नेपाल खानेपानी संस्थान
Nepal Water Supply Corporation

Technical Specification
Borehole Construction & Test Pumping

Introduction

1. Reference to existing Indian Standards have been included in the specification for:

    - IS 2800: Code of practice for tube well construction (Parts 1 & 2)
    - IS 4097: Specification for gravel for use as a pack-in tube well
    - IS 4270: Specification for steel tubes used for water well
    - IS 8110: Well screens and slotted pipes
    - IS 11189: Methods for tubewell development
    - IS 14476: Test pumping of water wells

2. In case of any disagreement between the Drilling Contractor and the project, it is expected that the quality of work will be consistent with that specified in the Indian Standards.

3. For this Specification reference is made to the construction and test pumping of a 'Borehole' as opposed to a 'Deep Tubewell' to avoid any confusion between shallow and deep tubewell construction. Where an Indian Standard refers to a tubewell or water well, it is assumed that the specification will apply to a borehole also.

General Description of Works

4. The works will consist of the construction, development, and test pumping of one new borehole to be used by the Nepal Water Supply Corporation (NWSC) for public water supply.

5. The following drawings are attached to this specification:

    - Drawing 1 – Typical Borehole Construction Design
    - Drawing 2 – Typical Wellhead Design

Site-Specific Description of Works

6. The location of the construction Site will be defined for each contract and the following drawings will be provided:

    - Drawing A – Map and Site Location Plan
    - Drawing B – Proposed Site Layout

7. The site address will be provided along with the Map and Site Location Plan (Drawing A).
8. The position of the borehole and working area will be shown on the Proposed Site Layout (Drawing B). The Drilling Contractor shall have sole possession of the working area during the contract and shall confine all operations therein. The exact location of the borehole will be confirmed by the Branch Manager before commencement.

9. The Drilling Contractor shall provide all necessary electrical power supplies and water supplies to the Site, as required during construction.

10. The Drilling Contractor shall be responsible for the provision of facilities associated with the welfare, health, and safety provision of all personnel on the Site.

11. The Drilling Contractor shall ensure that an experienced Lead Driller is engaged on the contract, or other person in charge of the drilling and borehole construction, who shall have overall responsibility for operations on site. The Lead Driller, or another person in charge, shall be competent to take all measurements and make all records and reports required by the Contract in connection with drilling, borehole construction, and testing.

General site procedures

12. A firm, level working surface shall be prepared on the Site for the operation of the drilling rig. Preparation of a temporary working area to create a suitable entrance and working platform at the borehole location will be undertaken by the Drilling Contractor before the start of any construction works.

13. The drilling rig shall include adequate means of support and adjustment to allow for any vertical adjustments and corrections to be carried out safely.

14. The Site shall be adequately fenced around the entire working area and kept secure during all phases of the work. No part of the Site shall either be entered or used for any purpose unconnected with the Works.

15. All visitors to the Site must undertake a site induction before admittance to any work areas and access shall be controlled at all times, via agreed routes and entrances.

16. All site rubbish, other waste, and surplus materials shall be promptly removed from the Site. Materials, plants, and equipment shall be positioned, stored, and stacked in an orderly manner.

17. All pipes and fittings shall be stored off the ground, in a clean environment to prevent any contamination of materials before their use.

18. The Works shall be carried out in such a way as to ensure that pollution of any ditches, streams, other water courses, or lakes does not occur.

19. The Drilling Contractor shall take great care in the use of any hydrocarbons (diesel, hydraulic oils, etc) to prevent spillages to the ground which could cause environmental pollution to surface waters or groundwater. All hydrocarbons used on the Site shall be stored securely in tanks within a properly bunded area or using some other equally secure means of storage. Spill kits will be available on Site (adsorbent granules, sand, or similar) for the control of spillages. If a hydrocarbon spillage does occur, the Drilling Contractor will inform the Branch Manager immediately to assess the extent of the spillage and to make any necessary clean-up arrangements to minimize the pollution risk.

