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Groundwater Irrigation – Shallow Tubewell

DEPARTMENT OF AGRICULTURE
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PHILIPPINES

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Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancement of Nutrient and Water Use Efficiency Through Standardization of Engineering Support Systems for Precision Farming" funded by the Philippine Council for Agriculture, Aquaculture and Forestry and Natural Resources Research and Development - Department of Science and Technology (PCAARRD - DOST).

As provided by the Republic Act 10601 also known as the Agricultural and Fisheries Mechanization Law (AFMech Law of 2013), the Bureau of Agriculture and Fisheries Standards (BAFS) is mandated to develop standard specifications and test procedures for agricultural and fisheries machinery and equipment. Consistent with its standards development process, BAFS has endorsed this standard for the approval of the DA Secretary through the Bureau of Agricultural and Fisheries Engineering (BAFE) and to the Bureau of Philippine Standards (BPS) for appropriate numbering and inclusion to the Philippine National Standard (PNS) repository.

This standard has been technically prepared in accordance with BPS Directives Part 3:2003 – Rules for the Structure and Drafting of International Standards.

The word "shall" is used to indicate mandatory requirements to conform to the standard.

The word "should" is used to indicate that among several possibilities one is recommended as particularly suitable without mentioning or excluding others.

Groundwater Irrigation – Shallow Tubewell

1 Scope

This standard specifies the procedures in shallow tubewell design, installation and development within the limits of the capabilities of a suction lift pump.

2 References

The following normative documents contain provisions through which reference in this text constitute provisions in this National Standard:

PAES 127:2002	Agricultural Machinery – Drilling Rig – Specifications
PNS/BAFS/PAES 217:2017 Requirements	Determination of Irrigation Water

3 Definition

For the purpose of this standard, the following definitions shall apply:

3.1
aquifer
geologic formation which contains water and transmits it at a rate sufficient to be economically developed for pumping with a well

3.2
confined aquifer
aquifer where groundwater is confined or overlain by a relatively impermeable layer

3,3
effective size
particle diameter corresponding to a 10% sieve passing

3.4
pumping test
pumping of water from a fully developed well at a controlled rate and observing, with respect to time, the drawdown in two or more observation wells, in order to determine the aquifer hydrologic properties

3.5
shallow tubewell
tube or shaft vertically set into the ground at a depth that is usually less than 15 m for the purpose of bringing groundwater into the soil surface with the use of suction lift pumps

3.6
unconfined aquifer
aquifer which has water table serving as upper surface of the zone of saturation

3.7
uniformity coefficient
ratio of the particle size at 60% passing to that at 10% passing

3.8
well log
a record of formation stratification of an aquifer showing the depth, thickness, lithology and other aquifer physical characteristics (Figure A.1)

4 Site Selection

4.1 The site shall ensure adequate yield, which can be reflected through transmissivity and specific yield, and meet the required irrigation water requirements.

4.2 The site shall have adequate recharge of the aquifer system such that there is enough quantity of infiltrating water or is located at a reasonable distance from surface water bodies.

4.3 The water quality conditions of the aquifer shall meet the minimum quality requirements for irrigation water imposed by the national implementing agency.

4.4 The site shall be at an area with low vulnerability to pollution and seawater intrusion potential.

4.5 The site's slope, distance from existing boreholes or wells and from physical discharges of aquifers shall be determined and considered.

Table 1. Aquifer properties and their importance in well design, drilling and development, and in selection of pumping units

AQUIFER PROPERTY	IMPORTANCE OR RELEVANCE
Lithological Properties	
a. Depth of water bearing formation	Well design, well depth
b. Aquifer thickness	Well design, length of screened or perforated portion of well
c. Presence or absence of confining layer (confined, semi-confined or unconfined)	Well design, methods of well drilling and development
d. Thickness and hardness of confining layer or layers	Well design, methods of well drilling and development
e. Particle size distribution of aquifer materials	Well drilling, specifications of well perforations and gravel envelop in artificially developed wells
Soil Water Properties	
a. Water table or piezometric level (annual range of fluctuations)	Feasibility of suction lifting, groundwater withdrawal amounts before water level goes down below suction lifting range, well design, practical limits to STW deep setting, selection of pumping units
b. Groundwater quality (salinity, presence of toxic elements)	Suitability of water for irrigation
Hydraulic Properties	
a. Hydraulic conductivity or transmissivity	Well design, economic worth of aquifer as water source, well discharged-drawdown relationships, spacing of wells, maximum discharge under suction lifting, determining specifications of STW pumping units
b. Specific yield or storage coefficient	Established head-storage volume relationships and head-pump discharge relationships, well design, spacing of wells, specifications of pump sets
Recharge-discharge Properties	
a. Probable recharge	Estimating safe yields, groundwater conservation and management, planning STW irrigation projects
b. Usable recharge	
c. Groundwater discharge	
d. Safe yield	Shallow aquifer conservation and management, allocating GW resources

SOURCE: David, W.P. and M.A. Dorado. n.d. Gintong Ani STWIP: Aquifer Characterization

5 Well Characterization

Before proceeding to well design, construction and installation, it is necessary to determine aquifer characteristics listed above without the expense of a regular well. In cases where well logs and necessary information are not available, methods listed in Table 2 may be used.

