WQPN 30, February 2006

Groundwater monitoring bores

Purpose

Groundwater monitoring bores are used to:

- determine the nature and properties of soils through which liquids may seep;
- provide access to groundwater for measuring its level, physical and chemical properties; and
- allow groundwater samples to be withdrawn for laboratory analysis.

The Department of Water is responsible for managing and protecting the State's water resources. It is also a lead agency for water conservation and reuse. This note offers:

- the Department's current views on the construction of groundwater monitoring bores;
- guidance on acceptable practices used to protect the quality of Western Australian water resources; and
- a basis for the development of a multi-agency code or guidelines designed to balance the views of industry, government and the community, while sustaining a healthy environment.

This note provides a general guide on issues of environmental concern, and offers potential solutions based on professional judgement and precedent. The recommendations made do not override any statutory obligation or Government policy statement. Alternative practical environmental solutions suited to local conditions may be considered. Regulatory agencies should not use this note's recommendations without a site-specific assessment of any project's environmental risks. Any conditions set should consider the values of the surrounding environment, the safeguards in place, and take a precautionary approach. This note shall not be used as this Department's policy position on a specific matter, unless confirmed in writing.

Scope

This note applies to the construction of screened or slotted casing groundwater monitoring bores. The bores may be installed using a variety of materials/ construction methods suited to their depth, intended use and the local soil strata.

Monitoring bores are primarily needed to assess changes to water table levels and groundwater quality. Impacts on groundwater result from contaminated water movement, leaching of surface pollutants caused by rainfall or irrigation water percolation, leakage of stored matter or the disposal of wastes. These bores consist of a vertical cased hole, with the casing screened or slotted to permit groundwater inflow, and allow field testing and extraction of representative fluid samples for analysis. Bores should also permit standing groundwater levels (SWLs) or confined aquifer water pressure to be determined.

The location of the slotted/screened interval depends on the type of strata penetrated and the nature of contaminants monitored. Certain contaminants float on the water table, some mix with the waterbody, and others will sink to the base of the aquifer.

Sometimes a cluster of bores will be needed at a single location to permit effective monitoring for contaminant concentrations at different depths. The intended *water sampling technique* (see later section) can influence selection of the bore casing diameter.

This note is not intended for use at contaminated sites. See the text on *Monitoring facilities at contaminated sites* and Appendix A for an overview and reference information on this topic.

Recommendations

Siting of monitoring bores

1. Bores are often required both up-gradient and down-gradient of contaminant management facilities (in the direction of groundwater movement) to monitor changes in groundwater level and quality across a site. In hard rock areas, bores should be located within geological features that are most likely to transmit fluids eg into fault lines/ weathered zones.

2. Where an existing water supply bore is strategically located, it may be suitable for water quality monitoring in place of a new monitor bore. The supply bore construction details should be known, and it must not be contaminated or interfere significantly with the accuracy of analysis of the contaminants under investigation. Such bores will generally be unsuitable for monitoring ground water levels and may influence contaminant travel paths, as pumping generally causes fluctuations in the water-table at the bore site.

3. Bore sites should be chosen to intersect probable contaminant flow paths and be offset sufficiently down-gradient from the contamination source to allow for effective mixing of leachate with groundwater to occur. Monitor bores however should not be so remote that substantial contaminant plume dispersion or external influences affect monitoring results. The bores should be located as close as practical (at least within 20 metres) to the sites proposed on the groundwater monitoring plan. A plan template for depicting the bore locations is provided at Figure 1 (see Appendix C, Maps and diagrams).

4. The anticipated path and fate of monitored contaminants needs to be carefully considered. Are contaminants likely to float on the water table or sufficiently dense to gravitate towards the bottom of the aquifer? Where uncertain, it may be better to install a cluster of monitoring bores at a single location to permit effective monitoring of the saturated zone. This can be achieved by the drilling of a large diameter hole and the installation of a number of monitoring tubes in the one bore hole. One challenge is to create effective grout seals between monitored intervals. Construction of discrete bores to provide the required information from each interval can sometimes be more cost effective and yield better sampling results without the risk of cross-contamination.

Monitoring facilities at contaminated sites

5. This note is not directed at monitoring facilities for known or suspected contaminated sites. Specialists experienced in contaminated sites mitigation, should be used to define a specific soil and groundwater investigation program and the selection of facilities needed. For more information contact the Department of Environment's Land and Water Quality Branch. Several key aspects are highlighted in the following recommendations.

6. Only personnel who have undergone the relevant Occupational Health and Safety training and are qualified to undertake such work, should conduct drilling and bore construction operations on contaminated sites. Specialised techniques and operator safety methods are necessary on such sites. The drilling rig and associated equipment used have generally been adapted to suit the special requirements of such sites.

7. Contamination investigation drilling has particular requirements. A site history should be obtained and the investigation method should be clearly defined prior to any bore drilling operations commencing. Measures must be in place to both protect the surrounding community and isolate any potentially contaminated soil or water removed during the bore construction from the "clean" environment. Extracted material should be either effectively tested as free of contamination or safely disposed of at an approved, secure location.

Bore construction

8. Refer to Figures 2 to 6 in Appendix C for diagrams depicting acceptable monitoring bore construction. The hydrogeology at the site selected should influence the bore construction technique employed.

9. Bores constructed into any artesian aquifer should be designed so that any subsequent water flow from the bore can be effectively controlled at all times. It is usually necessary to install and securely grout suitable conductor casing into a competent upper formation eg dense clay or rock prior to drilling operations proceeding further.

10. For artesian bores, the conductor casing should be equipped with a full bore gate valve that may be used to control water flow from the bore if necessary. This conductor casing should be at least three metres in length.

11. Refer to *Minimum construction requirements for water bores in Australia* (see Appendix A, 3a) for further details on bore construction.

Drilling techniques

12. The drilling and construction methods for the bore should be assessed and determined by the project proponent in consultation with an experienced and qualified hydrogeologist, prior to any equipment being moved on to site.

