National Groundwater and Contaminated Land Centre

Decommissioning Redundant Boreholes and Wells

Environment Agency

Decommissioning Redundant Boreholes and Wells in order to Protect Groundwater Resources.

1. Scope

This booklet has been published to assist with the decommissioning of disused boreholes or wells. It suggests a number of best practice options to ensure long term protection of groundwater quality and resources. Further advice can be obtained by contacting the local Environment Agency office, details of which can be found at the end, or by contacting a specialist well contractor details of whom may be obtained from the British Drilling Association.

2. Legal Framework

The Environment Agency is responsible for the protection of "controlled waters" from pollution under the Water Resources Act, 1991. Similar controls are in place in Scotland through the Control of Pollution Act, 1974 (as amended) and in Northern Ireland through the Water Act, 1972. It is an offence to cause pollution of controlled waters either deliberately or accidentally. "Controlled waters" includes all watercourses and groundwater contained in underground strata (or aquifers).

The Agency also has a specific duty to prevent groundwater pollution by certain listed substances under the Groundwater Regulations, 1998. These regulations complete the transposition of the EC Groundwater Directive (80/68/EEC) into UK law. Discharge into groundwater of substances in List I of the directive is prohibited, and discharges of substances in List II must be minimised so as to prevent pollution.

The Environment Agency in England and Wales also has powers under Section 71 of the Water Industry Act, 1991 to prevent wastage of water resources from uncontrolled artesian overflows.

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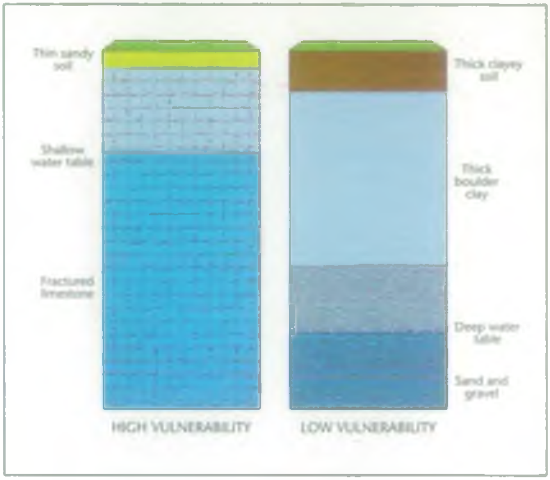


FIGURE 1
The factors controlling vulnerability of aquifers to pollution.

3. Introduction

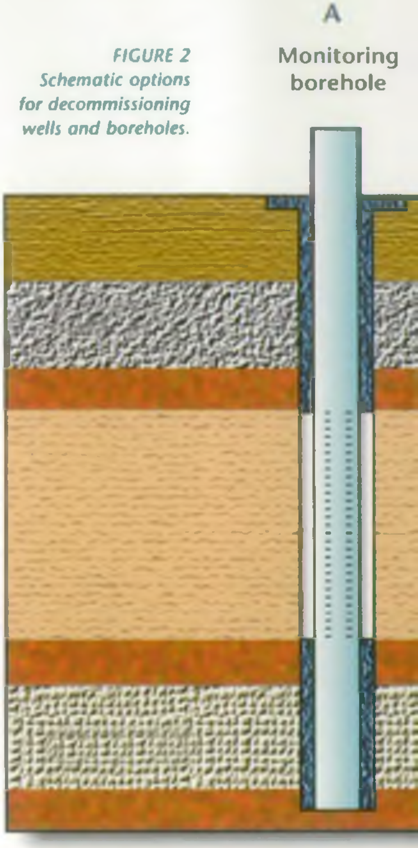
Boreholes and wells are constructed for a variety of purposes: to abstract water; to collect geological information; to investigate and sample soils and groundwater etc. Often, old wells are found on properties that are now connected to a mains water supply, and boreholes and wells may become redundant.