20. The Drilling Contractor shall be responsible for dealing with any waste, whether it be solid, liquid, or gaseous, arising during the course of the Works and shall clean and make good all working areas to their previous condition.

Proposed Borehole Design

21. The proposed borehole design will be defined on a site-specific basis for each contract based on the understanding of the local ground conditions.

22. For the majority of NWSC boreholes to be constructed, the target aquifer will be the sand and gravel formation in the alluvial deposits of the Terai. Where possible, lithological logs and Well Reports from existing boreholes will be used to inform the proposed borehole design.

23. Groundwater is expected to be encountered within the shallow gravel and sand formation in the overburden. The final borehole design will be such that cross-contamination from any shallow groundwater to the deeper formations will not be possible.

24. The borehole design will be similar to the typical design as presented in Drawing 1.

25. The generic borehole design will comprise a single string installation of a 12-inch (300mm) diameter mild steel casing and an 8-inch (200mm) stainless steel continuous wire wound screen with di-electric coupling joints (to prevent galvanic corrosion). The annulus between the drilled hole will be a minimum of 4 inches (100mm) to allow for the installation of a gravel pack. The upper length of the mild steel casing will be grouted from the surface to at least 20m below ground level.

26. The final borehole design will be informed by the information about the strata as provided during the construction phase and the outcome of the geophysical logging. The final borehole design will be agreed upon in writing with the Branch Manager.

27. The final borehole design will include the depths, lengths, and diameters of the casing pipes and confirmation of the slot size for the stainless steel continuous wire wound screen. The slot size is typically expected to be between 0.75 mm and 1 mm, dependent upon the strata encountered.

Borehole Casing & Screen Specification

28. The mild steel casing pipes shall generally conform to IS 4270: 2001 and the stainless steel continuous wire wound well screens shall conform to IS 8110: 2000.

29. Before installation, the Drilling Contractor shall confirm in writing that all casing pipes and screens comply with the standards, as described below, with appropriate certification from the casing pipe and screen supplier. The materials must be verified on site as per the specification and installation works shall only proceed with formal approval from the Branch Manager.

30. The thickness and tensile strength of the casing pipe shall meet or exceed those specified in the Indian Standard IS 4270: 2001Steel Tubes Used for Water Wells – Specification. For the avoidance of doubt, the recommended dimensions[1] for a typical design would be as follows:

Grade of steel	Fe 410 or Fe 450 (mild steel)
Diameter	300 mm /200
Thickness	7 mm / 6.4
Weight per meter	62.32 kg/m / 33.57

31. The casing pipes shall be beveled at one end and all pipe joints shall be -welded to ensure a continuous seal and 100% weld penetration. The welding layers shall include at least 2-3 coats to ensure a complete watertight seal.

32. The use of flat iron bars/coupling or ring to provide additional strength at the casing joints.

33. The thickness and tensile strength of the stainless-steel continuous wire wound well screens shall meet or exceed those specified in the Indian Standard IS 8110: 2000 Well Screens and Slotted Pipes. For the avoidance of doubt, the recommended dimensions[2] for a typical design would be as follows:

Grade of steel	X04 Cr18Ni10 (stainless steel)
Diameter	200mm
Thickness	6.3 mm
Tensile Load	186.39 kN
Collapse Pressure (for 0.75 – 1mm slot)	0.8 MPa

Note: The screen must be suitable for 200 m depth

34. Stainless steel welding rod shall be used when joining the mild steel casing to the stainless-steel well screen to prevent galvanic corrosion. Galvanic corrosion occurs when two dissimilar metals are coupled in water-saturated environments and a galvanic cell is created which results in the less corrosion-resistant metal corroding faster than normal thereby reducing the life of the casing pipe and the borehole. The Di-electric coupling uses a nonconducting insulating ring material to isolate the metal surfaces and prevent electrical contact.

