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Site identification and selection

IN THIS CHAPTER:

- The requirements for sand-abstraction. The conditions and situations in a river where sand-abstraction can be practiced
- Site selection – significance of the river catchment area; volume and velocity of flow; river profile, depth, width and length of sediment beds; ideal abstraction points in the river channel; the likelihood of damage to abstraction equipment.
- Sediment analysis – water storage potential, water yield potential.

Selection of a suitable river

Provided there has been some flow within the channel, water will always be retained to some degree in the sediment of a sand river each year. As not all sand rivers have the capacity to retain water all year round, it is necessary to identify those riverbeds that are suitable for sand-abstraction and to select optimum abstraction sites.

Primary factors in the identification of a suitable site:

- **Extent of the river catchment area.** Water flow in a river channel that drains a small catchment area is unlikely to be sufficient to recharge a riverbed aquifer to provide a year-round water supply. Although the river sediment itself may be fully recharged, unless the riverbank and riverbed are also recharged, water loss by infiltration to lower levels from the river channel may quickly deplete the reserve. Variations in annual rainfall within the catchment also have an effect on the recharge to the aquifer. An ideal catchment area is one where immediate runoff is impeded so that over time there is a slow, continuous recharge into the river channel.

- **Size of the river and volume of sediment.** It is necessary for a river channel to be wide enough and deep enough to contain sufficient sediment to retain water all year round. The length of sediment beds between obstructions in the river is also important. If too short and the aquifer too small, the water resource will be over-abstracted or will drain too quickly for a continuous supply. However, where there is an insufficient natural deposit, it is sometimes possible to increase the volume of sediment through the construction of a sand-dam.
- **Gradient of the river.** The velocity of flow through a river channel is important; if it is too fast, as is the case in headwaters, sediment will not be deposited or will be transported through the channel with a depth of disturbance sufficient to damage or dislodge abstraction equipment. As a general rule, where the slope of the riverbed is greater than 1 in 100, not only will there be an insufficient depth of sediment, but water will be lost to rapid drainage through the channel. Where the velocity of flow is exceptionally slow, sediment that is too fine for satisfactory sand-abstraction will be deposited.
- **Characteristics of the sediment.** The water storage potential of a possible abstraction site can be assessed through a number of observations and tests.
 - Fine sediment indicates an aquifer with a small total void space, which in turn provides limited water storage potential.
 - Well-sorted sediment that is primarily comprised of coarse grains with little silt will indicate a site with a suitable water storage potential. Water will flow quickly through sediment that has little ‘fines’ to the point of abstraction. Cementation — a process where the pores between grains of sediment become in-filled with smaller and smaller grains — indicates a low water storage potential and poor permeability.
 - Sediment that is friable or ‘loose’ with little cementation, where the packing is natural and not unduly compressed or compacted will have a large percentage void space available for water storage.

Photograph 3.1 shows a stable sand river where the gradient is low and the sediment is in equilibrium. Such a river can be expected to have a large water storage capacity and is suitable for water abstraction through well-points as explained in Chapter 4.

Photograph 3.2 shows an unstable river where the flow is fast and turbulent. When in flow, this river transports large material as can be seen from the number of boulders and cobbles.

Photograph 3.1. Maitengwe River, Matabeleland South, Zimbabwe



Photograph 3.2. Utete River, Mashonaland West, Zimbabwe



Photograph 3.3 shows a small sand river with a limited water storage capacity. Such a small stream may not provide a perennial supply of water.

Physical characteristics of a river

Selection of a suitable site

An ideal site for the installation of a sand-abstraction system is in coarse sediment in a former river pool or on the outside of a river bend in deep sediment in a slow moving river. A suitable site will require identification through surveys of the topography of the river channel. This will require definition of stages of the river channel and points of identification in the river where there is deep sediment or sediment-filled depressions.

To ensure a successful installation:

Identify a site where there is sufficient depth and volume of sediment to maintain a year-round water supply and where the abstraction equipment will not be disturbed by the river flow.