Improperly abandoned boreholes and wells may act as preferential pathways for contaminant movement, leading to the contamination of groundwater, or contributing to the loss of aquifer yield and potentiometric head (water pressure), or result in the mixing of groundwaters of variable quality from different aquifers. They may also present a physical hazard.

Boreholes and wells that are no longer required therefore need to be made safe, structurally stable and backfilled or sealed to prevent groundwater pollution and flow of water between different aquifer units. However, in certain circumstances they may be adapted for use as a groundwater monitoring facility, where this is appropriate. ***It is normally inappropriate and may be unacceptable to convert redundant wells and boreholes to soakaways for the disposal of foul or surface water due to the inherent risk of groundwater pollution.*** The advice of the Agency should always be sought in such cases.

Artesian boreholes (where groundwater in a confined aquifer is at sufficient pressure to cause water to discharge at the ground surface without any pumping) present different problems and warrant special attention to prevent wastage of groundwater resources either by the flow of water from one usable aquifer unit into another unusable unit, or by mixing of clean and polluted groundwaters.

FIGURE 2
Schematic options for decommissioning wells and boreholes.

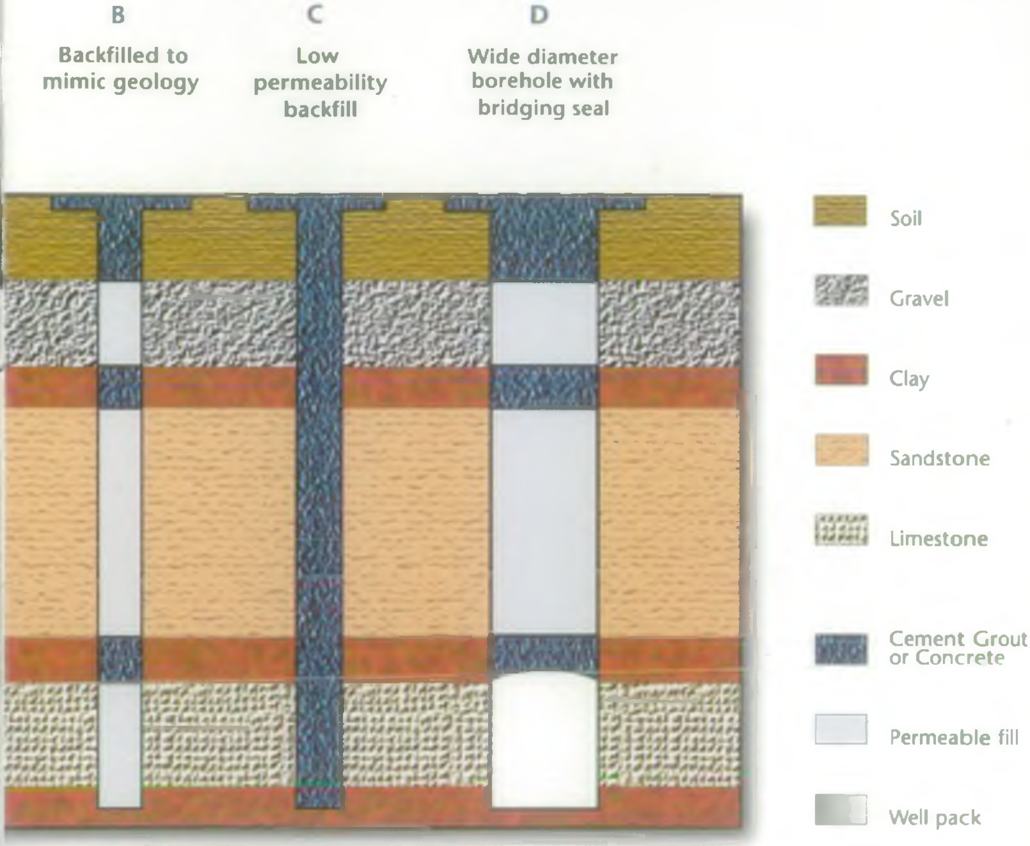


4. Borehole or well construction

Before considering how best to backfill and seal a borehole or well, or whether it can be put to an alternative use, for example as a groundwater monitoring facility, it is necessary to obtain information on the geological strata encountered by the borehole and its completion details. These will include the depth of the borehole, its diameter(s) and construction details (casing, screen and pack). These details may be obtained from site records, the original driller's log(s), or the British Geological Survey. Once all available information has been collated and assessed, the most appropriate course of action can be determined.