13. Mud rotary drilling techniques will enable down-hole pressures to be controlled and should be the choice in areas where artesian pressure is a possibility. Care must be taken that mud residues do not interfere with the ability to collect representative water samples.

14. Hollow auger drilling is suited to the installation of shallow monitoring bores, as the auger string keeps the hole open while bore casing is run. This technique is not suited to drilling in situations where groundwater is under pressure.

15. Techniques using air as the circulating medium are not recommended for the drilling of bores in areas where water levels may rise close to or above the ground surface level.

Drill samples and logging

16. An accurate drilling and lithological log of soil strata should be kept for all operations on the drill site. A clean representative sample of the soil formations intersected should be collected at all changes of strata and at a maximum drill depth intervals of three metres for all bores up to 50 metres deep. Samples should be laid out in an orderly sequence for inspection. For deep bores sampling should be matched to all soil strata changes.

17. Geophysical logging (gamma and resistivity logging) should be carried out for bores exceeding 50 metres depth and for all confined aquifer monitoring bores.

18. An experienced on-site hydrogeologist should carry out an inspection of the samples to determine screen or slotted casing setting depths. The depth at which water is first intersected should be recorded on the driller's log.

Depth of bores

19. Clusters of various depth bores are often used to check water pressure or quality in layered strata that features both relatively permeable and low permeability zones or for tracking non-miscible water contaminants. The following descriptions may be used to differentiate between bores in these settings:

    a. Shallow (S) bores are drilled to accommodate at least three metres of screen below the standing water level (SWL) in unconfined aquifers (or to the base of the aquifer, if very shallow). They are used to monitor water attributes at or near the water table.

    b. Intermediate (I) depth bores are used to monitor the middle or lower levels of an unconfined aquifer, or the upper layers of confined aquifers. All aquifers intersected should be isolated from water exchange by the use of suitable sealing techniques and materials.

    c. Deep (D) bores are used to monitor water quality and groundwater pressures at depth within unconfined and within confined aquifers. It is vital that all aquifers intersected be isolated using suitable outer casing seal materials.

Drilling diameter

20. Drilled diameter should be at least 60 millimetres greater than the permanent outer casing maximum diameter. The maximum diameter is generally accepted as that measured at the collar or top of the casing.

Bores installed vertical

21. All bores should be drilled, cased and finished vertical as defined in Item B.3 of the *Code of Good Practice for the Groundwater Industry,* prepared by the Western Australian Branch of the Australian Drilling Industry Association.

Main casing

22. Casing material should be selected to suit aquifer and ground conditions and in the case of contaminant detection/ water quality monitoring, the specific nature of the pollutants under investigation. Polyvinyl chloride (PVC) is generally the material of choice for monitoring bores and is suitable for saline water conditions. Casing thickness should suit soil pressures linked to the bore depth. If particular site conditions dictate eg depth exceeding 50 metres, it may be necessary to use other materials such as coated steel.

23. Unless otherwise approved, all bores should be cased with at least a 50 millimetre nominal bore pipe installed in a bore hole with a diameter at least 60 mm greater than the maximum diameter of the casing. The finished bore casing should extend 500 to 600 millimetres above the ground surface. The bottom of the casing string should be sealed with a competent end cap.

Screens/ slotted casing

24. The location of the slotted/ screened interval should be based on the type of strata penetrated, the depth to groundwater, the density of any contaminants that may come under investigation and the zone of interest.

25. The screen materials used should comply with the following:

    a. protection from corrosion or deterioration either by groundwater or bore maintenance chemicals;

    b. prevent contamination of water samples eg via lubricant or solvent residue;

    c. an aperture size suited to the monitored soil type and aquifer situation; and

d. minimal susceptibility to blockage, and may be readily cleaned when bore maintenance is needed.

26. For slotted PVC casing there shall be a minimum of 100 slots per metre, each slot to be 50 to 55 millimetres long on the inside of the casing, and have an opening width between 0.2 and one millimetre. A common slot width is 0.4 millimetres. The slots should be horizontal in the installed casing, about 25 millimetres apart in the vertical direction, arranged in three equal-spaced columns around the casing. External filter socks should be used where necessary to exclude very fine soil material from the casing.

Centralising of bore casing

27. Casing should be held in tension while gravel packing and grouting operations are undertaken. This is to avoid buckling of the casing that may lead to improper sand and/ or grout distribution within the bore annulus.

28. Casing centralisers of inert material should be used at maximum intervals of six metres in bores constructed into artesian aquifers.

Gravel pack

29. The annulus between the main casing and the drill hole should be carefully and evenly gravel packed to a maximum of two metres above the screened interval with a graded sand pack.

30. The pack material should generally be uniformly graded, with grain size suited to the particular application and the aquifer grain size. The gravel pack should consist of clean, coarse, sub-rounded to rounded silica sand or similar material, and be free from contaminants that may influence water monitoring results.

Sealing of the bore annulus above or between monitored intervals

31. Cement slurry or bentonite should be used to seal the annulus in shallow bores to prevent water movement down the casing from the surface. A seal may be achieved in low salinity bores by using a pre-determined quantity of bentonite pellets slowly inserted down the annulus. This Department recommends that bentonite not be used in the presence of saline water, ie with electrical conductivity greater than 450 milli-Siemens/ metre, as the clays will flocculate, reducing viscosity. Cement slurry may be incompatible with acidic groundwater.

32. The use of cement or cement-bentonite mix slurry of minimum 1.45 specific gravity is recommended. This slurry should be used in intermediate and deep bores for sealing the annulus above the gravel pack.

Bore development

33. Under most circumstances, bores may be initially developed to remove soil fines from around the screens by pump surging or air lifting. Bore development should continue until the salinity has stabilised and the water is clean and sand-free.

Bore completion

34. A minimum one metre seal of cement grout or bentonite should be placed on top of the graded sand, however shallow non-flowing bores may be completed by back filling the casing annulus above the gravel pack to within half a metre of the finished ground surface with a suitable stone-free, non lumpy and free running soil. Intermediate and deep bores shall be completed with cement or cement/ bentonite grout above the gravel pack.