Table 2. Various Methods Used for Well Characterization and Site Investigation

Methods	Principle
Surface Investigations	
Geologic Investigations	Preliminary basis in determining potential for groundwater development; consists of collection, analysis and hydrodeologic interpretation of existing topographic maps, aerial photographs, geologic maps and logs
Remote Sensing	Used to determine groundwater conditions from photographs of the earth taken from aircraft or satellite at various electromagnetic wavelength; specific methods include stereoscopic examination of black-and-white aerial photographs and infrared imagery
Geophysical Exploration	Uses scientific measurement of physical properties of the earth's crust for investigation of mineral deposits or geological structure; findings are interpreted in terms of rock type and porosity, water content and water quality
Electrical Resistivity Method	Determines actual resistivities from apparent resistivities computed from current and potential differences between pairs of electrodes placed in the ground surface; applications of this method include the delineation of geothermal areas, estimation of aquifer permeability, determination of areas and magnitude of polluted water
Seismic Refraction Method	Uses the introcution of a small shock at the earth's surface from the impact of a heavy instrument or by a small explosive charge, the time required for the resulting sound to travel to a known distance is then measured; these measurements are used to identify the type of geologic materials in the site and whether these are favorable or not for test drilling
Subsurface Investigations	
Test Drilling	Drilling of small-diameter holes to confirm geologic and groundwater conditions; often used as observation wells to measure water levels or for conducting pumping tests

	• Geologic Log – constructed from sampling and examination of well cuttings collected at frequent intervals during drilling • Drilling Time Log – consists of an accurate record required to drill each unit depth which can be interpreted in terms of formation and depth
Water Level Measurement	Determines the depth to groundwater, groundwater flow directions, changes in water levels over time and effects of pumping tests; variation of methods include electric water-level sounding, air-line method and automatic water level recording and the use of pressure transducers
Geophysical Logging	Uses sensing devices to determine a physical parameter which may be interpreted in terms of formation characteristics, groundwater quantity, quality, movement and physical structure of the borehole
Resistivity Logging	Uses current and potential electrodes in an uncased well to measure the resistivities of the surrounding media wherein the variation of its traces is related to depth
Spontaneous Potential Logging	Uses a recording potentiometer connected to two similar electrodes to measure the natural electrical potentials which is then used to determine permeable zones and to estimate total dissolved solids in groundwater
Radiation Logging	Uses the measurement of fundamental particles emitted from unstable radioactive isotopes in cased wells or open holes filled with any fluid; variation of this method include the use of natural gamma, gamma-gamma and neutron logging
Temperature Logging	Uses a recording resistance thermometer to obtain a vertical traverse measurement of groundwater temperature
Caliper logging	Uses caliper tools to measure the average diameter of a borehole which is used to identify lithologic properties and stratigraphic correlation, to locate fractures and other rock opening, and to correct other logs for hole-diameter effects

6 Types of Shallow Well

6.1 Dug Well – used in unconsolidated formations with large diameters which permit considerable water storage.

6.1.1 Materials - Wells are constructed through manual excavation using pick and shovel while the loose materials are hauled to the surface in a container.

6.1.2 Limitations:

- Walls must be lined or braced during and after construction
- Vulnerable to contamination from surface sources

6.2 Bored Well/Augered Well – used in formations with very shallow water depths

6.2.1 Materials – Wells are constructed using hand-operated or power-driven earth auger while the loose materials collected in the blades are removed and then boring is repeated until the desired depth and diameter of the well is achieved.

6.2.2 Limitation - Should only be used in formations that do not cave; otherwise, a casing is required to be lowered down the bottom of the hole.

6.3 Driven Well – used in unconsolidated formations with shallow water tables that contain not too many rocks

6.3.1 Materials - Consists of a series of connected lengths of pipe driven by repeated impacts to the ground below the water table. Water enters through the drive point at the lower end of the well with a screened cylindrical section. Driving can be done with a maul, sledge, drop hammer or air hammer

6.3.2 Limitations

- Cannot be used on formation with large gravel or rocks that may damage the drive point
- Joints between the pipes must be carefully made to prevent breakage and ensure airtight pipe system

6.4 Jetted Well – constructed by the cutting action of a downward-directed steam of water to excavate the hole and carry the excavated materials out of the hole.

7 Discharge

7.1.1 The irrigation water requirement shall be determined based on PNS/BAFS/PAES 217:2017 – Determination of Irrigation Water Requirements.

7.1.2 The required pump discharge shall be computed based on the following formula:

$$Q_r = \frac{IWR}{h} \times 24$$

where:

Q_r	is the required pump discharge (lps)
IWR	is the irrigation water requirement (lps)
h	is the number of hours of operation (h)

7.1.3 The maximum sustained yield that can be extracted from the aquifer shall be determined using the formula below:

7.1.3.1 Under a steady-state condition in confined aquifers,

$$Q_s = \frac{2\pi kb(h_2 - h_1)}{ln\frac{r_2}{r_1}}$$

where:

Q_s	is the maximum sustained yield (m^3/s)
k	is the hydraulic conductivity (m/s)
b	is the aquifer thickness (m)
T or kb	is the transmissivity (m^2/s)
h_2, h_1	is the piezometric water levels at r_2 and r_1, respectively (m)
r_2, r_1	is the distance from pumping well to observation wells 2 and 1, resp. (m)

7.1.3.1 For unconfined aquifers,

$$Q_s = \frac{\pi k({h_2}^2 - {h_1}^2)}{ln\frac{r_2}{r_1}}$$

7.1.4 Compare the required pump discharge and maximum sustained yield.

7.1.4.1 If Q_r is less than Q_s, the design pump discharge (Q_d) shall be Q_r.

7.1.4.2 If Q_r is greater than Q_s, Q_d shall be the adjusted value of Q_r. If Q_r is greater than Q_s by less than 15%, the value may be adjusted by increasing the hours of operation or area for non-rice crop. If Q_r is greater than Q_s by more than 15%, additional tubewell may be needed

8 Shallow Tubewell Design, Installation and Development in Confined Aquifer

8.1 Tubewell Design

8.1.1 The tubewell shall be designed such that the discharge is sustainable to meet the design water requirements, long economic life, low initial cost, low maintenance and operation costs of the system.

8.1.2 Based on the well log, the water bearing formation with the greater amount of coarse sand and/or gravel present in the aquifer shall be identified for tapping.

8.1.3 If more than one water bearing formation is identified, both formations can be tapped (as shown in Figure A.1.3) for cases where the expected yield from either formation is not sufficient to meet the projected requirements or where the characteristic well losses and pumping costs are to be minimized. In such case, the aquifer in the deeper portion of the well shall be developed first.

8.1.4 The tubewell may be designed such that a smaller diameter borehole is drilled all the way down to the second aquifer, and the open end of the pipe is nested on the lower confining layer as shown in Figure A.1.4.

