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NON-AGRICULTURAL USES OF IRRIGATION SYSTEMS: PAST EXPERIENCE AND IMPLICATIONS FOR PLANNING AND DESIGN

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I. INTRODUCTION

It can be assumed that the history of irrigation in many countries is as old as the culture of the country. In fact, irrigation in its various forms comprises the culture of some of the semi-arid countries. Life in an oasis depends entirely upon irrigation (Nir, 1974). In many cases, as with the qanats (tunnels up to 25 km long dug to intersect the water table and lead it to the surface, also called kareq, or foggaras), all of the water available for consumption and use by man, animals, and plants comes from the irrigation system (NAS, 1974). Ancient societies were clustered along river systems. It was only as water was controlled and withdrawn from rivers, such as in the Indus basin, and channeled across the desert that settlements were able to follow (Bennett, 1969).

The choice of a water source for domestic use traditionally is evaluated on the basis of access, taste, smell, and color. For some, flowing water is preferred over stagnent pools, and many people believe that water is of "good" quality if it is piped or covered (Elmendorf and Buckles, 1980). Water from irrigation systems has frequently been the best alternative under these criteria. Since irrigated agriculture allows high and frequently dense populations, one USAID engineer's estimate that over 95% of all irrigation systems are also utilized for non-agricultural purposes, is plausible. The most frequently observed uses are for animal needs and washing clothes, but bathing and drinking requirements may be equally important.

The multiple use of storage reservoirs for flood control, power, irrigation, and recreation has been an important factor in the development of dams on river systems. Multiple uses of irrigation systems which frequently involve domestic water use are, however, seldom considered in the justification of a system. Even though the non-agricultural usage of irrigation systems is observed to be high, it is not clear who the beneficiaries are nor what the implications are for irrigation system planning, design, and operation. Recognition that there is a knowledge gap in systems' usage leads to some basic questions. Are there improvements that could be made for providing better services, many of them family oriented, by formalizing the non-agricultural uses? What is the impact on the various users within the system--those living in the head end vs. those living in the tail end, landless and other disadvantaged groups, etc.? What is the marginal cost of making water available from the irrigation system for non-agricultural uses when compared to alternative water supplies? What are the consequences of such usage on health, agricultural production, the environment, etc.? The purpose of this project was to review existing practices in order to begin the search for answers to the basic questions.

The following list of questions was adopted from the terms of reference for the project and provided a guide to the investigation.

- What examples are there of irrigation and other water uses being mutually achieved?
- Who are the current and potential users of systems for non-agricultural purposes?
- Are there examples where there is direct competition for water from the irrigation system?
- What mechanisms have been employed to reduce conflict or achieve mutual objectives?
- What guidelines, relating to other uses, are being used in the development of irrigation systems?
- What are the economic factors that encourage or prevent other uses?

- What are the benefits and costs of multiple uses?
- How does the type and size of the system influence other uses?
- What are the health issues related to the use of irrigation systems?
- What influence does reliability and proximity of the water supply have on the user?
- How are irrigation system maintenance needs reconciled with domestic water needs?
- Does improved efficiency of water use for agricultural needs conflict with other use objectives?
- Do inadequacies of existing irrigation systems act as obstacles (real or perceived) to development of other uses?
- What are the administrative obstacles to other uses?
- What are the prospects for experimentation and innovation?
- What are recommendations for guidelines, "consciousness raising," experimental projects, involvement of poor groups, and research needs?

II. METHODOLOGY FOR REVIEW

A literature review was conducted to examine the documentation of non-agricultural uses of irrigation systems. Since the focus of the project was on direct family needs, the multiple uses of water reservoirs for irrigation, power, and recreation were specifically excluded from the review.

A computer-based information retrieval service was used to search the CAB, COMPENDEX, and NTIS data bases. In most cases, both the abstract and title were searched for key words such as: irrigation, non-agricultural, sanitation, potable, drinking, domestic (with) use, secondary (with) benefits, rural (with) development, and health. In addition, the subject index of the Cornell University Library card file, FAO Index (1977-81), Selected Water Resources Abstracts (1970-81), and

Applied Science and Technology Index (1970-81) were examined. A data base search and library review were also carried out by the International Irrigation Information Center in Israel (IIIC), Volunteers in Technical Assistance (VITA) in Maryland, and the Environmental Sanitation Information Center at the Asian Institute of Technology in Bangkok, Thailand.

Under a USAID contract, the Water Management Synthesis Project at Utah State University compiled the Document Review Summary of many USAID and World Bank-funded irrigation projects. These summaries, in addition to other project planning and evaluation documents at USAID, were examined as a part of the literature review.

Over 50 persons with experience in irrigation research and project development were contacted. Many of these people have had World Bank and USAID project experience. They were informally interviewed about their experiences and observations. The list of persons included engineers, environmentalists, administrators, anthropologists, and researchers.

III. NON-AGRICULTURAL USES

The literature review confirmed the thorough compartmentalization of water resource development. Irrigation is dealt with exclusively for agricultural production purposes. Water supply literature deals primarily with domestic needs and to a lesser extent with animal and industrial requirements. The few exceptions are references to multi-purpose reservoirs from which both irrigation and domestic/industrial water releases are made and to water supply systems used for irrigating home gardens. Papers such as one presented at the United Nations Water

Conference in Argentina (UN/FAO, 1977:10) reference the fact that irrigation projects in developing countries nearly always combine the provision of domestic supplies with water for agriculture.