35. Where bores must be licensed by this Department under the *Rights in Water and Irrigation Act 1914* or installed as regulatory requirement under the *Environmental Protection Act 1986,* location and construction information should be supplied to the relevant agency in electronic form using this Department's Form L *Particulars of completed borehole* available from http://licensing.water.wa.gov.au select *Licensing Forms*.

    This information is most important where bores are installed into confined (artesian) aquifers. For more information contact this department's Water Information branch.

Borehead

36. A 110 centimetre long steel standpipe, extending a maximum of 70 centimetres above the ground surface should be set in a concrete block to protect the bore top. The concrete block should be a minimum of 50 centimetres wide and 30 centimetres deep, with its top finished within five centimetres of finished ground level.

37. Details of bore-head works recommended by this Department are shown in Figure 7.

38. The standpipe should be fitted with a lockable steel cap or other vandal-resistant device approved by this Department. All bores should have an identification number permanently affixed on the standpipe on an embossed plaque or with welded characters. To avoid possible confusion, identification numbers should be on both the standpipe and bore cap at sites where there is more than one bore. A bore owner identification tag is also recommended.

39. Where traffic is likely to pass over or near the borehead, the headworks should finish just below the finished surface and have a watertight load-bearing cover fitted. This is to avoid damage to the bore casing and to minimise the possibility of contaminants entering the bore.

Water sampling techniques

40. Sampling of water from monitoring bores should be achieved by bailing or pumping. General guidance on sampling is covered in Appendix A.

41. Sampling requirements and the techniques employed should be tailored to the purpose for which the bore is constructed. The sampling equipment must be clean, in good condition and used by trained and experienced personnel.

42. Analytical data provided to this Department should conform to the protocol- *Requirements for the submission of resource information data in electronic format.* For more information contact this department's Water Information Branch.

Equipment and site hygiene

43. All drilling and sampling equipment shall be thoroughly cleaned before drilling commences. This should be normal practice, but is critically important when the bore may be used to monitor for the presence of trace contaminants.

44. Specific washdown requirements may vary dependant on the sensitivity of the location, bore specification and the work procedure. Where uncertain, advice should be sought from this Department's Water Investigation and Assessment branch.

45. For construction of bores specifically designed for the monitoring of trace contaminants, steam cleaning of the drill rig and ancillary equipment may be necessary before the drilling of each bore. All casing materials and down-hole components should be free from contaminants prior to installation. All water to be used in the construction operations should be tested to ensure it is free from contaminants.

46. Due care and attention should be taken to ensure that the drilling and construction operations do not result in contamination of areas around the bore or those that are accessed during the operations. Water contaminants, lubricants, oils, greases, solvents, coatings and corrosion-prone materials could affect the suitability of the bore for subsequent groundwater monitoring.

Bore disinfection

47. To lessen the possibility of iron bacteria contamination, the bores should be treated with sodium hypochlorite (swimming pool chlorine) solution at the rates indicated by the chemical supplier. The solution should be left in the bore overnight and then be removed by airlifting.

48. Safety requirements outlined in the sodium hypochlorite supplier's *Material Safety Data Sheet* should be strictly followed.

Driller Licensing

49. Only drillers qualified and licensed for the aquifer/s that exists at the site should construct groundwater monitoring bores. Licensed drillers may operate in various aquifer conditions, with each Licence Class covered in the following definitions:

Class	Description
1	Restricts the holder to drilling operations in single, non-flowing (sub-artesian) aquifers
2	Permits the holder to operate in Class 1 conditions, plus single and multiple non-flowing (sub-artesian), aquifers
3	Permits the holder to operate in Class 1 and 2 conditions, plus flowing (artesian) aquifers

50. Licensing details may be obtained from the Australian Drilling Industry Association (W.A. Branch).

More Information

We welcome your views on this note. Feedback provided on this topic is held on the Department of Water's file **13187**. This note will be updated periodically as new information is received or industry/activity standards change. Updates are placed on the Department's Internet site www.water.wa.gov.au select *Drinking water> Publications> Water Quality Protection Notes.*

To comment on this note or for more information, please contact the Water Source Protection Branch at our Atrium offices in Perth, phone (08) 6364 7600 (business hours), fax 6364 6525 or use *Contact us* at the department's Internet site, citing the note topic and version.

The State Government in October 2005 announced the formation of the Department of Water. From January 2006, the Department of Water has assumed primary responsibility for managing the State's water resources. Once the Department of Water is legally established, it will replace many of the present functions of the present Water and Rivers Commission and operate in parallel (with separate powers) to the Department of Environment. The custodian and recommendations made in this note will then change to match the assigned responsibilities of the departments of Environment or Water.

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Appendices

Appendix A - References and further reading

1. Driscoll F.G. *Groundwater and Wells* Johnson's Filtration Systems, Minnesota,1986.

2. Standards Australia
   a. AS/NZS 5667 *Water Quality Sampling;*
   b. AS 4439.1 *Wastes, sediments and contaminated soils;.*
   c. AS 2031.1 *Selection of containers and preservation of water samples for chemical and microbiological analysis;*
   d. AS 1726 *Geotechnical site investigations;*
   see web page www.standards.com.au/catalogue/script/search.asp.

3. Australian Government-National Water Quality Management Strategy
   a. *Minimum Construction Requirements for Water Bores in Australia* 2nd Edition, September 2003; *see web page* www.iah.asn.au/pdfs/mcrwba.pdf.
   b. *NWQMS- Australian Guidelines for Water Quality Monitoring and Reporting, 2000;*
   see web page www.deh.gov.au/water/quality/nwqms/index.html.
   c. *NWQMS-Guidelines for Groundwater Protection in Australia, 1995;*
   see internet site bookshop@awa.asn.au, or request a copy from a library service.

4. Australian Drilling Industry Association – Western Australian Branch
   a. *Code of Good Practice for the Groundwater Industry*;
   b. *Australian Driller's Guide* 1981;
   c. *Australian Drilling Manual* 1981-1992;
   see internet site www.adia.com.au.

