REDUCING WATER LOSSES AT FERTILLIS

Client : LDA/NDZALO/RESIS

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1 Summary, Scope and Background

Summary : This document proposes various ways of diverting more water from the Mohlapitse river into the extensive canal system at Fertillis, by correcting certain deficiencies in the weir. At the same time the canals are to be repaired to reduce the very substantial water losses in the canals that supply water to the 96 Ha communal farm. The scope of the repairs includes such aspects as *cleaning the canal and side verges, removal of troublesome trees, minor repairs, major repairs, and in some sections full reconstruction, as well as repairs of long weirs and outlets.* The lining of certain earth canals has also been provided for.

A rough estimate of cost and method of implementation is provided for each solution proposed. A more carefully worked design/solution will follow if the conceptual ideas put forward here are acceptable.

Scope : It may be seen from figure 1 that there is another communal farm to the north and east of Fertillis, called Mashushu. This farm gets its water from weirs no. 1 and 3, and all the canals leading to those lands are unlined earth canals, even the principal and primary canals. However, the irrigation system of Mashushu falls out of the scope of this evaluation – but may be considered at a further date. Thus the balance of this document is restricted to an analysis of Fertillis's irrigation system, followed by recommendations/solutions.

Background : On 5th October 2004, Gauta Molotane, Rachael Motloutsi, Rob McBean, Wimpy van der Linde of RESIS and Nicholas Papenfus of Dams for Africa visited Fertillis, and made an inspection of the diversion weir. Nicholas then followed the principal canal back from the weir to the bridge (where the road crosses over the canal) a distance of 1521m.

Along the way he was met by a French visiting student, Damien Chiron, presently living in Fertillis. Over the past four months Damien has been studying the effect that water (or lack of it) has on the social fabric of a rural village, as part of his masters degree. He has sponsorship/mentorship from French organisation, the National Centre of Agronomy for Developing Countries, and from the School of Agricultural and Environmental Sciences, Centre for Rural Community Empowerment, University of the North, South Africa. He has made an extensive study of the canals in Fertillis and Mashushu, and figure 1 has been prepared from aerial photographs and other sketches supplied by Damien, while table 1 (which indicates the lengths of the various canals) was also constructed from information supplied by him.

Damien explained that in the late 1950s the farms Fertillis and Mashushu were bought out by the government from three while farmers, and thereafter the black communities living further up the Mohlapitse river were resettle on these farms. The current population in these villages stems from the original 21 family clans resettled in Fertillis and the 3 resettled in Mashushu.

The irrigation system for Fertillis (see figure 1) was laid out in 1959 as a government initiative. From an engineering point of view the scheme was cleverly conceived and well constructed, and Fertillis was extensively covered with a network of secondary canals fed by a primary canal, following on from the principal canal that takes the water from the weir to the first gate. These canals were constructed to a high standard of workmanship from unreinforced concrete, but no maintenance has ever been done since then according to Damien. A well thought out system of roads and bridges also services the agricultural fields, so that it is not necessary for tractors to drive over the canals at any stage.

The canal system has been extended over the years, and these are indicated by the dotted arrows in figure 1. These extensions are all in the form of earth canals leading to new fields, necessitated in part by an increase in the number of farmers since 1959. According to Daniel there were approximately seventy farmers in 1959 operating on 70 plots, and this has now grown to 88 farmers operating on 92 plots. Plot sizes vary from 0,8 Ha to 1,2 Ha. In order to create additional space, the new fields have slowly been encroaching into the wetlands, and its vegetation is being progressively burnt in front of the advance of the additional plots. This tendency gained momentum after weir no. 2 was destroyed by the 2000 floods – and since then the amount of water in the canal has been severely restricted, and the farmers have thus been moving into the wetlands in search of moist ground.

It may be seen from figure 1 that there are 8 gates on the primary canal, leading to eight secondary canals (see figure 15 for a view of a typical gate). The respective distances of these gates along the canal, relative to the diversion weir, are indicated in the second column of table 1, while the lengths of the concrete lined secondary canals and earth secondary canals are shown in columns 3 and 4 respectively.

Table 1 : Lengths of Primary and Secondary Canals

infrastructural component	distance from weir (along primary canal)	lengths of secondary canals	
		concrete canal leading off gate	earth canal at end of concrete canal
	m	m	m
2nd weir	0		
1st gate - in primary canal	1521	1200	100
2nd gate - in primary canal	2101	220	100
3rd gate - in primary canal	2381	530	200
4th gate - in primary canal	2661	460	100
5th gate - in primary canal	2941	390	100
6th gate - in primary canal	3221	380	100
7th gate - in primary canal	3501	220	100
8th gate - in primary canal	**3781**	150	400
total		**3550**	**1200**

The figures given above are based on information supplied by Damien.

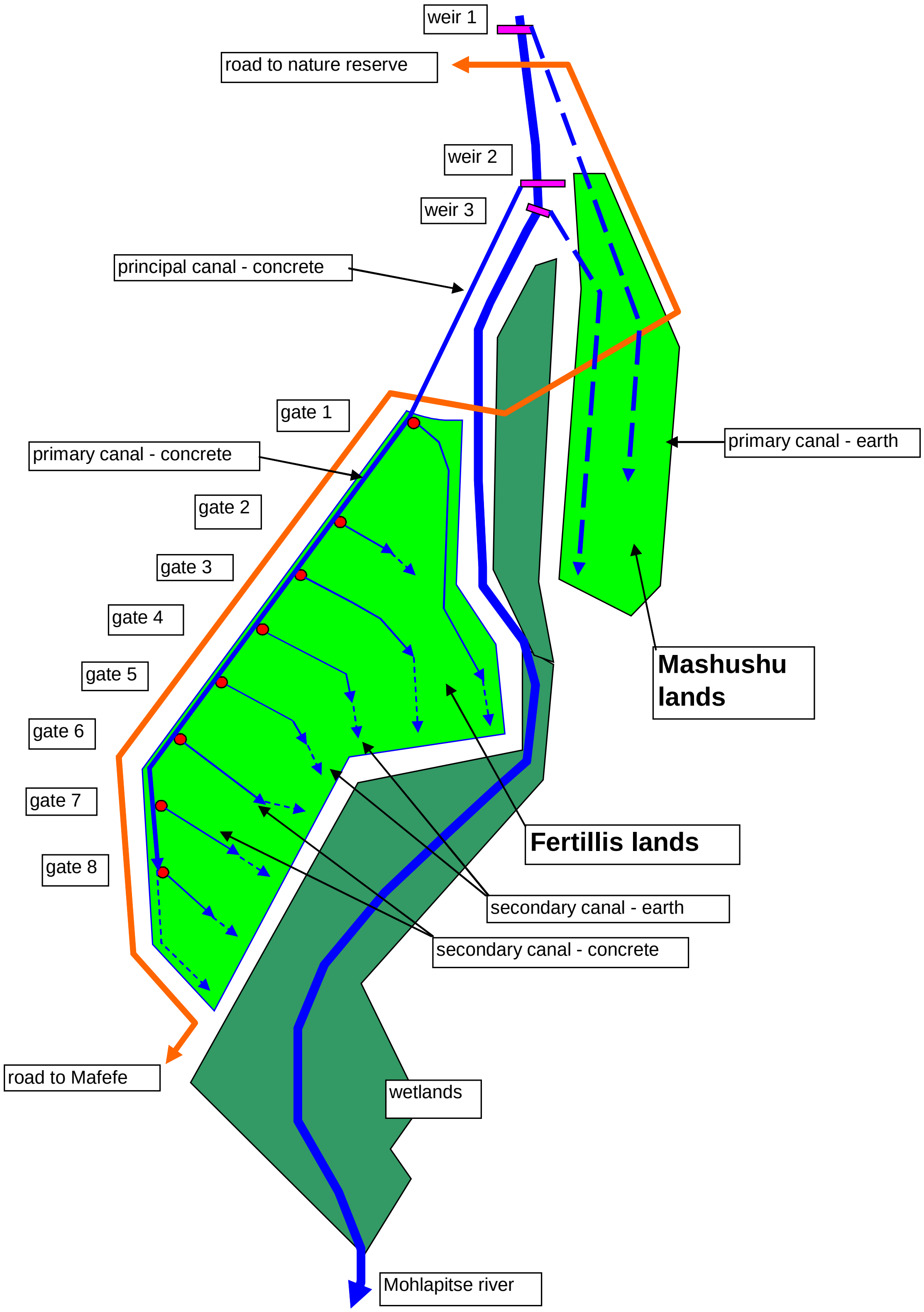

Figure 1 – An aerial view of Fertillis and Mashushu. Concrete lined canals are shown as solid, while earth canals are shown dotted. Fertillis's water is directed into the principal canal at weir 2. Thereafter is exits the primary canal via eight gates into secondary canals which are concrete lined some of the way.