> "...the large supplies needed for irrigated crops ensure that the much smaller human needs are satisfied without difficulty, almost as a by-product. This is particularly so in the very large irrigation schemes in Egypt, Syria and India. In those areas, the farming communities are always certain of adequate supplies from the irrigation channel networks or from shallow wells and the big problem becomes not the difficulty of provision but the need for unpolluted water for human consumption, which is rarely obtainable from the canals and ditches."

Examination of the Document Review Summary, compiled by the Utah State Water Management Synthesis Project, showed that fewer than 10% of the project papers reviewed made references to non-agricultural uses or health-related impacts. Since intensive and widespread non-agricultural uses of systems are observed, it must be assumed that either the users informally develop their own methods and patterns of use or that the inclusion of structures and design modifications to allow such use are completed in the country of the project and not reported in summary documents. In a few cases, "unquantified benefits" are reported which refer to domestic and other non-agricultural uses.

There is a significant body of irrigation-related literature dealing with the health impact of irrigation development. The majority of this literature is focused on shistosomiasis and to a lesser extent on onchocerciasis. Several books deal extensively with methods that have been employed in the design and operation of irrigation systems to control the spread of these diseases (McJunkin, 1975; Fogarty, 1977). The water supply and sanitation literature focuses on the range of water-borne, water-washed, and water-based diseases. Irrigation planning and design texts, however, seldom address the health issues and then only to warn against potential health hazards of irrigation. Little information was found in these texts and manuals on design procedures for reducing the negative health impacts; and they made no reference to beneficial, non-agricultural uses of irrigation systems.

A notable exception is a guidebook prepared for USAID by Harza Engineers (USAID, 1980). This book lists environmental design considerations for rural development projects and includes a complete section on small-scale irrigation. While assuming irrigation to be entirely production oriented, it recognizes and discusses benefits and effects of non-agricultural uses. It particularly stresses the need for simultaneous efforts in health education, sanitation, water supply, etc., if potential hazards resulting from the development of irrigation systems are to be avoided.

The following examples and discussion are a summary of the information from the literature review and observations and impressions from the interviews. They are grouped according to the main use that was reported. It must be emphasized that the major portion of this information is based on casual observation. The few documented reports are referenced.

A. Domestic Use

1. Drinking Water

It is assumed that water withdrawn from canals, wells, or taps and carried to houses includes water for drinking, food washing and preparation, and some for washing dishes. Very little is known about the dependency on irrigation systems for drinking water supplies. There have been observations of water withdrawal for human consumption from systems in almost every country, but in many cases the irrigation system is only used in certain seasons or when another water source temporarily fails. In India and Pakistan, however, there are many examples where all domestic water is directly withdrawn from a canal irrigation system. In some cases the canal near a municipality or village is allowed to flow through a pond to reduce the velocity and facilitate silt settlement. The drinking water is then withdrawn from the pond. The water may be treated before it is distributed in pipes to the municipality, but in many cases it is distributed without treatment. Frequently, water is dipped directly from a canal at the most convenient point and carried home by individuals.

In Nepal, mountain irrigation systems are channeled directly through villages when possible (or more likely houses are built along the canal) for a very convenient domestic water supply. Rubbish from the house and street is disposed of by dumping or brushing it into the canal.

A USAID small-scale, piped irrigation project in Guatemala is reported to have routinely installed a tap in each yard if the water source was from a covered spring (Annis and Cox, 1980). They found the extra cost to be very low for this service and in return gained additional cooperation in building, maintaining, and operating the systems.

Ground water used for irrigation is frequently promoted as a drinking water source. The USAID Bhairhwa-Lumbini Groundwater Project (Nepal/USAID, 1980) encouraged the use of irrigation tubewells for drinking purposes and suggested that, "gastro-intestinal diseases resulting from polluted water used by villagers is the most common health problem that the potable water from tubewells will solve." A serious limitation in using irrigation tubewells for domestic water supplies is their intermittent operation and the consequent requirement of storage facilities. The energy requirements for operating a pump for domestic needs when water is not required for crops is usually prohibitive.

In some areas of Bangladesh where tubewells were installed and operated for irrigation, the water table was lowered below the level of existing wells used for domestic water supplies. No information was available on the extent of this problem or the methods employed for resolving the conflict. In Pakistan and in some Sri Lanka projects, the seepage and percolation losses which directly reduce the irrigation system's efficiency, recharge the groundwater supply. This makes shallow wells possible which can be used for domestic needs and in some cases for supplemental irrigation.

A number of projects in Sri Lanka, including the Gal Oya, have had a mandate since their inception in the 1940's to supply water for domestic purposes. The design paper of the Gal Oya project suggested that provision should be made for treated drinking water for 20,000 people, in addition to flood protection, irrigation, and power generation (Unantenne, V.C.B.). It was never possible to supply treated water as planned and a practice of making special issues of water through the canals for domestic needs was started. A common schedule of release is a 3-day issue every 10 days, during the period between crops, when the canal would normally be dry.

Frequently, however, water is pirated for unauthorized crops and the domestic release does not reach the tail of the system. People are then forced to leave that area for part of the year due to lack of drinking water. In the view of the authors of the CH2M Hill (1979) report on the Gal Oya and other Sri Lankan projects, this led to the following problems:

1. It wastes large quantities of water. With the possible exception of Uda Walawa, we found no case where this reached as much as 10 percent of total annual issues, and in most cases it is far less. However, the rate of wasteage of domestic water issues is very high. It is almost always issued into dry channels, and thus a great deal is lost by wetting of canal perimeters and by percolation. Domestic water issues seldom reach the tail ends of systems.