Photograph 3.3. Mahuwe River, Mashonaland West, Zimbabwe



Practical site assessment

- Observe the course of the river and where sediment is retained — sediment will be deeper on the outside of a bend, against the steeper bank in the course of the river or behind a dyke or outcrop of rock on the riverbed.
- Determine the extent of the sediment bed, its width and length. Probe the sediment to determine the greatest depth of sediment. A deep sediment bed indicates a useable reserve of water that is less likely to dry out. The more extensive the sediment bed the greater the volume of water.
- Observe the gradient — the slope of the river sediment surface. A low, gentle slope will indicate a useable length of sandbed with a flow rate through the river channel sufficiently low to prevent damage or wash away of any equipment in the riverbed or on the riverbank.
- Observe and carry out appropriate tests to determine the nature of the sediment. Coarse grained sediment will indicate the possibility of a large storage capacity, fine sediment will indicate a reduced storage and abstraction potential.

REMEMBER

A small river generally indicates a small water supply.

Table 3.1 provides a rough assessment of the suitability of a river for sand-abstraction.

Riverbed profiles

Typically, a sand river is not a continuous length of silted river that is even in its depth or length, but is comprised of a series of sections or reaches of river between obstructions such as rock bars or sub-surface sills or dykes. These break up the river channel into water yielding sections or compartments. Within these reaches there are likely to be natural depressions and undulations that create shallow and deep sections in both the length and width of the river channel. Such conditions occur particularly in the slower flowing and wider reaches of a sand river where there is likely to be a greater potential for sand-abstraction. Deeper sections tend to coincide with the main course of river flow that invariably meanders even within the river channel, particularly when the river flow is not excessive. Identification of deeper sections of river where there will

Table 3.1. Overview of the suitability of a river for sand-abstraction	
River characteristic	Site assessment
Large wide river	Probably an ideal site can be identified.
Small, narrow river	Limited volume of sediment, therefore likelihood of limited water retention.
Straight river section – low banks	May be ideal, but may have a limited depth of sediment.
Straight river section – deep banks	Greater depth of sediment to retain water but increased likelihood of abstraction equipment being disturbed or damaged by sediment transport when the river is in flow.
Inside bend	Limited depth of sediment, therefore limited water retention. May require a long length of inlet pipe to reach a satisfactory abstraction point.
Outside bend	Greater depth of sediment but when river flows may be too fast and cause damage or disturbance to abstraction equipment.
Rocky outcrops	May help to retain sediment and thus water upstream. May increase the turbulence and velocity of river flow and thus the likelihood of damage to equipment downstream. May indicate small, disconnected alluvium beds with limited water storage potential.

be an increased volume of water is critical to a successful sand-abstraction installation, particularly in marginal areas.

There is sometimes a possibility of using a site on the inside of a river bend or alongside a river section where the riverbank is alluvial and the well-point can be installed deeper than it could be within the actual river channel. Figure 3.1 indicates preferred locations for abstraction sites within a sand river channel.

Site selection tests

Observations and tests will be required in order to identify potential sites within suitable rivers. For a satisfactory site it will be important to determine the nature of the sediment and to estimate the likelihood of a permanent supply of water. Methods through which this may be achieved are:

- **Local knowledge of the area.** Local people will generally be able to provide an accurate, if only preliminary, assessment of the water supply potential and the permanence of a prospective site.