8.1.5 The tubewell may be designed as a well point system such that two wells are drilled as shown in Figure A.1.5 where each well shall be developed separately then joined and pumped by a single pump set.

8.2 Pipe Selection

8.2.1 The pipe diameter shall be based on the design discharge. For practical purposes, Table 3 presents the recommended pipe diameters for various design discharge and cropping area.

Table 3. Recommended Pipe Diameter Based on Discharge in a Rice-Based Cropping System

Design Discharge, lps	Area, ha	Pipe Diameter, mm (in)
3.8	<1	50 or 75 (2 or 3)
7.6	>2	75 or 100 (3 or 4)
>7.6	>2	100(4)
NOTE: The above recommendations are based on the irrigation service area are for crop water requirement of about 11 mm/day and a 10-hour per day pump operation.		

SOURCE: David, et al, Technical Bulletin No. 1 Gintong ani shallow tubewell irrigation project: design, installation and development of shallow tubewell. DA-UPLBFI STWIP, 1997

8.2.2 For a well point system, the combined cross-sectional areas of the pipes shall not be less than that recommended for a single pipe of similar discharge.

8.2.3 Pipe materials may be selected as GI or PVC. Table 4 shows the recommended materials based on the type of well and confining layer.

Table 4. Recommended Pipe Materials

Type of Well	Pipe Material
Artificially developed	Schedule 20 GI or PVC
Naturally developed with design depth of ≤ 9 m (30 ft)	Schedule 20 GI
Naturally developed with relatively soft confining layer	Schedule 20 GI
Naturally developed with hard confining layer	Schedule 40 GI

SOURCE: David, et al, Technical Bulletin No. 1 Gintong ani shallow tubewell irrigation project: design, installation and development of shallow tubewell. DA-UPLBFI STWIP, 1997

8.3 Extent of Aquifer Penetration

Table 5. Aquifer Penetration Based on the Type of Well

Type of Well		Extent of Aquifer Penetration
Artificially developed		100%
Aquifers of > 4.6 m thickness		85% of the aquifer thickness
Naturally developed	design discharge of < 15 lps	< 25%
	design discharge of > 15 lps	50% - 100%

SOURCE: David, et al, Technical Bulletin No. 1 Gintong ani shallow tubewell irrigation project: design, installation and development of shallow tubewell. DA-UPLBFI STWIP, 1997

8.4 Pipe Length

The total pipe length for a single borehole can be computed based on the formula below and Figure 1.

$$Pipe\ length = E + D + (B \times \%penetration)$$

It must be noted that at least 1.2 m (4 ft) shall be added for the nipples needed in the installation of the pumping unit.

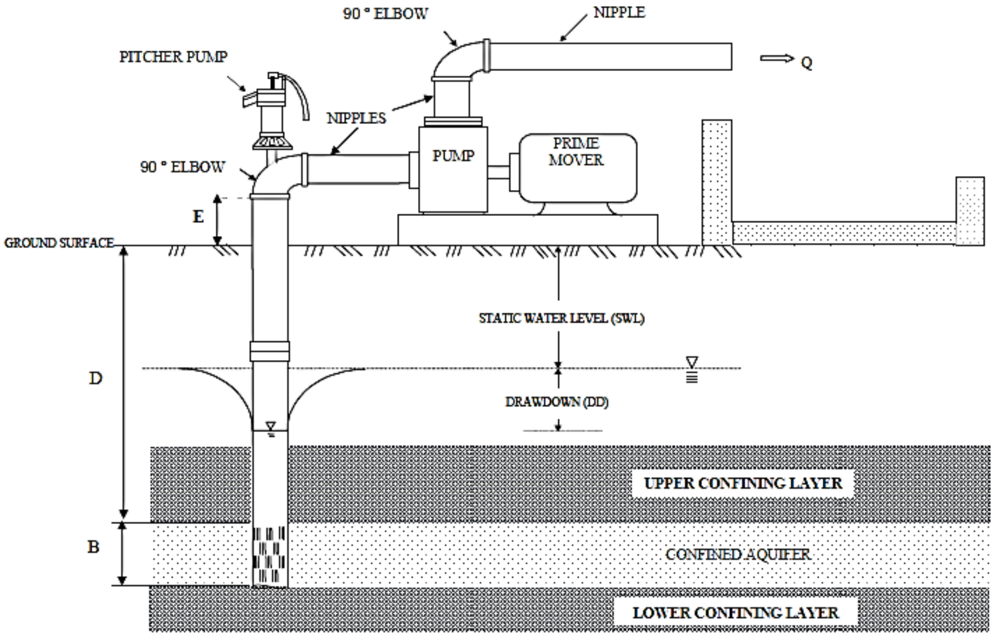

Figure 1. Pipe Length Estimation

8.5 Pipe Perforations

8.5.1 Well pipes can be perforated by cutting with oxyacetylene torch vertical slots 3 to 6 mm in width and 60 to 90 mm in length around the pipe sections penetrating the water-bearing formations.

8.5.2 The total area slot openings shall be at least 15% of the surface area of the pipe.

8.5.3 The pipe bottom shall be open.

8.6 Well Drilling and Pipe Installation

8.6.1 Using the suitable drilling technology, a pilot borehole shall be drilled down to the design depth. One of the most common drilling technologies is a drilling rig specified in PAES 127:2002 – *Agricultural Machinery – Drilling Rig – Specifications.*

8.6.2 The pilot borehole shall be reamed down to the upper edge of the confining layer if the confining layer is soft or less than 3m thick, or down to the lower 2 meters if the confining layer is hard, to ensure air-tight connection between the pipe and the confining layer.

8.6.3 The pipe can be installed as follows:

8.6.3.1 Lower the pipe into the reamed borehole. If resistance is encountered, turn the pipe gradually with two pipe wrenches held by one or two persons riding on them to enhance pipe penetration downward.

8.6.3.2 Drive by hammering the pipe through the confining layer down to its designed depth. Avoid turning the pipe during driving as it might destroy the air-tight connection between the pipe and the confining layer.