2. The major cost of domestic issues is that the channels are never dry for more than a few days at a time, and thus it is difficult to schedule regular maintenance.

3. In order to gain access to water, people and animals damage the banks of channels and exacerbate siltation problems. This is because of lack on all but a few systems of access steps and for special buffalo-wallows separate from the channels.

4. Farmers who have not adhered to agreed crop schedules can use an alleged need for domestic water as a pretext to obtain more water for their crops, thus relaxing further discipline.

5. The use of surface water for human consumption is more unhealthy than the use of well water.

The report further concludes that the practice of making water releases for domestic needs continues, for two reasons. One is that settlers have come to expect it and feel a strong moral entitlement. The other is that settlers sometimes actually need it as they have no alternative supply. Since the cultivators feel entitled to canal water for domestic needs, they have not made the same efforts to construct their own wells as the rural people who lived in the area before the projects.

2. Washing clothes and bathing

The most frequently observed non-agricultural use of irrigation systems throughout the world is for washing clothes and bathing. A 3500-ha irrigation project in El Salvador is called the longest bathtub in the world. The one canal through the center of the valley is a natural place for people to congregate, wash their laundry, and bathe. In central Java, where masonry, flow-measurement structures were constructed for research purposes in an unlined canal, they immediately became the most popular washing and bathing places. Clothes could be beaten against the wall and the higher water velocity through the structure kept the floor clear of silt, a great improvement over a mud floor bathtub. Canals in India and Pakistan are often lined near a village, and steps are constructed for easy access to the canal for washing and bathing. Although this increases the convenience to the users, the primary reason for the construction being done by the irrigation department is to protect the banks of the canal from damage.

3. Home gardens

There were only a few reported observations of home gardens being maintained by water from irrigation systems. A possible reason for this is the need to protect the garden by having it in very close proximity to the house. Distance to the water supply, therefore, excludes gardening as a major use of irrigation water.

In Bangladesh, where land holdings are extremely small and hand pumps are frequently used to irrigate, they are also commonly used for home gardens. Some of the garden produce is also sold commercially and gardens are viewed as an agricultural activity.

A project in Thailand (ATIT/ILACO, 1971) promoted a practice also common in Vietnam. Ponds were constructed for fish culture. The earth removed from the pond was mounded to provide a site for the family to construct its house. The pond provides water for a garden in the dry season, as well as for drinking water if no other source is available.

The Resource Utilization and Conservation Project proposed by USAID for Nepal suggests that home gardens will be a component of the small-scale, hill-irrigation systems. Annis and Cox (1980) reported that in the piped irrigation schemes in highland Guatemala where there is adequate water to encourage home gardens, they are a valuable source of food. The gardens are used both for home consumption and cash generation. They further suggest that, "with surplus greens from vegetables, some families also choose to raise small animals such as rabbits or provide fodder for a cow (whose manure in turn fertilized the vegetables and so forth)."

B. Sewage Disposal

In Indonesia, latrines are built directly over irrigation canals, and streams and rivers are preferred for bathing. The same practice has been reported in Egypt and Nepal but not to the same extent as in Indonesia. Observations while carrying out irrigation research in several villages in central Java showed careful separation of water source uses. The irrigation system was used for defecation and rarely for other water needs, although there was contact with the water in land preparation, rice planting, and weeding. Wells were used for drinking water which was reported to be boiled. The river was used for washing clothes, and bathing was done both at the river and at wells. Distance to the stream and no access to a well, however, forces many people in Indonesia to also bathe and withdraw drinking water from irrigation canals that have been used for excreta disposal. Particularly with rice cultivation, if channels are used as sewers, it is nearly impossible to keep people from contact with fecal material. As a result, reports of cholera epidemics and other water-borne diseases are frequent in Indonesia. Even though defecation in canals is considered a dangerous practice and sewage disposal is never willfully designed as a function of an irrigation project by development and lending institutions, the alternatives for Java are not clear. The engineers of a USAID contractor, designing irrigation systems in Indonesia, have been confronted with this problem. They know that the system that they design and build will be used for excreta disposal as well as bathing and other domestic requirements, but they do not have the mandate to design and build alternatives nor does a facility exist to provide the long-term education that may be required to change existing habits.

In many parts of Latin America, India, and Africa, people defecate in fields and either carry water with them or use the most convenient water course for anal cleansing. Anal cleansing, as well as washing clothes in the water course, may be a serious source of fecal contamination of the irrigation water. Water courses, including irrigation channels, are also frequently used to dispose of rubbish and street sweepings.

Using human excreta as fertilizer is a common practice in many parts of the world and is particularly widespread and important in China. A common form of sewage disposal from urban centers in many countries is by using the effluent, either treated or in some cases raw, to irrigate crops. The effluent is diluted with water to provide the correct nutritive value for the crops that are being grown. This is usually done on carefully controlled farms, and crops are selected that minimize the health hazard of disease transmission by contact or injestion. This practice is well-researched and documented and may provide useful information on the hazards of the less formal sewage disposal through irrigation (Feachem, 1977; Papua, New Guinea, 1974; Sastry, 1975).

C. Animal Requirements

Irrigation systems are an important source of drinking water for animals in many countries. A lift irrigation project in northern Afghanistan proposed ponds to provide drinking water for sheep so that they would not use the irrigation channel and destroy it. The same reasoning has been applied to provide animal access to irrigation water throughout Asia. Special ponds off of the main water course are provided for water buffalo in many parts of Pakistan and India. One source reported that buffalo preferred the cooler moving water in the canals and that ponds have been abandoned. Lining, to protect the canal, and easy-access steps are now routinely provided for water buffalo in many systems (Irrinews, 1980:1).

