) diameter pipe, can be used for depths to 60-90 meter (200 to 300 feet). An additional string of smaller size, such as 75 mm (3 inches) diameter pipe, is placed inside the first string if the well is sunk much deeper.

8B.4.4.2.1 Washing in Casing

(1) Before washing the casing into the hole, cut the lower end of the casing to form a toothed cutting end (Figure 8B-44). Four to six teeth 25 mm

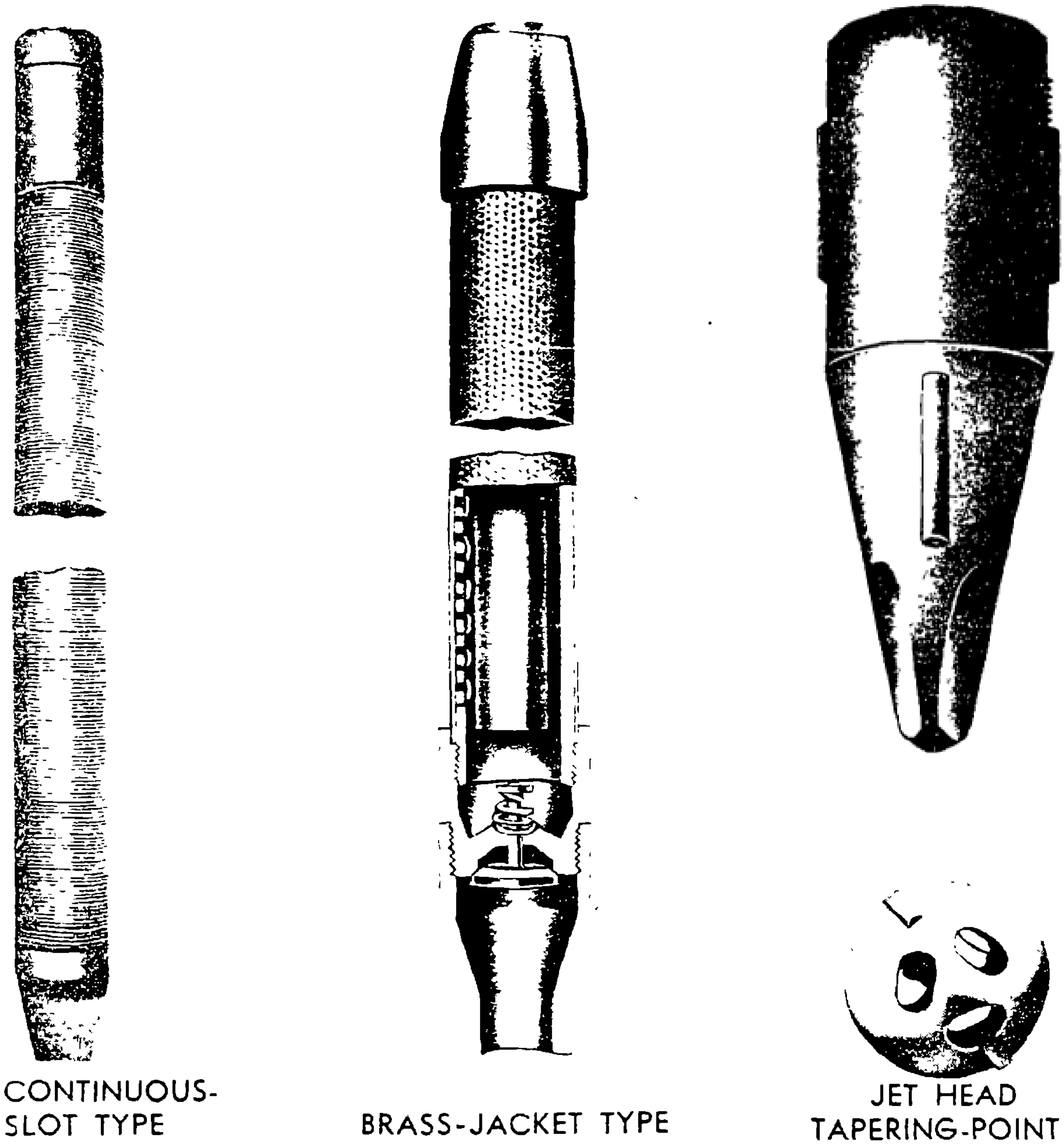


Figure 8B-43A Self-jetting well points.

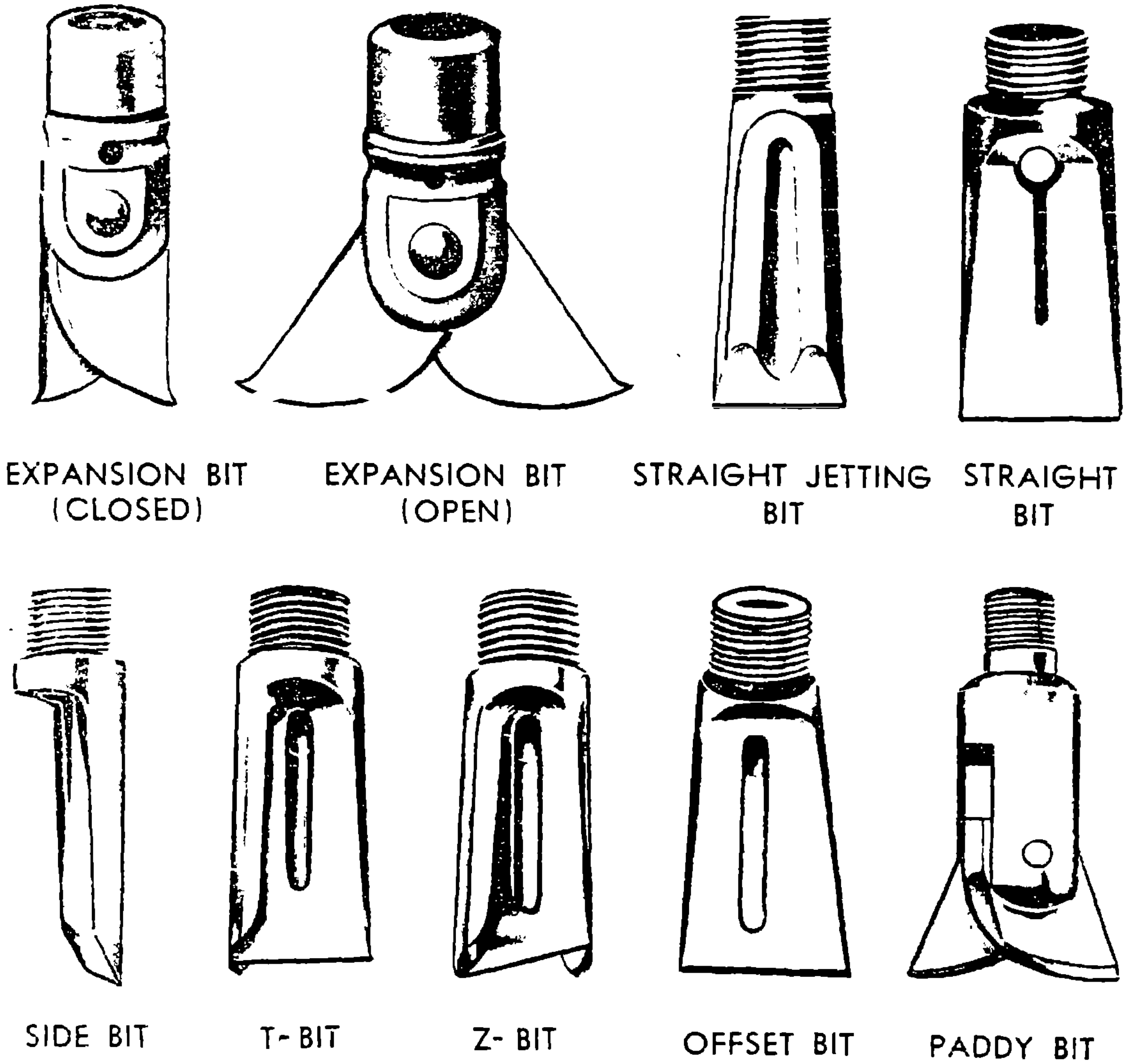


Figure 8B-43B Bits for jetting equipment.

(1 inch) in length (or longer) are usually enough. Mark the outlines of the teeth on the casing. Using a power drill or cutting torch, drill or cut holes in the casing to form the gullets of the teeth. Then cut the sides of the teeth with a hacksaw or oxyactylene torch to meet the outside circumference of the drilled holes. Rounded holes are desirable so that the teeth can readily clear clear themselves of gravel or other material. Half of the teeth should be bent outward so that they cut a hole slightly larger than the casing.

(2) Place a cap on the top of the casing and attach the discharge hose from the pump to the connection provided in the top of the cap. Suspended the casing vertically, by the use of a hoist. Permit the cutting head to rest on the ground, preferably in a shallow had dug hole. Almost the entire weight of the casing should rest on the ground. Operate the jetting pump at full capacity. The casing will fill with water and begin to sink by its own weight as the ground is washed out from beneath it. The hoist should retain enough tension on the casing to keep to vertical. If some resistance is encoutnered which stops the downward movement of the casing, it can be lifted .6 or 1 meter (2 or 3 feet) and dropped. Chain tongs or wrenches can be used to rotate the casing so that the teeth at the lower end will cut into the bottom of the hole.

(3) If more than one length of casing is to be washed in, the hole and first length of casing must be kept full of water at all times while the second length of pipe is being attached and the pump connected to it. This process maintains fluid pressure against the walls of the hole and should prevent casing.

(4) When the casing is sunk to the desired depth, stop the pump and remove the cap at the top of the casing. If the casing is to remain in the hole, telescope a well screen through the casing until it rests on the bottom of the well. Pull the casing up until the screen is exposed to the water-bearing formation, and cut the casing off at a point about 0.35 meters (15 inches) above the ground surface. If the casing is a temporary installation, attach a well pipe to the screen before lowering it into the casing. When the screen is resting on the

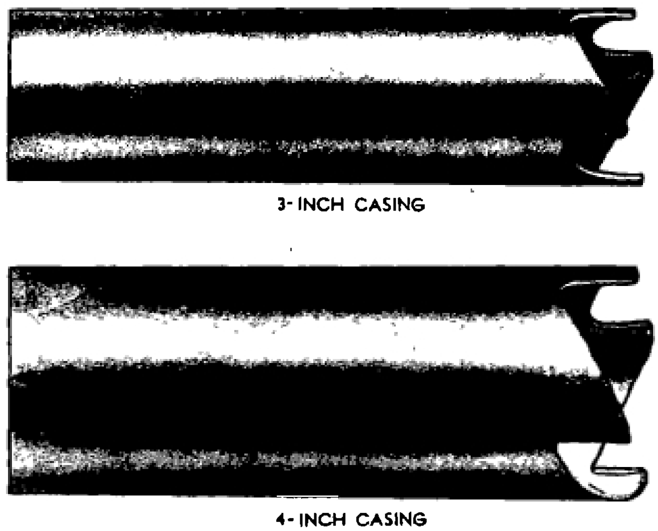


Figure 8B-44 Teeth cut on lower end of casing.

bottom of the hole, pull the entire length of casing out of the hole. This casing can be used again for drilling at another site.

8B.4.4.2.2 Sinking Self-Jetting Well Points

(1) The equipment necessary to sink a well point of this type includes: the self-jetting well point, a well pipe, a small swivel to permit turning the pipe to facilite jetting; a pressure hose, a pump, and a source of water.

(2) Couple the well point at the bottom of the riser or well pipe. Attach the swivel to the other end of the well pipe. Connect the discharge hose of the pump to the swivel.

(3) Dig a shallow hole. Up end the well point assembly with well point standing vertically in the hole. Start the pump and partially open the discharge valve. The jet of water will displace the self-closing valve in the well point and flow through the openings in the head. The soil is washed from under the well point, allowing the point to sink into the ground. Up-and-down movement of the well point assembly will speed penetration.

(4) As the jetting continues, increase the flow of water by further opening of the pump discharge valve. In most sands a pressure of 2.8 kg/sq. cm. (40 psi) at the well point nozzle will displace material readily. Pressures of 7 to 10.5 kg/sq. cm. (100 to 150 psi) may be needed to move gravel or penetrate clay. If a regular jetting pump is not available, two standard centrifugal pumps operating in series may work satisfactorily.

(5) When the well point has been sunk to the desired depth, remove the hose from the riser pipe. Couple the pipe to the suction side of the pump. Develop the well by quickly opening and closing the discharge valve while the pump is operating at the moderate speed. Continue this operation until all of the fine material is cleaned from the well point screen.

8B.4.5 Percussion (Cable Tool) Drilling

The percussion method of drilling a well employs the principle of a free falling heavy bit delivering blows against the bottom of a hole and thus penetrating into the ground. Rock point. In addition, jetting may be used to sample the general character of a formation. Well cuttings are extracted from the return flow at the surface.

8B.4.5.1 Jetting Equipment

The essential jetting equipment includes a hoist, a jetting pump with hose, a water swivel, an adequate supply of jetting fluid, a drive weight, and a set of heavy pipe tools.

(1) Hoist. A hoist is needed to handle the drill pipe and casing. Hand-operated equipment such as a tripod with tackle may be used (Figure 8B-40). If available, it is desirable to use a percussion type drilling rig with a power hoist.

(2) Pump. A pump with suitable hose connection and capable of delivering 3 to 6 l/s (50 to 100 gallons per minute) at a pressure of 3/5 kg. per sq. cm (50 psi) is adequate. The quality of water needed to jet a well varies with the type of sediment being penetrated. Sandy soils require the most water, but high pressure is not necessary. 2.8 kg/sq.cm. (40 psi) nozzle pressure at the bit is adequate in most cases. Clay and hardpan require less water but they are not readily displaced expect by a small cutting stream delivered at high pressure. Pressure as high as 19 kg/sq. cm (200 psi) can be obtained from small nozzles in the drill bit.

(3) Swivel. The water swivel (Figure 8B-41) must be able to carry the weight of the drill pipe and to sustain the maximum pressure delivered by the pump. Figure 8B-42 shows a connection that may be used at the top of small diameter jetting pipe in place of a swivel.

(4) Jetting fluid. Plain water is commonly used in jetting wells, but a jetting fluid of greater viscosity and weight may be prepared by mixing clay or a commercial bentonite with water. This heavy fluid tends to seal the wall of the hole and to prevent loss of water into the formation being penetrated. Jetting fluid is channeled from the hole to a settling pit where cuttings (material washed from the hole) settle to the bottom. The fluid can be picked up again by the jetting pump and recirculated.

(5) Drive weight. A small weight may be added near the top of the drive pipe to help it penetrate clayey or semi-firm soil.

(6) Jetting bits. Different types of self-jetting well

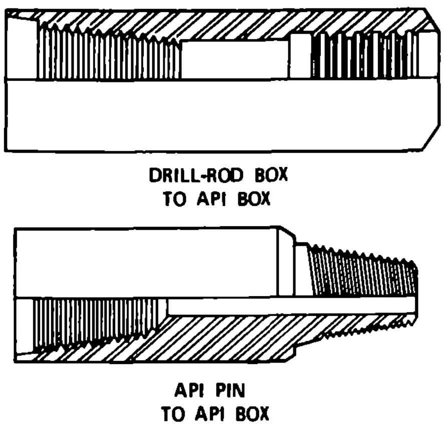


Figure 8B-45 Pin and box screw joints for drill stem connections.

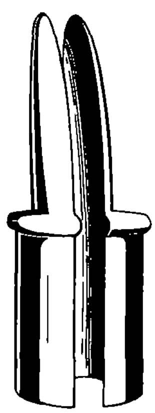


Figure 8B-46 Rope saver.

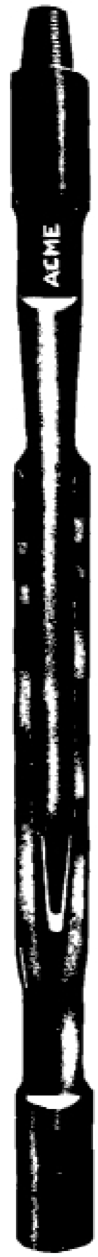


Figure 8B-47 Drilling jars.

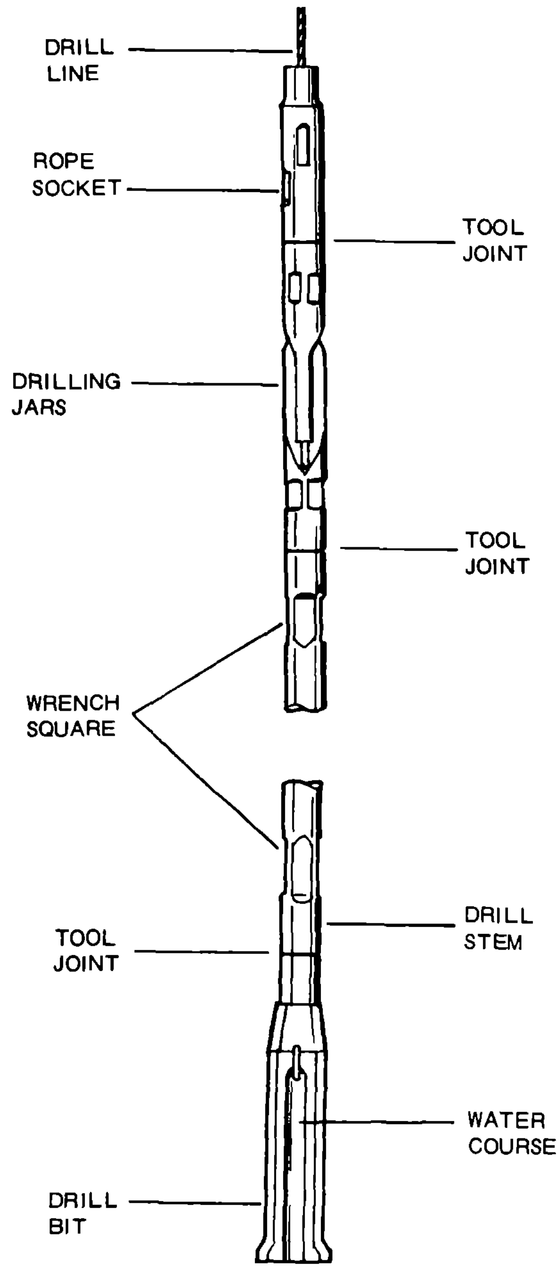


Figure 8B-49 Drill string.

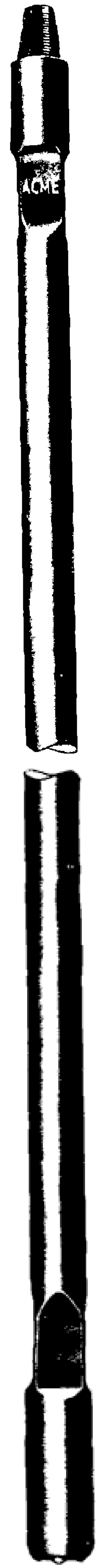


Figure 8B-48 Drill stem.

meters (20 feet long). The drill stem helps keep the hole straight.

When a cable-tool drilling machine is used, drill cuttings are removed from the well by a bailer or a sand pump. The dart valve bailer (Figure 8B-50A) is used in most bailing operations. The dart valve opens when it contacts the cuttings at the bottom of the hole. A slight up-and-down motion of the bailer tends to draw the mud or cuttings into it. When the bailer is withdrawn, the dart valve automatically closes, trapping the contents in the bailer.

The sand pump (Figure 8B-50C) is used in sand and gravel where the dart valve bailer will not pick up the materials. It is made of tubing with a hinge-flap valve and a plunger that works inside the barrel. The sandline is attached to the top of the plunger rod. The sand pump is lowered to the bottom of the hole, allowing the plunger to drop to the bottom of the tool. When the plunger is raised, the material is sucked into the bailer. When the plunger reaches the top of the sand pump, it raises the pump and the hinge valve closes. To empty it, upend the sand pump in the trough by swinging on the plunger rod.

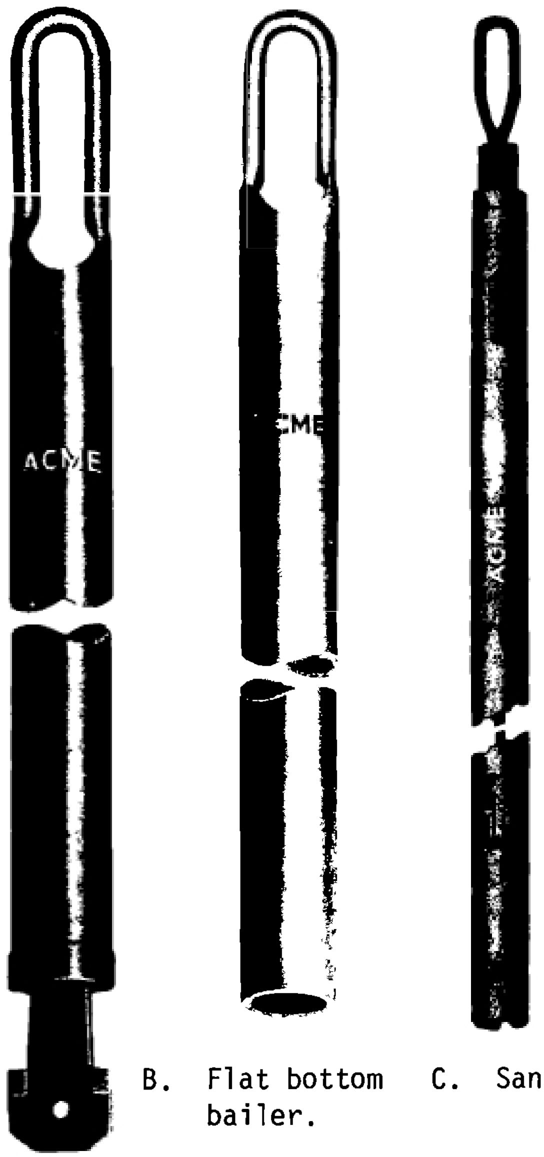
Fishing tools are a special set of tools (Figure 8B-51) designed to recover lost parts of the drill string, casing or other materials that are difficult to recover from the well. Many drillers have fabricated special fishing tools to meet special circumstances that have arisen while drilling a well.

The bit, which does the actual drilling, is the most important part of the string of tools. It consists of the cutting edge, the body, the square wrench, the shank, and the pin (Figure 8B-52). The bit is never allowed to wear down below gage size. This is particularly important when drilling in harder formations, since the diameter of the hole decreases as the gage of the bit wears down.

The drill bit has four important functions. These are penetration, crushing, reaming and mixing. The bit must penetrate the unconsolidated or consolidated formation. As a function of penetration the formation is crushed. The crushed rock is then mixed with water in the hole to form a slurry that can be bailed from the well. The outer cutting edge of the bit reams the hole to permit installation of the casing.

8B4.5.2. Cable Tool Drilling: Operation and Well Construction

The number of men required to operate a cable-tool drill efficently depends upon the experience and ability of the



B. Flat bottom bailer.

C. Sand pump.

A. Dart valve bailer.

Figure 8B-50 Types of bailers.

Figure 8B-51 Types of fishing tools.

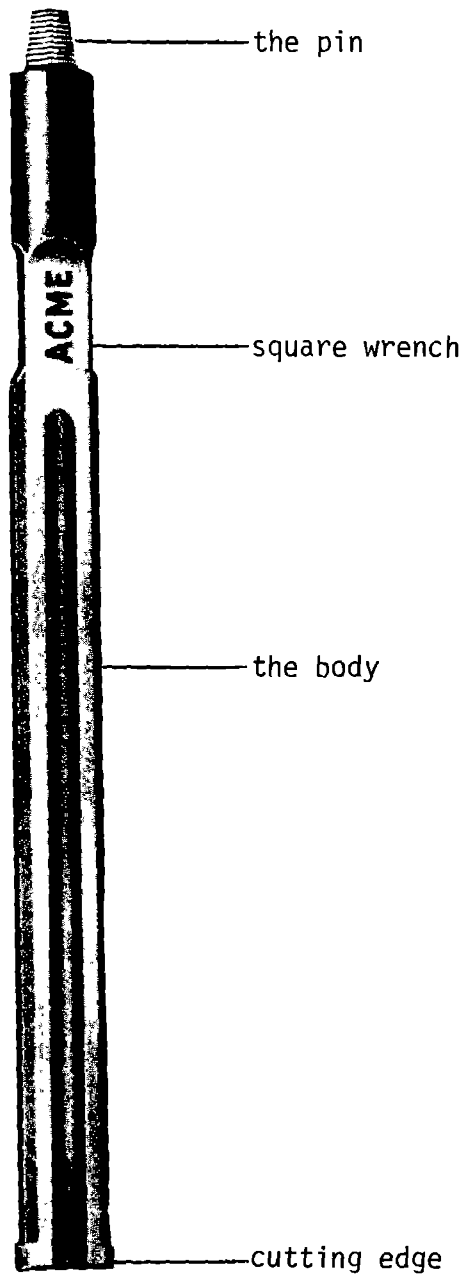


Figure 8B-52 Cable tool bit.

drilling crew, and to a certain extent, upon the type and size equipment. Most rigs used for level I projects are skid mounted and must be unloaded and mounted on cribbing (Figure 8B-53). At least four men are needed for unloading and set up. However, two experienced men can easily operate the equipment.

A water supply nearby is advantegeous for drilling wells with a cable-tool rig. Adding water to the dry hole often facilitates the bailing operation.

In setting up the drilling machine, first place the crib mount in the desired place. Make sure the cribbing is level, and has enough mud sills, properly distributed, to prevent settling or misalignment of the drill after drilling has started. Four 5 by 30 cm. (2 by 12 inch) timbers will do unless the well is drilled in a swampy or a poorly drained location. In such cases, additional mud sills are installed. Figure 8B-53 shows the drilling machine in place with the mast erected ready for drilling. After the mast is raised, the drilling tools to be used for spudding-in are assembled. They are the swivel socket and swivel, drill stem, and drill bit. When units operate in isolated areas or where drilling water is required for extended periods, a tank for liquid storage with a 1900-2250 liters (500-60 gallon) capacity should be requistioned and carried as an accessory to support the drilling operation.

When starting a hole in soft unconsolidated formations, dig a hole about 1 meter (3 feet) deep with a shovel. Let the tools down until the bit rests on the bottom of the hole, then fill the hole with water around the bit. Start the tools by throwing in the spudder-beam clutch; run them slowly and guide their movement by hand until a depth of 2 meters (or 6 feet) is reached. If a tool guide is not available for use in steadying the top of the tools, station a man on the mast for that purpose. When starting a hole in hard rock, dig or chisel out a hole 15 cm. (6 inches) deep at the spot where the drill is to work. Set in a hole a 2 meter (5- or 6-foot) length of pipe, of the same size as the hole to be drilled. Brace and chain the top of the pipe to the mast, as a guide for the tools; if it is securely installed, the tools can be run at a comparatively high drilling speed.

Caution: When chiseling the rock, wear protective goggles.

Drilling operations differ with the character of the formation and the depth of the hole. Adjustments of the spudder assembly eliminates line whip, drill shock and

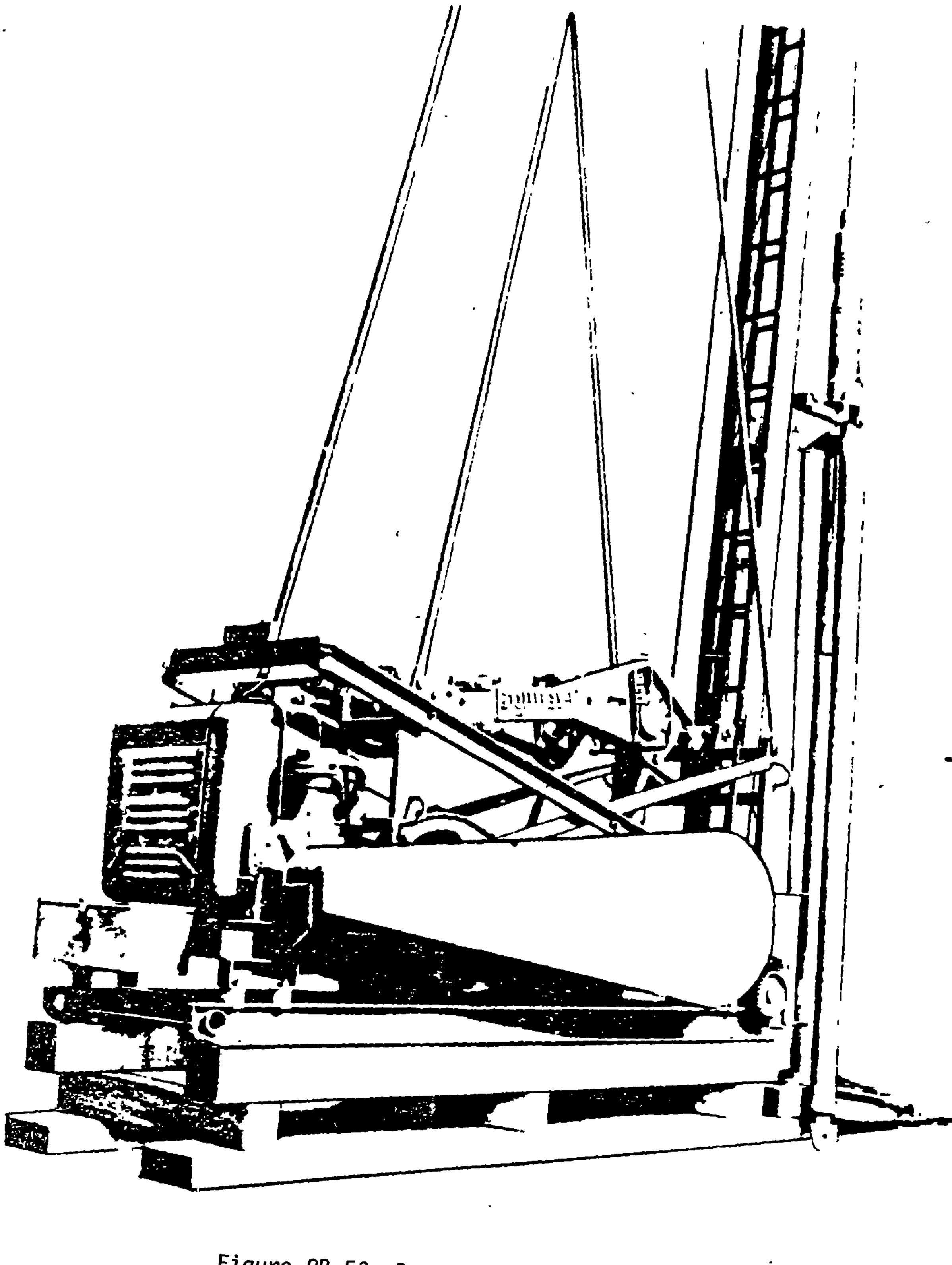


Figure 8B-53 Percussion drill on cribbing.

vibration, and increases the efficiency of the machine. Operating speeds will also differ with the depth and character of the hole. The drill should be run only fast enough to permit smooth operation, and to let the bit drop with a clean hard blow.

If the drilling progress is not satisfactory, yet the hole is straight and the tools are working freely, change to either a shorter or longer stroke. A one meter (39 inches) stroke with about 765 kg. (1,700 pounds) of tools works best in 90 percent of the consolidated rock formations. As a guide use the following data:

58-65 strokes/min.	0.5-m. stroke	(18 inch stroke)
15-57 strokes/min.	0.56-m. stroke	(22 inch stroke)
44-50 strokes/min.	0.80-m. stroke	(32 inch stroke)
35-43 strokes/min.	1.0-m stroke	(40 inch stroke)

8B.4.5.3. Cable Tool Drilling in Various Formations

Each type of material that is drilled through presents its own set of problems. It is important, therefore, to know how to handle the pipe under various conditions.

8B.4.5.3.1 Formation Recognition

Factors to notice while drilling hard and soft formations are as follows: hard rock drilling imparts distinct vibrations to the drilling cable and requires slightly less power to operate the machine at a given speed. Therefore, if the drilling tools reach a noticeably harder formation after drilling in a soft formation, there will be more vibration on the drilling line and a slight increase in the speed of the drilling engine. The converse effect will be found when the drill passes from a hard rock into a soft one. To determine the exact kind of rock being drilled, it is necessary to take samples of the cuttings at intervals of at least 2 meters (6 feet) or every time the drilling characteristics change.

8B.4.5.3.2 Detection of Water-bearing Beds

It is not difficult to detect water-bearing beds in cable tool holes under ordinary conditions, because fluid in the hole does not tend to seal off the water-bearing formation. For this reason a sudden rise or decline in the water level ususally indicates that a permeable bed has been entered. Crevices or soft streaks penetrated while drilling hard formations often are water bearing. Sand, gravel, sandstone, and limestone produce the largest quantities of water. It is advisable, therefore, to be especially watchful while drilling in these formations.

Several water yielding formations may be encountered while drilling. As each formation is reached, test the well to determine its approximate yield. A capacity test of limited extent can be made with the rig by bailing water rapidly from the well.

8B.4.5.3.3 Drilling in Soft Clay

Drilling in soft clay can be difficult because the clay does not mix well with the water and builds up on the bit so that the water channels become closed and the tools do not fall freely during drilling. As soon as this situation happens, pipe should be driven. Because the clay is soft, the pipe or casing is driven easily and can be pushed far down ahead of the hole. In fact, in some clay formations it is not unusual to drive pipe as much as 22.86 m. to 30.48 m. (75 to 100 feet) at a time before removing the drive clamps and cleaning the hole. Pipe can be driven in this way until it stops moving under the driving blows. If the mixture changes to clay and fine sand, it is still alright to drive ahead of the hole but for shorter distances, such as 1.5 m. to 3.0 m. (5 to 10 feet). Sand causes greater friction against the casing, and the casing will move better if it is cleaned out and the hole is opened up a meter below the casing. Casing will move well in sand formations but not with the soft, springy action as in soft clay. However, there is some danger of damaging the casing when driving it ahead of the hole. Where boulders may be present, short drives are safer.

8B.4.5.3.4 Drilling in Hard Clay

Hard clays generally do not present any drilling problems, and if there are no stones, big boulders, etc. to change the course of the drilling bit and cause the hole to bend, the driller can continue drilling below the pipe until it appears that the bottom of the hole has started to cave. Actually when drilling in clay, it is good practice to drive pipe after the open hole has been drilled to the length of the drilling tool string.

8B.4.5.3.5 Drilling Boulders and Hard Pan Formations

Hard pan refers to extremely hard clays with a possible mixture of boulders. Drilling holes through boulders creates a problem because the drill bit tends to glance off the boulder and the hole can become crooked. The driller can ususally tell when the drill bit glances off a boulder or the boulder strikes against pipe because the pipe will vibrate. This can be felt when the driller grabs the drilling cable. When this happens he should stop drilling and drive his casing with great care.

In cases where drilling is extremely difficult, dynamite sometimes succeeds in opening up the hole. If this is not successful, the driller can reduce the diameter of the drive pipe or else he must start a new hole.