35. The outer casing pipe shall extend by a distance of 500-600mm above the finished ground level as indicated in Drawing 2. The top of the casing pipe shall have a flange welded on to which a 3mm rubber gasket and blank head plate will be bolted at all times that the borehole is not attended by the Drilling Contractor.

36. All pipework shall be stored on-site safely and hygienically before installation and shall be thoroughly cleaned before assembly.

[1] Refer to IS 4270: 2001 Page 4, Table 3
[2] Refer to IS 8110: 2000 Page 8, Table 8.3.3.3 & Page 10, Table 8.3.4.3

37. Casing shall be installed with suitable centralizing devices and during installation, a verticality test shall be carried out.

38. Verticality and alignment shall be carried out using a plumb or plunger by the method described in Indian Standard IS 2800-2: 1979 Code of Practice Construction & Testing of tubewells[3].

39. The permissible deviation from the vertical shall not exceed 1/100 of the depth at the point being tested, the lateral dimension is measured from the vertical line through the top of the borehole or casing (so for example, at 100m the allowable deviation from vertical would be 1m)[4].

40. All tests for verticality and alignment will be witnessed by the Branch Manager unless otherwise agreed. The Drilling Contractor is expected to drill all boreholes and shall install all casing and screens within the specified tolerances.

Borehole Construction

41. The method of drilling shall be cable tool percussion or hydraulic rotary drilling (direct or reverse) and shall be proposed by the Drilling Contractor.

42. The Drilling Contractor shall be responsible for determining the requirements for temporary casings and appropriate drilling diameters to complete the borehole as specified and indicated in Drawing 1. Consideration should be given to the use of a shallow large diameter conductor pipe to ensure the stability of the drilling rig during the construction process.

43. The drilling method shall be agreed upon in advance and method statements provided to include details about the drilling method, any proposed drilling muds, installation and testing of casing including grouting operations.

44. If drilling mud is required, it shall consist only of bentonite and/or a degradable polymer mud of high viscosity and low solids. All additives must be compatible with potable water. For the avoidance of doubt, the use of cow dung or similar is not permitted in the construction of potable water supply boreholes.
45. The Drilling Contractor shall be responsible for arranging for the provision of any water required to facilitate the boring and any other operations. Only potable quality water shall be used for the boring of water supply boreholes.

46. If drilling by rotary methods, good control of the drilling fluid shall be exercised to ensure that all cuttings are brought to the surface and the drilling fluid is contained within the working area agreed for drilling and construction. Every effort shall be made by the Drilling Contractor to maintain a good fluid return and to obtain representative formation samples during drilling. If partial or full loss of circulation of the drilling fluids is encountered, the Drilling Contractor

[3] Refer to IS 2800-2: 1979 Pages 2-4 Verticality & Alignment

[4] Note that this allows for greater deviation than specified in IS 2800-2 (10cm per 30m) but is considered satisfactory for the purposes of installing submersible type pumps

shall produce a plan to restore and maintain circulation so that progress can be made toward completion.

47. Geological samples shall be taken where the strata change and otherwise at intervals not exceeding 1m.

48. With rotary drilling, samples shall be taken from the circulation fluid immediately upon exit from the borehole casing before any settlement or segregation can occur.

49. Samples recovered shall be the property of NWSC and the Drilling Contractor shall be responsible for their safe-keeping until they have been handed over in an agreed manner. The samples of strata will be collected and stored in sealed polyethylene bags. All samples shall be marked in waterproof ink according to depth and shall be stored in an orderly sequence (ideally retained on Site in approved boxes).

Electrical Resistivity Survey

50. After completion of the borehole the Drilling Contractor shall make arrangements for the completion of an electrical resistivity survey and interpretation by a qualified Hydrogeologist.
51. Based on the geological log and results from the electrical resistivity survey, the Drilling Contractor shall identify the target aquifer formations and recommend a suitable design for the borehole casing and screen assembly. The proposed design shall be based on the generic design as presented in this Specification.

