

Hand-dug Shallow Wells

Seamus Collins



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Context

Access to adequate water, sanitation, drainage and solid waste disposal are four inter-related basic needs which impact significantly on socio-economic development and quality of life. The number of people around the world who still do not have access to these basic facilities, despite enormous global effort over more than two decades, provides sufficient evidence that conventional approaches and solutions alone are unable to make a sufficient dent in the service backlog which still exists. Numerous initiatives are ongoing at different levels to improve strategies, technologies, institutional arrangements, socio-cultural anchorage, and cost effectiveness, all to enhance efficiency and, eventually, to have an impact on the sector's goals. In addition, the ever-increasing scarcity of water brings policymakers together to find solutions to the challenge of water resource management. This series of manuals is intended as a contribution to these efforts.

Background

The decision to produce this series of manual was prompted by the positive experience gained with a practical manual based on the experience of Helvetas (a Swiss NGO) during the 1970s in Cameroon, which has become outdated with the passage of time. SDC (the Swiss Agency for Development and Co-operation) supported SKAT's initiative to produce this series, working with professionals with longstanding practical experience in the implementation of rural water supply projects. Lessons learnt during the workshops held by AGUASAN (an interdisciplinary working group of water and sanitation professionals from Swiss development and research organisations) over the last 14 years have been included where appropriate. In particular, there is an emphasis on documenting and illustrating practical experiences from all regions of the world.

The Manuals

As can be seen from the table below, this series of manuals is primarily aimed at project managers, engineers and technicians. However, given the wide range of subjects covered, it is also an important working tool for all actors in the sector, ranging from those involved with policy development to those constructing systems at village level. The series has a clear focus on water supply in rural settings. It proposes technologies with due consideration for socio-cultural, economic, institutional and regulatory requirements. This approach is in keeping with the SDC water and sanitation policy, emphasising the balanced development approach leading to sustainable programmes and projects.

It should be noted that the present series deals almost exclusively with water supply. The importance of sanitation is however clearly established in Volume 1, which deals predominantly with the software aspects necessary to achieve an impact. It includes some proposals for optional tools, approaches and institutional arrangements and is intended as an overall introduction to the other, more technical, volumes of the series.

Some final comments

The water and sanitation sector is constantly evolving. We would welcome any queries, comments or suggestions you might have. Your feedback will be made available to other interested users of the manuals.

Finally, we hope that these manuals will be useful for the practitioner in the field as well as for the planner in the office. If the series can be a contribution to providing water to more people in need on a sustainable basis, we will have achieved our goal.

The production of this series has only been possible through the continuous support of colleagues from all over the world. Our sincere thanks to all of them.

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It goes without saying that any errors which remain in the text are my own.

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1.

Introduction

This Manual, Volume 5 in the SKAT series on Rural Water Supply, deals with the planning, construction, management, operation and maintenance of hand-dug wells for water supply to communities in the South. It is intended to be used by planners, engineers and technicians in the Water Sector, with the aim of facilitating the decision on the type of technology to use in a given situation and, where relevant, to outline the implementation of that technology. It is hoped that the manual will also be useful to those involved in village liaison work, in giving an idea of the technical aspects related to improving village water supplies.

Because of its essentially organic and dynamic nature, the process of development in any given geographical or sectoral area is heavily dependent on existing conditions. As a result, the process does not have a uniform pace throughout the world, or even within one country. A cursory glance at the Water Sectors of different countries will reveal widely varying degrees of institutional, policy and human resource development, together with a range of technologies to cater for the different situations (social, cultural, economic and technical) encountered. It is beyond the scope of this manual to try to cover all possible permutations of institutional and technical variations. However, an important aspect of the manual is that, while the focus is primarily technical, attention is given to the many non-technical factors which must be considered in any water supply system. It is hoped that the overall picture of the water supply process is conveyed, and that the need for consideration of both technical and non-technical factors, at all stages of the process, is established. With regard to the management aspects of the water supply process, the reader is referred to Volume 1 of this series of Manuals – Project management.

At the time of writing, 1.3 billion people in developing countries do not have access to safe water, while over 2.5 billion do not have access to sanitation. Two water-borne diseases, diarrhoea and dysentery, account for an estimated 20% of the total burden of disease in developing countries. Polluted water is the cause of almost 2 billion cases of diarrhoea each year¹. Given the complex inter-relationships between the health, water and sanitation sectors, it is clear that any initiative confined to only one sector will have a limited effect on the improvement of the quality of life. Nevertheless, the availability of cheap, easily-applied water supply technologies can make a significant contribution to the development of solutions in a multi-disciplinary approach to the improvement of living standards in the South.

Hand-dug wells provide a cheap, low-technology solution to the challenges of rural water supply, in addition to affording an ideal opportunity for a high level of community participation during all phases of the water supply process (see, however, the note on safety precautions in Section 8.5). In areas which are geologically suited to the technology, where local capacity-building is a priority and where circumstances do not dictate the use of faster or more sophisticated methods, the construction of hand-dug wells can be easily assimilated by a relatively unsophisticated water sector, especially in the technical sense. Hand-dug wells can provide a viable alternative to unhygienic, unprotected sources while avoiding the capital and maintenance costs associated with sophisticated drilling programmes or reticulated pumped systems. A range of lining types and water lifting technologies² can be chosen to match the financial and management capacity of the participants in the water supply process.

¹ UNDP, Human Development Report 1998, p. 68

² See Volume 7 in this series - Water Lifting

This manual concentrates on the construction and maintenance of hand-dug wells with a diameter of 1.0-1.5m. Wells of this type have been excavated to depths in excess of 60m, sometimes using a greater diameter. Local conditions, in addition to considerations of safety and economy, will indicate the average depth of hand-dug wells in a particular area. Beyond a certain depth, the option of mechanically-drilled boreholes must be considered as preferable in terms of safety, cost (both capital and maintenance), and time.

In the case of hand-dug wells, as the name implies, excavation is done by hand and the well may be lined using any one of a number of options as described later in this manual. For the sake of brevity and accessibility, the manual deals more specifically with the use of concrete lining, both reinforced and unreinforced, precast and cast in-situ. Local conditions, technical expertise, tradition and capacities must be taken into account in any decision. To assist in the decision with regard to the technology to be adopted in any given situation, Chapters 2-5 contain a series of checklists which can be used during the decision-making process. The manual is structured around the process of providing water to a rural community, dealing at first with more general considerations before concentrating on the technology of hand-dug wells. The topics treated are:

- the non-technical aspects of rural water supply, including health, hygiene, management, institutions and economic, social and environmental aspects;
- •the technical background, the water cycle, water quantity and quality;
- the options for the exploitation of drinking-water sources;
- principles of hand-dug wells;
- site investigation;
- practice and procedures in hand-dug well construction;
- management, operation and maintenance of hand-dug wells

It will be noted that the more technical aspects of well construction are sandwiched between chapters on the somewhat less tangible aspects of the water supply process. Thus Chapter 2 deals with the non-technical aspects of the process, while Chapter 14 highlights the important subject of management, operation and maintenance. It is hoped that this layout will serve to emphasise the fact that

water supply as an activity is not purely technical in nature.

It is important to mention community participation. This phrase is used throughout the manual, though it is accepted that the concept may be interpreted very differently by different people. In this manual, the phrase is used to imply the full and voluntary participation of the community in all phases of the water supply process, including the submission of an initial request for the provision of such a supply. The institutional framework within which this participation may take place will vary widely from country to country. It is clear that the situation described above is the ideal rather than the reality in many cases. The community, for various reasons, may not participate to the extent of either its willingness or its ability. The water system may be imposed rather than requested. Nevertheless, we have referred throughout the text to "community participation" in the terms outlined above, in the belief that, while many water supply systems are built with a less-than-desirable degree of community involvement, those that are constructed with the full participation of the end users constitute a more lasting contribution to the improvement of health and living conditions in the South. The issue of community participation is treated in more depth in the Manual on Management of Water Supply Systems.



2. *Rural water supply — The non-technical aspects*

2.1 *Introduction*

At its most basic level, the physical activity of providing improved water supply systems in rural communities is undertaken with a view to contributing to an improvement in the quality of life of the end users of the systems. The expected result of the activity is that, after completion of a new or improved system, the standard of living of the community will be better (in terms of the general quality of life as reflected in the occurrence of disease, the amount of time consumed in tasks such as water collection and washing and in the improved quality of water as perceived by the consumers), than it was before the system was built or improved. However, in many cases, it has been noted that the desired effect either was not achieved, or was not achieved to the expected degree. It has become clear that the provision of rural water supply systems is not simply a technical undertaking, but that it must be considered in the overall context of the end-users and the providers of the technical inputs, and the relevant limitations of any given situation. In planning, consideration must be given to many different aspects, such as health, education, the local and national economy, the environment and the institutional set-up which applies.

Because the introduction into a rural community of an improved water supply is only one element in the overall development of that community, the impact on other development areas must be carefully estimated, monitored and evaluated. Desired improvements in living standards are then more likely to be sustainable.

It is important to bear in mind, throughout the planning process, that the provision of water to a rural community introduces a new element into an already complex system of social, cultural, economic and institutional interaction, and the expected impact of such a system must be planned, measured and evaluated in terms of this complex situation.

In addition, it must be borne in mind that the activity itself is complex in nature, involving as it does a variety of actors with different backgrounds, expectations, priorities and rhythms of work. Unfortunately, water supply activities are frequently undertaken in an atmosphere of haste, and the tangible result of a constructed or rehabilitated supply is often given precedence over the more difficult-to-measure health, economic and institutional impacts of the new system.

While it is obvious that inefficient, unprofessional or inappropriate technical inputs will have a severely detrimental effect on the impact of a water supply project, and may even render the system unmanageable, it is clear also, that the provision of a rural water supply is not a simple physical activity, but that there are many intangible aspects to be given careful consideration.

2.2 *Health and hygiene education in relation to water supply*

2.2.1 *Water-related diseases*

While it is a vital element in the sustenance of life, water, or the lack of it, can also be a significant factor in the spread of disease. Water-related diseases may be classified under four headings:

- **water-washed diseases**
These are diseases which occur through a lack of sufficient water for body cleansing. Examples are scabies, tropical ulcer and trachoma.
- **water-borne diseases**
Examples are cholera, typhoid and hepatitis. The disease itself is carried in water. Poor personal hygiene, the use of dirty utensils and the washing of food in infected water also provide channels for the spread of water-borne diseases.

■ water-based diseases

Bilharzia and guinea worm are water-based diseases, where the parasitic organism which is the cause of the disease spends part of its life-cycle in an aquatic host.

■ water-related insect vector diseases

In this case, the diseases are insect-borne and the insects breed in and around water. Malaria falls into this category, as do river blindness and sleeping sickness.

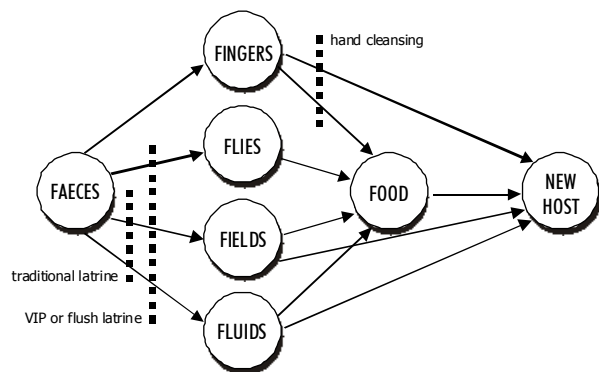


Figure 2-1 - Possible barriers to infection routes from faeces

The incidence of “water-washed” diseases in a community can be reduced in part by the provision of plentiful supplies of water for washing. To achieve a reduction in the occurrence of the water-borne diseases, water must be of a good quality at the point of use (which, in almost all cases involving hand-dug wells, is not the same as the collection point). This implies the necessity for proper procedures with regard to collection and storage. The subject of water quality is treated in more detail in [Section 3.4](#). For a more detailed treatment of water-related diseases, refer to Volume 2 in this series. A more comprehensive coverage is outside the scope of this present Manual.

2.2.2 Hygiene Education and Water Supply

Throughout the water supply process, it is vital to bear in mind the important linkages between health, hygiene education and water. An awareness of the intimate relationships between these factors should inform the activities of all participants in the process. Unfortunately, this is not always the case. There may be a lack of understanding on the part of the service providers (water department, village liaison service, construction crews, private sector

firms) or, if an awareness does exist, there may be a lack of the necessary time or resources to impart the message to the end users. Such a situation can be a significant contributory factor to the failure of water supply systems to bring about improvements in the health of target groups.

The need to establish the linkages in the understanding and practices of the providers and users of the systems is of paramount importance. Work must be done with the community, from an early stage, to ensure a full understanding of the concepts involved. These steps may also involve insuring that the necessary awareness exists at the level of the institutions providing the service.

Before the arrival of a new or improved water supply system, a village will have a certain set of practices with regard to the collection, storage and use of water. For example, the idea of transmission of disease through contaminated water may not be accepted or understood in the community.

Consequently, unhygienic practices in the collection, storage and use of water may be a source of illness and death in that community. On the other hand, a community where water is collected from an unprotected but well-maintained source, where the need to boil water thoroughly before drinking or cooking is well understood, may show a better health profile than another community with protected sources but bad water handling habits. The introduction of a new system will affect some but not necessarily all of the established practices, and unless there is a good awareness, beforehand, of the extent of the changes which will be caused by the new system, it will be difficult to assess its impact and effectiveness. The providers of the service may end up wondering what went wrong when

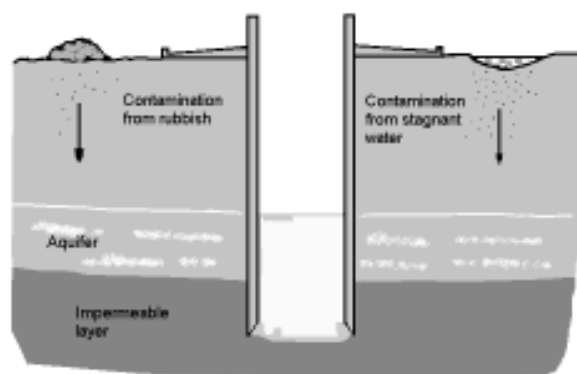


Figure 2-2 - Contamination of a Well

the health indicators for the village do not display the hoped-for improvement.

It must be borne in mind that changes in habit are only absorbed over a long period of time, and the educational process to establish the changed habits can be initiated at a number of different levels at the same time (for example, among women's groups, in schools, with the village hierarchy, etc.) Also, it must be remembered that it is very difficult in practice to demonstrate a direct health impact from the implementation of an improved water supply as there are so many contributory factors.

Cleanliness in the area of the waterpoint is an important factor in the overall impact of the introduction of a new or improved facility. If the surrounding area is not kept clean and free of animals, debris, waste and stagnant water, the waterpoint could have the very undesirable effect of providing an ideal site for the transmission of disease. In this respect, the ability of the community to manage the system and ensure regular cleaning of the waterpoint is vital.

Photograph 2-1 shows a situation which could contribute to the spread of disease or illness within a community. Many communities in rural areas use open wells to as a source of water supply and, indeed, in some communities, such wells are the preferred technology. However, in the photograph, individual buckets and ropes are being used to collect the water. If these are not kept clean, the well may become contaminated. It would be preferable to have a single rope and bucket for water lifting. The cracks in the apron are another source of possible contamination, since they may provide a route for dirty water from the surface to infiltrate back into the well. There is no evidence of a cover which could be put in place when the well is not in use, and the lack of a fence around the well can allow animals to contaminate the area. On a positive note, the existence of the wall around the well is very effective for guinea-worm control.

To summarise this section, the **Checklist for Health and Hygiene Aspects** covers the necessary considerations with regard to the health and hygiene education aspects of the water supply process.



Photograph 2-1 - A (potentially) very unhygienic situation

Checklist for Health and Hygiene Education Aspects

- 1. Is the link between water, sanitation and health understood**
 - a) in the providing institutions**
 - b) among the village contact workers**
 - c) in the community in question?**
- 2. If the above link is not understood, is a practice or capacity in place to bring the understanding to the relevant group, effectively and using appropriate methods?**
- 3. Do the intended users of the new or improved system display an awareness of the need for hygiene in water collection, storage and use?**
- 4. If not, does an institution exist to work on developing such an awareness, and does it have the necessary capacity, particularly in relation to the use of participatory methods?**
- 5. How much is currently known about the knowledge, attitudes and practices of the target group with regard to water use and health in general?**
- 6. If little is known, does the capacity exist to conduct a detailed study of these aspects?**
- 7. If there are already waterpoints in the community, are these well maintained?**
- 8. Are there other activities, complementary to the provision of a water supply (e.g., latrine construction) taking place in the community already?**
- 9. What is the degree of co-ordination, in the office and in the field, between the water, sanitation, health and education sectors?**

2.3 The management of construction, operation and maintenance

The idea that the activity of providing water supplies needs to be managed is so obvious that it may be overlooked at the planning stage, and this oversight has often led to problems, both during the execution phase and during the operation and maintenance phase. In particular, the management of a system after its inauguration does not always receive due attention, and it is in this area that the concept of sustainability comes under the greatest pressure. Assumptions made and activities undertaken during the planning phase must be examined for long-term implications, and measures must be taken to ensure that the sustainability of the system is not compromised.

The management of all phases depends critically on the degree of community participation in each of the relevant activities. Community involvement and participation is a vital and indispensable element in the long-term sustainability of water supplies, and this concept must be reflected in the activities of planning, installing and managing the system. This involvement is of vital importance in the development of the critical sense of ownership which can contribute to the long life and effective use of a water supply system. Such a sense of ownership cannot be created instantly at the moment of inauguration, but must be nurtured carefully from the very beginning of the water supply process. To this end, for the overall success of a given system, strong and capable institutions must be in place before any work is done¹.

¹By the word **institution** we mean not only government institutions, NGOs, the private sector, etc., but also village level groups and committees. In addition to describing an entity such as an agency, a department or a committee, the word is also taken to mean an established habit or an accepted activity.

In relation to the installation of a water supply system, a given set of tasks must be executed and these must be undertaken by some person or entity capable of doing the job efficiently and effectively. Obviously, there must be sufficient resources on hand to allow this to happen. The following points are relevant to the process:

- establishment of initial contact with the community;
- discussion with the community to ascertain priorities with regard to water supply in particular and the overall development of the community in general;
- an explicit request, on the part of the community, for the provision of a new or improved water supply system;
- collection of information (demographic, social, economic, technical) about the project area;
- development or enhancement of a management capacity among the end users, which will ensure that the community should be able to perform such tasks as preventive and corrective maintenance, financial management, erosion control, routine cleaning and resource management in times of scarcity;
- carrying out an accurate technical survey, to allow informed proposals to be made about technical options;
- preparation of relevant technical documentation, to be presented and explained to the community, leading to the selection of one option by the community;
- execution of work in accordance with well-defined standards;
- supervision of work during construction;
- enabling and monitoring of the operation, maintenance and management of the completed system;
- inclusion of the community in a properly organised distribution network for spare parts, if possible using existing structures and institutions (such as the private commercial sector);
- depending on the installed technology, establishment of a qualified capacity to execute repair work beyond the normal scope of the user community (e.g., a handpump mechanic)
- eventual replacement of broken, worn or obsolete parts (or entire systems)

The efficient performance of the above tasks is especially important in relation to community participation, since the confidence of the users is a necessary element in the value which will be ultimately placed on the system and in developing the all-important sense of ownership which can contribute to the long life of the installation. All the institutions involved in the process of planning, providing and managing a water supply must be strong **before** the first activity gets under way, or at the very least be capable of developing at a pace with the new installations and the consequent increase in the demand for services from those institutions.

Representatives of the community (committees, action groups), of the government (both technical and administrative, at each relevant level), of any involved NGO and of the private sector if such is the case, must be able to absorb the workload intro-

duced by any new system. A good relationship between institutions and users is also vital during the operation, maintenance and management phase because it can ensure the collection of information in the long term.

The concept of preventive maintenance is important in the management of any water supply system. The long-term use of the installations can be assured by regular replacement of wearing parts, annual measures against erosion, frequent cleaning of the well and surrounding area and the development of an awareness of the value of the waterpoint to the community.

Closely related to the development and interaction of institutions, the importance of coherent policies cannot be over-emphasised. In addition to helping define how the various institutions interrelate, policies can facilitate the planning and implementation process through the establishment of procedures to be followed in each phase of an activity. Policies can contain guidelines for the provision of and payment for services, in addition to technical parameters and standards. Establishment of clear procedures

with associated documentation can also help to ensure that no steps in the process are omitted and that each community is treated in a similar way. Procedures also make things easier for the implementing agency.

If clear and cohesive (but also flexible) policies exist before any activity is undertaken in the field, there will be less confusion throughout the planning, construction and management phases, and no need to make one-off, **ad hoc** decisions which could create conflict at a later time. Policies can define who gets water, when, in what quantity, what technologies can be offered, what is the degree of financial contribution from the users of the system (for both construction and running costs), what are the relative responsibilities of each of the actors in the process, etc. It goes without saying that any policy should also be sufficiently flexible to allow regional, cultural, economic or technical variations to be taken into account without having to redefine the whole policy.

The issue of scale is also important. Projects involving the construction of ten and one hundred waterpoints will have different overall impacts but the impact on the users of the new wells will be similar in each case, and guidelines must be in place to ensure the success of the process. The need for coherent policies is the same in any case, since a clear and flexible approach will be adaptable to changing circumstances and will avoid the need for frequent reversals or changes in the direction of policy.

The following checklist summarises the points which should be considered in relation to the management of the water supply process, from the planning stages to long-term operation and maintenance.

Checklist for Management Aspects of Rural Water Supply

- 1. Does a coherent water policy exist at national, regional or district level?¹**
- 2. If not, do the capacity and conditions exist to develop such a policy at the relevant level?**
- 3. Do the capacity and conditions exist to allow an implementation of the policy?**
- 4. Any new management system should be based on existing capacities and structures. To what extent do these already exist, and will they be able to support the new system?**
- 5. Does each institution involved in the water supply process a) know its responsibilities and b) possess the necessary human and other resources to execute the project and manage the end result, including the increase in demand on existing or planned resources?**
- 6. If not, is it possible to develop the necessary resources (through Institutional and Human Resource Development activities) during the project period?**
- 7. Are structures and procedures in place which will allow the water supply process, including any associated negotiations, to take place in an atmosphere of inclusion and transparency?**
- 8. In particular, will it be possible to have an informed decision on the choice of technology, taking into account the relevant requirements for long-term operation and maintenance?**
- 9. If the resources for planning and construction do not exist locally, is it possible and acceptable to import the necessary resources for these phases?**
- 10. In particular, is there a well-defined, experienced and trusted agency, with a proven capacity in the application of participatory methodology, operating in the field of village contact and community participation?**
- 11. What is the degree of participation of the communities in all phases of the water supply process?**
- 12. Does the community or village have well-defined structures which allow all those concerned to be involved, and to be heard, in the process of water supply?**
- 13. Is there an effective information-gathering system in operation and can this be used to collect data before the construction phase and during the operation and maintenance phase?**
- 14. Does the capacity exist among the user group to manage any funds associated with the operations and maintenance of the system? If not, is the relevant training available and are there individuals in the community who will be able to avail of the training?**
- 15. What are the possibilities for the gradual increase in the complexity of the supply system (e.g., open well – well with handpump – well with motorised pump) in line with an increase in the economic and management capacities of the users?**

¹ Throughout the Manual, we have used the hierarchy **National–Regional–District–Village**

2.4 Economic implications and impact

The construction, operation and maintenance of water supply systems is never free, whether the payment is made by the government, by a donor, by a private individual or by the community itself. In most cases funding comes from a mixture of these sources. The construction of a rural water supply introduces a new element into the economy, either local, regional or national, and the impact of this must be catered for. Even the most basic economic unit, the family or individual producer, will be affected in some way, since a certain amount of household income will be absorbed by the new system.

Depending on the technology applied costs will vary, both for the capital investor (government, donor, community, NGO, private sector company or a combination of these) and for the long-term operators and users. If a choice is allowed by the ground conditions, the range of possible technologies which can be applied must be drawn up. If it is envisaged that the local and national economy will grow, the water supply system may be installed in a step-wise process, allowing expansion in size and/or increase in technology and running costs as (and if) the local economy develops the necessary financial (and management) capacity. If the economic capacity of

the end users is unable to meet the demands of operating a certain technology, then unless there is a viable and sustainable alternative for meeting operation and maintenance costs, the proposed technology must be reviewed and a more viable option chosen. If the proposed technology is the only technically viable solution, and if other factors demand that a service be provided, a clear policy must be formulated which takes account of the situation but which serves to introduce the highest possible degree of sustainability into the installed system. In the ideal situation, the future users of a system should be presented with the range of viable options and the associated capital and running costs, and should decide which option they want to adopt.

The state of activity of local economies is an important factor in a number of other aspects. If there is a vibrant local economy, there may be private traders who would be willing to carry a stock of spare parts, thus avoiding the need to set up a separate distribution system and allowing the responsibility for routine repairs to pass solely to the users or managers. In such a situation also, it will be easier to set up water vending or maintenance cost recovery schemes. Of course, the success of such schemes depends to a great extent on the level of priority afforded to their water supply by the community in question, and this relates back to the concepts of community participation and education.

Checklist for Economic Implications and Impact

- 1. Who, or which institution, is expected to provide the necessary finance for each of the planning, construction and management phases?***
- 2. Is there any objective evaluation of the willingness and ability of the community to pay for water?***
- 3. What is the present economic capacity of each of the actors in the water supply process, including the end users?***
- 4. Is this economic capacity sufficient to meet the planned contribution to each of the phases mentioned above?***
- 5. If not, what policies are to be applied?***
- 6. Will the new system be managed by a private operator? If so, does this private operator have the economic capacity to ensure a proper operation of the system?***
- 7. Will the community be expected to pay for water? For spare parts? For repairs?***
- 8. Is there a clear policy and legal basis for these payments?***

Two critical aspects in ensuring long-term viability of water supply systems are ability and willingness to pay, on the part of the users, for the service provided. An ability to pay may be reflected in a buoyant local economy, but, without a corresponding willingness, the future operation and maintenance of the system cannot be assured. The various aspects of payment for water supplied to rural communities are the subject of a large body of specialised literature, and are beyond the scope of this manual. The interested reader is referred to the relevant titles indicated in Appendix 1.

2.5 Social, cultural and environmental aspects

Among other aspects which must be considered are the impact of the proposed system on the local environment. For example, the operation of the system may involve the emission of waste gases or liquids, or the catchment and consumption of water may deny a supply to other human users, wildlife or plant life. Again, the construction of a system might create problems with erosion in the area of the installation. The possibility of increased use with increased availability, and the possibility of increased consumption with an increase in population must be taken into account at the planning stage.

In many societies the collection of water has a definite place in the social fabric of a community, and the roles of various groups in relation to water collection and use are well-defined. For many women, the collection of water provides an opportunity for social interaction and is an important part of the day. Whether or not the collection of water is a burden on a particular group within a community cannot be judged accurately from outside, without understanding the place of the activity in the whole social fabric of the community. The introduction of a new system, perhaps in a different location or using a different technology, can have social repercussions and can lead to some intangible problems in the operation and maintenance phase. In this respect, the full participation of all members of a community throughout the whole process of constructing a new or improved water supply is of the utmost importance.



Photograph 2-2 - Women congregating at a waterpoint. The daily collection of water is very much asocial activity.

Of particular importance in this respect is the gender division of labour with regard to water collection, storage and use. The daily collection of water is a task performed by women and children throughout the world, and it is a task which has developed a definite niche in the social fabric of community life. A new or improved water supply system will have an effect on the equilibrium of this activity as it relates to other tasks which are the responsibility of women. The establishment of a waterpoint closer to the village may mean that time formerly spent travelling to collect water becomes available for other tasks. Again, the shorter time spent collecting water may yield less opportunity for social intercourse among the women of a village. Where water is subject to charges, for consumption and/or for maintenance, this will also have an effect on the household economy and on the family member responsible for the budget. Hence, the introduction of a water supply system may disturb the gender balance in a society, or within the family unit. This may become clear already at the planning stage, when it should become clear which group makes the decisions for a village. In many cases, this group may not adequately represent those to be especially affected by the proposed changes. For this reason, it is important that a balance be struck as early as possible in the planning process between all interest groups, including those formed on the basis of gender roles.