8B.4.5.3.6 Drilling in Quicksand

Quicksand frequently presents serious problems to the driller. It comes into the hole and must be bailed out in large quantities before casing can be driven further down and the drilling continued. Also, pockets of clay or coarse sand in a quicksand layer cause the driller to believe that he has passed through the quicksand. The coarse sand will not rise if the water velocity through it is less than about 76.2 cm. per minute (2 1/2 feet/min). The drive pipe will shut off water and quicksand above such a sand or clay pocket, but after the drill passes through the pocket, the quicksand flows in again and immediately rises in the pipe. If the bed is 6 m. (20 feet) or more thick, the pipe cannot be driven through it because of the resistance of the compacted sand. If water in the quicksand is under great hydraulic head and sand is forced above the point at which the bed was struck, further progress may be almost impossible. In some wells quicksand can rise in the pipe 30.5 m (100 feet) above the depth where it is struck.

Quicksand can only be confined by using water-tight casing. Quicksand not only requires laborious excavation, but the tools can get jammed in the hole and buried by sand unless they are withdrawn rapidly. Then the driller not only must clean out the hole but must also recover the tools. If the tools are stuck, sand should be bailed out and a wash pipe 2.5-5 cm. (1-2 inches) in diameter lowered down into the well. Water is then poured into the hole until the tools are partly freed. Then a slip socket is inserted over the upper end of the drill string and with the help of fishing jars it is jerked free. In removing tools from quicksand, they should be raised slightly at each upstroke and in this way they gradually become free. This should be done rapidly so that the sand cannot again pack about the tools.

One method of partly overcoming quicksand is to fill the bottom of the well with mortar or Portland cement which sinks into the quicksand and sets. The hole may be then drilled through the cement which forms a wall to prevent further inflow of quicksand.

Some drillers keep the drill hole full of water when drilling through quicksand. If the head of quicksand is 30 to 45 m. (100 to 150 feet) below the surface, the column of water in the well will exert enough back pressure to prevent the sand from rising in the pipe. The sand bailer may then be inserted and the well may be bailed through the column of water. Occasionally, because of uneven pressures in the hole, pipe may become bent when removing quicksand. Here again the remedy consists in keeping the hole full of water.

8B.4.5.3.7. Drilling in Sand and Gravel Formation

Sand and gravel formations are usually loose and have large amounts of water. Caving almost always happens during drilling in these formations, and it is necessary to drive pipe a few feet ahead of the hole. Because the driller will often want to complete his well in a gravel formation he should not drive pipe more than a few feet ahead of his hole as he may get his casing past the best part of the formation.

8B.4.5.3.8 Drilling in Bedrock

When a driller reaches bedrock he can frequently drill down without adding any additional casing. However, it is necessary that a tight joint be made between the pipe and the rock in order to avoid leakage into the well at this point and possible contamination.

Actually, it is good drilling practice to go 1 to 1.5 meters (3 to 5 feet) down into bedrock with the casing shoe held a meter above the rock formation. This of drilling results in a slight taper forming as the hole is drilled down. Then a tight joint is created when the pipe is finally driven into the rock. The driller should note that pipe will bind considerably after each blow and the pipe should be carefully watched to see if it is actually moving deeeper into the hole.

A good seal depends on the type of rock. In hard formations, for example, a good seal can be made after driving down for about 25 cm. On the other hand, it may be necessary or desirable to drill 3-4 meters (10-13 feet) into shale to insure a good seal. The driller can usually tell if a good seal has been made when no foreign materials such as sand or small stones are mixed with the cuttings.

Sometimes it is desirable to cement the hole shut at the joint between the pipe and the rock. This, of course, requires a larger hole than the pipe diameter so that cement can be poured in the space between the hole wall and the pipe. This cement can either be forced down with a pump or poured down through a small diameter pipe which extends nearly to the bottom of the hole.

8B.4.5.4 Bailing

The cuttings are bailed out as the hole is drilled. One to two meters (four to six feet) of hole generally can be made at each run of the tools. However, conditions differ greatly, and no rule can be set. A clean hole drills better than one filled with thick mud, but in soft formations the mud tends to prevent the hole from caving. Therefore, it is sometimes better not to bail out all the mud and water but only the thicker, heavier part at the bottom of the hole.

When drilling in a consolidated formation, the bailer operation is quite regular. After each run, the tools are pulled from the hole and swung aside while the bailer is used. If the bailer goes to the bottom and the hole is in good condition, the pickup will be indicatd by two jerks on the sandline. The jerks will appear about 1 second apart and are the result of the pickup of the bailer, and the pickup of the bailer dart valve plus the fluid within the bailer. After lifting the bailer 2 meters (6 feet), it is lowered and raised once or twice more, since this tends to draw into the bailer any sand or material that might have settled to the bottom of the hole. If the double jerk referred to above is repeated each time the bailer is lifted, it is safe to assume that the hole is in good condition.

If only one jerk is noticed as the bailer is lifted, it indicates the bailer did not reach the bottom of the hole, and the trouble must be corrected before attempting to drill deeper. The trouble may be caused by the failure of the drill bit to turn, thereby creating a hole which is not round; or the hole may be so crooked that the bailer will not reach the bottom. Other causes could exist, such as a ball of mud or a boulder projecting into the hole.

A sand pump gives a signal on the line in the same way as a bailer, except that the jerks are much further apart. If the pump is allowed to rest in the bottom of the hole and the plunger is lowered to the bottom of the tube, the first jerk will indicate the pickup of the plunger and the second jerk will be the pickup of the tube. The two signals will be some seconds apart, owing the length of the plunger.

8B.4.5.5 Driving Casing

When the casing does not follow the bit down into the hole, it is necessary to drive it in. Casing is driven with the drilling tools, the drive clamps and the drive head (Figure 8B-54). First drive clamps are bolted to the upper wrench square of the drilling stem for driving casing. Next, a length of casing is set up and screwed into, or welded onto the casing string already in the hole. The drilling tools are then lowered down into the pipe far enough so the upper square on the drill stem is just above the top of the casing to be driven. If necessary, when setting the first length of casing, the drive clamps can be used on the lower wrench square if sufficient shoulder is available. After the drive clamps are placed on the wrench square, pull up on the tool so drive clamps are several inches above the drive head or top of the pipe. Start the spudding action on the machine and slowly lower the tools until the drive clamp makes contact.

After driving for a few feet, the driving speed often will slow down or stop. As the diameter of the hole decreases to less than the outside diameter of the casing shoe, driving or forcing the shoe down through the smaller hole often plugs the pipe. The bit is now used and the tools are run to the bottom to widen and clean out the hole.

Drillers should not drill farther ahead of the drive shoe than is necessary to drive in one length of casing at a time.

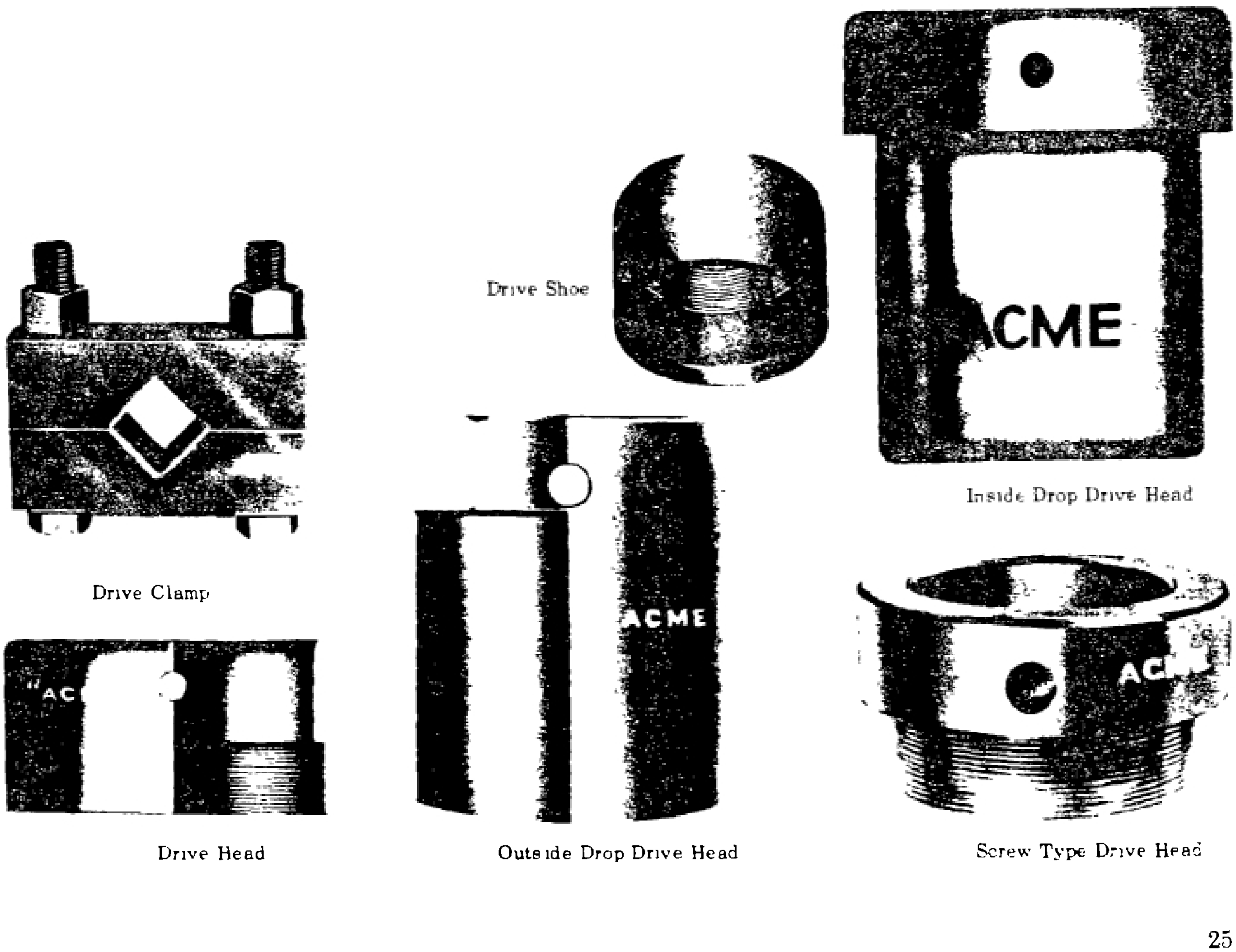


Figure 8B-54 Tools for driving casing.

8B.4.6 Hydraulic Rotary Drilling

The hydraulic rotary method of drilling combines the use of a rotating bit for cutting the borehole, with that of continuous circulation of drilling fluid to facilitate removal of cuttings and debris from the hole.

At the present, the number of rotary drilling rigs is small when compared to the number of cable tool rigs operating in the Philippines. The high cost of rotary drilling equipment will probably prohibits its widespread use for construction of level I wells. However, its chief advantage is the speed with which drilling can progress. Whereas, a cable tool rig may require weeks or months to drill a well, a rotary rig can drill the hole in a few days or a couple of weeks.

The small diameter holes required for level I systems can be installed by rotary drilling very rapidly, making it possible for the driller to install many wells per year. In emergency cases, where a barangay may be in desperate need of a few wells installed quickly, the waterworks engineers and technicians may wish to consider hiring a company that has rotary drilling equipment.

8B.4.6.1 Rotary Drilling Equipment

The basic parts of the conventional rotary drilling machine or rig (Figure 8B-55) are a derrick or mast; a hoist; a power operated revolving table that rotates the drill stem and drill bit below it; a pump for forcing drilling fluid via a length of hose and a swivel on through the drill stem and bit; and a power unit or engine. The drill stem is in effect a long tubular shaft consisting of three parts: the kelly (Figure 8B-56); as many lengths of drill pipe as required by drilling depth; and one or more lengths of drill collar.

The kelly or the uppermost section of the drill stem is made a couple of meters longer and of greater thickness than a length of drill pipe. Its outer shape is usually square (sometimes six-sided, or rounded with a couple of groves). It fits through a similar shaped opening in the rotary table so that the kelly is able to move freely up and down while the rotary table imparts rotation to it. The rotation is then transmitted down the entire length of drill pipe to the bit. At the top end of the kelly is the swivel which is suspended from the hook of a traveling hoist block (Figure 8B-57).

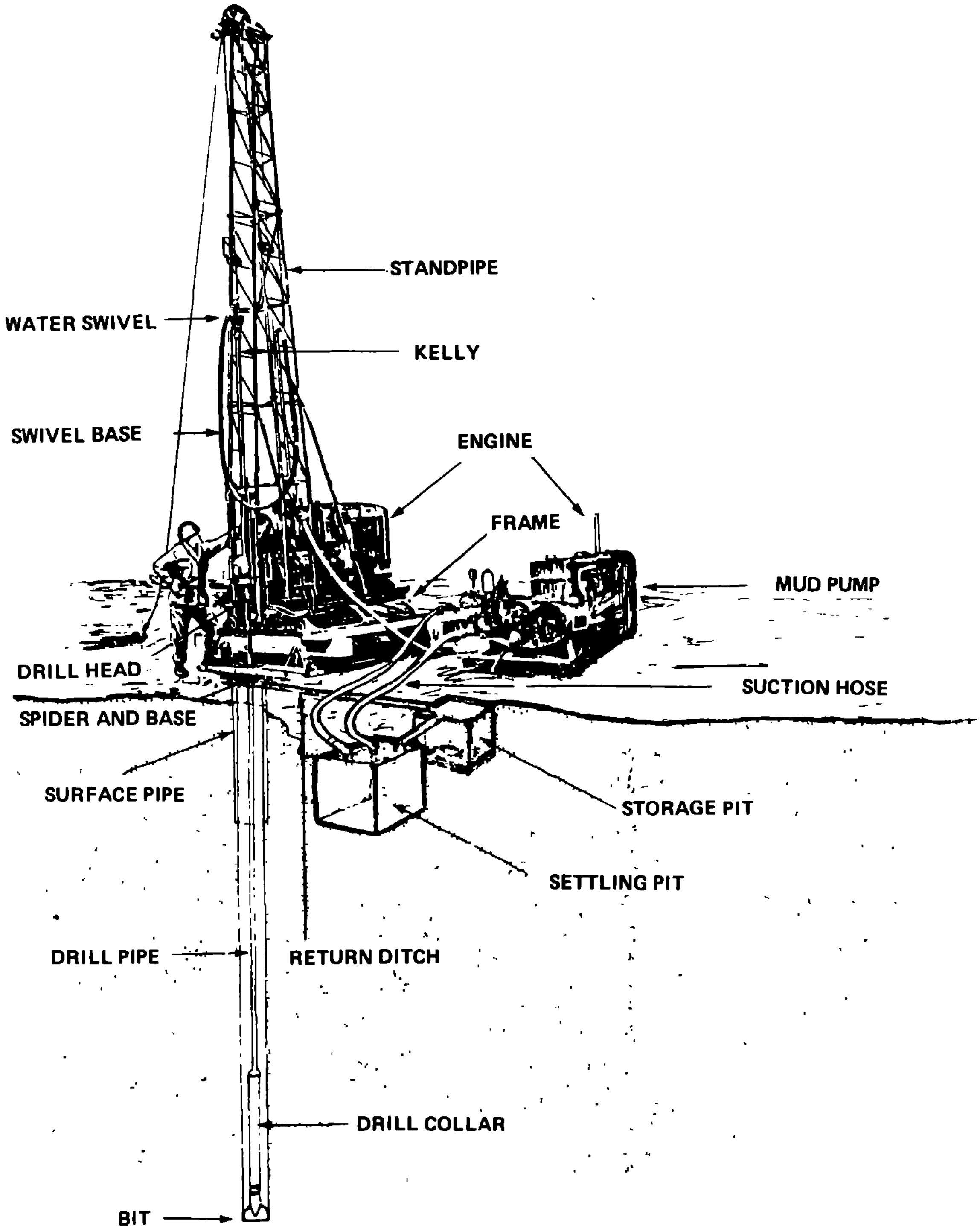


Figure 8B-55 Typical equipment for rotary drilling.

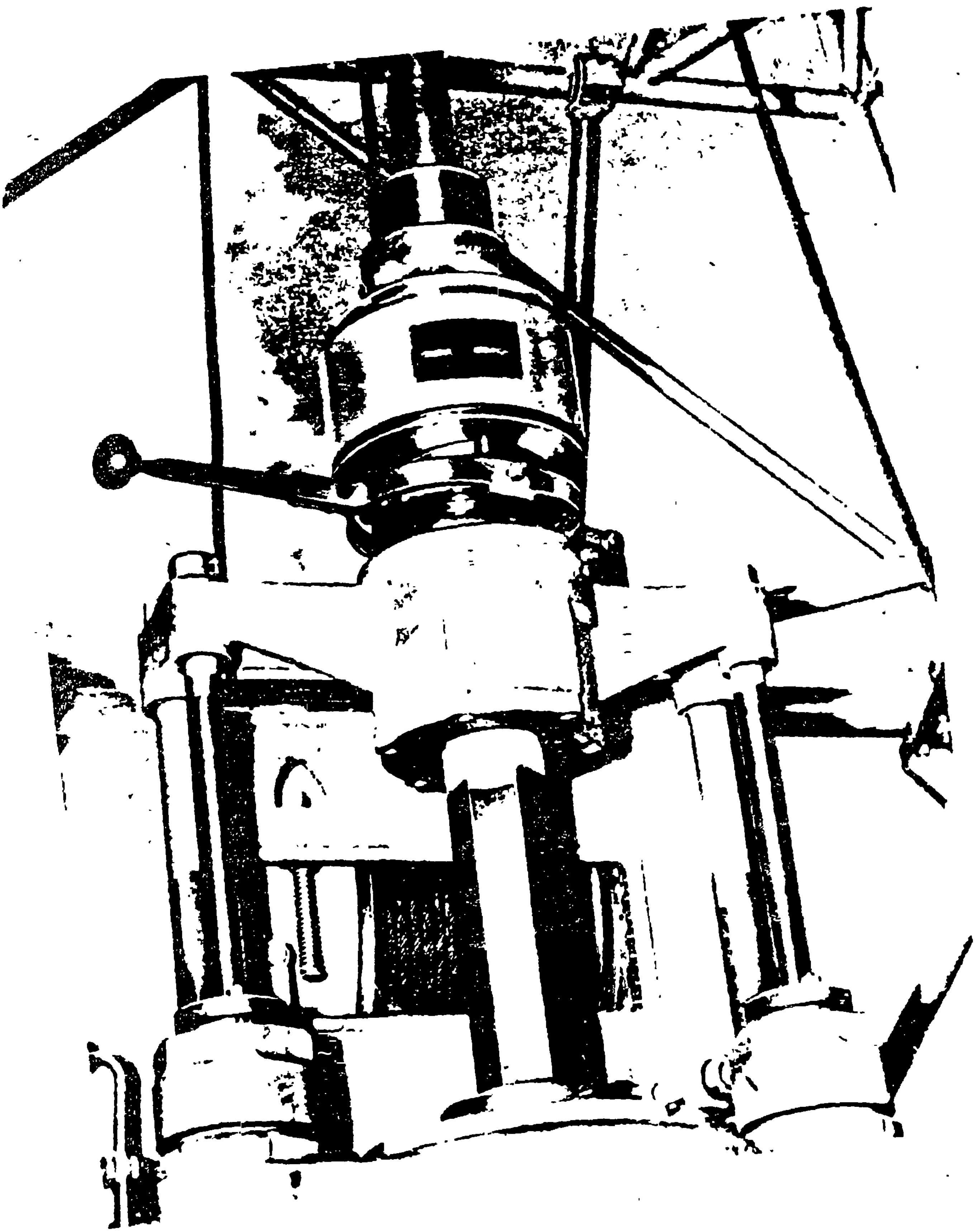


Figure 8B-56 Power feed mechanism and kelley.

Below the kelly are the drill pipes, usually in lengths of 3 to 6 meters (10-20 feet). Extra heavy walled drill pipe may be attached immediately above the bit. These add weight to the lower end of the drill stem, and so help the bit to cut a straight vertical hole.

The bits that are best suited to use in unconsolidated clay and sand formation are drag bits of either the fishtail or three-wing design (Figure 8B-58). Drag bits have short blades forged to thin cuttings edges and faced with hard-surfacing metal. The body of the bit is hollow and carries outlet holes or nozzles which direct the fluid flow toward the center of each cutting edge. This flow cleans and cools the blades as drilling progresses. The three-wing bit performs smoother and faster than the fishtail bit in irregular and semi-consolidated formations and has less tendency to be deflected. However, it cuts a little slower than a fishtail bit in unconsolidated clay and sand formations.

Coarse gravel formations and those containing boulders may require the use of roller-type bits (Figure 8B-58). These bits exert a crushing and chipping action as they are rotated, thus breaking up gravel or effectively cutting through consolidated formations. Different roller cone bits are available for drilling through different types of formations. A nozzle is located near each roller through which drilling fluid is jetted to clean and cool the bit and carry cuttings up to the ground surface.

At the surface, the fluid flows into a ditch, to a settling pit, where the cuttings settle out (Figure 8B-59). From here it overflows into a storage pit where it is again picked up by the pump and recirculated. The settling pit should be of a volume equal to at least three times the volume of the hole being drilled. It should be relatively shallow, approximately one meter deep (3 feet), and about twice as long in the direction of flow or it is wide and deep. In accordance with above rules, a hole 150 mm (6 inches) in diameter, 30 meters (100 feet) in depth, would require a settling pit 2 meters (6 feet) long, 1 meter (3 feet) wide, and .1 meter (3 feet) deep. Placing baffles across the pit will help well cuttings settle out of the drilling fluid. Well cuttings should be periodically removed from the pits and ditches as is necessary.

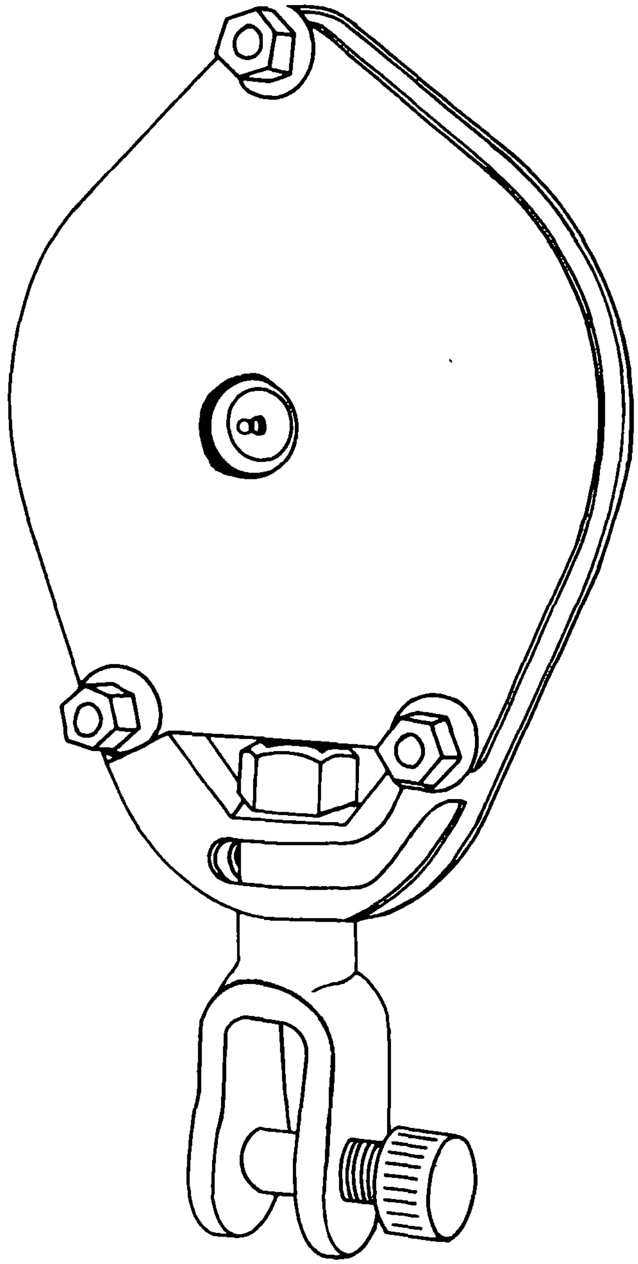


Figure 8B-57 Traveling block.

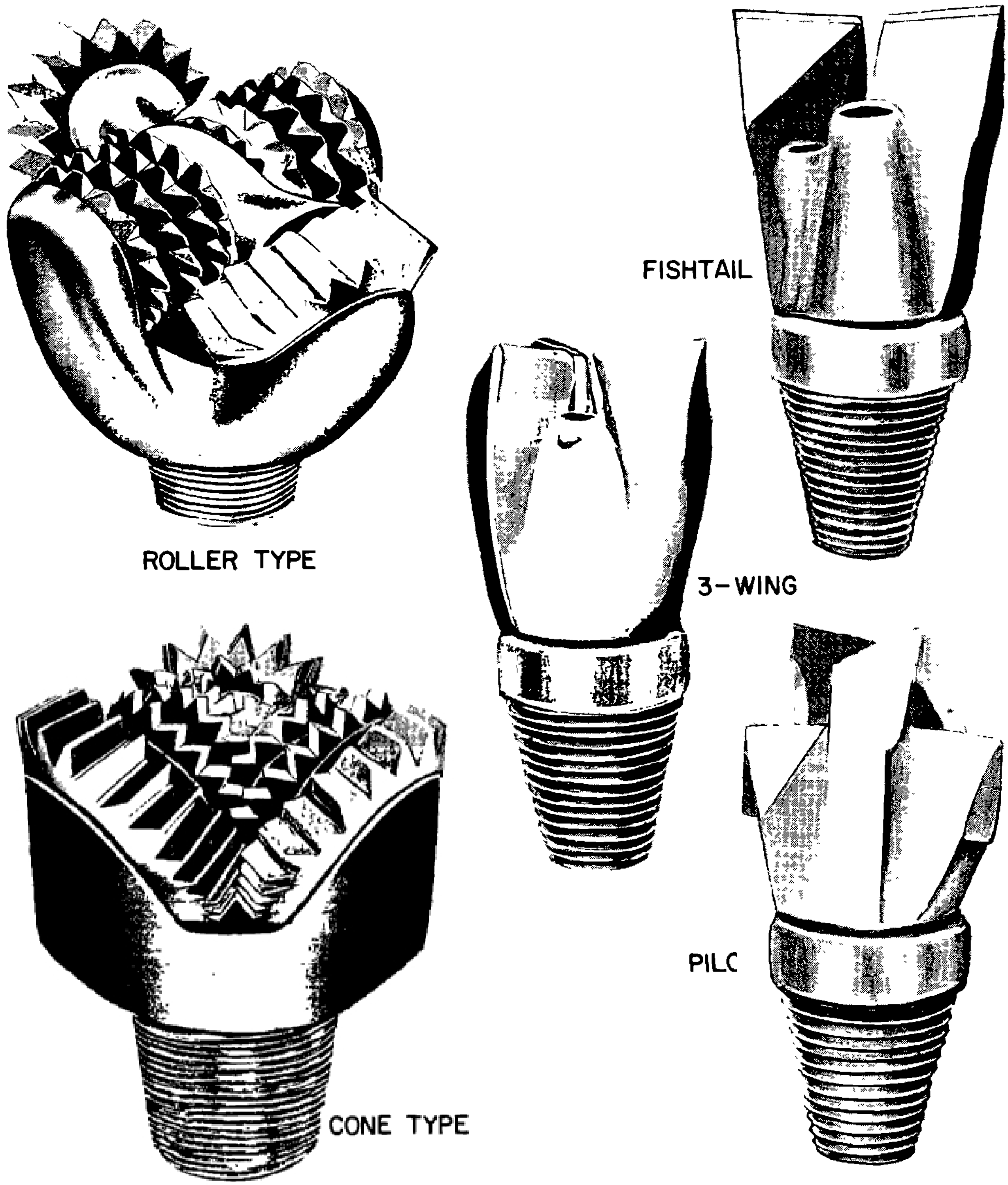


Figure 8B-58 Types of rotary drilling bits.

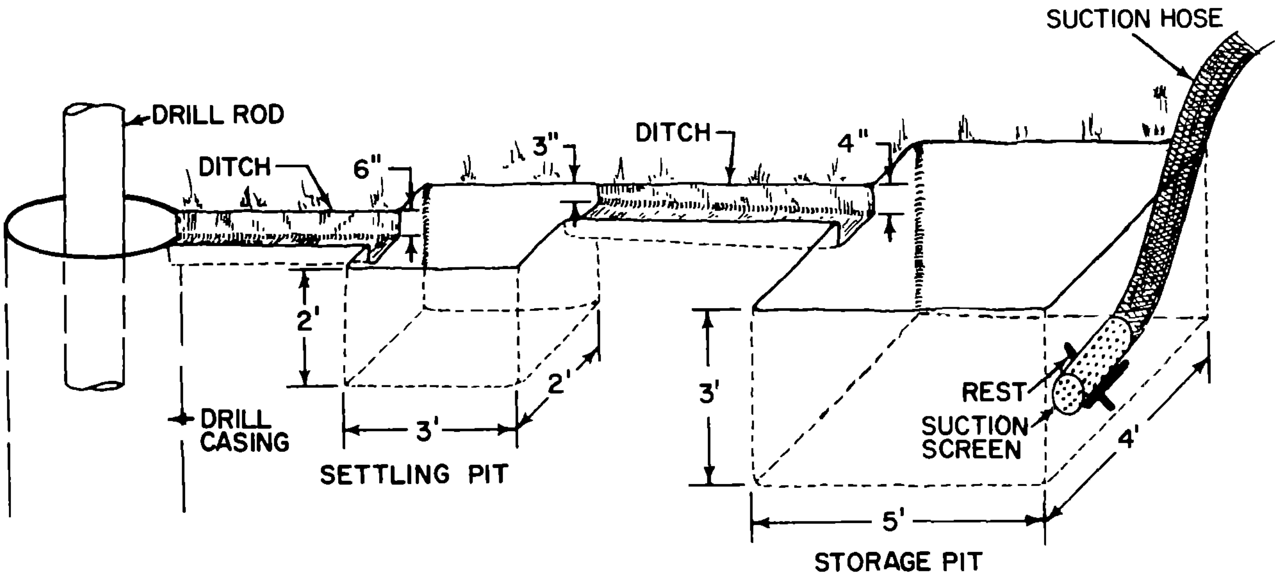


Figure 8B-59 Slush pit arrangement.

Rotary drilling equipment for small diameter wells consists of the derrick or mast, power plant and rotary table mounted on a flat bed truck, trailer, or skid, or may consist of a simple tripod made of 50 mm (2 inches) or 75 mm (3 inch) galvanized iron pipe with power plant placed on a ground. With the tripod, a small suitable swivel can be suspended by a rope through a single-pulley block from a U-hook fixed by a pin at the apex of the tripod. One or two men can use chain tongs to rotate the drill pipe. With the exception of the drilling bit, this equipment is identical with that described for the jetting method in section 8B.4.4.

8B.4.6.2 Drilling Fluid

Holes drilled by the rotary method in unconsolidated formations generally tend to collapse unless the properties of the drilling fluid can provide adequate support for the wall of the hole. Drilling muds are usually viscous mixtures of water, natural or commercial clays such as bentonite or special purpose polymers. The weight of the drilling fluid must provide enough pressure to exceed subsurface pressure or any artesian pressure in the aquifer which would cause the hole to collapse. The drilling fluid should also form a mud cake which lines the wall of the borehole. This lining holds the loose particles of the formation in place, protects the wall from being eroded by the upward stream of fluid, and seals the wall to prevent loss of fluid into permeable formations such as sands and gravel.

The drilling fluid must also be capable of maintaining clay particles in suspension, even if the drilling is temporarily halted.

The driller must be able to use his judgement in arriving at a suitable fluid thickness. Too thin a fluid results in caving of the hole and loss of fluid into permeable formations. On the other hand, fluid that is too thick can cause difficulty in pumping. The drilling fluid should be no thicker than is necessary to maintain a stable hole and satisfactory removal of cuttings from it. The experienced driller can adjust his fluid mixture to a satisfactory level by visual inspection. There are, however, two aids which a driller can use in the field to check the fluid characteristics. These are a balance for determining the density of the mud and a Marsh funnel for determining its viscosity (Figure 8B-60). For most water well drilling, a fluid density of about (9 pounds per gallon) is usually satisfactory.

Figure 8B-60 A marsh funnel and a blance for checking drilling fluid characteristics.

A good drilling mud of density 9 pounds per gallon would have a Marsh-funnel viscosity in the range of 30 to 40 seconds. Sand picked up by the drilling mud from the cuttings has the effect of increasing the density while reducing the Marsh-funnel viscosity. In contrast, native clays can be expected to increase the density and the viscosity of the fluid. Water and/or clay should be added periodically to the drilling mud as is necessary to keep the density and viscosity withing the above limits

8B.4.6.3 Sampling Geologic Formations

Sampling geologic formations while rotary drilling can be accomplished by raising the bit off the bottom of the hole, and continuing circulation of the drilling fluid until all the cuttings from the selected sample interval are cleared from the hole and caught in a sample catcher or fine mesh net before entering the settling pit. The driller can select any interval he may wish to sample or take a sample when he thinks his tools have entered a different geologic formation. Most commonly, samples are taken at 2 meter (6 foot) intervals. Sample quality, however, decreases as hole depth increases, and greater mixing occurs between new cuttings and materials caving off the borehole wall.

An experienced driller can usually tell when highly permeable formations are encountered by recognizing one or more of the following phenomena:

1. excessive, or total loss of drilling fluid which means the drilling fluid is seeping into the formation;

2. a noticable increase in the volume of the returning circulation fluid, which means that an artesian aquifer with a higher hydrostatic pressure than the mud column in the hole has been penetrated; and

3. rapid thinning or a decrease in viscosity may indicate the entrance of water into the borehole.

8B.4.6.4 Casing and Screen Installation

Because a rotary drilled hole should not collapse, casing does not have to be installed until the drilling has been completed. The casing string is usually installed in one complete process.

In unconsolidated materials the screen or intake structure is placed in the hole. Casing is either welded or screwed onto the length of screen and lowered into the hole until just the top of it stands out at the surface. The next length of casing is then attached and lowered into the well. If desired, a screen may be placed at different points between casing so that multiple aquifers can contibute to a flow of water into the well.

Because the borehole is usually 5-8 cm larger than the casing diameter, gravel pack or formation stabilizer can be introduced in the annular space and placed adjacent to screened intervals. The placement of this material is usually through a 3 to 4 cm diameter tremie pipe lowered to the bottom of the hole, and lifted as the gravel or sand fills up around the screen. If zones of undesirable water are encountered then cement can be injected through the tremie pipe to seal off the annular space to prevent vertical migration of poor quality water. Likewise, the upper 3 to 6 meters (10-20 feet) of the annular space should be grouted with cement to prevent leakage of surface fluids into the well.

8B.4.6.5 Advantages and Disadvangates of Rotary Drilling

The hydraulic rotary drilling method usually penetrates unconsolidated materials faster than is achievable by any other method. This can result in appreciable savings in time and cost, both of which can be major considerations in a well construction program. Since the borehole need not be cased until drilling is complete, the hole can be abandoned if necessary without the trouble of pulling or leaving a string of casing behind. A third advantage is the greater ease with which artificially gravel-packed wells can be constructed.