5. Department of Environment (WA)
   Contaminated sites management series
   a. *Reporting on site assessments;*
   b. *Assessment levels for soil, sediment and water (draft);*
   c. *Development of sampling and analysis programs;*
   d. *Use of monitored natural attenuation for groundwater remediation (draft);*
   see web page http://contaminatedsites.environment.wa.gov.au, select *Publications.*

6. Department of Water (WA)
   a. *Perth Groundwater Atlas;*
   b. *Hydrogeological Atlas;*
   c. *Requirements for the submission of resource information data in electronic format;*
   see internet site www.water.wa.gov.au select *Water information.*
   d. Form L (*Particulars of completed bore-hole);*
   see internet site www.water.wa.gov.au select *Licensing > Licensing forms.*

Appendix B. - Statutory requirements and approvals may include the following:

What's regulated	Statute	Regulatory body/ agency
Impact of significant development on projects the values and ecology of land or natural waters	*Environmental Protection Act 1986,* Part IV Environmental Impact Assessment	Minister for the Environment advised by the EPA
Licensing and Works Approvals for prescribed premises that may contaminate water resources	*Environmental Protection Act 1986,* Part V Environmental Regulation	Department of Environment– regional office
All artesian bores, and any bores operated for commercial gain within *Groundwater Management Areas* shall be licensed	*Rights in Water and Irrigation Act 1914,* Part III Control of Water Resources	Department of Water- regional office
Management of public drinking water source catchments	*Metropolitan Water Supply, Sewerage and Drainage Act 1909*	
	Country Areas Water Supply Act 1947	
Land planning and development approvals	*Town Planning and Development Act 1928*	Department for Planning and Infrastructure; Local government council
Management of human wastes, Community health issues	*Health Act 1911*	Department of Health; Local government council;
Emergency response planning	*Fire and Emergency Services Authority of WA Act 1998*	Fire and Emergency Services Authority; Local government council
Safety of workers	*Occupational Health and Safety Act 1984*	Worksafe WA.
Aboriginal Interests (see Department of Environment Water Note 30)	*Aboriginal Heritage Act 1972*	Department of Indigenous Affairs
Mineral and petroleum exploration and operations	*Mining Act 1978*	Department of Industry and Resources

Appendix C - Maps and Diagrams

Template below depicts a suitable map format showing location of site facilities, infrastructure, ground surface topography, drainage paths, surface water features, water supply bores or wells, and monitoring bores.

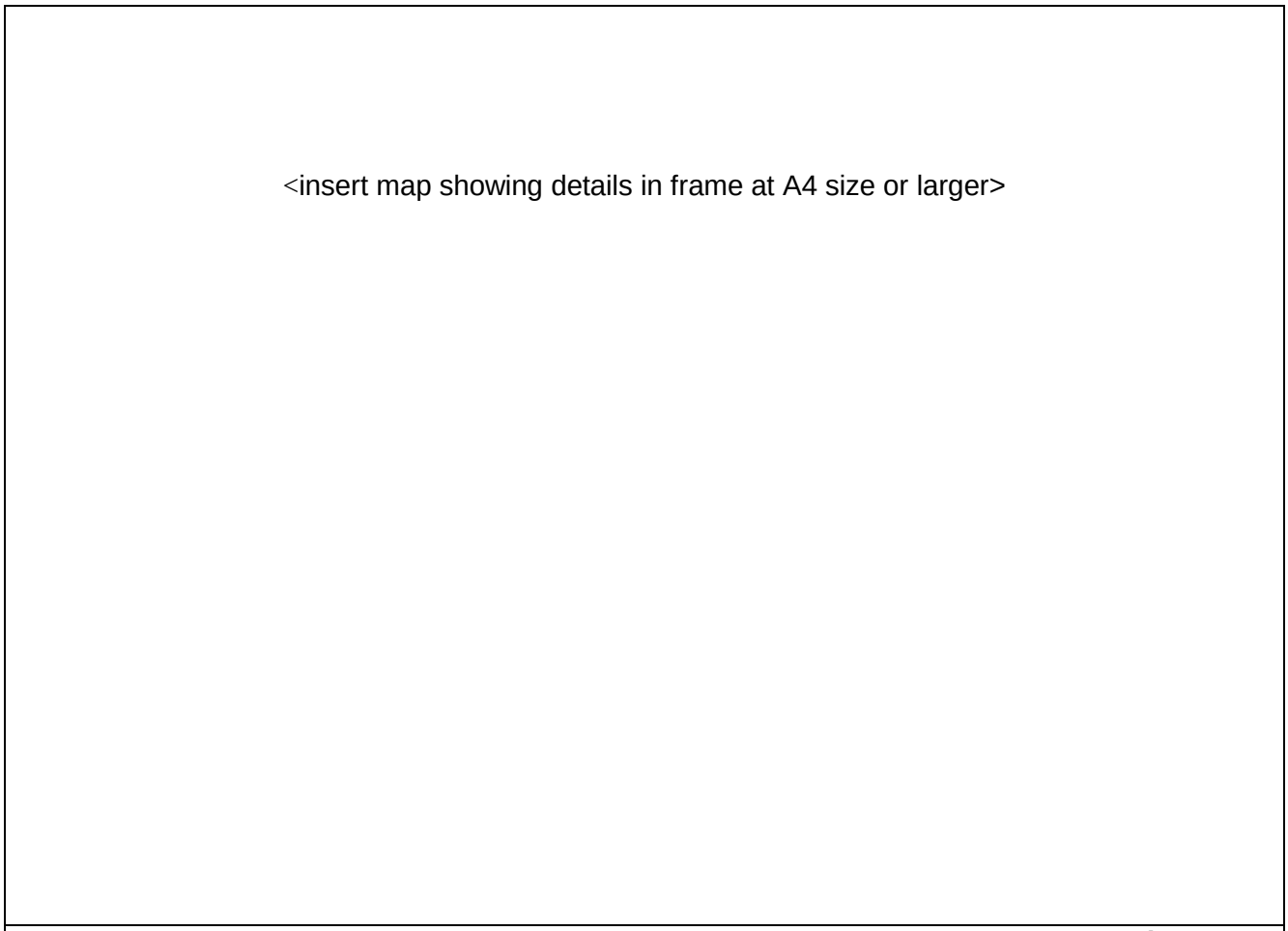

Figure 1

Location plan for monitoring facilities at
< insert name & location>

North
⇑
⇐ ⇒
⇓

Map Scale: 1 = < insert eg 5,000>

Legend

- • WB 1: Existing water supply bore
- ⊕ S7- 99: Shallow monitoring bore no. 7, installed in 1999
- ⊕ I8- 02: Intermediate depth bore no. 8, installed in 2002
- ⊕ D9- 03: Deep monitoring bore no. 9, installed in 2003