2 Proposed Repairs and Betterments

It is proposed that the community be involved in as much of the work as is possible, under the leadership of a ‘turnkey engineer’. Only where the work is of a specialised nature should a contractor be procured – who will report to the ‘turnkey engineer’. For a more detailed description of the capabilities and responsibilities of the ‘turnkey engineer’ see appendix 4.

Four problematic areas have been identified that, if addressed, will dramatically affect the delivery of water to the lands. These may be stated as:

1 Raise the water level of the impounded water behind the diversion weir, and provide a controllable output into the principal canal
2 Repair all canals to reduce seepage losses. This will involve cleaning them, making minor and major repairs, and doing a complete reconstruction in a few places.
3 Line the earth canals with concrete
4 Construct plot canals, and reorientate the furrows in the plots

The first step involves increasing the water supply into the principal canal. The second and subsequent steps involve reducing the losses (which are very significant) from the canal system. These steps are now considered in more detail.

2.1 Diversion Weir

As mentioned earlier the original structure was totally destroyed during the 2000 floods. The writer witnessed this on 19th Feb 2003, and figure 2 which is a picture taken on that day, shows an unsuccessful makeshift weir subsequently put together. (Following that visit and at the request of the community, the writer prepared a short report for repairing the weir and other infrastructure and a basic business plan to do commercial farming at Fertillis and Mashushu, but was unsuccessful in raising the required capital to launch the project. These two documents are appended to provide additional background information – see appendix 1 and 2 respectively - it is believed that these options may still have merit and should be considered).

On 14 th November, 2003, the writer again visited the sight at the request of the community. He observed a diversion weir that the community had constructed subsequent to his first visit. The materials were sponsored by the Department of Agriculture. The structure is shown in figure 3 and figure 4.

The reason for the request for the writer to again visit the site was that the government sponsored weir was not diverting the water into the canal as the farmers had hoped. A simple explanation for the ineffectiveness of the weir follows, as well as a proposed solution later on. The weir in its current state, has a highly permeable geofabric material on the upstream face of the structure (see figure 3), and the water simply passes straight through the fabric, and then through the ‘gabions’ – the word is used in a generic sense as the actual cages are smaller than those supplied by African Gabions (Pty) Ltd. The structure therefore does not raise the level of the water sufficiently to divert it into the canal. While this material may eventually become clogged with tiny particles of debris, and there is evidence that this is happening, this process may take years, which is not helping the farmers at the moment. Also, the material is decomposing from the harmful affects of ultra violet light. (Geofabrics should not be exposed to UV radiation for long periods – the process of decomposition accelerates after 2 years).

Apart from being so permeable, the weir suffers from a second inadequacy – it is not level at the top and will therefore concentrate the flow of water at the low points except for flood conditions. This will lead to wear/abrasive effects at these points, with the possibility of differential settlement that will further exacerbate the problem. It will also result in a relatively rapid rise in the height of the impounded water until the overflow is distributed evenly across the full width of the weir. This will require constant adjustment of the gate (to be constructed – see solution) so that the canal does not overflow on the one hand or deliver too little water on the other.

On the positive side it may be said that the structure is very squat relative to the small head of water behind it – it is about 4m wide for an apparent height of only 2m. It will therefore certainly not *overturn*, even if when corrective action has been taken to render the structure impermeable .

It was however not possible to determine the founding depth with certainly, which appears to be 2m below the overflow level. It is therefore not possible to say with certainty that the material in front of the weir will develop sufficient passive resistance to prevent the weir from *sliding* in flood conditions. However sufficient shear resistance against sliding will very likely develop at the bottom of the structure under the action of it own weight to prevent sliding, considering again the small head.

It is also not known whether the various gabion cages were correctly stitched together so that they all behave as a unified massive structure rather than individual blocks (although there probably is sufficient interlock from protruding bulges in adjacent units to ensure a degree of force transfer, especially in such a squat structure, and for such a small head of water – only about 1m is required to ensure adequate flow into the canal). Fortunately the structure is correctly arched, so that any displacements of the central zone (where the flow is strongest), in the downstream direction, will generate compressive stresses in the ‘arch’ that will further improve the interlock of the gabion units.

Figure 2 – A view of the hopeful farmers and committee members on 19th Feb, 2003. Their devastated weir, destroyed in the 2000 floods, is partially in view on the right of the picture. The canal leads off at the back.

Figure 3 – A view of the gabion structure built by the community in July 2003 with material supplied by the Lebowakgoma offices of the Department of Agriculture. Some of the community leaders are in picture. The geofabric may be seen on the upstream side of the weir, and decomposition from UV attack will accelerated after 2 yrs.

Figure 4 – the top of the weir is not horizontal – with undulations of approximately 200mm, which may be corrected by applying a concrete topping

Proposed Solutions (see 2.1.1 through 2.1.3)

A correctly functioning diversion weir will perform three tasks. Firstly it will *raise the level of the impounded water* sufficiently to divert sufficient flows into the canal. Secondly, it will have an *adjustable gate* that allows the inflow into the canal to be adjusted as required. Thirdly, it should be sufficiently *wide and essentially horizontal*, to stabilize the level of the impounded water so that the gate can be left alone, in the position that maximises the flow in the principal canal. Only in the case where the water rises substantially as a result of heavy rains in the catchments, or where maintenance work must be done on the canal should it be necessary to adjust the opening of the gate.

Ways of achieving these three objectives will now be considered.

2.1.1 Solution : Raise the Level of the Impounded Water to Divert Sufficient Water into the Canal

One way of doing this would be to construct a reinforced concrete wall to a substantial depth immediately behind the existing gabion structure, which may be relatively thin as the gabion structure would provide the necessary stability against overturning. This method would however require a substantial diversion canal to allow construction activities to proceed in relatively dry conditions. This solution is described in Appendix 3, at an estimated cost of R183 000 excl VAT and design fees.

However, there is an alterative solution whereby the ‘gabions’ are sealed by placing earth behind the geotextile. Once a temporary diversion canal has been excavated as shown in figure 5, the loose rocks and loose sand immediately behind the gabions are moved a distance of about 1m away from the structure (see figure 5), and then a 200mm layer of bentonite/soil mixture is placed immediately against the geotextile and compacted using hand stampers. Behind this material, gravelly/soil should be placed to provide lateral support. This material may be sourced from the river bed upstream or downstream, and should be selected such that the proportion of gravel and soil will compact sufficiently simply by the action of trampling on it. This material may be brought in by wheel barrows running on top of the existing structure and then be thrown into a simple chute that directs it behind the bentonite/soil layer to provide it with lateral support. The gravel/soil is in turn supported by the rocks that were removed and stockpiled earlier – see figure 5. Finally a 3m long Reno mattress structure, lined beneath with geofabric, is constructed on top of these elements to protect the clay from wave action and to keep it from washing away in flood conditions.

Cost: It is estimated that the cost of making the existing gabions structure essentially impermeable will be **R 63000**, on the basis of the community doing the work under the supervision of a ‘turnkey engineer’. A team of 6 persons should be able to complete the work in 21 days, while a TLB is budgeted for one week to bring in the soil, gavel, rocks etc.

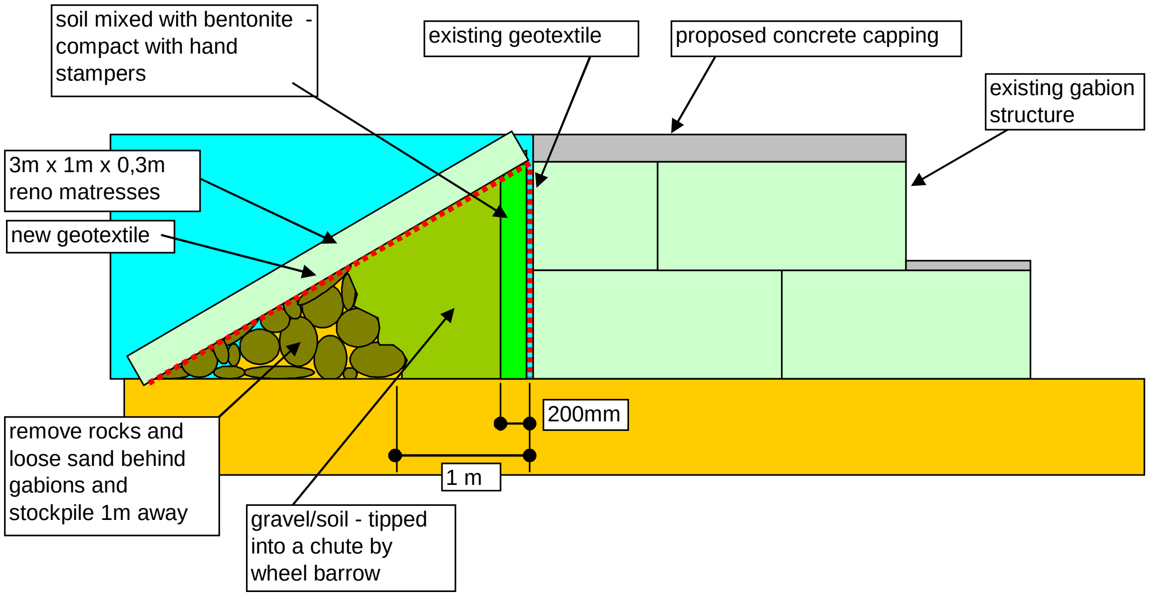

Figure 5 - Section A A (relative to figure 6) through the gabion structure, showing the proposed method of sealing it.