The hydraulic rotary method also has some disadvantages. The accurate sampling and logging of formations penetrated can be difficult for the driller because of the differential transport of cuttings out of the borehole. The need for mud control also requires considerable experience on the part of the rotary driller. The training of rotary drillers requires more time. Finally the equipment used is usually more expensive and more difficult to maintain.

WELL CONSTRUCTION CHECKLIST

1. What type of equipment and materials are available for well construction?

2. What type of skilled and unskilled labor is available to assist well construction?

3. What type of geologic materials will be encountered during drilling?

4. What is the anticipated depth of the well?

Based on the answer to the above questions;

1. Select a method of well construction.

2. Develop a work plan.

3. Collect and organize the equipment and materials necessary for well construction.

4. Clear and prepare the site to be drilled.

5. During drilling sample at 2 meter intervals or at changes in formation characteristics.

6. Prepare a well log (See Section 8B.11)

7. Select an appropriate intake structure and the depth interval for its installation.

8. Properly seal the annual space to prevent ground water contamination (Section 8B.6.).

When consolidated formations are encountered under unconsolidated formations casing can be set 2 to 3 meters into the consolidated rock and grouted into place. A small diameter bit is then used to drill down through the casing into the underlying rock formations.

8B.5 RECOMMENDED PRACTICES USED IN THE INSTALLATION OF PLASTIC WATER WELL CASING

Plastic water well casing and screen has been used throughout the world for over 20 years. Sufficient knowledge is available on the limitations and capabilities of plastic well casings to ensure trouble-free and structurally sound wells.

Manufacturers of plastic pipe in the Philippines are presently producing plastic pipe material that is acceptable quality for use as well casing. Plastic well casing offers a number of advantages over steel and GI pipe for casing. It is corrosion resistant, easy to handle and join together, relatively inexpensive, and provides long service life.

However, there are disadvantages associated with the use of plastic water well casing. Since it is not as strong as steel or GI pipe it cannot be driven or jetted. In some respects, greater care must be taken with it during the installation process, than with metal pipe.

Upon completion of this section the manual user will:

1. understand the causes of plastic well casing failure and know how to prevent it from occuring;

2. know how to install plastic well caing in wells drilled either by rotary or by cable tool equipment;

3. be able to make successful solvent weld casing joints, and

4. be able to properly grout the plastic well casing in the borehole.

8B.5.1 Plastic Water Well Casing Collapse due to Extreme Differential Hydrostatic Pressures

Where conventional mud rotary drilling methods are used, the mud helps to prevent the borehole from collapsing during drilling operations. During casing installation, either water or drilling mud fills the casing to equalize internal and external hydrostatic pressures. This prevents the casing from collapsing. Once the screen is set, compressed air is generally used to develop the well. As the air is fed into the casing, it reduces the specific gravity of the drilling mud and causes it to rise out of the well.

However, this change in the specific gravity of the material inside the casing upsets the pressure balance between the interior and exterior of the well. This pressure differential could cause the casing to collapse, especially when the casing has low resistance to external hydrostatic pressure and the external support may be incomplee or inadequate. The greater the rate of incomplete or inadequate. The greater the rate of air injection into the casing, the greater the pressure differential. Therefore, caution must be exercised in determining the rate of air injection.

Some other reasons for differential pressures occurring in the thermoplastic casing are:

1. rapid removal of the bailer full of drilling mud from the bottom of the well reduces internal pressure as a result of the suction; and

2. extreme drawdowns caused by over pumping during some well development procedures.

Other causes of plastic casing failure include improperly constructed joints, pipe fracture due to rough handling, and deterioration of the casing due to excessive exposure to sunlight.

In the following sections methods of installation, joining and handling are described which will reduce the possiblity of well failure.

8B.5.2 Plastic Well Casing Installation Methods for Rotary-Drilled Boreholes in Unconsolidated Materials

There are several satisfactory techniques for installing plastic water well casing and screens into unconsolidated aquifers. One method involves capping the end of the screen or casing and filling the entire casing with water or drilling mud to reduce the buoyancy of the casing string and to balance the pressure exerted by the water and/or drilling fluid on the outside of the empty casing. The screen and casing are then lowered into the borehole.

Commonly, several lengths of casing are joined together to form 12 meter (40-foot) sections before casing installation begins. This helps speed up the installation of greater length of casing in a shorter amount of time. Several lengths of casing are solvent cemented together in the horizontal position and allowed to cure during the installation procedure. It works best if the drilling mud is heavy enough to prevent any of the surrounding formation materials from filling the borehole (i.e., no sloughing or swelling should occur that would impede installation of the casing into the borehole).

When the casing has been successfully placed at the desired depth, clean water is pumped through it to remove any drilling mud that has entered the screen or casing, as well as any mud that has impregnated the borehole sides.

8B.5.3 Installation of Plastic Water Well Casing in Rotary-Drilled Boreholes in Consolidated Formations

Wells drilled in consolidated formations should have the borehole diameter 4 to 5 cm (1 1/2 to 2 inches) larger than the outside diameter of the casing. The well casing should be grouted at least 3 meters (10 feet) into consolidated rock. Once the borehole is properly drilled, the installation of plastic casing can begin.

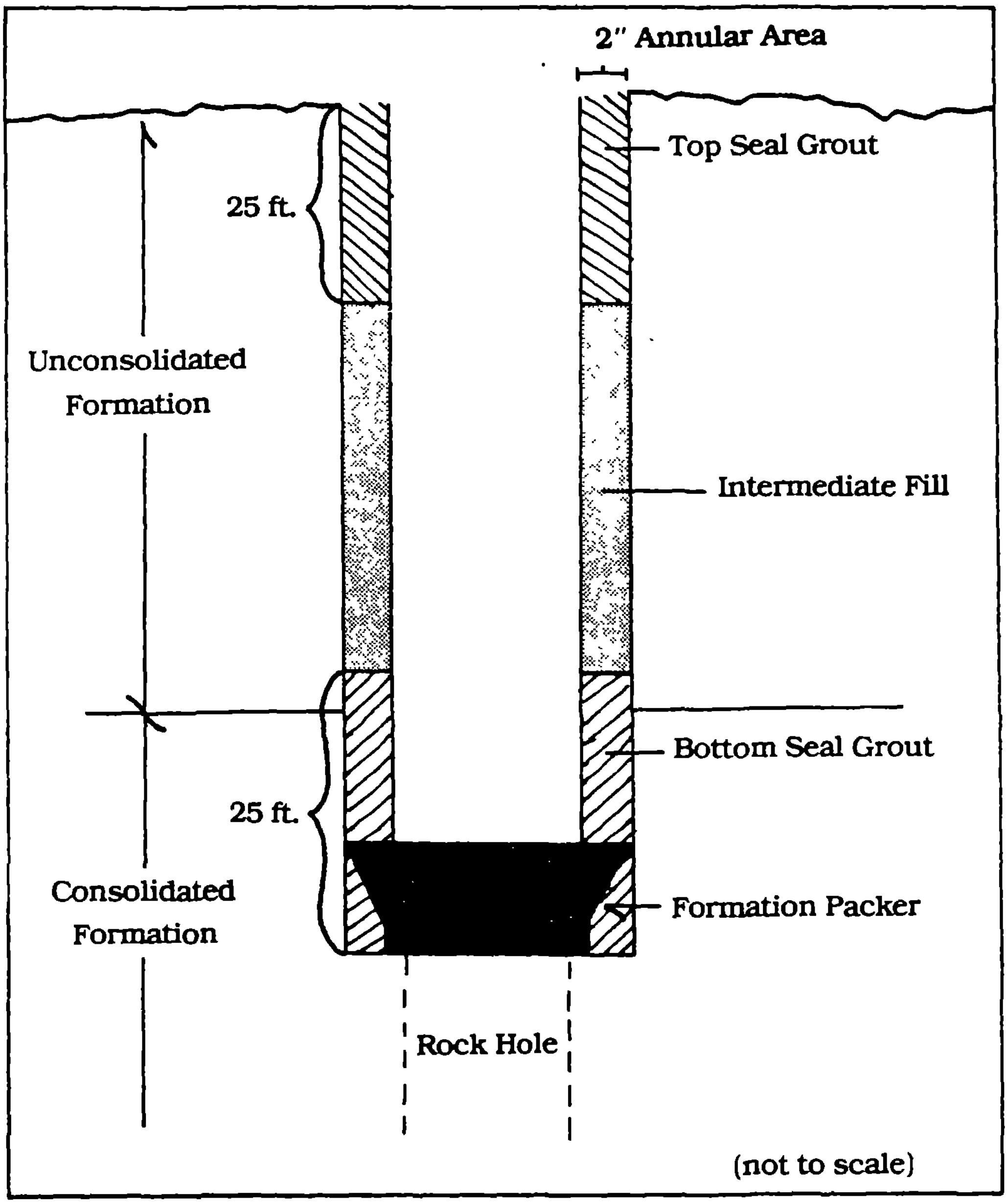
Because plastic casing cannot be driven into rock, the contractor must use a formation packer to form the bottom seal (Figure 8B-61). After the formation packer has been attached to the bottom of the casing and the casing string has been lowered into the borehole, the bottom sealing material is introduced into the annular space. This sealant may consist of puddled clay or neat cement, or it can be a combination of the two materials. Puddled clay has certain adhesive properties that makes it suitable for use in forming a watertight seal. The contractor should use enough sealant to fill the annular space to at least 8 meters (25 feet) above the bottom of the casing (Figure 8B-61).

When the bottom seal has been completed, the intermediate filling can proceed. Intermediate fill can consist of rock cuttings, puddled clay or bentonite. The intermediate fill should extend to within 7 meters of the surface. The surface seal is then added to complete the filling process. Surface sealant usually consists of the same material used to form the bottom seal.

The importance of controlling the rate of back-filling cannot be overstressed. Fill materials should be placed in the annular space at a slow, even rate. The adverse effects of bridging can usually be avoided when the annular space is filled in this manner.

8B.5.4 Installation of Plastic Water Well Casing Using a Cable Tool Rig

Because plastic water well casing is not designed to be driven, the extent to which it can be installed in a well constructed with a cable tool rig is limited. Attempts to drive it will damage the casing. Plastic casing, however, can be set using the "pull-back" method when a cable tool rig is used to drill the well.



Cross section illustrating the position of intermediate fill and grout to ensure the sanitary protection of the well.

Figure 8B-61 Schematic of plastic well casing installed in bedrock.

Step 1. Steel casing is driven into the chosen aquifer using standard procedures.

Step 2. The plastic casing is then inserted into the steel cased well bore.

Step 3. The plastic casing is filled with water to ensure that it does not float.

Step 4. The contractor then jacks the steel casing out of the borehole for later use.

Step 5. Backfill material or grout is emplaced as the outer steel casing is withdrawn.

8B.5.5 Cement Grouting of Plastic Well Casing

Plastic well casing is sensitive to high temperatures produced by the setting of cement. If the width of the annular space exceeds 150 mm (6 inches) then the heat build up by the setting of cement may cause the plastic well casing to deform and collapse. This problem can be avoided by:

1. trying to limit the size of the annular space;

2. circulating water inside the entire well casing to help dissipate heat; and

3. adding bentonite to the cement to increase the time required for the cement to set.

<u>Never</u> use quick-setting cement when using plastic well casing, because it generates higher setting temperature than regular cement.

8B.5.6 Joining Methods for Plastic Water Well Casing

Solvent Cementing:

Step 1. A solvent cement is spread over the surface areas where two sections of casing are to be joined. It is sometimes used in conjunction with a primer which contains an active solvent agent that clean and etches the surfaces. This improves solvent cement penetration.

Step 2. The two sections are assembled while the cement is wet, allowing the active agent to penetrate and soften the casing surfaces to be joined. Joint strength develops as the cement dries.

Use of the proper technique for joining casing sections with solvent cement is critical in providing adequate handling strength and maintaining the integrity of the completed well. Structural failure of the casing or joint may result when solvent cement is carelessly applied. For example, weak spots in the casing next to the joint may develop when, prior to installation, a pool of solvent cement collects at the bottom of two pieces of casing that have been joined in a horizontal position. Also, a joint may pull apart if the curing time is not sufficent to develop the proper bonding strength, if the casing ends are dirty, or if the joint fit is not proper. These problems can be alleviated by rigidly adhearing to simple, systematic procedures for joining thermoplastic well casing sections. These procedures have been developed by manufacturers and others' who have worked extensively with plastic water well casing (Section 8B.5.7).

Two types of solvent cement socket joints are currently being used. The are the "belled-end" pipe and the molded coupling.

A "belled-end" plastic casing section has, as its name implies, a socket or bell at one end of each section of casing. The dimensions of the integral socket are designed to provide an interference fit. Special manufacturing control is exercised to make certain that the thickness of the casing walls remains constant throughout the length of the pipe. This helps ensure that the structural integrity of the casing is maintained as the belled socket is formed and that the bell is concentric with the pipe.

The second type of socket joint utilizes a joining collar, or coupling, which is a separate, cylidrical, plastic fitting with tapered sockets at both ends. Each end accommodates the straight end of a section of plastic casing to form a tight interference fit. While most couplings are made to connect sections of casing having the same diameter, some are designed to join casing sections of different diameters. The sections are solvent cemented to the coupling using the techniques described below.

8B.5.7 General Procedures for Making Solvent-Weld Plastic Casing Joints

Materials needed for joining operations include:

1. A fine-toothed saw

2. A mitre box

3. A small knife, file or bevelling tool

4. Fine-grained, abrasive paper

5. Clean dry cloth or paper towel

6. Cleaner and/or primer

7. The proper solvent cement: i.e., a solvent cement is designed to join only with a specific plastic material

8. A natural bristle brush approximately half the diameter of the casing being joined or a specially designed applicator which may be included in the solvent cement container.

The preparation of the surfaces to be bonded is an important consideration in the solvent-cementing process. The following steps describe good joint preparation and solvent-welding procedures.

Step 1. If the casing is to be cut, a fine-toothed saw is used to avoid rough or uneven ends. Use of a mitre box will ensure even cuts.

Step 2. Smooth the cut end and remove all burrs before the sections are solvent cemented. A knife, file or sandpaper can be used to remove the burrs.

Step 3. Wipe the contact surfaces of the pipe end and the socket clean and dry. Moisture and dirt can be removed with a clean, dry, cotton cloth or paper towel. Grease must be removed with a cleaner recommended by the solvent cement manufacturer. Roughening these surfaces with abrasive paper aids in the development of a better bond.

Step 4. Check the interference fit. A good "dry fit" should show the spigot end entering the socket about 1/2 to 2/3 of its depth. Some manufacturers supply casing with marks to designate proper fit. If there is no proper dry fit, a good joint may not result and the incorrectly dimensioned pipe, bell or coupling should not be used.

Step 5. A primer may be used to prepare the inside surfaces of the socket. Apply the primer with a scrubbing motion to ensure good penetration of the primer into the PVC. The primer often requires more time to soften belled-end casing sockets than to prepare sockets of a molded coupling.

Step 6. A primer may also be applied to the outside surface of the casing (spigot) end to prepare it for joining. The entire area of the surface to be cemented should be totally coated with the primer.

Step 7. Apply a uniform coat of solvent cement to the spigot end of the casing taking care not to leave any portion uncoated.

Step 8. Forcefully insert the spigot end of the casing into the entire depth of the socket while both the inside socket surface and the outside surface of the casing are completely coated with wet cement.

Step 9. Hold firmly in place the socket and casing section for approximately 15 to 20 seconds or until initial set takes place.

Step 10. Wipe excess cement from the end of the socket. A properly cemented joint should show a bead of solvent cement around the entire circumference of the casing where it meets the socket.

Step 11. Allow the joint to remain undisturbed until an initial set time is reached (5 minutes). If the bond is broken, it is necessary to remake the joint.

Many contractors report success with shorter set times than normally recommended. Usually two to seven minutes allows the joint to develop sufficient strength to withstand normal handling and installation. However, such set times are based on the contractor's own experience with various products and local conditions. Generally, set times are shorter with belled end joints, smaller diameter casing, and when temperatures are warm and humidity low.

8B.6 CASING SEAL OR GROUTING

Grouting is a process of sealing the space between the casing and the borehole to prevent the entrance of undesirable water into the well which may cause deterioration of the water quality.

Upon completion of this section the manual user will understand how:

1. to grout shallow and deep wells;

2. to prepare a proper cement slurry; and

3. to grout using a tremie pipe inside or outside the casing.

8B.6.1 Mixing Cement and Introducing Grout Seal

Grouting materials may be cement or puddled clay. Cement grout is prepared by mixing Portland cement and water at the ratio of 0.5 to 0.6 liter of water per kilogram of cement. It should be emphasized that a correct water-cement ratio is important for effective bridging of cement particles. Puddled clay may be used as an alternate grouting material, provided it is used at a depth where drying and shrinkage of mud will not occur and where water movement does not wash clay particles away.

The introduction of grouting material is always started at the bottom of the space to be sealed using a grouting or tremie pipe 19 mm or 25 mm (3/4 or 1 inch) in diameter. As the grout rises, the grout pipe is raised proportionately. However, its bottom end should remain submerged in the slurry during the entire time that the grout is being placed. In cases where operations are interrupted for any reason, the pipe should be raised above the grout level and should not be lowered into the slurry to continue grouting until all air and water has been displaced from the pipe. This process of introducing grout from the bottom minimizes dilution and has been proven to be effective in distributing cement grout uniformly around the pipe casing. To avoid cracks in the cement, cement grout should be placed continuously.

8B.6.1.1 Grouting of Shallow Wells

1. Provide the bottom of the annular space to be grouted (usually 6 meters below the ground surface) with a cement basket (Figure 8B-62) which serves as a catch for the grout. The cement basket is installed by bolting it to the pipe casing prior to lowering it into the borehole. The cement basket (see detail in Figure 8B-62) is fabricated by welding a 6 mm thick x 25 mm wide flat bar into a holder forming a well-like structure. To seal the joint between bars and to prevent cement from going further below the basket, a cover made of sack cloth is provided. A rubber packer will also work as a cement packer.

2. Prepare a cement grout slurry.

3. Set up the tremie pipes. The bottom end of the first tremie pipe is usually installed near the cement basket while the bottom of the second pipe is installed 0.5 meter higher than the first.

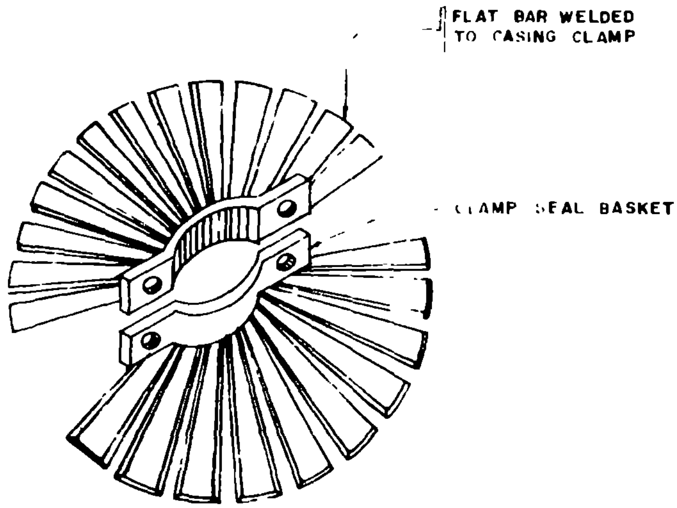
4. Start pumping the grout through the tremie pipe keeping the bottom end of the pipe extended into the grout at all times, but raising it slowly as the grout is emplaced in the well (Figure 8B-63).

8B.6.1.2 Grouting of Deep Wells

1. Grout Pipe Placed Outside the Casing: The principle for grouting a deep well is similar to the principle of grouting a shallow well. The casing is driven solidly into the formation at the bottom of a hole and cement grout is placed directly into the annular space using a group pipe (Figure 8B-64).

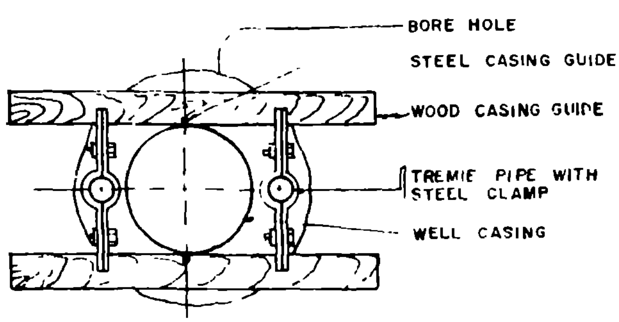
2. Grout Pipe Placed Inside the Casing:

   a. Place the grout or tremie pipe inside the casing with its bottom end terminating in cementing shoe (Figure 8B-65). The cementing shoe (Figure 8B-66) which is fitted tightly at the end of the casing bottom is equipped with a back pressure valve which prevents the backflow of grout material.



DETAIL OF CEMENT GROUT BASKET

Figure 8B-62



DETAIL OF CASING GUIDE

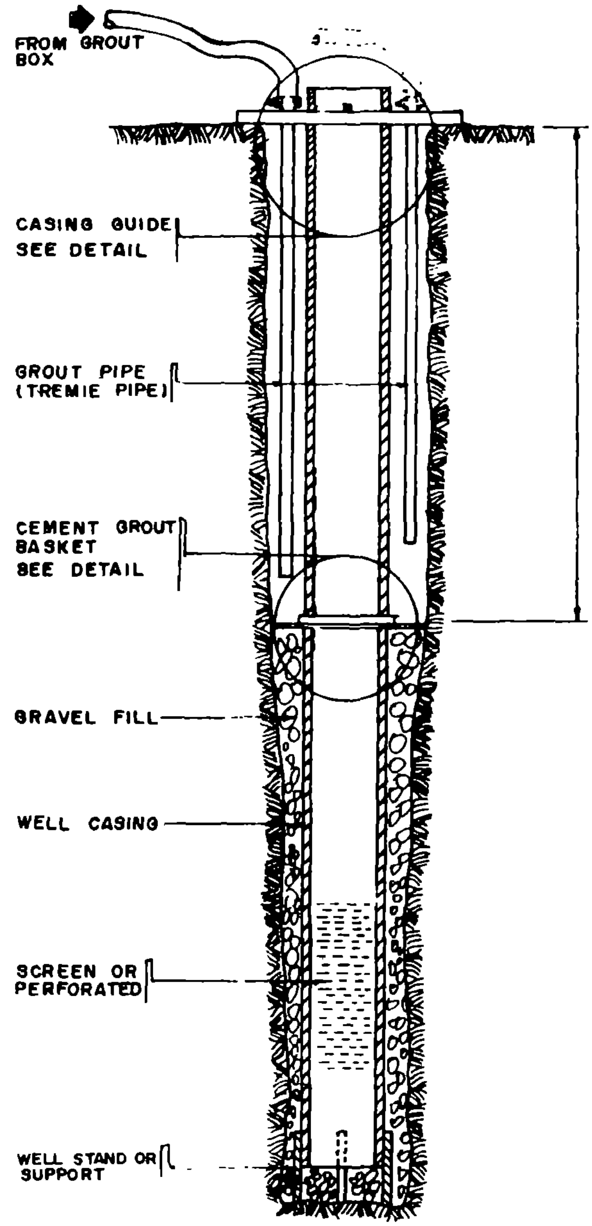


Figure 8B-63 Set up for grouting a shallow well.

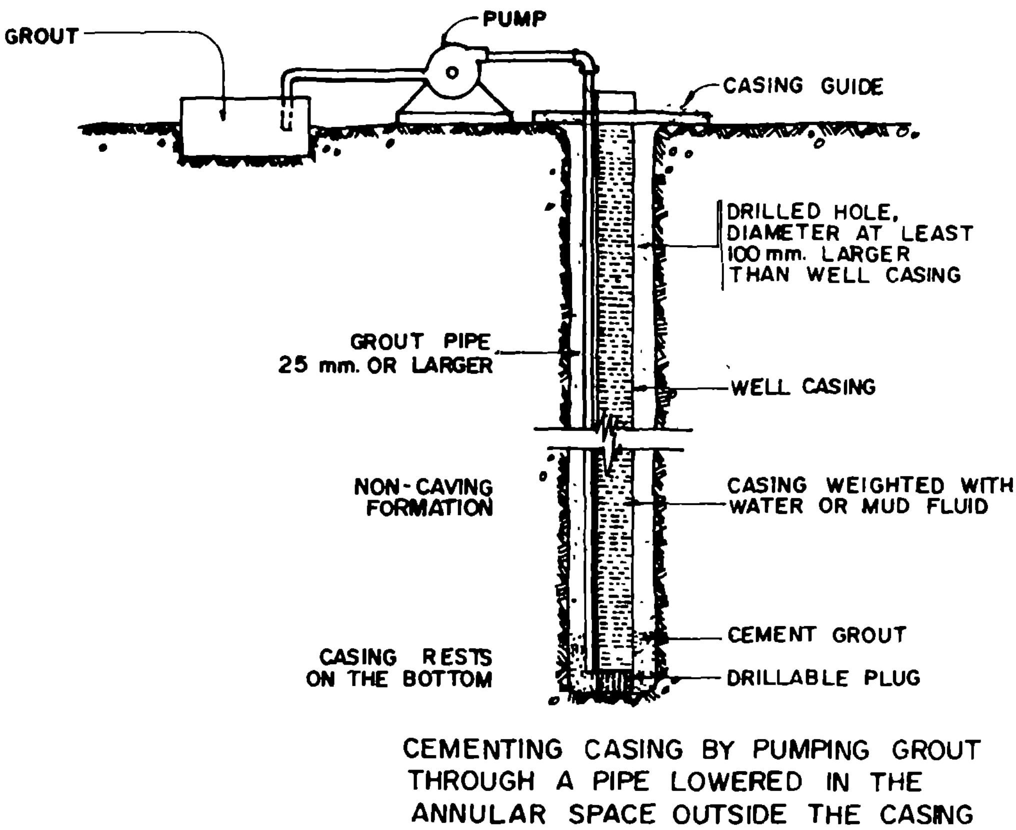


Figure 8B-64 First method of grouting deep wells.

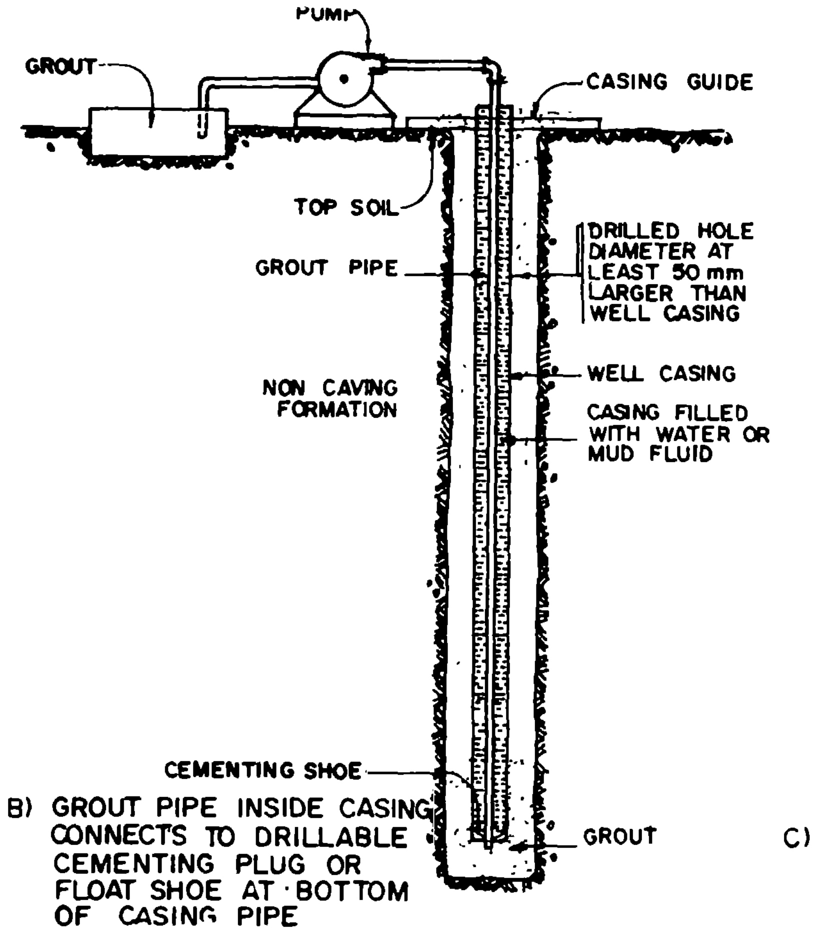


Figure 8B-65 Second method of grouting deep wells.

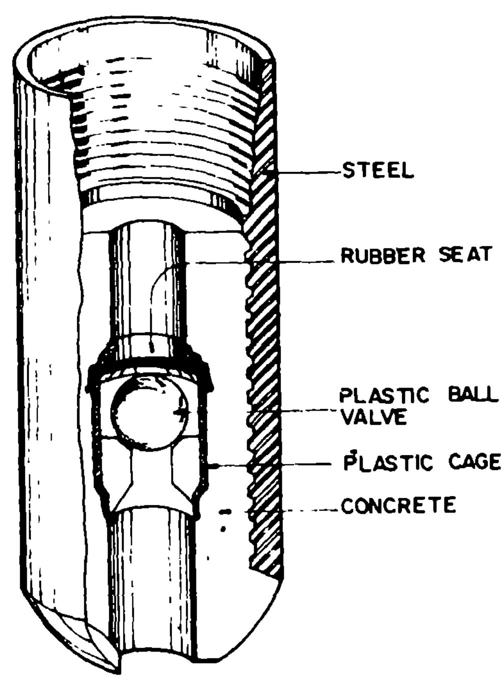


Figure 8B-66 Detail of cementing shoe.

b. Pump the cement grout into the space to be grouted through the grout pipe. When the cement in the annular space rises to the surface, the grout shoe is disconnected and removed.

c. Remove the tremie pipe after the completion of grouting.

Method one is preferred over method two because well drilling can be continued within the casing while the cement is hardening, thereby saving considerable time. Also, the hardening time of cement may be reduced by addition of certain materials, such as calcium chloride, to the cements slurry.

8B.7 WATER WELL DEVELOPMENT

Water must flow through a complex network of pores and fractures as it moves toward a pumping well. As the water moves through the formation toward the well there is a pressure decrease due to the friction between the water molecules and the particles that compose the formation. Therefore, for water to flow into the well the pressure in the well must be lower than in the surrounding formation. (Water flows from areas of high hydraulic pressure to areas of low hydraulic pressure).

The total pressure difference between the aquifer and the water is represented by the amount of drawdown (Figure 8B-67) that occurs in the well in response to the withdrawal of a given amount of water. The water level in the aquifer slopes toward the well from every direction within the area of influence of the pumping well. The water table within this area takes the form of a depression, shaped like an inverted bell, which is called the "cone of depression." At any point within the cone of depression, the distance that the water surface drops below the original static level is the drawdown at that point. This may be determined in an observation well at any desired location, just as the drawndown in the pumping well is measured. Figure 8B-67 illustrates the drawdown at various distances from a pumping well. The shape and extent of the cone of depression vary with the rate of pumping and with the permeability of the aquifer.

For a particular type of well to be constructed, the yield of the well for any given drawdown is directly proportional to the permeability of the formation. This property of permeability of the formation varies through wide ranges. For example, the permeability value of a coarse sand stratum is several hundred times that of a fine sand stratum of the same thickness. Permeability increases with

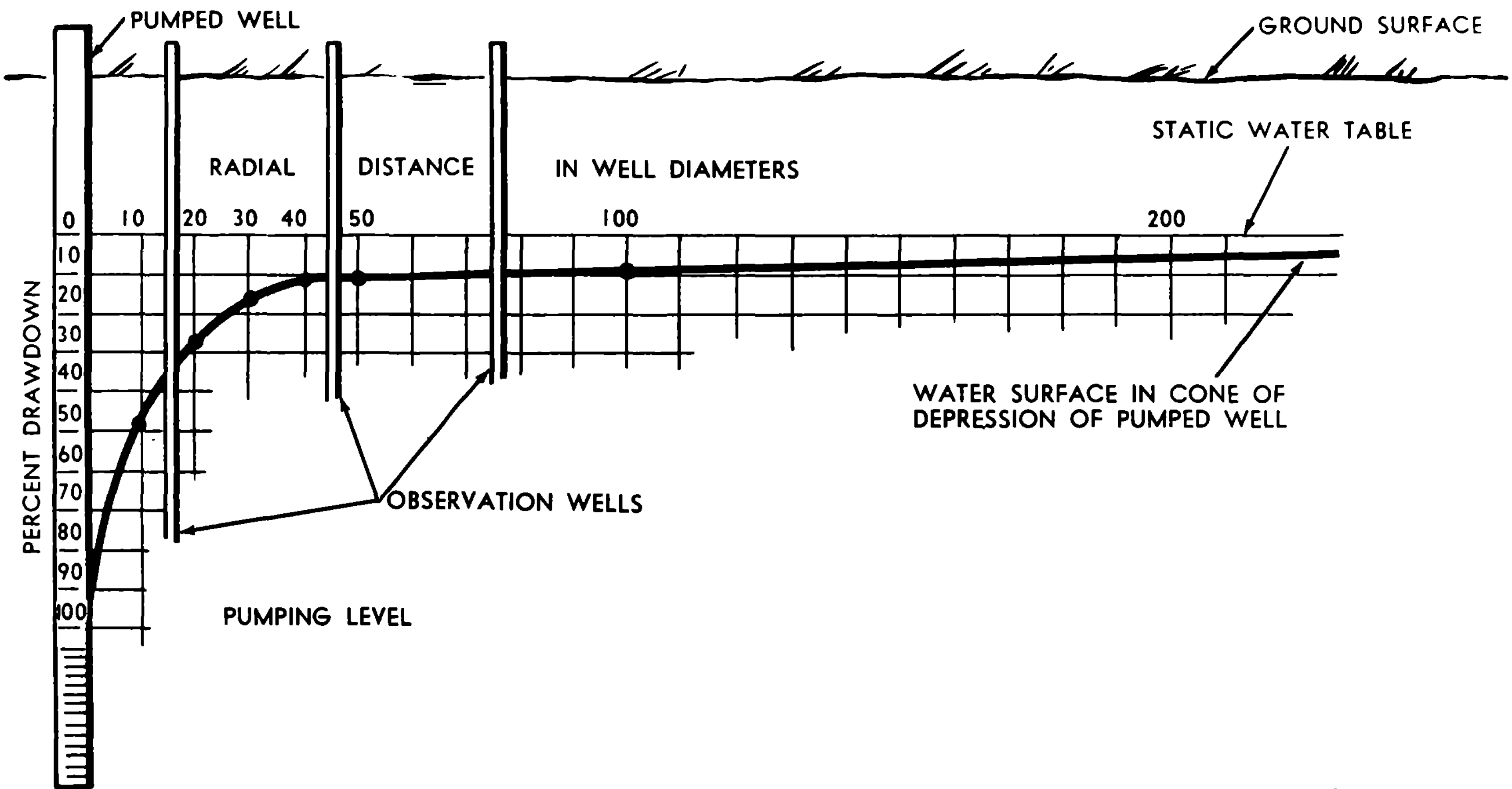


Figure 8B-67 Curve showing drawdown at various distances from a pumped well.

coarseness of the sand and decreases with the compactness of the material. It increases where the sand grains are more nearly uniform in size. It decreases when fine sand and silt fill the voids between larger particles. The permeability of a rock formation, like limestone, varies with the number and size of the fractures, crevices, and solution channel.

