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WATER SUPPLY FOR GEDAREF; ARE INFILTRATION GALLERIES THE ANSWER?

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Summary

A number of technical alternatives for improving the water supply to Gedaref, Sudan, are investigated. Of the short term improvements proposed, none is likely to improve upon the present system of continual digging of a channel to convey river water to the silted intakes. In the long term, construction of a radial collector well infiltration gallery system appears to offer advantages over a new surface intake and improvements to the existing treatment plant.

1. Introduction

This paper investigates some of the problems associated with the water supply for Gedaref in South Eastern Sudan. The aim is to review some of the technical solutions and provide a basis from which a more detailed technical and economic analysis could be carried out. Due largely to the lack of field data, the calculations are by no means exhaustive, and economic analysis has not been attempted.

The present population of Gedaref is about 150 000; improvements to the traditional water supplies from shallow wells and rain water storage tanks were made in 1960 when a number of boreholes were sunk to the south west of the town (8,13). The supply was further increased in 1970 when a river intake and treatment works were constructed on the Atbara river at El Showak, 70 km north east of the town. The treatment comprises coagulation using alum and lime, rapid sand filtration and chlorination. Treated water is pumped through a 500 mm spun iron pipeline to Gedaref. The works provides about 8200 m³/day, although the design capacity is about 12 500 m³/day (13).

2. Problems at El Showak

Major problems have arisen due to the high suspended solids load in the Atbara river in the wet season. Deposition caused radical changes in the river channel geometry, with the result that after less than two years the intake works had silted and ceased to be used; over 6 metres of silt had accumulated. Two pumps were then sited on the river bank, and a channel dug from the low flow channel across to the pumps, figure 1; maintaining this channel requires fifty men for eight months of the year, at considerable cost. The high suspended solids load causes problems in the clarifier, and the rapid gravity sand filters clog up very rapidly. The treated water still contains some silt, and to add to the problems, the transmission main to Gedaref was not provided with washouts. Due to lack of spares, pumping and mechanical equipment does not function adequately. There is no shortage of raw water; in 1980 the discharge ranged from about 15 m³/s to 3100 m³/s.

3. Remedies for the problems

A number of remedies have been proposed by different organizations; to overcome short term problems they include:

(a) construction of a causeway across the river to carry the pumps to the low flow channel;
(b) continuous dredging by excavator;
(c) construction of a low diversion wall in the river;

and for long term problems:

(d) construction of sedimentation tanks and additional filters;
(e) a new intake works;
(f) rehabilitation and expansion of the borehole system;
(g) construction of an infiltration gallery.

4. Assessment of short term remedies

4.1 Causeway and excavator

A causeway to carry the pumps to the low flow channel could suffer serious damage during the wet season. The proposal to sink two rows of piles across the river, along which an excavator would run is frought with practical difficulties. Neither proposal is considered realistic.

4.2 Diversion wall

The object of constructing a low diversion wall out of gabions is to divert water from the low flow channel to the intakes. The effects of such training works on unstable rivers in alluvium are unpredictable, and the proposal was investigated using a hydraulic model. A distorted scale Froude number model having horizontal and vertical scale ratios of 200 and 50 respectively was used (1). The prototype hydraulic characteristics and sediment loads, table 1, were estimated from Lacey's regime equations, and Petersons universal flow charts (6); the cross section of the main river channel is shown in fig 1b. The model was run using the minimum 1980 discharge of 15 m^3/s, and an intermediate flow of 300 m^3/s, at which it was estimated that the diversion channel would flow bank-full. The resulting cross sections and longitudinal section are shown on figs 2 and 3. The main problems found were:

(a) severe scour around the intake house, with holes up to 7m below original bed level, and possible collapse;

(b) severe recession of the river bank where the abstraction pumps are placed;

(c) scour in front of the gabion wall which may lead to its collapse, even at minimum flow;

(d) the system is highly unstable at a flow of 300 m^3/s;

(e) the gabion wall is unlikely to survive at 3100 m^3/s.

The gabion diversion wall seems to create more problems than it solves, and is not recommended.

5. Assessment of long term remedies

5.1 New intake works

The Atbara river is clearly unstable, and there is no guarantee that a new intake further upstream would not suffer the same fate as the existing one.

5.2 Improving the treatment works

During and after high river flows, sediment loads in excess of 1000 ppm may well be common, and values as high as 16 000 ppm have been known. If sedimentation tanks providing up to 2 days retention are provided, sludge may accumulate at rates between 200 and 2500 m^3 per day, assuming 80% solids removal (4). At least three tanks of 15 000 m^3 capacity, and further pumping, would be required. If smaller horizontal flow tanks having a retention time of about 4 hours were used sludge would accumulate rapidly, requiring either mechanical cleaning or a large number of tanks in parallel. Whilst reducing the sediment load, operation and maintenance requirements would be increased. The benefits from these proposals cannot be realized until the basic problem of the intake works has been solved, given that the gabion wall is unlikely to survive the wet season.

