Marib Dam: the importance of environmental and health impact studies for development projects

I.A.A. Basahi[1]

سد مأرب: أهمية دراسات الأثر البيئي والصحي للمشروعات الإنمائية

إلهام علي عبد الله باصهي

خلاصة: بني سد مأرب من دون إجراء دراسة لتقدير أثره البيئي، الأمر الذي نشأت عنه منازعات كثيرة. وفي العامين 1995 و1996 تمت دراسة أثره في نوعية المياه، وفي الزراعة، وتعويض المياه الجوفية، وجوانبه الاجتماعية والاقتصادية. إن مياه البحيرة يمكن أن تصاب بالخصوبة الطحلبية الكثيفة عندما تضعف الفيضانات ولا يمكن التحكم في نمو الطحالب. ولقد أتاح استعمال التِلابيّة النيلية مكافحة بيولوجية لنمو الطحالب. ولكن السد كانت له آثار إيجابية على الزراعة والمياه الجوفية في إطار نظام الري الموضوع، وإن كانت آثاره سلبية عليهما في خارج هذا الإطار. كما كانت للسد آثار سلبية في الأحوال الصحية، وزاد من المنازعات على توزيع المياه. وكانت آثاره إيجابية على النساء حيث يسّر لهن العمل بالزراعة والمشاركة في اتخاذ القرارات. كما أنه زاد مستويات دخل المزارعين وشجّع السياحة.

ABSTRACT Marib Dam was built without an environmental impact assessment study which created many conflicts. In 1995 and 1996 its impact on water quality, agriculture and groundwater recharge and socioeconomics was studied. Lake water could suffer severe eutrophication when floods are weak and algae growth is not controlled. Introducing *Tilapia nilotica* provided biological control of algae growth. The dam positively affected agriculture and groundwater within the designed irrigation scheme but negatively affected them beyond it. The dam also negatively affected health conditions and increased conflicts over water distribution. It positively affected women by allowing them to work in agriculture and participate in decision-making. The dam raised income levels of farmers and encouraged tourism.

Le barrage de Marib: étude de cas sur l'importance des études d'impact sur l'environnement et la santé pour les projets de développement

RESUME Le barrage de Marib a été construit sans qu'une étude d'impact sur l'environnement ait été réalisée, ce qui a généré de nombreux conflits. En 1995 et 1996, son impact sur la qualité de l'eau, l'agriculture, la recharge de la nappe souterraine ainsi que sur le plan socioéconomique a été étudié. Les eaux du lac peuvent devenir eutrophes lorsque les crues sont peu abondantes et la croissance algale n'est pas contrôlée. L'introduction de *Tilapia nilotica* a permis le contrôle biologique de la croissance algale. Le barrage a eu un impact positif sur l'agriculture et la nappe souterraine dans le périmètre du projet d'irrigation mis en oeuvre mais un impact négatif à l'extérieur de cette zone. Le barrage a également affecté les conditions sanitaires et a fait augmenter les conflits relatifs à la distribution de l'eau. Il a eu un effet favorable pour les femmes en leur permettant de travailler dans l'agriculture et de participer au processus de prise de décision. Le barrage a permis d'accroître les revenus des agriculteurs et de promouvoir le tourisme.

[1] *Faculty of Engineering, Sana'a University, Sana'a, Republic of Yemen.*
Received: 20/05/98; accepted: 24/05/99

Introduction

Marib has been one of the most famous areas in the Republic of Yemen since ancient times. It was well known historically as "Arabia Felix" or the "Land of the Two Paradises". A great civilization flourished there under the famous Queen of Sheba. It was also known for the "Great Ancient Marib Dam" and irrigation canals that suggest that the Yemenis were the pioneers of irrigation systems.