Well development is important because it increases the uniformity of grading of the sand and gravel around the intake structure (screen) by removing the finer particles. The type of screen openings, the spacing between openings, and the size of the openings all affect the degree to which proper development can occur. The size of the screen openings should be large enough so that the desired proportion of the finer material in the aquifer will pass through the screen into the well. When these finer materials are brought into the well, the coarser particles are held out by the screen. The result is called "natural gravel packing" since the coarser and more permeable material left around the well screen is actually a part of the natural formation (Figure 8B-68). The natural gravel pack is coarsest next to the screen where all the fine particles have been pulled through the screen openings. A little farther out some of the medium-sized grains remain mixed with the largest grains. Still farther outside this zone, more medium-sized sand and some fine sand remain. From this it is seen that the whole envelope of material left around the screen grades gradually from the coarsest particles next to the screen to the unchanged natural formation at some distance outside the screen that is beyond the affective reach of the method of development employed.

The methods of development and something about their relative effectiveness are discussed in the next few sections. The fundamental purpose in each development operation is to induce alternate reversals of flow through the screen openings that will rearrange the formation particles, thus breaking down bridging of groups of particles. Figure 8B-69 shows how small particles bridge between large particles and across screen openings when the flow of water through the sand is in one direction only. During development, the direction of flow is alternately reversed by surging the well. The outflow portion of the surge cycle breaks down bridging, and the inflow portion them moves the fine material toward the screen and into the well.

Well development also removes fine materials and drilling mud that may have penetrated into pores or fractures in a formation during the well construction process. It should be mentioned that development of a rock well (open borehole) is as important as development of a well with a screened intake structure.

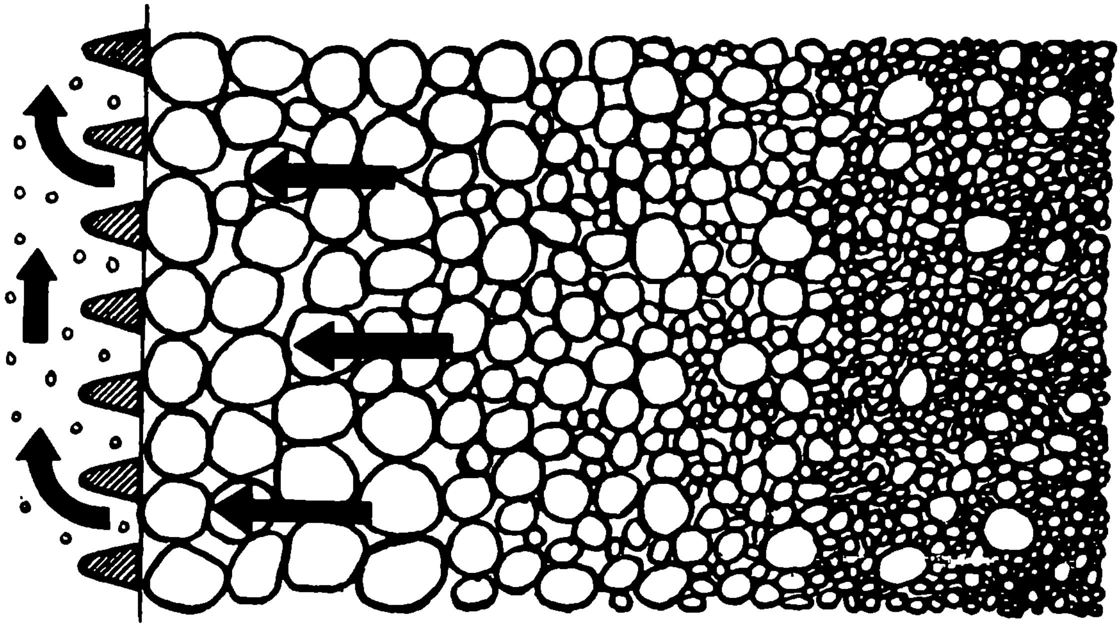


Figure 8B-68 A natural gravel pack. Fine materials closest to the well are pumped into the well leaving only coarse material adjacent to the screen.

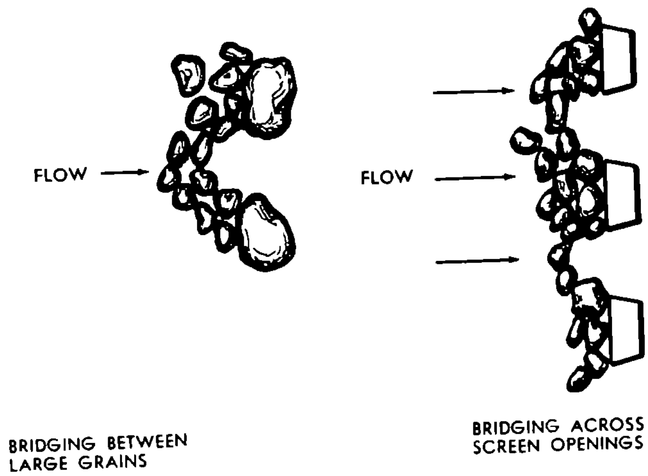


Figure 8B-69 Bridging of sand grains

Upon completion of section 8B.7, the manual user will be able:

1. to understand the importance of well development;

2. to select an appropriate method of well development based on the well design, aquifer characteristics, and the advantages and disadvantages of different types of well development techniques; and

3. to supervise or actually perform the well development.

8B.7.1 Methods of Well Development

There are several methods of developing wells, some of which are specially suited for specific situations. These include: surging, either with a surge plunger or with compressed air; backwashing by jetting, by starting and stopping a pump; and the mechanical removal of fine materials using devices such as wall scratchers.

8B.7.1.1 Surge Plunger

Surging is one of the most effective means of well and aquifer development. This method is accomplished by operating a plunger up and down in the casing like a piston in a pump cylinder. While there are other methods of surging, which have special advantages under certain conditions, most drillers prefer to use a surge plunger or surge block. Surge blocks can be classified into two general types; a solid plunger or swab, and a plugner equipped with a valved opening (Figure 8B-70). The valve type plunger gives a lighter surging action than the solid type plunger. This is an advantage in developing tight formations since it is always best to start surging slowly and increase the force of the operation as the development proceeds. Plugging the valve of the plunger converts it to a solid type plunger which can be used when greater surging force is necessary.

Enough weight must be attached to the surge plunger to make it fall on the downstroke at about the same speed that the drilling machine lifts it on the upstroke. A common mistake in using a surge plunger is not having it weighted enough. The drill stem provides the weight required for the surge blocks.

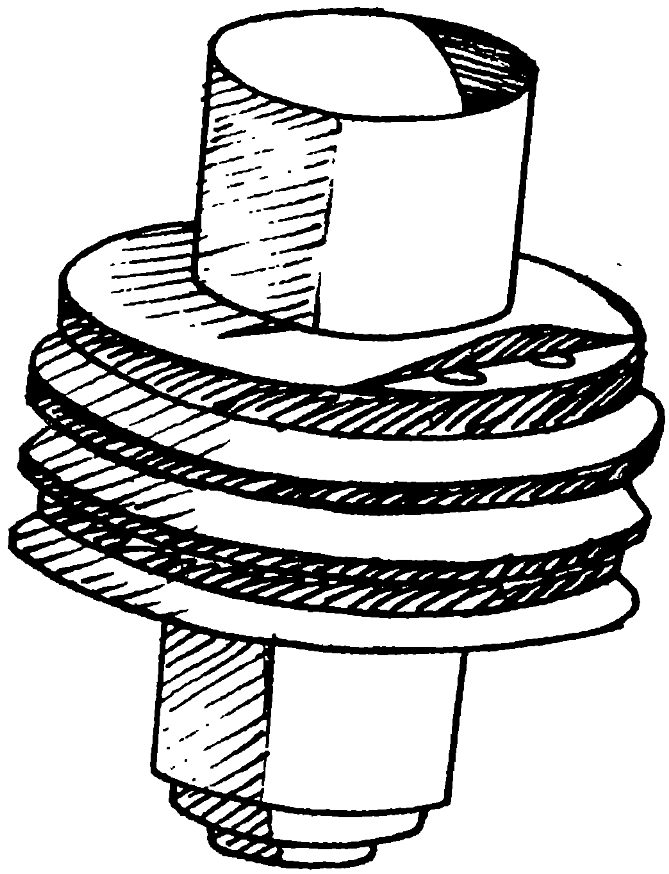


Figure 8B-70 Typical valve-type surge plunger

The operation of the surge plunger for well development is as follows:

(1) Lower the surge plunger in the well until it is in the water, but above the top of the screen; keep the plunger a few feet above the screen so that it will not strike the lead-packer (if there is one) while surging.

(2) Start surging slowly, gradually increasing the speed until the surge plunger rises and falls without letting the cable slacken. Work the plunger on a relatively long stroke. If a cable tool rig is being used, set the spudding motion on long stroke. If a rotary rig is being used, lift the plunger 1 meter (3 or 4 feet) before dropping it. Control the movement by using the hoist brake and clutch if the sand line is being used, or by manipulating a line around the cathead.

(3) Continue surging for several minutes, then pull the plunger out of the well and lower the bailer or sand pump into the screen. When the bailer rests on the sand that has been pulled into the screen, check the depth of the sand in meters (or feet) by measuring on the sandline. Bail all the sand out of the screen.

(4) Repeat the surging operation and compare the quantity of sand with that brought in the first time. Bail out the sand, and repeat surging and bailing until little or no sand can be pulled into the well.

(5) Lengthen the period of surging as the quantity of sand removed decreases. The total time for development may range from about 2 hours on small wells to 2 to 3 days on large wells with long screens.

8B.7.1.2 Air-Surging

Another method of surging can be accomplished with compressed air. The system for air-surging is constructed by placing two pipes into the well, each capable of being lifted and dropped independently. The larger pipe is called the drop pipe or eductor pipe and is about 2 to 3 cm. smaller than the well casing. Inside the drop pipe is the smaller air pipe, usually about 1.5 to 2 cm., depending on the drop pipe inside diameter.

(1) For successful development by this method it is necessary to have a ratio of submergence of at least 60 percent. Submergence means the extent to which the air pipe is submerged in the water as compared to that part of the pipe between water level and ground level. The efficiency of the work drops off rapidly as the submergence becomes less than 60 percent. In deep wells with considerable head of water above the bottom, even though the submergence is low, some effective work can be done by "shooting heads," as is described later. If both the head and submergence are low, this method of development is of little value.

(2) Figure 8B-71 shows the proper method of placing the drop pipe and air line in the well. The drop pipe may be conveniently handled with the hoist line. The air pipe should be suspended on the sandline. A tee at the top of the drop pipe is fitted with a short discharge pipe at the side outlet. A sack is wrapped around the air line where it enters the drop pipe to prevent the water from spraying about the top of the well. The discharge from the compressed air tank to the well should be the full size of the air line in the well or the next larger size. A quick-opening valve must be connected in the line near the tank. A piece of pressure hose at least 5 meters (15 feet) long is required to allow for moving the drop pipe to and air line up and down.

(3) At the start of development lower the drop pipe to within 1 meter (3 feet) of the bottom of the screen. Place the air line inside the drop pipe with its lower end 0.3 meter (1 foot) or more above the bottom of the drop pipe. Permit air to enter into the air line and pump the well in the manner of a regular air lift until the water appears to be free from sand. Close the valve between the tank and the air line, allowing the tank to be pumped full of air up to a pressure of from 7 to 10.5 kg/sq. cm. (100 to 150 pounds per square inch). In the meantime, lower the air line until it is 0.5 meter (1.5 foot) or so below the drop pipe. Throw open the quick-opening valve to permit the air in the tank to rush with great force into the well. A brief but forceful head of water will emerge or shoot from the casing and from the drop pipe. Pull the air line back into the drop pipe as soon as the first heavy load of air has been shot into the well. This will cause a strong reversal of flow in the drop pipe that will effectively agitate the water-bearing formation.

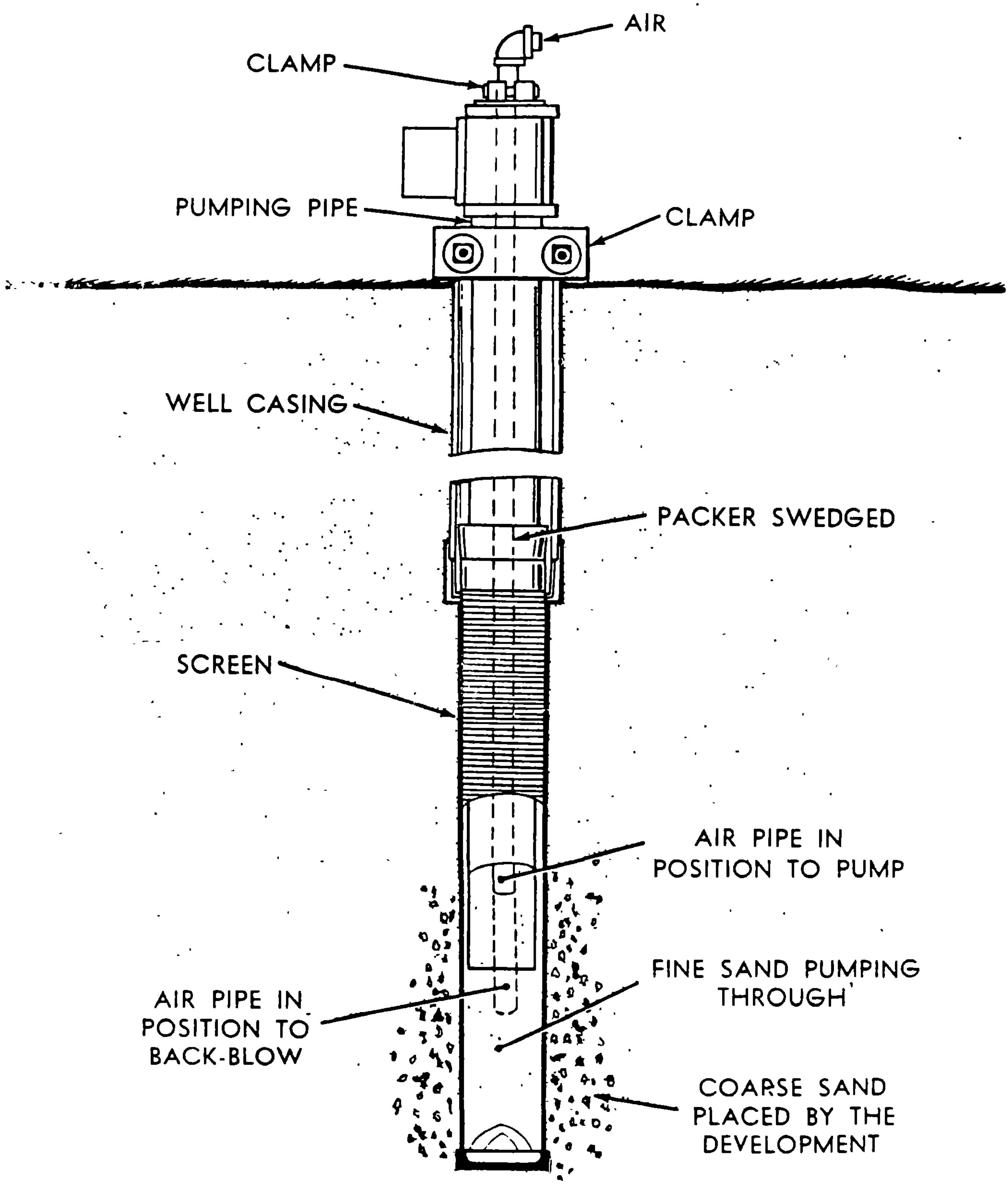


Figure 8B-71 Hookup for developing well with compressed air by open-well surging methods.

(4) Allow the well to pump as an air lift for a short time, and then shoot another head. Repeat this procedures until the absence of further sand shows that the development is complete at this point.

(5) Lift the drop pipe to a position one meter (3 feet) higher in the screen and follow the same procedure. In this way the entire length of the screen is developed a few feet at a time. To complete the development and thoroughly clean out any loose sand, pull the air line up into the drop pipe and use it as an air lift to pump the well.

8B.7.1.3 Development by Backwashing

The surging effect, or reversal of flow required to develop the formation can be obtained by three or four backwashing methods. One of these methods consists of alternately lifting water to the surface by pumping and letting the water run back into the well through the pump-column pipe. About the only type of pump besides the airlift that can be used practically for this purpose is a deep well turbine pump without a foot valve. The pump is started, but as soon as water is lifted to the ground surface the pump is shut off. The water then falls back into the well through the column pipe. The pump is started and stopped as rapidly as the power unit and starting equipment will permit. the effect is to intermittently lower and raise the water level in the well which produces the inflow and outflow, respectively, through the screen openings. During the procedure, the well may be pumped to waste from time to time to remove the sand that has been brought in by the surging. After completing the surging, the pump must be removed and any material remaining in the screen must be bailed out.

Another method is to backwash by pouring clean, disinfected water into the well as rapidly as possible, thus producing outflow through the screen openings. Inflow through the screen is then produced by bailing water out of the well as rapidly as possible. As can be seen, this is not a very rapid means of surging as the time required for a complete cycle will be several minutes under best conditions. If the static water level is high enough to permit pumping by suction lift, a small centrifugal pump can be used instead of the bailer and this will speed up the work. If there is room in the well casing, the discharge side of the pump can be connected to a string of small diameter pipe that is let down in the well, so that the water added is pumped down inside the screen. The turbulence thus created inside the screen will assist in development of formation.

The third method which can be used if a rotary or a jetting-type rig is available is to improvise a little jetting tool that can be operated inside the screen. To do this, screw a coupling to a 2.5 to 5 cm. (1- to 2-inch) pipe and weld a plate over the open end of the coupling. Drill two or three 0.6 cm. (1/4-inch) holes, located so they will pass through both the wall of the coupling and the pipe (Figure 8B-72). Commercial jetting tools are also available. Lower this tool into the screen on a string of pipe. Connect the upper end of the pipe to the kelly or to the discharge side of the mud pump. Pump water into the screen and rotate the jetting tool very slowly so that the horizontal jets of water will wash out through the screen openings. Raise the string of pipe little by little and continue rotating to backwash the entire inner surface of the screen. A pump pressure of 7 kg/sq. cm. (100 pounds per square inch) should be used if possible. This method of backwashing is particularly effective in removing the cake of drilling mud that has been plastered on the walls of holes drilled by the rotary or jetting method. Its disadvantage is that considerable supply of potable water is required.

8B.7.1.4 The Hole-Wall Scratcher (adapted from a description by J. Cooper)

Many wells drilled into consolidated rock have several meters of surface casing but the intake structure of the well is simply open borehole. During the well construction operation drilling fluid, crushed rock, or natural muds may clog the fractures and pore spaces which transmit water into the well.

The petroleum industry has used borehole scratchers for well development for many years, but only recently have they been applied to water well development.

A borehole scratcher can be produced from locally available materials. The procedures is as follows:

(1) Use a drill-rod adapter, with double female ends, one to two meters (three to six feet) in length.

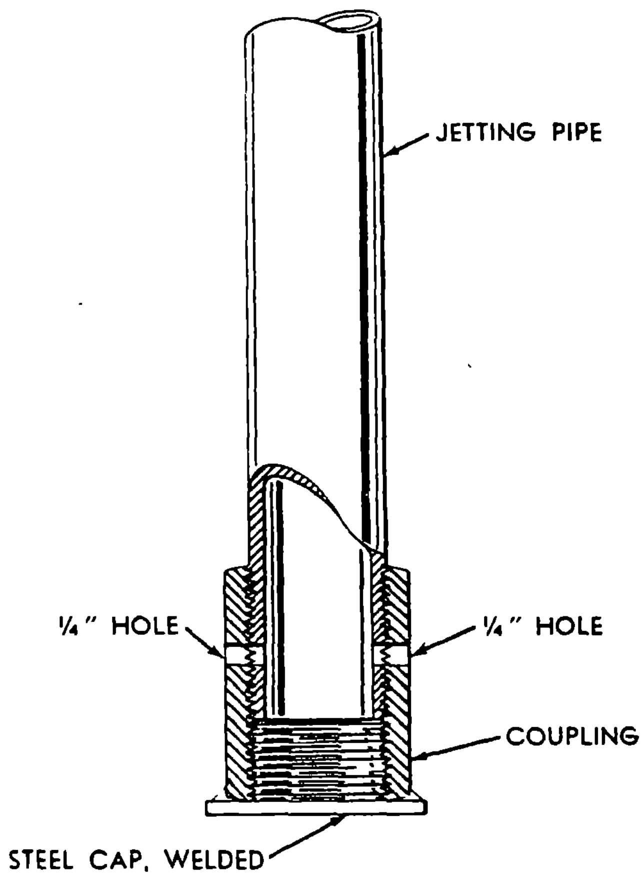


Figure 8B-72 Improvised jetting tool.

(2) Cut the required number of lengths (L_2) of 15 mm (1/2 inch) wire rope:

$$L_1 = \frac{H_D - P_D}{2}$$

L_1 = length of rope from rod to hole-wall
H_D = diameter of drill hole
P_D = outside diameter of drill rod

L_2 = L_1 + 1 inch (to allow for seating in hole drilled in drill rod and for the flexing of wire-rope ends during operation in hole).

(3) With brass welding rod, braze one end of each length of wire rope, to prevent separation of individual wires after fraying for "scrubbing" of hole wall.

(4) Drill 15 mm (5/8-inch) holes in drill rod, 50-75 mm (two or three inch) centers, on a spiral center line (Figure 8B-73); each spiral line is equidistant around the drill rod 50-75 mm (2-3 inches) apart; drill holes are staggered on each spiral line for maximum separation of wire-rope lengths.

(5) Finish brazed end of rope segments with file, and insert brazed end into the drilled hole.

(6) With a brass welding rod, make a circular weld around the brazed end of wire rope to affix securely into and on the drilled drill-rod.

The following steps describe how the scratcher is used:

Step 1. Attach the "scratcher" to the bottom of the drill string and run it to the bottom of the hole accompanied with continued circulation of clear water and slow rotation of the drill string.

Step 2. Position it at the hole bottom, stop rotation and circulate water at maximum rate until the discharge at the well head runs relatively clear.

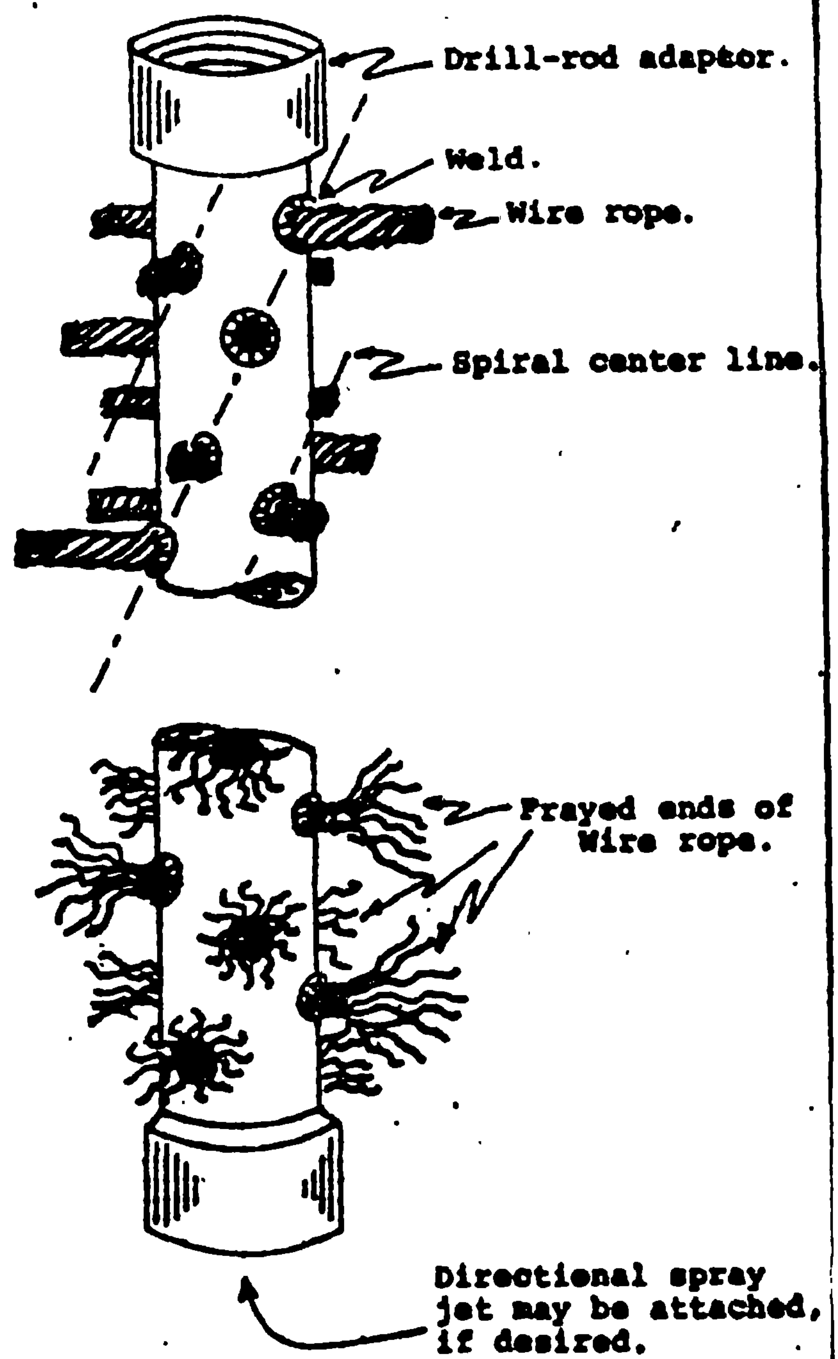


Figure 8B-73 Hole-wall scratcher

Step 3. Continue water circulation at less than maximum rate and commence rotation at a moderate rate, without raising and lowering of the drill string.

Discharge at well head should run slightly heavy and muddy, carrying considerable mud and/or cuttings which have been trapped in the drill mud matrix during the drilling operations. It should run relatively clear again when the mud/cuttings materials have been removed from the hole wall in the area being scratched.

Step 4. Continue circulation and raise the drill string up the hole a distance slightly less than the length of the "scratcher." Discharge at the well head should appear the same as described in Step 3. When it runs relatively clear, then go to the next step.

Step 5. Raise the drill string another interval (slightly less than the length of the "scratcher") and repeat the procedure, as described in Steps 3 and 4 above.

Step 6. Repeat the scratching procedures, in intervals, until the section of the hole, desired to be cleaned out has been processed.

Step 7. Repeat the entire procedure a second time, beginning at the bottom of the hole, simultaneously raising and lowering the drill string at least the length of one drill rod.

After finishing the second processing, run the drill string to the bottom of the hole and flush the hole thoroughly.

Step 8. Remove drill string and "scratcher"; install the test pump; and allow the static water level to recover to original depth, or nearly so.

Step 9. Conduct a pumping test in accordance with Section 8B.8; compare test results with previous test data. If a satisfactory improvement in productivity of the well has been obtained, the operation is complete; however, if no significant improvement has been accomplished, the operational procedures with the "scratcher should be repeated a second time. If no significant improvement is indicated run through the procedures a third time. Failure to improve well performance on the third operation indicates that the operations should be discontinued unless a larger-diameter "scratcher" is available for the fourth attempt.

It should be noted that for soft or medium-hard, fine grained, and relatively impermeable formations, the rotary "srubbing" is sufficiently effective; whereas, in hard-rock formations, strong vertical "scrubbing', accompanied by a slower rotary action is most effective. Clean-out of fractures and fissures is enhanced by the addition of a jet-spray below the "scratcher". The jet action, directed against the hole wall, enters the fractures and washes out the materials more effectively than the use of only the "scratcher" and circulation of water.

8B.7.1.5 Overpumping

Overpumping consists of of pumping a well at a discharge rate considerably higher (125 to 150%) than the design capacity. This method is of questionable value except in thin, relatively uniformly grained, permeable aquifers.

The pump used for development is set above the top of the screen, therefore development is primarily concentrated in the upper one-quarter to one-half the screen length. With the water moving in one direction only, stable bridging of sand grains occurs as long as pumping continues. When pumping is stopped, the water in the drop pipe flows back into the well causing a reverse flow which destroys the bridging. When the well is again pumped, sand will enter the well until stable bridging is re-established.

A well developed by this method may pump sand for several minutes each time the pump is started. This may continue for months.

8B.8 WELL TESTING

Following the construction of a water well it is desirable to test the well to determine the amount, and from what pumping level the water will be produced. One would quickly recognize that the selection of the most efficient pump for the well must be based upon known pumping rates and depths.

But it is also for other reasons that wells are tested. The geologist and hydrogeologist are interested in the behavior of the aquifer from which the water is drawn. Engineers and water agencies are interested in the safe yield of the aquifer, how the well will be affected by other wells in the area, the water quality, and the efficiency of the new well.

Upon completion of this section the manual user will be able:

1. to understand the terminology associated with testing a well's performance;

2. to select and use the appropriate equipment for the well test;

3. to measure depth to water and well discharge; and

4. to perform and evaluate a well test.

8B.8.1 Definition of Terms

In order to understand the procedures for testing a well it is necessary to define the following terms:

1. Static Water Level. This is the level at which water stands in a well that is not being pumped. It is generally expressed as the distance from the ground surface (or from a measuring point near the ground surface such as the top of the well casing) to the water level in the well. A flowing well, where the static water level is above the ground surface, is measured by valving off or shutting off the flow of the well and measuring the head in meters (feet). This is sometimes referred to as the shut-in head.

   When we say the static level in a well is 80 meters, it means that the water stands 80 meters below the measuring point in the well when there is no pumping. When we say that a well has shut-in head of 10 meters we mean that the water would rise 10 meters above the measuring point in a pipe extended above that point. Static water levels should always be measured before pumping a well.

2. Pumping Level. This is the level to which the water is lowered during pumping. It is generally expressed as the distance from the measuring point at the ground surface to the water level in the well.

3. Drawdown. Drawdown in a well refers to extent of lowering of the water level during pumping operations. It is simply the difference between static level and pumping level in the well. We should understand that the drawdown represents the head in meters (feet) of water, that causes water to flow through the aquifer material toward a well at the rate that water is being taken from the aquifer. A highly permeable sand and gravel formation would require less head or "drawdown" to produce a given quantity of water than a less permeable sand which contains streaks of clay--both formations being of the same thickness.

4. Residual Drawdown. After pumping is stopped, water levels rise and approach the static water level observed before pumping started. During such a recovery period, the distance that the water level is found to be below the initial static water level is called residual drawdown.

5. Well Yield. Well yield is the volume of water per unit of time discharged from a well, either by pumping or by free flow. It is measured commonly as the pumping rate in gallons per minute (gpm). Other units employed are liters per second. The well yield is sometimes referred to as the pumping rate.

6. Specific Capacity. The specific capacity of a well is its yield per unit of drawdown. It is commonly expressed as the "gallons per minute per foot of drawdown." For example: If a well was producing 200 gallons per minute and had a drawdown of 10 feet after a period of pumping, the specific capacity would be 200 divided by 10, or 20 gallons per minute per foot of drawdown.

Normally, wells will continue to drawdown with time. It is best to determine the specific capacity from measurements taken after a given period of time. A commonly used period of time is 24 hours. However, it is probably only necessary to test a level I well for four to six hours.

8B.8.2 Instruments Used

Time, water levels and capacity flow rates are three measurements to make during a puming test. Making accurate measurements, together with the planned program of testing procedures, will not only allow the contractor to properly select the pump best suited for the well, but also provide valuable information about the aquifer. To measure these values the following instruments can be used:

1. Time. In the measurement of time, the common watch is all that is required for successful well testing. It is important to record time during a well test since pumping levels change as a function of time.

2. Water Levels. To make reading to any water level, the simplest and also the crudest way is to use a heavy weight or float on the end of a steel tape or chalk line. Readings taken in this manner often vary from 5 to 15 cm. (2 to 6 inches) from true readings depending on the kind of line and whether or not the weighted end will float. The most satisfactory methods is to use either an air line or an electric circuit. Measurements to the static or pumping level are always important and the use of an air line (or some other means more accurate than a weighted tape) are generally required.

Measurements to the pumping level are particularly important because they not only furnish the basis for estimating pumping levels for various capacities, but they also determine the power costs and the proper setting of the pump bowls if they are of the deep well turbine type.

Figure 8B-74 shows a well in which an air line is installed to determine accurately the static level, pumping level and drawdown. This apparatus is inexpensive, easy to install and remove, and is generally accepted for all but the most accurate tests. It consists essentially of enough small diameter pipe or tubing which extends from the top of the well to a point below the static or pumping level depending on which is being measured.

On top of the tubing or pipe is an ordinary altitude or pressure gauge which is attached to a tire pump or pressurized air tank when it is available. Any small diameter 3.0 mm to 60 mm (1/8 to 1/4 inch) of iron, brass or cooper tube may be used.

If the air line is to be left in the well for permanent use, it should be of some non-corrosive metal; if jointed and coupled, the joints must be absolutely air tight. Plastic tubing is now commonly used for air lines.

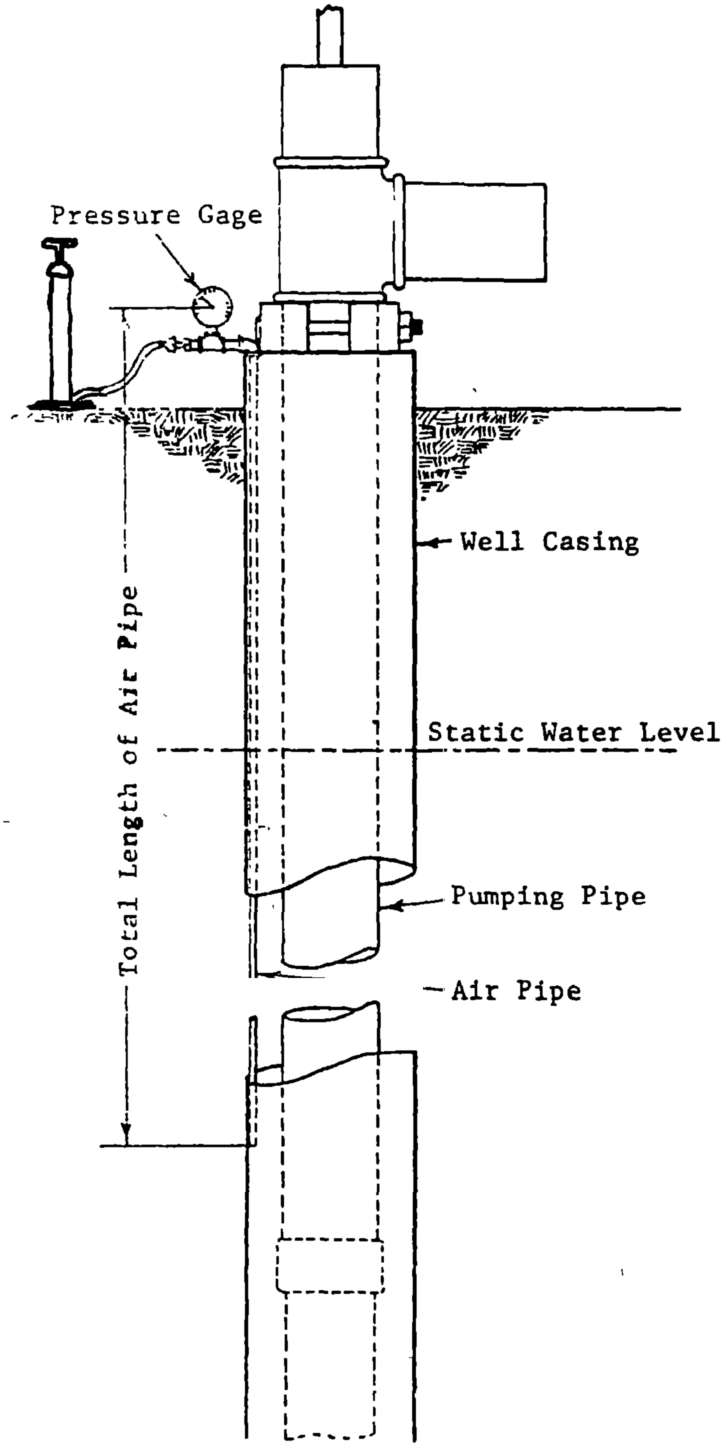


Figure 8B-74 Well with air line installed to accurately determine the static level, pumping level, and drawdown.