52. Approval for the proposed borehole casing and screen assembly must be agreed in writing with the Branch Manager before installation. If required, the Branch Manager shall be permitted time to request independent expert verification of the proposed design. Any changes to the proposed design will be agreed in writing between the Drilling Contractor and Branch Manager.

Gravel pack installation

53. All gravel to be used as a filter pack in the borehole construction shall conform with IS 4097: 1967 Gravel for Use as Pack in Tubewells[5].

54. The generic borehole design has been specified to allow an annular space of a minimum of 100mm for the installation of the gravel pack.

55. The gravel pack shall consist of thoroughly washed, non-calcareous, hard quartz (96% SiO_2) and well-rounded gravel.

56. The final specification will be determined based on the results of the particle size analysis determined during the borehole construction and the electrical resistivity survey.

57. The final size grading will be dependent on the slot size specification of the continuous wire wound screen, but it is most likely to be sized by IS 4097: 1967, clause 4.1:

[5] Refer to IS 4097: 1967 Page 3 (Physical characteristics) and Page 4 (Gravel Sizes)

Grade A (fine gravel, over 2mm to 3.35mm), or
Grade B (fine gravel, over 3.35mm to 4.75mm).

58. The gravel shall be agreed upon and inspected by the Branch Manager in advance and before installation.

59. The gravel pack shall be placed in a continuous operation using suitably sized tremie pipes. Use of the back-wash/airlift pumping during installation will reduce the risk of bridging in the annular space and thereby reduce the risk of possible damage to the borehole assembly by the sudden collapse of bridged gravel.

60. The depth of the gravel pack will be agreed upon as part of the final design but will be a minimum of 5 meters above the shallowest length of the screened section. The level of the gravel pack shall be tagged and monitored during the borehole development and topped up as necessary.

Borehole development

61. Borehole development should follow the methods as specified in IS 11189: 1985 Methods for Tubewell Development, to ensure a maximum sand-free yield.

62. The starting point of the borehole development shall be clearance pumping and circulation of clean water through the drill string of the drilling rig to remove as much drilling mud residue and drilling material as possible. Methods like innerwash, backwash, Surging, jetting, Plungiing and, bailing shall be used for the development.

63. The next stage of development shall require airlift pumping using a compressor and airline[6]. This stage of development will ensure complete settlement of the gravel pack and stabilization of the sand. Fine material shall be removed from the formation by surging the borehole and working the airline down from above the well screen to the base of the borehole.

64. The borehole shall be alternately surged and pumped with air until sand-free water is produced throughout the borehole's column.

65. The final stage of development shall be to install a submersible pump sized as such to overpump the borehole (by at least 50% of the expected discharge rate) as specified by the Branch Manager[7]. This stage of development shall include surge pumping to remove the very fine material from the formation and gravel pack. Surge pumping shall be in the form of on-off cycles to produce relatively rapid changes in the pressure heads in the well to agitate the water, remove the finer sand grains and prevent bridging of the gravel pack. This procedure needs to be repeated for sufficient duration until the well is sand free.

[6] Refer to IS 11189: 1985 Page 2 (Clause 4.2 Compressed Air)
[7] Refer to IS 11189:1985 Page 2 (Clause 4.1 Pumping)

66. The final discharge should be completely free of sand at the end of the development cycles and turbidity shall be lower than 10 NTU as measured at the wellhead.

67. Drawdown water levels, approximate rates of discharge, and appearance of the water quality shall be measured and recorded, and retained on site.

68. Sufficient time allowance shall be given for the successful completion of borehole development, which will be agreed upon and signed off as complete by the Branch Manager.

Grouting

69. A grout seal is required around the permanent plain casing. The methodology for the grouting operations shall be produced by the Drilling Contractor and submitted to the Branch Manager for acceptance in advance.