Checklist for Environmental, Social and Cultural Aspects

- 1. Does the environment in the target area merit special attention (for example, due to wildlife, plant life, susceptibility to erosion) above the normal considerations?***
- 2. Will the construction or operation of the proposed system introduce practices which could be harmful to the local environment in the short or long term?***
- 3. Will the operation of the system cause an appreciable drop in the local water table and will this affect the environment adversely?***
- 4. Is the proposed technology compatible with the local environment?***
- 5. Do current practices in the target area, in relation to water collection, mean that certain technologies cannot be considered?***
- 6. Within the target community, do the traditions of decision-making allow for the voices of all groups to be heard and considered?***
- 7. In particular, are women included fairly in decision-making processes?***
- 8. Are all the relevant cultural aspects of water collection and use understood?***
- 9. In particular, what is the role of women with regard to water collection, storage and use?***
- 10. What is the tradition regarding the intra-household distribution of resources?***

2.6 ***Preconditions for successful water supply activities***

The foregoing has shown that the introduction of a new or improved water supply system into a community is much more than a straightforward technical activity. Similarly, the decision to construct a hand-dug well cannot be made only by following a set of technical criteria. The criteria listed below must be satisfied if a water supply process is to be assured of any degree of success.

- A cohesive and comprehensive water policy is in place.
- The institutional set-up in the Water Sector is such that the construction activities, and the subsequent operation, maintenance and monitoring of the systems (including the distribution of spare parts), will not overload the Sector or any of its components.
- Community participation is assured.
- Future management of the system is assured through the existence of the necessary institutions.
- There is a clear policy on the financing of construction, operation and maintenance costs, whether this involves direct payment by the users, government subsidies, contracting of private individuals on a commercial basis etc. All those involved understand their roles and responsibilities and are in a position to fulfil them.
- Links are established with the relevant institutions in the areas of health, education and agriculture.
- There is adequate information available about the knowledge, attitudes and practices in the community with regard to health, hygiene and water collection, storage and use. In addition, there is a capacity to follow-up on this information and to put in place a process of continued training/education and enforcement.
- There is sufficient technical information about the groundwater regime in the proposed location, or a capacity exists to do a survey or contract the necessary expertise to do it.
- Technical expertise, and the necessary resources, exist at the appropriate institutional levels, and are available to construct, supervise and maintain the system.
- Requirements for the location of the proposed sites, as detailed in Section 6.3 are satisfied.
- The proposed sites are accessible to the various types of transport which will be necessary during the planning, construction and maintenance phases, or such access can be guaranteed by the required date.

2.7 Conclusions

There may be other points to consider in a particular case, such as the logistics of bringing heavy equipment over long distances or the availability of suitably-qualified staff at the planned location. In any case, it will be clear that there are complex inter-relationships between the various non-technical aspects of the water supply process. No single aspect can be considered in isolation, since this would involve making limiting assumptions about the influence of the other parameters. In the end, a decision must be made on the relative priorities of each aspect, considered against a community's need for a supply of drinking water. In this respect, a set of basic principles as defined in a good water policy is of particular importance.

This chapter has attempted to give a brief overview of the important non-technical considerations in relation to rural water supply projects and systems. For a more comprehensive treatment of the subject, the reader is referred to Volume 1 in this series of Manuals.

3.

Technical aspects of rural water supply

3.1 Introduction

The previous section considered the non-technical aspects of the introduction and management of a water supply system. This section will focus on the technical side, and will emphasise the technical considerations related to the construction of hand-dug wells. At the outset, it is important once more to put the technical aspect of water supply in context. For any given situation, there will be a range of **technically** feasible solutions. However, even the most appropriate technical solution will not prove

sustainable if due consideration is not given to non-technical aspects, as treated in Chapter 2. Similarly, an inappropriate technical solution will make a system unmanageable and unsustainable even when all other non-technical factors are considered and resolved in the most sustainable manner possible.

3.2 The occurrence of groundwater

3.2.1 The Hydrological Cycle

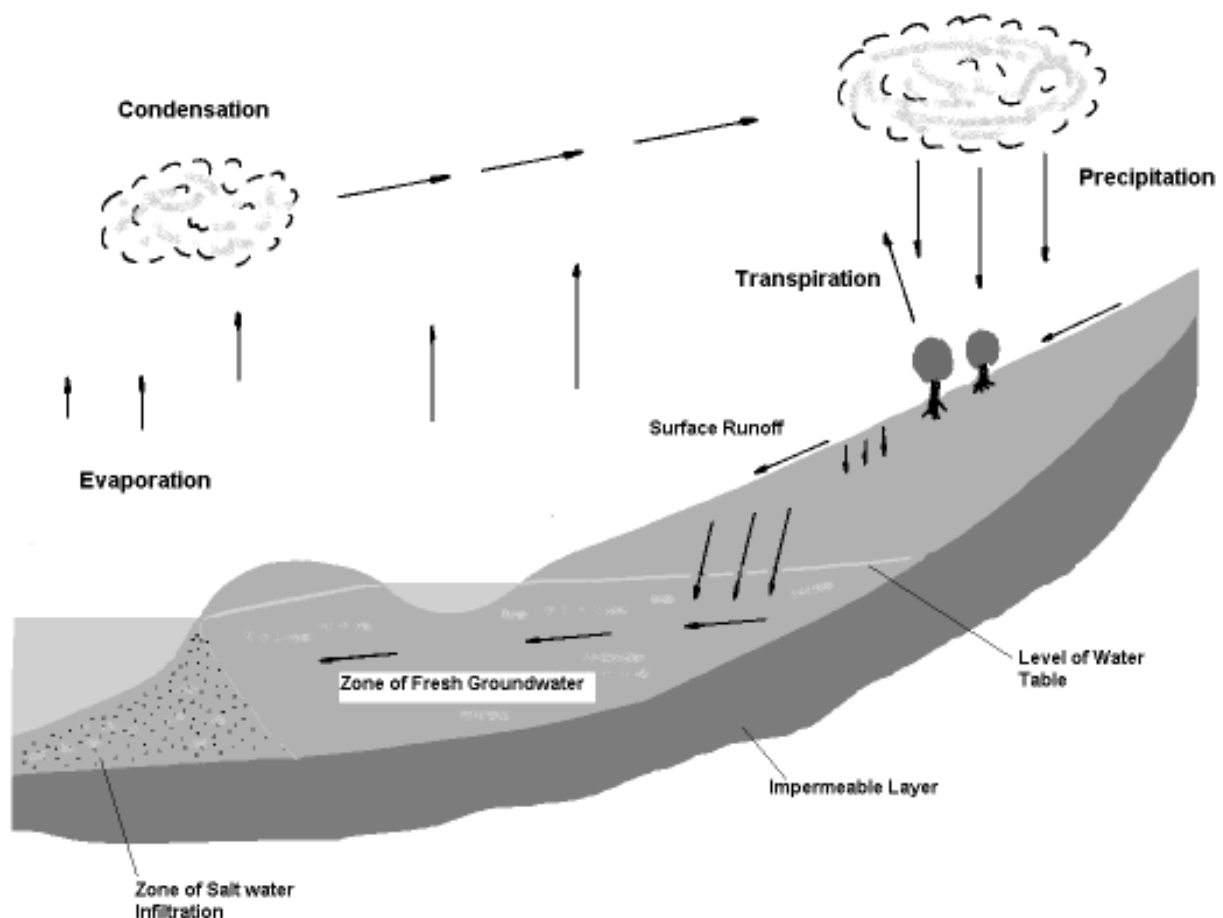


Figure 3-1 - The Hydrological Cycle

The hydrological cycle, also known as the water cycle, is the constantly-occurring process whereby, in simplified terms, water falls to the ground as rain, or other precipitation, runs along the ground under the force of gravity or percolates down to an impermeable layer of soil or rock, appears again at the surface, eventually reaches the sea or a lake and evaporates to form clouds which produce rain. This process is represented graphically in Figure 3.1. In its use of water for various activities, the world's population intervenes in this cycle at a number of points. For the purpose of this manual, we are interested only in the exploitation of water as it passes through shallow aquifers, when it is referred to as groundwater.

3.2.2 Types of aquifer

Figure 3.2 illustrates the various types of aquifer

which can occur. Aquifers may be classified broadly in three categories, namely,

- **confined aquifers** are water-bearing strata which lie between two impermeable layers. Water in these aquifers is often under pressure and, if the upper impermeable layer is breached by a borehole, the water from the aquifer will rise to its piezometric level. Where this piezometric level is above ground level, water will emerge from the borehole under pressure and will gush up into the air. This is referred to as an artesian well. In a case where the piezometric level is **below** ground level, but above the level of the top of the confined aquifer, this is known as a sub-artesian well. Note that the piezometric pressure line refers only to the water in the confined aquifer.

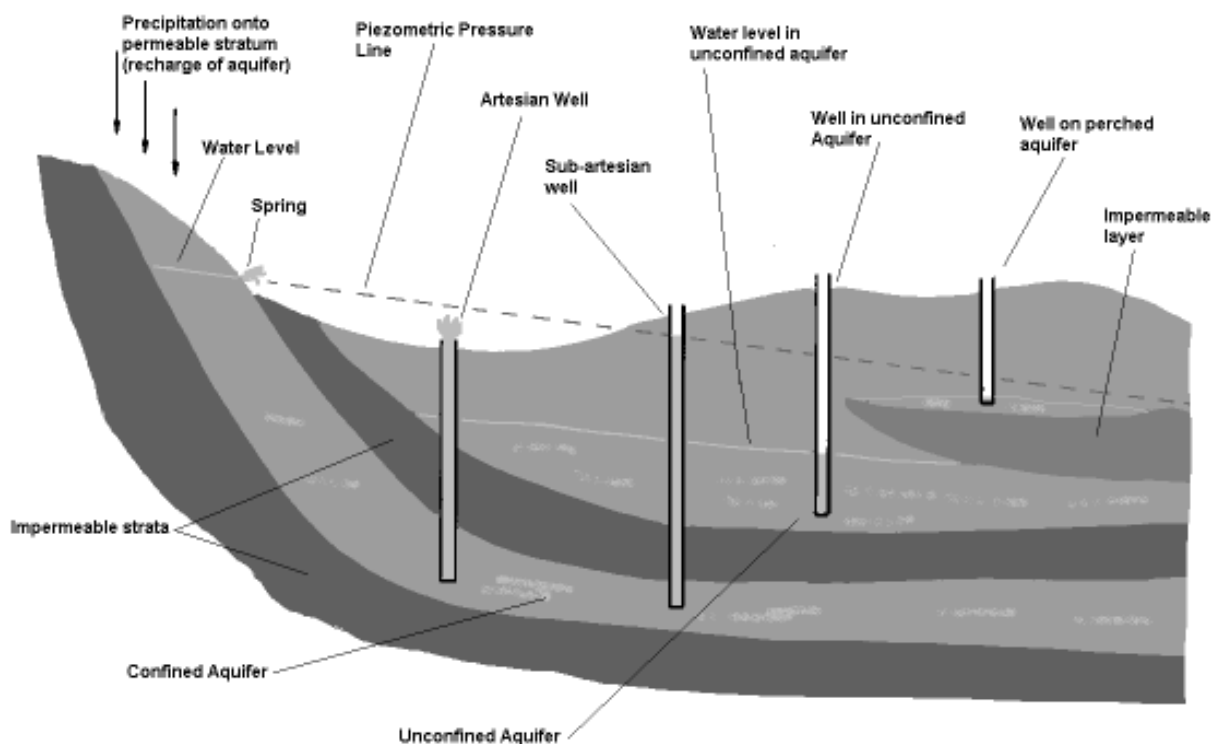


Figure 3-2 - Types of Aquifer

- **unconfined aquifers** occur when the water-bearing stratum is not covered by an impermeable layer. In this situation, the water in the aquifer is not under pressure, and will not rise in a borehole or well which reaches the level of the aquifer. The level of water in this aquifer will fluctuate with the seasons, and care must be taken when exploiting such an aquifer for water supply purposes.
- **perched aquifers** are a special case of unconfined aquifers. These occur where water, as it percolates down from the surface, is trapped by an isolated impermeable layer, of limited extent, within otherwise permeable strata. Unless the impermeable stratum is very extensive, a perched aquifer is recharged only by locally-occurring rainfall and will provide at best a seasonal supply of water.

3.3 Water quantity

3.3.1 Supply and demand

The consumption of water is a question of supply and demand, and increased availability and accessibility usually lead to increased consumption, at least up to a certain point. It is difficult for planners to predict the future rates of consumption in order to have some guidelines for dimensioning a planned

system. Many agencies do not have the resources to conduct detailed surveys in each location during the planning stage. In any case, the introduction of a survey into a particular community might even have the effect of temporarily altering consumption patterns and thus yielding a false basis for planning. In most cases, planners depend on broad estimates and, taking physical and financial limitations into account, try to allow generously for increased consumption and population growth in the future. It is essential that relevant guidelines exist, so that a degree of cohesion and equality can be ensured in a country's water supply programme. Estimates for the consumption of water in rural communities vary from country to country, but the table below is indicative of the normal ranges applied.

Countries will adopt their own coverage criteria in accordance with the general policy for water supply, taking into account demographic, physical, financial, economic, technical and other considerations. In some countries the target level of coverage may be expressed in a given quantity of water per person per day. In others, it may be given as the provision of a waterpoint within a certain maximum walking distance from a given number of users. Whatever the situation, the providing agency must define its objectives in terms of the level of service to be provided to the rural communities and pursue programmes and technologies which guarantee this level.

Type of Supply/User		Typical Daily Consumption (litres per person per day)
Communal well with handpump at:	1km distance	5-10
	500m	10-15
	250m	15-25
Neighbourhood well/standpipe		20-15
Standpipe in yard (exclusive to household)		20-80
Water piped into house (single tap)		30-60
Water piped into house (multiple taps)		70-200
School	- day students, per student	6-15
	- boarding students, per student	40-80
Hospital, per bed		200-500

Table 3-1 - Ranges of Water Consumption

During the planning process, it must be borne in mind that the concept of an acceptable or appropriate level of service may be interpreted differently by the different participants in the water supply process. It is important that all possibilities and perceptions be thoroughly debated, explained and negotiated to an acceptable compromise at the planning stage, to avoid confusion, misunderstanding or disappointment later. It is vital that a new or improved water system satisfy the users in terms of their general expectations, (for example, in the increased convenience brought by the system or the volume of water which will be available), and that the limitations of any technical solution are explained clearly. If this is not done, and if there is not sufficient education about proper practices in relation to water collection and use, the community may well ignore the maintenance of the new system and opt to use less hygienic sources. If the community's expectations are unrealistic (in terms of the sophistication of the new system, the real capacity of the aquifer to be exploited, the probable costs of operation and maintenance, the price to be paid by the consumers, the input expected from the community in terms of management of the system etc.), representatives of the service providers must ensure that people are informed of what is actually possible in a given situation.

The level of use of a system must be taken into account in the planning stage. If, for example, a ratio of 1 waterpoint to 500 people is applied, the installations will receive twice as much wear as if a ratio of 1 to 250 were applied. Obviously, the investment costs in the latter case will be greater than those in the former but, in the long term, considerations of use, wear and tear and routine maintenance must be taken into account in relation to considerations of initial capital investment. Moreover, a higher level of service will normally result in an increased willingness to maintain and pay for a system.

3.3.2 Exploiting and managing the water resource

To ensure the long-term sustainability of a resource, its consumption must be balanced with the capacity for renewal and the needs of the users of the resource. The amount of water made available and collected on a given day will depend on the yield of the source, the time of year and the capacity of the

applied technology to carry the water to its point of use. In many cases, since the amount of water available will vary with the time of year, or from year to year, it will be necessary for the users to manage the water provided, particularly (but not only) at times of scarcity.

While it may be obvious that the basic goal is for everyone to have access to water in whatever month of the year, at whatever time of the day, this assumption may be limited by the physical conditions at a given location. Planners must take into account these factors, and propose a technical solution which assures the highest possible degree of service at all times of the year. Drilling a borehole into an aquifer that does not recharge at a reasonable rate, and installing a handpump, will lead to damaged equipment and frustrated users. Excavating a hand-dug well in an area where the water table is known to be unreliable and subject to a high degree of fluctuation will have the same effect.

While the focus of the present Manual is primarily on the supply of water for domestic consumption, it may happen that not all the users of a well will draw water for this purpose. Also, within a small area, the same aquifer may be exploited for a number of different purposes and at a number of different locations, both private and public. Activities such as irrigation or a commercial activity such as a laundry service can consume a high volume of water on a daily basis. In such a situation, priorities must be defined and the exploitation of the water resource regulated so that essential needs are satisfied before the water is used for non-domestic purposes. For example, the use of water for large-scale irrigation must not be allowed to depress the water table to an extent which would deny a supply to domestic users. Another important consideration is the recharge of the aquifer, and the protection of the recharge area against contamination. Since the location in which recharge takes place is not always near the point of use of the water, the existence of a comprehensive water policy is very useful in such cases.

3.4 Water quality

3.4.1 Drinking water quality and monitoring

The provision of water in plentiful quantities is a significant factor in the improvement of the health status of a community, particularly in relation to the water-washed diseases mentioned in Section 2.2.1. However, contact with contaminated water during washing can result in infection with other diseases such as those classified as water-borne or water-based. In addition, if the water is to be used for food preparation and drinking, it must be borne in mind that infectious diseases caused by pathogenic micro-organisms or by parasites constitute the most common health risk related to drinking water. Taking this into account, the final decision on the construction or improvement of a waterpoint cannot be made unless there is evidence that, as well as providing water in sufficient quantities, the resulting waterpoint will constitute a real improvement in the quality of water available to the community.

Whether or not water is provided treated or untreated at the point of collection will depend on the degree of purity of the raw supply, the mechanisms and resources in place for monitoring and treatment and the accepted practices in the community with regard to the collection, storage and use of water. It must be stressed that the provision of clean water at the point of collection does not guarantee the availability of clean water at the point of use.

The World Health Organisation has produced a series of guidelines for drinking water quality.¹ The point is made that the values given, for various microbiological, chemical and other indicators, serve merely as guidelines, and each national water authority will develop standards based on the local situation. The guidelines cannot be viewed in isolation from environmental, social, economic and cultural factors, and any national standards, whether or not they are based on the guidelines, should take all these factors into account. Also, it should be borne in mind that an intervention in a particular water supply situation may not result in a supply of water which satisfies national guidelines, but does result in a considerable improvement over the

initial situation. One possible example could be the provision of rainwater catchments in an area where the groundwater conductivity is above nationally-accepted guidelines. At least during the rainy season, the users would have an alternative supply of drinking water. The need for improved water supplies exists even in areas where national standards cannot easily be met.

One of the most common indicators used for drinking water quality is the presence of coliform bacteria. Testing may be done for faecal coliforms or for all types of coliform. An indication of the presence of faecal coliforms in a water sample shows that there has been contamination by humans or other warm-blooded animals, which in turn indicates the danger of infection by other pathogens. Testing for total coliforms is less useful, since other coliform bacteria are quite common in the environment, and their presence in a water sample does not necessarily indicate faecal contamination. The WHO guidelines suggest that no coliform (*E. coli*, thermotolerant or other coliform) bacteria should be present in any 100ml sample of water.

However, it is frequently not possible, for financial, logistical or personnel reasons, to be able to conduct regular and frequent monitoring of water quality, especially at a local level. In any case, measuring water quality at the point of collection does not take account of transport and storage practices. Another problem with water quality monitoring is that the results of a test, however careful and accurate, indicate the situation at one point in time, making no allowance for the possibility that the situation could deteriorate soon after the extraction of the sample.

The best option in such cases is to adopt a regime of risk assessment and risk minimisation called a sanitary survey. This is a very valuable technique, requiring very little investment or training for field application, and is of particular value for hand-dug wells. The quality of water at the point of collection can only be assured by introducing measures for pollution control at the well itself. These can include lining the well, observing the guidelines for the positioning of the waterpoint (see Section 6.3), covering the well, fitting a self-priming handpump, constructing an apron at the well-head and

¹ WHO, *Guidelines for drinking-water quality*, 2nd ed., Vols. 1-3, Geneva, 1993

ensuring that the area around the well is kept clean and free of stagnant water and animals. These measures should ideally be implemented in tandem with a programme of education on hygiene and health in relation to water use. If the sanitary survey is repeated at regular intervals (for example, once a year), an increase in the assessed risk will indicate the need for corrective measures.

During the initial visit to a proposed waterpoint site, the technical team may not be in a position to do an in-depth water quality analysis. An extensive range of indicators cannot be measured in field tests, and will also be outside the scope of many laboratories in countries of the South. A number of criteria, mainly empirical, may be applied in the field which will indicate whether or not it is advisable to continue with the installation of a waterpoint. Water should be tasteless, odourless and, after settling in a container, clear and colourless. It should not contain any visible living organisms such as worms, nor any waste, oil or plant matter. For quick field measurement of the concentration of certain chemicals, specific indicator strips are available, and litmus paper can be used to check the pH.

A word of caution is necessary here. While it is not at all intended to discourage the establishment of systems for the continuous surveillance of drinking water quality, anyone considering the setting-up of such systems must take into account all the associated implications. Surveillance is a necessary part of the operation and maintenance phase of any water supply system², but the type of surveillance regime adopted must be compatible with the given situation, and must produce reliable, useful results. At first glance, the surveillance of drinking water quality may seem like a straightforward technical activity, but it must be borne in mind that this activity takes place within the complex situation of water supply systems, often in areas which are badly served by infrastructure, communications and resources (both human and material). While field kits are available to check for the presence of specific contaminants, no testing regime should be initiated unless there are concrete guarantees that the necessary resources are available to ensure long-term, frequent and regular testing. Data from isolated tests can only give a distorted view of an already-

complex situation. For these reasons, it is advisable that any surveillance regime take full account of existing and future resources.

Again, quite apart from the technical considerations, mechanisms must be in place (and adequately resourced) to allow for a rapid response to the results of quality testing. If, for example, a well is shown to be contaminated, a procedure must be defined (and accepted beforehand by all actors) for closure of the well, repetition of the test, treatment, further testing and eventual reopening. It is not sufficient merely to ascertain that a source is polluted. In this regard, the strength of the operation and maintenance regime, and of the institutions involved in it, are critical.

In conclusion, it can be said that a good and effective water quality surveillance regime need not necessarily include frequent chemical testing, either in the field or in a laboratory. An appropriate scheme will include proper siting of the waterpoint and the regular assessment and minimisation of the risk of contamination, in association with a comprehensive regime of sanitary management.

A more in-depth discussion of water quality analysis is outside the scope of this manual and the interested reader is referred to the specialised texts mentioned in [Appendix 1](#). For a more comprehensive introduction to the subject, the reader can consult the relevant chapter in Volume 2 of this series.

3.4.2 Disinfection

During the construction phase the water in the well will become contaminated due to labourers standing in it, debris falling in etc. Upon completion of the well, but **before** any water is collected and used, a disinfection of the well must be carried out using, usually, chlorine. The subject of disinfection of a completed well is treated in more detail in [Section 10.2](#).

During the normal operation phase of a waterpoint, the decision about a disinfection regime should follow the considerations outlined above for the surveillance of water quality. Essentially, any such

² The subject is treated at some length in volume 3 of the aforementioned WHO *Guidelines for Drinking Water Quality*

procedures must take account of local capacities and practices. While disinfection at regular intervals would be generally desirable, local conditions (institutions, resources and level of supply) must allow for the closure of the well, testing of the well after treatment and the capacity to declare the water safe for human consumption once more (free from residual traces of the disinfecting agent). The hazardous, ineffective and unregulated treatment of waterpoints could have a detrimental effect on the health of the users, to say nothing about the negative effect on the sense of ownership or responsibility for the system.

In cases where there is an outbreak of a water-related disease, such as cholera, suspect waterpoints must be closed and disinfected in accordance with strict guidelines, normally overseen by the health sector.

3.5 Technical requirements for construction, operation and maintenance

It is stating the obvious to say that, in order to construct a water supply system, the capacity to do so must already exist. Leaving aside for the moment the important non-technical aspects of community contact and capital funding, the ultimate provider of the water system must have a variety of technical, human and other resources available. The following checklist gives an indication of these resources.

Checklist for Resources Necessary for Water Supply Construction and Maintenance

- 1. Resources for the carrying out of detailed surveys of the water resources in a given area, including:**
 - a) Information on the geology of the proposed location from maps, a relevant data base or other reports;**
 - b) Information on the groundwater resources in the area from previous installations, reports, borehole logs, etc.;**
 - c) Information on the rainfall patterns in the area;**
 - d) Information on activities (agricultural, mining, industrial, etc.) in the area of recharge of the aquifer to be exploited;**
 - e) Equipment to perform the necessary survey, whether geophysical soundings, a manual test borehole, spring measurement etc.;**
 - f) Personnel to perform the survey and interpret the results. In the case of geophysical surveys, a qualified hydrogeologist will be needed;**
 - g) Personnel to receive and check the report on the survey.**
- 2. Resources to design the proposed system, including the production of relevant drawings, technical standards and contract documents.**
- 3. Personnel capable of doing the physical work in accordance with the prepared instructions.**
- 4. Personnel capable of conducting the necessary supervision of the construction work to ensure compliance with standards and efficient execution of work.**
- 5. Personnel to work in the area of capacity-building (teaching the users to manage and use the system), using effective and appropriate participatory training methods.**
- 6. Transport for survey, construction (personnel and materials) and supervision.**
- 7. Resources to guarantee the smooth introduction and management of the Operation and Maintenance phase.**

Hand-dug shallow wells

In the early stages of a project, all the above-listed resources may not be available, and initial works may be used as part of a staff training plan. The construction of water supplies may well go ahead without some of the resources, but the project will eventually run into difficulty at some stage. Once again, the scale of the undertaking is important. Large-scale projects covering a considerable area or population will require much more resources than smaller works. What is critical is that procedures are in place which can be adapted to the size of any undertaking. It is not necessary that all the above listed resources be located in one organisation or agency, but the resources must be available to the project, either directly from the agency implementing the process, or through contracts awarded by that agency.

4. Options for water supply technologies

4.1 Introduction

Hand-dug wells do not provide the only option for the exploitation of groundwater, and there are many cases in which the application of the technology would be quite inappropriate. While the range of technologies for well construction and for water lifting is quite broad, there are basically three methods for gaining access to groundwater for collection purposes. Apart from these three basic options, water may be taken directly from a river or lake, or captured when it falls as rain. The options are summarised in the following list:

- Rainwater catchment
- Surface water intake
 - River
 - Lake
 - Artificial dam
- Groundwater exploitation
 - Spring catchment
 - Bored well
 - Hand-dug well

There are other specialised technologies such as, for example, cloud harvesting and the use of reverse osmosis to convert sea-water to potable water, but these are of limited application in rural communities. It is outside the scope of this Manual to give an in-depth treatment to all the possible technical options for water supply systems. However, this chapter will give a brief overview of the available technologies for groundwater exploitation, with the intention of showing the option for hand-dug wells within the overall context of rural water supplies. For more detailed information regarding the range of options available, the reader is referred to the publications mentioned in [Appendix 1](#).

4.2 Spring catchments

Strictly speaking, we are not dealing with groundwater in this case. As shown in Figure 3.2, springs occur where water which has been flowing along through an aquifer appears at ground level. Rainwater infiltrates into the soil and passes through a permeable stratum. The water continues to seep downwards until it reaches an impermeable layer, flowing along the top of this layer until it reaches the surface. This is known as a gravity contact spring. There are other types of spring also (fracture and tubular, back-stowing, mountain slide and artesian) and the reader is referred to the more comprehensive treatment in the Manual on Spring Catchment ¹. The essential nature of a spring is that water appears flowing freely at ground level and has to be “captured” in order to be stored and used. This catchment involves a structure to direct the water from the spring to a storage chamber, from where the water can either be collected directly by the users or piped (normally under gravity) to a distribution system.

The main advantages of a spring catchment are that it can provide a plentiful supply of clean water and, with a distribution system, can bring water directly into a village using a system requiring little maintenance, the costs of which are comparatively low. The disadvantages are that a system is not easily extended to cater for increased use, as this could involve the capture of a new spring, essentially a whole new construction project, and the flow in the spring can be influenced greatly by rainfall levels.

¹ Volume 4 in this series

4.3 Bored wells

Bored wells (also called tube wells) are wells of a small diameter (500mm and less), which do not allow direct access for maintenance purposes. These wells are generally distinguished by the technology used in their construction, and the various types of bored well may be listed as follows:

- driven tube well
- bored tube well
- jetted tube well
- mechanically drilled borehole
 - percussion rig
 - rotary rig

These options are discussed briefly below and a comparative table of the available technologies, including those mentioned in [Section 4.1](#), is given in [Section 4.3.5](#).