Erkenci (1977:103) stated that in two provinces of Turkey, 235 small reservoirs were feasible that would supply water to 365,000 cattle and sheep as well as irrigate 18,000 ha of land. It was not clear, however, if the animals would be watered from the canals of the irrigation system, or separately from the reservoirs.

The fish grown in reservoirs, tanks, and channels, as well as in rice paddies, make an important contribution to the diet of many people in South and Southeast Asia. Except for the Thailand case (ATIT/ILACO, 1971) already cited, nothing was found in the literature review linking fish and fowl to irrigation development. Observations in central Java indicate that raising a few ducks, which use the irrigation channels freely, is an important part of the farming system for many families. As was previously the case with all animals, fish and fowl seem to be overlooked as contributors to family welfare in subsistence farming.

D. Power

1. Electricity

Although the multiple uses of reservoirs for hydroelectric power were excluded from the literature review, several examples of irrigation canal drops being used for the generation of electricity were found. A project in Nepal, funded by the Asian Development Bank, has incorporated an 80-kW hydroelectric project in the main canal. The electricity will be used for lighting and light industry in the community served by the irrigation system. Other examples of a similar nature exist in the hilly areas of Thailand, India, and Pakistan.

2. Milling

Crop drying, rice hulling, and flour grinding are typically the tasks of women in Nepal. Food processing by hand utilizes about 10% of the female population's total work burden (Molnar, 1980). Both the time involved and drudgery of this work have encouraged mechanization of food processing wherever possible.

Water powered grain milling has been practiced for thousands of years. In mountainous countries such as Nepal, a vertical-axis water wheel is frequently incorporated into a drop in an irrigation canal to drive a stone flour mill. Since 1965 there has been an effort in Nepal to replace diesel engines with water turbines for driving modern rice mills. These water turbines are operated from existing irrigation systems. In addition to grinding flour, they hull rice and press oil from seeds. These operations typically require from 4 to 10 kW of direct mechanical power. Recently a heat generator, which converts mechanical energy to heat by air turbulance, has been introduced for crop drying at the water powered mills (DCS, 1980).

E. Transportation

Most surface irrigation systems have roads and paths along canal embankments. The roads are used for inspection of the system and provide an important means of access to the irrigated area. Frequently embankment roads provide the first motorized access to rural areas. Paths along canals are usually adequately drained for easy travel during the rainy season, and they have an easy gradient for bicycles and walking.

Water from the irrigation system is also used in India and Pakistan for maintaining the roads. In the dry season, while water is not needed for crops, roads are flooded to soften the surfaces, which can then be scraped to smooth and repair them.

Boat transport of people and goods on the irrigation canals themselves is another important use of systems, particularly in Southeast Asia and China.

F. Other Uses

1. Religious

In addition to providing water for ablutions, irrigation systems become an important part of many religious customs. At Hardwar at the head of the Ganges, an extremely important pilgrimage point for Hindus, most of the ritual bathing and religious ceremonies are performed on the left bank canal rather than along the river itself. The designers of the canal in the 17th century were very sensitive to the religious and cultural needs and incorporated this use into the design of the access steps. Throughout areas of Hindu influence, there are temple gardens, ponds, and lakes which are supplied with water from irrigation systems. Although the primary purpose for their establishment may have had religious significance, their aesthetic nature provides an additional benefit for many.

2. Trees

In some countries trees are carefully avoided near irrigation systems. The roots can cause damage to canal lining and water requirements for trees can be high, although possibly insignificant as a fraction of the total water in the scheme.

The irrigation department in Pakistan plants trees at about 30-m intervals along all of the major irrigation canals. The benefits of shade and beauty in an otherwise treeless countryside can be enjoyed by all, regardless of assets or status in society. However, the major benefit is in revenue from their sale for construction and fuel needs.

IV. FACTORS AFFECTING COMPATIBILITY OF USES

A. Hydrologic Environment

The climate, rainfall intensity and distribution, soil moisture regime, topography, etc. have direct influence on the availability of water for domestic needs and the degree to which it might be supplemented by an irrigation system. These same factors control the need for irrigation and greatly influence the type and size of irrigation systems that can be developed. Such environmental factors have little scope for manipulation and change very slowly over time. However, they greatly influence technical alternatives that might be considered for water needs.

1. Water sources

When the irrigation water is from a protected source, such as the springs in some of the systems reported in Guatemala, no filtration or treatment may be necessary in using the water for domestic needs. The same may be true for water supplied from tubewells, although there have been examples where taste was not acceptable and tubewell water was rejected in favor of the traditional surface source.

If the irrigation water is from a surface source, the water quality will be lower and likely highly variable. The cost and reliability of water treatment must be compared to alternate, better-quality sources. Epidemics are more easily spread when a large community uses a single water source that is susceptible to contamination. Multiple sources such as wells, even if recharged by surface water, may provide better disease control.

2. Conveyance methods

Although only a small proportion of irrigation systems are piped from source to field, they represent the most compatible system for domestic uses. Since the pipes are vulnerable to being broken by villagers for clandestine water supplies, such systems will likely have larger losses of water if domestic taps are not supplied than if they are planned for the system. A Dole plantation in the Philippines sized the pipe delivering water to the village so that even if the taps are not closed, the losses would be acceptable.