Marib is in the eastern region of the country at latitude 15.30 °N and longitude 45.20 °E. It is approximately 1200 m above sea level. The climate is typical of arid regions with an estimated annual rainfall of 50–100 mm and an average potential evaporation of 2700 mm. March–May and July–August are the seasons of rain and flood in Marib. Temperatures are typical of arid regions with a large diurnal variation; absolute maxima of approximately 40 °C occur in the July–August summer season and absolute minima reach 0 °C during the December–January winter season.

The new Marib Dam was proposed in 1980, but the idea was not initiated by the beneficiaries. Environmental impact assessment practice was still unknown in the Republic of Yemen and construction began without it. Some studies were conducted after the dam had begun operation in 1987 [*1–4*]. Floods which occurred twice yearly began filling the dam in 1986. Annual flood inflows in million cubic metres for the years 1986–96 were recorded as: 85, 135, 90, 50, 50, 25, 130, 196, 27, 48 and 370 respectively. The flooded land was previously a flood passage which was owned by tribes but was too dangerous to settle upon. Landowners received compensation from the government.

The Marib Dam is an earth dam with a maximum height of 40 m, crest length 763 m and maximum retention volume of 398 million cubic metres. Dead storage is 5 million cubic metres. The dam has one outlet with an invert level of 1.0 m above the lake bottom. The dam is connected to the first diversion lake by a natural wadi, or earth canal, about 11 km long. The released flow is subject to 30%–40% losses due to seepage and evaporation on the way to diversion lake A of 2.85m depth and 200 000 cubic metres capacity which irrigates an area of 405 hectares. The rest of the flow is directed to another earth canal, 5 km long, that conveys the water to diversion lake B, which has a maximum water height of 5.2 m and a capacity of 1.08 million cubic metres which irrigates an area of 700 hectares. The total area irrigated by the diversion lakes A and B is approximately 1100 hectares. The total length of the irrigation canals was designed to irrigate a final total area of 7403 hectares of agricultural lands (Figure 1).

In the summer of 1993 lake water began having quality problems. The lake suffered from severe eutrophication conditions. Algae blooms were observed covering large areas of the lake surface and bad smells were reported to occur at different times. Algae counts of up to 10 000 units/mL were reported from random water samples from the surface of the lake in January 1994 [*5–6*]. Algae species were identified as a mixture of green algae, blue-green algae and diatoms. Green algae was the dominant species.

The present work had six objectives:

- to study the impact of water retention on the quality of lake water;
- to study the impact of using retained water for irrigation purposes and its effect on soil and crop yield and on the efficiency of modern irrigation techniques;