CONSTRUCTION DIAGRAM
SHALLOW MONITORING BORE
IN AN UNCONFINED AQUIFER

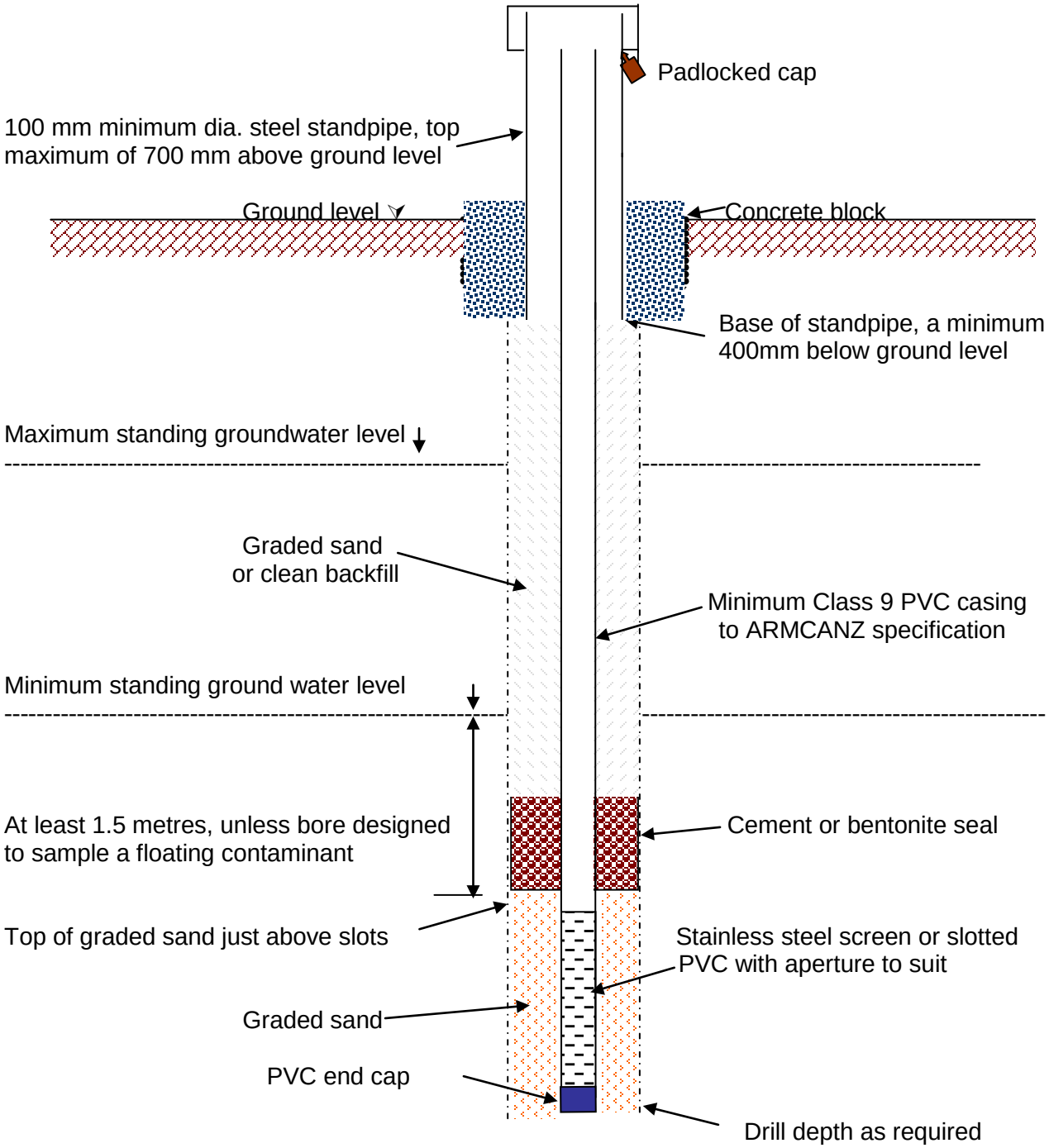

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Figure 2

CONSTRUCTION DIAGRAM-
INTERMEDIATE DEPTH MONITORING BORE
IN A CONFINED OR UNCONFINED AQUIFER