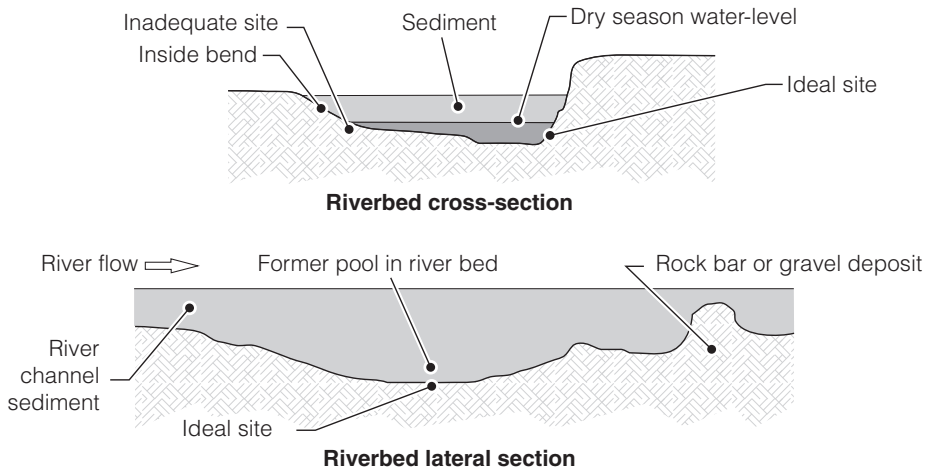


Figure 3.1. Riverbed profiles indicating preferred sites

- **An indication of the water supply potential** may be obtained by observation of riverine vegetation, which will generally be large and possibly verdant where there is a channel aquifer with a plentiful supply of water, as shown in Photograph 3.4.
- **Appraisal of existing open sand wells.** The suitability of a possible site may be gathered through the inspection of any traditional sand wells in the immediate vicinity towards the end of a dry-season. If there are useable quantities of water the scoop wells will generally be in use, but if the water-level has been depleted the wells will be merely dry, sand-filled depressions.
- **Probing the sediment depth** with a pointed steel rod as shown in Photograph 3.5, is a quick and relatively easy method of gauging whether or not water is present below the sediment surface. This can be done by noting the depth of sediment and whether or not there is moisture on the probe on removal from the sediment. By assessing the ease or difficulty required to insert the probe and by observing the particles adhering to the probe, it is also possible to gain an indication of the nature and consistency of the sediment.
- **Excavation.** If there are no existing scoop wells the level of water within the sediment at any one time may be accurately established by digging a temporary well or pit.
- **Identification of water within river sediment** could be established by the ancient practice of water-dowsing. Although it may be possible to

Photograph 3.4. Riverine vegetation indicating good water potential



Photograph 3.5. Establishing the depth of sediment with a probe



identify a source of water, however, it is unlikely that reliable data can be obtained on either the depth of sediment or the depth of water.

- **Augering.** Samples of sediment from within the aquifer may be obtained by augering to the river basement. However, the extraction of samples from saturated sediment is difficult without specialist equipment due to fluidization of the sediment.
- **Electromagnetic resistivity.** A technically advanced solution is to undertake a geophysical survey of a proposed site. This has the potential to determine both the water-level and the base of the riverbed. However, such equipment is more generally used to determine fracture zones in deep aquifers and there is the possibility of misinterpretation when attempting to establish the depth and profile of a relatively shallow riverbed. Although it is possible to establish the boundaries of differing materials it is not always possible to determine the actual material and whether or not it is the riverbed base, or merely a gravel layer caused by bedload sorting, within the river channel.

A piezometer tube installed into the riverbed through which the water-level in the river alluvium can be measured will provide a long-term record of the depth of water at any time within the sediment.

POROSITY

The amount of water that is contained within the sediment

SPECIFIC YIELD

The amount of water that can be abstracted from an aquifer —
in this case the river sediment

PERMEABILITY

The rate at which water is able to pass through sediment

VOID RATIO

The ratio of the fraction of voids to the volume of total particles
in which they occur

Systematic in-field assessment of a sand-abstraction site

A series of observations and tests may be conducted on-site for a quick assessment of a possible abstraction site. Although specialist equipment is required to provide any degree of accuracy an indication of the yield potential may be gained through quick, practical, rule-of-thumb tests using basic equipment such as a probe, a sieve and small container, a 50m and a 3m tape measure and a shovel, as shown in Photograph 3.6.