5.3 Borehole rehabilitation and extension

Eight boreholes south west of Gedaref could be rehabilitated to provide about 10% of the demand (8). Unconfirmed pump tests in the region of the El Showak works indicate that a further 18 boreholes may be required to supplement them. The running costs of such a large number of pump sets could prove prohibitive.

5.4 Infiltration galleries

Infiltration galleries are horizontal permeable conduits which intercept and collect groundwater which is often principally derived from infiltration of nearby surface water; they have been widely used in India and USA (10). Galleries can be constructed within a river, or along the banks, with open jointed or perforated pipes projecting under the river bed, fig 4. If the river bed is coarse sand or gravel the potential yield may be high; the 'rule of thumb' used in South India is 20 m^3/day per metre of gallery. The advantages offered include (9,10):

(a) the recharging river water is effectively filtered by sand or gravel, reducing turbidity, colour, organic and bacterial pollutants;

(b) comparatively little skilled supervision is required during operation;

(c) running costs involving chemicals and mechanical and electrical plant are low;

(d) disinfection is usually the only treatment required.

Preliminary calculations indicated that a gallery may need to be 15 m to 20 m below the Atbara river bed level. Indian practice (12) is to lay open jointed pipes in a manually excavated trench up to depths of 8 or 10 metres below bed level. When the depth has to be greater, perforated steel pipes are jacked out radially from a concrete caisson sunk into the river bed, fig 4. This radial collector well system is also known as a Ranney well. A graded gravel pack is usually placed around the gallery pipes; this is not usually feasible with pipe jacking, but as the pipe is jacked into position, fine materials are removed from the vicinity of the pipe, and a natural pack tends to develop. (9,11, 14).

The following calculations are based on the design procedure used in South India (12). The system is designed to provide 12 500 m^3/day (the capacity of the treatment works) which should be sufficient to provide the existing population with 50 litres per person per day.

If the entrance velocity of the water through the perforations is limited to 6 mm/s (2,12), the required open area of pipe is 24.1 m^2; if the pipes have an open area of 18%, and operate with 40% blocked, the required length of 300 mm diameter pipe is

$$24.1/(0.18 \times 0.60 \times \pi \times 0.3) = 237 \text{ metres.}$$

Thus 4 N° 60 metre lengths would be required; for optimum yield, the angle between pipe centrelines should be greater than 20°; in this case, 30° would be adequate, as shown in fig 4.

In order to fix the invert level of the radial collector pipes, the lowest water table level in the dry season, and the drawdown resulting from abstraction from the aquifer must be known. Estimation of the drawdown is extremely complicated, but in practice a reasonable result can be obtained empirically from using the Theiss equation for unsteady flow in an unconfined aquifer, assuming that the system behaves as a vertical well with an effective radius 0.75 times the length of the radial collector pipes (12). The unconfirmed pump tests and preliminary geophysical survey indicate that the sand and gravel aquifer has a transmissivity of about 2880 m^2/day, and a minimum dry season water table 14 m below existing bed level. The maximum drawdown will occur if there is little or no recharge from the river in the dry season. Data on recharge are not available, and so a 90 day period without recharge is assumed.

Thus $y = \frac{Q}{4\pi T} W(u)$ where $u = \frac{r^2 s}{4Tt}$

and Q = abstracted flow (12 500 m^3/day), T = transmissivity, r = effective radius (45m), t = pumping time (90 days) S = aquifer specific yield (assumed to be 0.2) and y is the drawdown estimated for the effective radius r. Thus:

$u = 4 \times 10^{-4}$ and w(u) = 7.25, obtained from standard tables (5); the drawdown is hence about 2.5 metres. Allowing for the pipe thickness of 0.3 m, and a "safety" allowance of 0.5 metres (12), the invert level of the radial collector pipes should be 17.3m below river bed level (fig 4). It must be stressed that these calculations are based on inadequate data, and only serve to indicate a possible design method.

A problem with infiltration galleries and radial collector wells is the possible reduction in yield over a period of time due to clogging, and organic growths and inorganic encrustations around the perforations. However, such systems have operated satisfactorily for many years (10).

6. Conclusions

(a) None of the short term proposals appear to offer advantages over the present system of digging a channel through to the pumps.

(b) There is no obvious solution regarding improvements to the silted intake house. There is no point in improving the treatment works unless this problem can be satisfactorily resolved. Cleaning out new sedimentation tanks and overloading of the clarifiers and filters is likely to continue to cause operational problems when the sediment load in the raw water is high.

(c) Boreholes could satisfy the water demand, but initial indications are that the number required may be prohibitively large.

(d) A radial collector well consisting of 4 No. 60 metre lengths of 300 mm pipe jacked into the aquifer beneath the Atbara river bed would appear to satisfy the present water demand. The only treatment required is likely to be disinfection; equipment is available at the El Showak treatment plant. Other units in the plant are unlikely to be necessary. A detailed site investigation of the aquifer is required to enable more accurate calculations to be performed.