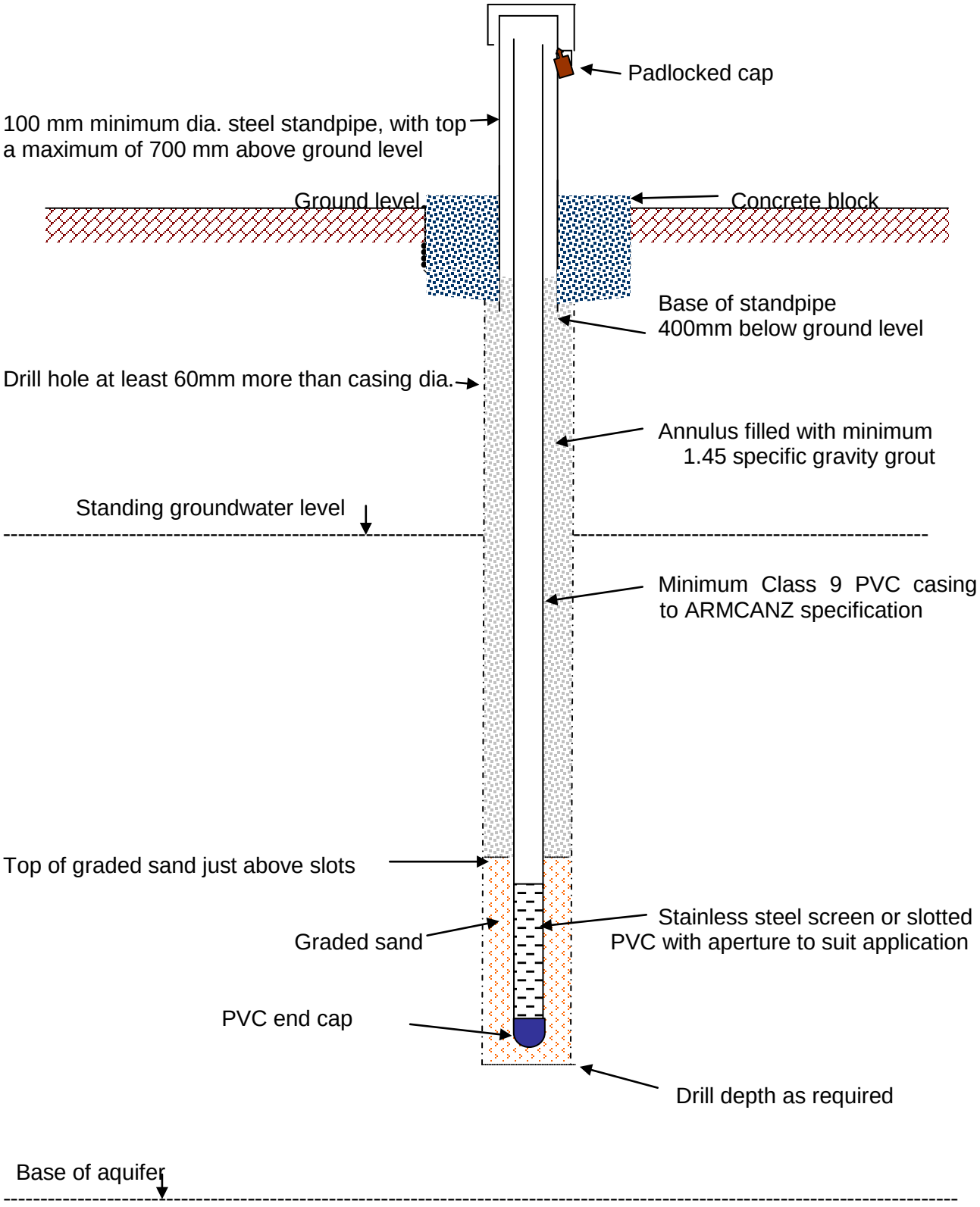

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Figure 3

CONSTRUCTION DIAGRAM –
DEEP MONITORING BORE
IN A CONFINED OR UNCONFINED AQUIFER

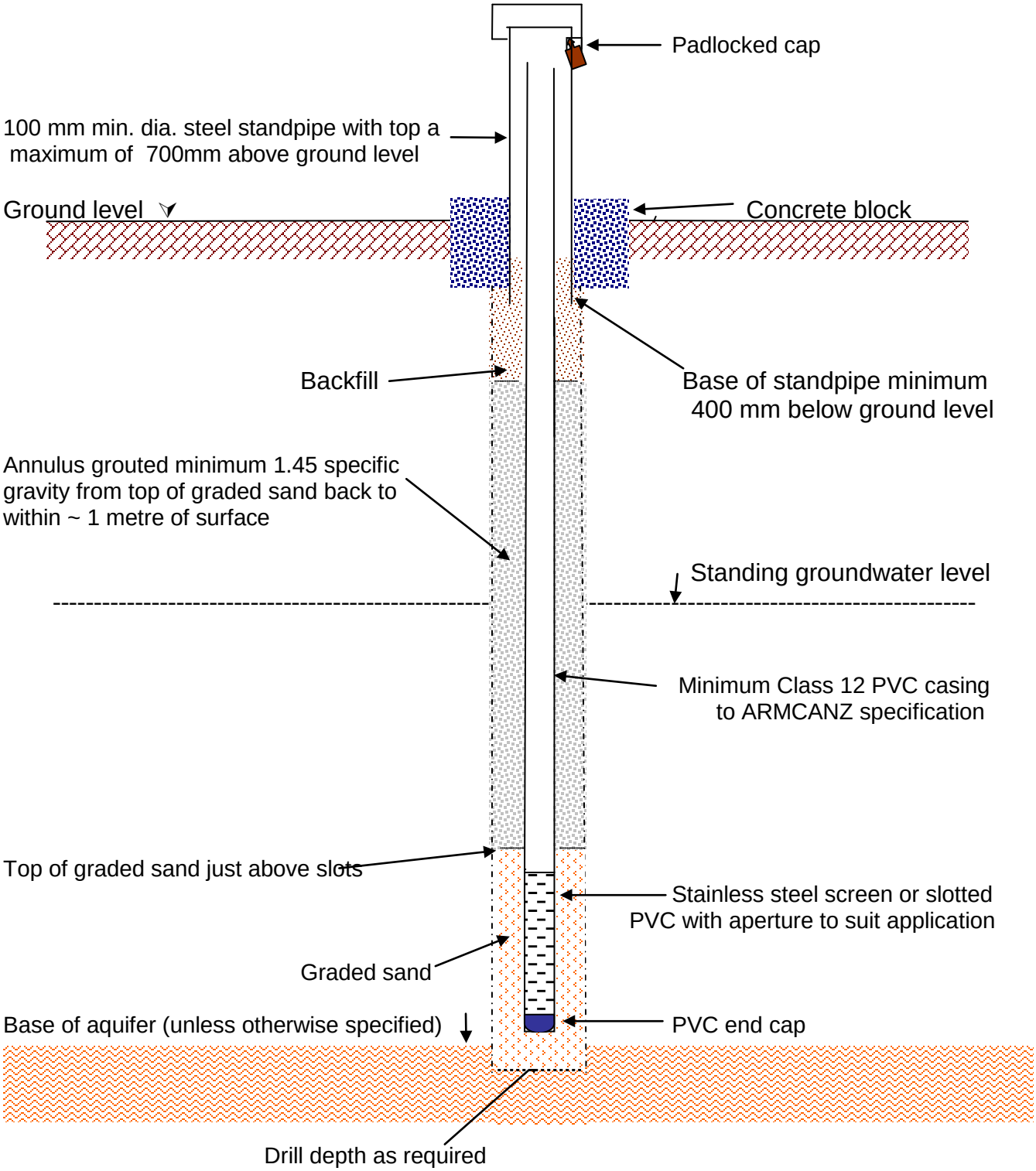