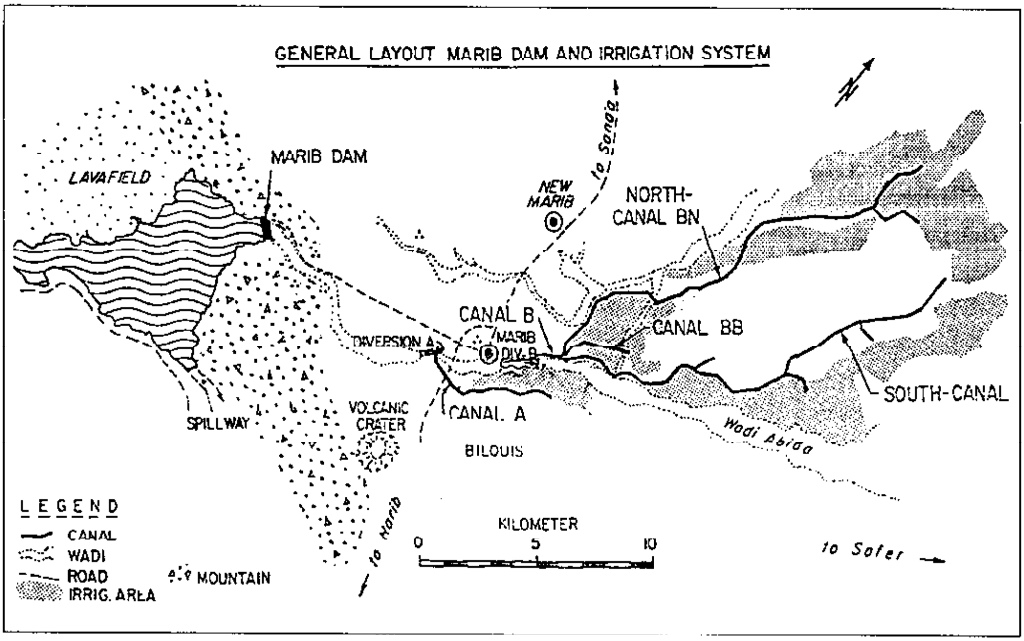

Figure 1 **General layout of Marib Dam and irrigation system**

- to study the impact of building the dam and its irrigation canals on the health of humans and animals;
- to investigate the impact of using lake water for groundwater recharge and its effect on the quality of drinking water extracted from surrounding wells;
- to evaluate socioeconomic impact of the dam; and
- to present mitigating measures.

Methods

A work programme was designed to study the nature and morphology of the lake in addition to water quality conditions at defined locations and depths in the lake. A sampling programme was designed for January–June 1995. Water samples were collected every 2 weeks from three stations along the centre line of the lake. The stations were fixed at distances of 0.02 km, 0.5 km and 1.0 km from the body of the dam. Water samples were collected from each station from the surface, from 1.0 m below the surface and from 1.0 m above the bottom of the lake. Additional samples were also taken at 2.0 m depth intervals for temperature and dissolved oxygen measurements. The depth of the lake at the beginning of the sampling was approximately 12.765 m. At the end of the programme the depth had increased to 18.580 m because of floods entering the lake in March 1995.

A similar sampling programme was designed to extend from March to December 1996. The programme included regular biweekly visits to the Marib Dam and its irrigation system where water samples were collected from the previously fixed stations and depths of the lake. Water samples were also collected from main canals, diversion lakes and some of the surrounding wells at various distances from the dam and recharge points.

Physical and chemical tests to analyse water samples from the lake and other locations on the irrigation scheme were chosen carefully to identify changes in water quality due to retention and the suitability of the water for irrigation purposes. Water samples from the lake were tested for Secchi Disk measurement, temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), nitrates (N), orthophosphates (P), total hardness, chlorophyll A and/or algae count and identification.

Levels of nitrates and of total coliform bacteria were measured in wells used for drinking water. Calcium, magnesium and sodium were tested in both surface and well water to calculate the sodium adsorption ratio (SAR). Boron levels were also tested in both ground and surface water.

Surface samples from the diversion lakes and main earth canals were analysed for algae species, the existence of snails and *Schistosoma* larvae as well as insects such as flies and mosquitos. The samples were taken when the canals were empty and contained residual stagnant water from previous releases and floods from tributaries and also when water was flowing after the opening of the dam outlet.

All tests were carried out according to the *Standard methods for the examination of water and wastewater* [7].

The work programme also included interviews with farmers, families, staff members of the Eastern Region Agricultural Development Authority (ERADA), the Marib Agriculture Research Centre, medical staff working in the health unit and a paediatrician who ran a private clinic in Marib.

Results

During the 1995 study period, the Secchi Disk depth was 0.35 m in January, rose to an average of 0.70 m during April and reached 1.1 m in May and June. The transparency of the water was affected by extensive algal growth in January 1995 but had improved in April due to dilution by entering floods in March. The pH values were 7.2 for surface samples and 6.6 for bottom samples. Dissolved oxygen levels were between 9.8 mg/L and 5.6 mg/L at the surface and 8.5 mg/L and 3.2 mg/L at the bottom of the lake. Temperature at the surface was around 16.5 °C in the winter months and rose to 26–28 °C in May and June. Temperature differences between surface and bottom water samples were 1°C during the winter months and increased gradually to 4 °C in June 1995. Chlorophyll A concentrations averaged 17 mg/L; nitrate-nitrogen was 0.15 mg/L and rose to 3.48 mg/L after the entrance of floods; and orthophosphate-phosphorus levels were 0.075 mg/L and rose to 1.68 mg/L after the entrance of floods. Turbidity and electrical conductivity measured after the entrance of floods were 39 FTU and 600 mmhos/cm respectively. Total hardness averaged 65 mg/L as calcium carbonate

The results of the tests and the size of the lake indicate that the lake can be considered as a single stirred tank that has a special type of thermal stratification with higher temperatures always maintained at the top. Mechanical mixing of the lake was only due to wind action. The lake was considered eutrophic and remained aerobic throughout the water column.