Photograph 3.6. Site assessment equipment



D. Ngwenya

1. Water resource

- *Vegetation* — Prolific and/or massive vegetation will indicate the likelihood of an extensive reservoir of water within the river channel.
- *Volume of sediment bed* — (width length breadth). Measure the width and length with a tape measure or by pacing. Assess the depth by probing with a steel rod to the base of the river channel, marking and measuring the depth of sediment. Accuracy will be increased with the number of probe readings made to provide an average depth of the aquifer.

2. Specific yield

- *Porosity* — The fineness or coarseness of sediment at the proposed site will provide an indication of the void ratio. Run a sample of sediment through the fingers onto a small plastic sheet. Coarse sediment will fall straight down, fine sediment will drop slowly and will be moved by air currents and thus tend to fall away from the main pile. An appraisal of the proportion of coarse to fine sediment will indicate the water storage potential, the finer the sediment the more likely that it will pack together to decrease the void space.
- *Packing* — The size and shape of a sample of sediment grains will provide an indication of the void ratio of the sediment and the potential for water yield. Rub a sample of sediment grains between the palms of the hands to assess the texture through a coarse or smooth feel. Observe the general size of particles, the uniformity of size and the roundness or elongation of grains. The more rounded the grains and the more uniform the size, the greater the void space will be between grains. Sharp or elongated grains indicate a likelihood that the grains will pack together to reduce the total void space.
- *Permeability* — A thorough assessment requires an in-field permeability test. A fair indication may be obtained from the:
 - Void space* — Check for fines, coarseness and sorting of sediment and for compaction and cementation of the sediment. Excavate a pit in the sediment; note the stability of the sides, the consistency of the material, the layering of sediment deposits and any orientation of sediment grains. The more stable and vertical the sides of the pit the greater the extent of fines and compaction, and consequently, the smaller the void space with reduced permeability.
 - Saturation of sediment* — Examine the nature of the sediment by digging into the water-bearing sediment. Fluidized sediment indicates a high degree of permeability. Non-fluidized sediment indicates considerable contact between the sediment grains and poor permeability.

3. Water loss from sediment

- *Coarseness of sediment* — fine sediment indicates a greater likelihood of loss through increased capillarity and subsequent evaporation.
- *River gradient* — a steep gradient indicates a greater propensity for downstream drainage than a more level riverbed.
- *Riverbed base* — An unconsolidated riverbed indicates susceptibility to seepage to the underlying water-table. A riverbed with a rock base will indicate a reduced seepage potential. A dense layer of clay on the base of the of the river channel may effectively limit seepage

4. Security of installation

- *High or low energy flows* — A fast flowing river has the potential to damage an installation during periods of peak flow. Observe the riverbed gradient, the depth of the riverbank sides and the occurrence of cobbles on the sediment surface or the sides of the riverbank. A meandering river will not be fast flowing. The depth to which sediment is transported through a river channel increases exponentially, (not just proportionally) with the depth of flowing water and thus increases the likelihood of damage to equipment.
- *Flotsam* — Observe the height to which debris is deposited above the riverbed. The greater the height of water flow above the dry-season sediment surface, the greater the depth of river flow and hence scour below the sediment surface and the greater the risk of damage to the well-point and/or connecting pipes of an installation.

Site yield assessment — physical characteristics of the sediment

Figure 3.2 indicates the comparative water storage potential of coarse, moderate and fine grained sediment.

General indication of water storage potential

- Large grains of sediment with few fine grains indicate a good water storage potential.
- An even distribution of large to fine grains indicates a fair water storage potential.
- Small grains with a lot of fines indicates a limited or poor water storage potential.