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Figure 4

CONSTRUCTION DIAGRAM–
ARTESIAN DISCHARGE AREA
CONDUCTOR CASING INSTALLED

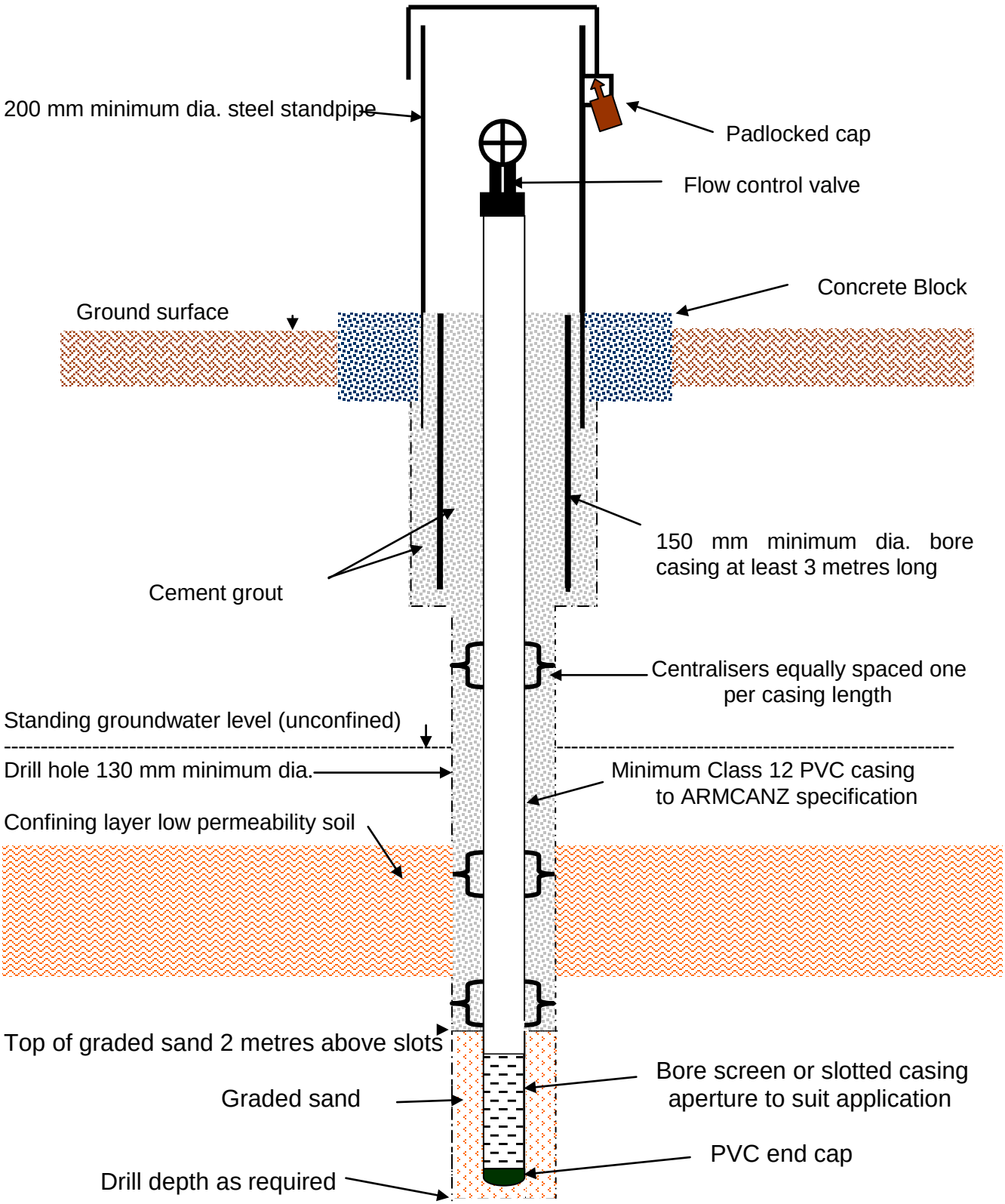

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Figure 5

CONSTRUCTION DIAGRAM-
ARTESIAN DISCHARGE AREA-