4.3.1 Driven tube well

In this case, a pointed metal tube known as a wellpoint, generally between 30-50mm in diameter and with perforated sides, is fitted to the end of a pipe and driven into the ground, usually through being hit by a heavy hammer. As the point sinks into the ground, extra pipes are added at the top, and the process continues until the water table is reached. A driven well may be constructed in unprepared ground, or may be inserted in an already-existing tube well developed by another method (such as jetting), and continued into the water-bearing stratum.

Driven tube wells are a suitable option in soft ground, to depths of up to 15m. They are unsuited to dense clay or rocky terrain.

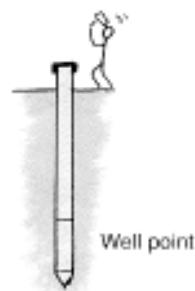


Figure 4-1 - Driven tube well

4.3.2 Bored tube well

These wells are normally bored using manual tools consisting of a series of drill-bits or augers for various applications and a set of rods which are fitted to the bits, and extended as the bit descends into the ground. The auger is screwed slowly into the ground, being removed at frequent intervals to remove the soil which collects in it. Special fittings are available to pass through small rocks, to remove loose soil and to bail out waterlogged material from below the water table.

With a well of this type, it will probably be necessary to insert casing in the hole below the level of the water table, to prevent the hole from caving in with the flow of water. It may even be necessary to case the full depth of the well, depending on soil conditions.

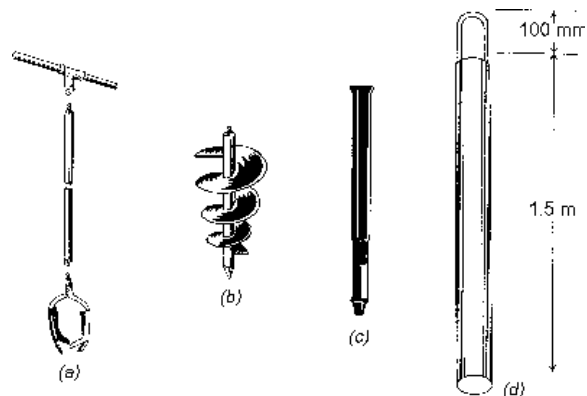


Figure 4-2 - Equipment for drilling a manually bored well

4.3.3 Jetted tube well

In this technique, as the name implies, a jet of water is used to help to develop the borehole. This requires specialised equipment and a plentiful supply of water, so the possibilities for application may be limited. When appropriate, depths of up to 80m can be reached.

A modified, simple variation on this method is known as the **palm-and-sludge** method, which does not require a pump and uses quite elementary equipment.

4.3.4 Mechanically drilled borehole

This is the most expensive method for constructing boreholes. There are two basic technologies available - percussion drilling and rotary drilling. In percussion drilling, a heavy weight is dropped into the ground, pulverising rock and soil to allow it to be removed easily from the hole. Rotary drilling is a highly sophisticated, mechanised version of the hand-drilling method mentioned in [Section 4.3.2](#). Depending on soil types, this technology can drill 50m per day.

Both percussion and rotary drilling rigs are expensive in terms of operation and maintenance, and require a high degree of logistical back-up in the field. Government agencies can find it difficult to maintain a mechanical drilling capacity of this nature, with the result that more and more private contractors are entering the field. Cased boreholes can cost around \$100 per metre, and unsuccessful boreholes are also invoiced to the client. With the expense involved, it is advisable to conduct a detailed hydrogeological survey of the area beforehand, in order to reduce losses due to dry boreholes. However, success rates of 60-70% are considered acceptable.



Photograph 4-1 - A percussion drilling rig



Photograph 4-2 - A rotary drilling rig

4.3.5 Comparison of methods

The various technological options described in this chapter are summarised and compared in the following table.

Option	Soil Type	Depth	Main Advantages	Main Disadvantages
Rainwater Catchment	-	-	■ With a proper catchment, water is clean when it enters storage ■ O+M costs very low ■ Can exploit large roof areas of public buildings to serve schools, hospitals, etc.	■ Capital costs may be high (also for individual families) ■ Difficult to manage consumption when more than one family is involved ■ If local roofing materials are not suitable, it may be necessary to construct special catchment areas.
Spring Catchment	-	-	■ Can be used with a gravity-based distribution system ■ Water is usually clean ■ Maintenance costs are low	■ Spring can "escape" ■ Difficult to expand the system with increased demand
Surface Catchment	-	-	■ Maintenance of intake is easy ■ Small dams are easily built and maintained	■ Water will need treatment ■ Possible legal problems with downstream users
Hand-dug Well	All soil types except solid rock	Up to 60m	■ Simple technology ■ Low maintenance costs ■ Well may be left open or closed ■ A more detailed listing of the advantages and disadvantages of hand-dug wells is given in Section 5.3	■ Excavation can be dangerous ■ Water level can fluctuate
Driven Tube Well	Soft	Up to 15m	■ Fast drilling time ■ Wellpoint is reusable ■ Cheap, simple technology	■ Wellpoint is small ■ Difficult in rocky soil ■ May need casing
Bored Tube Well	Soft	Up to 25m	■ Fast drilling time ■ Cheap, simple technology	■ Difficult in rocky soil ■ May need casing
Jettied Tube Well	Soft	Up to 60m	■ Fast drilling time	■ Equipment can be expensive ■ Requires a plentiful supply of water ■ Requires casing
Mechanically-Drilled Borehole	Hard	Up to 100m (or more)	■ Rotary rigs can drill quickly ■ Best option in rocky ground	■ Expensive ■ Need for a preparatory hydrogeological survey

In addition, rainwater catchment, spring catchment (especially with a distribution system), hand-dug wells, driven and bored tube wells provide ideal opportunities for community involvement and participation in the construction phase, which is not necessarily the case with the more technologically sophisticated methods. A further possible disadvantage of the tube well and borehole options is that a handpump (or a mechanical pump) has to be installed as a lifting device. This may not be within the economic capacity of the users. Also, tube wells, because of their small diameter, are unsuitable for use in shallow aquifers with low yields, since an insufficient area of the aquifer would be exposed to allow satisfactory recharge.

5. *Principles of hand-dug wells*

5.1 *The technology of hand-dug wells*

5.1.1 *Introduction*

The fundamental principle of any water supply system is to gather water in a location from which it can either be collected by the consumers or transported to a point of use. In the case of water supply systems with a distribution network, water is first stored at central storage tanks before being released into the distribution system. This system may bring water directly to households or to public standpipes. With individual waterpoints such as boreholes and hand-dug wells, water is collected by the consumers directly from the point of exploitation of the aquifer. The purpose of the well is to provide a safe and reliable means of accessing the water in the aquifer.

To make the construction of a hand-dug well viable, water in sufficient quantities must be found at a depth which will allow safe excavation and economically feasible exploitation of the water resource (this will depend, of course, on a range of specific local conditions), but at a depth which does not allow easy pollution of the groundwater in the aquifer. The quantity of water made available by a well will depend on the soil type at the particular location and will also be influenced by the diameter of the hole made to extract the water and by the depth of penetration into the water-bearing stratum.

5.1.2 *Soil conditions*

Groundwater is normally found occupying the spaces between the particles of an aquifer. The type of material which constitutes the aquifer is important in that, while some soil types retain water quite well, the relative size of the pores between the soil particles may not be conducive to allowing the water to flow along the aquifer – an important consideration in the recharge of waterpoints. Strata which have large pores will allow water to flow more

freely, and as a result, layers of sand and gravel tend to provide good locations for wells and boreholes. Other good locations are in weathered rock in granite areas, along the edges of valleys in mountainous areas or in a river valley where there may be sandy deposits under the banks.

The limiting factor is, of course, that the bulk of the excavation must take place in material which allows work by hand. As a result, hand-dug wells are normally located where there are unconfined aquifers in alluvial deposits or in the weathered zone above a consolidated or crystalline basement rock. Hand-dug wells are usually constructed in unconfined aquifers.

5.1.3 *Well diameter*

For a given thickness and type of aquifer, and considering equal depths of penetration, a larger diameter hole will expose a greater area for filtration, and therefore give a faster recharge, than a smaller hole. For example, for an aquifer of 2m depth, a 1.3m diameter well will expose 8.17m² of the aquifer for infiltration of water while a 150mm diameter borehole will expose only 0.94m² (see Figure 5.1).

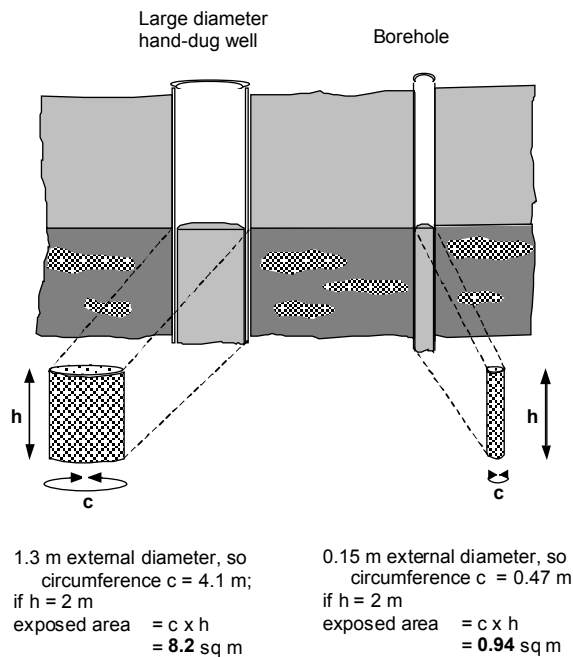


Figure 5-1 - For equal depths, a greater area of aquifer exposed by a larger diameter well

5.1.4 Depth of well in aquifer

For a given aquifer, the yield of a well is proportional to the square of the depth of penetration into the aquifer. This is illustrated by the draw-down effect as shown in Figure 5.2.

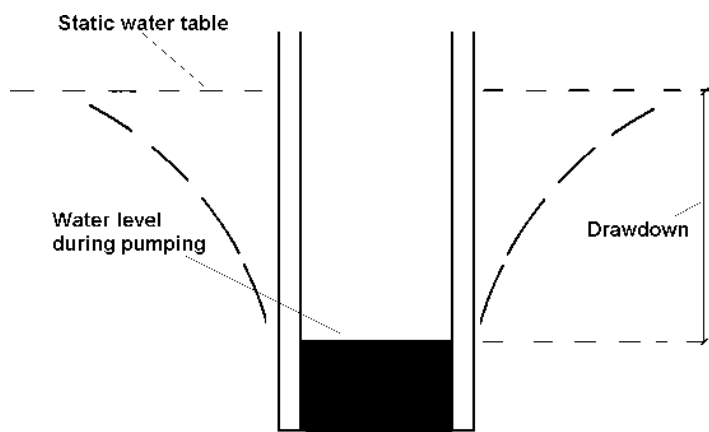


Figure 5-2 - The draw-down effect

Water flows into the well through the porous areas of the intake until water levels inside and outside the well are equal. When water is extracted by pumping or by bucket, the water level inside the well drops relative to the water level in the aquifer, causing a pressure difference. This results in an inward flow of water through the intake pores. The amount of drawdown depends on the yield of the aquifer, the rate of removal of water from the well and the depth into the aquifer at which water is being

extracted. This principle is especially important in tube wells, but will also apply to hand-dug wells constructed in weak aquifers, or in strata which do not allow a free flow of water.

5.2 Elements of a hand-dug well

5.2.1 Introduction

The basic elements of a hand-dug well are illustrated in Figure 5.3. The three main elements are:

- The **Well Head** - this is the part of the well which is visible above the ground. It generally consists of a protective apron and a superstructure which depends on the type of extraction system in use.
- The well **Shaft**
- The **Intake** - this is the part of the well in contact with the aquifer. It is constructed in such a way that water flows from the aquifer into the well, from where it can be extracted using a bucket, a pump or another method.

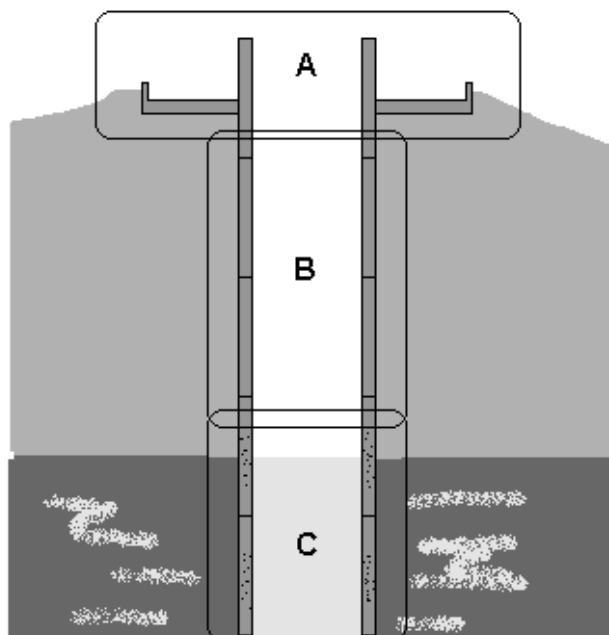


Figure 5-3 - Elements of a Hand-dug Well

Each of these elements is now considered in turn.

5.2.2 Well Head

The design of the well head will vary with local conditions and with the type of water extraction system to be used. It is important that the well head be constructed in such a way as to contribute

to the overall hygiene and cleanliness of the waterpoint. This will normally involve an impervious apron around the well, with a method of removing spilt water from around the well, to a soakpit or to a planted area. This subject is treated further in [Section 10.3](#).

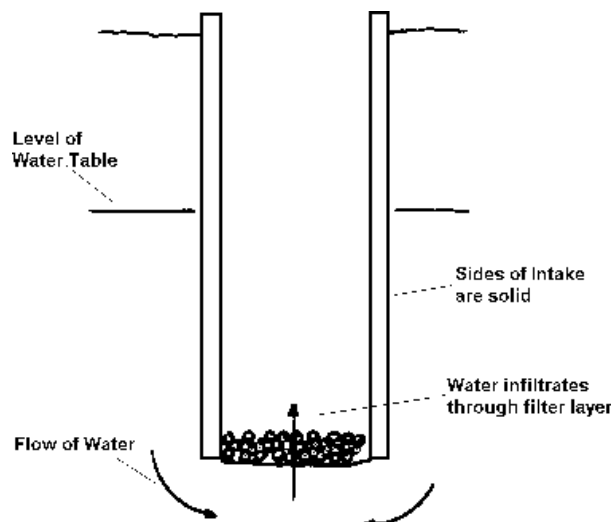
5.2.3 Shaft

This is the section of the well between the head and the intake. As with all elements of the well lining, it must be constructed of a strong, durable material which can easily be kept clean and which will not in itself constitute a health hazard. Well shafts are normally circular in shape, and various options for shaft lining are discussed in [Chapter 7](#). There are two important considerations. Firstly, the size of the shaft must be sufficient to allow excavation work to continue within it. The minimum space for one person to work is 80cm. For two people, this should be 1.2m. Secondly, the initial diameter of a well shaft should allow for possible future deepening of the well, for example if the water table drops or if there is increased demand. It will not always be feasible to construct such an extension, but normally a well should be built first with a shaft of internal diameter 1.2-1.3m, to allow the later insertion of smaller diameter lining rings (see [Section 13.2.3](#)).

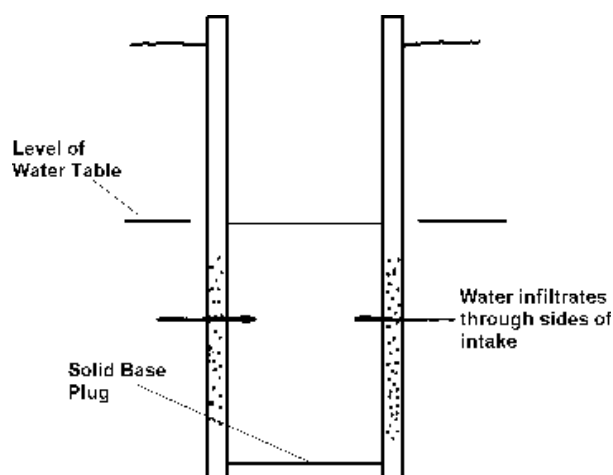
5.2.4 Intake

This is the part of the well which is in contact with the aquifer. The walls of the intake are constructed in such a way as to allow water to pass from the aquifer into the well, thus creating a storage area which can be accessed by bucket or pump, while at the same time ensuring that this part of the well does not cave in. Depending on the type of soil in the aquifer, infiltration may occur through the sides of the intake, through the bottom or through a combination of the two. Local conditions and experience will indicate the best strategy to adopt, but the following points may act as general guidelines:

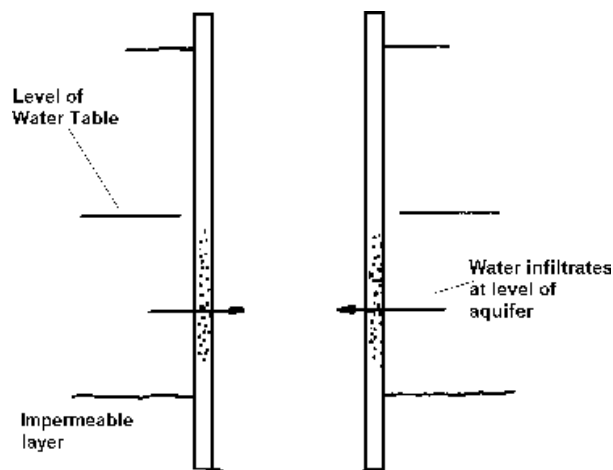
1. For a **highly permeable aquifer**, with water travelling at a high velocity through it, allow infiltration only through a filter layer placed on the bottom of the well.



2. For a **less permeable aquifer** (water travelling at a lower velocity), allowing infiltration through the sides of the well only is a better option.



3. In each of the above cases, the bottom of the well is located still within the water bearing stratum. When the well can be extended down to an impermeable layer, it is not necessary to put either a plug or a filter layer at the bottom, and infiltration takes place only at the part of the well which is in contact with the aquifer.



A further advantage of the situation shown in paragraph (3) above is that the part of the well which is within the impermeable layer acts as storage for water filtering in from the aquifer. If the aquifer is weak, water can filter in slowly overnight and at other times when the well is not in use, thus helping to reduce the time spent queuing for water (see Figure 5.4). More details on intake construction are given in [Section 8.3](#).

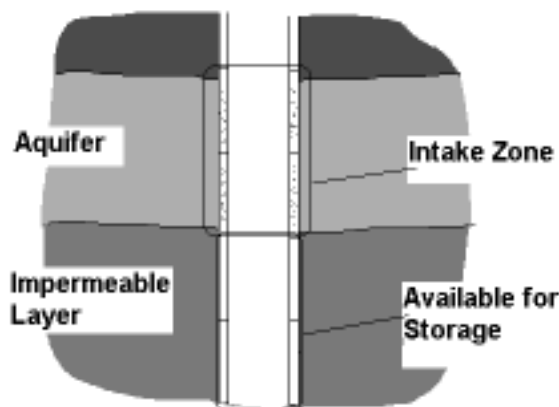


Figure 5.4 - Reserve of water in a weak aquifer

5.3 Advantages and disadvantages of hand-dug wells

Each of the different technologies available for the installation of rural water supplies will provide the optimum solution in a given specific case, while it will prove quite inappropriate in another case. No single technology is universally applicable. As far as hand-dug wells are concerned, the advantages and disadvantages are as follows:

Advantages

1. The community of users can become involved from the very beginning of the process. This can lead from an information campaign to the submission of a request by the community, to the planning and construction steps, and to preparation for the operation and maintenance phase. The relatively slow pace of hand-dug well preparation and construction allows plenty of time for valuable contact with the community.
2. The technology provides a perfect opportunity for community participation in contributing unskilled labour to the preparation of the construction site and the excavation of the well. Depending on the arrangements in a particular case, villagers may

also assist in the prefabrication of lining rings or bricks, or in the mixing of concrete for in-situ placement.

3. In most cases where hand-dug wells are an option, excavation is relatively easy and does not require sophisticated equipment.
4. Where construction is concerned, it is cheap in comparison with other technologies such as the mechanical construction of boreholes, which can cost from \$125-250 per metre for successfully completed boreholes, with all costs considered. A complete set of vehicles and equipment for rotary drilling can cost up to US\$300,000,
5. Construction and maintenance do not require very sophisticated equipment. Routine ground-level maintenance such as the repair of cracks in the apron can be done by somebody within the community, thus eliminating the need for an extensive, centrally-controlled corrective maintenance network.
6. Construction teams require minimal technical and logistical support in comparison to other methods. However, this is not intended to diminish the importance of having competent field and supervisory staff.
7. Given the relative simplicity of the technology, the involvement of the private sector at local level is encouraged.
8. Apart from cement, the materials needed for construction are normally available locally. The provision of these materials from nearby sources is another opportunity to increase community involvement in the construction phase.
9. When construction takes account of local soil conditions and proper construction standards are applied, the well will rarely require any down-the-hole structural maintenance.
10. A number of options are available to increase the yield of the well if the need arises.
11. Depending on the water-lifting device installed, it can provide years of trouble-free water supply.
12. If a handpump is installed, the quality of water supplied can be brought to a high level.
13. Where technical conditions permit, and in a situation where the construction of water supply infrastructure is demand-driven, it is a good mid-range option between traditional sources and mechanised systems, to offer a community. A positive experience with a low-technology, easy-to-manage system will encourage the community to develop its water supply system as demand and economic capacity increase.

14. Wells can be excavated in harder soils where hand-drilling is difficult.
15. A large-diameter, hand-dug well exposes more of the aquifer, thereby allowing a greater volume of water to flow into the well, and creates a larger reservoir for water storage.
16. In the case of a closed well, if the handpump experiences a serious breakdown, there is alternative emergency access to water via the inspection cover.
17. While the construction phase may be longer than with other technologies, the longer time will be useful in assuring the acceptance of the new system by the villagers since the community will have more time to witness the development and "arrival" of the new system.
18. Hand-dug wells are in many cases very similar in form to traditional water collection systems. As such, the technology can be readily accepted by the community, and provides an ideal basis for future development of the system (for example, from an open well to a covered well with a handpump, and from there to a system with a motorised pump).
5. Supply is greatly influenced by water table fluctuations.
6. Since most hand-dug wells exploit shallow aquifers, water in the well may be susceptible to pollutants infiltrating from the surface.
7. In open hand-dug wells, the water can be contaminated by mud, vegetation, bird and animal droppings or even by rubbish thrown into the well.
8. Again in an open well situation, the use of multiple buckets and ropes can lead to contamination of the water.
9. An open and unprotected well can be dangerous for the users. Small children, especially, can fall in.
10. A programme of shallow well construction needs much more supervision capacity per person served, since it is normally necessary to make several visits to a construction site over a period of weeks during the construction phase. With a drilling programme, wells in one village could be completed with a single visit of a few days' duration.

Disadvantages

1. Community participation may be difficult due to safety considerations (see Section 8.5). Excavating a well is a hazardous undertaking, even in ideal conditions, and the work cannot be passed lightly to inexperienced workers. If, on the other hand, the work is given to a private contractor, he or she may not wish to be dependent on a supply of voluntary labour over which there is very little control, given the many demands on the time of rural farming and fishing families.
2. Excavation can be dangerous for a number of reasons. At depths of over 2 metres, access to the well by those doing the excavation must be subject to strict safety controls. Also, in some areas, the process of excavation may release harmful gases.
3. During excavation, a method of keeping the well pumped dry after reaching the water table is required. This will normally involve a motorised pump, which in turn will require a power source. The capacity to dewater the well will limit the extent to which excavation can continue below the top of the water table.
4. The lowering of lining rings weighing up to 900kg can be a dangerous operation.

6. Information collection

6.1 *The information gathering process*

Once a decision has been made in principle about the construction or rehabilitation of a water supply system in a particular community, the next step is to conduct a thorough investigation of the area in order to assess the possibilities in terms of the type of source to be exploited, the quantity of water available, the quality of that water and the range of technically feasible options for the construction of a water supply system. Ideally, the site investigation will take place only after initial contact has been made with the village through an established social marketing capacity (a Government Department, an NGO, a local community group). Since the agency performing the site investigation may not have been involved in these initial contacts, and may simply be a technical company contracted to do the investigation, it is important that the technical team is accompanied by someone who already knows the community and has earned its confidence, to ensure that the purpose of the visit is understood within the overall context of the water supply process. The visit may also provide an

opportunity for the technicians who will be responsible for the design and construction of the system to meet the community.

The most important element in planning is the availability to the planners of reliable, up-to-date information. Even before leaving for the first site visit, the technician responsible should check up on any sources of information on the water supply situation in the proposed location through, for example, topographic and geological maps of the area, aerial photographs if these exist, records of boreholes drilled or a database of wells already constructed. For maximum reliability, this information should be available for as long a period as possible. In the case of a proposed spring catchment, for example, measurements should be taken at the peak of the wet and dry seasons, preferably for five years but at least for two. For boreholes and hand-dug wells, information on the behaviour of the water table over a number of years is very useful.

Objectives of the Site Visit

- 1. To observe existing water collection practices from a technical viewpoint.**
- 2. To assess the current water supply situation in the community, in terms of quantity and quality.**
- 3. To assess the possibilities of future water supply systems in the community.**
- 4. To assemble a range of technical options, together with the associated construction and O+M costs, which can be offered to the community.**
- 5. To gather information in order to estimate the institutional and management requirements for the operation and maintenance of the system, with a view to satisfying these requirements during the planning and construction phases.**
- 6. To facilitate the planning of financial, material, capacity- and institution-building, personnel and logistical inputs to the proposed system.**

Once the general information on the water situation has been collected, (and an agreement has been reached, in principle, among all participants in the process), the next step is to try to decide on the locations for the proposed wells. The sanitary survey of the site of any new well should show that it conforms to the guidelines as indicated in [Section 6.3](#). Information about the possible presence of groundwater at a given point is available from a number of sources, in addition to the documentation mentioned above:

It is important to note the importance of physical investigation in relation to checking possible well sites. While it is essential to consult with the local community, the opinions expressed by local people should always be tested in some way by the surveyor. Persistence and consistency are important factors in the search for sources.

Sources of information on the presence of shallow groundwater

- 1. Contact with villagers, especially with traditional well diggers. Members of the community will be able to indicate areas liable to flooding, old water collection points etc. In addition, they can indicate sites of cultural, historical or spiritual importance to the community, which may be out of bounds for well construction.**
- 2. Visits to existing water sources, whether rivers, springs, or “traditional” waterpoints, including sources that have dried up temporarily or permanently.**
- 3. Where a spring occurs at the foot of a slope, a waterpoint situated farther up the slope will more than likely yield water. Alternatively, if conditions and water quality permit, the spring itself may be captured.**
- 4. The presence of certain types of vegetation indicates shallow groundwater. Vegetation such as banana plants, bulrushes, sugar cane and date palms can indicate the presence of water, as well as providing an ideal dispersal area for spillage.**
- 5. If the village is near a river, the flood plain of the river can provide a good location for a hand-dug well (always remaining above the seasonal flood level). However, alluvial deposits tend to be clayey in nature and therefore provide poor conditions for the flow of water through the aquifer. Alluvial deposits of high permeability may be found at places formerly on the outside of a bend in an old river alignment. A test borehole will give an indication of suitability in these cases.**
- 6. Cliffs and other outcrops of rock may indicate a break in an aquifer from one side to the other.**
- 7. Low-lying areas are more promising for well construction.**

6.2 Technical site investigation

6.2.1 Testing methods and equipment

When visiting the proposed location for a well-digging project, existing wells and waterpoints must be visited and as much information as possible collected from local sources. When planning to work in an area for which reliable information is not readily available, it is advisable to drill a trial borehole and conduct a yield test before committing resources to the construction of a waterpoint. The presence of groundwater can also be indicated by geophysical tests involving electronic equipment, which may not be within the budget of many water development agencies, and is generally more suited to the sinking of deeper boreholes (over 25 metres). The work is specialist in nature and is outside the scope of this manual (see suggestions for further reading in Appendix 1). In any case, it is advisable that, even when water is indicated by such a method, a test drilling be done to ascertain the yield of the aquifer.

It is necessary to consider the economic aspects of conducting tests prior to initiating construction work. For a large project involving the drilling of boreholes with rotary or cable-tool equipment, it is advisable to collect as much geophysical information as possible before signing a contract with a drilling firm. If the technology to be applied is relatively basic, such as driven or bored tube wells or hand-dug wells, and the scale of the project is small, it may be more efficient in the long run to start excavating or drilling at carefully-chosen sites, without doing any previous trial boreholes.

If testing is to be carried out, the best time to do so is towards the end of the dry season, since a good result at this time will augur well for the presence of water throughout the year. Essentially, the test will consist of a trial borehole (recording the type and thickness of strata encountered, the depth of the water table and thickness of the aquifer), and an associated yield test. The borehole may be developed manually or using motorised equipment. The important factors are that strict guidelines be followed in the recording of the material encountered during the drilling, and in the carrying out of the yield test afterwards. This information will be important in the planning of any construction work.