2.1.2 Solution : Build a gate to allow an adjustable Inflow into the Principal Canal

An impermeable weir that raises the level of the water sufficiently to fill the canal should be supplemented with an adjustable gate that allows the inflow into the principal canal to be adjusted as required. A relatively short concrete wall will also be required to house the gate and to close off the space between the right flank of the river and the gabion structure (see figure 6). The completed concrete wall and gate will look similar to that seen in figure 7, with the principal canal leading off as shown. The structure should protrude at least 1m above FSL and thus divert storm waters flows (but not flood waters) back into the river.

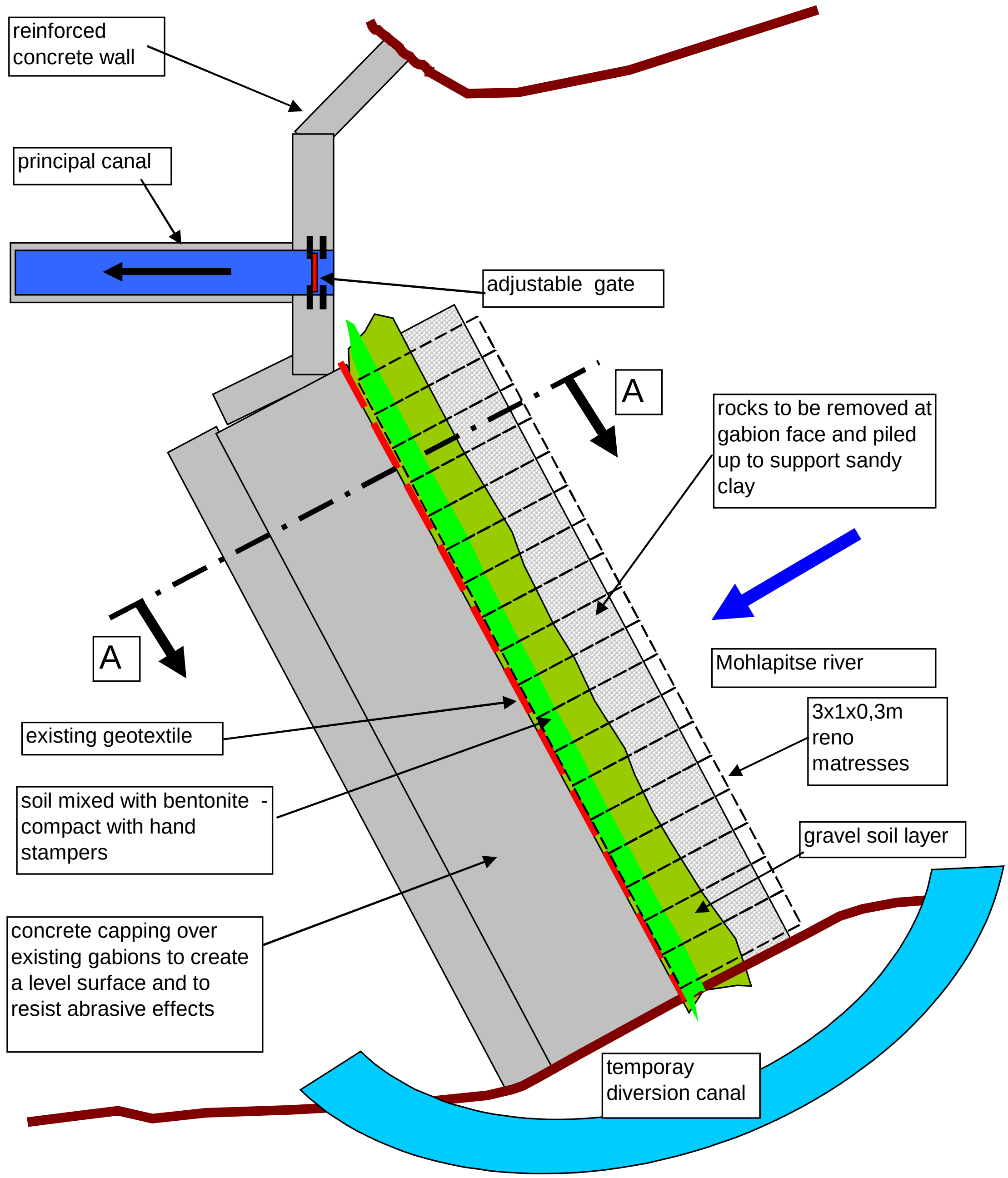

Figure 6 – Schematic plan of weir, showing the canal gate on the right flank of the river

Figure 7 – Example of an adjustable gate which is able to regulate the water flowing into the principle canal. The gate and all its components should ideally be galvanised.

Cost: It is estimated that the cost of building an adjustable gate near the right flank of the river, complete with an 8m long concrete wall which has a depth of 1,5 m below FSL and a height of 1m above FSL will be **R 73000 (excl VAT).** It is recommended that this work be done by a contractor that has experience with shuttering and reinforced concrete. The contractor should be able to work without supervision, although it is advisable that his progress be monitored by the 'turnkey engineer'. It should be possible for him to complete this work in 20 days – including the time taken to establish a dry working area.

2.1.3 Solution : Cap Gabion Weir to make it Horizontal

As explained earlier a weir should be sufficiently wide and essentially horizontal to ensure that the water flows over the weir in a relatively thin sheet (see figure 6 of appendix 3 for an example of this) so that the FSL does not vary significantly. This ensures that the gate does not require continuous adjustment to achieve a constant flow in the principal canal. It is estimated that the average thickness of the capping will be 200mm in order to overcome the substantial inundations (see figure 4). A further advantage of capping with concrete is that the galvanised wires of the gabions will be protected from the abrasive effects of pedestrian traffic and continuous flow (especially when the water is muddy). Note that the manufactures of the gabion cages recommend the practice of encasing the wires in concrete when they are used as spillways.

Cost: It is estimated that the cost of capping the gabion weir with an average thickness of 200mm of concrete **R 22 000** **(excl VAT).** The community will be able to do this work under the supervision of the ‘turnover engineer’ (see appendix D). Once the engineer has given the critical levels, has provided the mix design and sourced the aggregate from a suitable area near the river, the workforce should be able to carry on with minimal supervision providing that there are one or two of the crew who already have experience as builders/bricklayers/plasterers.

It should be possible for a crew of 10 to complete this work in *10 days* – including the time taken to establish a dry working area.

2.2 Irrigation Canals

The irrigation canals may be classified into three groups – the principal canal, the primary canals and the secondary canals, and the secondary canals may be either concrete lined or unlined. The upgrading of the unlined/earth canals will be considered in 2.3.

The main canal that takes water from the weir to the first gate is referred to as the principal canal. After this point the main canal is referred as the primary canal, which in turn has secondary canals coming off it at regular intervals, i.e. at 8 gates along the canal as indicted in figure 1. The lengths of the principal canal, the primary canal and the various secondary canals were indicated earlier in table 1. The table also shows to what extent the secondary canals have been extended as unlined earth canals.

The same procedures that are recommended for upgrading the canals at Success and Koedoeskop may be applied here. They will be summarised briefly in 3.2.1 through 3.2.4 – for a fuller description see the document relating to Success. These procedures should be taken very seriously as the water losses from the canal system at Fertillis can only be described as alarming. For example, Damien’s measurements have shown that only about a third of the water entering the principal canal at the weir reaches the first gate, i.e. a flow of 97 litres/second entering the principal canal at the weir is only 32 litres per second at the first gate. Measurements taken in the secondary canals are no less comforting; an initial flow of 14 l/s measured at the gate - the start of a secondary canal system - is reduced to 8 litres per second further down the canal.

Figure 8 below shows a view of the principal canal, while figure 9 is a view of a secondary canal as it leads away from a gate.