5. Conversion to groundwater monitoring points

Redundant boreholes have the potential for conversion into groundwater monitoring boreholes if the data collection exercise described in Section 4 (above) indicates that the boreholes intersect important aquifer units (in terms of resource and quality), and are constructed so that representative groundwater samples may be collected or water levels measured. The ideal borehole construction and completion is dictated by the geological strata encountered and its intended use. Boreholes which intersect a single aquifer unit may be cased through the unsaturated zone, but open hole



(or screened) below the watertable. Boreholes in more complex geologies are likely to require casing over most of the depth of borehole with the exception of the aquifer unit(s) of interest *(see Fig.2 (A))*. These details must be established when considering conversion of the borehole to a monitoring point along with the ultimate purpose that the monitoring facility will serve.

a) Environment Agency strategic monitoring boreholes.

The Agency has a duty to monitor groundwater quality and watertable elevation, and a network of Agency and privately owned boreholes and wells is used for this purpose. New monitoring points are often required to improve coverage or to replace boreholes which have been taken out of use.

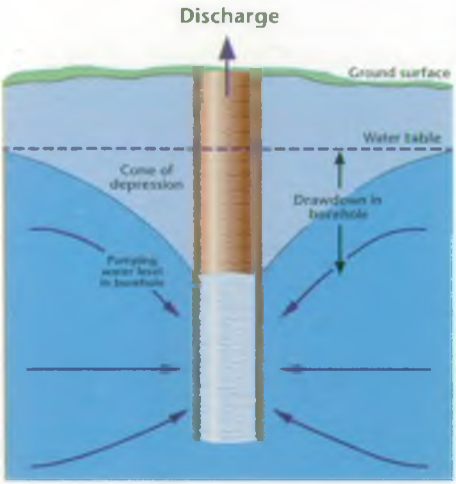


FIGURE 3
The drawdown of the water table around a pumping borehole to form a cone of depression.

When a borehole is constructed such that it allows a representative sample of groundwater to be collected or water levels to be measured, and is located in an area where additional monitoring points are required, consideration should be given to converting it to an Agency monitoring borehole. The Agency may be prepared to pay for the costs of conversion, but in return will require access to the borehole and/or its long-term lease.

b) Contaminated land/landfill monitoring point.

Site investigation boreholes which have been installed as part of a ground engineering investigation, land contamination study or scientific investigation may lend themselves to adaption to longer-term groundwater monitoring facilities.

The design of boreholes on or adjacent to sites which may be contaminated is particularly important because they will act as potential conduits for the vertical migration of contaminants within the soil or fill layers if incorrectly designed. Such boreholes should be cased through the unsaturated zone and the casing sealed with an impermeable cement or bentonite grout to prevent any movement of potentially contaminated water around the outside of the casing. The top of the borehole must also be suitably protected and fitted with a robust lockable cap to prevent the unauthorised entry of objects into the borehole. Where the top of the borehole casing is below ground level it must be surrounded by a suitably constructed, watertight housing.

Boreholes close to contaminated land, landfill sites or other sources of soil gas may also require a venting facility to prevent the build up of noxious gases within the borehole.

FIGURE 4
Decision Flow Chart.