Since access to a canal cannot easily be restricted, it will be used for domestic needs unless more acceptable alternatives are available. The convenience and perceived quality of alternative water sources are very important factors in a villager's choice of a water supply (White, 1972). If shistosomiasis is endemic, for example, control can only be effective if safe water is used. This water supply must be more acceptable by the villager's evaluation of convenience and quality than the traditional source, which might be the canal. In such a case discussion of the compatibility of the canal water for other uses has no relevance. It will be used as a water supply unless there is a better alternative. Disease control mandates the investigation of better water supply alternatives which will be acceptable to the community. Even though the irrigation system may not be compatible for domestic use by WHO standards, it must be considered among the alternatives within the community's and country's technical and financial resources. If no better alternative supply can be delivered, incremental upgrading of the canal water may be possible by using infiltration galleries, storage, or other treatment methods. Health and sanitation education can also be carried out to change what is acceptable by the villager. Such education is essential but may require a generation to be effective. In the comparison of alternatives for a domestic water supply, the irrigation water source and conveyance method together, indicate the irrigation system's feasibility.

B. <u>Cultural Environment</u>

Social, religious and cultural practices are perhaps more important than unchanging environmental factors in considering alternative uses of an irrigaton system. For some, body relics, especially excrement, must not be touched if the body is to be protected. By implication, people who must handle such materials have to be regarded as untouchables, if the integrity of the group is to be protected (Curtis, 1978). The logic of ritual purity does not coincide with the logic of epidemiology, although in some cases the practices themselves may be compatible. The frequent bathing, careful cooking, and other dirt avoidance practices by high caste Hindu families probably corresponds with good "scientific" hygiene. Other practices definitely do not. By the curious process of inversion, common in many cultures, dirt may be used in ritual cleaning practices. There is also no agreement between science and ritual on the subject of what is dangerous and polluting.

Religious observance may be an important health factor if it leads to uniform practices. Ablution (the ritual washing before prayer, five times daily) as practiced by Muslims is an example. There is evidence in Bangladesh that water-related disease infestation is more likely to occur due to ablution and bathing than from water use in the home for drinking and food preparation, even though the source of the water is the same.

Farooq, et al., (1966) examined the personal, social, and religious habits of the population of an Egyptian province as they relate to water contacts. Frequency and type of water contact varies greatly by age, but certain major opportunities for cercarial (larva in the life cycle of schistosomes that infect man) infections are important. For young males, virtually all contact is through bathing and playing. For older males, principal contact activities are washing of cattle and ablution, all at the water's edge. Young females bathe and play also but their most frequent contact is while washing utensils. Utensils are washed by women and children while standing in the water. Washing of clothes is done in similar fashion.

Habits may differ between groups of people served by even a small irrigation system and may dramatically alter the options available for water use. Generalizations that are drawn from limited observation of habits cannot be applied universally or even regionally, unless there is certainty that the option chosen is the best alternative for the worst situation possible in the community. In situations of limited information, treated drinking water piped to all households has been the solution chosen to cover the worst possible situation. Unfortunately, economic and maintenance constraints limit the choice of alternatives in rural areas to standards usually far below those for treated water. A sociocultural survey that identifies traditional water use, hygiene, and sanitation practices of all groups within the irrigation system, will be essential to establish planning and design criteria for the use of water for non-agricultural purposes.

C. Health Environment

The relationships of water supply to health has led to a considerable number of investigations and publications on exactly how and why water supply influences health. Feachem (1978) classifies water-related infections according to the following taxonomy:

1. Fecal-oral diseases: (e.g. cholera, typhoid, diarrheas, dysenteries, hepatitis, ascariasis) These are all infections transmitted by the fecal-oral (feco-oral, ano-oral and also fecal-nasal and feco-ocular) route. They may be water-borne or water-washed.

2. Water-washed diseases: (e.g. infections of the skin and infections of the eyes) These are all infections related to poor hygiene (therefore water-washed) but which are not fecal-oral and are not water-borne.

3. Water-based diseases: (e.g. guinea worm, schistosomiasis, clonorchiasis) These are all the helminths which have an aquatic intermediate host.

4. Water-related insect vector: (e.g. malaria, filariases, yellow fever, trypanosomiasis [Gambian only]) These are all infections transmitted by insects which either breed in water or bite near water.

The terms "water-borne" and "water-washed" are given a precise meaning. Water-borne transmission occurs when the pathogen is ingested in polluted water. Water-washed transmission occurs when the pathogen is passed from man to man by a route which reflects poor personal or domestic hygiene and, therefore, which might be controlled by the use of more water as an aid to hygiene. Water-borne transmission is thus related to water quality while water-washed transmission relates to water quantity.

Numerous studies were summarized by Feachem (1978) demonstrating that several fecal-oral diseases (diarrhea, cholera) are not reduced by improved water quality. A second theme which emerges from these studies is that the provision of public taps in a community may not in itself change hygiene or water-use patterns and may not even increase the water used per capita. A third theme is that where the availability of water is greatly improved, and particularly where communal washing or laundry facilities or house connections are provided, a marked reduction in water-related disease may be found. He further summarizes the extent of our knowledge about the impact of water on health.