Figure 8 – View of principal canal

Figure 9 – View of the first secondary canal coming off the first gate

2.2.1 Cleaning and levelling of verges

Whether in preparation for the repair team or whether as a matter of good practice, the canals should be cleaned of all organic matter, as well as the growth 500mm on either side of the canal. Furthermore any build up of ground that may have accumulated next to the canal as a result of cleaning operations in the past should also be removed a distance of 500mm. Having clean and level shoulders next to the canals will significantly reduce the occurrence of 'wash-in' when it rains. Such a level area will also encourage people to walk on these 'path-ways' and his will help to keep the grass from taking root again. This work can be done by the local community and supervised by a team leader who works alongside the others. Tools will be limited to shovels and a few picks, and after one or two days of on-the-job training, the team is likely to perform very well with only occasional inspection from the project leader required.

A fixed number of meters should be set for the team to achieve daily and payment should be linked to this goal.

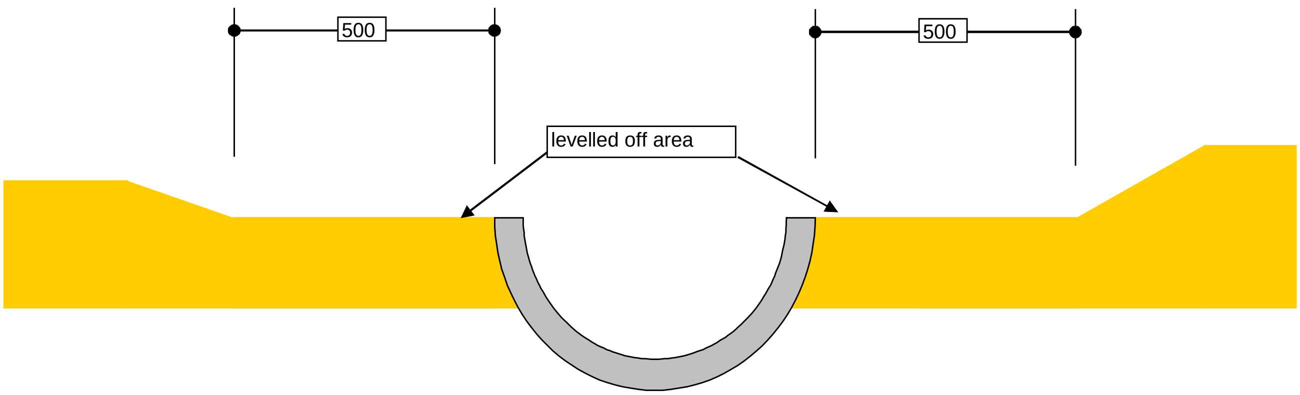

Figure 10 – proposed detail for clearing of grass and levelling

Cost : From experience that the writer has in work of a similar nature, a distance of R50 wages for 50m is both realistic and achievable. However, Damien has indicated that many of the secondary canals have become buried over the years. Taking this into consideration as well as the fact that most of the secondary canals were unsighted by the author, the production rate should be significantly reduced for the initial budget estimate – say to R50 for 25m, or R2 per m. From table 1 it maybe seen that the total length of the various concrete canals is approximately 7400m, and hence the budget for this work would be **R15000**, excluding the cost of the overseeing turnkey engineer. This cost is dealt with separately in point 6**.** A team of 10 should be able to complete the work in approximately *30 days.*

2.2.2 Minor repairs

The secondary canals are made up of short sections (assumed to be 1,2 m long). This accommodates slight amounts of differential settlement and prevents shrinkage cracks from developing in the concrete. Generally these interfaces are soon sealed by silt so that the joints eventually become virtually impermeable.

In spite of the joints, cracks do sometimes occur as a result of settlement as a result of poor compaction during construction, and upliftment – which is often induced by vegetation. Also grass may grow into the joints, particularly where the joint is not tight. The sandy conditions of the ground means that any crack or break will result in substantial losses, as has been alluded to earlier.

Proposed Solution: The following approach to repairs is recommended:

- If a crack is still tight (has not opened) nor affected the shape of the canal, it is recommended that this crack be treated as a joint, and nothing need be done. The crack should seal in the same way that a joint does.
- If the crack has opened slightly, it is recommended that this crack be grooved with a small angle grinder to a depth of 30mm. This groove should then be washed clean of all debris and dust. Later a non shrink grout should be applied taking care to press the grout into the groove as it begins to stiffen. A suitable tool should be used for this so that a degree of pressure can be applied.
- If grass is growing in the joints, then the same procedure as above should be applied, except that the groove should extend right through the joint to ensure that all the growth is cleared away.

The above three approaches are illustrated in figure 11.

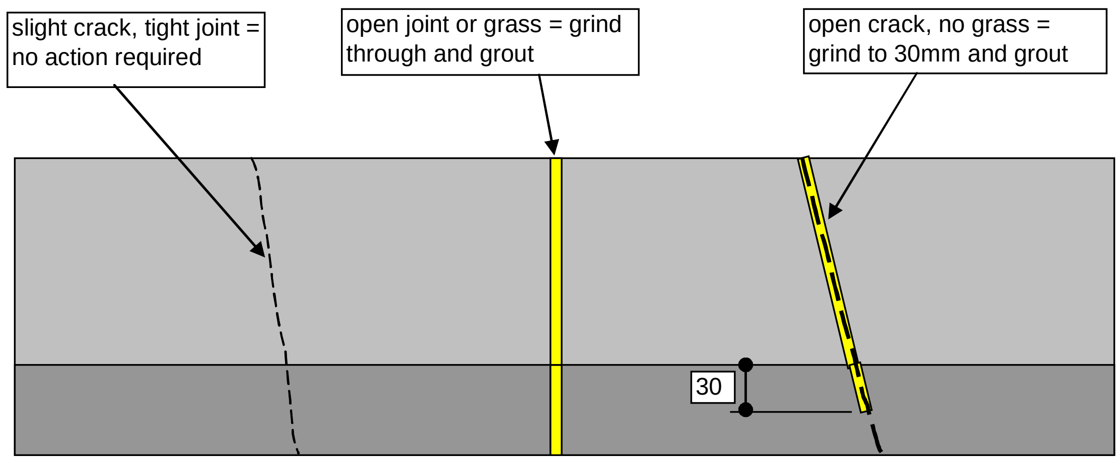

Figure 11 – Longitudinal section through a canal showing the possible actions that should be taken to repair cracks and eliminate growth in the joints.

Cost: For budget purposes it will again be assumed that there is a joint or crack every 2m that requires grinding and grouting (as was assumed for Success) in the secondary canals, and one joint every 4m in the principal and primary canals. It may therefore be calculated that the total repair will cost **R35000.** As with Success this includes the cost of purchasing a 5 kVA generator and two small angle grinders. It also requires 90 diamond tipped cutting discs, petrol, low shrinkage grout, labour, and an assistant supervisor reporting to the 'turnkey engineer'. The task should take a team of 6 about 40 days.

2.2.3 Major repairs

Where multiple cracks occur in close proximity to each other, or where chucks of concrete are missing, then it will be necessary to break out the broken pieces and recast.

An example of this is shown in figure 12.

Figure 12 –A broken left shoulder, just before the bridge, necessitates a 'major repair'

Proposed Solution : In the canal in figure 12 the left shoulder of the canal may be seen to be broken up for a stretch of about four meters. When affecting the repair, it is not necessary to break out the whole section as the right shoulder and the base are unbroken. The recommended repair in this case will take the form of figure 13. The broken pieces are taken out with a pick or a chisel and hammer. The unbroken section is trimmed into a reasonably straight line where it will interface with the new concrete. The sides of the excavation should be nearly perpendicular, and the base should extend about 50mm below the base of the old section. The inside profile can generally be achieved by trimming the concrete here with a scraper made from a 3mm plate that has the correct profile. Although a 20MPa concrete has adequate strength, 30 MPa concrete will dissolve much more slowly (calcium, the main ingredient of concrete, leaches out of its surface when it is subject to continuous flows of water, especially where the water is very pure).