Two things are necessary to make accurate readings with this device. First, the exact vertical distance between the center of the pressure or altitude gauge and the open end of the air line as it is installed in the well must be determined. This measurement is obtained by carefully measuring the air line as it is placed in the well. With pipe this can be done accurately; with tubing it sometimes becomes a problem since the tubing has a tendency to curl. For this reason it is necessary to take special pains with tubing to get the vertical distance accurately.

Second, the air line must be air tight from one end to the other, including the connections at the guage and air pump.

8B.8.3 Using an Air Line to Test Wells

Be sure all joints and connections are air tight, then pump air into the line until the maxium possible pressure is reached. Air forced into the line creates pressure which forces the water out the lower end, leaving the line full of air. Readings should not be taken, of course, while air is being pumped in. The head of water above the end of the line maintains the pressure and the gauge registers the actual pressure or head above the end of the line. A gauge graduated in meters (feet) shows directly the amount of submergence of the end of the line.

Subtract this figure from the length of the line and you have the water level. Just as drawdown is measured, so is recovery measured after pumping has stopped. In fact, recovery can be observed directly from the action of the needle as it moves to the right due to the column of water in the well rising to the static level when pumping is stopped. For active wells in good, open aquifers this rise is very rapid, occurring in a few minutes. In poorer formations the recovery of the static level may be a matter of hours. In any case, no well ever recovers the last few inches until a period of 24 to 72 hours has elasped.

For a practical example, let us say that the gauge is an altitude gauge reading in feet and it takes 46 feet of head or pressure equivalent to this amount of head to force all of the water out of the air line. We have created a condition whereby the air pressure inside the air line is just sufficient to balance the pressure of the water on the outside of the line. In this case it is 46 feet by direct reading on the altitude gauge.

If the distance from the center of the gauge to the open end of the air line is 95 feet, then the distance from the gauge to the static level is the difference between 95 feet and 46 feet, or 49 feet. If the gauge is above or below the ground surface, this must be considered if measurements are being referred to the surface.

Suppose now we start our test pump. It will be noticed that the pressure on the gauge drops as the water is lowered in the well. This is as it should be, since the water in the well is being lowered and there is not as much pressure above the open end of the air pipe as there was before pumping started. In most gauges the needle actually moves to the left, or counter clockwise, to indicate a drop in pressure.

Most altitude gauges have two needles, one red and the other black. It is customary to set one needle, usually the red one, at the first reading -- the reading taken before starting to pump the well. Read the moveable, or black needle. The difference between the two needles can be read directly and the drawdown determined instantly.

Let us say our movable needle reads 22 feet after pumping has started. The difference between 46, our first reading, and 22 is 24 feet, that is the drawdown for the quantity of water that is being pumped. A few trials will be sufficient for anyone to become familiar with the use of an altitude gauge and air line.

If a pressure gauge is used, it operates exactly the same way except that the readings are in pounds per square inch and must be converted into feet of head for practical use. To do this, multiply the readings in pounds by 2.31 to obtain feet in head. For example, if the gauge reads 40 psi, then the head in feet would be 40 x 2.31 or 92.4 feet.

8B.8.4 Electric Sounder for Depth Measurements

A popular device for measuring water levels is the electrical depth gauge or electric sounder (Figure 8B-75). This tools is available from several manufacturers. A shielded electrode is suspended by a pair of insulated wires and a volt meter indicates a flow of current when the electrode touches the water surface. Flashlight batteries supply the current.

To get accurate readings, the electrode and cable should be left hanging in the well between readings. This eliminates any

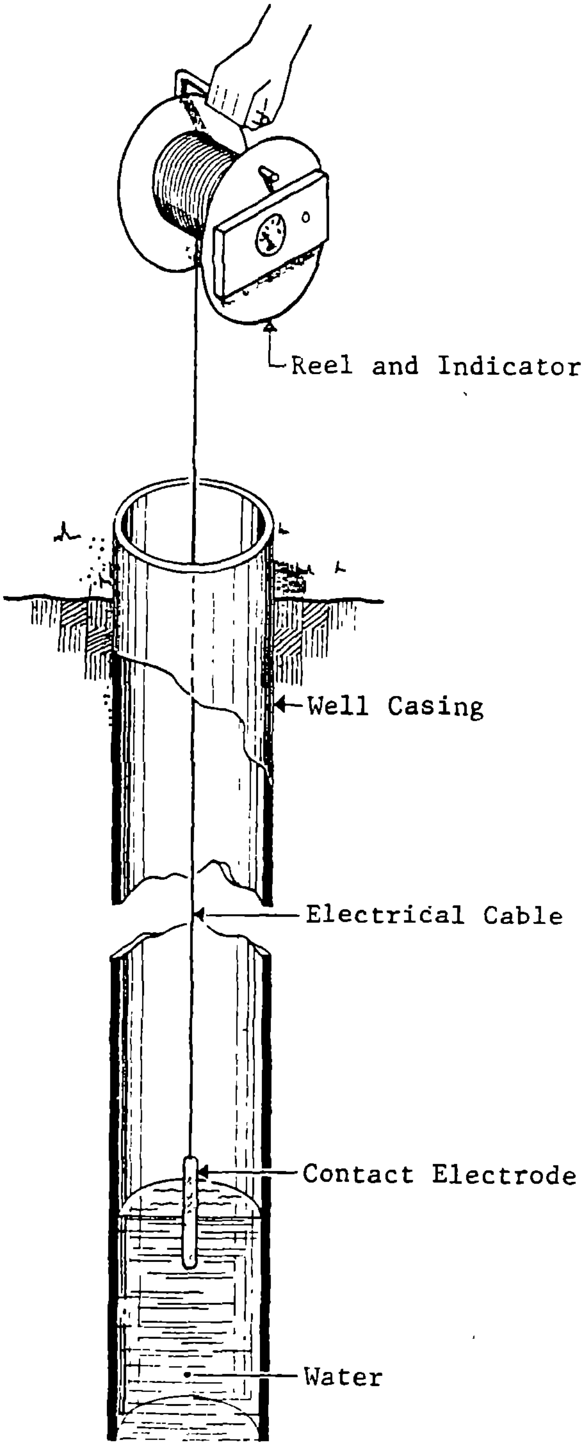


Figure 8B-75 Electric sounder to measure water level any errors from kinks or bends in the wires which may change the length slightly when the device is pulled up and let down.

For greater accuracy, the change in water level should be measured along the cable with a steel tape rather than using the metal marker which are usually attached to the cable by the manufacturer. One fixed mark may be used to indicate the static level and to serve as a base mark for subsequent measurements with the tape.

8B.8.5 Wetted Tape Method

The wetted tape method is an accurate way of measuring depth to water and can be readily used for depths up to 27-30 m (80 or 90 feet). First, a lead weight is attached to a steel measuring tape. The lower two or three feet of the tape is wiped dry and coated with carpenter's chalk or keel before taking a reading. The top is let down in the well until a part of the chalked section is below water, with one of the foot marks held exactly at the top of the casing or other measuring point. The tape is then pulled up. The wetted line on the tape can be read to a fraction of an inch and this reading is subtracted from the foot mark held at the measuring point to get the actual depth to the water level. A disadvantage of this method is that the approximate depth to water must be know so that a portion of the chalked section is submerged each time to produce a "wetting line."

8B.8.6 Measuring Flow Rates

While the vertical measurements to water levels are being made, the measurements of quantity being pumped at those levels is also being made. The most accurate and fundamental method of measuring the rate of flow of a steady continuous stream of water is by collecting it in a container of known size and measuring the time required to collect it. Since this method is inconvenient and impractical for the average well job other methods are employed. These involve the use of Venturi meters, pitot tubes, current meters, orifices, flow gauges, weirs and similar devices. A description of the use of all these instruments is beyond the scope of this section. Three of the most commonly used methods are as follows:

8B.8.6.1 Filled Bucket Method.

Perhaps the simpliest method of determining flow rate for level I wells is to allow the discharge to flow into a 5 gallon or 20 liter can, and time how long it takes to fill up the can. If it takes 2 minutes to fill the can the flow rate is either 2.5 gallons per minute or .17 liters per second.

$$\frac{5 \text{ gallons}}{2 \text{ minutes}} = 2.5 \text{ gpm}$$

$$\frac{20 \text{ liters}}{2 \text{ mins.}} = \frac{10 \text{ liters}}{\text{minute}} \text{ or } \frac{10 \text{ liters}}{60 \text{ seconds}} = .17 \text{ liters per sec.}$$

8B.8.6.2 Orifice Bucket

The orifice bucket is a device that was developed for readily measuring modest (less than 50 gpm) flow rates. It consists of a small cylindrical tank or container with one or more inch holes accurately bored through the bottom. The water to be measured flows into the tank and discharges through the one-inch orifices. The container fills with water to a level where the pressure head causes the discharge through the orifice to just equal the inflow.

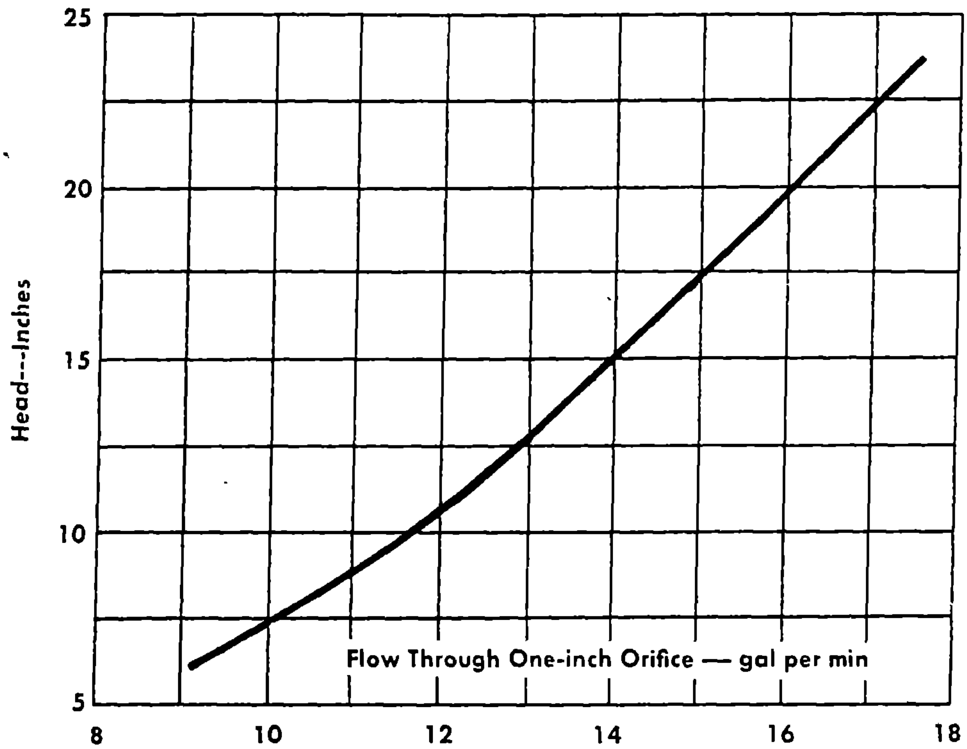
A gauge glass or a simple piezometer tube is connected into the wall of the continer near the bottom. A suitable vertical scale is fastened to the outside so that the piezometric level and be read accurately. A calibration curve shows the rate of discharge through a single one-inch orifice for various values of the pressure head.

The flow rate taken from this curve multiplied by the number of orifices used gives the total rate of discharge through the device.

Figure 8B-76 shows the rating curve for a one-inch orifice as determined in laboratory. It shows, for example, that when the water is 16 inches deep in the container, the flow through one hole is 14.4 gpm. If the bucket used is made with five holes, the total rate of flow with 16 inches of pressure head would be 72 gpm. One of the practical uses of the orifice bucket is for measuring the discharge from the plunger pump or rig-operated pump where the flow is not constant.

Figure 8B-76

Rating curve for one-inch-diameter orifice in orifice bucket. Multiply values from this curve by number of orifices to get total rate of flow.



8B.8.6.3 Circular Orifice Weir

The circular orifice weir consists of a steel plate centered over the end of a discharge pipe in which there is a perfectly circular hole with clean edges, smaller in diameter than the discharge pipe. Back two feet from this plate is a small pipe tapped smoothly, at right angles into the discharge pipe at the horizontal center line. The discharge pipe should be at least 2 meters long overall. A clear plastic tube is installed over the small (3 mm pipe nipple) pipe and is held vertically during the testing (Figure 8B-77)

The pressure caused by the restriction of the water passing through the orifice plate causes water to rise in the tubing. The water level in this piezometer tube is measured from the center of the discharge pipe to the top of the water column. The amount of water being pumped is a fraction of this height and is determined from Table 8B-2. The accuracy of this method is dependent upon how carefully the well tester observes and understands certain limitations of the instrument. First, the pipe on which the orifice is used must be horizontal and the discharge must be allowed to fall freely.

Second, the edges of the orifice opening must be sharp and clean, perferably chamfered to 45° with the sharp edge upstream.

Third, combinations of pipe and orifice diameters, must be such that the head build up will be at least three times the diameter of the orifice.

Fourth, the orifice must be vertical and centered in the discharge pipe.

The apparatus and setup are show in Figure 8B-76 for all oridinary tests.

8B.8.7 Procedures for Conducting a Well Test

We have examined the terms used and the instruments employed by the water well industry in conducting well tests. The practical application of these tools comes from experience and a fundamental understanding of the behavior of ground-water flow. It should be kept in mind that a pump test is a test of the finished well as a structure, and not necessarily a test of the water yielding ability of the formation in which the well is constructed.

Table 8B-2 **Table of Flow Rates Through Circular Orifice Weirs**

Head of Water in Tube Above Center of Orifice	4-inch Pipe 2½-inch Opening	4-inch Pipe 3-inch Opening	6-inch Pipe 3-inch Opening	6-inch Pipe 4-inch Opening	8-inch Pipe 4-inch Opening	8-inch Pipe 5-inch Opening	8-inch Pipe 6-inch Opening	10-inch Pipe 6-inch Opening	10-inch Pipe 7-inch Opening	10-inch Pipe 8-inch Opening
5 inches	55 gpm	89 gpm	. . . .	. .	. . .	. . .		.	. . . . .	. . . .
6 "	60 "	97 "	82 gpm	158 gpm	144 gpm	240 gpm	390 gpm	. . . .	. . .	.
7 "	65 "	105 "	88 "	171 "	156 "	260 "	420 "	370 gpm	540 gpm	830 gpm
8 "	69 "	112 "	94 "	182 "	166 "	275 "	450 "	395 "	580 "	880 "
9 "	73 "	119 "	100 "	193 "	176 "	295 "	475 "	420 "	610 "	940 "
10 "	77 "	126 "	106 "	204 "	186 "	310 "	500 "	440 "	640 "	990 "
12 "	85 "	138 "	115 "	223 "	205 "	340 "	550 "	480 "	700 "	1080 "
14 "	92 "	149 "	125 "	241 "	220 "	365 "	595 "	520 "	760 "	1170 "
16 "	98 "	159 "	132 "	258 "	235 "	390 "	635 "	555 "	810 "	1250 "
18 "	104 "	168 "	140 "	273 "	250 "	415 "	675 "	590 "	860 "	1330 "
20 "	110 "	178 "	150 "	288 "	265 "	440 "	710 "	620 "	910 "	1400 "
22 "	115 "	186 "	158 "	302 "	275 "	460 "	745 "	650 "	950 "	1470 "
25 "	122 "	198 "	168 "	322 "	295 "	490 "	795 "	690 "	1020 "	1560 "
30 "	134 "	217 "	182 "	353 "	325 "	540 "	870 "	760 "	1120 "	1710 "
35 "	145 "	235 "	198 "	380 "	355 "	580 "	940 "	820 "	1210 "	1850 "
40 "	155 "	251 "	210 "	405 "	370 "	620 "	1000 "	880 "	1290 "	1980 "
45 "	164 "	267 "	223 "	430 "	395 "	660 "	1060 "	930 "	1370 "	. .
50 "	173 "	280 "	235 "	455 "	415 "	690 "	1120 "	980 "	1440 "	.
60 "	190 "	310 "	260 "	500 "	455 "	760 "	1230 "	1080 "	1580 "	.

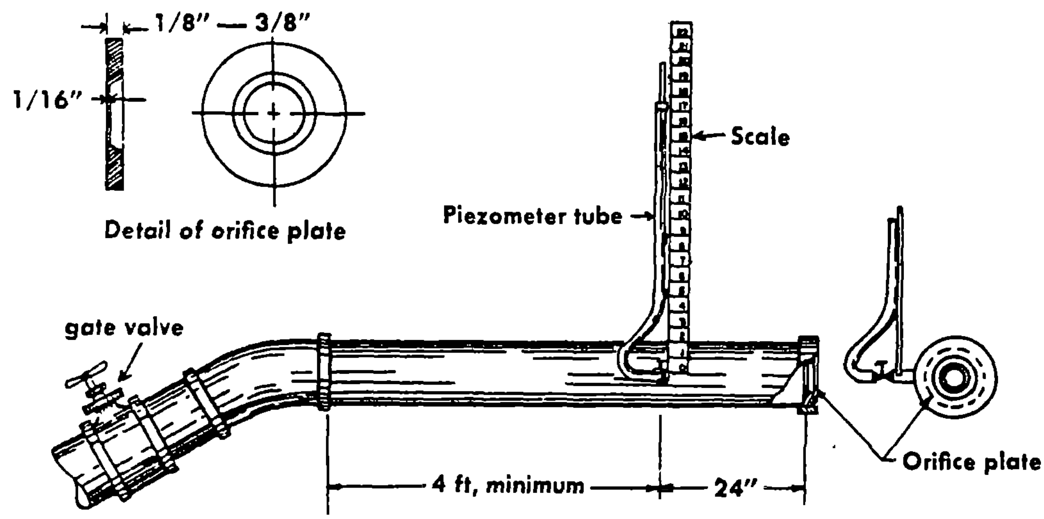


Figure 8B-77 Essential details of the circular orifice weir commonly used for measuring pumping rates when pumping by means of a turbine pump. Discharge pipe must be level.

Various contractors, engineers, geologist, etc., have certain procedure for testing wells which are based upon their specific needs in evaluating the well. The contractor may desire to know at what pumping level a given quantity of water is obtained after a specified number of hours of pumping. In this case, the measurement of capacity and pumping level should be made after the passage of time.

An excellent procedure for anyone to follow in well testing which will answer both the contractor's needs and provide some geological data is as follows:

1. during preliminary well pumping, establish the maximum rate that can be pumped from the well with the equipment employed. For example, assume a well can be pumped at 20 gallons per minute for several hours without breaking suction with the test pump or dewatering the aquifer below the top of the screen.

2. by use of a discharge valve (such as a gate valve) throttle the pump to about 80 percent of the maximum capacity.

3. stop the pump and allow the well to recover to its static level. Normally this requires an overnight shutdown.

4. measure (prior to testing) the static level of the well.

5. noting the time, commence pumping at the established flow rate.

6. measure the drawdown every minute for the first ten minutes, hence every five minutes for the first two hours of pumping, being careful to maintain exactly the same pumping rate by adjusting the gate valve. Measurements of pumping levels after the initial two hours can then be spaced every thirty minutes as the test continues. What will be observed is that the water level will fall rapidly during the early period of pumping (thus the reason for frequent measurements) then less rapidly as the test continues.

7. calculate the specific capacity of the well based upon the measured or calculated pumping level at 4 hours.

8. The desired pumping level for other flow rates lower than the tested capacity may be safely calculated from the specific capacity obtained.

8B.9 WELL MAINTENANCE AND REHABILITATION

Every well, regardless of design or environment will, sooner or later require maintenance. We often overlook this fact because if properly designed, constructed, and developed most wells provide relatively care-free operation. However, a well is simply a machine, a mechanism by which water is extracted from ground. A well, like a machine, must be kept in good working order through a program of maintenance if we are to avoid well damage.

Upon completion of this section the manual user will be able:

1. to understand the causes of well yield deterioration and well failure;

2. to evaluate the physical condition of a well;

3. to select an appropriate method of well rehabilitation based on evaluation of the physical condition of the well, and water quality characteristics;

4. to carry-out several types of well maintenance or rehabilitation without the assistance of a water well contractor.

8B.9.1 Water Quality and Its Effect on Well Performance

Water, as it exists in nature, has two possible effects on a well. Some water will cause metals used in well construction to corrode. Other types of water will cause the build up of scale (incrustation) on the well intake (screen) or in the surrounding formation. Under some conditions corrosion and incrustation can occur simultaneously.

The chemical characteristics of water that will typically cause corrosion of most metals are:

(1) pH (measure acidity) that is less than 7;

(2) Concentration of dissolved oxygen greater than 2 parts per million (ppm);

(3) the perceptable presence of hydrogen sulfide (smell of rotten eggs);

(4) total dissolved solids (TDS) concentration in excess of 1,000 ppm;

(5) carbon dioxide concentration is excess of 50 ppm;

(6) chloride concentration in excess of 300 ppm; and

(7) appreciable quantities of organic acids that may be present in peat or coal formations, or refuse dumps.

For each one of the above characteristics found in water there will be an increase in the likelihood that corrosion will occur.

Water that will cause incrustation has the following chemical characteristics:

(1) total carbonate hardness is in excess of 300 ppm;

(2) iron concentration is in excess of 2 ppm;

(3) manganese concentrations greater than 1 ppm;

(4) pH greater than 8 (alkaline conditions);

If more than one of the above characteristics are present in the water the potential for incrustation is increased.

8B.9.2 Evaluation of the Physical Condition of a Well

Because periodic well evaluations are the exception rather than the rule, most well owners do not become aware of well deterioration until very obvious symptoms develop. For level 1 wells, evidence of problems with the well may take the form of:

(1) an obvious reduction in well yield;

(2) difficulty in pumping the well;

(3) discoloration of the water;

(4) the presence of an unusual taste or odor;

(5) the presence of particles of sand, or silt; and

(6) the appearance of particles of rust.

Corrosion will usually cause introduction of sand or silt into a well that previously had no problem because casing perforations, or screen openings have enlarged to permit the entrance of formation materials into the well. Particles of rust, or a change in water color from clear to orange or reddish-orange may be an indication of casing deterioration. The decrease in depth of the well may also indicate the entrance of formation materials or even complete rupture of the casing or screen.

Incrustation is the clogging of the well screen or water bearing formation resulting from chemical precipitation, mechanical blockage, or the growth of bacteria. The most obvious symptom of incrustation, therefore, is reduction of well yield due to the inability of water to flow freely into the well.

If a pump and a drop pipe are pulled from the well and are coated with a red, brown or even black colored slime, then there is a strong likelihood that bacteriological incrustation is taking place. The slime may be a combination of the bacteria and the by-products of their growth. If its present on the pump parts, it probably present on the well screen and in the surrounding formation.

White, tan, or brown chalk like material on the pump parts may be an indication of chemical incrustation.

It is very important to realize that the reduction of well yield may be a result of factors unrelated to the condition of the well. It can be a function of pump wear, a regional lowering of the water level due to drought or aquifer depletion, or interference due to the pumping of near by wells.

8B.9.3 Well Maintenance Methodologies

"An ounce of prevention is worth a pound of cure" is perhaps the best way to begin our discussion of the methods of perfomring well maintenance and rehabilitation. Proper well design and the selection of appropriate well construction materials will go a long way in reducing the potential for corrosion, or the frequency and degree to which incrustation will occur. Early recognition of problems with a well is far better than waiting until the problem develops to such a point that it becomes extremely obvious. This means that when the waterworks technician is inspecting the pump he should also make a visual examination of the water, check for any tale-tell signs on the pump that a related problem is developing, check the static level and run a pump test to determine if there have been any changes in the specific capacity of the well (Section 8B.8). Early maintenance is far easy to perform then prolonged and difficult well rehabilitation that is needed when a problem goes undetected too long.

8B.9.3.1 Dealing with Well Corrosion

For level I wells, the best method of treating corrosion is good well design and the proper selection of well materials. If the water has corrosive characteristics then the well should be constructed of corrosion resistant alloys or non-metallic materials.

If corrosion takes place in an existing well, short of abandoning the well, it may be possible to install a smaller diameter plastic well casing and screen through the existing well. Then backfill with coarse sand between the old well screen and the plastic screen to a level at least 3 meters above the top of the new screen (Figure 8B-78). The rest of the annular space between the old casing and new casing should be grouted with cement up to the surface. This procedure can only be successful if the original casing diameter is large enough to permit the installation of a smaller diameter casing and screen, and still leave enough annular space to permit the installation of a gravel pack and grout.

8B.9.3.2 Treatment of Incrustation Problems

The methods of well rehabilitation for problems of incrustation all have one thing in common, they involve redevelopment of the well by surging or agitation.

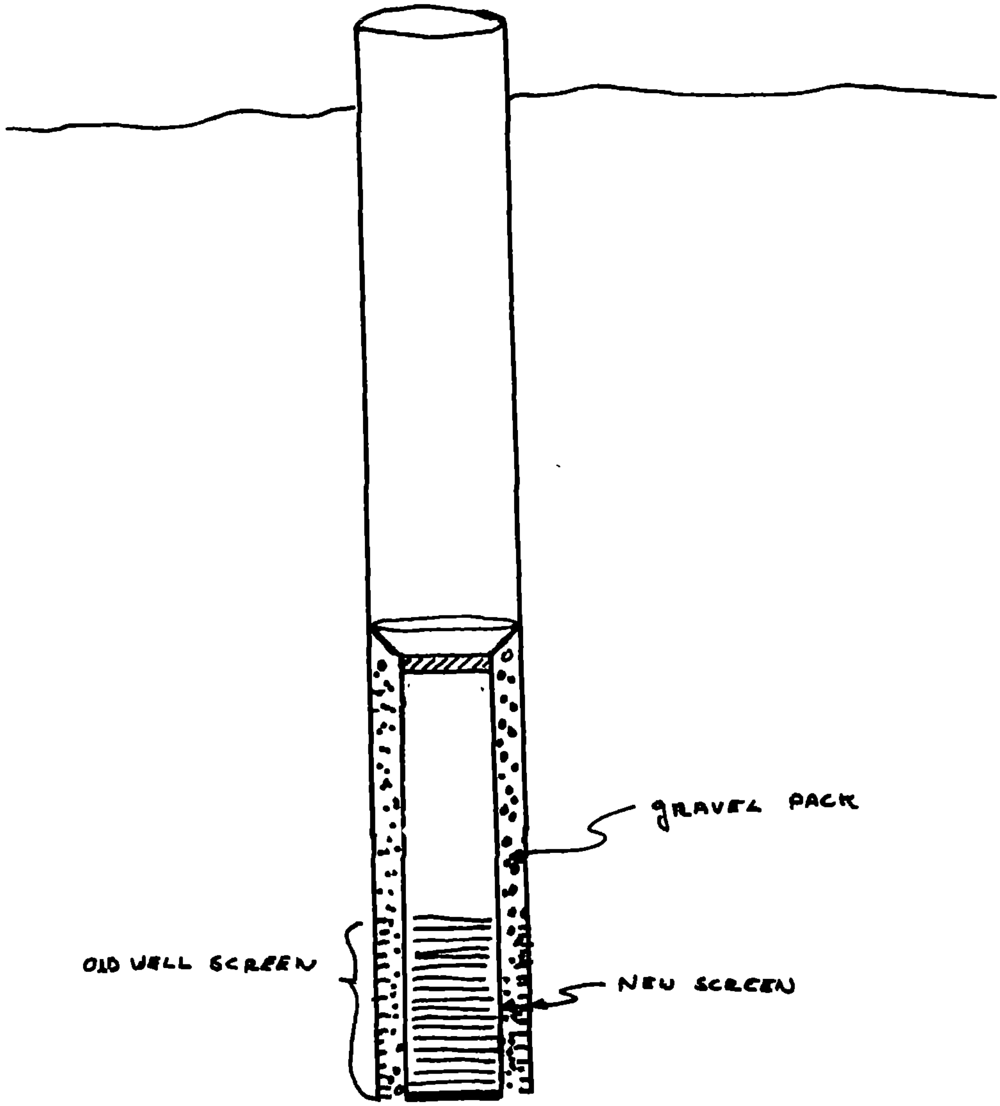


Figure 8B-78 Screen replacement.

The selection of chemicals to be used in conjunction with redevelopment will depend on whether the incrustation has been caused by chemical precipitation, biological infestation, or mechanical blockage.

8B.9.3.2.1 Chemical Incrustation Treatment

Acidization is the most common method of dealing with problems of chemical incrustation. Three types of acids are typically available: Hydrochloric acid for severe incrustation; sulfamic acid for moderate incrustation; and hydroxyacetic acid for mild incrustation and problems with rust.

Hydrochloric acid is a clear yellow solution typically available in 28 percent concentrations for well maintenance. The procedure involves removal of the pump, and installation of a plastic pipe with a diameter of 2.5 to 5 cm (1 1/2 to 2 inches) down to within 1.7 meters (5 feet) of the bottom of the screen (Figure 8B-79). A volume of hydrochloric acid, twice the volume of the 1.7 meter (five feet) screen section, is poured down the plastic pipe. If the well screen is longer than 1.7 meters (five feet), then it is lifted in 1.7 meter (five feet) increments and another two volumes of acid is poured into the next section of the screen. The reason the acid is poured into the well this way is to prevent diffusion and weakening before getting to the area in the well where the treatment is desired.

Once the acid is emplaced in the well, it must be forced through the well screen and into the surrounding aquifer. This is done by surging or jetting (Section 8B.7). Agitation should last for an hour. The well should then be allowed to sit idle for an hour, and then it should agitated again for an hour. When this done, all of the spent acid and debris is removed from the well by bailing or with the use of an old pump that is specifically used for well maintenance operations.

The procedure may have to be repeated a few times until desired results are obtained. After each treatment the well's specific capacity should be tested as a means of keeping track of the effectiveness of the treatment.

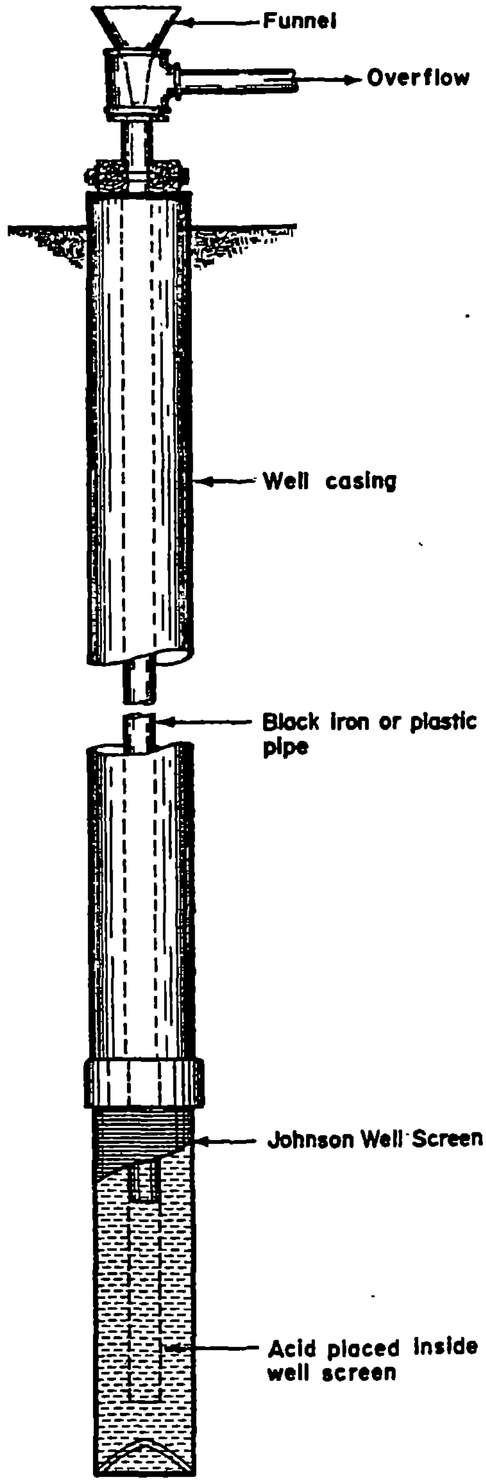


Figure 8B-79. Typical arrangement for introducing acid inside well screen to avoid dilution of the chemical by water standing in the well.

A few points of warning are necessary when using hydrochloric acid:

(1) it is very corrosive to most metals, so it should only be used when the screen is made of stainless steel, silicon-manganese-bronze, silicon red brass, or a non-metallic material.

(2) it can cause severe skin burns so protective clothing, including rubber golves and safety goggles should be worn when handling the acid.

(3) finally, it may give off toxic fumes so it should only be used in a well ventilated area and a protective breathing device should be worn.

Sulfamic acid can be purchased as a white granular material. To use sulfamic acid the following steps are followed:

(1) mix 8 kilograms (20 pounds) of granular sulfamic acid with 38 liters (10 gallons) of water. Dissolve thoroughly;

(2) emplace the liquid into the well in the identical manner in which hydrochloric acid was emplaced into the well;

(3) agitate for 1 hour and displace the acid through the screen. Allow the acid to remain in the well overnight. Because it is not as strong as hydrochloric acid, sulfamic requires a longer contact time to dissolve mineral incrustation;

(4) pump the spent acid and debris out of the well;

(5) repeat the procedure until desired results are achieved;

Sulfamic acid is less likely to cause corrosion of metals or irritate the skin. However, it is still a good idea to wear protective clothing and safety glasses when handling any acid.

Hydroxyacetic acid is a liquid organic acid available in 70 percent concentrations. It dissolves mild mineral scale and also kills bacteria. Four liters (1 gallon) of 70 percent concentration of hydroxyacetic acid is used for every 20 liters (5 gallons) of water standing in the well screen. The acid is emplaced and agitated in the same manner as used for hydrochloric acid. Hydroxyacetic acid should be allowed to stand in the well for at least 24 hours before pumping it to waste.