The results of the second sampling programme from March to December 1996 were very much influenced by the huge quantities of floods entering the lake during the months of March–July 1996.

The floods began entering the lake in March at the beginning of the first rainy season of 1996. During the months of April and June, many regions in the Republic of Yemen were subjected to disastrous floods and Marib was announced a disaster area. The Marib Dam protected the agricultural lands directly downstream, but other flood passages and tributaries caused extensive damage. The damage included loss of human and animal lives, demolition of houses and hydraulic structures and washing away of fertile agricultural lands. The irrigation canals were greatly affected by the floods and one of the structures at diversion lake A was flushed away. The lake was almost filled to its maximum storage capacity for the first time since the dam was constructed. The water depth reached 32 m although the outlet was constantly open while the lake received the incoming floods.

In the lake, the temperature ranged from 26 °C at the surface to 21 °C at the bottom and the pH value fluctuated from 6.5–7 at the surface to 6.5 at the bottom. The lake remained aerobic throughout the water column but low concentrations of dissolved oxygen reaching 3.3 mg/L were recorded in June at the depth of 22 m below the surface. The turbidity measured just after the entrance of floods was 110 FTU. Average concentrations of nitrate-nitrogen fluctuated slightly between 0.7 mg/L and 0.8 mg/L, while those for orthophosphate-phosphorus were within the range of 0.1–0.3 mg/L. The electrical conductivity range was 380–450 μS/cm.

Algae were mainly of the green microscopic species and concentrations were always below the detectable levels of the chlorophyll A method. This was mainly due to the continuous entrance of floods into the lake which caused dilution, mixing and high turbidity levels. A weak growth of algae was observed during the month of August. Experts from the Arab Organization for Agricultural Development identified algal species and counts during the months of September–December 1996. Algae counts at the three fixed stations on the lake averaged 23 units/mL and the algae were identified as a mixture of green algae, blue-green algae and diatoms. The counts were found to be higher at the shores reaching 447 units/mL in December 1996 [*6*].

In early September 1996, it was decided in consultation with experts from the Arab Organization for Agricultural Development to feed the lake with 4000 fish of the species *Tilapia nilotica*. The fish were brought from Sudan and were fed in two stages into Marib Lake. This type of fish is common in river waters and is known to feed directly on algae as its primary food. Reproduction rates of this fish are very high. A female fish produces 2000 eggs every year and the mortality rate is low because of to the nature of breeding in which the mother keeps its young in its mouth until they are mature enough to fend for themselves. A female fish can produce eggs 4–5 times a year. The fish is known for its quick growth (sexual maturity is reached in 6 months) and its great tolerance for the decay of dead algae and poisons produced by some algae species. Unlike Chinese carp fish that already inhabited the lake, this fish usually thrives only in the upper layers of water and does not go to levels deeper than 8 m from the surface. This is considered an advantage as it ensures that the fish will not escape from the lake with released water unless the water level drops to that depth.

Before opening the dam gate in October, the beds of diversion lake A and the main canal leading to diversion lake B were covered by a thick layer of algae which formed a cardboard-like mat. The bed of the empty diversion lake B could be clearly observed by naked eye to be infested with insects and it was evident that no maintenance had been performed for a long time. The analysis of surface samples taken from diversion lakes A and B, the main canal and the seepage ponds formed along the side of the canal detected the presence of cercariae of *Schistosoma*.