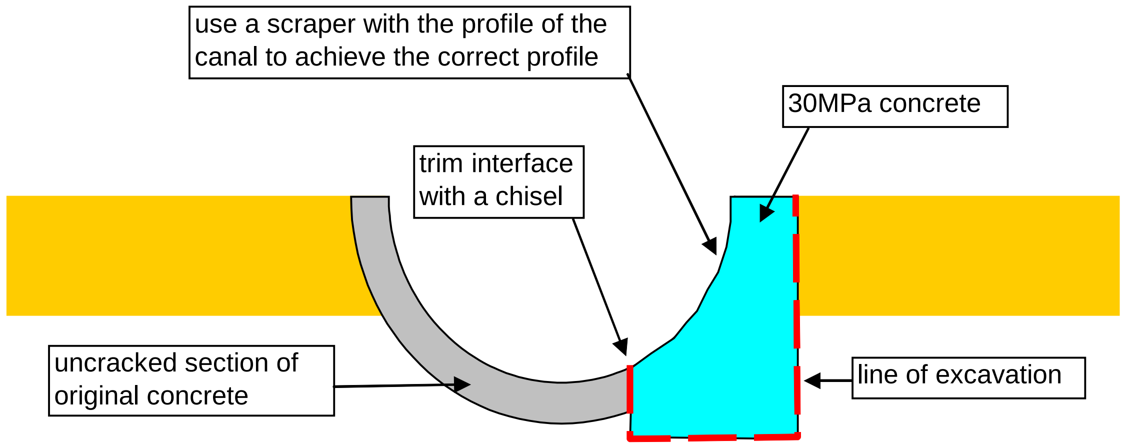

Figure 13 – The steps involved in making a major repair are indicated

Cost: From table 1 it may be seen that there are 3550m of secondary canals in the system, and if it is further assumed that there is a major repair required every 25m (to be confirmed) the cost of the 142 repairs has been estimated as **R 26000**. This allows for breaking out the broken concrete, trimming, mixing, materials, placing, trimming and floating. The work should take two teams of three approximately 47 days. At least one person in the team should be a regular bricklayer or plasterer, and there are a number of these persons in the vicinity.

It may also be seen from table 1 that there are 3751 m of main canal (principal and primary) in the system, and if it is assumed that there is a major repair required every 50m (to be confirmed) the cost of the 75 repairs has been estimated as **R 38000**. The work should take two teams of three approximately *50 days*.

2.2.4 Reconstruction

The high losses in the *principal* canal (97litres/sec down to 33 litres per sec) as recorded by Damien do not fit the observed condition of this canal, which appears to be in a good state most of the way. There are however some areas that are obviously causing leakage, notably a section of 50 m at the beginning where the canal was seriously damaged by the floods in 2000. There is also a section of about 100m where there is a buried pipeline that carries the flow. It is possible that ground settlement has occurred here so that the buried pipeline is no longer sealed, accounting for much of the observed losses. If it is confirmed that losses are indeed occurring here, then it is proposed that a surface canal be constructed so that continuity is once again established in the canal. Other than these two areas, totalling to about 150m (to be confirmed), the remainder of the canal does not require reconstruction. This represents about 10% of the length of the principal canal. The writer also inspected the primary canal by running along the length of it to get some feel of its condition (the sun was setting and walking would have meant loss of light before the end of the canal could be reached). A rough estimate of the areas requiring reconstruction would be 5% of its length, 115m. There is also an unlined section at the end of the canal of about 115m – the total length of main canal requiring reconstruction is therefore 380m.

Figure 14 – Intake to 100m buried pipe. The canal may be seen to be coming in from the right.

Cost: Based on the above stated assumptions it is estimated that it will cost R **152 000** for reconstruction works of the main canal. It is estimated that it will cost **R 34 000** for the secondary canals, assuming again that a reconstruction is required every 50m and that each repair is 2,4m in length (same criteria as Success, to be confirmed). It is advisable that this work be given to a specialist canal contractor, who would employ local labour for the most part. Estimated time is 30 days for the major canal and 10 for the secondary.

2.2.5 Gates to Secondary Canals

The flow of water into the eight secondary canals is controlled by means of a short 80mm galvanised pipe, that is meant to close by means of a socket and plug arrangement to either allow flow or prevent flow (see figure 16).

Figure 15 – View of gate 1. Water flows from the primary canal (background) into the secondary canal by means of an 80 mm galv pipes. (In this picture the flow is slow as the pipe has been blocked with a plastic bag and rock on the other side – see figure 9).

Proposed Solution: The arrangement shown in figure 9 is considered by the writer as inadequate, and it is proposed that the 80mm pipe be replaced with larger 100mm pipe, which will allow 56% additional water into the canal. This arrangement will create a much better flood condition in the furrow, allowing water to move along the furrow relatively quickly, resulting in uniform soaking along its whole length. Rather than use more water, it will result in the faster and more efficient use of water.

Doing this modification will require the chiselling out of the old pipes and enlarging the hole slightly after which a new 100mm pipe may be epoxied in. (The use of epoxy is recommended to achieve a strong bond between the pipe and old concrete, given that the pipe will be subjected to constant handling/turning motions - the pipe may get loose if it is fastened only with a cement based grout). The proposed new arrangement is shown in figure 16.

Cost: It is estimated that it will cost R750 per replacement including labour and supervision, so for 8 pipes, the cost will be **R6000,** on the basis of the turnkey engineer training *one person* to do the work. Total *days = 6.*

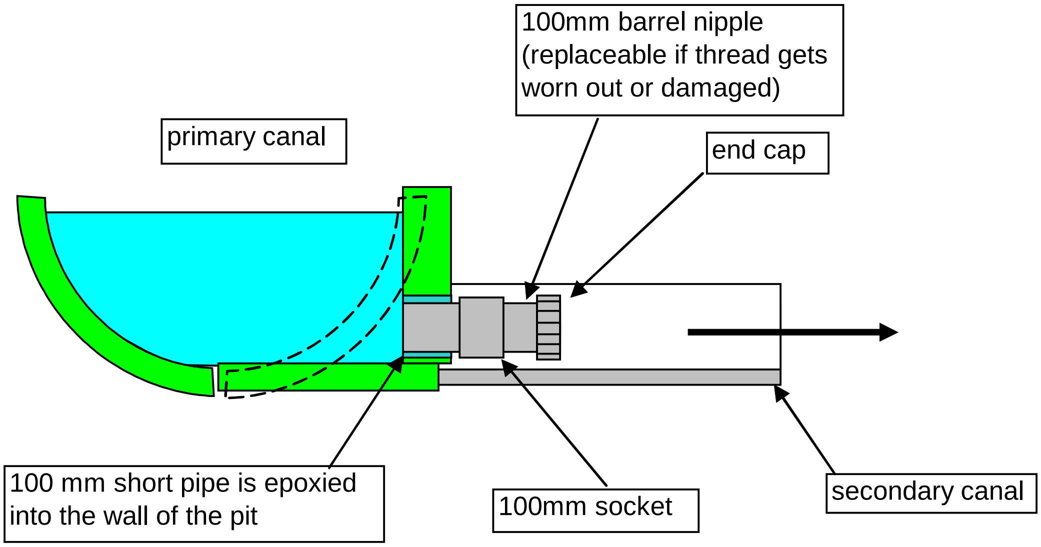

Figure 16 – New 'gate' arrangement for supplying water to the secondary canal

3 Lining the Earth Canals

Damien has reported that the ground at Fertillis may be classified as sandy/loamy – and a high rate of seepage may therefore be expected. Carefully controlled measurements taken by Damien in a secondary canal showed that there was a drop in flow from 6,5 litres per second to 4,5 litres per second over a distance of 43m – a drop of nearly 50%. It is therefore recommended that the 1200m of secondary canals be lined with concrete.

Cost: Based on a cost of R200/m it is estimated that these canals can be constructed for **R 240 000**. It is advisable that this work be given to a specialist canal contractor, who would employ local labour for the most part. Estimated time is *30 days.*

4 Plot Canals

In Damien's professional opinion (and it must be emphasised that he is a qualified agronomist with a very deep appreciation of the local conditions) the soil at Fertillis is loamy/sandy, which results in rapid soaking of furrow irrigation water. The problem is exacerbated by the fact that the irrigation canals run almost parallel to the contours, at a slight slope. Although this is normal practice, it does not work well in Fertillis as the water soaks into the ground so fast that it takes a long time to reach the other end of the 120m long furrow, and the end result is that an unacceptably low percentage of the land receives water in the allotted time that each farmer has.

Damien's recommendation is that new concrete lined canals, which may be called 'plot canals' should be built on the upper contour of each plot so that water may be diverted laterally off the secondary canals into the plot canals and flow the full 120m with minimal seepage. These canals should have regular off takes so that water can be directed into reploughed furrows that now run downhill. The gravity assisted flow will then reach the end of the furrow with a much reduced seepage loss, resulting in a more uniform application, and the farmer in question will be able to water his entire field in the allotted time.