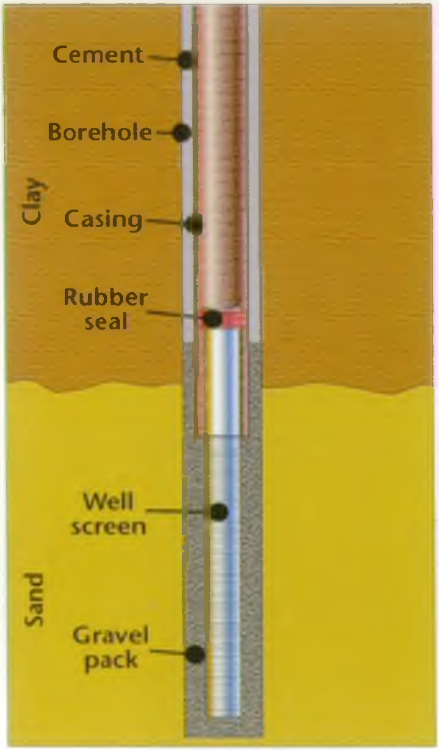


FIGURE 5

Section of a borehole showing a well screen and gravel pack (or filter) in unconsolidated sands.

c) Private monitoring boreholes.

A site owner may wish to convert a redundant abstraction borehole to a groundwater monitoring facility, particularly where the borehole is on or adjacent to contaminated land, or land where potentially polluting activities are being undertaken.

There are many good reasons for so doing including;

- To validate the success of any remedial works being undertaken on the site.
- To demonstrate that activities are not causing pollution, and hence prove regulatory compliance.
- As part of the 'requisite surveillance' required under the Groundwater Regulations, 1998 or the Waste Management Licensing Regulations, 1994.
- To monitor water levels in an urban area where rising groundwater levels may threaten buried structures (tunnels, basements etc.).

6. Decommissioning redundant boreholes and wells

If conversion to a groundwater monitoring point is not possible or necessary, the following borehole abandonment procedures are recommended. However, every borehole and well is different and may require variation from the detail of the approach. For the best results, the employment of a proficient well contractor with a good knowledge of the local geology and well abandonment procedures is recommended.

a) Defining the objectives.

Each site has its own particular characteristics that must be considered when planning how to decommission a borehole or well.

The following objectives may apply, although additional objectives may also be applicable;

- Remove the hazard of an open hole (safety issues).
- Prevent the borehole acting as a conduit for contamination to enter groundwater.
- Prevent the mixing of contaminated and uncontaminated groundwater from different aquifers.
- Prevent the flow of groundwater from one geological horizon to another.
- Prevent the wastage of groundwater from overflow of artesian boreholes.

The method of decommissioning should be capable of achieving each of the objectives that are applicable to a site.

b) Removing headworks and casing.

Ensure that the borehole or well is free from all obstructions that may interfere with the sealing of the hole. In particular, the pump and pipework should be removed together with any other infrastructure (dip tubes etc.). The condition of any borehole casing and grout must be examined to ascertain whether its retention in the hole would prejudice any of the objectives of the abandonment. For many holes, examination of the casing from the ground surface will be adequate, however deep boreholes may require the use of a down-hole Closed Circuit Television (CCTV) to examine the casing at depth.

Where casing has corroded or broken, or the grouting has failed, it may be necessary to remove those materials in order to prevent flow of groundwater around the outside of the borehole. Care should be taken, however, to ensure that removal of the well casing does not result in the collapse of the borehole walls (particularly in unconsolidated materials) and possible subsidence at the ground surface. The advice of a specialist well contractor should be sought over these issues. If it is decided that the well casing needs to be removed, various techniques are available to do this and the well

contractor can advise on the most appropriate technique for a given site.

c) Backfilling the hole.

For most purposes the ground should be restored as closely as possible to its pre-drilled condition. The borehole or well should be backfilled with clean (washed), uncontaminated, excavated materials such that the permeability of the selected materials are similar to the properties of the geological strata against which they are placed. The backfilled borehole will then mimic the surrounding natural strata and groundwater flow and quality will be protected.