6.2.1.1 Manually operated drilling equipment

This equipment is similar to that described in Section 4.3.2 on manually bored tube wells. It consists of a set of drill bits of various diameters, usually 100mm and 70mm, attached to steel rods and driven into the ground using a manually-turned handle. In favourable soils (loose sands with little gravel and a low clay content), this equipment can be used to a depth of 18 metres. In clays and rocky strata, the range is reduced to about 8-10 metres. Manually-operated equipment is cheap and easy to use and again provides an ideal opportunity for community participation as villagers can assist in the drilling. However, see [Section 6.2.1.3](#).

6.2.1.2 Motorised drilling equipment

From an economic standpoint, motorised drilling equipment should only be considered if its use is essential to the success of a project. In the range of depths to which hand-dug wells are constructed, manual equipment will normally be sufficient. While machine drills have the advantages of being capable of achieving greater depths, and of completing a test borehole in a shorter time, the equipment is costly and requires careful and skilled handling, in addition to the need to maintain a more extensive stock of spare parts. Light motorised equipment may encounter problems in crystalline basement complexes (see below).

6.2.1.3 Problems in crystalline basement complexes

Manually operated and light motorised drilling equipment do not work very well in crystalline basement complex areas where there is often a hard layer which has developed near to the surface. There may also be large unweathered fragments in the zone just above the main bulk of unweathered rock. These fragments will probably stop a hand-driven drill-bit and may lead to an under-estimation of the true depth of the weathered zone. The main problem is that it is precisely in the area just above the unweathered rock that permeability is highest, and promising well sites may be missed as a result.

In such areas, an economical alternative to the use of such equipment is to excavate by hand to the dimensions of the proposed well. Instead of using concrete rings to line the excavation, timber shoring, supported by internal steel hoops, is used

(this is the modified Chicago method). If water is found in sufficient quantities, a permanent lining may then be introduced. If the site proves negative, the timber shoring is withdrawn and the excavation backfilled. The cost of labour in this case will normally be less than the cost of motorised equipment.

6.2.2 Test procedure

Drilling may be done in one particular spot or on a grid of locations, depending on the information required. Obviously, the more tests that are done, the more reliable will be the final result but this must be measured against other financial criteria. In general, manual equipment should be used as much as possible, with mechanical equipment being brought in only in difficult areas.

As drilling proceeds, the material extracted from the ground is laid carefully in 1 metre lengths and recorded on an appropriate sheet¹. Samples should be collected and kept in a sample box, which can be stored for further reference during the construction phase, and may also be used to contribute to the general information on the geology of the area.

When water is encountered for the first time, a note must be made of the level of the water table. In an artesian situation, water will come to the surface. In a sub-artesian well, the level will rise, but not to the surface. While drilling through the aquifer, it may be necessary to insert some casing in the hole to prevent caving-in. The casing should follow through into the underlying impervious layer, if one is encountered, and be securely pressed into this layer, to prevent sand entering from the aquifer. The test borehole should continue through the water-bearing stratum, and for a depth of 1.5m below it, in order to collect information over the full depth of the proposed construction. If an impermeable layer is not reached, the trial may be stopped at a depth previously defined as the maximum to which excavation will take place.

Once the test borehole has been completed, a yield test may be performed. The purpose of this test is to ascertain if the construction of a waterpoint is

feasible in that particular location (taking into account the expected consumption) and, if so, the type of technology which is most appropriate to the yield. The test is performed by installing a handpump on the borehole and pumping in a set pattern while measuring the yield and the dynamic water level. The procedure is as follows:

1. Install the pump as low as possible in the test borehole.
2. Pump out five buckets of water to “develop” the borehole.
3. Measure the static water level.
4. Begin pumping at a steady rhythm, and continue for one full hour.
5. Pump into a bucket of known capacity, preferably with graduations.
6. In the first minute, and for every tenth minute thereafter, measure the number of buckets pumped in that minute, and the dynamic water level. Write these values in a record sheet.
7. From minute 40 to minute 50, pumping should be done as fast as possible.
8. Measure the water level at the end of the test (i.e., after 60 minutes).
9. Continue to measure the water level, at 61, 62, 63, 64, 65, 70, 75, 80 and 90 minutes. This will give an indication of the speed of recharge of the well. Cease measurements when water has returned to within 100mm of the pre-test level, or at 90 minutes.

It may happen that the level of water in the borehole will be drawn down to such an extent that the pump will start pumping dry. If this is the case, continue to pump slowly, and note the fact on the record sheet.

6.2.3 Interpretation of test results

The diameter of a constructed well will be different to that of the test borehole, and care must be taken in the interpretation of the results of the yield test. The yield of a completed well is related to the yield of a test borehole by the following equation²:

$$Q_t = Q_w \frac{\log(R / r_w)}{\log(R / r_t)}$$

¹ An example of such a sheet is given in Appendix 2, together with a sheet for recording the yield test values.

² From “Handpumps - Issues and concepts in rural water supply programmes”, Technical Paper No. 25, IRC, The Hague, 1988

where:

Q_t = the yield of the test borehole, in litres per hour

Q_w = the yield of the completed well, in litres per hour

R = the “radius of influence”, which has a typical value of 20m

r_w = the outside radius of the completed well, including any gravel packing, in metres

r_t = the radius of the test borehole, in metres

Taking some typical dimensions, and assuming that the desired yield of a well will be 1000 litres per hour:

Q_w = 1000 l/h

R = 20m

r_w = 0.75m

r_t = 0.05m

then the yield during the test should be 548 litres per hour. This calculation is quite theoretical, and in practice the following values are adopted:

yield in test borehole =	200 l/h or more -
	suitable for a hand-dug
	well (large diameter)
yield in test borehole =	500 l/h or more -
	suitable for a borehole
	(small diameter)

6.3 Guidelines for the siting of a waterpoint

Even if a particular site gives very positive indications for the presence of shallow groundwater, certain conditions must be fulfilled before continuing with a trial borehole or with actual construction. Internationally accepted guidelines for the location of a waterpoint may be summarised under two sets of criteria, one general and one relating to the proximity of other structures or facilities, as follows.

1. General points

The proposed waterpoint or source should:

- a) be above the flood level of any nearby river or lake;
- b) be in a location which allows the free access of all users all year round. This refers to physical access (i.e. that the pathway is passable) but also to legal access. A right of way must exist to the well.
- c) (ideally) be within the specified distance from the intended users;
- d) be in an area which will allow the rapid dispersal of spilt water;
- e) be in a location where the level of the water table is at a depth of at least 2m all year round.
- f) not be located in any other area liable to seasonal flooding;
- g) not be located in any area where pesticides or fertilisers are spread on crops;
- h) not be in an area liable to erosion;
- i) not be in an area where the fluctuating fresh water table is influenced by a saltwater table;
- j) not be in an area where the sinking of a well will pierce the saltwater table;
- k) not be below, in terms of the direction of groundwater flow, any source of pollution such as a pit latrine, abattoir, dumping site, fertiliser or pesticide store etc. In addition, the minimum distances, **in any other direction**, to such sources of pollution, are given in the next list.

2. Specific distances

<u>Facility, Location or Building</u>	<u>Minimum distance from waterpoint in m</u>
a) Communal dumping site	100
b) Store for pesticides, fertilisers or fuels	100
c) Cemetery	50
d) Abattoir	50
e) Dwelling house	10
f) Pit latrine	30
g) Animal pen	30
h) Private (domestic) dumping site	30
i) Large trees or any tree with extensive root systems	20
j) Roads, airstrips, railway lines	20
k) River or lake	20
l) Laundry or washing slab	20

These criteria are represented graphically in Figure 6.1. If these guidelines cannot be fulfilled, either by choosing an already-appropriate site or by making

the necessary adjustments (for example, by the closing down of a communal or private dumping ground or of a pit latrine), then another site should be chosen. In the case where a dump, pit latrine or pesticide/fertiliser store is to be relocated to make way for a waterpoint, sufficient time must be allowed for the existing pollutants to dissipate in the ground, before beginning to use the water for human consumption. The water quality should be tested to ensure that all pollutants have been dispersed. In certain specific circumstances, the distance from a pit latrine may be reduced, but if there is any uncertainty about fulfilling these conditions, it is advisable to comply with the 30m criterion given above.

Where pit latrines are in use, the bottom of the latrine pit should be normally no less than 1m above the top of the aquifer.

In all cases, the local community must be fully involved in the decision about the location of waterpoints.

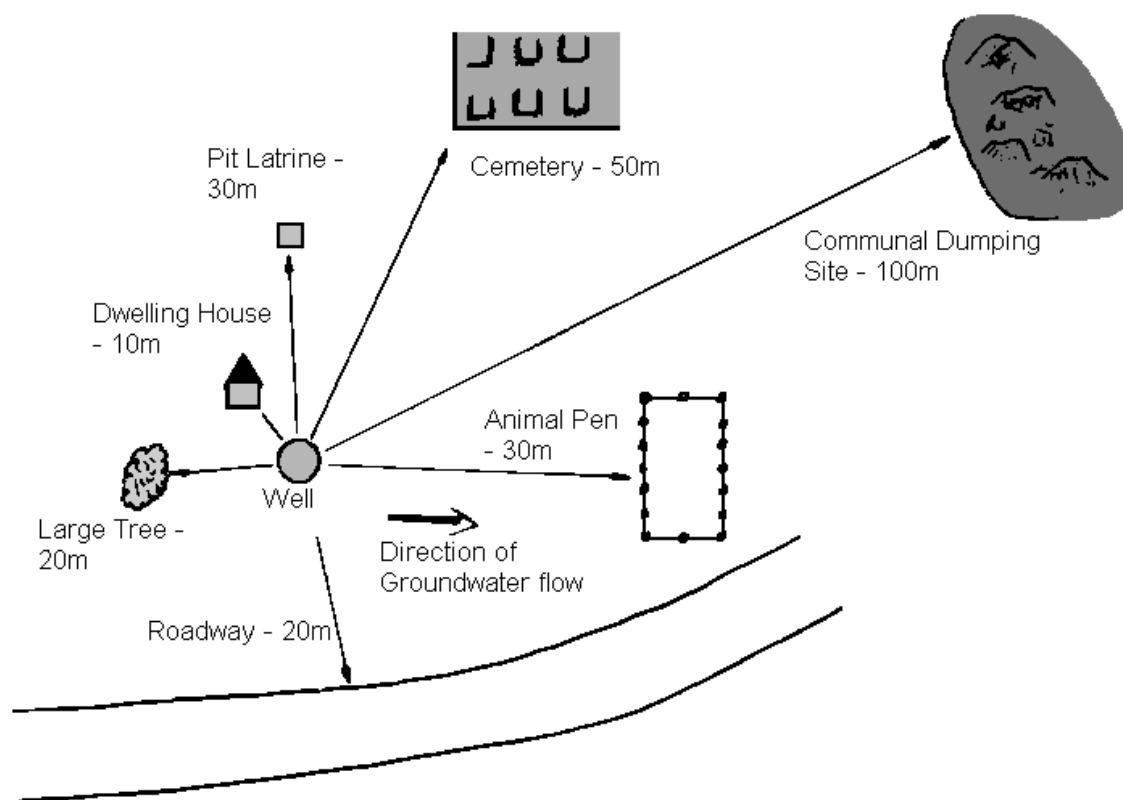


Figure 6-1 - Location of a Well

6.4 Making the decision

The decision to propose the construction of a hand-dug well in a particular location can be made once the following specific criteria have been met:

Criteria to Satisfy	If not satisfied, the following options are still open:
1. The community has displayed a preference for and a willingness to accept the technology of a hand-dug well system.	■ The community may opt for an improvement of existing sources.
2. The community will be able to perform the expected tasks of operation and maintenance in a sustainable manner	■ Consider the basic improvement of existing waterpoints.
3. The community will be capable of making the expected contribution to construction costs (where this criterion applies).	■ If the community cannot support the installation of a handpump, propose a windlass & bucket system³. ■ If the community cannot afford to have a new system constructed, propose the improvement of traditional sources, if possible.
4. The local economy will be able to absorb the operation and maintenance costs.	■ If it is the O+M of a handpump which is the obstacle, install a windlass & bucket system instead of the handpump. ■ If the community still cannot meet O+M costs, propose the protection of existing traditional sources, if possible. In cases, this may be the ideal initial step in a gradual process of improvement in the supply system.
5. A survey indicates the presence of groundwater at a level of more than 3 metres (but less than the agreed maximum depth of excavation), in at least one aquifer of more than 1 metre thickness.	■ If conditions permit, consider the sinking of a deeper borehole. In this case, the implications in terms of construction cost, and the O+M costs of a medium- or deep-well pump must be taken into account.
6. A test on a 100mm trial borehole shows a suitable yield (see Section 6.2.2).	■ If the yield is inadequate, consider extending the exposure of the aquifer by using radial drains (see Section 13.1) or by drilling through the bottom of the well. ■ If the yield is still inadequate, look for another site.
7. There are no geological conditions in the area which would render the construction of a hand-dug well inadvisable or unsafe.	■ Look for another, safer site.

³For hygiene reasons, communal users of a windlass and bucket system should not be allowed to use individual buckets and ropes.

The above list is intended as a general guideline, and local conditions and experiences will at all times take precedence over the content shown. In particular:

1. With regard to point 3, if the community cannot afford, or is not willing, to make the expected contribution to the most basic technical option, the decision to continue with the construction or improvement of water systems is not technical in nature. In this case, priorities must be set and a clear policy put in place to guide the project. It may be necessary to place greater emphasis on the creation of awareness within the community with regard to the advantages of improved water supply.
2. For points 5 and 6, experience in a particular area, and the size of the project in question, will dictate whether or not extensive surveying, including the sinking of trial boreholes, will be necessary before committing resources to construction.
- 3 For hygiene reasons, communal users of a windlass and bucket system should not be allowed to use individual buckets and ropes.

7. The lining of hand-dug wells

7.1 Lining options

The purpose of the lining is to ensure that the well retains its excavated shape, allowing access to the water in the aquifer, while at the same time helping to prevent contamination of the aquifer. A variety of different linings may be used, and these may be used over the full depth of the well or only partially, as shown in Figure 7.1. The most common types of lining are summarised below:

3. **Reinforced Cast In-situ Concrete:** Using one leaf of formwork, concrete is placed directly against the walls of the excavated well. See [Section 9.3](#).
4. **Cast In-situ Mass Concrete:** As above, but with thicker walls to compensate for the lack of reinforcement.
5. **Brick or Masonry Lining:** Brick and masonry linings are also used, but the porosity of the materials in question impairs their suitability for

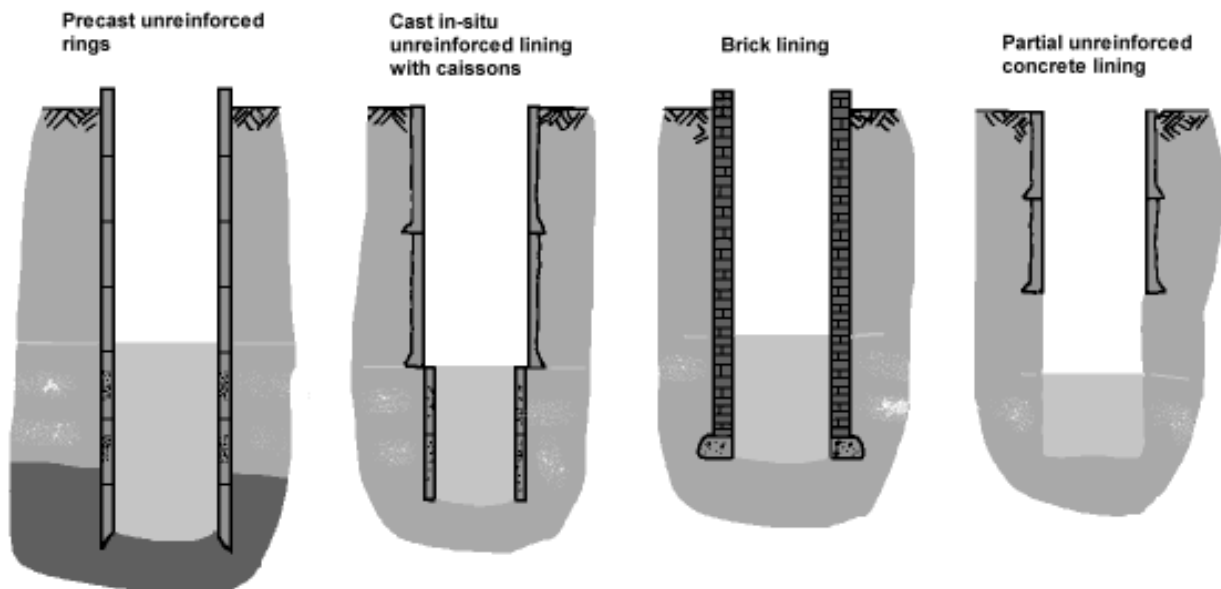


Figure 7-1 - Some options for lining hand-dug wells (well head details not shown)

1. **Unreinforced Precast Concrete:** Using specially-made formwork, concrete is cast in rings with an internal diameter of 1.2-1.3m and a thickness of 7.5-10cm. The height of the rings can vary from 50cm to 1m. See [Section 9.5](#) and [Chapter 11](#).
2. **Reinforced Precast Concrete:** As above, concrete is cast in special formwork, but using steel reinforcement and with a reduced thickness (5-7.5cm), depending on whether the ring is to be transported over long distances or rough terrain. See [Section 7.4](#)

this particular application. Any gaps between the pit wall and the lining should be filled with a plaster mix to develop some small degree of impermeability in the important top section of the well. The inside of the lining should also be plastered for at least the top 3 metres. This work, as well as the initial placing of the bricks or masonry, will necessitate the suspension of workers within the well shaft, or the erection of awkward temporary platforms in the pit. In addition, it may be necessary to clean weeds from the joints of the brickwork on a regular

basis. Because of these hygiene, construction and maintenance factors, this method of lining is discouraged.

6. Other Lining Types: This manual concentrates on the construction of wells for the provision of drinking water, and as a result deals with lining methods which are long-lasting and easy to keep clean. In emergency situations, or where the water is not intended for human consumption, other lining materials can be used. These include timber and bamboo, as well as corrugated iron or fibre-glass. These materials may not be suitable in other cases due to considerations of hygiene or cost. If timber is to be the lining material, the excavation should be square, and the lining will be comprised of vertical planks shored up at least every two metres. Split bamboo poles may be used as vertical lining, with other split poles bent around as horizontal strengthening. Corrugated iron sections have also been used on occasion.

7.2 Concrete for use in well lining

Concrete, mass or reinforced, is the most popular material for well lining and consists of four ingredients: cement, sand, gravel and water.

- **Cement** for use in the concrete must be Ordinary Portland and it must be clean, dry and less than six months old. Cement which has hardened while in storage should not be used.
- **Sand** (fine aggregate) should be river or quarry sand. It should be clean and free from silt and organic matter.

The use of beach sand is the subject of some debate. A feasibility study (see reference in [Appendix 1](#)) has shown that concrete of a reasonable quality (with 78-90% of the strength of concrete made with river sand) can be made using beach sand. The two factors to take into account when considering the use of beach sand are the particle size distribution and the salt content. A fine size distribution will result in a less workable concrete, which could lead to spaces in the finished product. With regard to salt content, the maximum allowable value expressed in terms of the weight of cement in a mix is 1%. Also, with reinforced concrete, salt in the mix will attack the reinforcement bars. In general, local conditions and traditions will

indicate the advisability of using beach sand. If used, it should be sieved to give a particle size distribution similar to good river sand. As a rule, beach sand should not be used in concrete to be used with reinforcement.

- Coarse aggregate, or **gravel**, should be clean, hard and non-absorbent. Granite, quartzite, and hard limestones and sandstones produce good aggregates.
- Water to be used in the mixing should be fresh and clean. Sea water is not acceptable.

It is advisable to conduct an investigation in the area of the planned waterpoints, well in advance of the commencement of construction work, to ascertain the availability of the necessary raw materials in the required quality and quantities. Members of the community may be asked to begin stockpiling sand and gravel, and even water, before the construction crew arrives on site.

For best results, the concrete should be mixed using a machine. If this is not possible, mixing can be done by hand but the quantity of cement in the mix should be adjusted to take account of this. Hand mixing must be done on a clean and level surface, and preferably on a concrete slab cast especially for the purpose. For both hand- and machine-mixing, strict supervision and careful preparation and organisation of raw materials are necessary. Where possible, mixing and pouring should be done in a shady location. When dealing with pre-fabricated lining rings, it should be borne in mind that the completed rings cannot be moved for 7 days after casting, so the location in which the prefabrication takes place should be at least big enough to cater for 7 days' production of precast elements. For machine-mixing, ensure an adequate supply of fuel.

Concrete for the normal (non-filtering) type of lining should be mixed in the proportions 1:2:4 (cement:sand:gravel) with enough water added, slowly, to the mix to make it workable and easy to place. As a general rule, the amount of water is usually 22 - 33 litres per 50kg of cement. For hand mixing, the amount of cement should be increased by 10%, and all dry ingredients should be mixed thoroughly before any water is added.

The most important factor in the preparation of the concrete is good quality control. The recommended proportions should always be observed and the

mixing area and all equipment should be kept clean. When pouring concrete, there should be no long delays during a pour. Casting should take place in one smooth, uninterrupted process, with the concrete being well compacted as pouring proceeds. If these pointers are observed, the resulting concrete will be of a good quality and will be able to withstand the predominantly compressive loads when in place. It should not be necessary to go to the trouble of preparing concrete cubes and performing crushing tests. In any case, the application of such a test does not take account of the curing applied to the finished product, a factor which can invalidate the test results.

Steel to be used in reinforcement should be mild steel, and it should be clean and free from loose scale, rust, oil and any other material which would impair the bonding process with the concrete. The reinforcement cages should be tied together using suitable soft-iron wire.

7.3 *Advantages and disadvantages of using precast concrete lining elements*

The use of precast concrete lining rings presents a number of advantages over other methods of well construction, as listed below.

Advantages

1. From the point of view of safety, the work of pouring concrete is done at ground level, so workers spend less time down the excavation.
2. Quality control is easier to perform and the consequences of sub-standard workmanship or materials can be avoided.
3. When elements are precast at the well site, it provides an ideal opportunity for community participation, in the provision of raw materials and in the mixing, placing and curing of the concrete. This precasting may be done before the well excavation commences.
4. The use of precast rings in deepening an existing well is straightforward. Also, a number of telescoping rings may be installed at the bottom of a well during construction, overlapping with the standard rings. If the water table falls over time, or during a particularly dry period, the well

can be deepened without the need to construct or transport new rings, and the work can even be carried out by local well diggers.

5. The use of precast rings for deepening existing wells can be applied to other well types.

Disadvantages

1. The rings are heavy and difficult to manoeuvre, especially when lowering into the well.
2. Once a number of rings have been placed, it is difficult to rectify errors in vertical alignment.
3. If precasting is done at a central location, transport can be difficult and expensive, and can result in damage to the precast elements.
4. The position of the filter rings is set at the beginning of excavation, and cannot be altered.

The weight disadvantage may be avoided by using rings of 50cm or 75cm, though a 50cm ring will still weigh 400kg. If the vertical alignment is checked regularly and carefully during excavation, the need for realignment will be reduced.

7.4 *Precast reinforced concrete rings*

When reinforcement is introduced into the lining rings, the strength of the concrete is increased and the thickness (and thereby the weight) can consequently decrease, while the ring will still be able to withstand the loadings imposed during transport and placement. When a ring is in place in a well, the loading on it is usually only compressive in nature, either vertically from the weight of the rings above it or horizontally from the pressure of the surrounding soil and water. This horizontal compressive loading will normally be more or less uniform around the circumference of the well but, if it ceases to be so, tensile forces can be applied to the ring. If the ring is thin enough (10cm is adequate), the inherent flexibility will be able to deal with the imbalance in horizontal forces. As a result, the main advantages of using reinforcement in lining rings are due to the reduction in size, allowing for the use of less material and also making transport and placement easier, since the ring can be up to 50% lighter than the unreinforced version.

The minimum thickness of the ring is dictated by the necessity to provide adequate concrete cover to the reinforcement bars. In a hand-dug well, 20mm

cover to the reinforcement is adequate, so rings of 50mm thickness can be built, with a cage of 6mm reinforcement (see [Appendix 3](#)). The aggregate size should be 13mm maximum, and the concrete well-compacted during the pour, in order to ensure there are no gaps between the steel and the concrete. 50mm should be taken as the minimum possible thickness for a lining ring.

The introduction of reinforcement demands an extra skill in the precasting team, and brings in considerations of the cost of purchasing, transporting, cutting and bending the reinforcement and making it up into cages for placing in the formwork. Extra care must be taken in the selection of coarse aggregate. Care must also be taken in placing the concrete to ensure that the reinforcement is well covered.

When using reinforcement, the steel should first be put together in a cage and the formwork assembled around it. Spacers (such as suitably sized pebbles, or plastic spacers made in various widths especially for the purpose) should be used to ensure that the reinforcement is properly located in the ring. While pouring the concrete, the compaction of each layer will be made more difficult by the narrowness of the

openings at the top of the formwork, and it may be necessary to use a mechanical vibrator applied to the outside using a special fitting.

Steel reinforcing bars, locally available in most countries, should be mild steel, and it should be clean, and free from loose scale, rust, oil and any other material which would impair the bonding process with the concrete. The reinforcement cages should be tied together using suitable soft-iron wire.

The decision whether or not to use reinforcement will be based on economic criteria and on the availability of the necessary skills in the area in question. The possibility of purchasing suitable steel in the local market is also an important consideration.

Apart from the placing of the reinforcement, the procedures for prefabricating a reinforced concrete lining ring are exactly as those described for an unreinforced ring in [Section 11.3.1](#). If a rebate is to be cast in such a thin ring, great care must be taken in transport and placement, and, if transport takes place over rough terrain, such a ring would only be a suitable option if it were to be cast alongside the well site.

8. Hand-dug well construction procedures – General

8.1 Introduction

The important considerations with regard to the overall construction process are the participation of the community to the fullest possible extent, the assembly of the necessary equipment in good working order, the proper layout of the well site, adherence to safety procedures (as detailed in [Section 8.5](#)) and the availability of the relevant survey report for consultation.

8.2 Equipment

The equipment needed will depend on the lining method adopted and the construction procedure to be followed. The following list gives an indication of the main items which should be considered when planning the provision of equipment:

1. **Formwork:** Either one or two leaves of each form will be needed, depending on the lining procedure. Details of possible formwork are given in [Section 11.2](#) and in [Appendix 3](#).
2. **A device for lowering materials and equipment into the well:** The type of device used will depend on the lining method. For precast concrete rings, a tripod with a block-and-tackle of 2.5 tonne capacity is recommended. A similar capacity will be necessary if precast caissons are to be placed in a well with a cast in-situ shaft lining. If the intake is to be constructed in-situ, the capacity may be reduced, since only shuttering and buckets of concrete will be lowered into the well.
3. **A dewatering device:** This will be necessary at some stage, irrespective of the lining type and the procedure adopted. When using a motorised pump, as will normally be the case, the arrangement should be such that the motor is permanently outside the well, to avoid the dangers of inhalation of exhaust fumes by those

down the well. Care should be taken that the capacity of the pump is sufficient to keep the water in the well at a safe level.

4. **A method of lowering workers into the well:**

An important consideration is the provision of a safe method of entering and leaving the well, especially after the depth exceeds 2m. This is best done by rigging up a type of “bosun’s chair” with a strong piece of wood and a rope (see [Figure 8.1](#)). This can then be lowered into the well using the tripod. On no account should workers attempt to climb out and in using foot-and hand-holds in the sides of the well. When down the well, workers should wear protective helmets, and should at all times comply with relevant health and safety guidelines.



Figure 8-1 - Two Possible Designs for a Bosun’s Chair

8.3 Intake Construction

The principles of the intake part of a well were introduced in [Section 5.2.4](#). In practice, the type of intake constructed will depend on the lining option selected, and on the construction sequence adopted. The possible variations may be summarised as follows:

- The well is excavated and lined in-situ to the top of the water table. The intake lining is then prefabricated and sunk, through continued excavation, into the aquifer. This procedure is described in [Sections 9.3](#) and [9.5](#)
- The well is excavated to below the level of the water table. A pump is used to keep the well dry while the intake is constructed in-situ. This method is described in [Section 9.4](#).