On analysing a surface water sample taken from one of the irrigation canals of a small field, the following were obtained:

Temperature:	30.1 °C
pH:	8.8
EC:	330 μS/cm
Sodium:	1.57 meq/L
SAR:	1.35
Boron:	1.3 mg/L

The samples taken from wells between March and June exhibited distinct differences in most tested parameters between the wells near recharge points and the wells far from those locations. The nitrate levels of samples from the nearby wells were 44 mg/L on average, whereas the concentrations of nitrates in the far-off wells averaged 22 mg/L. The EC of the wells near recharge points reached 1000 μS/cm whereas the EC of the far-off wells averaged 690 μS/cm. The same applied to total hardness. Bacterial contamination was detected in all wells tested. The levels of the total coliform bacteria in both the nearby and far-off wells were > 16 per 100 ml.

The effect of groundwater recharge could be seen in the analyses of samples collected in November from a nearby and a far-off well. The nearby well was 50 m deep and the rise in water level due to recharge was approximately 6 m. The far-off well was 22 m deep and the rise in water level due to recharge was about 4 m (Table 1).

Table 1 **The effect of groundwater recharge in two wells**

Variable	Nearby well	Far-off well
Temperature	30 °C	30 °C
pH	7.8	7.3
Electrical conductivity	410 μS/cm	385 μS/cm
Sodium	3.7 meq/L	2.9 meq/L
Sodium absorption ratio	3.27	2.36
Boron	0.45 mg/L	0.85 mg/L
Nitrates	6.6 mg/L	11.44 mg/L
Total hardness ($CaCO_3$)	128 mg/L	152 mg/L

Sodium and boron were tested only after recharge. If the soil is not the source of sodium and boron, then their occurrence in higher concentrations during spring and summer is highly possible, especially in the far-off wells. A boron level guideline value as low as 0.3 mg/L has been proposed for drinking water [*8*].

Discussion

Impact on soil

Farmers stated in interviews that during the past 2 years the dam water carried a lot of suspended matter which made the water much slower to penetrate the soil than well water. The infiltration problem was magnified by the growth of algae on the surface of irrigation water which could remain as stagnant water in the field for up to 3 days before percolating into the soil. Salt deposits were also left on the soil after the evaporation of water. The farmers said that the surface of their land became as hard as rock after irrigation with lake water as a result of deposits of salts, algae and silt in the surface water. This burdened them with extra work and expenditure to remove the hard layer through constant ploughing and turning soil to improve permeability for the irrigation which usually followed after 2 weeks. The farmers also mentioned that ploughing and turning soil was impossible for some crops like corn, maize, barley, wheat, fenugreek and sesame. The agricultural lands planted with such crops had suffered from severe permeability problems during the past two irrigation seasons.

SAR values obtained during the study indicated that groundwater had SAR levels of 2.36–3.27 after the recharge of the wells. These levels were near or exceeding SAR value 3 which is recommended for irrigation water for sensitive plants [*8*]. The salinity hazard of both groundwater and surface water however could be classified as medium [*9*].

Boron levels in groundwater were within the range of tolerance by sensitive plants, while the concentration of boron in surface water was potentially harmful [*9*]. Boron levels should be rechecked to determine if it naturally occurs in the soil.

Groundwater levels were too deep to consider soil salinization a serious problem in the area as a result of capillary rise and diffusion of water in the unsaturated profile.

Some farmers mentioned that they noticed that when using dam water for irrigation, many strange plants grew along with their crops and these had to be cut regularly to allow healthy growth of the main crop. This suggests that the dam water might be tainted with the seeds of undesirable plants.

The majority of the farmers interviewed lived within 20 km of the dam and the recharge points. These farmers preferred to irrigate their lands from shallow or deep wells dug or drilled in their lands and were happy about the recharge their wells received from the dam and its diversion lakes and earth canals.