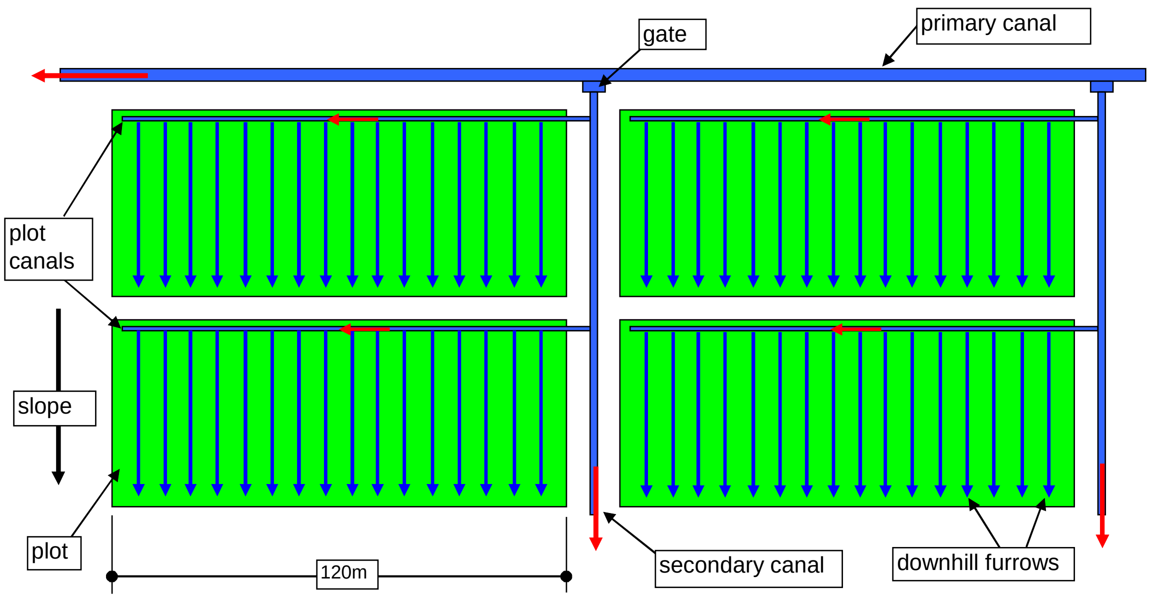

Figure 17 – Plot canals running nearly parallel to contours with furrows running downhill

Cost: Assuming that the average plot is one hectare in area, and that the 96 hectares each have one plot canal of 120m long as indicated in figure 17, the total cost at a cost of R100/m will be R 1152 000. It is advisable that this work be given to a specialist canal contractor, who would employ local labour for the most part. Estimated time is *60 days.*

5 Supervision

If it is a requirement that most of the work be done on a ‘turnkey’ basis, then it is recommended that a practical ‘turnkey engineer’ be sourced to oversee the various tasks. Table 1 below gives an indication of how the various stages of the project could be managed and executed. The engineer should have the ability to both source and train labour from the local community.

The cost of such an individual, including the use of a bakkie and accommodation for a *3 month* period (to allow for the initial planning phase, and for accurate measure) is likely to be **R 105000**.

6 Conclusion and Recommendation

As may be seen from the above table 2 the total cost of a project of this nature amounts to R2255 000, but this should only be regarded as a rough estimate.

Table 2 - Summary of Implementation costs incl Supervision

reference	task	cost R	time days	labour/contractor and supervision
2.1.1	weir - raise overflow height	63000	21	local labour x 6, trained and supervised by turnkey engineer
2.1.2	weir - adjustable gate and wall	73000	20	specialist contractor monitored by turnkey engineer
2.1.3	weir - horizontal concrete cap	22000	10	local labour x 10, trained and supervised by turnkey engineer
2.2.1	canals - cleaning, and level verges	15000	10	local labour x 10, trained and supervised by turnkey engineer
2.2.2	canals - minor repairs	35000	40	local labour x 6, trained and supervised by turnkey engineer
2.2.3	canals - major repairs to main canal	38000	50	local bricklayers x 6, trained and supervised by turnkey engineer
2.2.3	canals - major repairs to 2nd canals	26000	47	local bricklayers x 6, trained and supervised by turnkey engineer
2.2.4	canals - reconstruction to main canals	152000	30	specialist contractor monitored by turnkey engineer
2.2.4	canals - reconstruction to 2nd canals	34000	10	specialist contractor monitored by turnkey engineer
2.2.5	canals - gates to secondary canals	6000	6	local plasterer x 1, trained and supervised by turnkey engineer
3	lining of earth canals	240000	30	specialist contractor monitored by turnkey engineer
4	construction of plot canals	1152000	60	specialist contractor monitored by turnkey engineer
5	supervision	105000	3mths	Fertillis
	sub total	1961000		
	allow 15% contingencies	294150		
	Total	**2255150**		

It is recommended that these proposals be considered by LDA/NDZALO/RESIS, and if they are found to meet their criteria, then they should be submitted to the management committee of the Farmers at Fertillis. If approved by them, an accurate cost estimate should be carried out based on a detailed design supported by appropriate sketches. Included in this phase will be a return visit to site where the whole day will be dedicated to accurately measuring quantities, and classifying the various repairs into their respective categories.

Following this phase it is recommended that a tender document be prepared complete with a bill of quantities and working drawings.

A final word of thanks goes to Damien who provided much information on the canals and some useful historical background. However, while Damien has highlighted the importance of rectifying the entire irrigation system at Fertillis as covered in this document, he is of the opinion that **fencing** is equally important, as the difficulty in controlling the movement of goats results in ongoing conflict between farmers.

He also suggested that providing **canals for Mashushu** would greatly benefit their water supply, since their soil has an even higher soaking problem. He has determned that losses in their main canals are approximately 1 litre/meter of canal! He is impressed with their industrious attitude to work and believes that any assistance given to them would produce lasting results. It is therefore recommended that Mashushu be considered at a future date.

APPENDIX 1

Report on Water Supply for the Farming Communities in the Fertilis/Mafefe Area, Sekukuneland, Limpopo Province

Prepared by Nicholas Papenfus
PhD(WITS), MICT, Pr Eng

31-03-2003

This report tables the findings of an investigation carried out by Nicholas Papenfus and Antony Maakana of Dams for Africa on 20-02-2003 at the request of the community at Fertillis. The meeting was facilitated by Mr Lawrence Moroasui of Peoples Agricultural Development together with the Mafefe Churches Association.

Background

There are 101 farmers in the village of Fertillis. Together they have 157 Ha of arable lands that are serviced by a system of irrigation canals which are fed by a diversion weir in the Mohlapitse river. The catchments area upstream of the weir is approximately 300km^2 . The Mohlapitse is a perennial river and is a tributary of the Olifants, which is about 16km south of the weir. The weir is situated at E 29^0 07’ 00” and S 24^0 06’ 20”.

Sadly, the extreme floods in 2000 damaged the weir to such an extent that the water in the river now flows past the canal. This has given rise to a very serious situation - the drought conditions have largely resulted in failure of the summer crops – and famine is looming unless winter crops such as vegetable can be grown. This however requires irrigation, and to do this the level of the weir needs to be raised by about 400mm, so that water will once again be diverted into the canal. The weir in its current state can be seen in figure 2. The current operating level in the canal can be seen in figure 3.

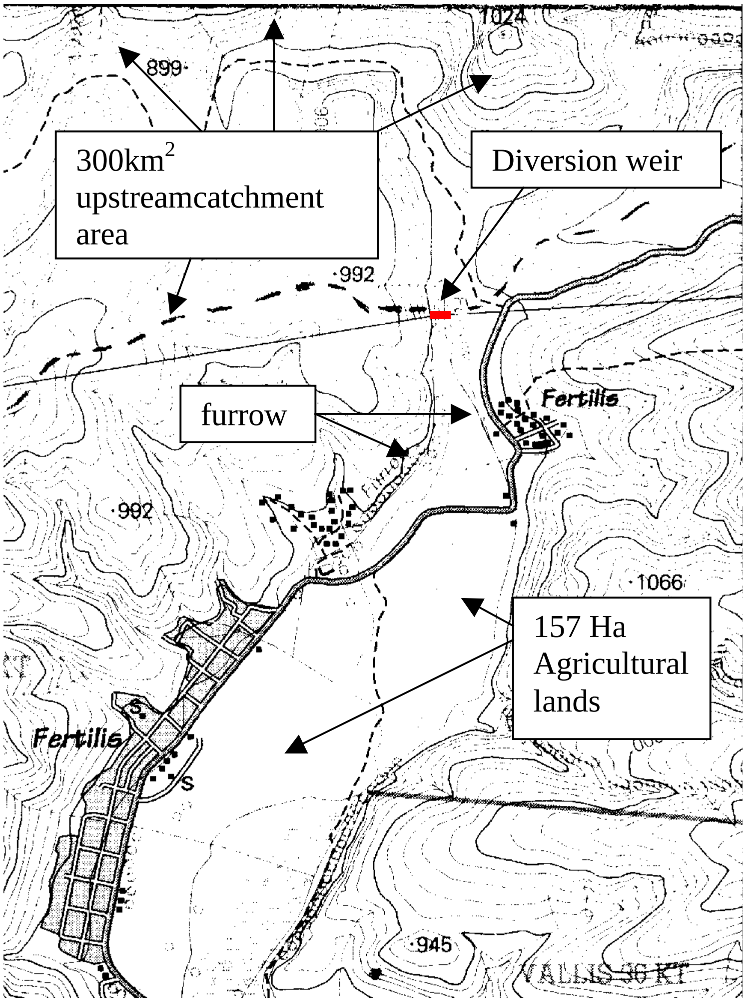

Figure 1 – Topographical map of the Fertillis area, showing the river, weir, lands and furrows

Figure 2 – The flood damage to the diversion weir is evident. Water currently percolates freely through crude rock/soil makeshift structure. The upstream level should be approximately 400mm higher than at present in order to divert enough water into the canal. The mouth of the canal is out of view, but is to the top centre of the picture.