- The well is excavated to the top of the water table. A complete prefabricated lining is put in place, with porous elements positioned to eventually coincide with the aquifer. Further excavation is done to allow the lining to settle into the correct position. This procedure is shown in [Section 9.5](#).

8.4 Site layout

The layout of the construction site should allow for easy access to the well with the necessary materials, for the easy and appropriate disposal of the soil excavated from the well and for the rapid and safe dispersal of the water from the dewatering phase. A typical site layout is shown in Figure 8.2.

Vital information with regard to the excavation of the well is contained in the report from the test borehole or boreholes drilled at the site. Other important information will be available from previous work in the area and from local knowledge of the groundwater conditions. Without the gathering of all possible information on the proposed site, construction work should not begin.

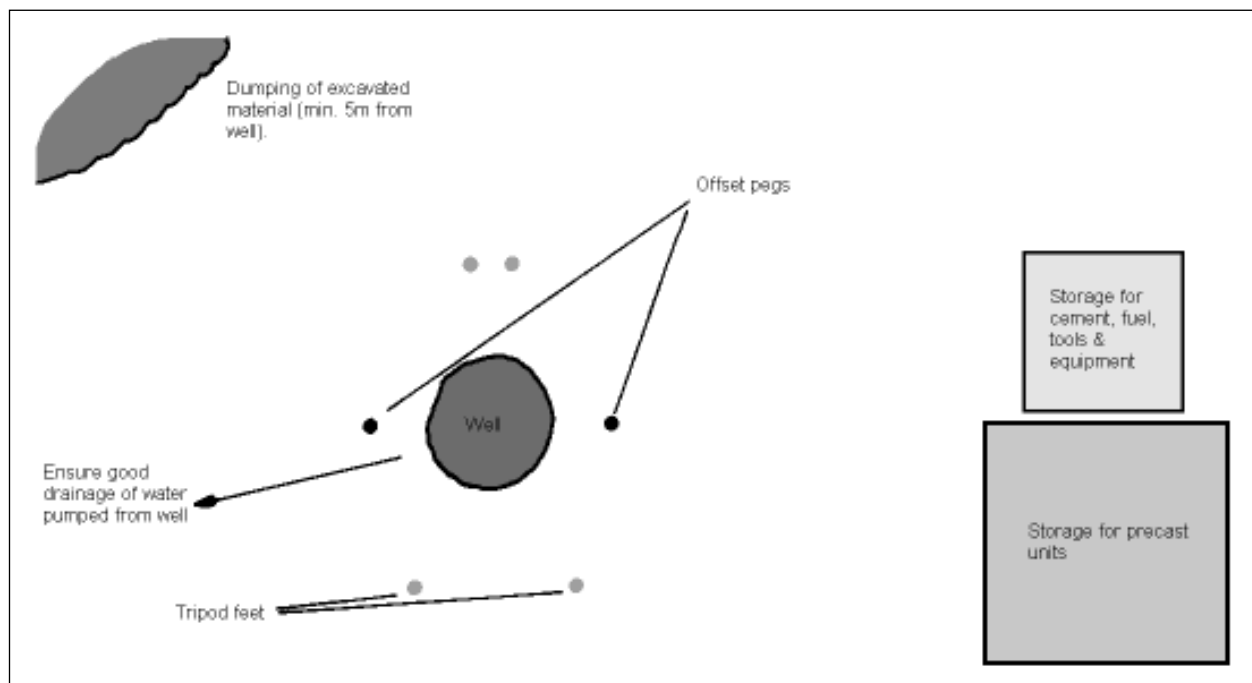


Figure 8-2 - A Typical Site Layout

The above layout may be modified where concrete is being placed in-situ, or where precasting of lining elements is being done adjacent to the well site (see Figure 11.1).

8.5 Safety precautions

Shallow well construction can be a dangerous activity, and some project managers may hesitate to allow unskilled or uninsured personnel down an excavation. This may limit the degree of community participation possible, but it is better to err on the side of safety in these cases.

In the excavation of hand-dug wells, the most common causes of injury are sub-standard equipment, collapse of the well, and equipment or materials falling down the well. On occasion, the excavation may liberate harmful gases which could cause asphyxiation. The following precautions should be taken at all times during excavation and construction of a hand-dug well:

- Ensure that all equipment is in good working order, regularly maintained and checked, and replaced when necessary.
- When workers are down the well, there should always be somebody on the surface to attend to them.
- The diggers should always be assured quick access to an emergency escape (by ladder, rope, etc.)
- Well diggers should enter and leave the well in a safe manner.
- Well diggers should always wear safety helmets, which should be replaced after any impacts.
- Ensure that no objects or people can fall into the well. Provide guard rails and, at night, cover the well or make sure that someone is on guard to prevent animals or people from falling in.
- Do not excavate greater than 5m without temporarily or permanently securing the sides of the excavation.

It is a good idea to provide temporary shoring at the top 2m of the pit. This can be arranged with vertical planks, held in place with steel hoops and wedges. The top of the planks can be allowed to protrude above the top of the pit, thus providing a barrier against people and materials falling into the excavation. If it is found that the excavation needs to be supported below 2m, there are two options. Firstly, the timber shoring may be continued by the addition of more planks and hoops. This is called the Modified Chicago Method. Alternatively, the first of the lining rings may be placed and excavation may continue as described in [Section 12.2](#).

9. Examples of construction sequences

9.1 Introduction

The following sequences refer to the options for lining and intake construction outlined in Section 8.3. For the purpose of describing the construction sequence, we are assuming that the overlying strata at the well site are firm. There are particular problems related to excavating in loose soils, and these are treated in [Section 12.2](#).

9.2 Location of excavation

Where possible, the well should be constructed directly over the site of a successful trial borehole. If a grid of trial boreholes was made, the well should be located within the limits of the grid, close to or at the highest-yielding borehole. Before beginning the construction of the well, the technician responsible should consult the trial borehole report(s) in order to have a good idea of the soil conditions which will be encountered, the probable depth at which water will be reached, the thickness of the aquifer(s) and

the existence of impermeable strata below them. In cases where there is sufficient knowledge of the groundwater regime in a particular area, it will not be necessary to do a trial borehole. No construction work should go ahead without consulting those with local knowledge of the area.

Before excavation begins, it is necessary to define the centre point and thereby the vertical axis of the well. Since any mark at the centre of the well will be affected by the excavation, the point is marked using offset pegs, located on an extended diameter of the well, sufficiently far back from the expected edge of the excavation not to be affected by it, as shown in Figure 9.1. While excavation continues, the diameter of the well can be checked by means of a length of stick suspended at the centre of the well, using the offset pegs to properly locate it. The stick, which should be suspended through its midpoint, should be 10cm greater in length than the outside diameter of the lining rings. A plumb line can also be suspended from the centre point to check the vertical alignment of the excavation.

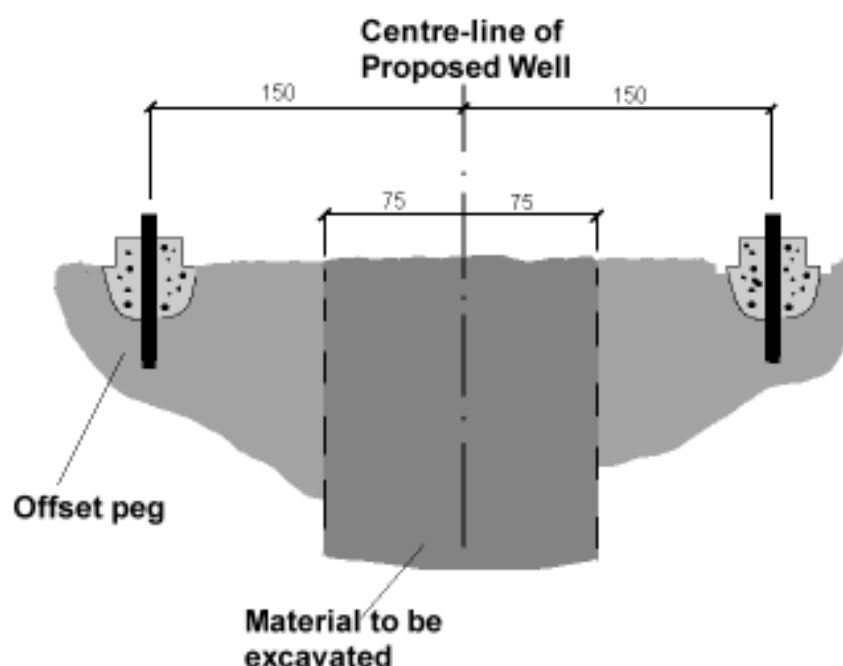


Figure 9-1 - Using Offset Pegs to Define the Centre of a Well

Locate the offset pegs securely using pieces of steel bar driven into the ground and embedded in concrete. Ensure that the pegs are positioned so that they will not be affected by later excavation and construction activities. Excavation may now commence.

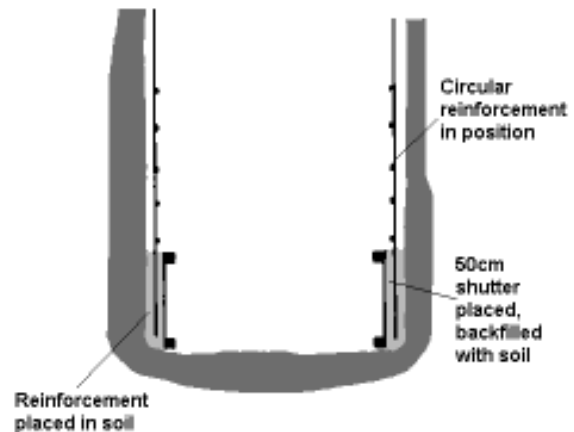
9.3 Cast in-situ concrete lining with prefabricated caisson intake

One of the main advantages of this option is that the need to transport and/or lower heavy items down the pit is reduced (but not altogether eliminated), since the main lining is not precast. However, it is normally only the lining of the well above the level of the water table which is cast in-situ. As with the precast option, lining may be mass concrete or reinforced, and the procedure will generally be as given in the following summary. The subject has been dealt with comprehensively in other publications¹ and it is not necessary to repeat the full details here.

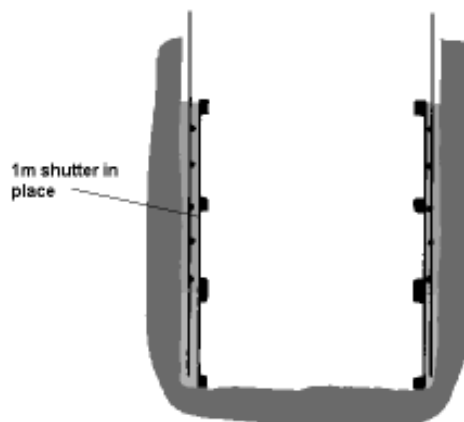
1. Excavate at the desired diameter down to a depth of 5m, or to the top of the water table, whichever occurs first. (Unless the soil is particularly stable, it is not advisable to excavate further without pouring the first lift of lining). The diameter of the excavation will be 15cm greater than the desired internal diameter of the finished well shaft. Care must again be taken when centring and plumbing the excavation, since parts of the lining which are too thin will weaken the structure while areas which are too thick will result in a waste of material.

After properly trimming the excavation, the shuttering may be placed for the first lift. In this instance, only one leaf of shuttering is used, and it is built up in a column from the bottom of the excavation. The plumbing of the formwork is facilitated by the placing of a 50cm "levelling" shutter at the bottom of the excavation.

The space between this shutter and the wall of the pit is filled with well-compacted soil and vertical reinforcement bars are embedded in it. In this way, the steel will be held in place during the pouring operation. Horizontal reinforcement, in the form of circular bars, is fixed to the vertical bars with soft steel wire.

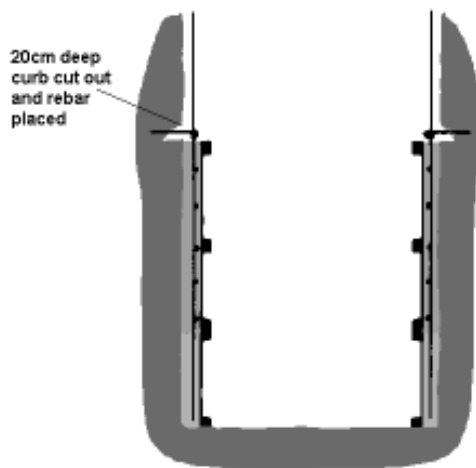


2. A 1m high shutter is now placed on top of the "levelling" shutter and fixed firmly into position. Concrete is poured up to the level of the top of this shutter.

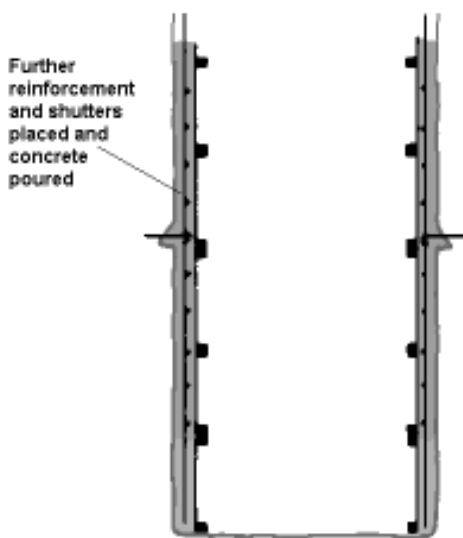


3. At the top of this shutter, a triangular curb is cut into the surrounding soil to a depth of 20cm. The purpose of this curb is to provide some purchase for the lining in the walls of the excavation, to help to counter forces due to self-weight. Reinforcement bars, with a hook at the outer end, are driven into the soil at the back of the curb, and the hook is fixed around both a vertical and a horizontal reinforcement bar.

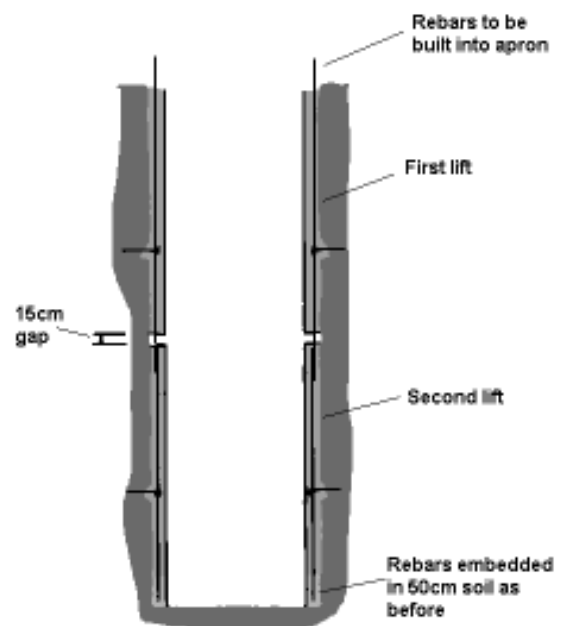
¹ See Watt, S.B. and Wood, W.E., *Hand Dug Wells and their Construction*, London, 2nd ed. 1979, ITDG



4. Once the curb has been prepared, concrete is placed in it by hand. Shuttering may be placed and the rest of the lift poured. At the top of the well, reinforcement bars are left protruding from the top of the lining. These will later be bent over and incorporated into the construction of the well-head.



5. Once the first lift has been poured, the shuttering is left in place and excavation continues down for a further 4.65 metres or until the water table is reached. The depth of 4.65m is specified because of the already-existing depth of 50cm below the bottom of the first lift, which was packed with soil to allow the setting-up of the reinforcement. The only access to the second shutter, in order to pour concrete, is through this gap, and it is not possible to install the shuttering flush with the end of the first lift. As a result, a 15cm gap is allowed between the lifts, and this is later filled in with blocks.



The soil which was used to position the first set of reinforcing bars is removed, and the bars are used to help to provide continuity of reinforcement throughout the lining. The setting of a levelling shutter is repeated at the bottom of the second lift, and reinforcement is put in place.

6. The steps outlined above for the first lift are repeated.
7. The 15cm gap between the lifts is now filled in.
8. The above steps are repeated until the water table is reached.
9. The situation at this point is that excavation has ceased at the level of the water table, and the pit has been fully lined to this level. It remains to continue the well into the water table. This is done by making a column of porous rings (caisson), placing it in position inside the lined shaft and sinking it in much the same method as that described for excavation in loose soils in [Section 12.2](#).

This method is more time-consuming in the construction phase than using precast lining rings. It is possible to avoid problems with vertical alignment, since it is much easier to correct the alignment of a steel shutter, before pouring any concrete, than a very heavy column of precast rings. However, especially during the second and subsequent lifts, it is necessary that work is done in places which

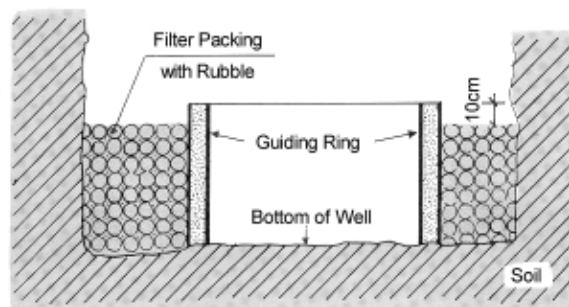
are accessible neither from the top nor from the bottom of the excavation, necessitating the frequent use of a bosun's chair as a working platform and not merely as a method of reaching the bottom of the pit. The safety of workers must receive due consideration in this instance.

9.4 Concrete lining with built in-situ intake

Using this method, excavation is first carried out to the desired finished level of the well, using a dewatering device to keep the well dry. The concrete shaft lining may use precast or cast in-situ elements, but the distinguishing feature of this method is the in-situ construction of the intake in its final position. Because the well is lined from the bottom up, it is a suitable method only in areas where the soil is stable, unless temporary shuttering is to be used. Using cast in-situ concrete lining, a precast guiding ring is first placed in the bottom of the well. Formwork is placed on top of this ring and the first of the cast in-situ rings is poured. After it has hardened sufficiently, the formwork is removed and placed on top of this ring in turn. The process is repeated up to ground level. A more detailed sequence is given below.

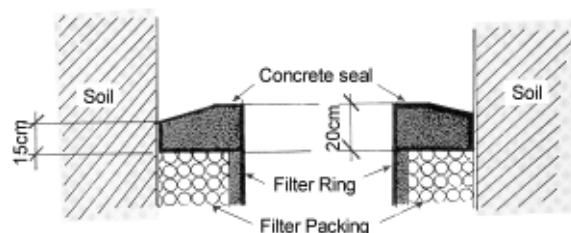
1. Excavate the well to the desired finished level. Once the excavation passes below the water table, a dewatering device must be used. The diameter of the excavation must be 60cm greater than the outside diameter of the well lining, to allow assembly and dismantling of the formwork inside the well.
2. If necessary (see [Section 5.2.4](#)) insert a base plug of porous material.
3. Place a precast concrete guiding ring on the bottom of the well. This is a precast ring of the desired diameter and wall thickness (usually 5 or 10cm). The purpose of placing this ring is to provide a starting level for the first cast in-situ ring, so the guiding ring must be plumbed carefully to avoid problems with vertical alignment further up the well. Depending on the desired area of inflow into the intake (bottom, sides or both), the guiding ring will be of solid or porous concrete. For information on precasting lining rings, see [Section 11.3](#).

4. Backfill the space between the sides of the excavation and the guiding ring with 20mm gravel, as shown.



Section through Bottom of Well

5. Clean off the top of the guiding ring, fix formwork and cast a filter ring on top of the guiding ring.
6. Repeat the previous two steps until the complete depth of the exposed aquifer has been lined with filter rings.
7. Seal the top of the intake lining with concrete (1:2:3) as shown in the diagram.

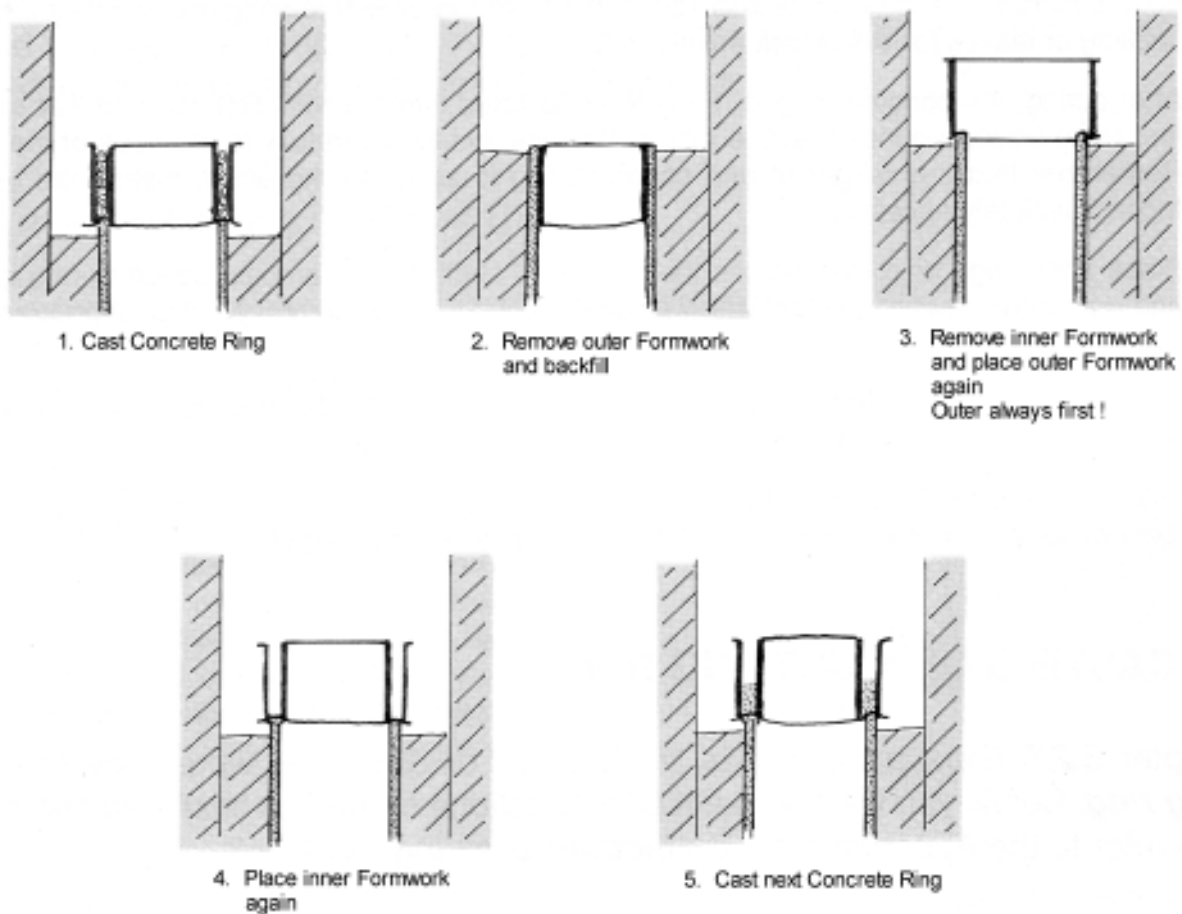


Section through Concrete Seal

8. The construction of the intake is now complete and the lining of the shaft may be completed. This is accomplished by placing formwork, pouring the concrete, allowing it to set and removing the formwork. Above the level of the intake, the backfilling between the excavation wall and the lining ring may be done with some of the excavated soil. The sequence is shown in the following figure.

In this method, precast rings may also be used after the intake has been constructed. In such a case, the diameter of the excavation needs only to be 20cm greater than the final outside diameter of the lining, since no formwork will be assembled inside the well shaft.

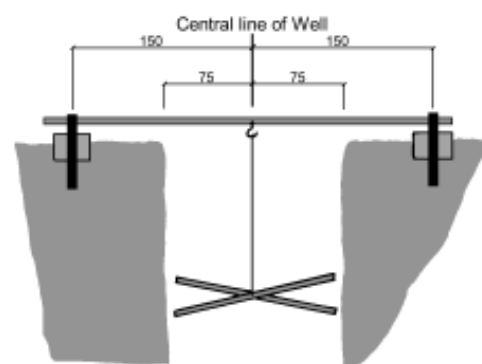
Sequence of forming and casting in-Situ of Concrete Rings



9.5 Prefabricated concrete lining rings

The following sequence describes a typical excavation procedure in firm ground. Details of precasting of lining rings and other elements are given in [Chapter 11](#).

1. Begin excavation, disposing of the excavated material so that it will not cause an obstruction later. The diameter of the pit should be checked regularly by using trimming rods (5cm shorter than the desired diameter), suspended at the axis of the well, which is defined using offset pegs. For a well using 1.3m external diameter rings, the pit diameter should be 1.5m, so the trimming rods are 1.45m long.
2. The trimming rods can be made of wood or steel (reinforcement bar is suitable), and they should be fixed together at the centre loosely enough to allow them to swing open in the pit.

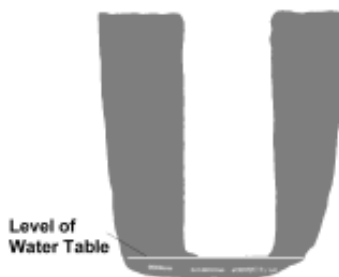


During the excavation, the trial borehole report should be on hand for consultation. An independent record should be kept of the material encountered during the well excavation, for the purposes of comparison. The information may be recorded on a form similar to that shown in [Appendix 2](#).

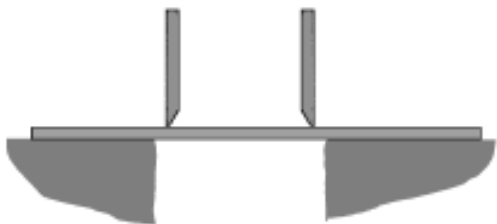
Hand-dug shallow wells

As already mentioned, it may be advisable to put temporary shuttering on the upper 2m of the pit.

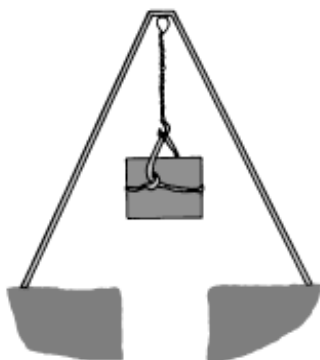
3. When the water table is reached, level off the bottom of the well and stop excavating.



4. Set up the tripod with block-and-tackle over the centre of the well. Bring a cutting ring of the desired type to the top of the excavation and carefully place it, cutting edge down, over two securely positioned steel pipes or some strong pieces of timber across the top of the hole.



5. Fix a strong rope (remember, the ring weighs around 900kg) to the ring and to the chains of the block-and-tackle. Lift the ring slowly and carefully to allow removal of the pipes. Make sure that the ring is securely held, and that it hangs vertically.

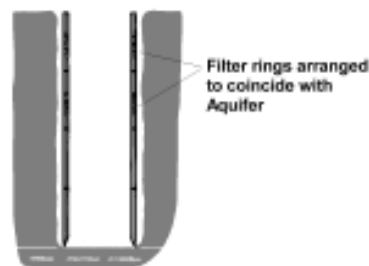


6. Lower the ring slowly into the well and settle it in place on the bottom. Check the vertical alignment.

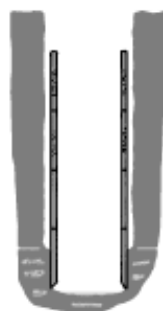


7. Follow the same steps with enough rings to come up to ground level, always checking the vertical alignment. The sequence of types of ring should follow that suggested by the trial borehole report, with filter rings placed to coincide with the aquifer once excavation is complete.

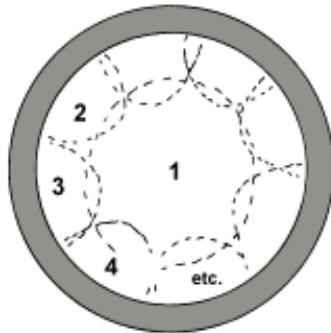
Before each ring is placed, put a layer of mortar of 1 part cement to 3 parts sand on top of the preceding ring.



8. Recommence excavation, using pumping equipment to keep the bottom of the well as dry as possible (pump not shown). Ensure rapid dispersal, in a direction away from the excavation, of the water being pumped out of the well.



9. When excavating now, work slowly from the centre of the well out to the walls of the ring, and work evenly around the well, otherwise the rings may go out of plumb. Ensure that the rings settle uniformly within the well.