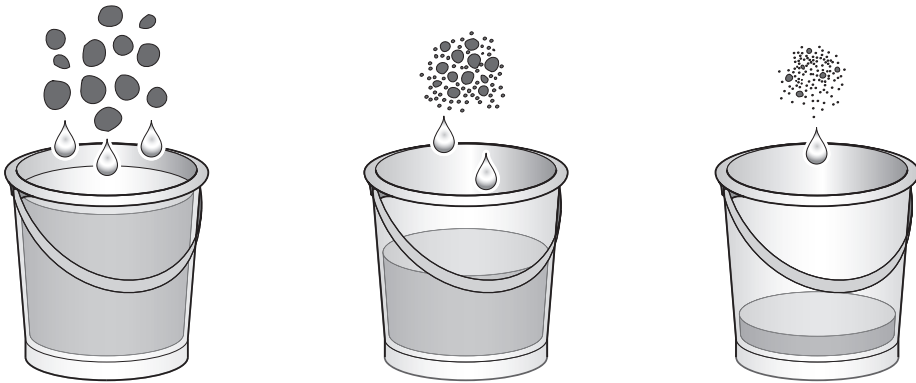


Figure 3.2. Indication of water storage potential

Assessing the possible water yield from sediment

Once a site that has a potential for sand-abstraction has been selected it will be advisable to assess the water storage capacity. Determining the water storage capacity and the yield of a site is a science in itself requiring accurate grading of the sediment to determine the range in size of individual grains and the percentage of each size in the sample.

Although it may not be possible to obtain sediment samples from three or more metres deep, or to undertake such accurate grading of sediment, in order to indicate the characteristics of a sample of sediment from a river that is ideal for sand-abstraction a sediment grading analysis is given (see Table 3.2). To determine a sediment grading curve, a sample of riverbed alluvium is passed through a series of six sieves, usually with apertures of 2.00, 1.00, 0.50, 0.25, 0.125 and 0.063mm. The sample is agitated for 10 minutes in a specialist shaker and the resulting data used to plot a logarithmic graph similar to the one shown in Figure 3.3. From the table and graph below it can be seen that 30% or more of the sediment particles in the centre and lower levels are of a dimension of 2.00mm or more at their narrowest point which is ideal for a well-point sand-abstraction system. Less complex methods of assessing sediment suitability are discussed later in the chapter.

Specialist equipment is also required to achieve a degree of accuracy in determining the porosity and permeability of a sample of sediment. However assessed, porosity is a calculation of the void space of the sediment and thus the pore space that is available for water storage and permeability is a measure of the rate of flow through a sample.

Table 3.2. Grading curve of sediment obtained from the upper, centre and lower levels of the Manzamnyama River at Huwana, Matabeleland South, Zimbabwe

Sieve (mm)	Upper sample (gms)	% retained	% passing	Centre sample (gms)	% retained	% passing	Lower sample (gms)	% retained	% passing
5	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0
2	119.7	17.4	82.6	255.3	33.6	66.4	270.0	30.5	69.5
1	285.5	41.6	41.0	286.2	37.6	28.8	730.8	48.7	20.9
0.5	180.4	26.3	14.7	147.0	19.3	9.5	140.5	15.9	5.0
0.25	62.0	9.0	5.7	40.3	5.3	4.2	27.2	3.1	1.9
0.125	21.2	3.1	2.8	12.4	1.6	2.6	10.9	1.2	0.7
0.063	14.9	2.2	0.4	14.9	2.0	0.6	4.0	0.5	0.2
Base	<u>3.0</u>	0.4	0.0	<u>4.7</u>	0.6	0.0	<u>2.1</u>	0.2	0.0
Total	686.7			760.8			885.5		