8B.9.3.2.2 Biological Incrustation Treatment

Chlorination is the treatment most frequently used to destroy bacteria and remove the incrustation resulting from its growth. A chlorine solution with a concentration of 300 ppm must be prepared at the surface. The volume of chlorine solution used should be twice the volume of water standing in the intake portion of the well. The solution is then poured into the well in the same manner that hydrochloric acid would be poured into a well. Next the solution is forced into the aquifer by agitation or by flushing the solution through the screen by adding clean, chlorinated water into the well (the volume of water added should be equal to 50 times the volume of water standing in the well). After 12 to 24 hours the well is pumped until a chlorine odor is no longer detectable. The well is then tested. If desired results are not achieved the procedure may have to be repeated.

The determination of the amount of chlorine solution to prepare for well disinfection is described in Section 8C.7. Table 8C-2 shows the amount of various chlorine compounds to add to water to produce a 30 ppm concentration. Multiply the quantity of the compound by 10 to produce a 300 ppm solution.

8B.9.3.2.3 Mechanical Incrustation Treatment

Dispersing agents are used to remove clay and silt that cause mechanical blockage of the screen or surrounding formation. Chemicals belonging to the sodium phosphate family (sodium hexametaphosphate and sodium tripolyphospate) are the most typical dispersing agents used. These chemicals are commercially available as powders or crystals and must be mixed with water before being placed in the well, Mix 13.5 kilograms (30 pounds) of the sodium phosphate chemical in a tank of water for every 400 liters (100 gallons) of water standing in the well. The liquid mix at the surface can then be jetted into the well, or placed in the well through a plastic drop pipe.

Vigorous agitation is needed to help break up the clay and silt clogging the well. The dispersing agents simply help keep the particles in suspension so they will not settle to the bottom of the well and cause it to clog again. The agitation must therefore mechanically dislodge and break-up the incrustating material. Agitation should last 2 to 4 hours, then the solution should be left in the well for 16 to 24 hours. Before pumping the well to remove the chemicals and debris it is useful to agitate the well again for an addditional hour.

Phosphate materials are nutrients for bacteria, therefore they promote bacteriological growth. To avoid bacteriological contamination about 0.5 kg (1 pound) of calcium hypochlorite should be added to the phosphate solution for every 40 liters (100 gallons) of water in the well.

Wetting agents are an additional chemical that can be added to other chemical solutions to help break down the surface tension of water. The wetting agent permits the chemical solution to flow more rapidly into cracks and pores in the formation, thus increasing the effectiveness of the treatment. A common wetting agent is Pluronic F-89. A 1/2 kg. (1 pound) of wetting agent should be added for every 400 liters (100 gallons) of water standing in the well. Whatever wetting agent is selected it must have low sudsing properties. Some wetting agents produce soap-like suds that may damage the well and surrounding formation.

8B.9.3.3 Special Well Maintenance Considerations

Sudden vigorous agitation can damage a well or cause the well to collapse. Whether surging, jetting, air lifting, etc. the agitation should begin slowly and gently. When the operator "feels" the incrustation break up and as flow into the well improves, agitation intensity can be gradually increased.

Another problem associated with well maintenance relates to the disposal of chemicals pumped from the well. These chemicals may be harmful to humans, causing skin irritation or illness. The chemicals may also destroy vegetation. When such chemicals are pumped from a well, take precaution to direct the discharge away from people, animals and vegetation. It is also very helpful to thoroughly wash down the area where the chemicals were disposed with several hundred liters of water to further dilute the chemical mixture.

8B.9.3.4 Well Maintenance and Rehabilitation Checklist

1. Obtain and examine existing well records to ascertain the depth and the length of intake structure.
2. Pump test the well to determine the present specific capacity.
3. Remove existing pump
4. Evaluate the possible causes of well deterioration.
5. Select an appropriate method(s) of well treatment.
6. Gather all necessary tools and materials at the well site.
7. Calculate the volumes of chemicals to be used.
8. Select a site to discharge spent chemicals from the well.
9. Add the chemicals to the well in an appropriate manner.
10. Agitate.
11. Let the well sit idle.
12. Agitate.
13. Pump spent chemicals and debris to waste.
14. Pump test the well.
15. Repeat procedure if necessary.

8B.10 WELL ABANDONMENT

Unsealed abandoned wells constitute a hazard to public health, safety and welfare, and to the preservation of the ground water resource. The sealing of such wells presents a number of problems which are functions of the design of the well, the geologic formations encountered, and the hydrologic conditions. To seal and abandoned a water well properly, several things must be accomplished: (1) elimination of a physical hazard; (2) prevention of ground water contamination; (3) conservation of yield and maintenance of hydrostatic head of artesian aquifers; and (4) prevention of the mixing of potable with non-potable waters.

Upon completion of this section on well abandonment the manual user will be able:

1. to understand the need for proper well abandoment;

2. to properly prepare an unused well for abandoment; and

3. to seal both artesian wells and water table aquifer wells.

8B.10.1 Factors to Consider in Well Abandoment

The basic concept governing the proper sealing of abandoned wells is the restoration, as far as feasible, of the hydrogeologic conditions that existed before the well was drilled and constructed. An improperly abandoned well might serve as an uncontrolled invasion point for contaminated water. Any well that is to be permanently abandoned should be completely filled in such an manner that vertical movement of water within the well bore, including vertical movement within the annular space surrounding the well casing, is effectively and permanently prevented, and the water is permanently confined to the specific zone in which it is originally encountered.

To seal an abandoned well properly the character of the ground water must also be considered. If the ground water occurs under unconfined or water table conditions, the chief problem is that of sealing the well with impermeable material so as to prevent the percolation of the surface water through the original well opening, or along the outside of the casing, to the water table. If the ground water occurs under confined or artesian conditions, the sealing operation must confine the water to the aquifer in which it occurs. This prevents the loss of artesian pressure by circulation of water to the surface, to a formation containing no water, or to one containing water under a lower head than that in the aquifer which is to be sealed.

8B.10.2 Perparation for Abandonment

Efforts should be made to remove all materials from a well which may hinder its proper abandonment. This is especially important where specific zones must be sealed.

If a screen has been installed in a well by telescoping, its recovery is usually possible by installing a string of fishing tools, at the bottom of which is a sand hitch which will be firmly attached to the inside wall of the bottom of the screen (figure 8B-80). Following the setting of the sand hitch, lifting force, applied either by mechanical or hydraulic jacks, will usually withdraw the screen from the well.

In recovering steel casing extending to the surface, the least expensive and least hazardous method is to apply a lifting force to the casing by the use of jacks, or with the drilling machine, or with the two in combination. However, the use of a jarring head applied at the top of the casing string and used in combination with lifting devices is more effective.

If a drive shoe is attached to the bottom of the casing string to be extracted, it is often advantageous to separate the casing from the shoe. The preferred method for cutting casing is by using a casing cutter.

8B.10.3 Abandonment of Flowing Artesian Wells

A flowing artesian well with an improperly sealed casing, and with water escaping around the outside of the casing either to the surface or to another formation presents a special problem. Before sealing can occur, it is necessary to bring the flow under control. This can be accomplished by several methods. Some of these are:

1. pumping the well to reduce the hydrostatic head;

2. introducing dense fluid at the bottom of the borehole and filling the hole with fluid until all flow ceases;

3. introducing stone aggregate, lead wool, steel shavings, a well packer, or lead plug to restict the flow; or

4. pressure injection of neat cement, or a sand and cement mixture emplaced in the intake portion of the well.

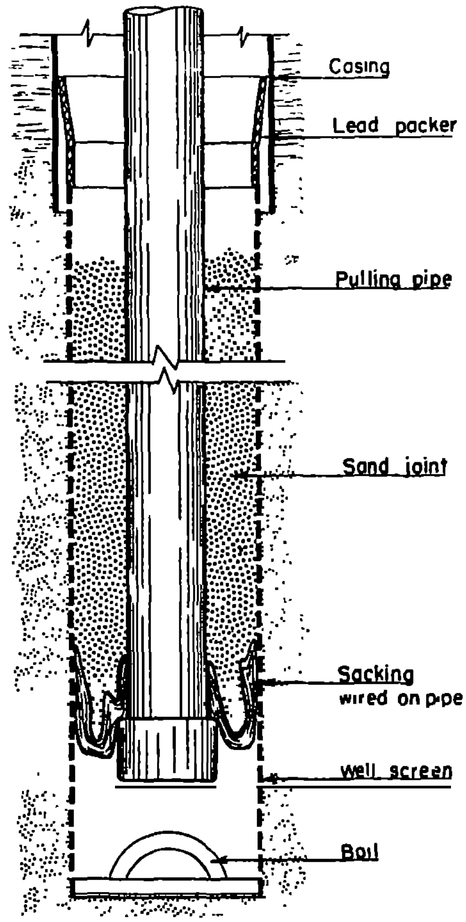


Figure 8B-80 Sand hitch for removing screens.

8B.10.4 Abandonment to Deep Wells and Dug Wells

It is time consuming and costly to entirely backfill a well more than a hundred meters deep with impermeable materials. In such cases a permanent bridge seal can be placed in the well. The bridge forms a platform on which cement or other impermeable material can be placed. Below the bridge the hole may remain open (Figure 8B-79).

Dug wells present a special problem because of the volume of material that must be placed in the well. Stone aggregate can be placed in the bottom of the well to a level 1 meter above the highest anticipated water table. This is followed by a 1/2 meter of fine to medium sand. Three meters of cement or puddled clay is then poured on top to provide a seal. The rest of the hole can thus be filled using materials similar to the earth materials through which the well has been excavated.

8B.10.5 Specifications for Sealing Driven, Jetted, or Drilled Wells

This information is contained in the Well Abandonment section of the well construction specifications (Section 8B.12).

8B.11 WELL RECORDS

Well records are perhaps the most valuable tools that a geologist, well driller, engineer or waterworks technician can use for selecting a well site and designing a well. Records should be kept and updated throughout the life of the well thus describing the type of problems encountered during the well's life and the methods used to correct those problems.

Upon completion of this section the manual user will be able:

1. to understand the importance of keeping good well records;

2. to select appropriate data for the records and understand the significance of that data in relationship to future projects; and

3. to fill out a well log form.

8B.11.1 Data to be Recorded

Information to be recorded on a well log is listed on the Well Record. The directions on how to fill out the record and its importance is listed in Section 8B.11.2.

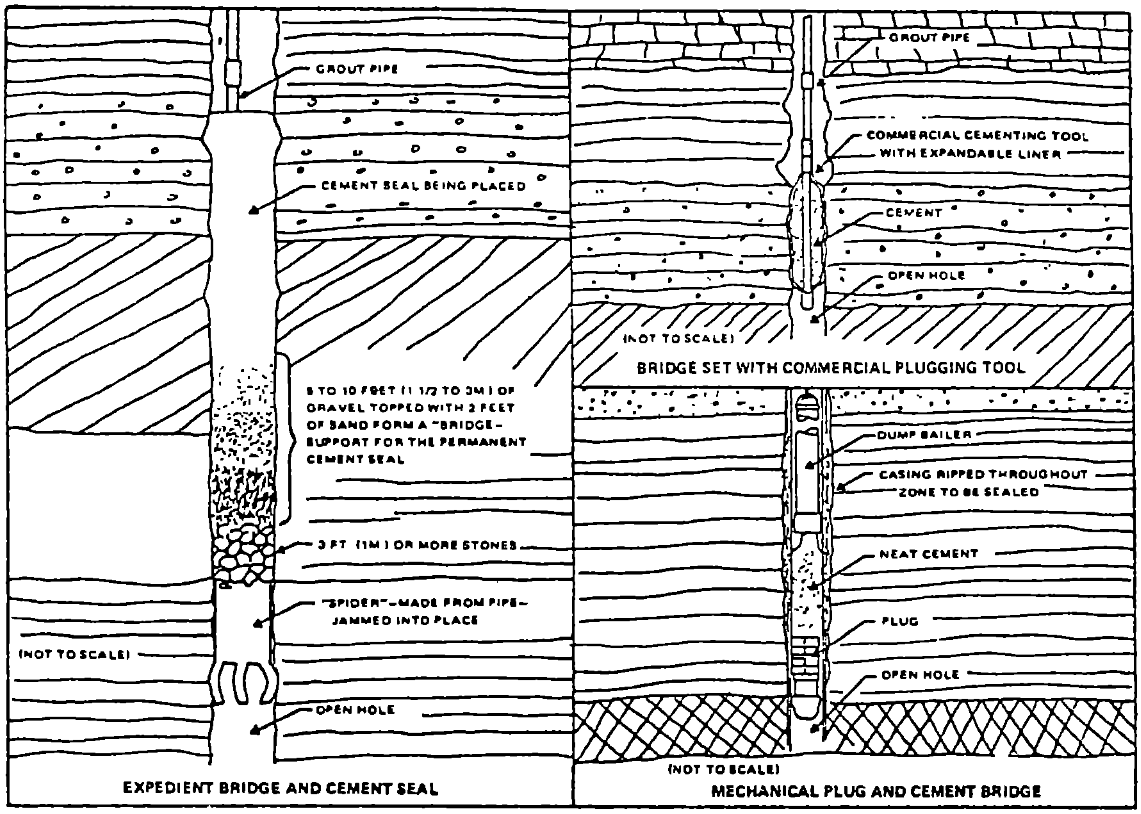


Figure 8B-81 Permanent bridge seals.

WELL RECORD

1. Owner's Name and Address ________________

2. Driller's Name and Address ________________

3. Well Number and Name ________________

4. Date Drilled

   a. Starting Date ________________

   b. Completion Date ________________

   c. Date Abandoned (If Abandoned) ________________

5. Location

   a. Province ________________ Barangay________________

   b. Location drawing (show major and minor roads within 1 kilometer of the well, and plot the location of the well with respect to keep geographic features)

6. Ground Elevation ________________ meters

7. Type of Well (dug, drilled, driven, etc.);________________

8. Well Depth ________________ meters

9. Casing: Dia. ________ mm; Material________________

   Depth ________________ meters

10. Intake Structure (Screen, Slotted Casing, etc.); ____________________

11. Intake Length ____________________

12. Aquifer(s) Type (Alluvium, Sandstone, etc.) ____________________

13. Static Water Level Depth___________ meters, date measured___________

14. Well Log

Depth Interval	Diagram of the well	Description (Rock type, color, etc.)

15. Samples Collected (Yes, No) __________

If Yes, method of storage ___________; Storage Location__________

16. Pump: Type_____________________; Capacity ___________________

17. Power: Kind_____________________; Horsepower _________________

Use: (Domestic, Irrigation, Public, Livestock, etc.)_____________

18. Water quality (Taste, color, odor) ______________________________

Temp. _____ °C; Bacteriological Test ___________________________

19. Method of Well Development________________; Date ______________

Length of Time ____________ hours

20. Record of Maintenance

Date	Description of Problem	Description of Maintenance

21. Specific Capacity

Date	Yield	Drawdown	Specific Capacity

8B.11.2 Directions for Filling Out the Well Record

1. List the name of barangay or head of the water committee

2. List the driller's name and address. This will enable BWP engineers or waterworks technicians to interview the driller, at some time in the future should additional information be needed. You may also wish to use the same driller if maintenance must be performed on the well.

3. List the well number or name, if any. It is useful to develop a well numbering system as a means of avoiding confusion, especially where there are several level I wells in the same area

4. Record the drilling start and completion dates. If the well had been abandoned; record the date of abandonment. The age of the well is a necessity in order to evaluate the effectiveness of well design and construction in relationship to the need for maintenance.

5. Record pertinent data related to the location of the well, including the province and barangay names. A map showing the location of the well in relationship to roads and readily visible geographic features is essential. Include distance from the road or key landmarks.

6. Record the ground elevation. If the well can be located on a topographic map it will be possible to approximate the elevation to within a few meters. This information is useful because it enables you to estimate at what depth the aquifer and the water table will be encountered in nearby wells. In addition, it will be useful in developing a map of the water table elevation which would be necessary to determine ground water flow directions.

7. Record the type of well. Denote whether it is a dug well, rotary drilled, driven, etc. It is also very useful to include a sketch of the well design showing depths screened, depths cased, diameter of the borehole, gravel pack, grout and other important design and construction features. This will simplify identification of problems that may develop during the well's service life and provide a basis for methods of well maintenance.

8. Record the well's depth.

9. Record the diameter of the casing, depth intervals with casing and the type of material used for casing.

10. Record the type of intake structure (screen, slotted pipe, open hole, etc.)

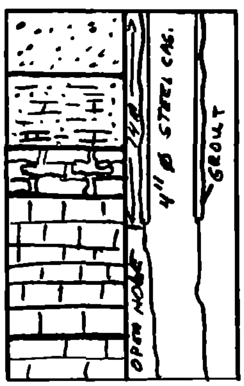
11. Record the length of the intake structure.

12. Record the nature of the aquifer material. If the well is screened in different aquifers, list the aquifer types and the intervals in which they are encountered. This will facilitate well maintenance should the need arise.

13. Record the static water level and date at which the measurement was taken. The first important measurement of the static water level should be made a day after well development has been completed. Fluctuations in the water level may occur daily and/or seasonally. The static water level should be checked every time the well or pump is inspected. Good water level records, will provide information pertaining to: well performance, the need for well maintenance, and long term trends in ground water conditions.

14. The actual well log is one of the most important aspects of the well record. This part of the record provides a full description of the rock formations the driller ecountered during the construction process. The report should contain precise information as to changes in subsurface formation characteristics.

For Example:

Depth Interval	Diagram of Well	Description
0-4 meters		Sandy brown soil, dry
4-9		Brown silty sand with limestone frag.
9-12		Lt. brown blocks of weathered limestone/wet
12-20		Fresh tan limestone, shell fragments (good water)
20-22		Gray crystalline limestone

15. Have well cutting samples been collected? Ideally, samples should be collected and stored in a safe place. These samples will help another driller interpret your rock descriptions, enable a hydrogeologist to correlate rock units in the area, and provide an additional record of the well should the well log be destroyed or misplaced.

16. Record information about the pump. By definition, level I wells will have hand pumps, but the type or make of the hand pump should be recorded, along with the pumps capacity at the time it was installed. If it is hand or wind powered then you cannot record horsepower.

17. Record the primary purpose of the well. Most BWP wells will be for public water supply. However, if it is only a livestock, or irrigation, record it as such. If its multipurpose, record its major use.

18. Describe any physical characteristics such as taste, odor, color or turbidity. Record the temperature. In some parts of the country the water may be heated by subterranean molten rocks. If the water is too warm residents may refuse to use it. The water temperature should not exceed 35°C. Before any well is put into service a bacteriological test must be performed to ensure that the water will not cause illness.

19. Record the method or methods of well development, the date of development and the period of time required to develop the well. This information is extremely useful if well yield is unsatisfactory or should radically change at some future date.

20. Record any and all maintenance performed on the well, including why the maintenance was needed, and an assessment of how well the maintenance procedure seemed to improve the well's condition.

21. Finally, whenever the well is inspected or maintenance is performed, specific capacity of the well should be determined. Procedures for determining specific capacity are described in Section 8B.8 of this manual. The specific capacity provides a means of comparing the relative performance characteristics of the well from time to time. A drop of 25 percent from the original specific capacity may signal the need for well maintenance, especially if the static water level was at or near it original level. A specific capacity test should be performed before and after all well maintenance as a guide to judging the effectiveness of the maintenance performed.

8B.12 WATER WELL CONSTRUCTION STANDARDS: BWP LEVEL I

8B.12.1 Methods of Construction

The CONTRACTOR shall choose the construction method(s) to be used, but it must meet with BWP approval. The construction methods accepted are:

1. digging or boring
2. driving
3. cable tool (percussion)
4. jetting
5. conventional hydraulic rotary drilling

Other methods are acceptable if shown to provide adequate sanitary protection, formation penetration capability, and cost effectiveness.

The CONTRACTOR shall provide all equipment and tools to ensure proper construction of the well.

8B.12.2 Daily Driller's Report

During the drilling of the well, a daily, detailed driller's report shall be maintained and delivered upon request to the WATER WORKS ENGINEER or his representative at the well site. The report shall give a complete description of all formations encountered, number of meters (feet) drilled, number of hours on the job, shutdown due to breakdown, the water level in the well at the beginning and end of each shift, water level at each change of formation if readily measureable with the drilling method used, meters (feet) of casing set, and such other pertinent data as may be requested by the OWNER or his representative. In rotary drilling, the fluid level in the hole should be measured daily prior to starting pumps.

Driller's Log. During the drilling of the well the CONTRACTOR shall prepare and keep a complete log setting forth the following:

1. The reference point for all depth measurements;
2. The depth at which each change of formation occurs;
3. The depth at which the first water was encountered;

4. The depth at which each stratum was encountered;

5. The thickness of each stratum;

6. The identification of the material of which each stratum is composed such as (Table 8B-3):

   a. clay

   b. sand or silt

   c. sand and gravel -- Indicate whether gravel is loose, tight, angular or smooth; color.

   d. cemented formation -- Indicate whether grains (if present) have natural cementing material between them, e.g. silica, calcite, etc.

   e. hard rock -- Indicate whether sedimentary bedrock, or igneous (granite-like, basalt-like, etc.)

7. The depth interval from which each water and formation sample was taken.

8. The depth at which hole diameters (bit sizes) change.

9. The depth to the static water level (SWL); the changes in SWL with well depth.

10. Total depth of completed well.

11. Any and all other pertinent information for a complete and accurate log; e.g., temperature, pH, and appearance (color) of any water sample taken.

12. Depth or location of any lost drilling fluid, drilling materials or tools.

13. The depth of the surface seal, if applicable

14. The nominal hole diameter of the well bore above and below casing seal.

15. The amount of cement (number of sacks) installed for the seal, if applicable.

16. The depth and description of the well casing.

Table 8B-3

VARIOUS SIZE GRADE SCALES IN COMMON USE

Udden-Wentworth	Values	German Scale' (after Alterberg)	USDA and Soil Science Soc. Amer.
		(Blockwork)	
Cobbles	-6	-- 200 mm --	Cobbles
--- 64 mm ---			--- 180 mm ---
Pebbles		Gravel (Kies)	
--- 4 mm ---	-2		Gravel
Granuler			
--- 2 mm ---	-1	-- 2 mm --	--- 2 mm ---
Very Coarse Sand			Very Coarse Sand
--- 1 mm ---	0		--- 1 mm ---
Coarse Sand		Sand	Coarse Sand
--- 0.5 mm ---	1		--- 0.5 mm ---
Medium Sand			Medium Sand
--- 0.25 mm ---	2		--- 0.25 mm ---
Fine Sand			Fine Sand
--- 0.125 mm ---	3		--- 0.10 mm ---
Very Fine Sand			Very Fine Sand
--- 0.0625 mm ---	4	-- 0.0625 mm --	--- 0.05 ---
Silt		Silt	Silt
--- 0.0039 mm ---	8	-- 0.002 mm --	---0.002 mm --
Clay		Clay	Clay
		(Ton)	

+ Subdivisions of sand sizes omitted.
I Mesh numbers are for U.S. Standard Sieves: 4 mesh - 4.76 mm, 10 mesh
40 mesh = 0.42, 200 mesh = 0.074 mm.

17. The description (to include length, diameter, slot size, material, and manufacturer) and location of well screens, or number, size and location of perforations.

18. The sealing-off of water-bearing strata, if any, and the exact location thereof.

8B.12.3 Formation Sampling

The method of sampling shall be left to the discretion of the CONTRACTOR. He must collect samples every 2 meters (6 feet) and when characteristics of the drilling indicate a change in formation.

Where possible at least 300 grams of sample should be placed in an approved container that closes securely to avoid contamination and spillage. The container should be clearly labeled with waterproof ink and the following information contained on the label:

1. location of the well;

2. depth interval represented by the sample;

3. name or number of the well;

4. date taken.

The CONTRACTOR shall be responsible for the safe storage of the formation samples until such times as they are accepted by the OWNER.

8B.12.4 Well Casing Selection and Installation

8B.12.4.1 Selecting Casing Diameter

The minimum casing diameter for a shallow well pump is 63 mm (2 inches). The minimum casing diameter for a medium or deep well pump shall be 90 mm (3.5 inches). The maximum acceptable casing diameter for any level I well (with the exception of dug or bored well) is 160 mm (6 inches.

8B.12.4.2 Selecting Casing Thickness

The thickness of material used for well casing should be selected in accordance with good design practice and experience as applied to conditions found at the well site. The casing must be able to withstand the effect of forces imposed on it during installation and development. For metallic casing the minimum acceptable casing thickness shall be equivalent to or exceed Schedule 40 for any given pipe diameter. If plastic (PVC) well casing is used, then its SDR valve shall be no higher than 28.

8B.12.4.3 Well Casing Selection

All well casing shall be new and undamaged. The materials selected must be approved by the OWNER.

8B.12.4.4 Top of Casing

The top of the casing shall extend at least 35 cm above the surrounding ground level.

8B.12.4.5 Well Casing Installation

The CONTRACTOR shall select an appropriate method of casing installation with consideration given to the method of construction. The method of installation must be approved by the WATERWORKS ENGINEER. Casing lengths shall be joined watertight by a method appropriate to the material used, as selected by the CONTRACTOR and approved by the OWNER, so that the resulting joint shall have the same structural integrity as the casing itself. If metallic casing is welded, the standards of the American Welding Society shall apply.

If threaded and coupled joints are used, coupling shall be API or equivalent, made up so that when tight all threads will be buried in the lip of the coupling.

Plastic casing sections shall be joined watertight by solvent welding in accordance with the direction of the manufacturer of the materials used, or by the use of threaded and coupled joints.

When concrete pipe is used, the casing shall be joined in accordance with standards of the American Society for Testing and Material or the American Water Works Association. Special care shall be taken to avoid chipping or cracking the casing.

When asbstos cement pipe is used, the casings shall be joined in accordance with standards of the American Water Works Association. Special care shall be taken to avoid chipping or cracking the casing.

Other Materials: Casing made of other materials (aluminum, copper, brass, fiberglass, etc.) shall be joined in accordance with the manufacturer's instructions.

8B.12.5 Intake Structure

The CONTRACTOR shall select an appropriate screen and it must meet with the WATERWORKS ENGINEER approval. The screen shall provide enough open area to allow the well to be developed at a rate equal to 150 percent of the design capacity. The minimum screen length shall be 1 meter.

The selection of screenopening shall be based upon acceptable, good design practices and must be approved by the WATERWORKS ENGINEER or his representative.

The material selected for the screen must be able to withstand the corrosive nature of ground water and the corrosive characteristics of chemicals used in well disinfection and well treatment. The screen must also be able to resist the effect of forces resulting from installation and well development.

<u>Torch cut slotted casing is prohibited.</u>

If the well penetrates consolidated formations that will not become friable or slough, then an open borehole is acceptable as an intake structure.

8B.12.6 Gravel Envelope or Formation Stabilizer

If the well is designed to a require a gravel envelope or a formation stabilizer then the CONTRACTOR shall be responsible for acquiring gravel that is well rounded, has a maximum diameter or 4 mm., and had been disinfected by allowing it to soak in a 250 ppm chlorine solution for 24 hours.

The CONTRACTOR shall select a method of installation that will prohibit bridging and ensure a uniform packing around the well screen and casing. The gravel shall extend at least 3 meters above the top of the screen to allow for settlement and removal of some gravel during well development.

From the top of the gravel pack to within 6 meters of the ground surface the well shall be backfilled with disinfected dimensionally stable material.

In wells that have a gravel envelope one or more tremie pipes can be permanently installed as shown in Figure 8B-82. All openings shall be closed to prevent accidental entrance of any foreign material. The pipes shall permit the addition of gravel should excessive settlement occur.

8B.12.7 Surface Seal

With the exception of cable tool drilled wells and driven wells, all wells will have an annular space not less than 5 cm. From the ground surface to a depth of 6 meters this annular space shall be filled with cement grout.

The cement grout shall be emplaced under pressure or by tremie pipe starting from the lowest section working upward to the surface in one continous operation.

8B.12.8 Well Plumbness and Alignment

Well alignment and plumbness should be checked to see whether they are within the allowable limits prior to the installation of pumping facilities. Alignment refers to the straightness or

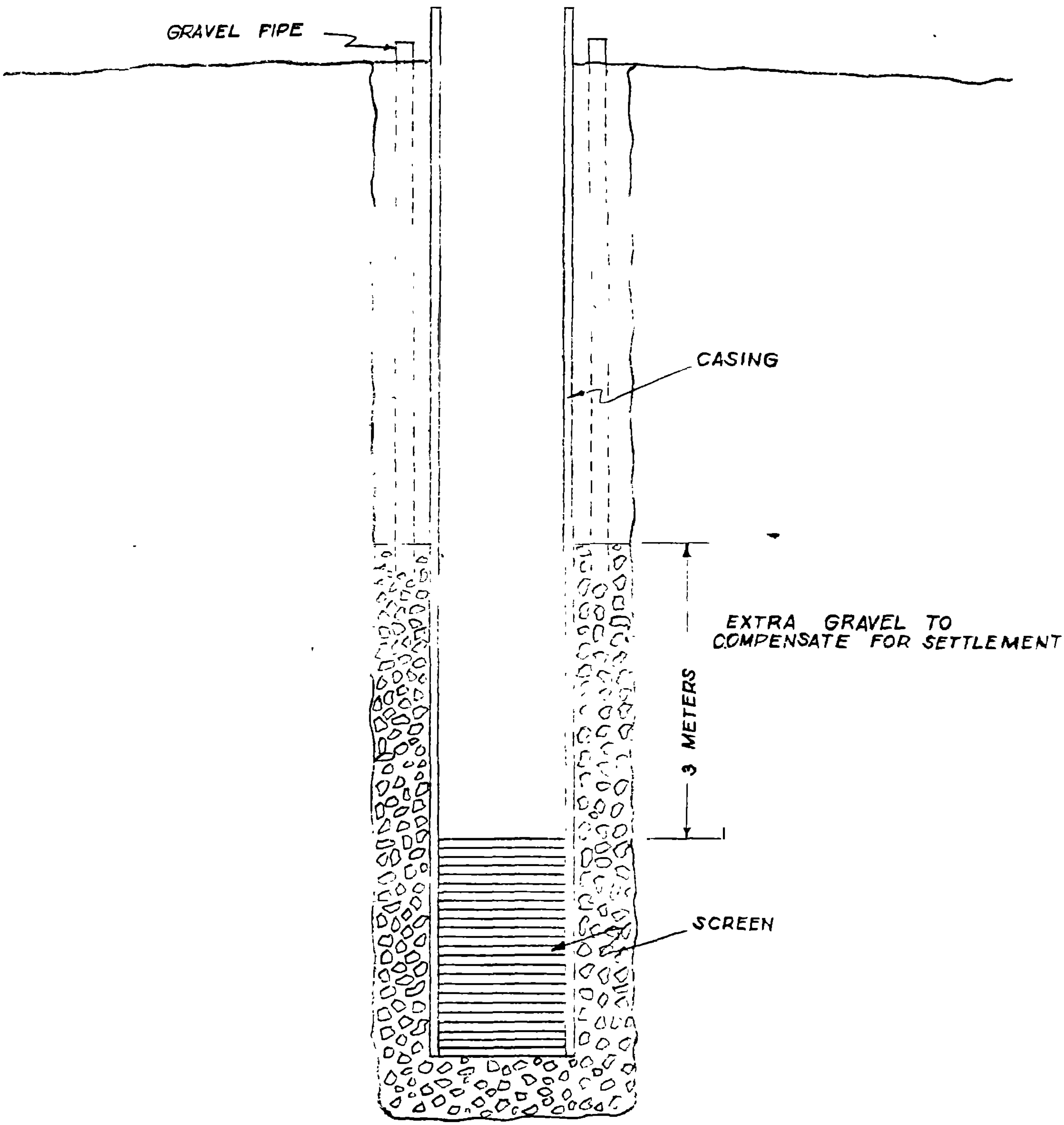


Figure 8B-82 Gravel pack well with permanent tremie pipes.

crookedness of the well hole, while plumbness is the deviation of the well hole from the vertical. Alignment is necessary in determing whether a pump of given size can be installed in the well to a desired depth. If the well bore or well casing is crooked beyond a certain limit, the pump cylinder and drop pipe will simply not go in. A well must also be plumb. Although a pump can be installed in a well that is aligned but out of plumb, it efficiency may be reduced significantly.

8B.12.8.1 Checking Well Alignment

The well alignment can be tested using a set up consisting of a tripod and a dummy (Figure 8B-83). The dummy may be a pipe with diameter slightly smaller than the well casing (perferably two commercial pipe sizes smaller than the casing) and length (normally 12 M) sufficient to detect undesirable deviations form the straight line. In general, the well is acceptable if the dummy moves freely throughout the length of the casing or to the depth of pump column is intended to be lowered.

Procedure:

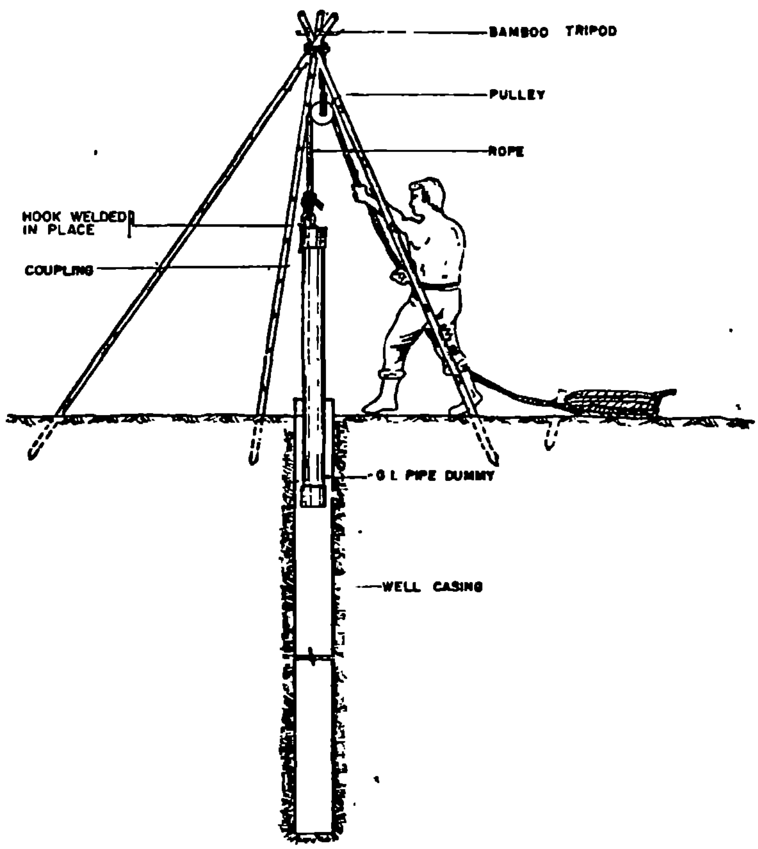
1. Assemble the tripod and install the pulley system as shown in Figure 8B-83.

2. Tie the upper end of the dummy pipe with a rope and suspend it from the tripod. Make sure that the lower end of dummy pipe is pointing directly to the center of the well.