8.6.3.3 Careful and controlled water jetting to unclog the pipe may be done if extreme difficulty is encountered in driving the pipe. Avoid jetting while the perforated portion of the pipe is in the confining layer. Avoid jetting when the upper end of the pipe being driven is still high above the ground. The high static head within the pipe may force water to seep through or bubble up at the side of the pipe.

8.6.3.4 When the upper end of the screen (slotted portion) has been driven below the confining layer, jetting or surging may be carried out with higher velocity water jet.

8.6.3.5 Use good quality couplings (do not use cast couplings). During driving, couplings may loosen out. Keep couplings tight during driving. However, avoid turning the lower portion of the pipe when tightening the couplings.

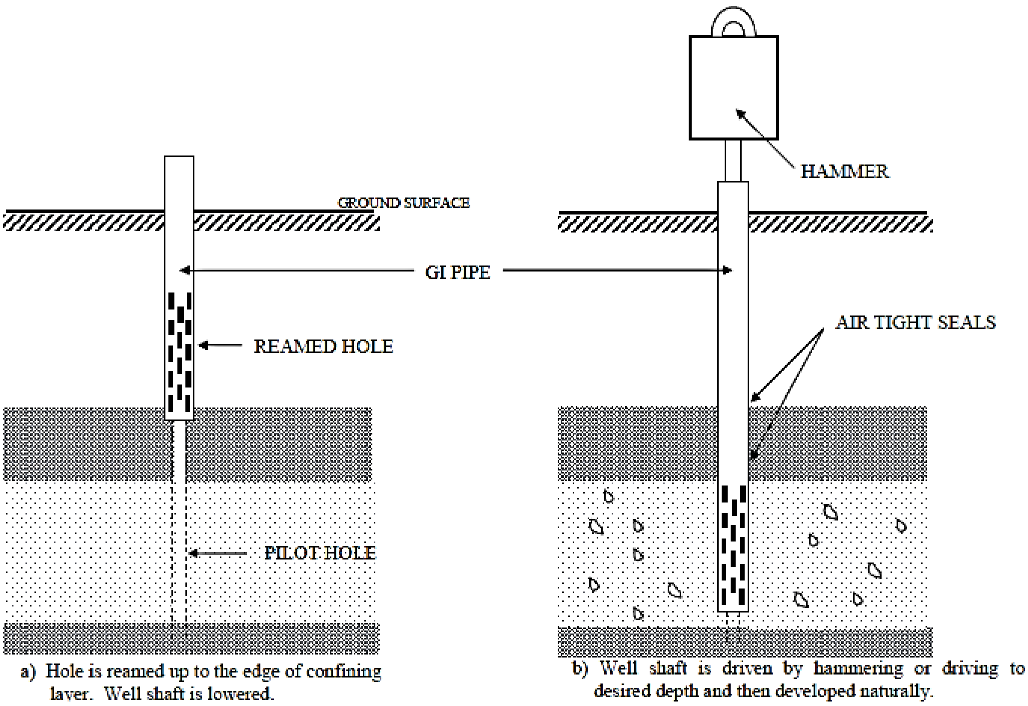

Figure 2. Method of constructing and developing shallow tubewell in shallow confined aquifer

8.7 Well Development

The well shall be developed to increase its discharge capacity, prevent sand pumping, attain sustained yield and obtain maximum economic life. Different methods can be used such as pumping, surging, surging with air, backwashing with air, hydraulic jetting or hydraulic fracturing.

8.7.1 Jetting

8.7.1.1 After installation, jet the well to remove the trapped drilling mud and the fine aquifer materials. The drilling stem may be fitted with an enlarged jetting head. Rapid up and down motion of the jetting head will cause water to surge in and out of the well openings.

8.7.1.2 Start jetting at the bottom of the well until the entire length of the perforated pipe is cleaned.

8.7.1.3 In aquifers with considerable amounts fine particles or in cases where considerable amounts of drilling mud are added to the drilling fluid to stabilize formation during drilling, surging may be done alternately with jetting to speed up the initial step in well development.

8.7.2 Pumping at low discharges

8.7.2.1 Attach a pump to the tubewell and initially operate at very low and controlled discharge by attaching to the outlet of the pump set a small hose (about 1 to 1-1/4 inch in diameter) and control the discharge further by restricting the opening of the hose.

8.7.2.2 After the initial pumping at low discharge, stop the pumping for about 10 minutes, after which, resume pumping.

8.7.2.3 Repeat the process until the discharge water clears up. Then slightly increase the pumping discharge and repeat the process of starting and stopping the pumping operation.

8.7.2.4 Complete the process until well discharge of clear water is at least a third of the design discharge.

8.7.3 Pumping at intermediate and higher discharges

8.7.3.1 Develop the well at intermediate discharges and up to a pumping rate that is 50 percent or more of the design pump discharge. This may require a bigger pump and/larger diameter pump outlet pipe or hose.

8.7.3.2 Pump at a discharge equal to or slightly higher than the highest level reached during the second stage of development. Maintain the discharge at this level until the water clears out.

8.7.3.3 Put the engine throttle to minimum for a few minutes then increase to attain pump discharge higher than the previous one. Continue pumping until the water clears out.

8.7.3.4 Repeat the process until the pumping rate that is 50 percent or more of the design pump discharge is attained.

9 Shallow Tubewell Design, Installation and Development in Unconfined Aquifer or with Weak Confining Layer

9.1 Pipe Selection

9.1.1 The pipe shall be designed for full aquifer penetration while the diameter and material shall be selected based on Table 3 and Table 4.

9.1.2 A gravel pack shall be designed to support the borehole against caving or formation collapse, to prevent sand pumping after the development and to minimize characteristic well losses.

9.1.2.1 The effective size (ES) and uniformity coefficient (UC) of the aquifer materials shall be determined from the mechanical analysis of the aquifer materials such as sieve-hydrometer and sieve-pipette method of particle size distribution analysis.