Farmers living beyond this distance from the dam and recharge points stated that the dam had a negative impact on their agricultural lands and wells. The released flow was never enough to reach their lands or to recharge their wells. They complained that their agricultural lands were threatened with desertification as a result of water scarcity and sand dune encroachment.

Impact on new irrigation systems

Modem irrigation systems have been introduced in Marib recently. The drip system is already functioning in many citrus trees farms. Only well water had been used for such systems before the building of the dam. The soil moisture holding capacity of those farms favoured the use of such systems as did their advantages in the conservation of groundwater resources.

Such systems however are limited by predictable blockages at the pumps and the nozzles when the well water salt content is high. These problems can be expected to increase if a combined system is adopted. Surface water contains high levels of suspended solids, including algae, which can create problems at the pumps and the nozzles and thus reduce the efficiency of the system and increase operation and maintenance costs.

Impact on health

Earth canals and diversion lakes form an effective breeding habitat for many vector species. Seepage ponds formed as a result of infiltration along the sides of the canals also provide excellent breeding conditions for many insects. The best time to observe and to take surface samples is usually 2 weeks after the release of water from the dam. After this period, the growth of vector species is easily detectable. Irrigation schemes in semiarid regions tend to lengthen the malaria transmission season [*10*]. Malaria, schistosomiasis, typhoid and diarrhoea cases have increased dramatically since the building of the dam and its irrigation system, with an especially sharp increase in the last 3 years. Official records of the number of cases, however, could not be obtained from the health unit in Marib.

Some case records were found at the private clinic of a paediatrician who had been working in Marib for the past 10 years. The records were kept for research conducted by the doctor and they were mainly those of malaria, diarrhoea and blue babies. Those records indicated that during 1995 there were 783 reported cases of diarrhoea, 391 cases of malaria and 6 cases of blue babies. Malaria and typhoid cases increased drastically after the 1996 floods [*11*].

No significant impact was noticed on animals drinking from canal water. Some farmers said that worms were common in the intestines of animals, such as sheep and goats, and that large numbers of worms could be seen when those animals were slaughtered.

Skin rashes were common among community members living near diversion lakes and canals. The people interviewed stated that they used surface water from the canals and diversion lakes for bathing and washing clothes and utensils. They complained of insect bites at night especially during irrigation seasons.

In 1994 no floods entered the lake. The lake suffered from extreme eutrophication, decay conditions were reached and offensive smells were produced. The 1995 rainy season did not improve the condition of the lake as incoming flows were very weak and the lake was at its lowest levels. Severe eutrophication is a very strong possibility in the future and should it occur, its negative impact on the health of humans, livestock and fish would be serious.

Building the dam in a hot and dry area like Marib encouraged swimming in diversion lakes. Swimming in such waters can pose a serious health hazard especially from *Schistosoma* which normally infects humans through the skin. Drowning is another serious health hazard. During this study, two fatal accidents occurred. In May, in the main earth canal leading to diversion lake A, a 10-year-old boy drowned with his mother and sister who had attempted to rescue him. The second event occurred in August when a 13-year-old girl drowned while trying to rescue her 3-year-old sister who had slipped into the main lake. There was no emergency help available and the body was not recovered until the early morning of the next day after divers were summoned from the coastal areas of the country.

Impact on the surrounding wells

The dam and its irrigation system had a positive impact on the quality and quantity of water in wells at distances up to 20 km from those structures. The wells received adequate recharge, which raised their levels to as high as 5 m or occasionally more. Tested chemical parameters exhibited a noticeable improvement due to dilution by the recharge. Nitrates levels were reduced to an average of 6.6 mg/L in wells near the dam which were subject to recharge in comparison with concentrations of 11.44 mg/L in wells far from the dam which did not receive recharge. The farmers living within the 20 km distance were very happy to have surface water free of charge for irrigation and recharge of their wells.

The dam however had a negative impact on wells beyond 20 km from the structures.

The farmers living beyond 20 km from the dam and its scheme claimed that the discharge from the dam was too small to reach their fields or recharge their wells. Consequently they had to bear the extra costs of annually deepening their wells and frequently replacing pumps damaged by the brackish water extracted.