3. Slowly lower the dummy to the bottom of the well, being careful not to damage the screen or casing. For a well to be acceptable, the dummy pipe should be able to reach freely the depth the pump column is intended to be lowered.

8B.12.8.2 Checking Well Plumbness

Well plumbness or the extent of the deviation of the well hole from the vertical can be tested using a plumb bob. The process consists of lowering the plumb



DETERMINATION OF WELL ALIGNMENT

Figure 8B-83

bob into the well and noting the distance between the plumb bob string and the edge of the top of the casing as the bob strikes the side of the casing at various depths. The horizontal distance traversed by the plumb bob is then determined by proportion. It represents the deviation of the well hole from the vertical. In general, a well to be acceptable should not deviate more than 0.70 times the casing diameter for each 30 meter length.

1. Assemble the tools and equipment in a manner shown in Figure 8B-84. Hang the plumb bob slightly above the well casing and adjust the plumb guide until the plumb bob is on the exact center of the well.

2. Put four marks on the top of the well casing. These marks will serve as end points of two imaginary perpendicular lines which intersect at the center of the well and will be used as reference points during the determination of the direction of the deviation of the well hole from the vertical. Name the four points north, south, each and west.

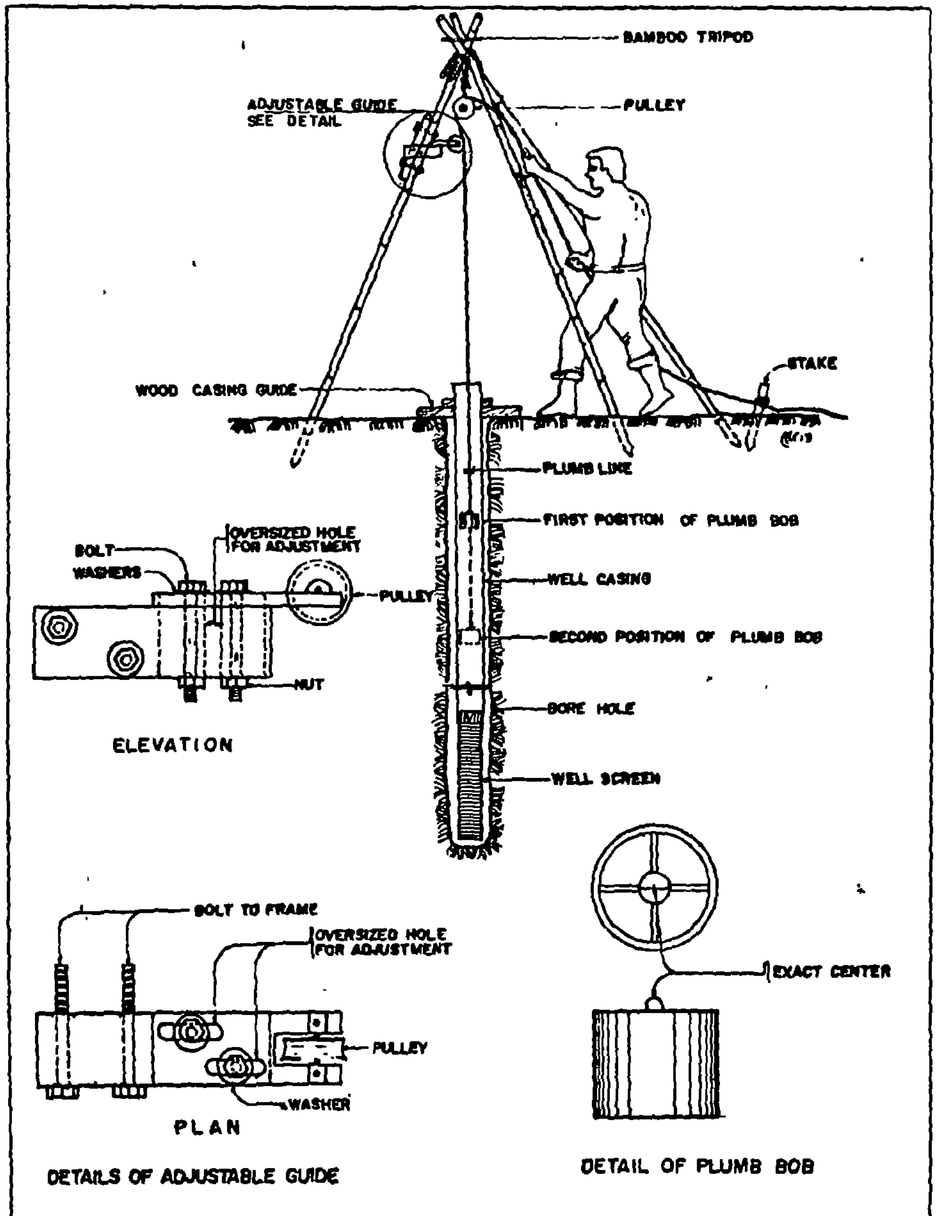
3. Measure the vertical distance from the center of the pulley to the top of the well casing. The center of the pulley is called the datum point.

4. Lower the plumb bob and measure the distance traversed by the plumb line from the center taking your mark points (north, south, east and west) as reference points for every meter distance the plumb bob is lowered. Should the plumb line touch the well casing, shift the point before taking the measurement.

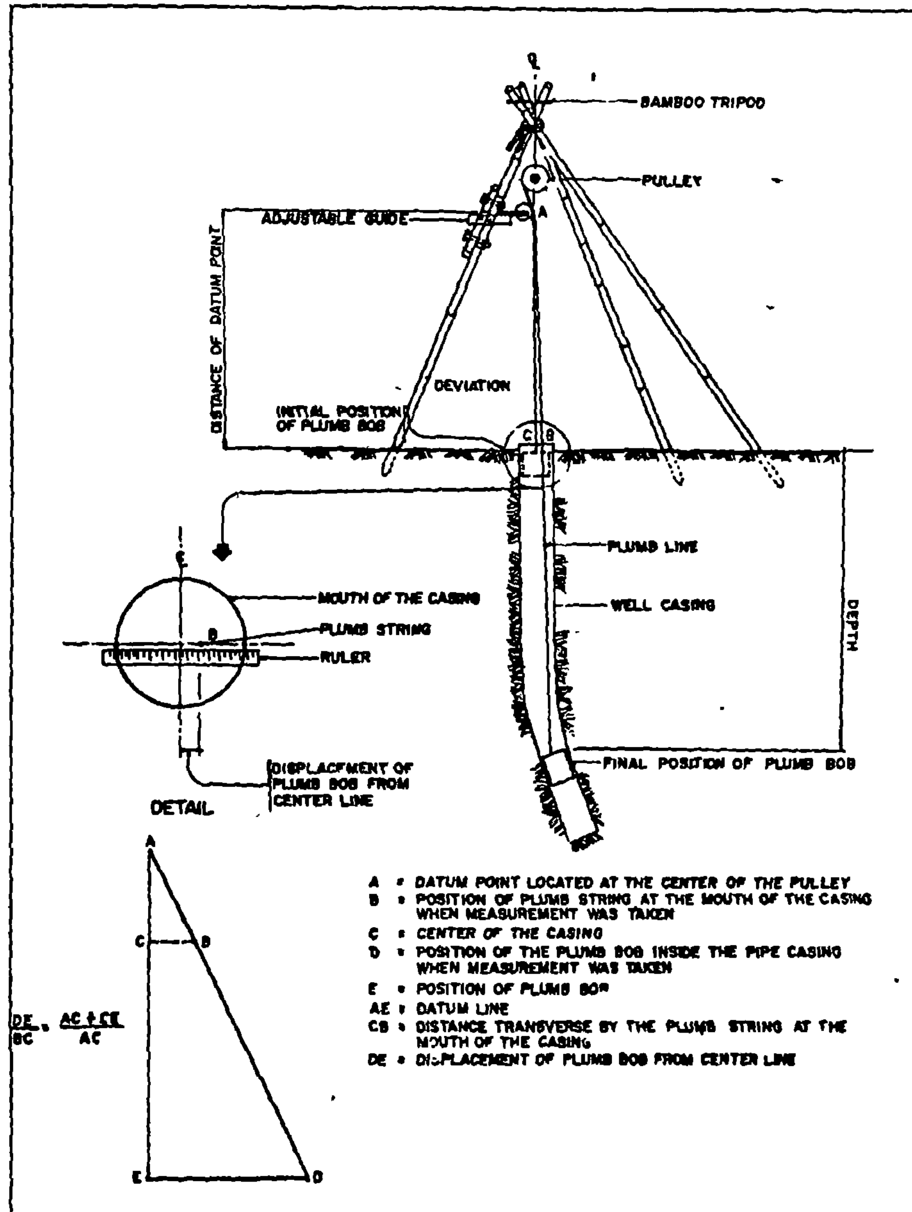
5. Calculate the deviation of the well hole from the vertical.

   a. If the Datum Point is Not Shifted - Figure 8B-85 illustratres the relative position of the plumb bob and plumb string from the datum point and line. From the figure it is shown that the deviation of the well hole at point D can be computed by ratio and proportion (Triangles CAB and EAD are similar triangles). Stated mathematically.

$$DE = \frac{BC\ (AB + CE)}{AC}$$



EQUIPMENT SET-UP FOR CHECKING WELL PLUMBNESS
Figure 8B-84



DETERMINATION OF WELL PLUMBNESS
(WHEN DATUM POINT IS NOT SHIFTED)
Figure 8B-85

where DE = Deviation of the well hole from the vertical depth CE (mm).

BC = Traverse distance of the plumb string at the mouth of the casing (mm).

AC = Elevation of the datum point (M).

CE = Depth (M)

b. If the datum point is shifted (Figure 8B-86). The deviation of the well from the vertical can be determined by the following equation.

$$DE = \frac{(AC + CE)\ (BC = AA') - AA'}{AC}$$

where AA' = distance the datum point is shifted, mm.

8B.12.9 Well Development

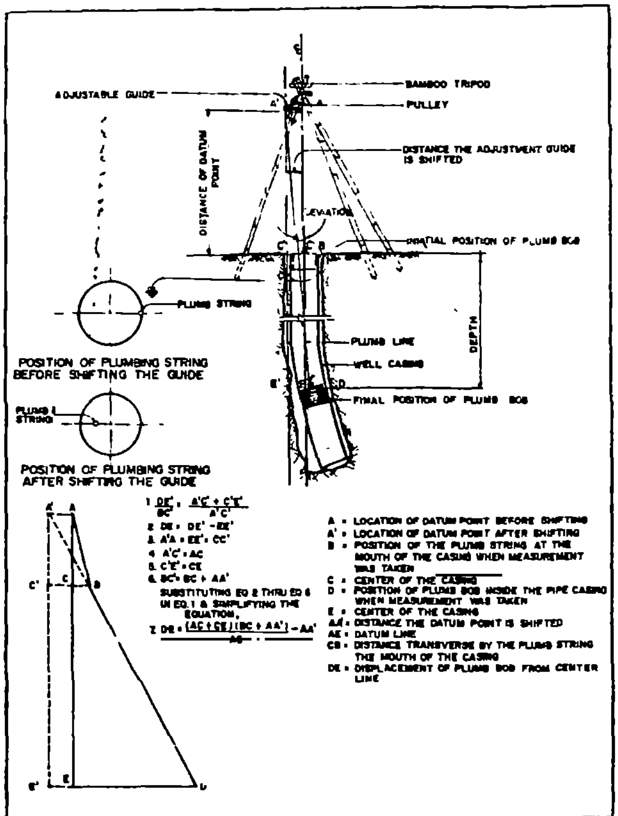
The CONTRACTOR shall select a method of well development. The CONTRACTOR shall supply all tools, equipment and material for well development. The development process should continue until the well is able to yield water with a sand content of 5 ppm or less when pumped at design rate. A centrifugal sand sampler shall be used to test sand content.

If the desired sand content is too high, then development shall continue until the OWNER or his representative orders it stopped.

8B.12.10 Well Performance Testing

The CONTRACTOR shall pump test the well at the desired yield and measure the water level periodically during the pump test. The pump test shall continue until the water level ceases to decline further or the test is ordered stopped by the WATERWORKS ENGINEER or his representative. Under no circumstances should the test be shorter than four hours.

With the data derived from the pump test, the well's specific capacity shall be determined.



DETERMINATION OF WELL PLUMBNESS
(WHEN DATUM POINT IS SHIFTED)

Figure 8B-86

8B.12.11 Well Abandonment

Each well abandonment shall be considered a separate problem, and methods and materials should be selected only after a detailed study of both the well design and hydrogeology.

8B.12.11.1 Aquifer Sealing Criteria

Aquifers shall be filled with disinfected, dimensionally stable materials, compacted mechanically if necessary to avoid later settlement. (Cement, cement-and-sand, and concrete do not require disinfection.)

Disinfection of aquifer fill materials shall be accomplished by using chlorine compounds such as sodium hypochlorite or calcium hypochlorite. Aquifer fill materials shall be clean (relatively free of clays and organic materials) before placement in the well. Disinfection shall be accomplished by dissolving sufficient chlorine compound to produce a calculated concentration of at least 100 ppm available chlorine in double the volume of water in the well., The fill material shall be placed in the well after the water in the well has been so treated.

8B.12.11.2 Permanent Bridges

Permanent bridges may be used to avoid having to fill very deep holes below the deepest point at which a permanent seal is required. Permanent bridges shall be composed only of cement or cement-bearing minerals. The cement shall be allowed to harden for at least 24 hours, if Type I cement is used, or for at least 12 hours if Type III (high early strength) cement is used, before backfilling is continued. Temporary bridges used to provide a base for the permanent bridge shall consist only of inorganic materials except that patented devices containing expandable neoprene, plastic, and other elastomers, and specifially designed for use in well construction are acceptable.

8B.12.11.3 Placement of Grout

Placement Operations. Concrete, sand-and-cement grout, or cement grout used as a sealing material in abandonment operations shall be introduced at the bottom of the well or interval to be sealed (or filled) and placed progressively upward to the top of the well. All such sealing materials shall placed by the use of grout pipe, tremie, cement bucket or dump bailer, in such a way as to avoid segregation or dilution of the sealing materials. Dumping grout material from the surface shall not be permitted.

Seals intended to prevent vertical movement of water in the well or borehole shall be composed of cement, sand-and-cement, or concrete--except that where such seals must be placed within casing or liners, only neat cement grout may be used. Cement seals shall be placed by means of pumping through drop pipe or by use of a dump-bailer, with placement beginning at the bottom and continuing upward. The minimum cement seal length, wherever dimensions permit, shall be 3 meters (10 feet).

Uppermost Aquifer Seal: A cement, sand-and-cement, or concrete seal shall be installed in the least permeable zone immediately above the uppermost water-producing zone. Such seals shall be placed only in quiescent (non-flowing) water.

Seals Placed Within Casing, Liners or Filters. Seals which must be placed in casing, liners, or filters require special attention. The material between the well and the face of the borehole shall be thoroughly perforated, ripped, or otherwise disintegrated as the necessary first step. Neat cement with a maximum of 5 percent by weight of commercially processed bentonite clay, shall be used as the seal. Either of two methods may be used.

1. The calculated amount of grout required to fill the well interval plus the annular space outside the lining shall be placed within the space to be cemented, running the cement through a special cementing packer manufactured for this purpose and installed immediately above the perforated or ripped zone. The cement shall be injected at a pressure calculated to be at least 50 psi greater than the normal hydrostatic pressure within the well at the point of injection.

2. The calculated amount of cement grout required to fill the casing interval plus the annular space outside the lining, plus sufficient cement grout to fill an additional 3 meters (10 feet) of the lining, shall be introduced at the bottom of the interval to be cemented.

8B.12.11.4 Placement of Fill

Non-producing zones above the aquifer shall be filled with stable materials such as sand, sand-and-gravel, cement, cement-and-sand, or concrete. Non-producing zones above the uppermost aquifer seal shall be filled with materials less permeable than the surrounding undisturbed formations. The uppermost 1.7 meters (5 feet) of the bore hole (at land surface) shall be filled with a material appropriate to the intended use of the land.

8B.12.12 Special Standards for Dug Well Construction (modified from a report by J. Cooper)

The following dug well construction standards are recommended to protect the quality of ground water resources from impairment.

8B.12.12.1 Well Locations

Well sites should be located on relatively "high" ground which is not subject to normal flooding and should be protected from surface or subsurface drainage from any source capable of impairing the quality of the ground water supply. In most areas, the topographic "lows are most probable sites for ground water occurrence, but the site selected should be slightly "up-slope" from the "low" rather in the center of it, in order to preclude the drainage water from entering the well. The well site should be located a minimum distance of 15 meters (50 feet) from septic tanks, cesspools, seepage pits, leaching lines, sewer lines, privies, garbage dumps, barns and barnyards, or other possible sources of contamination. Greater distances should be provided, where possible.

8B.12.12.2 Well Casing Material

The use of wood cribbing or casing should be avoided. Bricks or stone building blocks should be used only in the lowermost section of casing, unless a good quality mortar is used between blocks.

Casing material should be of sufficient strength, toughness and thickness to resist all forces and stresses imposed during and after installation, and should be capable of being joined with watertight joints. The material should be impervious, where required. No damaged or defective material should be used.

Concrete casing, poured-in-place or precast rings, should be adequately reinforced with steel rod and should be free from voids, blemishes or other defects which would impair its strength or watertightness. Precast concrete rings should be fabricated as interlocking rings or as tongue-and-groove to facilitate sealing during well construction.

8B.12.12.3 Well Casing Placement

Permanent casing should be placed in all wells to a safe depth below the ground surface to prevent entrance of undesirable surface waters and foreign material. All casing should be placed with sufficient care to avoid damage to casing sections and joints. Placement should be made in such a manner as to ensure that all joints are watertight, not chipped nor broken, nor damaged to the point of requiring removal.

Care should be exercised in the placement of poured-in-place concrete grout to ensure no honeycombing, air spaces or separation of grout materials. Concrete should not be allowed excessive "free fall". A drop pipe, dump bailer, or other suitable arrangement should be used to introduce the grout into the annular space between casing and well excavation.

Well casing should rest upon an adequate foundation, natural or manmade, to preclude rupture of the casing or damage to joints due to settlement.

8B.12.12.4 Joints

Joints on all well casing should be made completely watertight to the first impervious stratum or to the depth of water occurrence.

Joints on sections of precast concrete casing should be completely watertight, comprised of sealing devices, sand-cement mortar or other sealing compounds. If mortar is used, sufficient quantities are required to ensure that the sections to be joined are bedded in mortar.

Construction joints for poured-in-place concrete casing should be avoided, if at all possible. However, if joints are required, such joints should be cleaned and roughened before continuing the pour, to ensure watertightness. No construction joints should be permitted within the uppermost 5 meters (15 feet) of the well casing.

8B.12.12.5. Perforations

In areas of free ground water, the minimum depth to perforations should be 2 meters (6 feet) below the lowest expected pumping level and below the lowest sewage disposal facilities or appurtenances in the area. In no instance, should the perforations be less than 5 meters (15 feet) below the ground surface, depending upon local water table conditions and the feasibility of deeper construction below the static water level.

No perforated concrete casing should be employed other than standard sections made for the purpose. However, mortared building blocks with nonmortared sections may be used in lieu of perforated precast rings, only within the zone of water entry.

8B.12.12.6 Well-seal Protection

The annular space between well casing and wall of the well should be sealed with cement grout, neat cement or puddled clay, from the ground surface to a depth which will exclude surface water entry. The depth should be at least 5 meters (15 feet) dependent upon local ground water conditions, and no less than 3.5 cm (1-1/2 inches) in thickness.

The cement grout placed in the annulus should be applied in one continuous operation, beginning at the bottom of the interval to be sealed. Grout introduced into the annulus should be placed by grout pipe, which extends to the bottom of the interval to be sealed.

APPENDIX 8B-A

ORIGIN, OCCURRENCE, AND MOVEMENT OF GROUND WATER

(Modified from Ground Water and Wells,
Johnson Division, U.O.P., 1975)

The earth's water cycle, or hydrologic cycle, is the continuous circulation of moisture and water on our planet. The cycle has neither a beginning nor an end, but the concept of the hydrologic cycle commonly begins with the waters of the oceans, since they cover about three-fourths of the earth's surface.

Radiation from the sun evaporates water from the oceans into the atmosphere. The water vapor rises, then collects to form clouds. Under certain conditions, the cloud moisture condenses and falls back to the earth as rain, hail, sleet, or snow--the various forms of precipitation. Hydrologists and others call this "water of meteoric origin."

Precipitation that falls upon land areas is the source of essentially all our fresh water supply. We depend upon it to replenish the quantity of water that is taken from lakes, streams, and wells for man's numerous uses.

Some of this precipitation, after wetting the foliage and ground, runs off over the surface to streams. Another part soaks into the soil. Much of the water enters the soil is detained in the plant root zone and eventually is drawn back to the surface by plants or by soil capillarity. Some of it, however, soaks below the plant root zone and under the influence of gravity continues moving downward until it enters the ground water reservoir.

Upon joining the body of ground water, the percolating water moves through the pores of saturated subsurface materials and may reappear at the surface in areas at lower elevations than the level where it entered the ground water reservoir. Ground water discharges naturally at such places in the form of springs and seeps which maintain the flow of streams in dry periods. The streams, carrying both surface runoff and natural ground water discharge, eventually lead back to the oceans.

The hydrologic cycle, then, is the system by which nature circulates water from the oceans through the atmosphere and returns it both overland and underground back to the sea through various paths--some short and some long, in terms of both time and space. The forces involved in this process include radiation, gravity, molecular attraction and capillarity. The main features of the hydrologic cycle are shown in Figure 8B-A1.

The time required for a water particle to pass through one or more phases of the hydrologic cycle varies from a few hours to months or even to centuries. A water particle may be evaporated from the ocean and within a

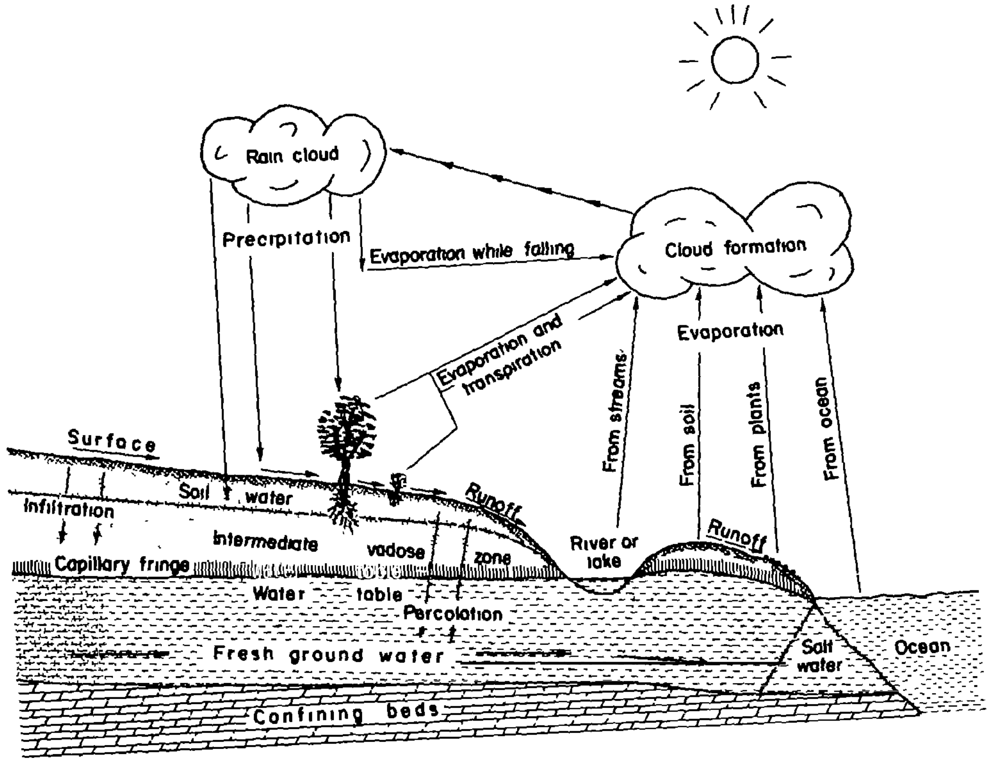


Figure 8B-A1 Schematic diagram of the earth's water cycle - the hydrologic cycle.

a brief period fall as precipitation on the same water surface. If a water particle falls as snow or hail on a high mountain, it may remain upon the land surface for months in solid form until it is melted and joined with similar particles on the long journey overland or underground.

If a water particle is evaporated from the ocean and carried into the polar regions, falling there as ice or snow, it may remain frozen within a glacier for centuries before finally returning to the ocean as part of an iceberg, or as melted outflow from the glacier.

SOIL MOISTURE AND GROUND WATER

Water that infiltrates the soil is called subsurface water, but not all of it becomes ground water. Basically, three things may happen to that water. First, it may be pulled back to the surface by capillary force and be evaporated into the atmosphere, thus skipping much of the journey through the water cycle described in the previous section. Second, it may be absorbed by plant roots growing in the soil and then re-enter the atmosphere by a process known as transpiration.

Third, water that has infiltrated the soil deeply enough may be pulled on downward by gravity until it reaches the level of the zone of saturation--the ground water reservoir that supplies water to wells.

SUBSURFACE DISTRIBUTION OF WATER

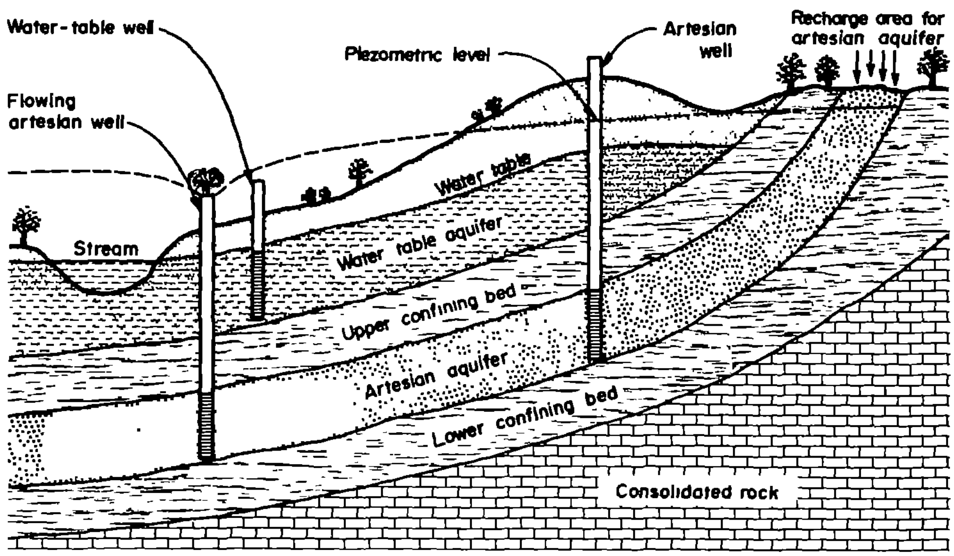
Understanding of ground water occurrence requires a study of the vertical distribution of water in subsurface geologic materials or formations.

Geologists call the earth's crust the lithosphere. When they speak of the lithology of a road cut or section through the crust, they mean the kind of rocks that occur in a succession of layers or strata below the surface that make up any part of the lithosphere. Geologists refer to all the materials of the earth's crust as rocks, whether they be unconsolidated materials such as sand or clay or consolidated materials such as granite or sandstone.

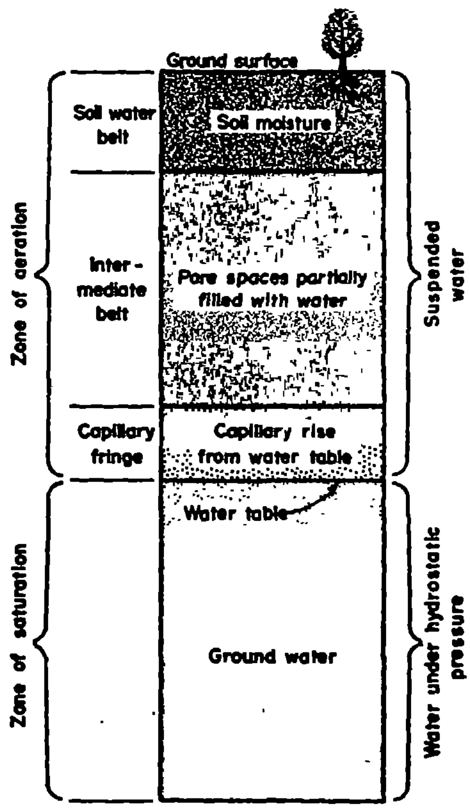
The outer part of the earth's crust is normally porous to a greater or lesser depth. This part is called the zone of rock fracture. The pores or openings in this portion of the lithosphere may be partially or completely filled with water.

The upper strata, where the openings are only partly filled with water, is called the zone of aeration. Immediately below this, where all the openings are completely filled with water, is the zone of saturation.

The zone of aeration is divided into three belts--the belt of soil water, the intermediate belt, and the capillary fringe. The belts vary in depth and their limits are not sharply defined by physical differences in



Subsurface and ground-water phase of the hydrologic cycle.



Ground water is the part of subsurface water within the zone of saturation.

Figure 8B-A2

the earth materials. A gradual transition exists from one belt to another (Figure 8B-A2).

The belt of soil water is of particular importance to agriculture because it furnishes the water supply for plant growth. Water passing downward from this belt escapes beyond the reach of the roots of most plants. The depth of the belt of soil water varies with the types of soil and vegetation and may extend from a few feet to some tens of feet below the surface.

The roots of some plants reach into the capillary fringe or the water table where these are relatively close to the surface. This occurs mainly along stream courses. Such plants, called phreatophytes, grow without dependence upon the belt of soil water.

Water is held in the belt of soil water for the use of plants by molecular at traction and capillarity action against the force of gravity. Molecular attraction tends to hold some water in a thin film on the surface of each soil particle. Capillarity holds water in the very small spaces between the soil particles. Only when sufficient water has entered this belt to more than satisfy the water-holding capacity of the capillary forces, does water start to percolate downward under the force of gravity.

Water that does pass through the belt of soil water enters the intermediate belt, and continues its movement downward by gravitational action. Like the belt of soil water, the intermediate belt holds suspended water by molecular attraction and capillarity, capillarity being the more important of the two forces. The suspended water in this belt is in dead storage, since it cannot be recovered for use. This belt serves only to provide a passage for water from the belt of soil water to the capillary fringe and to the zone of saturation below it. The thickness of the intermediate belt varies greatly, and this has a significant effect on the time it takes water to pass through it to recharge the zone of saturation.

The capillary fringe lies immediately below the intermediate belt and above the zone of saturation. It holds water above the zone of saturation by capillary force acting against the force of gravity. The thickness and the amount of water held in the capillary fringe depend on the grain size of the material.

The capillary fringe in silt and clay materials is sometimes as much as 8 feet thick. In coarse sand or gravel, it may be a fraction of an inch.

GROUND WATER

Water in the zone of saturation is the only part of all subsurface water which is properly referred to as ground water. Underground water and subterranean water are other terms used in referring to water in the zone of saturation, but ground water is the preferred term. The saturated zone may be viewed as a huge natural reservoir or system of reservoirs, whose capacity is the total volume of the pores or openings in the rocks that are filled with water.

Ground water may be found in one continuous body or in several separate strata.

The thickness of the zone of saturation varies from a few feet to many hundreds of feet. Factors that determine its thickness are: the local geology, the availability of pores or openings in the formations, the recharge and the movement of water within the zone from areas of recharge toward points or areas of discharge.

CONNATE WATER

An important exception to the foregoing description of the origin of ground water is the continued presence of ancient sea water in some sedimentary formations.

The openings or pore spaces of materials that have been built up on ocean floors by sedimentation were originally filled with sea water. Some of these sediments were uplifted above sea level by later geologic processes of great magnitude. Salt water entrapped in the pores of the sediments was, of course, raised above sea level along with containing formation. Ground water of this origin is called connate water. (Connate means "originating together.")

As uplift of the land continued, the salt water began to drain out under the influence of the hydraulic gradient created by the uplift. Fresh water from precipitation, percolating downward, followed and replaced the slowly departing salt water.

Continued addition of fresh-water recharge flushed out more and more of the salt water. In many cases, displacement of all the original sea water is not yet complete. Connate water remains, therefore, in some formations in the zone of saturation.

Knowledge of subsurface structural conditions and the various controls which determine the presence and movement of water within geologic formations is the key to understanding ground water as a natural resource.

Formations or strata within the saturated zone from which ground water can be obtained for beneficial use are called aquifers. An aquifer is a water-saturated geologic unit that will yield water to wells or springs at a sufficient rate so that the wells or springs can serve as practical sources of water supply.

Water-bearing formation and ground water reservoir are other terms often used in place of the word aquifer. To qualify as an aquifer, a geologic formation must contain pores or open spaces which are filled with water, and these openings must be large enough to permit water to move through them toward wells and springs at a perceptible rate.

Both the size of the pores and the total amount of all pores in a formation can be small or large, depending upon the type of material. Individuals pores in a fine-grained material like clay are extremely small, but the combined volume of the pores in such a formation is usually large. While a clay formation has large water-holding capacity, water cannot move readily through the tiny open spaces. This means that a clay formation will not yield water to wells, and therefore it is not an aquifer, even though it may be water-saturated.

A coarse material such as sand contains larger open spaces through which water can move fairly easily. A saturated sand formation is an aquifer, because it can hold water and it can transmit water at a perceptible rate when pressure differences occur.

The upper surface of the zone of saturation is called the water table. The shape of the water table is controlled partly by the topography of the land and tends to follow, in a general way, the shape of the land surface.

WATER-TABLE CONDITIONS

Ground water in some aquifers occurs under water table conditions. This means that the upper limit of the aquifer is defined by the water table itself. At the water table--the top of the saturated portion of the geologic formation--the water in the pores of the aquifer is at atmospheric pressure as if it were in an open tank.

Under this condition, the aquifer itself is referred to as a water-table aquifer. The terms unconfined aquifer, unconfined ground water, and free ground water, are also used with reference to this form of ground-water occurrence.

The hydraulic pressure at any level within a water-table aquifer is equal to the depth from the water table to the point in question and may be expressed as hydraulic head in feet of water. For example, ground water at a depth of 50 feet below the water table is under a static hydraulic head of 50 feet.

When a well is drilled in a water-table aquifer, the static water level in the well stands at the same elevation as the water table.

In some cases, a local zone of saturation may exist at some level above the main water table. This situation can occur where an impervious stratum within the zone of aeration interrupts percolation and causes ground water to accumulate in a limited area above that stratum. The upper surface of the ground water in such a case is called a perched water table (Figure 8B-A3).

The water table is not a stationary surface but periodically moves up and down--rising when more water is added to the saturated zone by vertical percolation, and dropping during drought periods when previously stored water flows out toward springs, streams, wells, and other points of ground water discharge.

The zone of saturation may include both permeable and impermeable layers of earth materials. The permeable layers are aquifers. Where an aquifer is found between impermeable layers both the aquifer and the water it contains are said to be confined. Because of the presence of the upper confining layer, the water of the aquifer is not open to atmospheric pressure. It thus occurs within the pores of the aquifer at pressures greater than atmospheric.