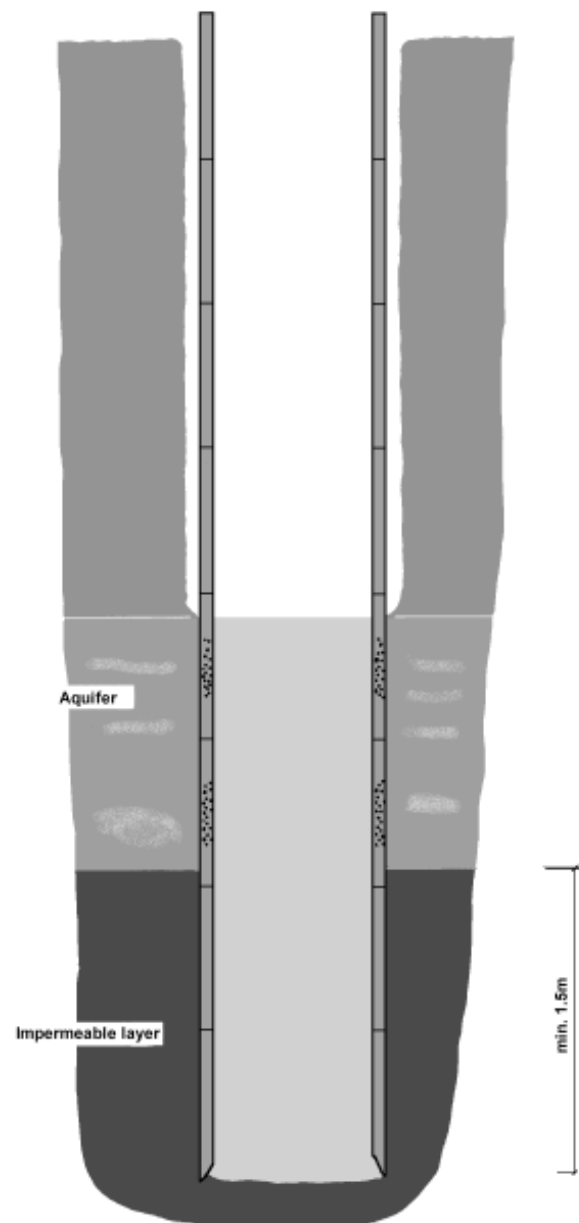


10. As the rings sink down into the well, continue to place more on top, placing mortar in the joints.



11. Continue excavating until one of three situations occurs:
- a) the cutting ring has passed into the impermeable layer by at least 150cm and the filter rings are aligned with the aquifer. This is the ideal outcome.
 - b) excavation has continued to a total depth of 15m without encountering an impermeable layer;
 - c) due to the influx of water into the excavation, the capacity of the pumping equipment to keep the well clear is no longer sufficient to guarantee the safety of the workers in the excavation.

In the case of (b) above, the well may be finished off by placing a plug on the bottom (see [Section 5.2.4](#)). In (c), the well should first be backfilled to provide a safe working environment, and then a base plug fitted if necessary. In either case, the positioning of the filter rings must coincide with the aquifer.



12. The construction is now complete and the following steps are necessary to prepare the well for use:
- The gap between the outer wall of the lining rings and the walls of the pit must be backfilled. This is important in the creation of a sanitary well. Below 2m depth, sand should be dropped into the gap and washed in with water, compacting it. From 2m to the surface, the area should be opened up wider than the gap and then backfilled using well-compacted soil. There will be no gap at the level of the filter rings since these will sink while in contact with the aquifer.
 - The level of the top of the last lining ring to be placed must be at least 20cm above the surrounding ground, if the well is to be fitted with

a handpump, and 80cm, if the well is to remain open (see Section 10.1).

- A yield test should be performed on the completed well. This is useful for record purposes, and may also be used to confirm (or change) the decision on which type of water-lifting device should be fitted.
- The well must be disinfected (see [Section 10.2](#)).
- If the well is to be fitted with a handpump, a cover slab must be put in place and the handpump installed.
- After sufficient time has elapsed to allow the ground around the well to settle, an apron must be constructed.

The foregoing procedure is based on excavating to the water table before placing any lining rings. If a comprehensive and reliable site investigation has taken place before construction, and if one can be reasonably sure of encountering water at a particular depth, rings may be placed from the beginning of excavation in a manner similar to that described in [Section 12.2](#) for excavation in loose soils. This has the advantage of protecting the workers as they progress down the pit, but requires care in attending to the vertical alignment of the shaft.

10. Concluding works

10.1 *Finishing off above ground*

The height of the top of the well above the surrounding ground will depend on whether or not the well is to remain open. If it is, water will normally be extracted by each individual consumer, using buckets. The headwall must therefore be made high enough to prevent animals and small children from falling in, but low enough to facilitate the lifting out of buckets of water. The height by which the well extends above the ground should also take account of the type of lifting system to be installed and the later construction of a protective apron around the well.

If the well is to remain open, the top of the last ring put in place should be a minimum of 80cm above the general level of the surrounding ground, before any apron is constructed. If the well will be closed, this may be reduced to 20cm. Since the desired height above the ground may not be reached using rings of 1m height, it is useful to be able to cast rings of 50cm or 75cm for this purpose.

For record and maintenance purposes, it is useful to assign a unique code to a completed well. This code may be used during the operation and maintenance phase to report a breakdown or to monitor maintenance inputs to the well and any water-lifting device fitted on it. The code can easily be incorporated into the apron, but the construction of the apron should not be started until the ground disturbed by the excavation process has had time to settle once more. In the meantime, the code can be inscribed in the top ring or the cover slab, or it can be kept in a safe place by a member of the community.

10.2 *Disinfection of the completed well*

It is more than likely that contamination will have entered the well during the construction phase. Before the well is used as a source of drinking water, this contamination must be removed. In this situation, the fact that the consumers must wait another few days before using what looks like a completed well must be carefully explained as early as possible during the supply process so as to avoid frustration and disappointment.

The most widely available agent for disinfection is chlorine, which can be purchased as ordinary commercial bleaching powder or liquid bleach, or as High Test Hypochlorite (HTH) solution. The amount of available chlorine varies with the source in question, being approximately 70% in HTH, 35% in bleaching powder and 5% in liquid bleach.

The disinfection of a well takes place in two stages - disinfection of the walls of the shaft and disinfection of the intake. To disinfect the shaft, mix 100g of bleaching powder (or the equivalent using another source of chlorine) in 10 litres of water, and use this solution to scrub thoroughly the walls of the well. Any liquid remaining after the washing should be poured into the well. Then proceed as follows:

1. Make up a solution using 100g of bleaching powder in 10 litres of water for each cubic metre of water held in the well, and pour it in to the well.
2. Begin pumping immediately, and pump until there is a distinct smell of chlorine from the water. If there is no pump, water may be removed quickly using a number of buckets at the same time.
3. Wait one hour.
4. Pump again until there is a distinct smell of chlorine.
5. Wait one hour.
6. Repeat steps 4 & 5 on two more occasions.

7. Let the water in the well stand undisturbed for at least 12 hours.
8. Pump to waste until there is no odour of chlorine.

10.3 Well apron

If the area around a well is allowed to become dirty, and waste and stagnant water is allowed to accumulate, it will become a source of infection for the users. Standing in bare feet in stagnant water or mud is a serious health risk in the tropics, and the open water also provides an ideal breeding ground for mosquitoes and other disease carriers. The idea of hygiene in water use must start at the collection point, otherwise the possible benefits from an improved water supply will be lost.

The construction of an apron at the well-head is an important contribution to the general hygiene in a community. In addition to discouraging the accumulation of stagnant water at the surface, the apron will help to prevent the contamination of the well through the infiltration of dirty water back into the aquifer.

A typical apron is shown in Figure 10.1. The shape

of the apron is not as important as the capacity to drain water away from the well as quickly as possible and ensure its dispersal in a hygienic manner. Where possible, the drain can lead to an area of vegetation, such as banana plants. If this is not an option, a soakpit can be built.

Depending on the lining method used, the apron may be connected to the well lining. When reinforced cast in-situ concrete is used, reinforcement bars are left protruding, around the circumference of the shaft, for 1m above the top of the well lining. These bars are then bent over and incorporated into the apron. When using precast units, this is not possible, unless holes are drilled in the lining ring. A more detailed drawing of one type of apron is given in [Appendix 3](#).

It is important that no construction of the apron commences until the soil around the well, which was disturbed by the construction activities, has had an opportunity to settle once more. While certain procedures advise waiting at least six months to allow this to happen, especially if the apron is to be constructed in mass concrete, this need must be balanced against health considerations relating to the state of the area around the well head. Local experience will again dictate the best approach.

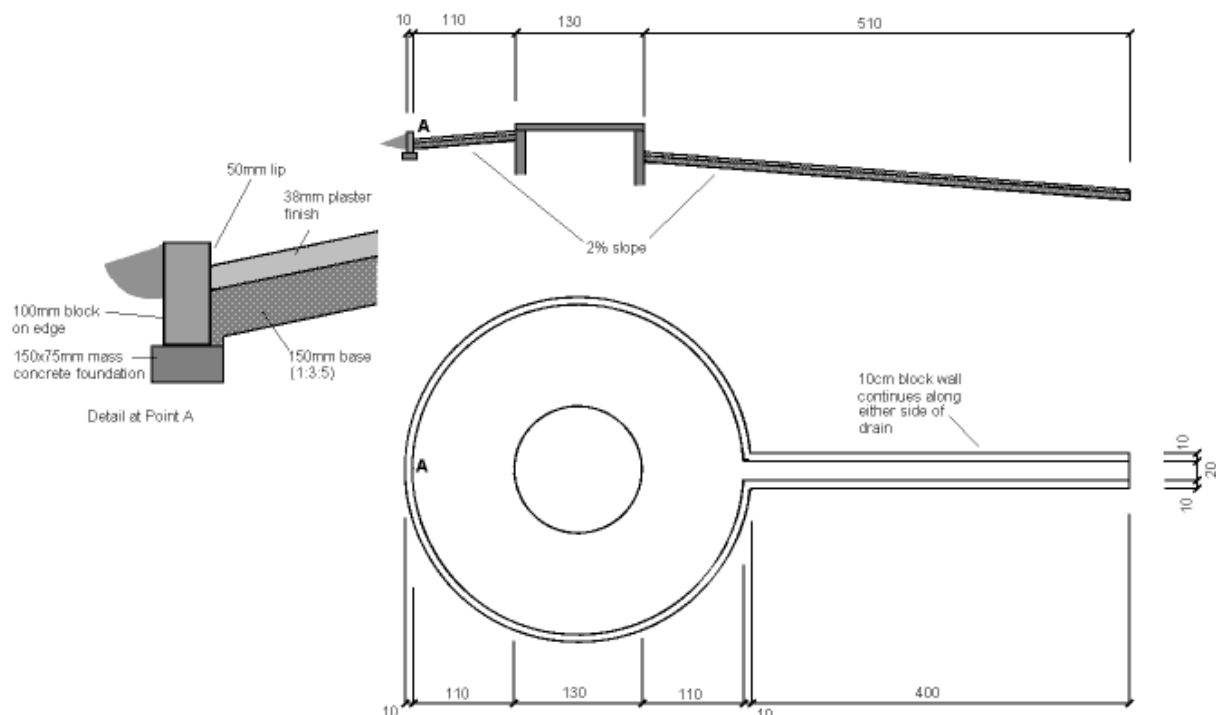


Figure 10-1 - A Circular Apron, with a surface drain, for a 1.3m diameter well

10.4 Fencing

In addition to constructing an apron, it is a good idea to erect a fence around a waterpoint. This can be done immediately after the construction of the well is finished, and should enclose an area roughly 10m by 10m around the well. The advantages of fencing are that it serves to define quite clearly, for the whole community, the area of the well and it keeps animals away from the well-head. In cases it may be necessary to have a gateway to keep out smaller animals such as pigs and goats.

The erection of fencing provides another ideal opportunity for community participation. The fencing can be made of suitable local materials such as bamboo. However, care must be taken that, after the initial construction with such materials, it will be possible (both financially and in terms of management) to arrange the periodic replacement which will be necessary. It may be better in the long term to opt for a more permanent type of fencing with wood, steel or wire. Even in these cases, some maintenance will be necessary. Problems of replacement and repair can be avoided altogether, and a more environmentally friendly solution applied, by using a living hedge as fencing. Whatever type of fencing is used, it is important that access by the well users is guaranteed.

10.5 Laundry slab

In many communities, the washing of clothes is an important social activity. Since the collection of water for washing clothes is a significant part of the daily chores, it is convenient to locate a washing area near to the water collection point. If the community which has built a waterpoint so desires, a washing slab can be constructed. This can be done at the same time as the well is being constructed, or it can be built together with the well apron.

In the construction of the washing area, it is important to take care that the grey water draining off the slab is not directed back to the well. The slab should be constructed below the well, physically and with regard to the flow of water in the aquifer, and at a distance of at least 20m. The slab should be provided with a drain and a soakpit.

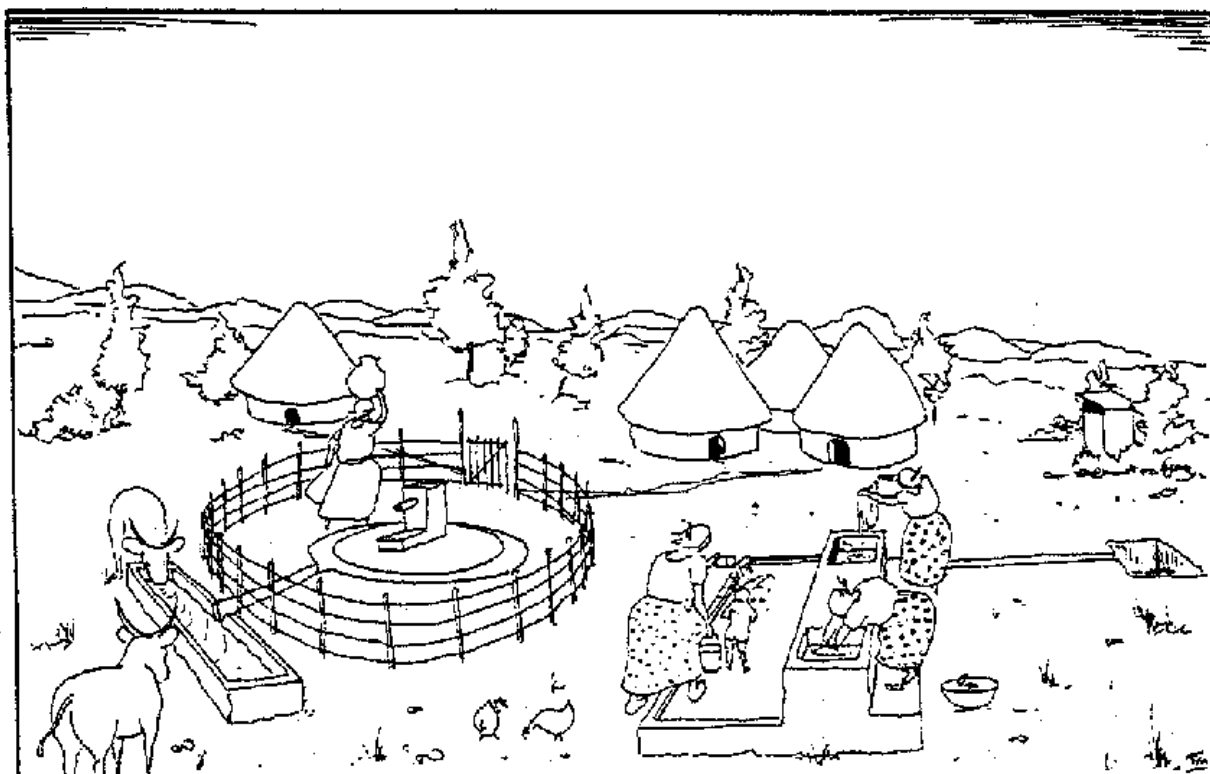


Figure 10-1 - A Well-protected waterpoint

11.

Precast concrete elements for hand-dug wells

This chapter deals with the prefabrication of lining rings and other elements used in constructing a well.

11.1 Introduction

The work of precasting the rings and other elements of a well may take place close to the proposed well, at a central location in the community (where more than one well is being built), or at a centralised workshop serving a number of separate locations in a district. As already mentioned, the former options provide good opportunities for community participation, but this advantage may be outweighed

by logistical or economic considerations which would necessitate the operation of a centralised precasting yard. In this case, the problem of transporting the completed rings arises, while at the same time the problems of transporting large volumes of cement, sand, gravel and water may be reduced.

Whatever the strategy adopted, the site for precasting must be prepared and laid out in such a way as to ensure an efficient output. Figure 11.1 shows a typical arrangement which takes account of easy access for delivery or raw materials and collection of completed rings, and a logical flow of work from beginning to end.

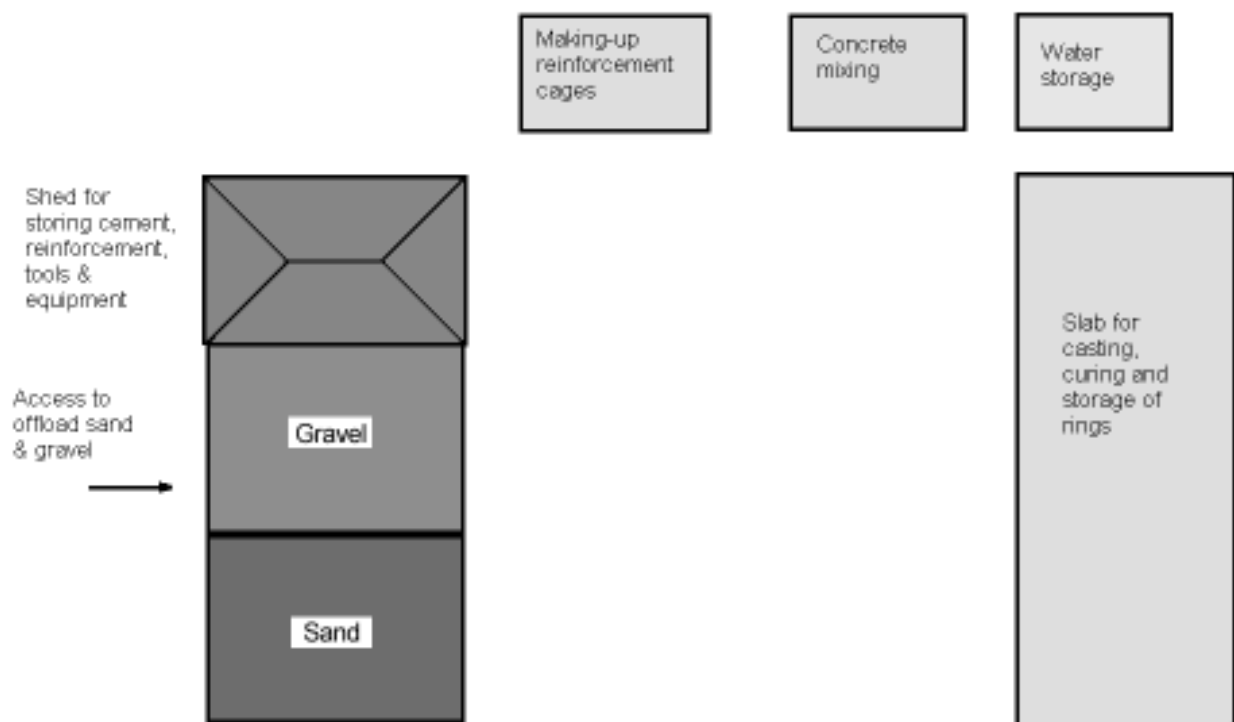


Figure 11-1 - Layout of area for precasting concrete rings

11.2 Formwork and equipment

The most important piece of equipment is the formwork. To allow frequent re-use, it should be of robust construction and preferably be made of steel. Dimensions may vary from country to country, and those adopted in this manual, with a standard height of 1m, a 1.1m internal diameter and a thickness of 10cm, (see below and Appendix 3) serve merely as a guide. In addition to making rings of the standard height, it is also useful to have formwork for making rings of 50cm and 75cm. These are used at the top of the well, in order to finish off the lining at the specified distance above the surrounding ground.

Since it is necessary during the excavation phase for work to be done while standing within a ring, the diameter should allow one person to work with ease and this is normally the limiting factor for dimensioning the ring. Typical formwork used for a standard ring is shown in the photographs.



Photograph 11-1 - Inner and outer formwork, dismantled

The outer shell of the formwork consists of two semi-circular pieces of steel plate, with three channel section stiffeners spaced evenly from top to bottom. At the ends of each section, perforated steel strips are affixed which allow the bolting of the sections together to form a cylinder 1m deep with an internal diameter of 1.3m.

The inner part of the formwork is an almost-complete cylinder with an external diameter of 1.1m, stiffened in this case on the inside surface, and with one removable section to facilitate striking of the formwork after pouring. The same fixing detail using perforated strips and bolts is employed. The inner leaf is also fitted with a 'handle' to allow its removal.



Photograph 11-2 - Formwork assembled and ready for use

The use of a concrete mixer is advisable in ensuring uniformity of mix and a smooth supply of concrete while the pour is in progress. Wheelbarrows or strong buckets can be used to transport the concrete for placing, while some 1.5m lengths of 10mm reinforcement bar can be used to rod the concrete to ensure compaction. It is important to have a steel plate or some plastic sheeting to place underneath the formwork while the concrete is being poured, though if this is not available, empty cement bags can be used. In any case, casting should be done on a level concrete slab. Heavy plastic sheeting is also very useful in the curing process.

11.3 Prefabricated concrete lining rings

11.3.1 Standard ring

This section deals with the casting of a typical unreinforced lining ring. Additional considerations with regard to reinforced rings are given in [Section 7.4](#). The following is a typical procedure.

1. Ensure that the formwork is clean. Apply a thin coating of lubricant (such as coconut oil), to the surfaces of the mould which will be in contact with concrete. This will facilitate the removal of the formwork afterwards. Place the prepared formwork on a sheet of plastic or metal, on level ground. Ensure that the inside and outside leaves are properly spaced.

2. Mix the concrete and place it in the mould. The concrete should be placed in layers of 20cm and each layer should be properly compacted by rodding with pieces of wood or reinforcing bar. Note the spacer at the front of the photograph, ensuring that the two leaves remain the required distance apart.



Photograph 11-3 - Pouring a ring



Photograph 11-4 - Rodding to ensure compaction

3. Finish off smoothly at the top of the formwork. Inscribe the date of casting in the wet concrete. Leave the formwork in place for 24 hours after placing the last layer of concrete. Wash off any slurry and concrete from the outside of the formwork immediately after finishing the pour.



Photograph 11-5 - Finishing off at the top of a ring

Concrete does not attain its full strength immediately upon placement. Care must be taken that the water in the mix, which is an important component in the strengthening process, does not evaporate too quickly. Also, concrete shrinks as it dries, and if it dries too rapidly, cracks will form. For these two reasons, it is important that, after removal of the formwork, the concrete is allowed to cure slowly, and that it is kept wet during the process. For curing, if the ring is in a location which is in permanent shade, it is sufficient to keep it wet by pouring water over it at regular intervals. If the location is subjected to direct sunlight, it is necessary to cover the ring. If it is covered completely with a heavy plastic sheet, the ring will stay damp due to condensation and the curing process will be assisted. Otherwise, the ring may be covered with heavy cloths or gunny sacks, which are constantly kept wet by dousing with water. Whatever the case, the ring must not be moved for the duration of the curing period, which should normally be seven days.

Care must be taken in the movement and transport of the heavy rings. For short distances, a ring may be rolled carefully to its destination. However, manipulating the ring onto its side in the first place is potentially dangerous for those doing it, and may also cause damage to the ring itself. The manoeuvre should only be done using a tripod and pulley.

For loading rings onto a truck, a temporary earth loading ramp can be constructed so that it is not necessary to roll the ring up an incline (see photograph). A similar arrangement should be used for unloading, ensuring that the rings are not simply dumped from the truck.



Photograph 11-6 - Loading a concrete ring using a temporary loading ramp

11.3.2 Filter ring

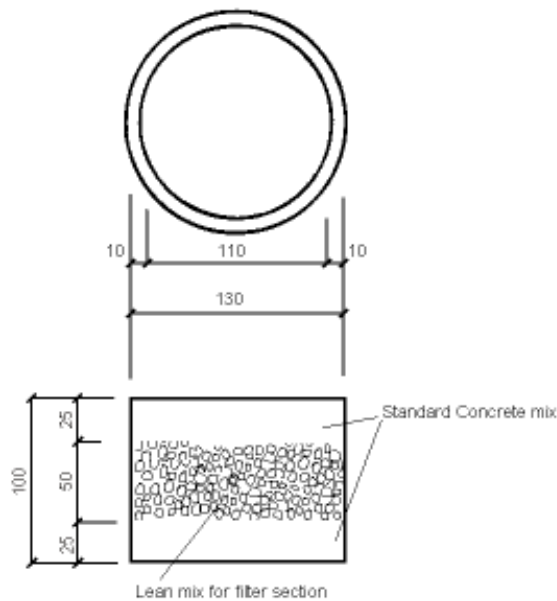


Figure 11-2 - A Filter ring (dimensions in cm)

Filter rings are placed at the depth of the well where the aquifer is exposed, and are designed to allow water to seep into the well while avoiding the infiltration of sand. A ring is cast of the same height, diameter and thickness as the standard ring, but the middle 50cm of concrete is made in a special mix to allow water from the aquifer to enter the well. This mix reduces the amount of sand and, instead of using the normal coarse aggregate, uses gravel with a maximum size of 20mm. If this is not immediately available, the coarse aggregate should be sieved to provide it. The mix is then made in the proportions of 1:4 (cement:gravel). Because of this special layer, the filter ring will be considerably weaker than the standard ring and greater care must be taken during transport and placement. Compaction of the concrete cannot be done using



Photograph 11-7 - A completed filter ring

rods in this case, since the three layers would become mixed up. During pouring, the outside and inside walls of the formwork should be tapped with a hammer to ensure compaction.

11.3.3 Cutting (Leading) ring

The sinking of the well can be eased if the first ring to be placed in the hole has a sharper leading edge. This can be achieved by using a trowel to bevel the top of a ring soon after the concrete has been placed (when it is soft enough to manipulate but sufficiently hard to hold its shape). The bevel for a 10cm thick ring has the dimensions shown in Figure 11.3. Two important points must be noted here. Firstly, the cutting edge will be formed at the top of a ring, just as the initial set is taking place, so it must be turned over before it can be used. Secondly, if the ring is reinforced, the cutting out of the bevel must not expose the steel, and an allowance must be made for the bevel in the placing of the reinforcement.

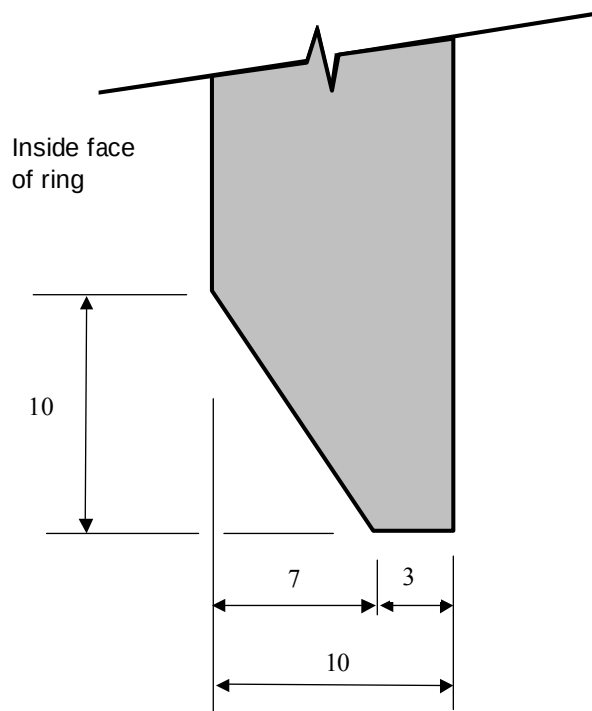


Figure 11-3 - Dimensions (in cm) for the bevelled edge of a cutting ring

11.3.4 Rings with rebate

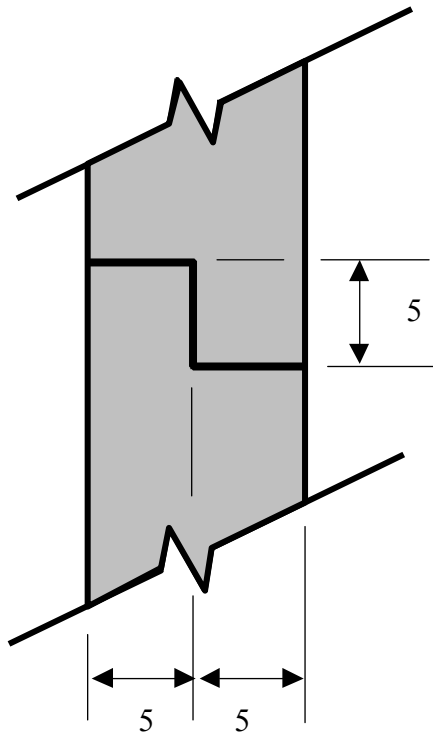


Figure 11-4 - Dimensions (in cm) of rebates for standard ring

In general, the main load on a lining ring will be self-weight and the weight of any rings above it. Lateral forces from soil and water pressure will more or less cancel out around the circumference of the well. If it is expected that some lateral movement could take place, or if it is felt necessary to prevent rings from moving in relation to each other during the excavation and placement process, it is useful to cast rebates at the top and bottom of each ring. By eliminating the movement of one ring relative to another, the inclusion of rebates also ensures that the mortar seal between rings is kept intact, thereby preserving a seal around the well shaft and reducing the risk of contamination by the infiltration of pollutants.