Restoration will require a variety of materials to be used so that permeable aggregates (e.g. pea gravel, sand) are positioned adjacent to aquifer horizons, whilst low permeability materials (e.g. clay, bentonite or cement grout, concrete) are positioned adjacent to low permeability horizons *(see Figure 2(B))*. Alternatively, the entire borehole or well can be backfilled with low permeability materials that will prevent significant vertical or horizontal movement of groundwater through or along the borehole *(see Figure 2(C))*.

The materials used to backfill a borehole or well must be clean, inert and non-polluting. Suitable materials include pea-gravel, sand, shingle, concrete, bentonite or cement grout and uncontaminated rock. **UNDER NO CIRCUMSTANCES SHOULD POTENTIALLY POLLUTING MATERIALS BE USED AS INFILL**. Consideration should also be given to the geochemical environment into which these materials will be placed, as under different environmental conditions the behaviour of materials may change (e.g. phenol contamination may prevent bentonite grouts curing).

Aggregates (pea-gravel, shingle, sand etc.) should be selected such that they have a grain size that allows easy delivery into the borehole and should be introduced in a controlled manner to ensure that accidental 'bridging' does not occur within the borehole. Concrete and grouts that are introduced in a liquid form should be introduced through an appropriate delivery pipe (e.g. tremmie pipe), to ensure that voids do not form.

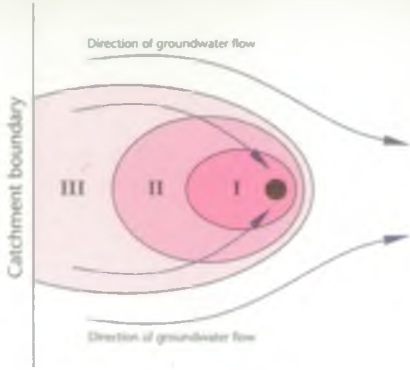


FIGURE 6
Source Protection Zones around a borehole.

I - Inner Zone
II - Outer Zone
III - Total Catchment

Boreholes that penetrate highly fissured aquifers, such as the Chalk and some limestones, present additional problems. Liquid grouts (particularly those injected under pressure), or fine-grained aggregates (e.g. fine sand) may be transported out of the borehole into the body of the aquifer through fissures. Careful monitoring of the process is required if these techniques are used, and in these cases it may be more appropriate to use coarser aggregate (e.g. gravel) as a backfill against fissured aquifers.

Where the site is in a very sensitive location (e.g. an Inner Source Protection Zone (SPZ I) ***(see figure 6)*** as defined in the Agency's Groundwater Protection Policy, or within 50 metres of a potable abstraction) consideration should be given to disinfecting the materials prior to its use as infill. Care must be taken, however, to ensure that the disinfectant does not, in itself, present a groundwater pollution risk. Agency and disinfectant manufacturers advice should be sought in such instances.