Socioeconomic impact

The concept of building the dam was not initiated by its beneficiaries and the dam was constructed without implementing an environmental impact assessment, which would have included a social impact study. It created enormous conflicts among the beneficiaries. The problems with the dam were reflected in the demolition of parts of the irrigation canals by angry farmers. Eventually funds were suspended and construction of phases of the project were brought to a complete halt [*3*].

Marketing and communication strategies should have been developed and ERADA should have been equipped to help farmers. The ERADA staff should have been trained and informed about proper and socially accepted channels through which disputes and conflicts could be resolved.

A higher water committee was established in 1993 with representatives from all tribes in the region. The committee settled conflicts according to tribal norms. The committee also controlled the distribution of surface water by estimating quantities released according to the areas to be irrigated.

The first cooperative in Marib was established by farmers in June 1996. The cooperative provided farmers with agricultural needs, such as insecticides, in addition to providing them with technical advice through arrangements with ERADA.

The idea of establishing farmer interest groups or water committees in certain sectors of the irrigation scheme to conduct daily management was not successful or practical as the farmers preferred to have their conflicts settled by their *hakims* or *sheikhs*. ERADA performs daily management of the canals with great difficulty because of limited staff and insufficient resources.

The impact of the dam scheme on women was positive. The expansion in irrigation led to an expansion in agricultural lands. Because additional labour was needed to work the new agricultural lands, women were allowed to work in the fields in addition to maintaining their responsibilities of tending livestock. Although more work was imposed on them, the women interviewed were happy for the gradual gain of additional power in decisions about agricultural matters.

The influx of outside investors in agriculture was another important and positive economic result of the Marib scheme. Investors from outside Marib established primarily citrus farms.

The area has a great potential for investment in other fields, such as tourism and services. The remains of the Ancient Dam, the new Marib Dam and other historic and pre-Islamic ruins are major attractions for visitors from all over the world. Tourists are been to visit Marib on their tours to the East, following the ancient incense route. Large tourist groups were keen in Marib throughout the period of this study.

Conclusions

Table 2 summarizes the impact of Marib Dam on the surrounding area and proposes mitagating measures which could be taken.

Table 2 **Impact of the Marib Dam and potential mitigating measures**

Area affected	Impact parameter	Severity of impact H	M	L	Mitigating measure
Irrigation	Soil salinity		–		Leaching water applied to soil profile; change irrigation techniques; use organic fertilizers.
	Soil permeability		–		Control algae and suspended matter; minimize evaporation.
	Soil boron content	–			Stop cultivation of sensitive crops.
	Crop type		+		Select crops that allow constant ploughing of soil.
	Crop yield		+		Select deep root crops to avoid salt accumulation in root zone.
	Pest plants			–	Constantly cut pest plants; check lake water for seeds.
	Within the dam scheme	+			
	Beyond the dam scheme	–			Complete designed canals; pump lake water.
Well water	Quantity in nearby wells	+			
	Quality in nearby wells		+		Improve quality of lake water.
	Quantity in far-off wells	–			Complete canals; pump lake water for recharge.
	Quality in far-off wells	–			Recharge.
Health of humans and animals	Typhoid	–			Stop defecation in canals; improve health services.
	Malaria	–			Community participation in vector control programme; prevent seepage lakes.
	Schistosomiasis (bilharzia)				Limit human contact with surface irrigation water.
	Methemoglobinaemia (blue babies)		–		Breastfeeding.
	Diarrhoea	–			Boil well water; properly wash raw vegetables.
	Skin rashes		–		Avoid contact with surface water with algae growth.
	Effect of boron on human central nervous system and testicular atrophy			–	Stop drinking from wells when levels are high; provide treated water for drinking.
	Drowning	–			Prohibit swimming in canals and diversion lakes; offer swimming lessons if lake is used recreationally.