9.1.2.2 The gravel pack specifications shall be determined based on the following critera:

9.1.2.2.1 In aquifers with UC less than 2.0 and ES less than 0.30 mm, a uniformly grained gravel envelop is needed. The gravel pack should be at least 15 cm thick.

9.1.2.2.2 In aquifers with UC greater than 2.0 but with ES less than 0.30 mm, a graded gravel pack is desirable. The gravel pack should be at least 15 cm thick.

9.1.2.2.3 In aquifers with ES greater than 0.30 mm, a gravel pack is needed solely for the purpose of supporting the borehole. A 4 - 7 cm gravel envelop will suffice.

9.1.2.3 For gravel pack material gradation, the following recommendations of the US Bureau of Reclamation may be adopted:

9.1.2.3.1 For uniformly grained sand (UC less than 2.0 and ES less than 0.30 mm)

- Multiply the diameter of the aquifer material at 50% passing by 5 and 10 to get two plotting points. Draw a straight line passing through these points on the same aquifer particle size distribution or gradation curve (Figure 3). The lines should be approximately parallel to the average slope of the aquifer gradation curve.

- The optimum gradation of the gravel pack should fall between the two lines or
limits. A more or less uniformly grained gravel pack can be used.

- Well screen or perforation slot size should be less or equal to ½ of 85% passing of the gravel pack materials. In the example shown on 3, the 85% passing is about 6 mm and the recommended screen size should be equal to or less than 3.0 mm.

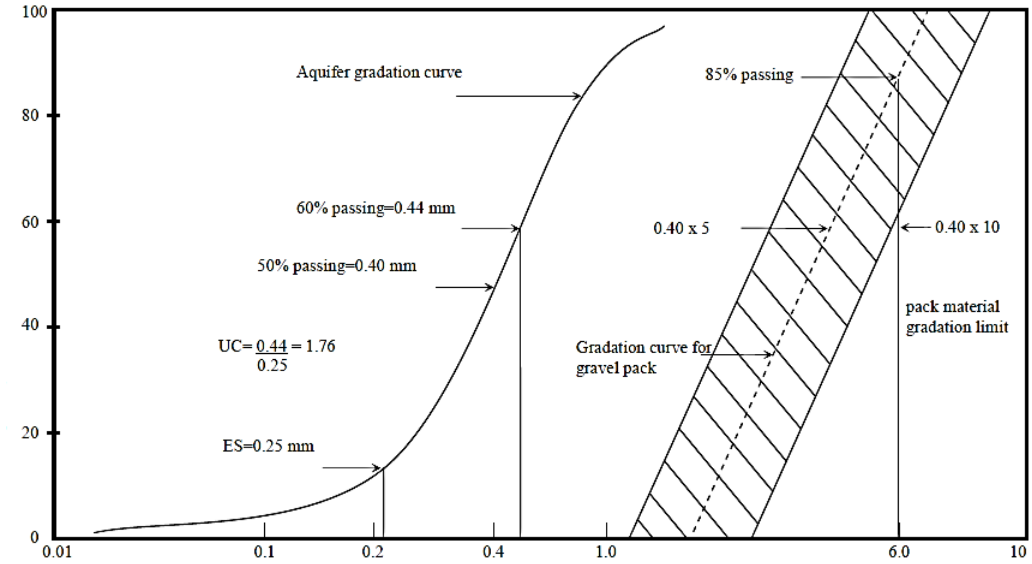

Figure 3. Gradation Curves for Aquifer Materials and for Uniformly Grained Gravel Packs

9.1.2.3.2 For graded pack aquifer materials (UC greater than 2.0 and ES less than 0.30 mm)

- Multiply 50% passing size of the aquifer material by 12 and 58; multiply 15% passing size by 12 and 40. Plot the points and limiting curves as shown on Figure 4.

- No pack material should exceed 15 mm. This will set an upper size limit to gravel pack materials.

- Gradation curve of pack material (as shown in dashed lines) should fall between the limits and should approximately be parallel to the aquifer gradation curve in between 10 and 50 percent passing.

- Screen or perforation slot sizes should be less than ½ of the 85% passing diameter of the graded gravel pack. In the example on Figure 4 the 85% passing of the gravel pack materials is about 14 mm and the screen size should be equal to or less than 7.0 mm.

- The screen opening for aquifers with ES greater that 0.30 mm should be determined as in the case of graded sands (UC less than 2.0 and ES less than 0.30 mm).

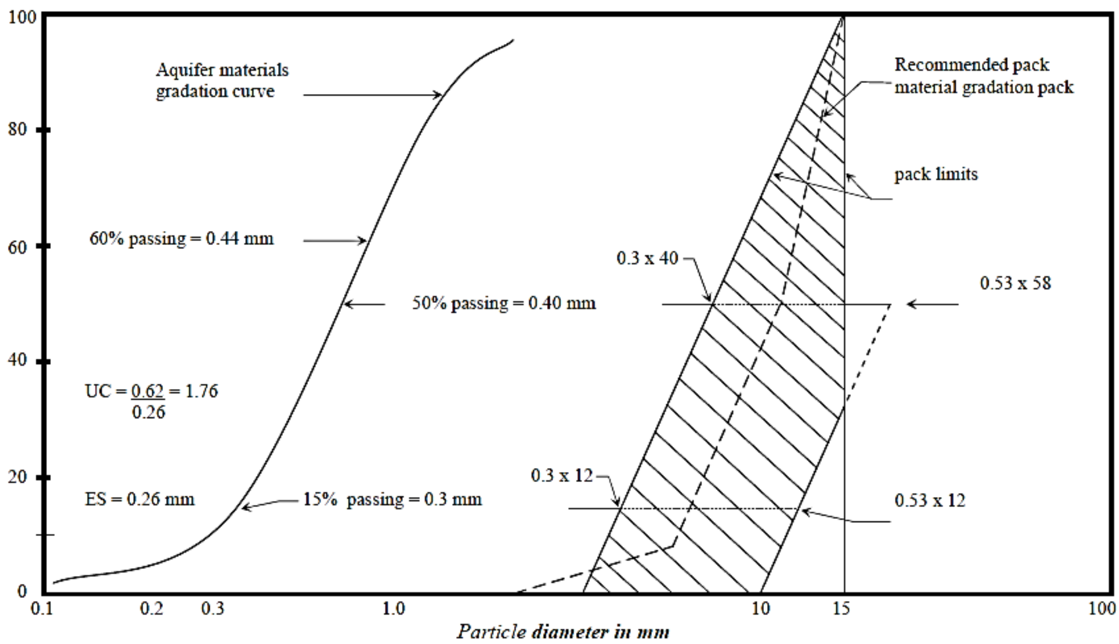

Figure 4. Gradation curve for aquifer materials and recommended gradation curve for gravel envelop