NO CONDUCTOR CASING INSTALLED

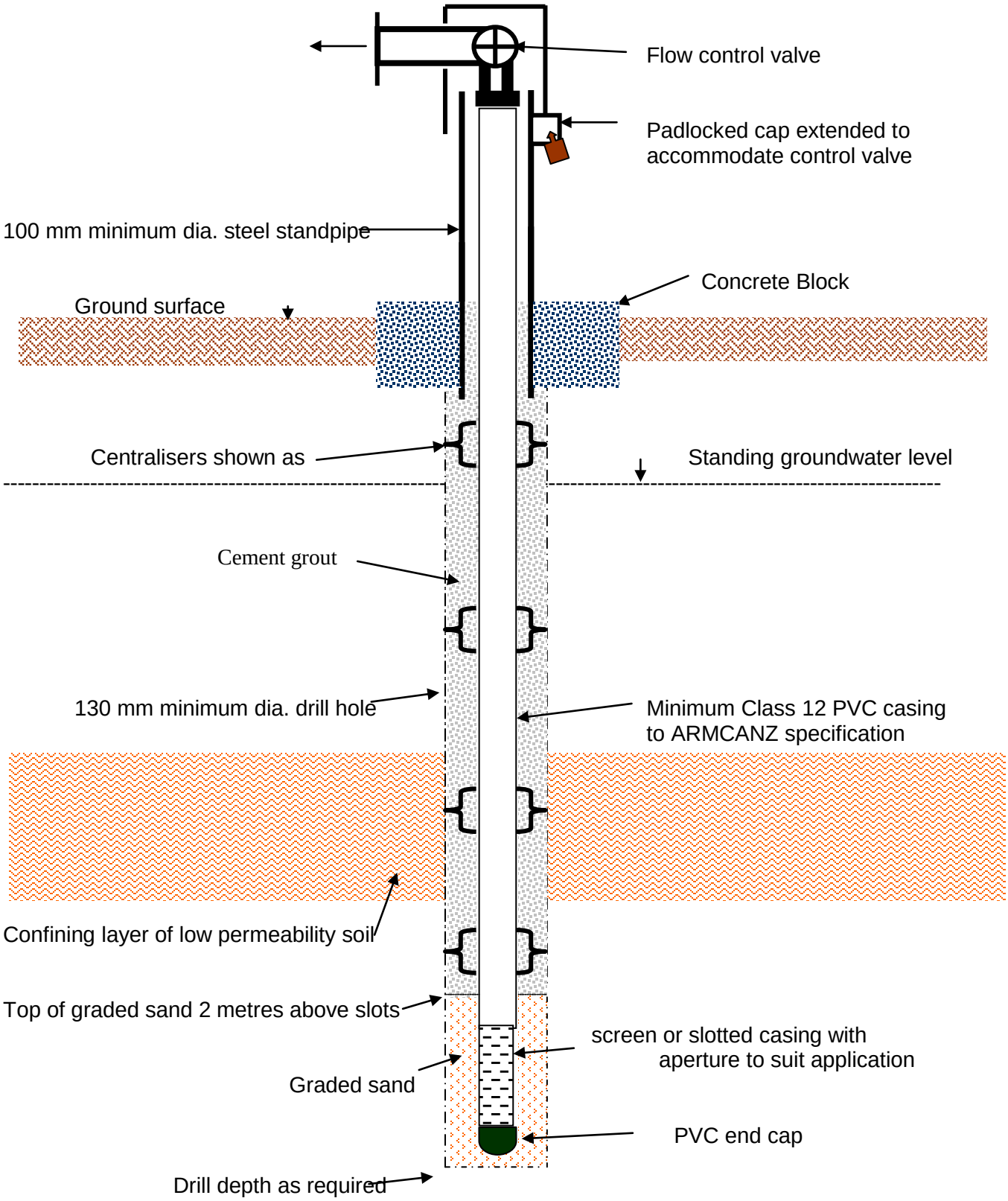

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Figure 6

MONITORING BORE
HEAD-WORKS

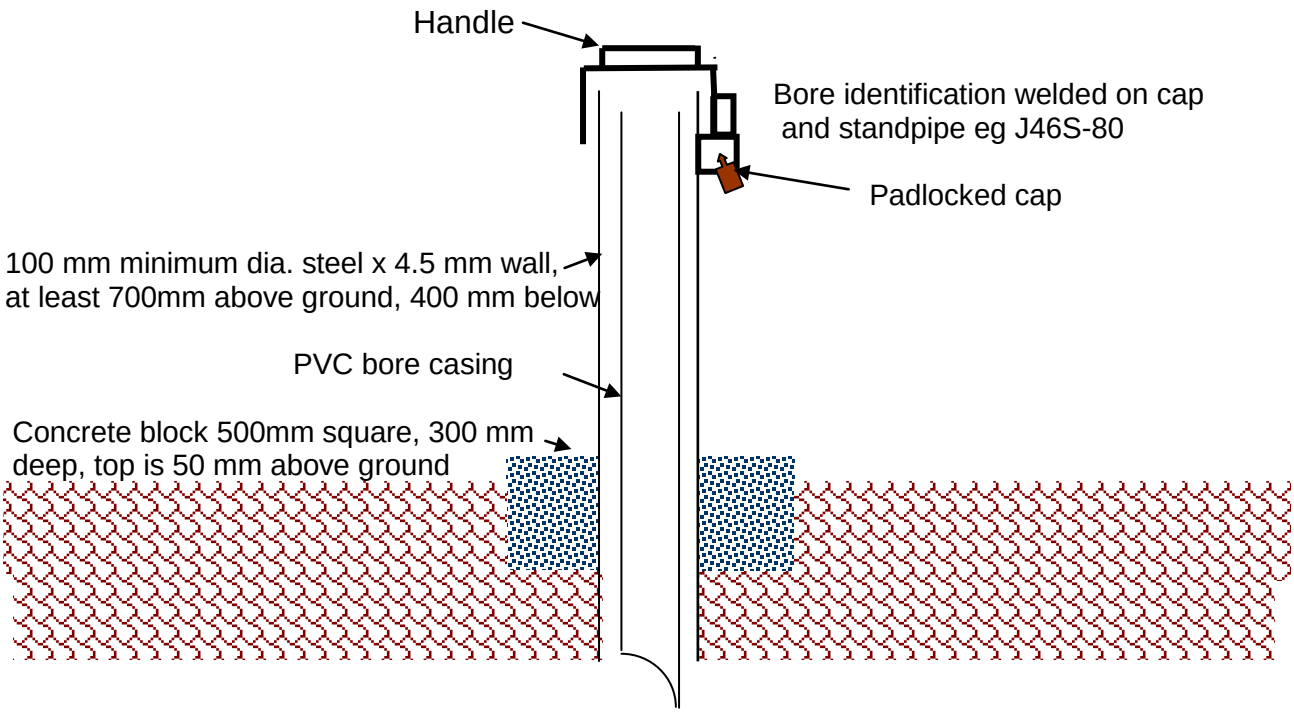

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Figure 7