> We know that good domestic water supplies in every home are a vital part of the wide ranging environmental improvements which, together with wealth, have caused such dramatic reduction in infectious disease in Europe and North America in the last 100 years.
>
> We know that if it were possible to transform the socio-economic, and environmental conditions (including water supply) of the poor in developing countries into those enjoyed in Europe or North America, a very dramatic reduction in infectious disease would follow.
>
> We know that improvements in environmental conditions must include good water supplies if they are to have their full effect on community health.
>
> We do not fully understand the role of partial and limited improvements in environmental quality as opposed to comprehensive improvements.
>
> We do not know what is the potential role of water supplies constructed in the absence of other inputs or changes and designed to low-cost specifications.
>
> We suspect that replacing dirty water by clean water in the absence of other inputs, will often have little effect on health.
>
> We know that it is difficult to induce changes in hygiene and water use practices but we suspect that such changes may be essential if improved water supplies are to improve health.
>
> We suspect that bringing plentiful water close to, or into, houses and providing washing and laundry facilities may improve health in many cases.

The main conclusions relating water supply to health are that an improved supply is a necessary but not sufficient condition for health improvement. For health benefits to be realized, sanitation and health education efforts must be carried out at the same time.

V. DESIGN CONSIDERATIONS

The designs of inspection roads and associated culverts and bridges are well developed. Local cost information is available in every irrigation department. Designs for animal uses of irrigation water have also evolved and the design for buffalo baths can be found in Trout and Kemper (1980). Considerable work on the development of water power for milling within irrigation systems in Nepal has been completed. Installations are reported to cost about $6,000 with 10 kW of shaft power and three milling functions--flour milling, rice hulling, and oil pressing (DCS, 1980).

Design considerations for domestic water use from irrigation systems cannot be generalized. In the piped small-scale gravity systems in Guatemala, they tapped small lines directly into the main pipe for stand pipes and house connections. No filtration or treatment was required since the water was from a safe source.

If irrigation water is contaminated, use of the irrigation system must be evaluated against the alternative supplies, treatment, or no treatment. An algorithm of this decision process is presented in Figure 1.

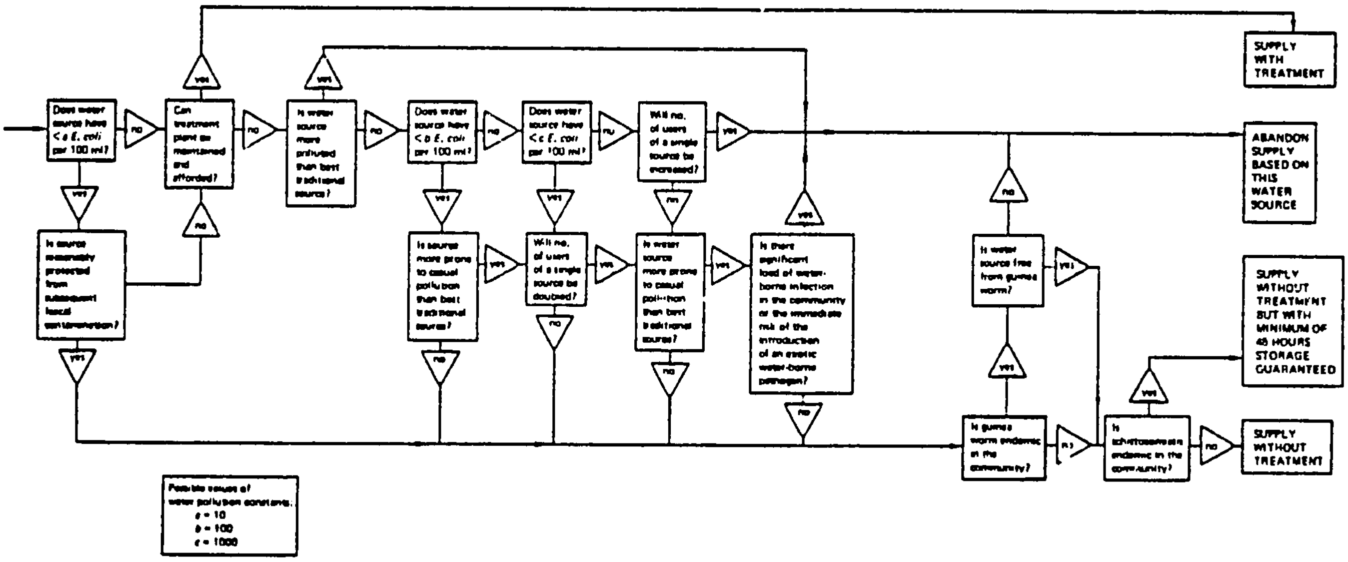

Figure 1. An algorithm of the decision to treat, not to treat, or to abandon a particular water source (Feachem, 1977:88).

The water quality distinctions in Figure 1 are in non-specific terms in order that they may be easily adapted to local conditions. Chemical water quality is not considered in this procedure since chemical-related problems tend to be very localized.

The water supply should receive the minimum possible treatment. The problem with treatment is that it needs looking after and even a very simple treatment process will fail if it does not receive adequate attention.

Designs for storage and various levels of treatment exist (see for example Feachem, 1977; Pacey, 1977; McJunkin, 1975; Mann, et al., 1976) but case studies and examples are few. Many more examples of the following nature, with better performance and cost data, are needed:

At Aurungabad in India, an infiltration gallery nearly three thousand meters long with a brick arch was built during the sixteenth century. The gallery was nearly four meters below the bed of the river and in 1886 yielded 7700 m^3 of water in 24 hours (Wallace, 1893; in Feachem, 1977).

Apart from low rainfall and rapid run-off during storms, the water supply problems of semi-arid areas are made more acute by the high rate of evaporation experienced in the tropics, which in extreme hot climates can dispose of as much as a 3-metre depth of water in a year. The long dry season demands effective, long-term storage, but the high evaporation rate makes open storage reservoirs exceedingly inefficient. One technique for controlling evaporation is to use reservoirs filled with sand and loose rock. Water is stored in the pores between the particles, and is shielded from evaporation below the surface of the sand.