9.2 Pipe Perforations

The length of the perforated section of the pipe should then be determined as follows:

9.2.1 Design for full aquifer penetration.

9.2.2 Estimate the maximum expected drawdown when pumping at the designed discharge.

9.2.3 Perforate or screen the pipe from the maximum expected drawdown down to near the end of the pipe. (The bottom of pipe should be plugged).

9.2.4 When the aquifer hydraulic and hydrologic characteristics are not known, it is not possible to estimate the maximum drawdown. In such cases, the following rules of thumb may be used:

9.2.4.1 In areas with good aquifer materials (gravel and sand) and where the water table or piezometric water level is not more than 6 ft from the soil surface even during the dry season, design for a maximum drawdown of 10 ft. Perforate the pipe from the estimated water level at maximum drawdown down to near the end of the pipe.

9.2.4.2 In all other cases, perforate the pipe from 22 ft depth (practical suction lifting range) all the way down to the end of the pipe.

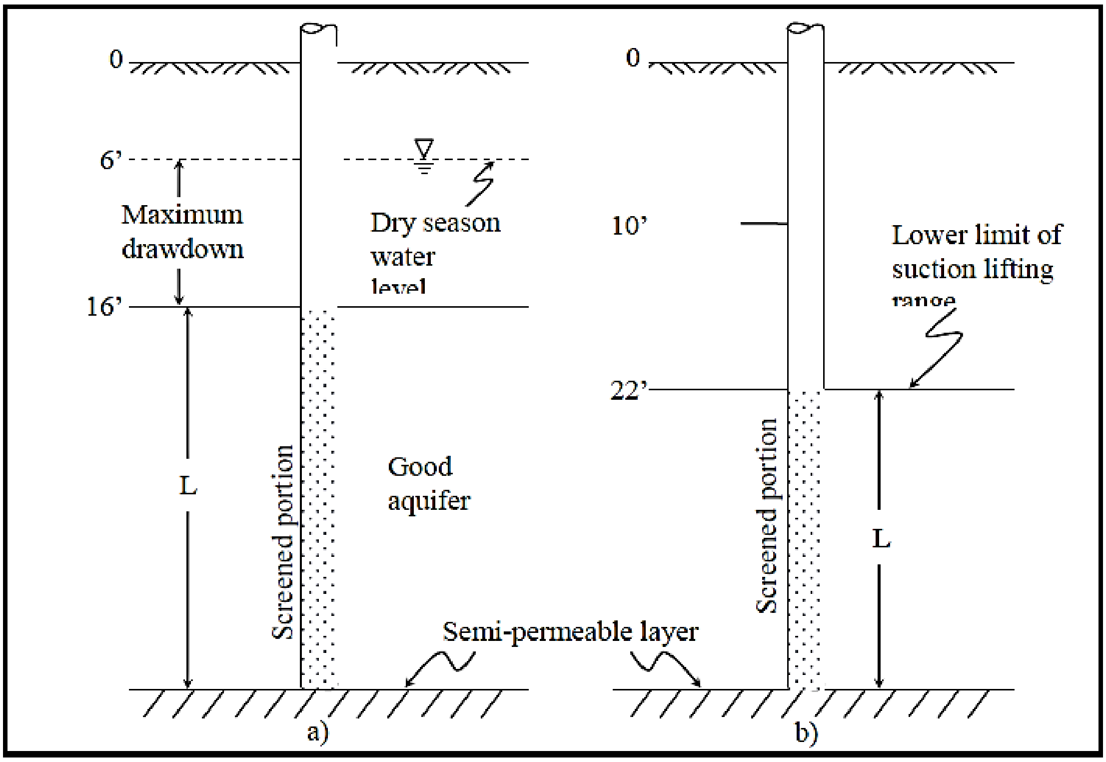

Figure 5. Recommended lengths of perforated pipe section

9.3 Pipe Installation

7.3.1 Enlarge the borehole down to the designed well depth using a 6-to-8-inch diameter drill bit. This will create an 8-to-12-inch diameter borehole. In loose, easy-to-disturb formations, stabilize the sides of the borehole by adding bentonite (or other suitable clay materials) to the drilling fluid.

9.3.2 Lower the pipe quickly and carefully to avoid disturbing the borehole.

9.3.3 Keep the pipe centered and aligned.

9.4 Gravel Pack Fitting

9.4.1 Pour the gravel in the space/clearance between the pipe and the borehole, up to near the soil surface to allow for setting or consolidation during the process of development.

9.4.2 If a thick (20 cm or more) gravel envelope is desired, a 2-to-2.5 inch diameter gravel pipe may be drilled near the wall of the pipe down to the upper edge of the well perforations.