70. The generic borehole design has been specified to allow an annular space of minimum 100mm for installation of the gravel pack which will also allow for emplacement of grout to the borehole wall in the mild steel casing section.

71. The grout mix shall either be a straight cement and water mix or mixed with bentonite if required to improve the fluidity of the mixture.

72. The ideal water-cement ratio should be 19.7 liters per 42.6kg sack of Portland cement to produce a slurry weight of 1,870 kg/m^3. Water for grouting must be potable free of oil and other organic material, and total dissolved solids should be less than 2,000 mg/l (and have low sulfate content).

73. If using bentonite, approximately 1.4kg to 2.3kg powdered bentonite should be mixed with 25 liters of water per 42.6 kg sack of Portland cement. If the amount of bentonite exceeds 6% then excessive shrinkage occurs which is not desirable.

74. The quantities of cement and water used in the grout mix must be accurately measured and a record kept. In preparing the grout, powdered bentonite should be mixed with water first and then the cement added. The grout shall be stirred continuously in its containing vessel and each phase of the grouting operation completed without interruption. The sequence of events through mixing and emplacement of grout must proceed without mechanical failure of cement mixing and pumping equipment; backup options should be available to minimize the risk of a possible failure of the grout seal.

75. Grout should be emplaced from the base of the casing upwards, ensuring a complete seal with no voids. Grouting shall be carried out in such a way that maximizes the grouted interval in each phase of grouting, whilst considering the potential pressures on the casing.

76. A minimum of 24 hours of grout setting time is required before any further work is carried out on the borehole under construction.

Test pumping

77. Following completion of the borehole development, test pumping shall be carried out by IS 14476: 1998 Test Pumping of Water Wells.

78. The test pump shall be of a submersible type capable of producing discharges at least 25% greater than the required yield of the well against the friction head of any temporary pipeline and rising main[8].

79. The pump shall be installed as deep as possible so that the maximum drawdown of water level is available to determine the well capacity. The pump should not be installed so close to the bottom of the boreholes that it may block if there is excessive settlement of any sediment.

80. Wherever possible, the pump should be placed in the cased section of the well such that potential damage to the well screen is avoided.

81. The pump shall be fitted with a non-return valve. The rising main shall include a sample tap, pressure gauge, and flow meter.

82. The point of discharge shall be sufficiently far away from the borehole to minimize the risk of recirculation during the period of testing. The point of discharge shall be agreed upon in advance with the Branch Manager.

83. During test pumping, the Drilling Contractor shall be responsible for measuring and recording groundwater levels at the borehole on standard forms by those set out in IS 14476: 1998[9].

84. Water levels shall be measured in a dip tube installed 2m above the pump intake. The Drilling Contractor shall supply and maintain at least one 50m (minimum) electric contact water level meter, accurately calibrated in 0.01m intervals, for measuring water levels.

85. The estimated duration and sequence of test pumping shall be as follows:

    - 24-hour recovery following borehole development (or as instructed by the Branch Manager)
    - Step discharge test (4 steps each 360 minutes duration)
    - 24-hour recovery following step testing (or as instructed by the Branch Manager)
    - 4-day constant rate test (or as instructed by the Branch Manager)
    - 1 day monitored recovery (or as instructed by the Branch Manager)

86. The Drilling Contractor shall ensure that the installed submersible pump has sufficient capacity to achieve the discharge rate as instructed by the Branch Manager, following a review of the information from the development phases.

[8] Refer to IS 14476: 1998 (Page 17; Part 3, Section 4: Pumping Equipment)
[9] Refer to IS 14476 (Page 19, Part 3, Section 7.2: Frequency of Water Level Measurements)

Step discharge test (4 steps)
(i) First: 0.5 Q
(ii) Second: 0.75 Q
(iii) Third: 1.0 Q
(iv) Fourth: 1.15 to 1.5 Q
Where Q is anticipated discharge of a well
An example of a typical step test for a borehole with an anticipated final yield of 20 l/s would be as follows:

Step	EXAMPLE: Flow rate (l/s)	Duration (mins)
1	10	360
2	15	360
3	20	360
4	25	360

87. Water level and flow data are to be recorded at the following frequency:

Time since start of step (mins)	Recording interval (mins)
0 – 10	1
10 – 60	5
60 – 100	10
100-240	20
240-360	30

The rest water level must be recorded before commencement of any pump testing and levels must be measured from an agreed datum point.