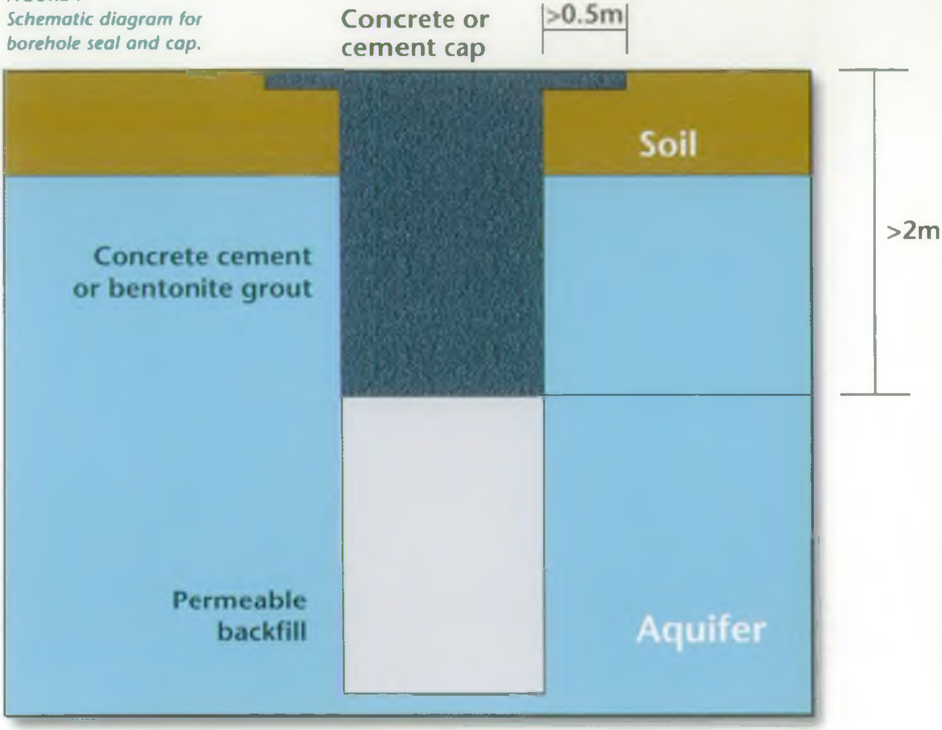
d) Deep and wide boreholes/wells.

In the case of very deep boreholes and wells with wide diameters, the volume of material needed to backfill the hole may be very large. In such circumstances it may be appropriate to adopt an alternative strategy, as long as this will not prejudice any of the original objectives.

Provided that the long term structural stability of the borehoie can be demonstrated, it is acceptable to place a permanent bridging seal, or plug, within the borehole and then to infill above this level using the approach given in Section 6c) ***(page 9) (see Figure 2(D))***. The bridging seal should ideally be positioned below the lowest aquifer horizon. However, where this is not possible, it is important that the open borehole beneath the bridging seal penetrates no more than a single aquifer unit thereby preventing flow of groundwater between different aquifers.

The material commonly used as a bridging seal is cement, although a combination of a mechanical plug and cement is acceptable. Cement seals must be allowed to set (cure) in place

FIGURE 7
Schematic diagram for borehole seal and cap.



before backfilling is continued and completed. The advice of a specialist well contractor should be sought for the most appropriate technique.

e) Sealing the top of the borehole.

In order to prevent potentially contaminated surface run-off or other liquids entering the backfilled borehole, it is necessary to complete the backfilling of all boreholes with an impermeable plug and cap. The final 2 metres (from ground level down) should be filled with cement, concrete or bentonite grout and a concrete or cement cap of suitable strength should then be installed over the top of the borehole and surrounding ground, such that its diameter is at least one metre greater than the diameter of the backfilled borehole *(see Figure 7)*.

f) Artesian boreholes.

For artesian boreholes, the de-commissioning process should aim to confine the groundwater to the aquifer from which it came in order to prevent loss of confining pressure, and the loss of water resources to the surface or other formations.

The first step is to control the artesian flow.

There are a number of ways to accomplish this depending, in part, on the water pressure in the confined

aquifer and the depth to which the water level must be lowered, for instance;

- Pumping the borehole to produce the necessary drawdown.
- Pumping nearby boreholes.
- Extending the casing above ground level beyond the potentiometric surface.
- Introduce dense, non-polluting, fluids into the borehole.
- Introduce a pre-cast plug at an appropriate level within the hole.
- Using an inflatable packer, pressure grout the void space below the packer.

Decommissioning of artesian boreholes is likely to be easiest in late summer, when groundwater levels and artesian flows are at their lowest.

Decommissioning artesian boreholes is a specialist job and requires expert advice.

g) Recording details on site plan.

Complete and accurate records should be kept of the abandonment procedures for possible future reference.

These records should include the following;

- The reasons for abandonment (e.g. water quality problems).
- Measurement of groundwater level prior to backfilling.
- The depth and position of each layer of backfilling and sealing materials.
- The type and quantity of backfilling and sealing materials used.
- Any changes made to the borehole/ well during the abandonment (e.g. casing removal).
- Any problems encountered during the abandonment procedure.