Small sand-filled dams using this principle have been constructed in semi-arid parts of America and Africa, and have been proposed in Botswana for the supply of drinking water to livestock and people. They can store water for long periods, and provide water during years of total drought, because when the water table is more than a metre below the sand surface, evaporation ceases for all practical purposes. The water is drawn off by a drainage pipe through the dam wall, or by a well dug into the sand, and having been filtered through sand, does not usually require any treatment (Pacey, et al., 1977:27).

In Otterthotti, in the Karnataka state of India, a series of small-scale water conservation works was put in by hand during the 1967-70 drought. They included fifteen small dams, and also field bunds which retain more of the rainfall on farm land, so that crops benefit and there is also more percolation into the ground. The village had traditionally relied on wells for domestic water and irrigation. There were around 100 of these, of which most dried up during the drought. The effect of the percolation dams was to ensure that when a new drought occurred in 1973-4, after 2 years of good rainfall, water tables remained at a high level in the wells, and intensive irrigation of rice and other crops could continue (Pacey, et al., 1977:29).

Of particular interest for canal irrigation systems are low cost infiltration galleries that can provide the first level of treatment, and storage facilities that will allow settlement which both clears the water and reduces the number of pathogens (Feachem, et al., 1977). If schistosomiasis is present, a minimum storage of 48 hr will effectively kill the cercaria. But the water supply needs to be adequate and reliable or people will still go into open water for washing clothes and utensils and become infested. Storage facilities along canals which receive water on rotation can supply domestic water while the irrigation water is directed to another channel. In effect, shallow wells near irrigation canals that are recharged by water from the system provide this function but they depend on the groundwater table remaining high.

In flat areas it is possible to pipe water by gravity to underground storage tanks in or near points of use. Piped distribution from most gravity irrigation systems, however, requires pumping.

The use of irrigation systems for sewage disposal, as reported in Indonesia, has been universally discouraged. Alternatives within the resources of communities have, however, not been identified. Research that both investigates the actual danger that exists from the present practice, and tests alternative designs that can cope with the high water table, is urgently needed.

The subject of sanitation in general needs equal attention to that of water supply in situations where health improvement is a goal in developing a water supply from the irrigation system. A variety of methods and designs are available for effective on-site excreta disposal without sewerage (see Feachem, 1977; Pacey, 1978; Kalbermatten, et al., 1980).

Figure 2 is a guide to the analysis procedure for the selection and design of a water supply in a low-income country. The procedure of Figure 2 must be used for each water source alternative in order to make a comparative analysis. Flexibility for incremental upgrading, as the need and resources become available, can also be considered.

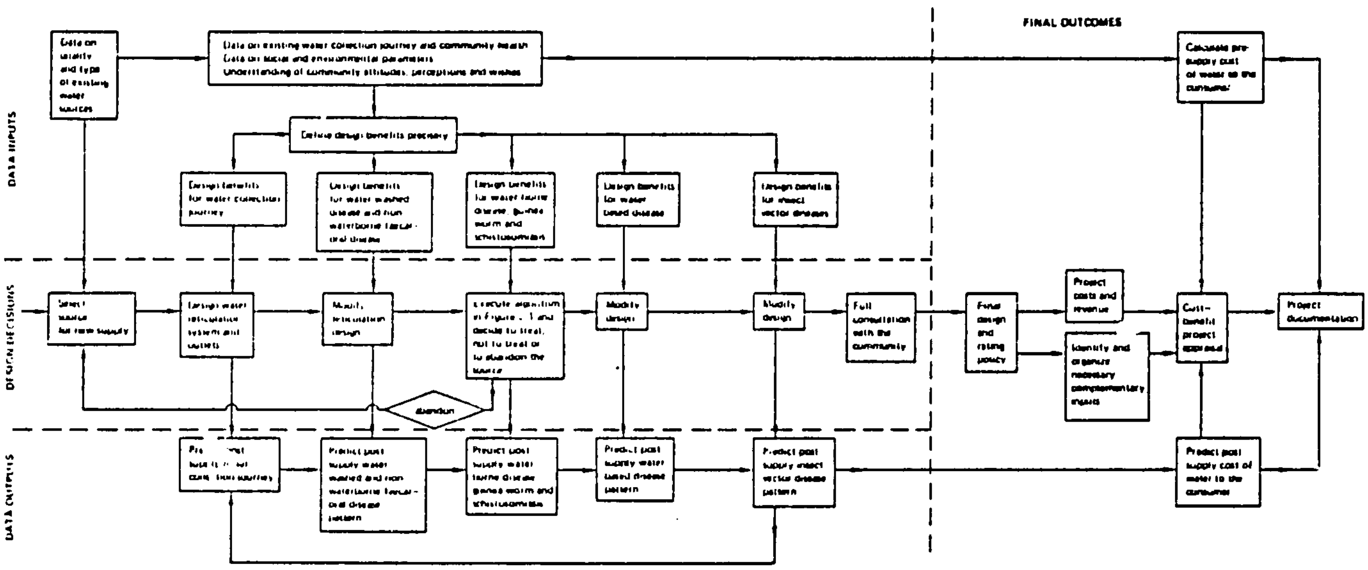

Figure 2. Analysis guide for a water supply in a low-income country (Feachem, 1977:93).