Figure 3 : The low level of the water in the reservoir results in minimal water flowing in the canal. An unsuccessful attempt to bring in water from the side was made.

Proposed Solutions

1 Weir

According to TR137 the large catchments area can given rise to a 1:200 year flow of 1780m3/s. To withstand a flow of this magnitude a properly engineered diversion weir is required. It is further important that the structure retain a degree of flexibility as the bed-rock is too deep to found a rigid structure. It is therefore proposed to build the weir from gabions across the full 40m width of the river. The construction programme will require a diversion canal to be constructed prior to this, followed with two berms to keep the working area dry. The existing canal will need to extended by about 15m to meet the new weir.

2 Pipeline

A second possibility is to build a pipeline from a distance of 200m upriver that is about 3m higher than the canal, to where the canal starts. A small diversion weir will divert water into the pipeline, and valves will be installed on either end to control flow as required. The pipes would be secured to the cliff.

Conclusion

The four elements required for the cultivation of high value crops are :

- Adequate *sunshine*
- Arable *land*
- Irrigable *water*
- Informed *people*

All four of these elements are present at Fertillis, even in winter. Note that the complete system is gravity driven and thus no energy costs relating to diesel or electricity are present.

Considering the hardships that the community is experiencing owing to the drought, and taking into account that irrigable water will allow immediate planting of high value crops all the year round, every effort should be made to urgently obtain the necessary funds.

APPENDIX 2

Business Plan - Fertilis - Bananas

	unit	qty	unit cost/price	total	
Capital Expendature			R	R	
Viability studies				100000	
Cost of dam (turnkey basis)				300000	
Repair of Canals (turnkey basis)				110000	
Additional canal network (turnkey basis)				300000	
Total Water works				810000	
Less DWAF subsidy	ha	157	10000	1570000	
Net cost				-760000	
Packing shed				existing	
Farm Establishment for Bananas incl irrigation	ha	157	25150	3948550	
Project management fees on farm development	%	7.5	3948550	296141	
Working Capital				3348631	
Training [5]	persons	101	2000	202000	7795322.2
Income at gate[2]	ha	157	33214	5214644	5214644
Expendature					
Production costs/ha (excl 15% depreciation)[2]	ha	157	17257	2709371	
Water usage [14]	m^3/yr	2496300	0.2	499260	
Telephones/electricity/stationery				40000	
Ongoing mentoring				100000	3348631
Cost of money					
7 yr loan required after subsidy [8]			7795322		
Interest at 12% on long term loan [3]	%	12		561263	
Repayment of long term loan	yrs	7		1113617	1674881
Distributable Surplus [6]					191132
Distributed surplus per individual					1892

Note

1 The selling prices used here may be regarded as conservative.
2 A unit value for production costs of R12000 to R15000 for a single crop was obtained from the Agricultural Reseach Commision (Dr Finnie Niederwieser), and pertains to cabbage, beetroot and onion production. They include such aspects as ploughing, fertilizing, seeds, planting, insecticides, weeding, harvesting, labour, supervision, fuel. They exclude capital items such as tractors, irrigation systems, sheds, etc. The lower figure of R12000 is used since 'supervision' is budgeted for under overheads. Furthermore the 'labour' cost is taken as zero, since the participants are all entrepreneurs who are remunerated via their share of the surplus.
3 Note that interest is only calculated on the outstanding loan, which is repaid over 5 years in 5 annual instalments at the end of each financial year. On this basis the average interest is 60% of the initial payment.
4 The 'utilization' is reduced to to 75% to allow for some inefficiencies.
5 Training will include the fundaments of cultivation, irrigation, productivity, bussiness principles, etc.
6 A record will be kept of each farmer's expenses and income to arive at the distributable surplus that each farmer is entitled to.
7 See table 2.
8 The long term loan equates to the sum of all the 'capital' items.
9 Farm establishment covers such aspects as clearing trees, ripping, etc.
10 Equipment includes such items as spades, hoes, sprayers, barrows etc.
11 This includes a pressure regulator between each tap and the 50mm surface pipe from which the dripper lines eminate (12mm x 1mm thick dripper lines spaced at 1m). Perforations are 1mm in diameter and are spaced 300mm appart. They allow 2 litres per hour.
12 Implies a simple scraping exercise with a grader, possibly with some shaping of the road's profile to get the water off. Thereafter each entrepreneur should maintain the road adjacent to his/her plot. A serviceable road is an important aspect of getting the produce to the market.
13 Start up capital is taken as 50% of the overhead costs, and allows for 6 months of 'overhead costs', after which this expense will be paid by income that is generated from the sale of produce.
14 Water usage is based on 6mm/day x 10 ha x 10000m2/ha x 365 days/yr. This is clearly conservative given that no irrigation is required when it rains, and that the projected production efficiency is only 75%, but it does allow for future expansion.
15 The short term loan relates to financing production (listed in note 2) as well as the cost of the water. It is taken as 1/3 of the 'production' and 'water usage' costs (i.e. it covers 4 months).

APPENDIX 3

Proposal

Upgrading of Diversion Weir

at

Fertillis

Limpopo Province

Prepared by Nicholas Papenfus
PhD(WITS), MSAICE, MICT, Pr Eng

of

Dams for Africa

for

Limpopo Department of Agriculture

24-11-2003

Summary

It is proposed that improvements be made to the diversion weir at Fertillis so that the level of the impounded water is raised sufficiently to divert water into the irrigation canal that services approximately 157 hectares of fertile communal land. A sluice gate should be incorporated at the beginning of the canal to adjust the flow.

The cost of this work is likely to be of the order of R183000, excl VAT. Implementation should commence as soon as possible to allow a crop to be grown this year.

Background

The heavy rains of 1999 and 2000 resulted in flood conditions in the Mohlapitse river. This resulted in the diversion weir being washed away, and damage to some sections of the concrete irrigation canal. This has caused considerable hardship to the farmers, who collectively operate 157 hectares in the fertile (Fertillis) valley. Accordingly the farmers requested that DFA make this representation to LDA on their behalf.

A Statement of the Problem

In June/July of 2003 a weir made of gabions was constructed across the river where the old weir had been. In this project the Limpopo Department of Agriculture (LDA) supplied the materials (gabion mattresses) and the community installed them. The structure is shown in figures 1 through 3, and the community leaders are seen in figure 2. While the structure appears to have adequate stability in most places, it also has some serious deficiencies, which may be summarised as follows:

1. Water flows freely through the gabions, and as a result the impounded water does not rise sufficiently for water to be diverted into the canal.
2. There is no means of controlling the amount of water that will go down the canal. Thus the flow in the canal depends solely on the level of the impounded water – which in turn depends on the amount of water coming down the river.
3. There is no flood control barrier at the entrance to the canal to protect it from excessive flows in flood conditions. This has resulted in water undermining the canal (see figure 4).
4. The top of the gabion weir is not level, rising and falling substantially in places. This means that instead of water flowing over it in an even sheet, it will be concentrated in places, thus increasing the probability of damage at these places.

Proposed Solution - Weir

It is proposed that a reinforced concrete wall be constructed immediately upstream of the new gabion weir. This wall need not be wide as it will derive its stability against overturning from the gabions, but it should be deep enough to act as a cut off. The top of the wall should be perfectly level to allow the water to overflow in an even sheet, and it should be higher at the flanks of the river so that the water remains in the stream zone. The additional height at the flanks also prevents excessive water from flowing down the canal. The flow in the canal should be controlled by a sluice gate.

Figure 5 shows the general arrangement of this solution, while figure 6 gives an example of a correctly designed/constructed diversion weir. Notice that the overflow level of the weir is appropriately higher than the invert level (IL) of the canal, allowing water to flow into the canal. Figure 7 shows the associated sluice-gate in operation. The flow is controlled by means of removable plates - a very simple cost effective arrangement.

Proposed Solution - Canal

DFA have specialised experience in rehabilitating canals and are in a position to evaluate the extent of the damage and thereafter give a price to reinstate it. Alternatively DFA can train handpicked individuals from the local community to do the repairs using a more labour intensive method.

Figure 1 - Gabion Weir as seen from the west bank - built by community and LDA

Figure 2 – Concerned community leaders at Fertillis on 14th November, 2003 – notice the geofabric in the foreground

Figure 3 - Upstream view of gabion weir – the water in the river passes directly through the gabions, and virtually no water goes into the canal.