Ground water in such a situation is said to occur under artesian conditions. The aquifer is called an artesian aquifer. The terms confined aquifer and confined ground water are also used to describe the occurrence.

ARTESIAN CONDITIONS

When a well is drilled through the upper confining layer and into an artesian aquifer, water rises in the well to some level above the top of the aquifer. The water level in the well represents the artesian pressure in the aquifer. The hydraulic head, expressed in feet of water, at any point within the aquifer equals the vertical distance from this level down to the point in question.

The elevation to which the water level rises in a well that taps an artesian aquifer is referred to by the technical term, piezometric level. An imaginary surface representing the artesian pressure or hydraulic head throughout all or part of an artesian aquifer is called the piezometric surface. This imaginary surface is analogous to the water table, in a water-table aquifer.

The hydrostatic pressure within an artesian aquifer is sometimes great enough to cause the water to rise in a well above the land surface. A flowing artesian well results. The static water level in this case is above ground and can be measured within the well casing if the pipe is extended high enough so that flow does not occur. Or, the flow can be contained by capping the well casing, after which the shut-in head can be measured with a pressure gauge.

INFILTRATION FACTOR

Explanation of the hydrologic cycle has shown that ground water occurrence is chiefly the result of infiltration from the soil and from streams and lakes, all of which receive their supply of water from precipitation--rain, snow, hail, dew, and frost.

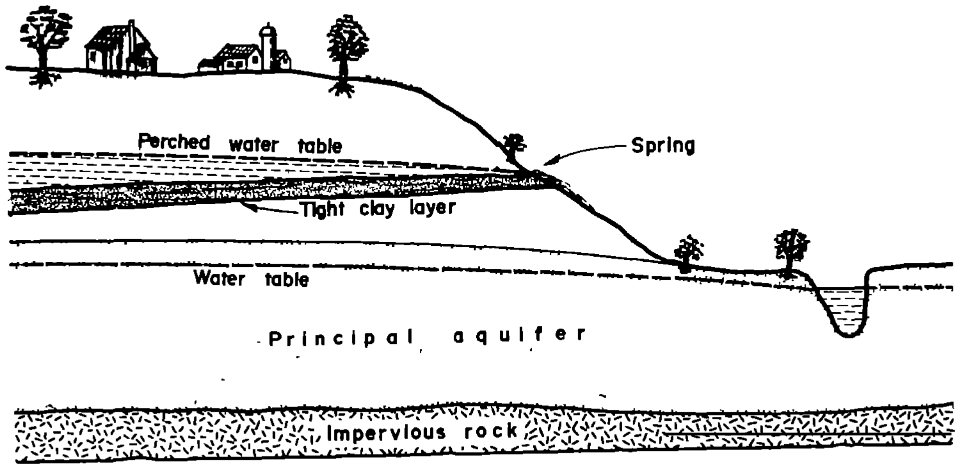
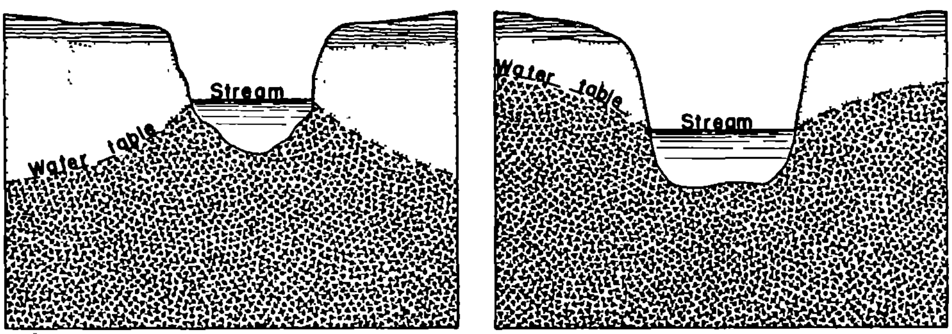
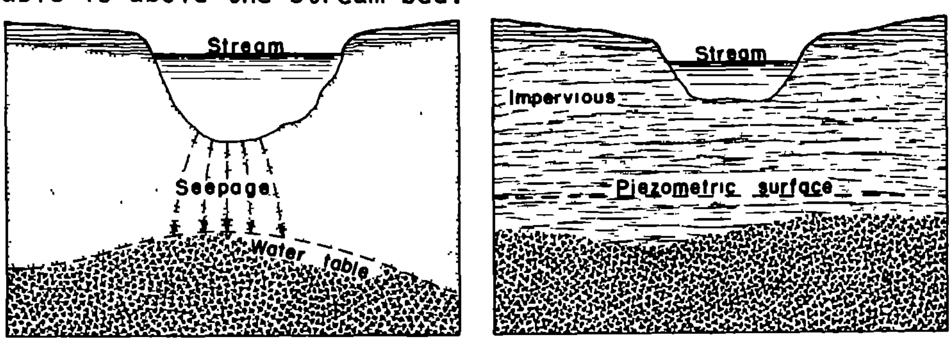


Figure 8B-A3 Perched water table occurs above impervious stratum and above the main water table.



Influent stream on the left loses water to the aquifer effluent stream on the right gains water from the aquifer because water table is above the stream bed.



Stream on the left flows only following periods of surface runoff, but is dry during droughts. Stream on the right is isolated hydraulically from artesian aquifer below it.

Figure 8B-A4 Ground water-surface water relationship

In some places, ground water reservoirs are replenished quickly by rain falling directly on the land surface above them. In other places, surface water in streams and lakes feeds the ground water reservoir, when water levels in these bodies of surface water are higher than the water table and where the stream channel or lake bed is permeable. A stream or a stretch of stream that contributes water to the zone of saturation is termed influent with respect to the ground water. If, on the other hand, ground water seeps into the stream channel from the zone of saturation because the water able is higher, the stream is termed effluent with respect to ground water (Figure 8B-A4). Some sections of a stream may be influent, whereas other stretches of the same stream may be effluent with respect to ground water.

The rate of replenishment to the ground water reservoir varies with the pattern of precipitation, surface runoff, and stream flow. It also varies with the permeability of the soil and other earth materials through which the water must percolate to reach the zone of saturation.

The opportunity for infiltration varies greatly with the condition of the soil, the moisture content of the soil at the time rain falls on the soil, and the drainage net within the water shed. The slope of the land surface is an important factor, too--steep slopes favor quick surface runoff; flatter slopes hold the water longer to favor infiltration. In many areas, gentle slopes seem to offer more favorable conditions than do the completely flat areas. Flat areas often develop tight surface soils. Soil texture as influenced by the land slope, then, plays an important part in the infiltration process.

Moderate rainfall over an extended period of time favors infiltration. Heavy rains saturate the surface soil quickly. Following this condition, most of the water falling during the storm runs off the surface to water courses. Heavy rainfall also compacts the soil and reduces its ability to absorb water. Infiltration of water from melting snow depends upon whether the sub-soil is frozen at the time melting occurs.

This brief discussion indicates that the factors which control infiltration of precipitation and natural recharge to the ground water reservoir fall into two groups. One group includes the size, slope, and other physical conditions of the watershed or drainage basin. The other group includes the climatic conditions, which vary greatly from season to season and year to year.

GEOLOGIC FORMATIONS AS AQUIFERS

The geologic history and the geologic processes that have acted in a given area have established the location, extent, and thickness of the water-bearing formations that we find today below the ground surface. Ground water occurs within the geologic framework. A good working knowledge of geology is needed, therefore, in order to apply the most practical and economical methods of getting ground water form the various sand and rock aquifers

Ground water occurs in consolidated rock materials (hard rock) and in loose unconsolidated materials (soft rock). Any type of rock--sedimentary, igneous, or metamorphic, whether consolidated or unconsolidated--may be an aquifer if it is sufficiently porous and permeable.

Sedimentary rocks constitute 5 percent of the earth's crust, but contain about 95 percent of the ground water. They are widely distributed and they possess excellent water-bearing properties. Materials deposited as sediments are derived from both weathering and erosion of pre-existing rocks. Deposition may take place in the ocean or on land. Sedimentary formations include both hard rocks and soft rocks.

One type of hard sedimentary rock is limestone which is chiefly calcium carbonate. A related sedimentary carbonate rock is dolomite which contains considerable calcium-magnesium carbonate. Most limestones and dolomites have little or no connected openings when first formed as marine sediments. Earth movemnts later produce fractures and crevices. Water enters these openings and, under some conditions, slowly dissolves a little of the rock. This action enlarges some of the openings to form solution channels. Where solution channels have developed, these hard rocks yield large quantities of water to wells.

Other kinds of sedimentary hard rocks have developed from sands and clays which have been transported by streams and deposited in the oceans. As layer upon layer of these sands and clays were laid down, the weight of the upper materials upon the layers below compacted the sands and hardened the clay into shale. Deposition of cementing materials in the voids of the sand layers during and after compaction hardened them into sandstones. Shale, and similar materials sometimes called siltstone or mudstone, are usually not aquifers. They may yield small quantities of waters to wells in local areas where earth movements have fractured these dense sediments.

Sandstone usually indicates deposition in a near-shore environment. It is principally silica (quartz) which is usually colorless. The wide range of colors seen in sandstone is due to the various agents that cement the grains together to form the rock. The water yielding characteristics vary widely because of the degree of cementation. Partially cemented or fractured sandstones yield the largest amounts of water.

Unconsolidated sediments that are aquifers include sand, gravel and mixtures of sand and gravel. These granular unconsolidated materials vary widely in particle size and degree of sorting, with correspondingly great variation in their water-yielding capabilities. As a whole, they are the best water-bearing formations. They are widely distributed, and they posses good storage and water transmitting characteristics.

Unconsolidated, sedimentary aquifers include marine deposits, alluvial or stream deposits, alluvial fans, and dune sand.

Many factors influence the water-bearing properties of sedimentary rocks. Weathering is an important one which includes both mechanical (disintegration) and chemical (decomposition) processes. If disintegration of rock is dominant, the resulting sediment is likely to be coarse-textured. If decomposition is dominant, a larger proportion of the sediment is silt and clay.

Disintegration is likely to be the main weathering process in cold and in arid climates, and where land slopes are steep. Decomposition is more common in warm, humid climates where land slopes are gentle.

Type of parent rock, mode of transportation, distance carried from source and environment of deposition are factors that can be more influential than weathering in particular cases. For example, disintegration of shale produces fine-grained sediments because of the nature of the parent rock. A sedimentary deposit derived from shale, therefore, will not be an aquifer. In contrast, sediments derived from granite or other crystalline rocks are likely to form good aquifers of sand and gravel.

IGNEOUS ROCKS

Igneous rocks are those formed when hot molten materials (magma) originating from great depths within the earth, cool and solidify. Magma which flows out at or near the ground surface is called lava. Solidification of lava flows produces fine-textured or glassy rocks because of relatively fast cooling.

Where the molten material solidifies at considerable depth below the surface, the cooling is slower and the resulting rock is coarse-textured. This latter is called intrusive or plutonic rock. Plutonic rocks usually are not porous, but in some places may supply small quantities of ground water. Granite is one of the plutonic rocks. The only openings they contain are crevices and fractures that occasionally occur in the upper part where the material has been weathered.

Materials that are ejected from a volcanic vent are called extrusive or volcanic rocks. Solidified lava flows, and ash or cinders that are thrown out as granular materials, are included in this class of igneous rocks.

Basalt lava (trap rock) is one of the chief volcanic rocks. Openings in basalt lava are commonly cracks or fractures. In some cases, highly porous rock has resulted from the development of gas bubble openings as the lava cooled. Basalt aquifers, then, contain water in crevices, interconnected vesicules (gas bubble openings) and brecciated or broken up tops and bottoms of successive lava layers.

Ash and cinders--fragmental materials erupted from volcanos--are called pyroclastics and are considered volcanic rocks. Particle sizes range from fine dust to large blocks. Deposits of these materials are stratified in complex fashion and their permeability varies greatly from place to place. Coarse ash or cinder bed deposits that are excellent aquifers are to be found in the Philippines and elsewhere.

METAMORPHIC ROCKS

Metamorphic rocks include igneous and sedimentary rocks that have been altered by heat and pressure. Under certain conditions, sandstone becomes quartzite; shale may change to slate and then change further to mica schist; and granite becomes gneiss. In general, these rocks are poor aquifers. The only water obtained is from cracks and fractures that may occur near the top of the geologic formation where the material has been weathered. One exception is marble, which is metamorphosed limestone. It is tougher than limestone but can be a good aquifer where fractured, and especially if solution channels have developed.

GEOLOGIC PROCESSES CREATE AQUIFERS

Geologic processes create rocks and aquifers--but later geologic processes can also destroy aquifers. New rocks are formed and spread upon older ones in a succession of layers. Once any sedimentary, igneous or metamorphic rock comes into being, continuing geologic events alter these same rocks in various ways that either improve or damage their water-bearing properties.

In the geologic scale of time, some changes may be said to occur rapidly. In man's scale of time, they occur so slowly as to be barely perceptible. But, mountains are being raised or lowered, valleys are being filled or deepened, seashores are advancing or retreating; and aquifers are being created or destroyed.

Rocks which form the crust of the earth have accumulated over eons of time. The history of these rocks is pieced together by geologists from the study of fossils found trapped in the rocks.

Ground water occurs in rocks of all ages. Generally, younger rocks are better aquifers than the older materials. The reason for this is that the older rocks are more likely to have been buried, compressed, and cemented--processes which have reduced their porosity and permeability.

Aquifers have a variety of shapes and structures. Some marine deposits of sandstone extend over large areas, are uniform in texture, and vary little in thickness. Other marine sandstones occur as discontinuous, lenticular beach deposits that may have limited hydraulic interconnection. Limestones, which are also marine deposits except in a few instances, occur as extensive formations. Their water yielding characteristics vary greatly from place to place because the degree of fracturing of the rock and enlargement of fractures as solution channels depend upon local conditions.

Basalt lava constitutes important aquifers in the Philippines. Water is found in cracks, fractures, interconnected vesicules (gas bubble openings) and brecciated or broken-up tops and bottoms of the rock layers. The water yielding capacity of basalt is difficult to predict because of the varied character of the openings. Wells situtated only a short distance apart may differ considerably in the rates at which they will yield water.

The joints and cracks in metamprophic rocks such as granite, gneiss, and quartzite, sometimes yield saml1 amounts of water. Aquifers in these types of rocks have no particular size or shape, but the ground water usually occurs near the top of the formation. The number and size of the openings diminish rapidly with depth. It is usually a waste of time, money, and effort to drill deeper than some tens of feet in these types of materials.

A number of unconsolidated sand formations which were deposited under marine conditions occur in low lying areas of the Phillipinees. They dip gently toward the sea. In terms of geologic time, they have been elevated only recently above sea level, and the lower portions of the aquifers still contain connate salt water. The aquifers are extensive and quite uniform in thickness.

TERRESTRIAL SEDIMENTS

Terrestrial sediments are materials deposited on land. They include stream, lake, and windborn deposits. In comparison to marine deposits, they are usually discontinuous and much less extensive.

Aquifers that are formed by alluvial or stream deposits generally are long and narrow. Usually they are the subsurace materials below the valley floor in the stream valley proper. Alluvial or stream deposits are also found as terraces above the valley floor. These are step-like relics from a time when the stream flowed at a higher elevation. Alluvial and stream deposits are also found in abandoned valleys where streams have left their old courses and followed new ones. The alluvial materials laid down by a stream along its abandoned course may later be buried under a blanket of windborn sediments, with the result that little evidence may remain at the land surface to mark the presence of the original valley. Material comprising alluvial aquifers ranges in particle size from fine sand to coarse gravel and boulders.

An alluvial fan is a special type of stream deposit. It is laid down at the base of a mountain where the land slope flattens. When a stream rapidly down a mountain slope encounters an abrupt change in gradient, the stream velocity decreases suddenly and the flowing water drops much of its sediment load. The load that it carries is material previously eroded from the upper slopes of the mountain. The result of this action is the deposition of large aprons of material at the foot of the slope, spreading out for some distance over the flatter terrain. Coarse sediments are dropped near the base of the mountain, finer sediments are carried farther but dropped successively as the stream velocity gradually decreases.

AQUIFER FUNCTIONS

An aquifer performs two important functions--a storage function and a conduit function. It stores water, serving as a reservoir, and transmits water like a pipeline. The openings or pores in the water-bearing formation serve both as storage spaces and as a network of conduits. The ground water is constantly moving over extensive distances from areas of recharge to areas of discharge. Movement is very slow, with velocities measured in feet per day or even feet per year. As a consequence of this and of the great volume represented by its porosity, an aquifer detains enormous quantities of water in transient storage.

Prior discussion has indicated that openings in subsurface geologic formations are of three general classes.

1. Openings between individual particles, as in formations of sand and gravel.

2. Crevices, joints, or fractures in hard rock which have developed from breaking of the rock.

3. Solution channels and caverns in limestone, and openings resultng from shrinkage and from the evolution of gas in lava.

Two properties of an aquifer related to its storage function are its porosity and its specific yield.

POROSITY

The porosity of a water-bearing formation is the part of its volume which consists of openings or pores--the proportion of its volume not occupied by solid material. Porosity is an index of how much ground water can be stored in the saturated material. Porosity is usually expressed as a percentage of the bulk volume of the material. For example, if one cubic foot of sand contains 0.30 cu. ft. of open spaces or pores, we say that its porosity is 30 percent.

While porosity represents the amount of water an aquifer will hold, it does not indicate how much water the porous material will yield.

When water is drained from a saturated material by gravity force, only part of the total volume stored in its pores is released. The quantity of water that a unit volume of the material will give up when drained by gravity is called its specific yield.

The part of the water that is not removed by gravity drainage is held against the force of gravity by molecular attraction and capillarity. The quantity that a unit volume retains when subjected to gravity drainage is called its specific retention. Both specific yield and specific retention are expressed as decimal fractions or percentages. Specific yield plus specific retention equals porosity.

If 0.10 cu. ft. of water is drained from one cu. ft. of saturated sand, the specific yield of the sand is 0.10, or 10 percent. Assuming that the porosity of the sand is 30 percent, its specific retention is 0.20, or 20 percent.

PERMEABILITY

The property of a water-bearing formation which is related to its pipeline or conduit function is called its permeability. Permeability is defined as a capacity of a porous medium for transmitting water. Movement of water from one point to another in the material takes place whenever a difference in pressure or head occurs between two points. Permeability may be measured in the laboratory by noting the amount of water that will flow through a sample of sand in a certain time and under a given difference in head.

Henri Darcy, a French engineer, investigated the flow of water through beds of filter sand and published his findings in 1856. His experiements showed that the flow of water through a column of saturated sand is proportional to the difference in hydraulic head at the ends of the column, and inversely proportional to the length of the column (Figures 8B-A5). This is known as Darcy's Law. It continues in use today as the basic principle that describes the flow of ground water.

It is expressed mathematically as: $V = P \frac{(h_1-h_2)}{l}$

where V is velocity of flow, $(h_1 - h_2)$ is the difference in hydraulic head, l is the distance along the flow path between the points where h_1 and h_2 are measured and P is constant depending upon the characteristics of the porous material through which the water flows.

By definition, the difference in hydraulic head $(h_1 - h_2)$ divided by the distance, l, along the flow path is fluid flow is the hydraulic gradient, I, so we have

$$V = PI$$

Usually the quantity of flow is of more interest than the velocity, so Darcy's Law can be written more conveniently as

$$Q = AV = PIA$$

where A is the cross-sectional area through which the water moves; and Q is a the quantity of flow per unit of time, for example, gallons per day.

In these equations, P is called the coefficient of permeability of the porous material. Its value depends on the size and arrangement of the particles in an unconsolidated formation and on the size and character of the surfaces of the crevices, fractures, or solution openings in a consolidated formation. It may change with any variation in these characteristics. The coefficient of permeability is the quantity of water that will flow through a unit cross-sectional area of a porous material per unit of time under a hydraulic gradient of 1.00 (100 percent) at a specified temperature.

For convenient use in well problems, P is expressed as the flow in gallons per day (gpd) through a cross-section of one square foot of water-bearing material under a hydraulic gradient of 1.00 and at a temperature of 60° F. The coefficient of permeability can also be expressed in the metric system using such units as liters per day per square meter under a hydraulic gradient of 1.00 and a temperature of 15.5°C.

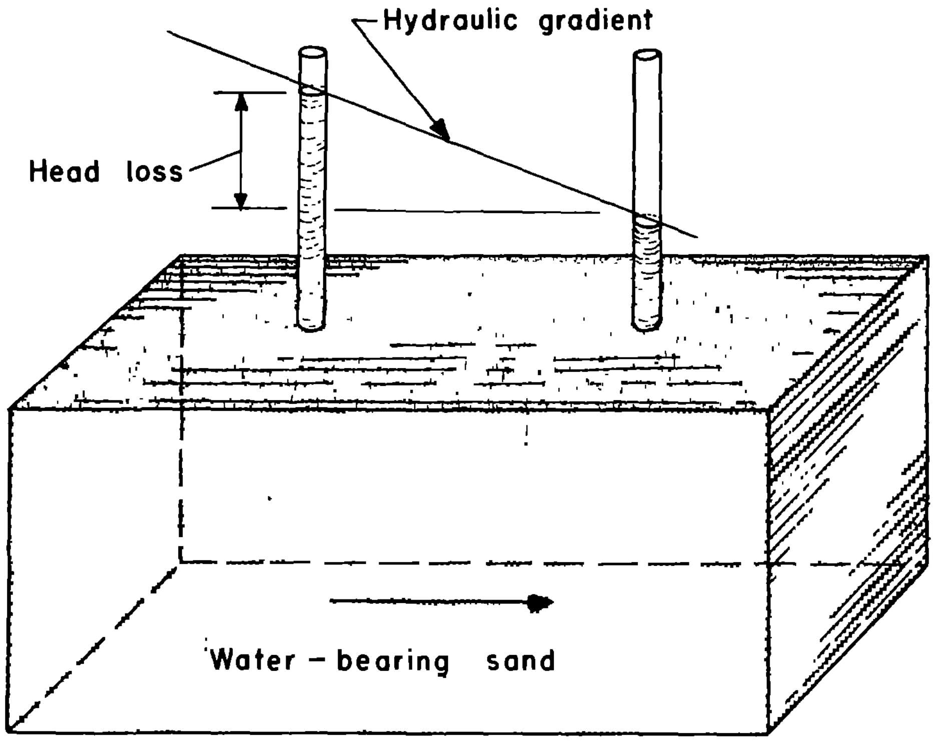


Figure 8B-A5 Head loss and hydraulic gradient must exist to cause flow of water through porous material. For a given sand, rate of flow is directly proportional to the hydraulic gradient. Gradient is the head loss between two points divided by the distance between the points.

APPENDIX H

Level I Seminar Training Schedule

APPENDIX H

LEVEL I SEMINAR TRAINING SCHEDULE
Batulao Resort, Nasaubu, Batangas
April 19 - 22, 1982
(As revised by Consultants during the Seminar)

	Time	Topic
DAY 1	8:00 - 11:00	Registration
	11:00 - 12:00	Opening Ceremony
	12:00 - 1:30	LUNCH
	1:30 - 2:15	Geology of the Philippines
	2:15 - 3:45	Introduction to Ground Water
	3:45 - 5:00	Well Siting
DAY 2	8:00 - 9:00	Well Siting (continued)
	9:00 - 10:00	Aerial Photos and Topographic Maps (Workshop)
	10:00 - 12:00	Water Well Design
	12:00 - 1:30	LUNCH
	1:30 - 2:30	Level I Waterworks Repair Shop and Spare Parts Inventory (by Oscar Basa)
	2:30 - 5:00	Installation and Repair of Hand Pumps (Practicum)
DAY 3	8:00 - 10:30	Methods of Well Construction and Development
	10:30 - 11:00	Well Testing
	11:00 - 12:00	Well Maintenance, Rehabilitation and Abandonment
	12:00 - 1:30	LUNCH
	1:30 - 6:00	Apron and Deep-Set Column Construction (Practicum)
DAY 4	8:00 - 9:00	Evaluation of Practicum
	9:00 - 10:00	Monitoring of Pumps (by Oscar Basa)
	10:00 - 11:30	Trouble-shooting Pump Problems (Practicum)
	11:30 - 12:15	Well Disinfection
	12:15 - 1:45	LUNCH
	1:45 - 2:30	Question and Answer Period
	2:30 - 3:00	Make-up Period (for late arrivers)
	3:00 - 4:00	Closing Ceremonies

APPENDIX I

Seminar Evaluation Results

APPENDIX I

**BWP LEVEL I HANDPUMP INSTALLATION AND MAINTENANCE
SEMINAR WORKSHOP - APRIL 19 - 22, 1982
BATULAO VILLAGE CLUB, NASUGBU, BATANGAS**

EVALUATION RESULTS

I. Relevance, Applicability and Practicability of subject matters discussed.

Subject Matter:	0 : Poor : 1	Fair : 2	S : 3	V.G. : 4	Avrg
1. Geology	1	16	53	20	2.47
2. Well Siting		13	45	28	3.17
3. Well Drilling		16	42	23	3.09
4. Well Development		13	42	31	3.21
5. Well Maintenance		15	42	29	3.16
6. Well Abandonement	2	17	43	28	3.08
7. Const. of Apron and Deepset Column		13	51	18	3.18
8. Installation and Repair of Handpumps	1	13	47	28	3.15
9. Level I WRS	1	16	47	22	3.05
10. Level I Monitoring	1	16	44	25	3.08
11. Trouble Shooting	4	13	44	22	3.01
12. Well Disinfection	2	14	47	23	3.06

Majority of the participants rated the relevance applicability and practicability topics as satisfactory. In their comments, it was stated that the topics were clearly delivered enough to be understood by the majority of the participants. The topics were presented well and more seminar of this type were most welcomed. Only it was further suggested that more time should be devoted to this kind of seminar activity.

II. Practicum

	Poor	Fair	S	V.G.	Avrg
1. Pump Repair	4	17	44	20	2.94
2. Apron Construction	1	21	52	12	2.87
3. Analysis of Aerial Photograph and Topographic Map	1	29	41	15	2.87
4. Trouble Shooting	2	19	43	19	2.95
5. Monitoring Circuit	3	16	45	22	3.00

Most of the participants rated the field exercises and practicums satisfactory. For the participants, the seminar workshop was a good experience having added another knowledge in their technical know-how especially in hand pump dismantling, assembling and installation.

III. Methodology Applied

	Poor	Fair	S	V.G.	Avrg
1. Lecture/Discussion		11	51	25	3.16
2. Film Showing	1	8	42	36	3.30
3. Workshops		8	28	37	3.40
4. Practicum		15	44	17	3.03
5. Open Forum		10	41	19	3.13

Effectivity of the methods used in imparting knowledge and skills.

The participants found the methodologies applied in the seminar workshop as effective and satisfactory in soliciting maximum participation.

IV. Resource Speakers	Poor	Fair	S	V.G.	Avrg
	0–1	1–2	2–3	3–4	
1. Tyler Gass		2	42	40	3.45
2. Alan Pashkevich		4	39	35	3.40
3. Oscar Basa		7	43	27	3.26

V. Administration of the Training

	Poor	Fair	S	V.G.	Avrg
1. Training Site	8	40	33	9	2.48
2. Accomodation	11	22	27	20	2.70
3. Food	18	19	33	14	2.51
4. Facilities	5	26	38	21	2.83
5. Others	2	3	8	6	2.95

Effectivity of the methods used in imparting knowledge and skills.

The participants found the methodologies applied in the seminar worshop as effective and satisfactory in soliciting maximum participation.

Effectivity of the Training in terms of the following:

a. Resource Speakers
b. Administration of the Training

The participants rated the resource speakers as satisfactory in imparting new additional knowledge and skills. On the other hand the overall administration of the training activity was said to be very satisfactory although it was suggested, however, that improvement in accomodations and facilities should be done better in the next training activities.

VI. Other Comments and Recommendations

A. Administration of the Training

1. Personnel managing the seminar should make a follow-up as to the accomodation of participants to see if they are comfortable. Some participants were not given the proper accomodations they expect it to be. Over crowding of participants in the cottages had cause inconvenience among the participants.

2. Proper accomodations should be given to the participants to make them ease and comfortable while away from home. Some of us slept in the floor while others were in bed.

3. Schedule of transportation facilities from Manila to Training site should be specified in the telegram or transportation facilities should be arrange for LGU's to avoid confusion of reaching the training site.

B. Methodologies

1. Part of the training activity should be sharing of actual experiences and problems encountered in well drilling and pump installation.

2. Devote more time for the question and answer portion; Devote more time for workshop/practicum.

3. During practicum or workshops, there should be no descrimination. Regardless of designation or position, everybody must participate in said activities.

4. Grouping of participants should be made by provinces since we will be the same persons working together when we reach our respective LGU's.

5. Techniks group must coordinate with the group especially in the discussion of topics to enable the participants to learn better.

6. Include Filipino consultants during seminars like level I since not all participants understands the English dialect.

7. Add more training hours and the manual should be bookbind so it will be nice for reference as the need arises.

C. Practicum/Workshops and Other Related Subjects

1. In the next training, lecturers should provide samples of water bearing rocks for identification.

2. More hours should be allocated for trouble shooting.

3. Photographs, film clips, slides to be shown during the seminars should be based on actual conditions and situations in the Philippines.

4. More training hours is needed in the explanation of Geology of Philippines/Introduction to Ground Water.

5. Pump installation should be made at proper sites of recipient barangays. Actual training on deepwell construction. Familiarization with deepwell pumps.

6. Include specification and procedures operating the testing kits, identification on wells and a practicum on how to accomplish a well log. Actual soil samples should be shown to the participants.

7. Pump repair and trouble shooting be given sufficient time. Laborers be hired to do actual work so that the participants can observe closely and perhaps learn more effectively.

8. Actual well drilling should be done. Technicians needs more training on deep well installation, motor pump showing actual demonstrations. Actual well drilling should be made on a place where there is actual water to observe how drilling is being done for the benefit of the new LGU's

9. Provision of all the necessary tools/equipments/materials should be made available to the seminarians, during practicum to facilitate better work. Apron construction and deepest column should be accompanied by well installation to be able to see actual installation of level I projects.

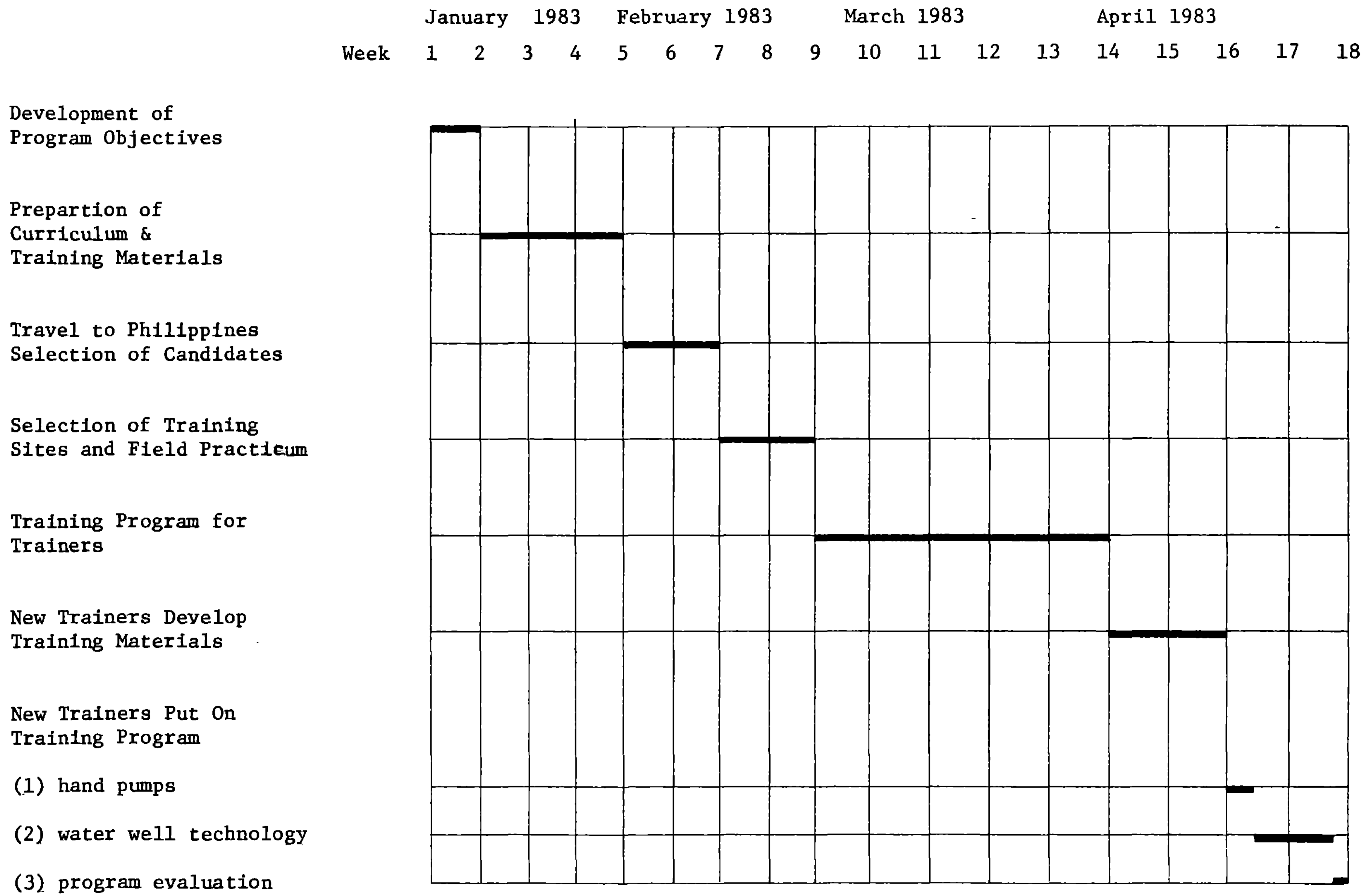
10. Dismantling and assembling of handpumps should be done by the participants in order that if they are already in the field they would be able to cope up with any deficiencies that might occur.

11. Field trips needed.

APPENDIX J

Recommendations for Future Training Seminars

PROPOSED SCHEDULE FOR TRAINING TRAINERS IN WATER WELL TECHNOLOGY



Training of USAID/Manila Engineers

At the present time, it is impossible to obtain training in the Philippines in the subject areas of hydrogeology and water well technology that would be of any value to the US/AID engineers. However, there are a number of one- to three-week courses given in the united States which would prove to be most valuable. Mr. Gass could probably arrange to have registration fees waived for attendance at these programs. Therefore the only cost for the training of the engineers would be airfare and lodging. In addition, the engineers could spend a week or two working with Mr. Gass in the field, so that they may observe methods of well site evaluation, well design and well construction.

Within three hundred miles of Columbus, Ohio, there are a half dozen rig manufacturers who could take these individuals through their factories and explain the operation of their equipment. This would be valuable since many LGU's have given serious consideration to drilling their own wells.

The combination of short course training, field experience, and evaluation of new drilling equipment could provide an excellent opportunity for enhancing the expertise of these individuals and thus add to the technical knowledge base of the Barangay Water Program.

WASH