9.4.3 Add gravel as needed after development. (Do not grout the well until well development is complete).

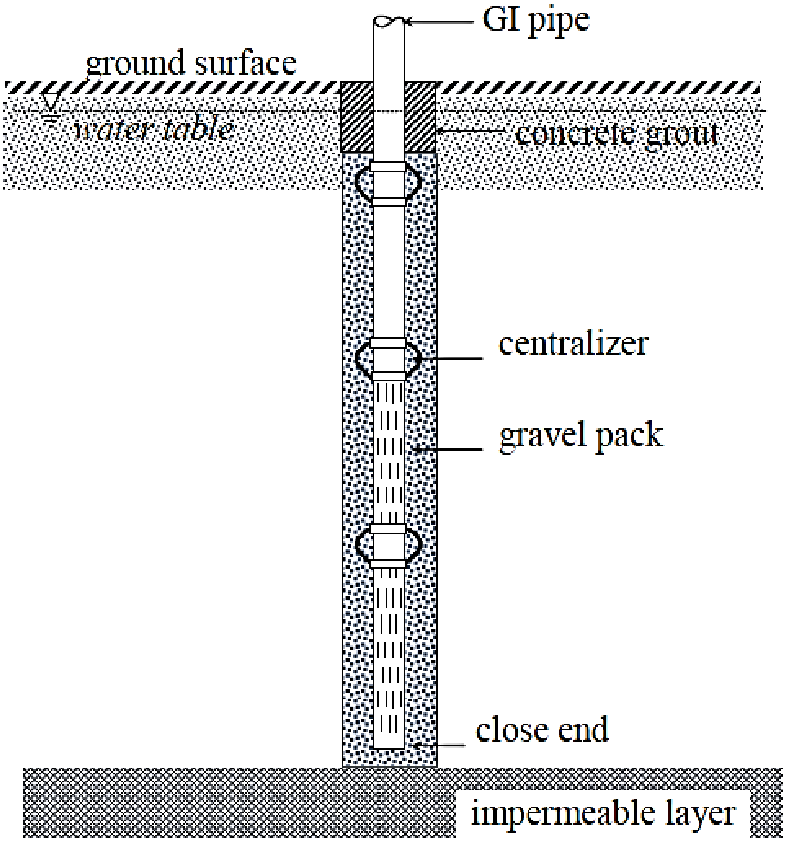

Figure 6. Vertical cross-section of a gravel-packed well

9.5 Well Development

A procedure similar to that for confined aquifer may be used in well development in
unconfined aquifer. However, the presence of the gravel envelope makes well development relatively slow. The use of a heavy duty air compressor is, therefore, desirable.

9.5.1 Use a ¾ to 1-inch diameter air line or pipe.

9.5.2 Initially, place the air pipe inside the well down to the top of the screened portion of the well.

9.5.3 Release a sustained air pressure of at least 100 psi (120-150 psi is desirable). This creates a powerful surge within the well forcing the water with drilled materials up the discharge pipe. When the water coming out of the well begins to clear, shut down the pressure for a few minutes before turning it on again. Keep the process of alternately switching the air pressure on and off until the water coming out of the well clears out of sand.

9.5.4 Lower the air pipe a few feet and repeat the whole process until the air pipe reaches the bottom of the well.

9.5.5 The air pipe may then be repositioned and the air pressure be quickly turned on and off until the water coming out is practically free of sand.

9.5.6 Add gravel into the space between the pipe and borehole as necessary, during well development.

10 Selection of Pumping Unit

10.1 Pump Power Determination

10.1.1 The total dynamic head shall be computed as follows:

$$TDH = SWL + H_f + DD + H_{sf}$$

where:

TDH	is the total dynamic head, m
SWL	is the static water level, m
H_f	is the friction losses in the pipes, m (Table 4)
DD	is the maximum drawdown when pumping at the design discharge, m
H_{sf}	is the 0.6 m (2 ft) to account for other head losses

Table 4. Friction losses on GI pipe per 3 m (10 ft) length

PIPE FLOW RATE		PIPE NOMINAL DIAMETER					
		2 inch (50.8mm)		3 inch (76.2mm)		4 inch (101.6mm)	
lps	gpm	ft	m	ft	m	ft	m
3.15	50	1.00	0.30	0.14	0.04		
4.73	75	2.12	0.65	0.29	0.09		
6.31	100	3.61	1.10	0.50	0.15		
7.89	125	5.47	1.67	0.76	0.23		
9.46	150	7.65	2.33	1.06	0.32	0.26	0.08
11.04	175	10.19	3.10	1.42	0.43	0.35	0.11
12.62	200	13.05	3.98	1.82	0.55	0.45	0.14
14.20	225			2.26	0.69	0.56	0.17
15.77	250			2.74	0.84	0.68	0.21
17.35	275			3.27	1.00	0.81	0.25
18.93	300			3.85	1.17	0.95	0.29
20.50	325			4.46	1.36	1.10	0.33
22.08	350			5.11	1.56	1.26	0.38
23.66	375			5.81	1.77	1.43	0.44
25.24	400			6.55	2.00	1.63	0.50
28.39	450			8.15	2.48	2.01	0.61
31.55	500			9.91	3.02	2.44	0.74

SOURCE: David, et al, Technical Bulletin No. 1 Gintong ani shallow tubewell irrigation project: design, installation and development of shallow tubewell. DA-UPLBFI STWIP, 1997

10.1.2 The brake horsepower shall be computed as follows:

$$BHP = \frac{TDH \times Q_d}{102 \times E_p}$$

where:

BHP is the brake horsepower (kW)
TDH is the total dynamic head (m)
Q_d is the design pump discharge (lps)
E_p is the pump efficiency (assume 55%)

10.2 The pump shall be selected based on the computed pump design discharge and total dynamic head and performance characteristics.

10.3 Prime Mover Specifications

The prime mover shall be selected based on the computed brake horsepower. Its full load continuous duty horsepower shall be greater than the pump brake horsepower. If such information is not available, Table 5 may be used.

Table 5. Estimated body indicated power rating of various prime movers

Prime Mover	Body Indicated Power Rating
Electric motor	$1.15 \times BHP$
Diesel, water-cooled	$(1.25 - 1.30) \times BHP$
Diesel, air-cooled	$(1.30 - 1.35) \times BHP$
Gasoline, water-cooled	$(1.35 - 1.40) \times BHP$
Gasoline, air-cooled	$(1.40 - 1.50) \times BHP$

SOURCE: David, et al, Technical Bulletin No. 1 Gintong ani shallow tubewell irrigation project: design, installation and development of shallow tubewell. DA-UPLBFI STWIP, 1997

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ANNEX A
(informative)

Well Logging

Procedures described below is a practical method of determining the physical characteristics of an aquifer adopted from Gintong Ani Shallow Tubewell Irrigation Project Technical Bulletin No.1. Other recommended methods include geophysical logging, resistivity logging, spontaneous potential logging, radiation logging, temperature logging, caliper logging, fluid-conductivity logging and other subsurface methods.