Figure 4 - The upstream level is too low to make the water flow in the canal. Notice how the supporting material has been eroded because there is no barrier wall at the start of the canal.

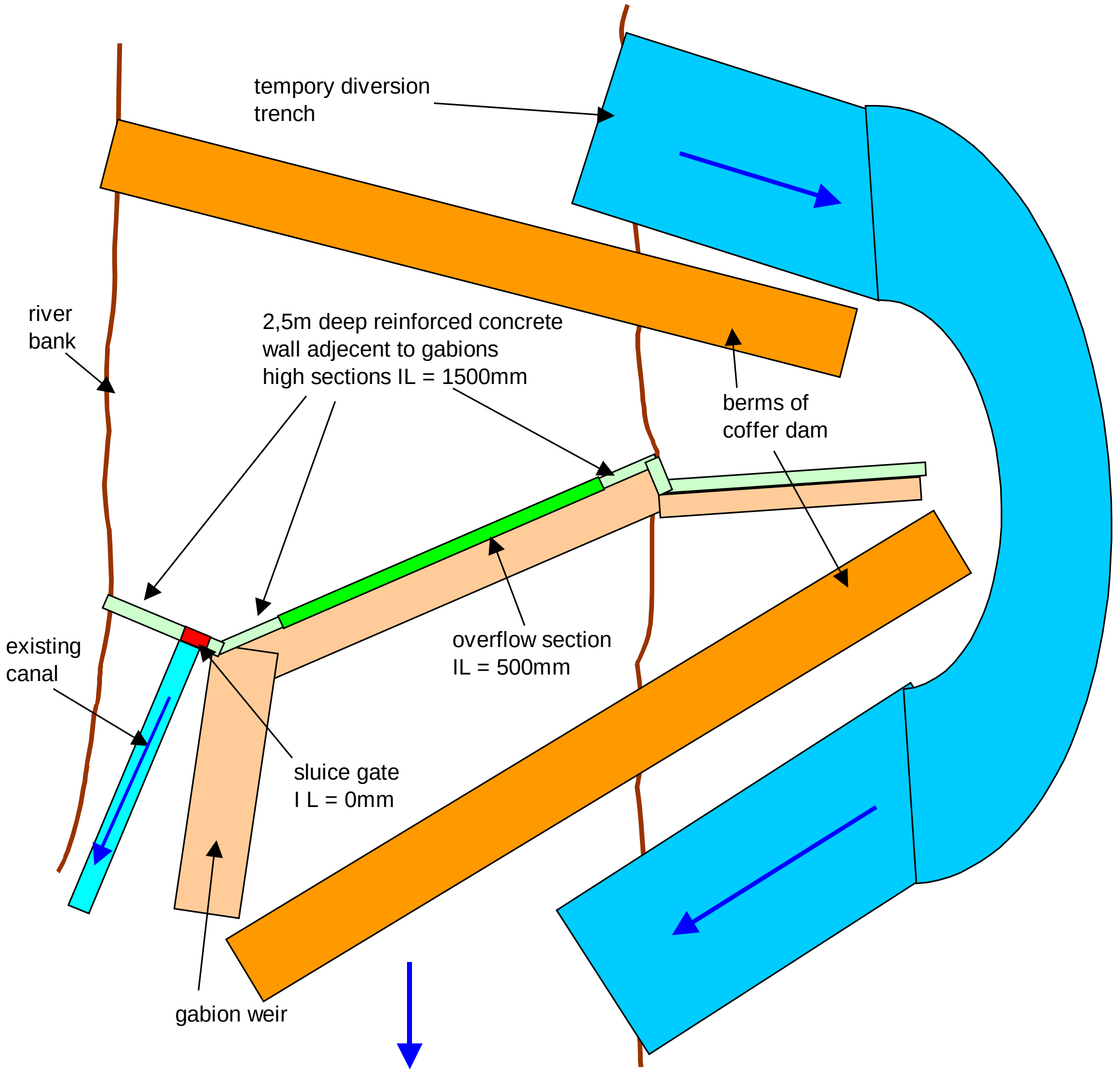

Figure 5 – General arrangement of proposed diversion weir. A deep RC weir is built directly behind the stable gabion weir, and is higher at the sides. A sluice gate is included. Note the temporary diversion trench, and the berms of the coffer dam.

Figure 6 – The diversion weir and sluice gate off-take at the start of the 7km canal at GaMathabatha (about 40km from Fertillis). The weir and this section of the canal were build by DFA in July 2003 and are additions to an existing 7km canal.

Figure 7 – A simple sluice gate, made from removable steel plates to allow adjustable flow.

Price

The combined price for upgrading the diversion weir, including establishment, construction of diversion trench, construction of a simple coffer dam, supply of materials, labour, supervision, travelling, accommodation, and administration is R183000 excl VAT. The assessment of the damage to the canal will be done at no charge once the construction team is established on site. However if an investigation, report and price are required as a separate exercise, a fee of R7000 will be required.

Implementation

It is vital that implementation commences as soon as possible to allow crops to be grown and harvested before the winter season.

Validity period

The prices given above are effective for 30 days.

Terms of Payment

Within 7 days of submission of monthly certificate.

Conclusion

Dams for Africa would like to be of service to the farmers at Fertillis by upgrading the diversion weir so that a flow, which is controllable, can again be restored to the canal system. A relatively small investment will have a large and lasting benefit in their water supply. DFA will also make an assessment of the state of the canals and teach the community how to repair them.

APPENDIX 4

Proposed TOR for Turnkey Engineer – Fertillis, Canyon and Lucern - RESIS programme

Written by Nicholas Papenfus and submitted to Marne de Lange for consideration.

Background

RESIS requires the services of a Turnkey Engineer (TE) for the revitalization of irrigation schemes on the farms Fertillis.

The nature of the revitalization work is such that one TE should be able to supervise the various projects at both sites.

On each of the sites some of the tasks are relatively complex and will require the services of a specialist contractor, while other jobs are relatively simple and may be done by labour sourced from the local community working under the supervision of the TE.

In the case of work done by the Contractor the TE is effectively is the link between the requirements of the Department and the Contractor. The Contractor will report to the TE, who must supply him with the correct drawings and documents, and show him where the various sites are. Thereafter the contractor is expected to execute the work from the working drawings with minimal guidance from the TE. Ideally the TE's involvement with the contractor should be limited to occasional monitoring to satisfy himself that the work is being carried out in accordance with the drawings and specifications, as well as measuring and checking the contractor's payment certificates.

On the other hand, the TE will need to be far more involved with the tasks carried out by the community. This will include recruiting and training at the start of a task, defining the daily task and ensuring that targets are met, defining the standard of work, and measuring up for payment. During the training stage, which will mostly be on-the-job-training, the TE will need to closely monitor activities until satisfied that the work is being done as required.

Some of this work will be of a very simple nature such as cleaning of canals and their verges, and teams should be operating at full efficiency within a day or two under the leadership of team leaders. However, for more technical tasks, such canal repairs, it may take a week of training before a measure of efficiency is reached. In this case the workforce should be sourced more selectively – ideally only bricklayers or plasterers that already have a trained eye/hand and who have a feel for concrete/cement should be chosen. However, such persons are generally available in the surrounding villages and can be sourced (via the grapevine) without too much difficulty.

The TE should respect the powers that be, and be sensitive to their feelings and fears, and should establish and maintain relations with the community leaders, the farmers and their leaders, the tribal authority, the municipal authority, the local department of agriculture, including the extension officers.

The ideal candidate for this position will be someone that has a diploma as a civil engineer and should ideally be able to design concrete mixes and work with concrete, and be sufficiently practical to show bricklayers and plasterers how to repair irrigation canals. Some exposure to sourcing and working with plant such as TLBs, mixers, and pumps will also be advantageous. A knowledge of gabion construction is also desirable.

The candidate should also be someone who can organise and work with labour, and should have a 'heart' for uplifting struggling farmers.

It is recommended that the SAICE guidelines be consulted and that the candidate be remunerated on the scale of a qualified technician with 10 years experience.

In using the locals wherever possible, and in teaching them certain skills, the TE will need to convey materials and tools and people on a regular basis – at one site, and between the two sites. The TE should therefore be equipped with a one tonne bakkie, which should be equipped with an air conditioner given the extreme temperatures of that region.

The TE should also receive a living out allowance, even if he/she commutes from Polokwane – as a means of compensating for the 70 minutes that it takes to get to site.

Finally, it will be an advantage if the candidate can communicate in the language of the Bapedi.

The contract period at these sites is likely to extend for two to three months, after which the TE must be prepared to locate to a different site/s in Polokwane, if called upon to do so. The total contract period is four years and the possibility of continuous employment for this period, assuming good performance, is good.