Photograph 11-8 - Rebate rings in position, awaiting assembly of formwork

For a 10cm ring, these rebates would be as shown in Figure 11.4. The rebates are cast by inserting a special metal ring at the bottom of the formwork before pouring, as shown in the photograph below, and fitting a corresponding ring at the top. When using rings with rebates, care must be taken that a ring is properly oriented before lowering it in the hole. Since the edges of rebated rings are thinner, more care must be exercised in transport and placing. Dimensions for the rebate base and ring are given in [Appendix 3](#).

11.3.5 Extension (telescoping) rings

In special cases where an existing well needs to be deepened due to a general lowering of the water table, rings are cast with a diameter which allows them to be lowered through the standard rings. These “telescoping” rings (see Figure 11.5) have a typical internal diameter of 85cm with a wall thickness of 7.5cm. This gives an overall outside

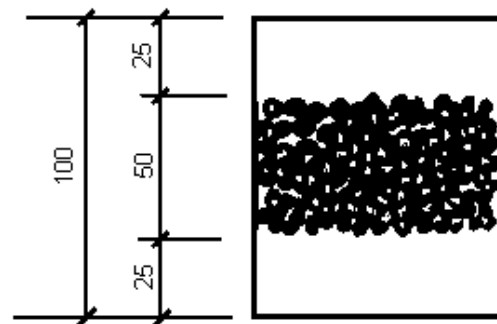
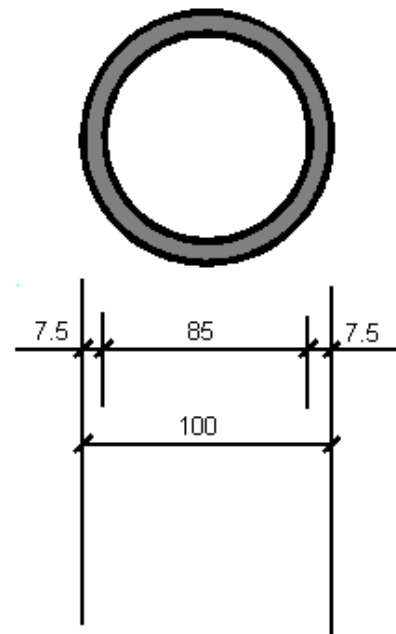


Figure 11-5 - Telescoping (extension) ring for a 1.1m internal dia. well (filter type shown)

diameter of 1m, which allows for the thickness of a rope when lowering the ring through a well of 1.1m internal diameter. The rings can be made in the same variations as rings of standard diameter (incorporating filters, rebates, cutting edges). Information from the initial survey, or a second if necessary, will indicate the types and numbers of rings needed. The formwork for this type of ring is similar to that for standard rings, with the diameters adjusted accordingly. The application of these rings is treated in Section 13.2.3.

11.4 Other precast concrete elements

11.4.1 Well cover slab

Except in a situation where the preference of the community or economic considerations have indicated the installation of a bucket system, the well will be covered to allow the installation of a handpump or other water lifting device. Whatever the type of lining used in the well (as long as it is capable of taking the weight of the cover), the covering slab should be precast concrete for reasons of durability and hygiene. Because the slab will be subjected to tensile loading under its own weight and that of users standing on it, it must be reinforced. Full details of dimensions and reinforcement of a cover slab are given in Appendix 3.

The slab can be cast in metal formwork (a 5cm deep, 130cm diameter strip of metal), on a suitable casting slab. Alternatively, if no formwork is available, it can be cast by excavating a hole of suitable depth (5cm) in firm, level ground. If this method is used, the sides of the slab will be rough and it is advisable to cast the slab with a diameter which will allow for the application of a 2cm coating of plaster after the slab had been placed on top of the well. The hole used for the precasting must be lined with plastic sheeting or cement bags prior to pouring the concrete.

Reinforcement for the slab should be properly located, spaced and tied in accordance with the specifications (see Appendix 3). As with the lining rings, the concrete should be poured in one smooth operation (using a mix of 1:2:4, with gravel size a maximum of 20mm) and the slab should be cured for 7 days. When casting the slab, allowance must

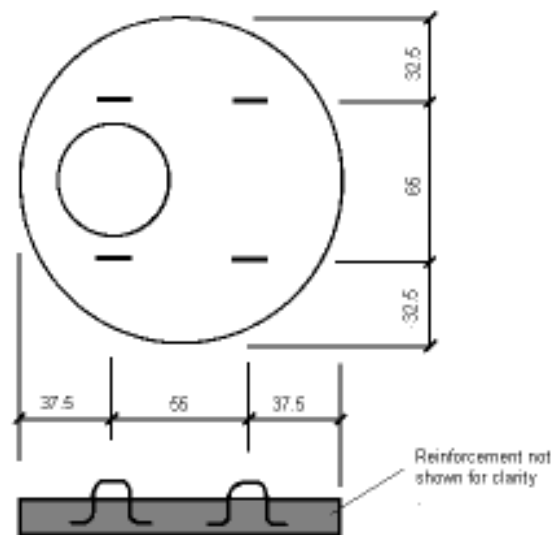


Figure 11-6 - Lifting rings in a cover slab

be made for the installation of the water lifting device (normally a handpump) and an inspection cover. Transport of the slab can be facilitated by the casting-in of 4 lifting rings, as shown in Figure 11.6. The location of the lifting rings will be dictated by the layout of the inspection cover and the handpump. Alternatively, the slab may be rolled carefully to its destination.

For the handpump, a PVC sleeve may be placed to create a cylindrical opening in the slab to allow the pipes to pass through. If it is available at the time, the holding-down assembly for the handpump may be cast directly into the cover slab.

In certain cases, due to abandonment or for health and safety reasons, it may be necessary to put a complete cover on a well which is no longer in use. In this instance, the cover is cast without allowing for these installations. Otherwise, it may be an option just to fill in the well with soil.

11.4.2 Inspection cover

As the name implies, the inspection cover allows access to check the situation down the well, for example if the pump rising main has become loose, if the well seems to have dried up or if there is a suspicion of serious contamination seeping into the well. In addition, in an emergency situation where the handpump is out of order and the repair will take a long time, the inspection cover can facilitate water lifting using buckets, though this system can be quite unhygienic.

The inspection cover should be made in such a way as to allow easy access when necessary but to also discourage frequent unnecessary opening. The cover can be made of concrete and kept in position using mortar, or it can be made of steel and kept secure using a padlock, the key to which is kept by a member of the community. Details of a concrete inspection cover are given in [Appendix 3](#).

11.4.3 Bottom slabs

In a situation where excavation to a safe depth has failed to pass through the aquifer to an impermeable stratum, and where the conditions in the aquifer are causing an influx of sand through the exposed bottom of the well (see [Section 5.2.4](#)), slabs as shown in Figure 11.7 may be placed to prevent this while allowing water to filter in. The slab is cast in two semi-circular halves (yielding a full slab with a diameter of 1.1m), using “no-fines” concrete, as in the filter rings, in the centre of each half. As with the cover slab, the bottom slabs may be cast in metal formwork or in a suitable excavation in solid ground.

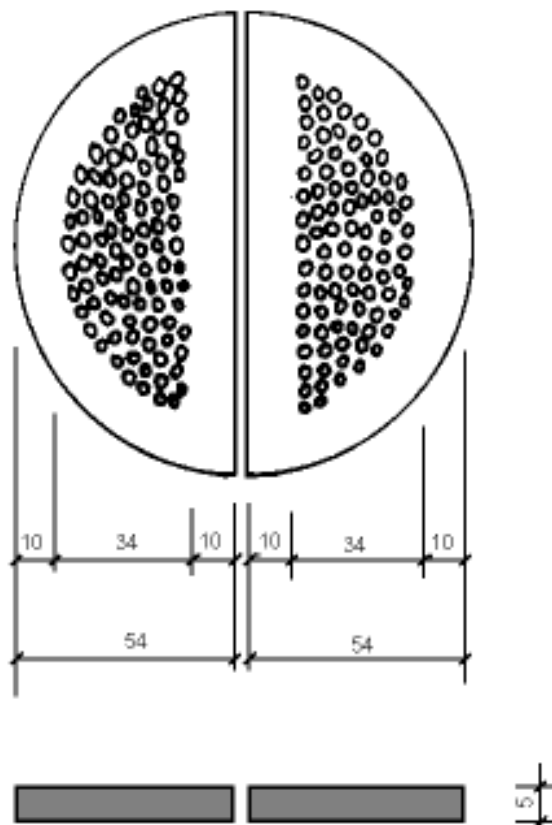


Figure 11-7 - Bottom slabs

12. Common problems

12.1 Introduction

This chapter details some common problems encountered in the construction of hand-dug wells.

12.2 Excavation in loose soils

Unlike firm soils, where the sides of a pit will more or less retain their shape during excavation, loose soils may assume an angle of repose of 30° or less. In such a situation, the construction of a hand-dug well would involve an enormous amount of extra excavation. Local experience and/or a site investigation should show whether a hand-drilled borehole or a tube well would be a better option. If this is not the case, and it is decided to go ahead with a hand-dug well, the use of a cast in-situ lining will not be feasible.

The first excavation is done only to the depth of one lining ring, and the cutting ring is then placed in the hole (Figure 12.1). Excavation continues, with extra rings being placed at the top as the column of rings drops down the well under the force of its own weight.

A dangerous situation can arise when the wet soil is so loose that the imposition of an extra load on it causes it to become “quick”. If the well is being pumped dry to allow excavation, the difference in water level between the inside and the outside of the rings will cause water, sometimes carrying sand, to flow quickly in under the bottom of the cutting ring. The sand can infiltrate so quickly that excavation is pointless and the rings will settle no further. Even placing further rings on top to increase the weight will not resolve this problem. Careful consideration of the test borehole results and profiles is necessary before committing resources to what could become an expensive failure.

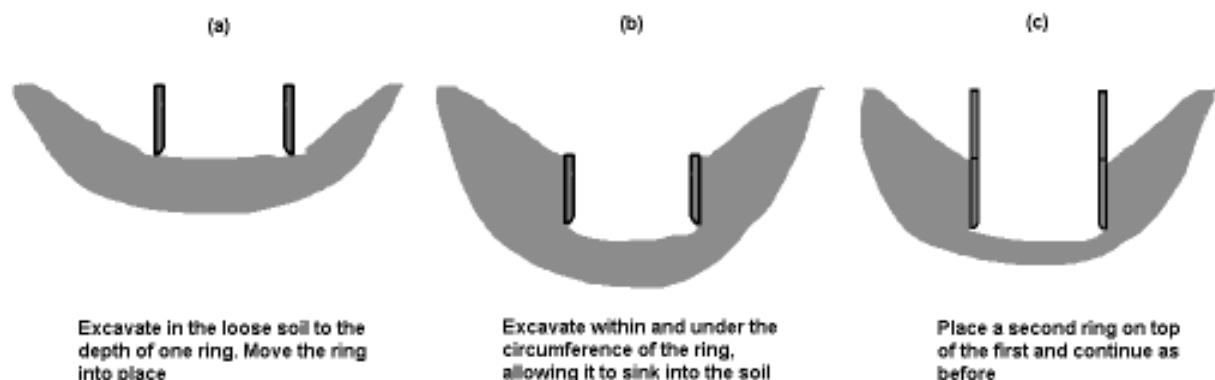


Figure 12-1 - Excavating in Loose Soils

12.3 Loss of vertical alignment

If the material being excavated is composed of different inclined layers, there may be some differential settlement of the lining rings, leading to a loss of vertical alignment. In this case, as shown in Figure 12.2, the mis-alignment is compensated for by excavating first under the lower side of the rings, and secondly under the higher side. Needless to say, this must be done very slowly and very carefully. The dangers and problems involved in the resolution of such a situation are such that strict attention should be paid to the regular and frequent monitoring of vertical alignment throughout the excavation phase, in order to avoid the need for dangerous remedial measures.

12.4 Arrested descent of lining rings

In certain soils, usually unconsolidated, it can happen that the column of lining rings will not descend under its own weight. While taking care not to precipitate a “quick” situation as described in the previous section, there are a number of options:

- increase the weight of the column by adding one or two rings at the top;
- lubricate the soil in contact with the rings already in place by pouring water down between the pit wall and the rings;
- as a final option, it may be possible to continue the excavation using the smaller diameter telescoping extension rings.

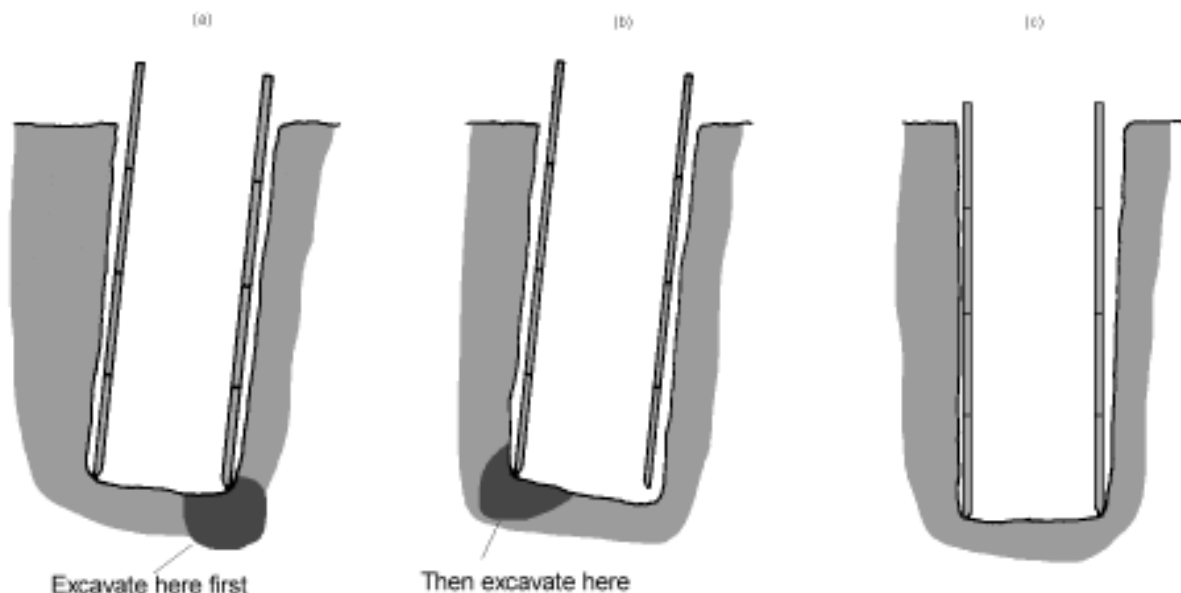


Figure 12-2 - Correcting Loss of Vertical Alignment
(angle of mis-alignment exaggerated)

13. Low-yield wells

13.1 New wells

In a situation where the only option for water supply open to a community is a very weak or very thin aquifer, the volume of water captured can be increased by increasing the area of aquifer exposed. Sometimes, the use of a large diameter well such as those described in the foregoing chapters is not sufficient, and other methods have to be used. In the case of a new well where the top of the aquifer is at least 2m below ground level, the desired increase in yield can be achieved by creating a large catchment filter in the aquifer. Since this involves

digging down from the surface, it is not suitable for a situation where the aquifer is very deep, as this would involve a tremendous amount of excavation. However, consideration of the danger of contamination demands that the aquifer must be at least 2m below ground level.

The catchment filter, made up of suitable gravel aggregate (minimum 40mm) should be placed to take advantage of the natural flow of water in the aquifer, as shown in Figure 13.1. It should coincide exactly with the aquifer, and should be sealed on top with a 3cm layer of concrete.

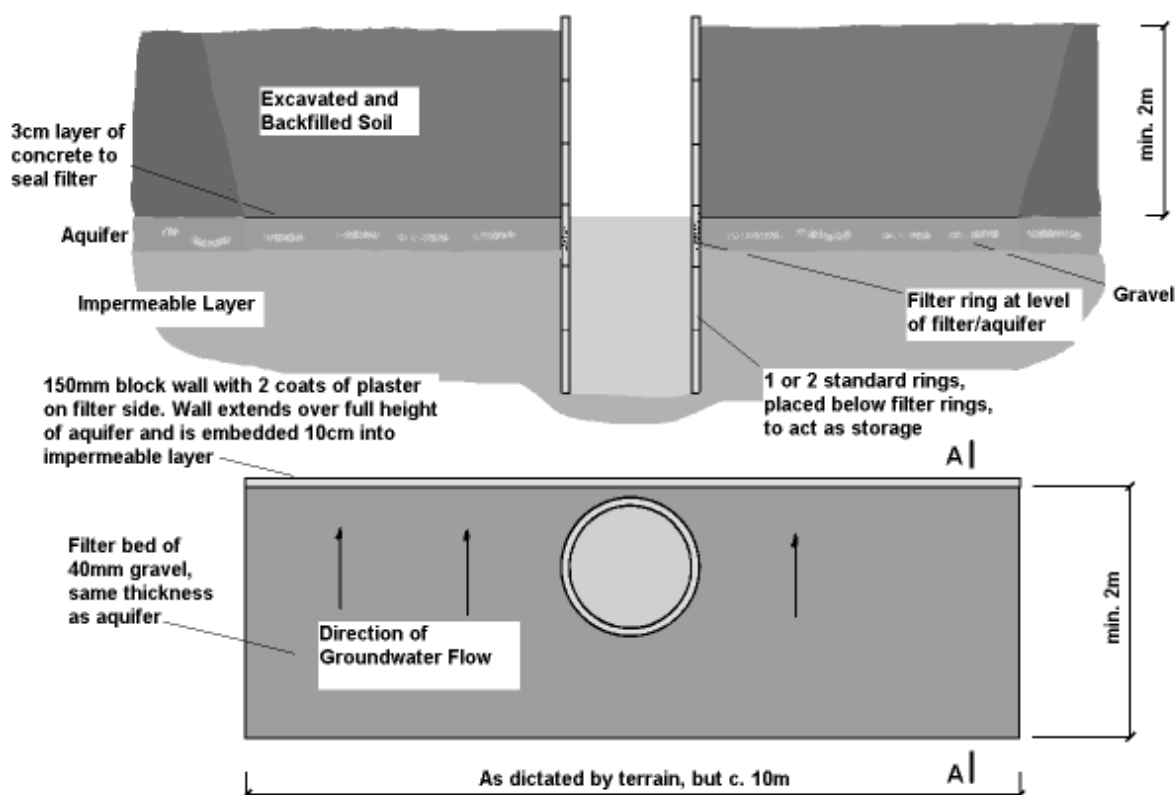


Figure 13-1 - Improving the Yield of a New Well (see also Fig. 13-2)

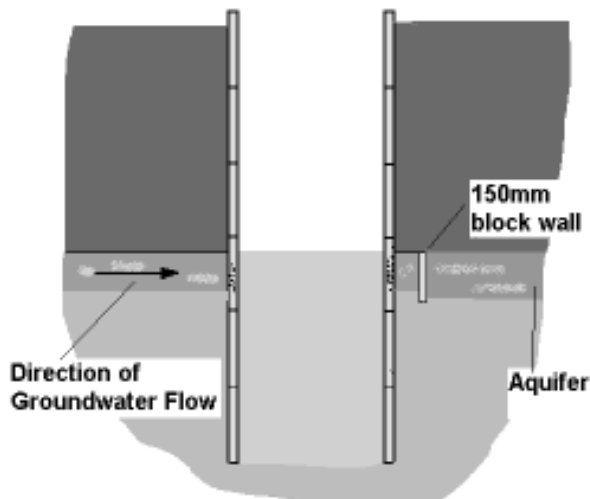


Figure 13-2 - Section A-A from Figure 13-1

A filter ring is positioned at the level of the aquifer, with at least one, and preferably two, standard lining rings underneath it, in the impermeable layer, to serve as a reservoir. Care must be taken during excavation not to dig through the bottom of impermeable layer, a situation which could allow the stored water to drain away. Consideration should be given to sealing the bottom of the reservoir if such a situation is feared.

It is clear that this option involves a much greater amount of work than the normal hand-dug well construction. In addition, there is the ever-present danger that the aquifer will “escape”, as can happen with normal spring catchments. As a result, the option cannot guarantee a long-term supply of water. Before committing resources to this type of construction, it must be clear that the community has no other option.

13.2 Improving the yield of existing wells

13.2.1 Introduction

When the yield of an existing well drops, or ceases altogether, there may be a number of options for continuing to use the same waterpoint. The particular option to be chosen will depend on whether the problem of the reduced yield is a consequence of a lowering of the level of the water table or a decrease in the yield of the aquifer. In one instance, the intake of the well must be extended to a greater depth, while in the other the exposed area of the aquifer must be increased in a horizontal direction.

Before any work is done, it is essential to do a trial borehole, either through the bottom of the well or immediately beside it, with the former being clearly the better option. The trial borehole and yield test are conducted in exactly the same manner as described in [Section 6.2.2](#).

13.2.2 Horizontal extension of well

Two common methods are shown in the diagrams below, involving the construction of tunnels or the insertion of perforated pipes through the walls of the well. Of the two methods, the former is the more difficult and potentially more dangerous.

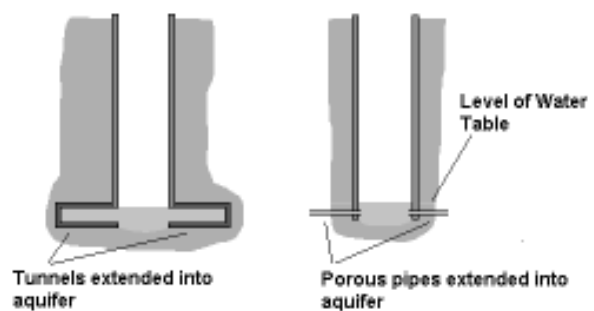


Figure 13-3 - Horizontal extension of Hand-dug Well

13.2.3 Vertical extension of well

In this case, there are two possibilities. If the trial borehole indicates a suitable yield, in either the existing or a lower aquifer, the best option is to manually drill a borehole through the bottom of the well. This method is not suitable for wells fitted with buckets or other non-pumping systems since, unless the aquifer into which the borehole is drilled is artesian in nature, the level of water in the well will not increase. If the well has been fitted with a handpump, the pump is simply re-installed with the foot-valve at a lower depth.

In most cases, since hand-dug wells exploit unconfined aquifers, the best option will be to use telescoping rings as illustrated in [Section 11.3.5](#) (see [Figure 13.4](#) below). It is not viable simply to continue excavating under the existing cutting ring and place new rings on top, since surrounding soil will have settled firmly against the existing rings, and the topmost of the rings is bonded to the superstructure. Also, the configuration of solid and filter rings might not suit the new aquifer to be exposed in the deepened part of the well.

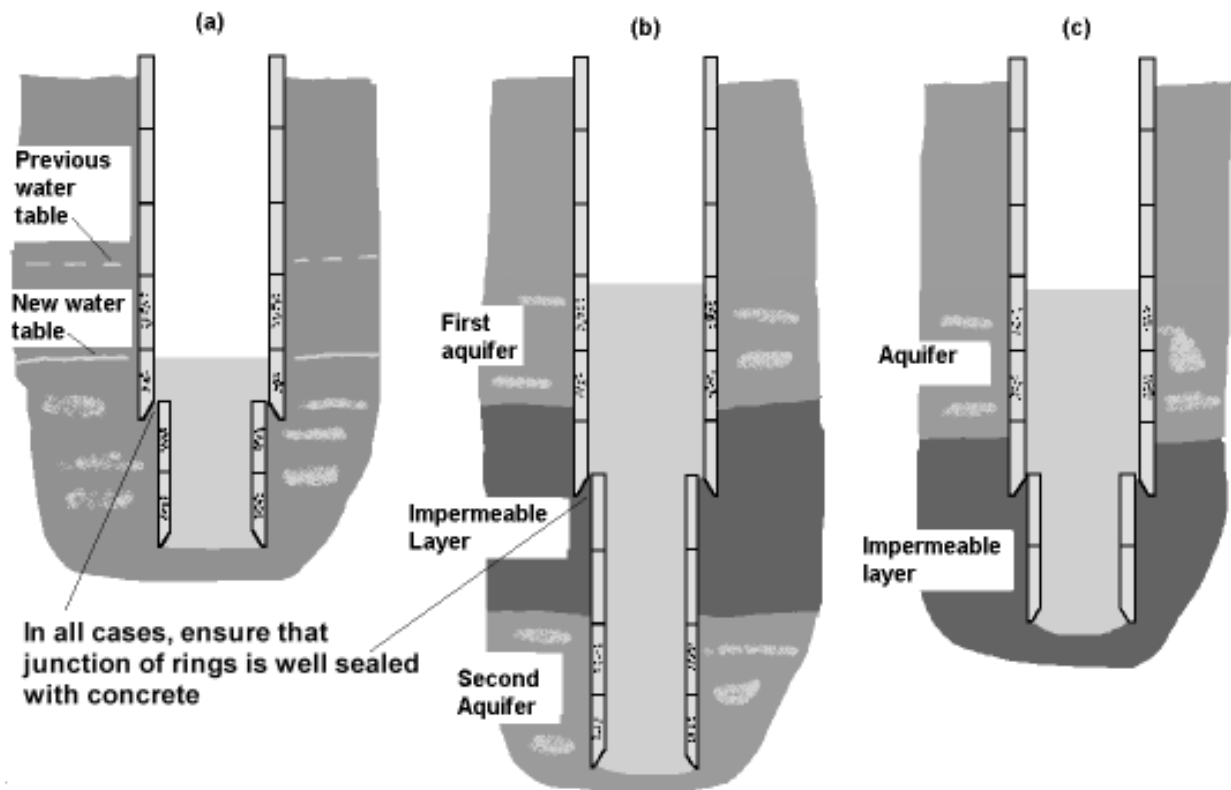


Figure 13-4 - Extending a Well using Telescoping Rings

As the figure shows, there are three situations in which telescoping extension rings may be employed. In (a), the well was constructed in an existing aquifer, and construction was halted before reaching an impermeable layer. Later, the water table dropped, making the yield of the well unsatisfactory. A trial borehole done at the bottom of the well during the dry season showed a continuation of the aquifer, so two extension rings were placed in the well.

In (b), the original well reached an impermeable layer and construction was halted. When the yield dropped, a further survey showed the presence of a second aquifer below the impermeable stratum, so the well was extended to exploit it. Note that the water level in this case will depend on whether or not there is water in the first aquifer.

In case (c), a second survey did not show the presence of further aquifers, so two standard (non-filtering) extension rings were introduced in order to increase the storage capacity of the well. This is a useful option when water collection is concentrated at certain peak times during the day.

The excavation and construction techniques will be similar to those indicated for a normal well. In all cases, it is advisable that there be a degree of overlap between the original rings and the extension rings and that any gap between the rings be properly sealed with concrete, in order to prevent the infiltration of material into the well.

14.

Management, operation and maintenance

14.1 Introduction

The completion of a hand-dug well, and the consequent supply of water to the community, is the end only of the construction phase. The most important phase in the life of the system is just beginning. Experience with capital-intensive, supply-driven programmes has shown the need to pay due attention to preparations for the management, operation and maintenance of the completed system. If this need is not recognised and addressed, the chances are that further capital investment, in the form of major repairs or rehabilitation, or even the construction of a new system, will be necessary before long. The operation, maintenance and management of a water supply may be centralised or decentralised, or any mixture of the two options, depending on the particular situation, but it would be foolish to neglect, when planning these activities, the tremendous resource available in the community itself. It has been stressed throughout this manual that one of the key aspects in the long-term sustainability of any water supply system is the full and enthusiastic involvement of the community in all phases (including operation, maintenance and management) of the water supply process. In institutional terms, this is only logical, since most water authorities or water supply organisations in the developing world have, at best, sufficient resources only for the planning and construction phases. But an increase in construction activities implies an increase in the need for management of completed systems and it is here that the community has the most vital role to play.