A.1 Drill a small borehole using a drill bit with a diameter of 2 inches or smaller. If drilling in unstable, easily disturbed formations, mixing one-to-one lattice clay (bentonite, potter's clay or termite mound) with the drilling fluid to plaster the wall of the borehole during drilling and reduced water jet pressure and revolutions per minute of drilling stem to reduce the horizontal component of the drilling mud velocity may be used.

A.2 Drill the borehole (as deep as 45 m or 150 ft if necessary) until a good aquifer is found. A good confined aquifer is one that is dominated by gravel and sand, with a thickness of at least 3 m (10 ft).

A.3 Use a pail to collect a sample of a predetermined volume (approximately 14 liters) of the drilled materials at every 1.5 m depth interval and when there is an indication of a change in geologic formation (change in the rate of penetration of the drill bit, in hardness of formation or in the particle size distribution of the drilled materials coming out).

A.4 Carefully pass each sample through a set of screens or sieves with the following openings: 2, 0.425 and 0.075 mm to retain gravel, coarse sand and fine sand respectively. However, for practical purposes due to the difficulty in sifting the particles, 0.6 and 0.15 mm sieves are sometimes used to retain very coarse sand and fine sand, respectively. Wash with clear water the drilled materials retained by each screen and place them in plastic bags labeled according to screen opening and depth. Record the relative amounts of gravel, coarse sand and fine sand for each sample.

A.5 In some of the samples containing very large amounts of gravel, coarse and fine sands as well as in samples containing very small amounts of these materials, collect the samples passing through the set of screens (silt and clay materials). Allow these to settle for at least an hour. Drain the water and place the solid particles in plastic bags labeled according to depth. Use these later to get the estimate of the total volumes of solids coming out of the borehole in confining layers and good water bearing formations.

A.6 Using the results of procedures A.1 and A.5, characterize or rank each sampling depth in terms of the relative amounts of gravel, coarse sand, fine sand and silt/clay (e.g. gravel - highest amount or rank 1, coarse sand – second highest amount or rank 2 and so on). Based on these relative amounts, characterize the textural composition of each depth (e.g. gravelly sand with fine sand; coarse sand with gravel; fine sand; hard clay, etc.). It must be noted that a more widely accepted method of characterizing the textural composition may be used such as the USDA Textural Soil Classification.

A.7 Prepare the well log as in Figure A.1.

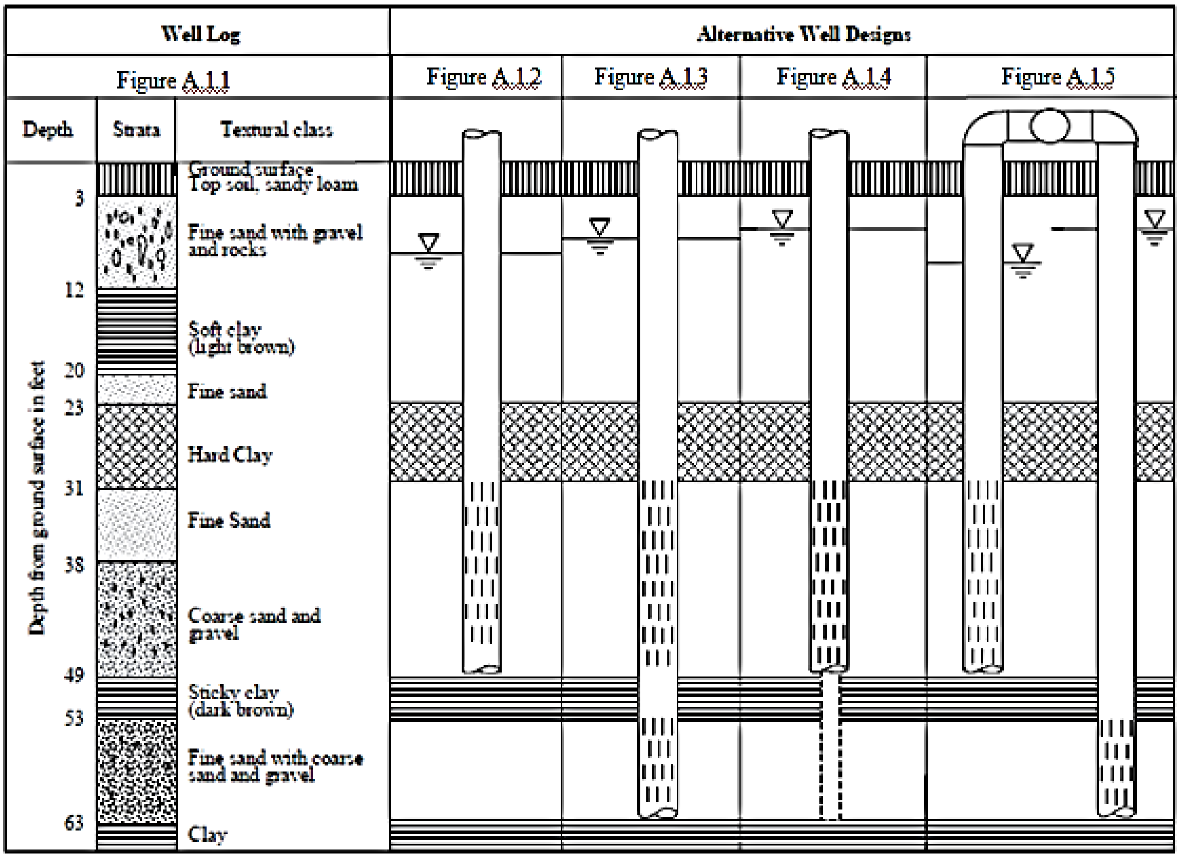

Figure A.1. Well log and alternative well designs

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