88. The means used to measure time should be capable of measuring to the nearest second. During the first 10 minutes of the test, an error in timekeeping greater than 5 seconds should be avoided. If a recording interval is missed, record it at the next interval. Timing devices should be synchronized before the start of the test. It is convenient to start a test at the stroke of the hour.

89. The changes in abstraction rate between steps shall be as nearly instantaneous as practicable.

90. Results from the step discharge test shall inform the flow rate for the constant rate test and will be agreed with the Branch Manager.

91. A constant rate discharge shall be performed following the period of water level recovery (minimum 12 hours but typically 24 hours) and will typically continue for 4 days, or as instructed by the Branch Manager.

92. Water level and flow data during the constant rate test are to be recorded at the following frequency:

Time since the start of the test (mins)	Water Level Recording Interval (every min)
0 – 10	1
10 – 60	5
60 – 100	10
100-240	20
240-720	30
>720	60

93. Water levels shall be recorded at the same frequency at the end of the test period to monitor the recovery, for up to 24 hours (or as instructed by the Branch Manager).

94. All test pumping data shall be recorded on suitable forms which will be held safely on site and handed over to the Branch Manager on completion of the test.
95. A sample tap shall be installed to allow for the collection of water-quality samples at intervals during the test pumping.

Well disinfection

96. Within three days of the satisfactory completion of testing the Drilling Contractor shall disinfect the borehole with a dilute solution of sodium or calcium hypochlorite (also referred to as high-test calcium hypochlorite).

97. The solution strength should be between 50 and 200 mg/l chlorine and applied to the entire length of the column via a tremie pipe. The water quality sample should be taken to analyze the total and fecal coliform content.