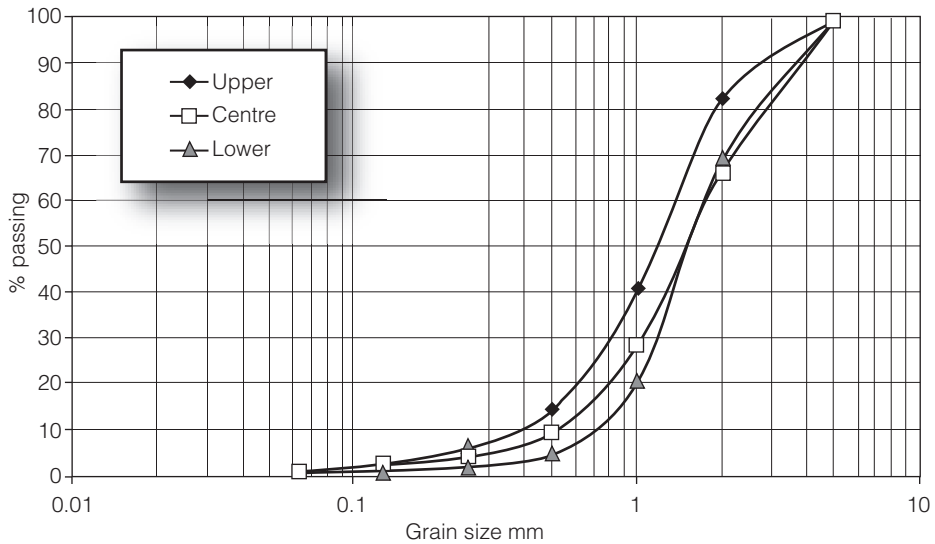
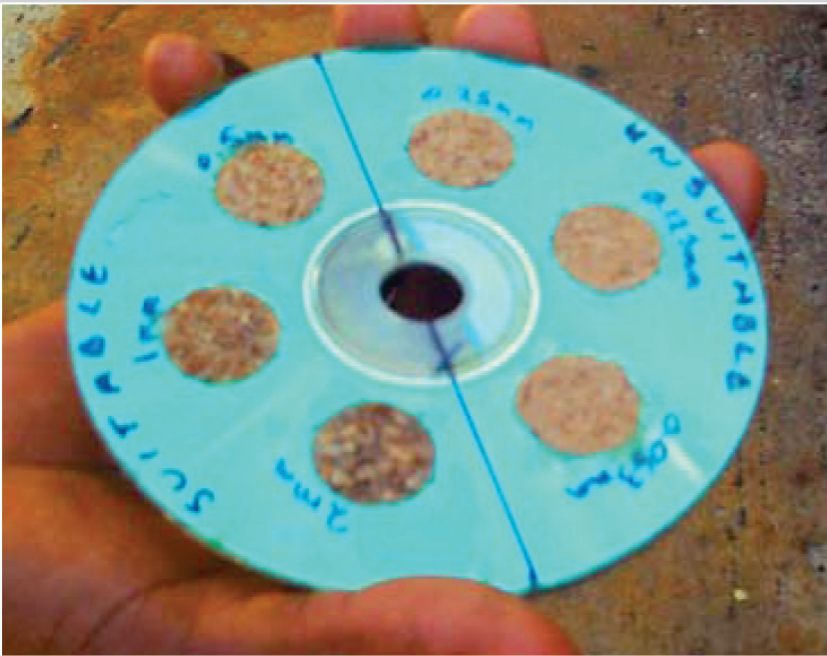


Figure 3.3. Manzamnyama River, Huwana – Sediment Grading Curve

Photograph 3.7. Sediment grain size gauge

Visual assessments and simple equipment such as a kitchen sieve and a $\pm 500\text{gm}$ tin and the sediment particle size comparator shown in Photograph 3.8 can be used to provide a rough and ready guide where purpose designed test equipment is not available. The comparator is made from two compact discs stuck together. The top disc has 20mm holes drilled through and the lower is a backing disc. The two together provide recesses into which particles of graded sediment have been glued and their size recorded for quick, visual comparisons with samples of river sediment.

Simple tests to provide an indication of porosity

Test 1: A rough and ready method of calculating porosity

1. Equipment — an empty $\pm 500\text{gm}$ tin, sound and open at one end. An empty, clear plastic 2½ litre bottle with the top cut off to make a $\pm 100\text{mm}$ aperture.
2. Method — fill the plastic bottle with 4 level tins of dry river sand, disturbed as little as possible but made level within the bottle.

3. Fill the tin full of water and slowly pour the water into the plastic bottle until the water-level is exactly at the surface of the sand.
4. If an entire tin of water has been added to the sand without overtopping the sediment level the porosity will be 25%. (One tin of water has been absorbed by 4 tins of sediment). Estimations of the quantity of water i.e. the amounts of a tin that have been absorbed by 4 tins of sand, will provide appropriate estimations of the porosity as shown in Table 3.3.