In many cases, the community will not be able to fulfil its role in the management of a system without adequate prior training. This must be given in both the technical and management spheres, and clearly one must complement the other and both must be specific to the situation in hand. Neither is this training an activity which can be undertaken in the final days of a construction phase. During the planning process, once the proposals and decisions have been made about the type of technology to be

implemented and the related management plan, key persons in the community must be identified who will be responsible for various aspects of the management of the system.

At least two people in the community must be capable of maintaining the handpump or other water lifting device. The pump should be introduced to the community as early as possible in the process and training initiated. Appropriate tools must be provided, and the installation of the pump provides an ideal opportunity for a final maintenance class. The community will also require some person with the capacity to do minor structural repairs. In most communities, finding such a person is not a problem, and the training is more concerned with identification of the need to repair, and the value of preventive maintenance, than with imparting specific working skills. It is an advantage if the person to be responsible for future structural repairs works directly with the technical team during the main construction phase.

The financing of the activities referred to in the previous paragraph is quite open to whatever institutional set-up applies in a particular case. The work may be done voluntarily by members of the community; the person responsible for maintenance and management may be a water vendor who signs a contract for the franchise on a given well; maintenance work may be done by a private individual who then invoices the work to the village. If the community is required to pay for water, in order to create a fund for maintenance, or in a water-vending system, rules must be laid down about the level of payment, conditions for exemption, penalties for non-payment, etc. It was already pointed out in Chapter 2 that a comprehensive water policy can smooth out the definition and introduction of such practices, but the capacity must also be in place to bring these ideas to the villagers and to impart them in a way that ensures a full understanding and acceptance, and which develops in the community the capacity to manage the new system.

A further advantage of community involvement in the management of a water supply system, from the point of view of the water authority, is the availability of a ready-made monitoring network. With the lack of resources faced by many water authorities, it is rarely possible to have an effective monitoring system in place, and the information which is vital for good planning is not always to hand at the right time. If a community is fully involved in the management of its system, small repairs are done promptly without drawing on central resources; more serious repairs are reported promptly; information about waterpoint use, static water level, frequency of handpump repair can be collected more easily. Planning and policy-making are thus done in possession of up-to-date facts.

It is necessary also to bear in mind that the management of a water supply system is interdisciplinary in nature. The physical activity of constructing a water supply may be a technical activity under the aegis of the water authority, but this should not be allowed to overshadow the importance of health, hygiene, sanitation and education in the whole process.

14.2 Hygiene and health considerations

The link between health, hygiene and water supply was already introduced in Chapter 2. In addition to being stressed during the planning phase of the water supply process, the creation of an awareness of this link must be a long-term priority in the management of the system. The management of the health and hygiene aspect of the waterpoint must always be to the fore. It is important to put these considerations in the overall context of general hygiene habits, water collection and use practices. While keeping a clean waterpoint will not in itself yield an automatic improvement in the health of the users, it will at least eliminate one possibility where sources of infection are concerned. Eliminating others will involve broader education in the areas of health, hygiene and sanitation. The following points relate specifically to safe and hygienic activities at the waterpoint.

1. Upon completion, the water in the well should be disinfected, as described in Section 10.2. This is normally done by the addition of chlorine in

proportion to the volume of water in the well. At regular intervals, and particularly if the well has recharged after lying dry for some time, the water should be checked and disinfected if necessary.

2. If properly located, the guidelines for the position of the well, as given in [Section 6.3](#), will have been followed. Care must be taken, after completion, that no new activities take place in the area of the well which could lead to contamination. The existence of new contamination risks for the well can be detected by carrying out regular sanitary surveys.
3. As already mentioned in [Section 10.4](#), fencing should be put in place to keep animals away from the well. This should be regularly maintained.
4. The area around the well should be kept clean of dirt, debris and stagnant water.
5. In the case of an open well, the container and rope being lowered into the well (there should only be one) should be checked regularly for cleanliness. Nobody should be allowed to stand on the headwall. This can be managed by ensuring that the headwall is too narrow to allow it.

14.3 Structural maintenance

The following points will need attention from time to time in the life of a well.

1. Cracks in the apron

Even seemingly harmless surface cracks in the apron should be dealt with as quickly as possible, to lessen the dangers of allowing dirty water from the surface to infiltrate back into the well. In repairing a crack, it is not enough merely to fill in the gap in the surface. Any loose concrete must be chipped away, and the crack thoroughly cleaned before it is filled with concrete in a 1:3 (cement:sand) mix.

Care must be taken in analysing the source of a crack. If it is due to normal wear and tear on the apron, the type of repair outlined above will suffice. However, the appearance of a crack may also be due to differential settlement in the underlying soil (if, for example, the apron was constructed without allowing enough time for the

soil disturbed by the construction process to settle once more) or to erosion and undercutting of the apron. In these cases, the problem is more serious, and a complete reconstruction of the apron may have to be considered.

2. Security of inspection cover

Whatever the material of which it is made, the inspection cover must be kept in place at all times during the normal use of the well. This is important from the point of view of hygiene and also in situations where water vending is practised. Metal inspection covers must be painted in lead-free paint and regularly inspected to ensure that they are not rusting and contributing to the contamination of the well. If the inspection cover is made of concrete, the mortar which keeps it in place must be checked regularly, and any cracks repaired as soon as possible. A covered well which loses its inspection cover contributes very little of use to the health profile of a community.

3. Improving the yield of a well

This may involve deepening the well or extending it horizontally, as described in [Section 13.2](#).

4. Infiltration of sand

If the excavation of the well concluded without reaching an impermeable layer, there is the danger of the well filling up with sand from the bottom. This can be treated by placing the bottom slabs already mentioned. Refer to [Section 5.2.4](#).

5. Collapse of the well

One instance in which collapse of a well may occur is in an area where ground conditions are hostile to concrete (for example, in soils with a low pH or excessive carbon dioxide). If this is known at the construction stage, the lining rings may be made using sulphate-resisting cement, but this may not always be readily available. When a collapse of this nature occurs, it can be because the aggressive element in the soil has broken down the weakest part of the shaft, namely the filter rings. This can be avoided by casting in holes to an otherwise solid ring and

not using the filter layer. These holes then fulfil the function of the filtering layer. Wire mesh may be fixed across the opening to stop the hole becoming clogged up.

6. Measures against erosion

As with cracks in the apron, this is often a situation which is not treated until it is too late. Heavy rains can produce fast-flowing flood waters which can quickly promote erosion when passing around the well apron, often undercutting the foundations. Care should be taken in the siting of the well and the area surrounding the apron should be checked frequently to ensure that flood waters can be rapidly dispersed without threatening the integrity of the apron. The apron should have deep foundations and should not protrude too much above the surrounding ground and act as a dam when heavy rains fall. Earth packed in around the apron should slope gently away from the well, and the soil in this area should be checked regularly during the rainy season.

14.4 Maintenance of water-lifting devices

This subject deserves consideration at all stages of the water supply process and must be considered against a range of factors such as the cost and availability of spare parts, the management capacity in the community and the frequency of routine maintenance. The matter is treated in more detail in the manual in Volume 7 in this series of Manuals.

Appendix 1

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¹ References 13-16 are publications from the work of the Operation and Maintenance Working Group of the WHO Water Supply and sanitation Collaborative Council. Also available, for example, are a Resource training package and a guide linking technology choice with operation and maintenance.

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Appendix 2.
Forms for use in Trial Borehole and Yield
Test

Trial Borehole Log

Village name		Borehole Location (Co-ordinates)		Longitude		Latitude								
		Borehole Location (Descriptive)												
Date Started	Date Finished	Borehole No.												
Borehole Record														
Depth (m)	Material Encountered		Consistency	Other Material Present	Water Content				Drilling Speed				Tool/Bit Used	
	Major Part	Colour			Gradation	1	2	3	4	1	2	3		4
0-0.5														
0.5-1.0														
1.0-1.5														
1.5-2.0														
2.0-2.5														
2.5-3.0														
3.0-3.5														
3.5-4.0														
4.0-4.5														
4.5-5.0														
5.0-5.5														
5.5-6.0														
6.0-6.5														
6.5-7.0														
7.0-7.5														
7.5-8.0														
8.0-8.5														
8.5-9.0														
9.0-9.5														
9.5-10.0														
Water found	Yes	No	Depth of Aquifer		m	Thickness of Aquifer		m						
Sample taken	Yes	No	Yield Test		Yes	No								
Borehole done by			Date		Checked by		Date							

Abbreviations to be used with Borehole Log Form

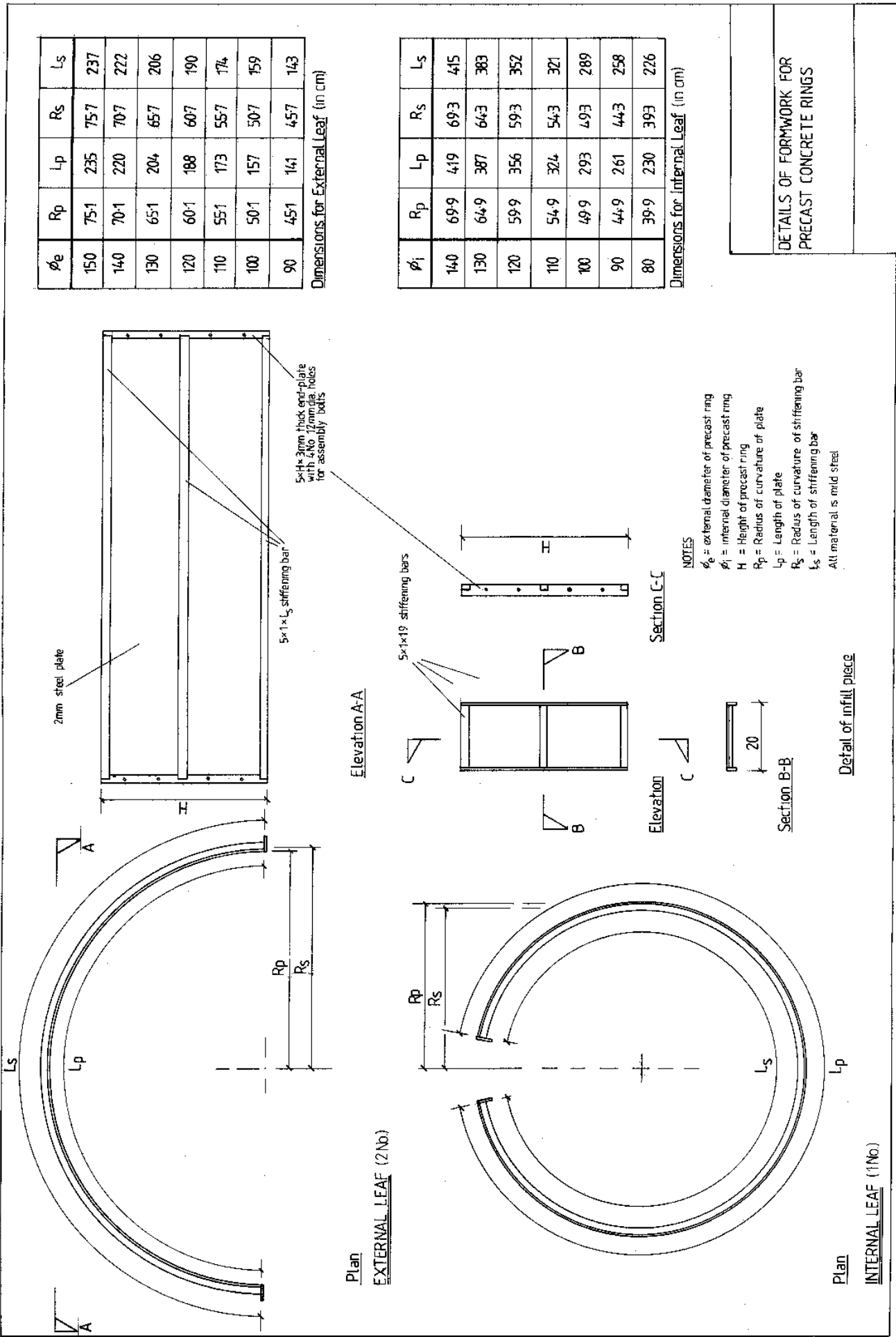
Major Part		Consistency	
clay	cl	soft	sft
loam	lm	loose	ls
sand	sd	dense	ds
gravel	gr	hard	hd
stones	st	weathered	wed
sandstone	sd.st		
laterite	lat		
calcrete	cal		
granite	grt		
Colour		Minor Parts	
black	blk	as major parts, with:	
blue	bl	few	few
brown	br	very	ve
green	grn	layers	ls
grey	gr		
red	rd		
white	wt		
yellow	ye		
Gradation		Water Content	
fine	fn	dry	1
medium coarse	md.cs	moist	2
coarse	cs	wet	3
		saturated	4
		Drilling Speed	
		slow	1
		moderate	2
		quick	3
		bumping	4

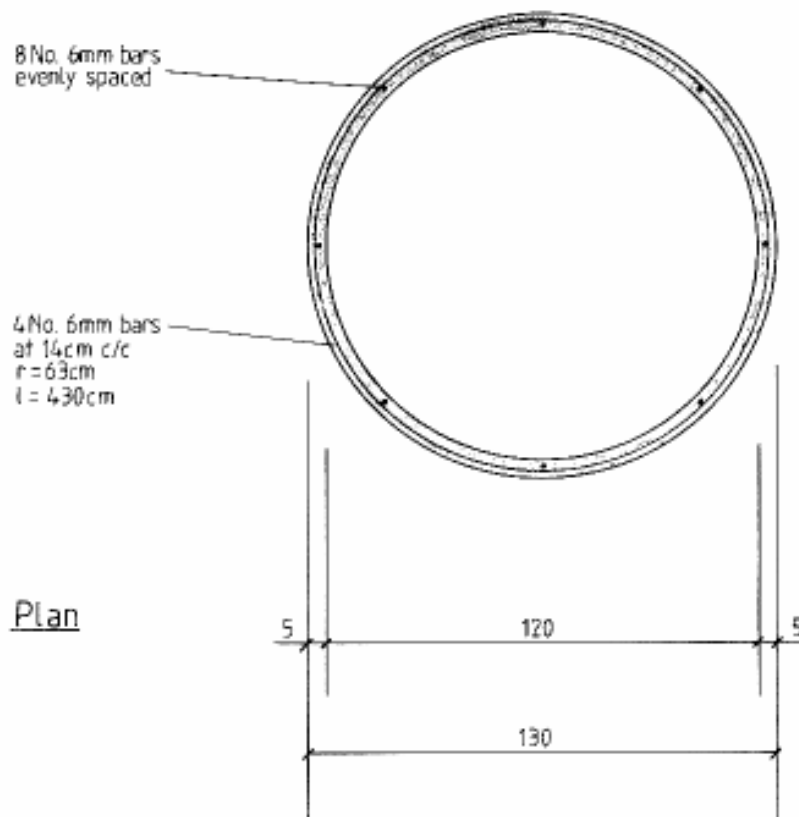
Form for Borehole Yield Test

Village Name	Borehole No. (as on Borehole Log Sheet)		
Date	Bucket volume		litres
Water level before test	m	Test start time (t0)	
Pump level for test	m	Test finish time (t60)	
Part 1 - Test Pumping			
Time	No. of Buckets	Water Level (m)	Remarks
t0			
t10			
t20			
t30			
t40			
t50			
t60			
Part 2 - Recharge Measurement			
Time	Water Level (m)	Remarks	
t61			
t62			
t63			
t64			
t65			
t70			
t75			
t80			
t90			
Test done by		Date	
Checked by		Date	

Appendix 3.

Drawings for Concrete Components

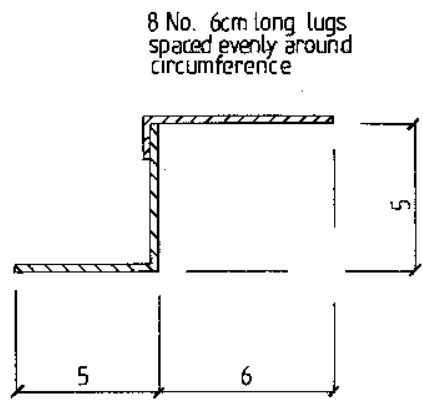
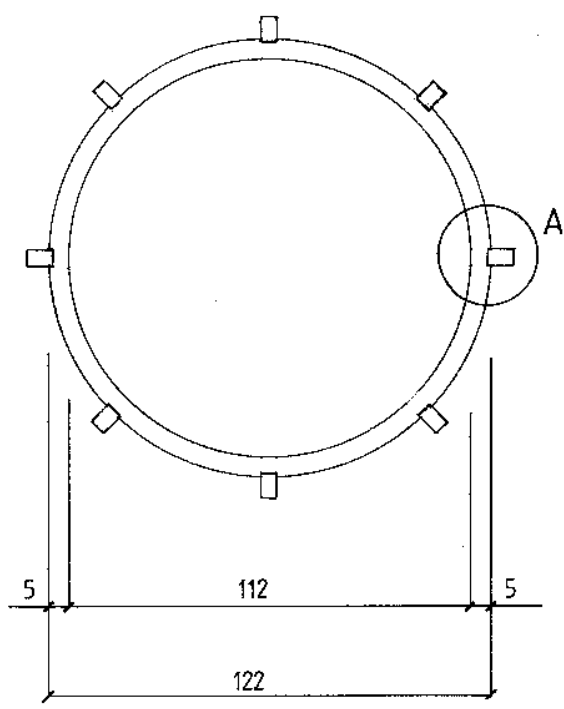




Section

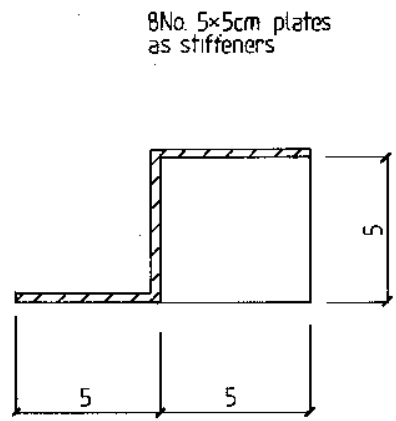
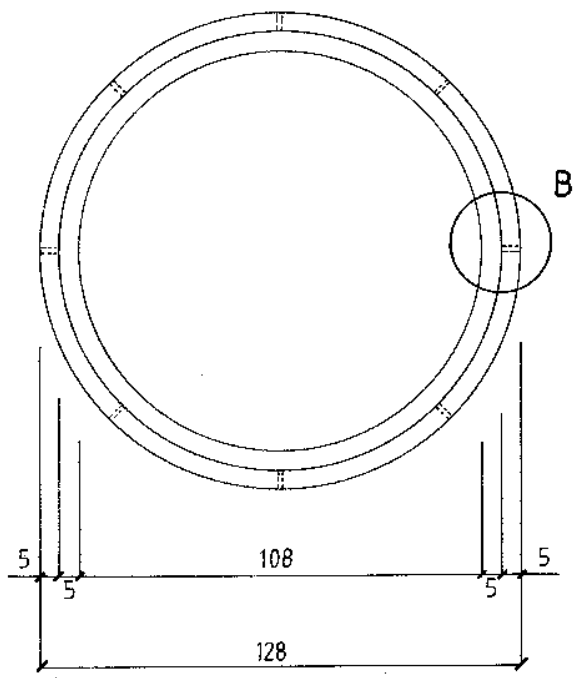
Scale 1:20

PRECAST REINFORCED CONCRETE
 LINING RING



Detail 'A'

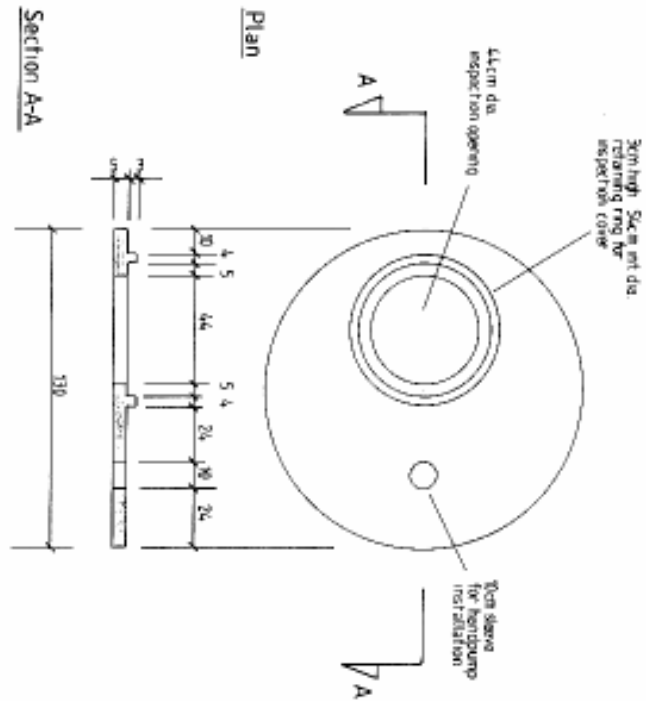
TOP RING
Plan
Scale 1:20



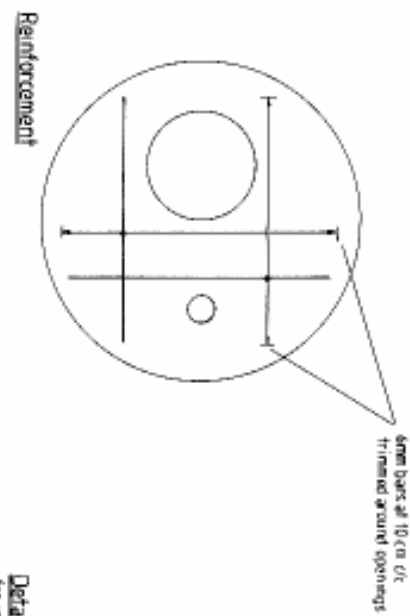
Detail 'B'

BOTTOM RING
Plan
Scale 1:20

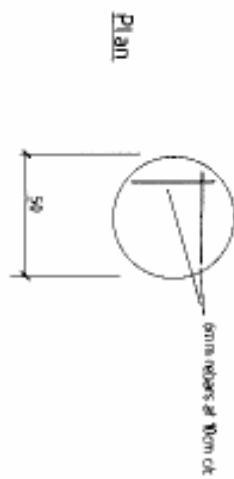
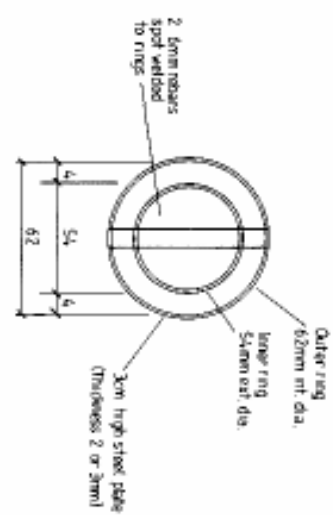
STEEL RINGS FOR REBATES



COVER SLAB DETAILS
Scale 1:20

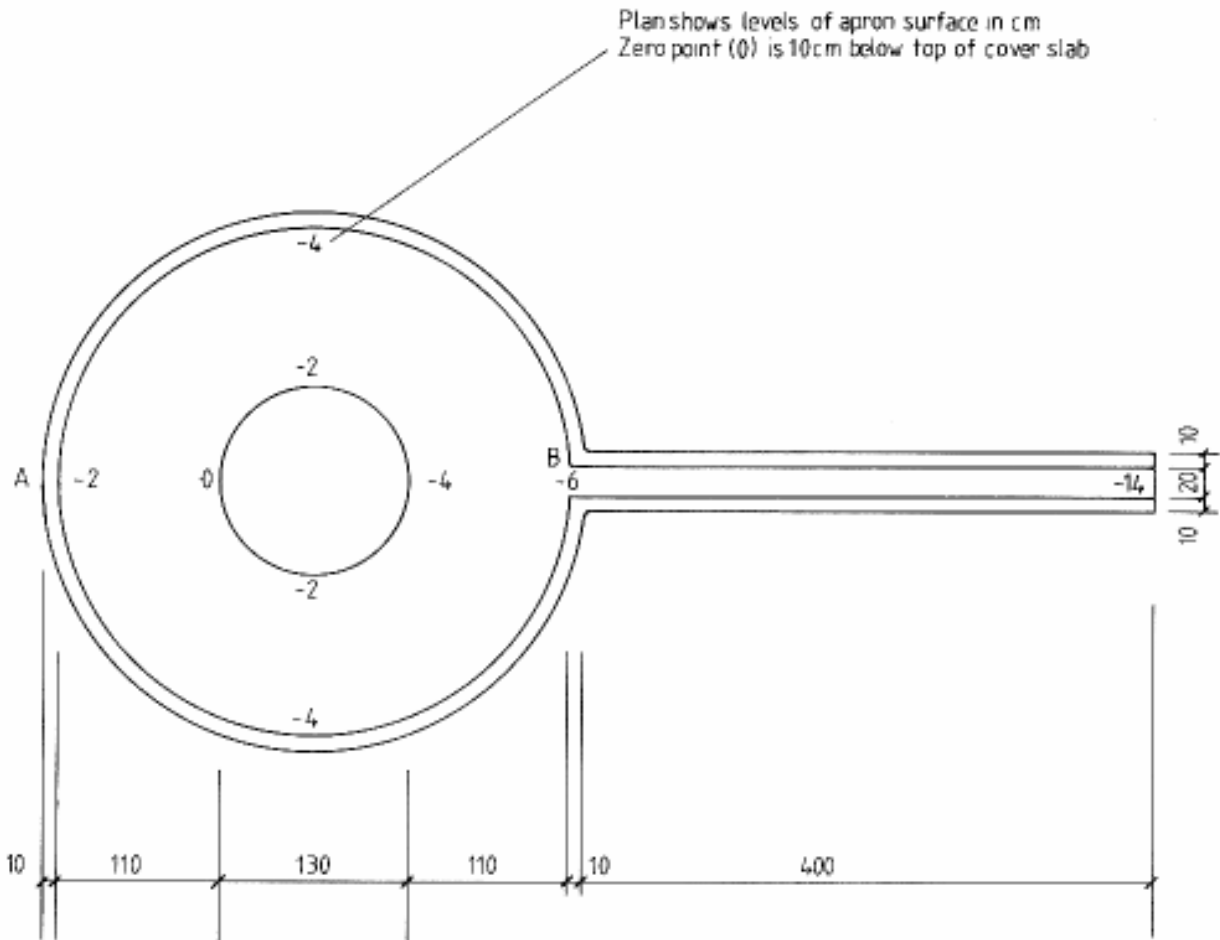


Detail of steel mould
for inspection cover retaining ring



INSPECTION COVER DETAILS
Scale 1:20

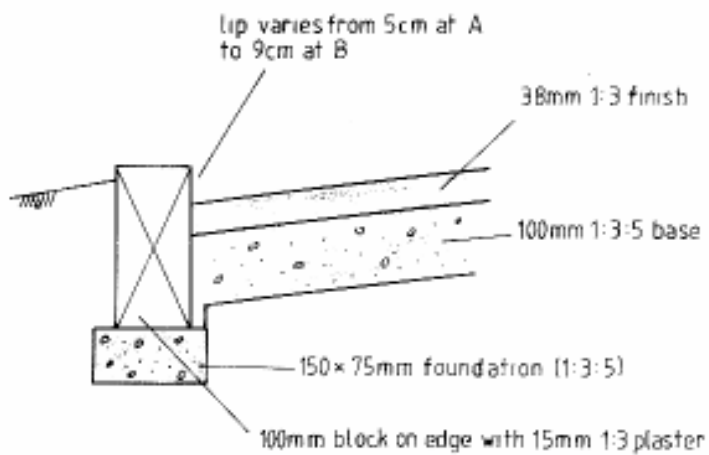
DETAILS OF PRECAST R.C.
COVER SLAB



Plan



Section



Edge Detail

TYPICAL APRON DETAILS

SERIES OF MANUALS ON DRINKING WATER SUPPLY

VOLUME	1	Management Guide
VOLUME	2	Engineering
VOLUME	3	Building Construction
VOLUME	4	Spring Catchment
VOLUME	5	Hand-dug Shallow Wells
VOLUME	6	Drilled Wells
VOLUME	7	Water Lifting

What you should know about this series of manuals:

It is a guide for	project managers, engineers and technicians
	but is also useful for all other actors in the sector
with a focus on	community based managed systems (predominantly in rural areas)
	water supply
	technologies
with an emphasis on	a balanced strategy including technical, social, institutional, economic and regulatory aspects for the
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providing options for	management
	strategies and approaches
providing linkages to	sanitation and health
limited to	experience in Swiss-supported projects, taking account of new developments
does not cover	sanitation
	drainage
	solid waste management
Volumes 2 to 7	should be used in conjunction with Volume 1