(e) There is ample scope for increasing the supply by installing more radial collector pipes to the well. In a more detailed design, the population projections and per capita water consumption for the design life of the project must be carefully considered.

7. References

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Table 1: Hydraulic characteristics

	Diversion channel		Main channel
Discharge (m^3/s)	15	300*	3100
Flow depth (m)	2.3	4.5	6.8
Mean width (m)	20	75	280
Sediment load (kg/s)	0	30	3100

*Estimated bank full discharge

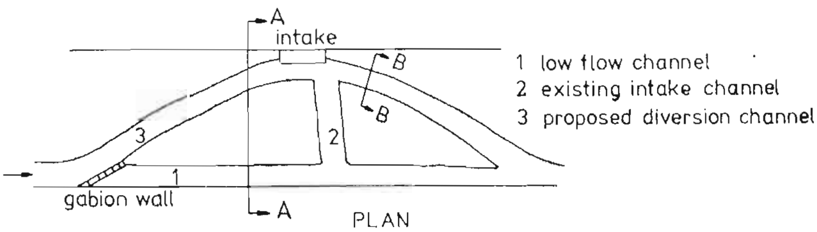

FIG 1 EL SHOWAK INTAKE WORKS

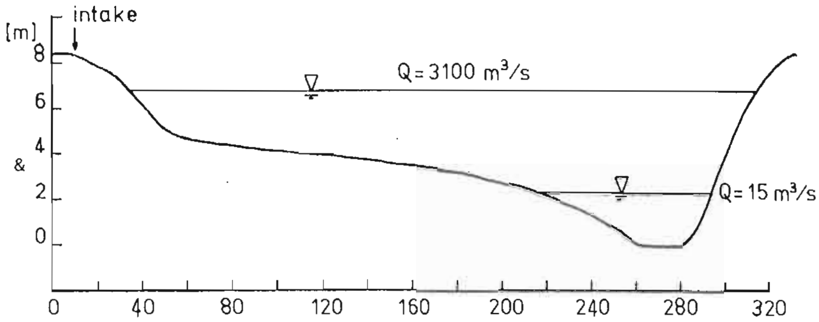

FIG 1b SECTION AA

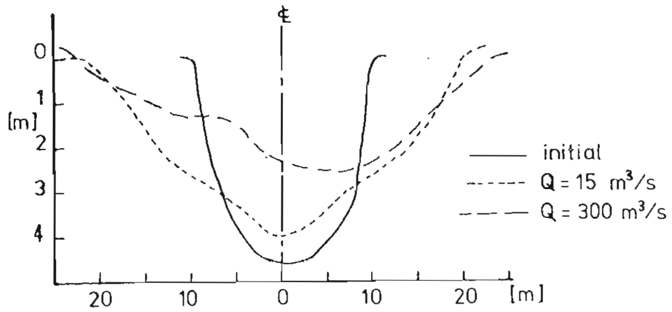

FIG 2 SECTION BB

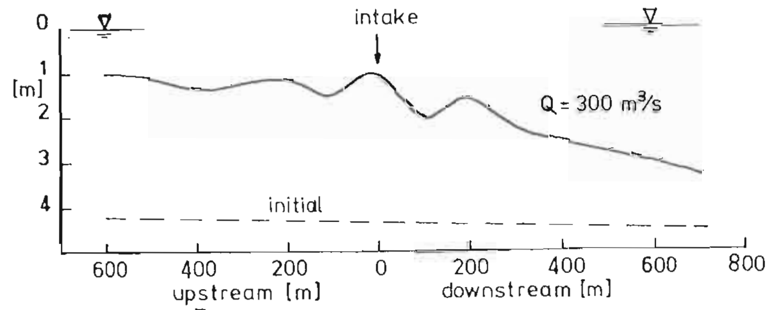

FIG 3 LONG^T. SECTION OF DIVERSION CHANNEL

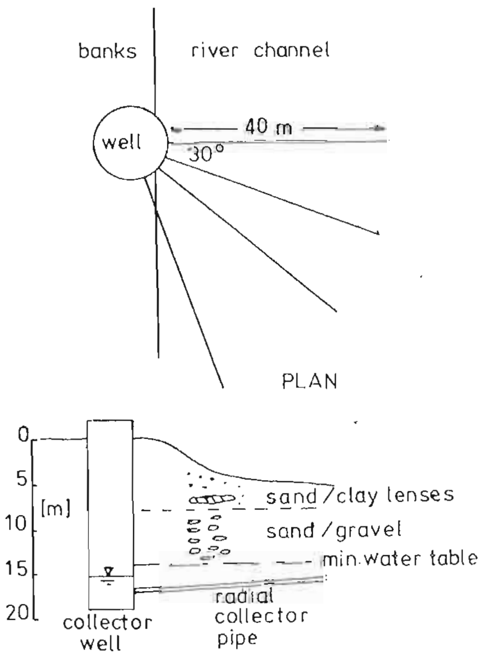

FIG 4 INFILTRATION GALLERY : SECTION