Reporting

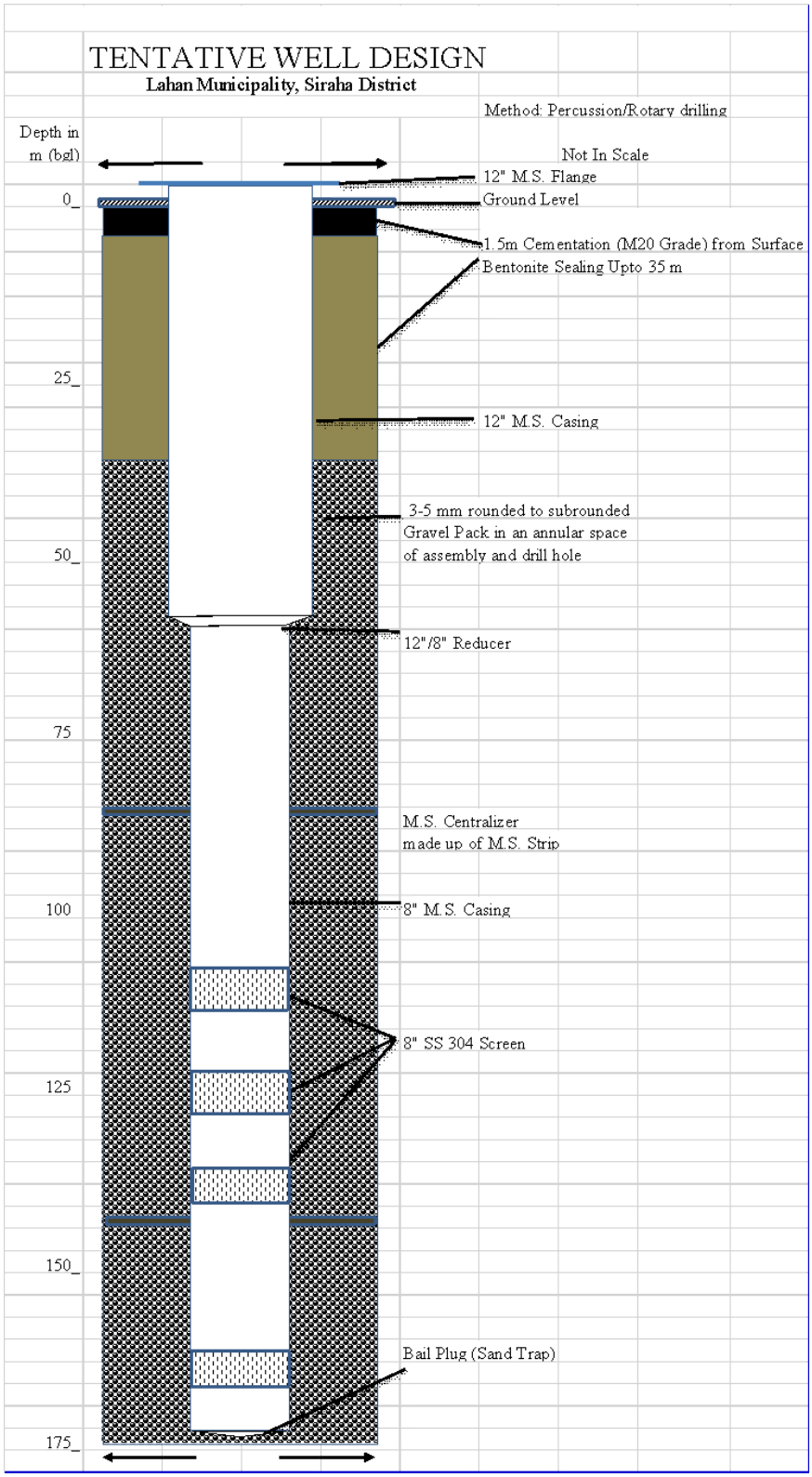
98. Upon completion of the works, the Drilling Contractor shall submit copies of the daily log sheets giving the following information as a minimum:

- an accurate description of the strata encountered and the depths at which the strata change;
- the rates of penetration during boring;
- details and depths of all casing installed (temporary and permanent);
- full details and depths of installed gravel pack including specification and quantities;
- weight and proportions of grout placed;
- levels at which groundwater is encountered and rest water levels for groundwater each morning before the start of work, recorded to an accuracy of 5mm to datum level;
- full details of development and test pumping;
- full details of installed pumps including pump depth and discharge rates.

99. Within 28 days of completion of the borehole the Drilling Contractor shall submit an accurate report of all construction and a summary of the time spent on all phases of activity. The report shall include the following:

    - drawings showing drilling and casing diameters and depths; strata encountered and formation samples collected; depths of gravel pack; depths of cement grout and bentonite seals (as appropriate);
    - records of water encountered and standing water levels;
    - records of bailing, pumping, and development with approximate quantities discharged;
    - drawings showing construction details for the wellhead completion; results of monitoring water levels.

Drawing 1 – Typical Borehole Construction Design


TENTATIVE WELL DESIGN
Lahan Municipality, Siraha District
Method: Percussion/Rotary drilling
Depth in m (bgl)
Not In Scale
12" M.S. Flange
Ground Level
1.5m Cementation (M20 Grade) from Surface
Bentonite Sealing Upto 35 m
12" M.S. Casing
3-5 mm rounded to subrounded Gravel Pack in an annular space of assembly and drill hole
12"/8" Reducer
M.S. Centralizer made up of M.S. Strip
8" M.S. Casing
8" SS 304 Screen
Bail Plug (Sand Trap)
0
25
50
75
100
125
150
175

Drawing 2 – Typical Wellhead Design