Table 3.3. Simple test to determine the porosity of sediment	
No. of tins of water absorbed by 4 tins of sediment	Approximate porosity (%)
1½	37
1¼	30
1	25
¾	19
½	13
¼	6

Coarse sediment with a porosity of 20-25% is ideal for sand-abstraction. A porosity of 10-20% is likely to be found in fine sediment and can be useable. Sediment with a porosity below 10% will require multiple or specialist abstraction equipment and may have a low total yield. Porosity greater than 25-30% can be expected in gravel beds; however these are often not deep.

Test 2:

A simple field test with a kitchen sieve as shown in Photograph 3.8 can be used to gauge the coarseness of sediment and thus provide an indication of the void space and the porosity.

Test 3:

Comparison with known foodstuffs to gauge coarseness of sediment.

Permeability test

The rate of flow through sediment

A scientific experiment can be conducted with a permeameter to determine permeability. The test will indicate how quickly water moves through the sediment. However permeameters are expensive and not easy to use.

A kitchen sieve provides a handy field test for those who do not have access to specialist equipment. Typically more than 50% of the sediment will pass through a kitchen sieve with a 1.25mm aperture.

Procedure

1. Take an empty ± 500 gm tin and fill with a random sample of dry river sediment.
2. Pour the sample from the tin through the sieve. Tap the sieve several times to ensure all the sand that can pass through will do so.
3. Tip the grains that remain in the sieve back into the tin.
4. The material now in the tin that did not pass through the sieve should ideally be at least one-quarter of the volume of the tin ($\pm 25\%$ of the total sample).

Analysis

A sample of sediment with approximately one third of the grains of 1.25mm diameter or larger will indicate a suitable site for a sand-abstraction installation. The sediment will be sufficiently coarse to create a void space with a useable specific yield.

If a kitchen sieve is not available, a less sophisticated method to establish the suitability of a sediment sample for sand-abstraction is to compare a sample of sand grains to well known granular foods.

1. At the proposed site take a handful of dry sand.
2. Trickle the sand from one hand to the other hand which is held approximately 250-300mm lower.
3. Repeat 5 to 10 times noting the size and distribution of the sediment grains as they fall into the lower hand
4. The observed sediment grains can then be compared with short grain rice, coarse sugar, salt and flour.

Rice size grains represent maximum water storage potential.

Coarse sugar represents good storage.

Salt represents low storage.

Flour or **mealie meal** represents poor water storage potential with poor potential for abstraction.

A good water storage site is therefore one with good porosity (large pore spaces for retention of water) and good permeability (to allow the passage of water through the sediment to the well-point). Almost invariably the two go together.

Photograph 3.8. Simple grading test using household sieve



Quick field test to determine permeability

A rule of thumb test based on the test for porosity can be used to establish a rough estimate of permeability.

The more fines that blow from your hand or from the kitchen sieve, the lower the permeability, with reduced water potential for abstraction.

Estimates of the volume of water available

A rough formula to calculate how much water is available in a sand river aquifer.

- The average width (*by measurement*)
- × average length (*by measurement*)
- × the average depth (*by probe measurement*)
- × void ratio (*by estimate from tests above*)
- + recharge (*by estimate*).

Chapter summary

The identification of a sand river that is suitable for sand-abstraction use and the correct identification of a prime water abstraction site are most important. The physical characteristics of a river must be closely studied to ensure that the most suitable site is identified, a number of tests should be carried out to establish the nature of the river channel and the volume and type of sediment. A grading analysis is required from which the porosity and permeability of the river sediment can be established and from this an approximation can be made of the water reserve and the overall potential of the site for the development of a successful abstraction scheme. With this information and the study of the river channel, a suitable method of water abstraction can be determined.

With an appreciation of the characteristics of a sand river and with a possible site in mind the next step is to review methods of water abstraction, or if an adequate site cannot be found, possible ways to improve the site.