Abandoned borehole and well locations should be marked on site records and, if possible, on the ground. Details of any decommissioning or modifications to borehole construction should also be forwarded to the British Geological Survey.

7. Conversion to soakaways

Redundant wells and boreholes have historically been used for the disposal of surface water, foul effluent and other waste liquids. In many instances this practice has resulted in groundwater pollution. It is not considered acceptable practice to use redundant abstraction boreholes and wells for the disposal of surface or foul drainage, or any other potentially polluting matter.

It is a criminal offence under Section 85 of the Water Resources Act, 1991 to 'cause or knowingly permit any poisonous, noxious or polluting matter or any solid waste matter to enter any controlled waters'. The definition of 'controlled waters' includes all groundwater.

Where the on-site disposal of surface or foul drainage into land or groundwater is necessary then the effluent should normally be treated before its discharge into a shallow soakaway. An authorisation from the Environment Agency is normally required and a discharge may be illegal without one, regardless of whether pollution occurs.

In determining an application for an authorisation the Agency will assess the particular risks of pollution by taking into account the potential for attenuation of contaminants before they reach the water table.

8. Specialist advice

It is recommended that the advice of a specialist well contractor and local Environment Agency staff should always be sought, and the site-specific characteristics of a site given full consideration when determining the best borehole abandonment solution. Details of specialist drilling contractors can be obtained from The British Drilling Association. Further advice can be obtained from the local Environment Agency office, or from the Agency's National Groundwater & Contaminated Land Centre.

9. Further Guidance and References

American Society for Test and Materials (ASTM) D5299-92, 1993.
Standard Guide for Decommissioning Ground Water Wells, Vadose Zones Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

Driscoll, F.G., 1986.
Groundwater and Wells.
Second Edition, Johnson Division.

Environment Agency, 1998.
Policy and Practice for the Protection of Groundwater.

State Co-ordinating Committee on Groundwater, 1996.
State of Ohio Technical guidance for Sealing Unused Wells.

The American Water Works Association, 1984.
AWWA Standards for Water Wells.
AWWA A100-84.

US Environmental Protection Agency, 1975.
Manual of Water Well Construction Practices.
EPA – 570/9-75-001.

British Geological Survey,
National Geosciences Information Centre (NGIC), Keyworth, Nottingham, NG2 5ED.
Tel: (0115) 9363100.

British Drilling Association,
P.O.Box 113, Brentwood, Essex, UK, CM15 9DS.
Tel: (01277) 373456

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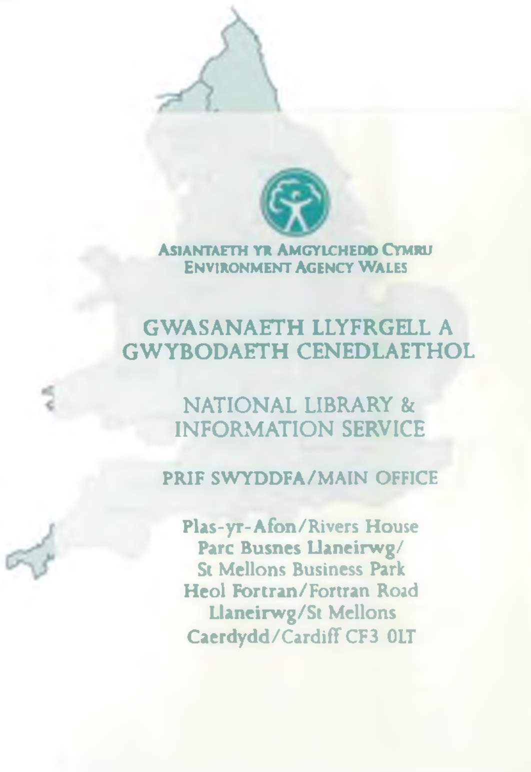

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