Table 2 (*continued*)

Area affected	Impact parameter	Severity of impact H	M	L	Mitigating measure
	Animal health			–	Control algae growth; establish a section for veterinary medicine.
Socioeconomics	Conflicts	–			Establish farmers' committees; use norms; train ERADA staff to deal with tribes.
	Income levels		+		Advise farmers; create marketing policy.
	Women's status	+			
	Farmer's organizations			+	Promote recent attempts at community participation.
	Private investment		+		Encourage investment and provide incentives.
	Water and sanitation services	–			Recruit participation in supply and sanitation projects.
	Education and awareness			+	Intensify awareness programmes; upgrade education standards.
	Tourism	+			
	Security conditions	–			Enforce security conditions.

H = high M = medium L = low
+ = positive impact – = negative impact
ERADA = East Region Agricultural Development Authority

The Marib Dam project illustrates the importance of environmental, health and social impact assessment studies for development projects. The negative environmental, health and social impacts caused by the project might have been recognized before building the dam and design changes in the irrigation scheme could have been enforced to avoid negative impacts and to increase the positive effects.

An environmental impact assessment study during the early stages of the project could have detected the possibility of eutrophication of the lake. Such a study could have suggested guidelines for the design of a water quality management programme, for training courses in water quality management and for the establishment of appropriate laboratories.

An environmental impact assessment study at the onset of the project might have resulted in design changes for the dam which would have provided for additional outlets to irrigate more agricultural land. The open earth canals might have been replaced by closed conduits to avoid evaporation and seepage losses and to avoid the formation of seepage ponds, which are the habitat for vector breeding and which allow people to defecate and urinate in the canals. Closed pipes for distributing the water would have eliminated drowning hazards and also made possible the construction of intermediate covered reservoirs to store water for later pumping to more distant areas for underground recharge or irrigation.

A health impact assessment study might have predicted the health impact and special actions could have been chosen to support health facilities in the area to combat vector-borne and other diseases. Similarly, a social impact assessment study might have provided solutions for social and tribal conflicts over water rights and the passage of irrigation schemes through privately owned lands.

An environmental impact assessment study might also have upgraded the positive impacts of the dam. It could have encouraged women's involvement in agriculture and the development of their skills to promote their role in agricultural and health committees. Furthermore, it might have addressed social problems obstructing the promotion of tourism in the area.

References

1. *Sediment transport and accumulation. Wadi Adhana and Marib area.* Sana'a, Water Resources Assessment Yemen, 1990 (WRAY Report No. 15.6).
2. Neefles K. *To assess irrigation and crop production aspects in the Marib area. Mission report.* Sana'a, Ministry of Oil and Mineral Resources and the Hague, the Royal Netherlands Embassy, Ministry of Foreign Affairs, 1991.
3. *Socioeconomic study in the Marib area. Mission report.* Rotterdam, IWACO, TNO, and Sana'a Water Resources Assessment Yemen, 1991 (WRAY Report No. 4).
4. *Water resources, Wadi Adhana and Marib area. Water resources management study.* Sana'a, Water Resources Assessment Yemen, 1993.
5. Al-Layla MA, Basahi IAA. *Report on the Marib Lake.* Sana'a, Faculty of Engineering, Sana'a University, 1994.
6. Madani YI. *Project for the protection of Lake Marib environment.* Khartoom, Arab Organisation for Agricultural Development, League of Arab States, 1995.
7. *Standard methods for the examination of water and wastewater*, 16th ed. New York, American Public Health Association, 1985.
8. *Guidelines for drinking-water quality. Volume 1, Recommendations.* Geneva, World Health Organization, 1993.
9. Todd DK. *Groundwater hydrology*, 2nd ed. New York, John Wiley and Sons, 1980.
10. Henderson-Sellers B. *Engineering limnology (Monographs and surveys in water resources engineering 8).* Great Britain, Pitman Publishing Incorporated, 1984.
11. *Report on field visit to Marib Governorate.* Sana'a, Environment Protection Council, 1996.