VI. UNRESOLVED ISSUES

The non-agricultural uses of irrigation systems that do not directly involve human health such as fish culture, animal watering, milling, etc. are well established and to some extent institutionally accepted. Some, such as transportation and trees, are even formally included in the design and planning of projects. The issue with such uses is generally not the availability of technology, but their cost effectiveness and benefit distribution.

Some common problems exist at both the national and international level that must be dealt with if non-agricultural uses of irrigation systems are to receive planned input. Issues relating to benefit distribution, cost, and design alternatives are very site specific but they need to be addressed systematically in order to allow maximum transfer of knowledge between sites.

A. Design Alternatives

In the past few years, with increased recognition of the need for sanitation improvement along with safe water access, some effort has been made to understand the planning and design alternatives for both water supply and sewage disposal. The extent of the research and development effort, however, has not been in proportion to the need. A great deal is known about methods for achieving high water quality standards but very little is documented on the intermediate levels of treatment. No organization or program was found that is focusing on the development of design alternatives for the utilization of irrigation systems for domestic water needs.

B. Cost Effectiveness

If animals or people are destroying canal banks and causing siltation, the chief beneficiaries of a structure to facilitate access to the water are the irrigators, since it will improve the performance of the canal. The same is true of culverts and bridges for crossing the canal and roads, since they give the farmer access to the field. The decision to build these structures is usually on the basis of cost effectiveness to the irrigator, even though the general populace of the area also benefits from the improvement.

The impact, and to some extent the value, of multiple uses of an irrigation system is dependent on who will be participating in the uses. It is also dependent on the alternatives that are available. Since White, _et al._, (1972) initiated data collection and analysis of rural water supplies, interest in this field has been growing. However, no data has been collected on the use of irrigation systems for domestic needs. At best there are observations that some people both pollute and withdraw water from a system; but who they are, how many people, what alternatives exist for them, or even exactly where they are, is unknown. Even in a resettlement project like the Gal Oya scheme in Sri Lanka where there is currently a rehabilitation program for the irrigation system that includes the domestic needs, there is no information on the number or nature of the target group.

The numeration of costs and benefits and the evaluation of alternatives is somewhat simpler for uses such as milling, fish culture, trees, transportation and even animal needs than for domestic water use. Savings of time and energy are important benefits for water supply and milling improvement. In most countries these tasks are the responsibility of women. One method for quantification of these benefits is to express the time spent in the activity (water collecting or milling) as a percentage of the total available daily activity time. Alternatively, some investigators (White, et al., 1972) have placed a monetary value on the water collection journey by costing the amount of staple food required to produce the number of calories which are needed for the activity. This is attractive since it provides a monetary value which can be used directly in a benefit/cost calculation; but it has logical weaknesses, particularly in a society based on subsistence agriculture. Water supply benefits have an added complication in the health component.

Feachem, et al., (1977) states that the fundamental aim of water supply improvement for low-income communities should be to reduce the cost of water to the consumer. The cost of water to the individual, as suggested by White, et al., (1972), is made up of the sum of:

(a) any cash payment made to the water authority, to the standpipe owner, to the water carrier or vendor, etc.;

(b) the value of the time-energy expended in collecting water where the individual lacks water supplied to the dwelling;

(c) the cost of sickness related to the use of polluted water, to the use of insufficient water or to disease acquired in the course of water collection.

A water supply designed for domestic use that does not meet WHO standards is a risk-taking design. Unfortunately, the standards do not suggest quantity criteria to balance the quality requirements and in many cases, there must be a trade-off between the two. Risks of epidemics are always present and it is better that these should be explicit than concealed. Research in tropical epidemiology will increase the ability to quantify the risk associated with particular levels of polluted water supply. As this ability develops, it will be appropriate to use monetary values for illness and death in analyses which consider the costs and benefits of different levels of water treatment (Feachem, et al., 1977).

Costs for domestic water use cannot be generalized. Piped, gravity, small-scale irrigation systems are reported in Guatemala that cost $340 per family including standpipes for domestic use. These were compared to piped drinking water systems for the same service at $175 per family (Annis, 1980a). The range of size, distance to the water source, command area, and other related factors are infinite and site specific, but a large information base analyzed systematically may disclose universal cost relationships between alternatives.

Countries, lending institutions, and aid agencies frequently recognize domestic water needs but lack knowledge about engineering alternatives and lack the necessary information about cultural constraints to choose between the feasible alternatives. Being unable to supply the fall-back position of treated water, they choose to do nothing at all rather than be criticized for making an error. Unfortunately, the most common decision by agencies with regard to the use of irrigation systems for the supply of domestic water needs is to defer the choice of water source to the villager, who has no resources for improving it.

In order for effective planning and design for non-agricultural uses of irrigation systems, an information base is needed. This should include sociocultural practices of different groups and detailed field and engineering data for benefit and cost evaluation.

C. Standards and Professionalism

The traditional method for achieving consistent results has been to set standards. Although national and international standards for water quality are valuable for the purposes of surveillance, considerable judgment and flexibility is required in application. Water considered unsafe by WHO standards may, nevertheless, represent a marked improvement over the previous supply.

The inability to guarantee that water taken from an irrigation channel will meet the accepted standard frequently prohibits donor agencies from promoting its use. Unless there is economic justification for the expensive materials and equipment required to meet these standards, and certainty that they will be used properly if installed, the only option is to do nothing. "Better-than-nothing" solutions are available that would meet the economic and operational ability of many situations and more could be developed if flexibility would be politically acceptable. Standards must be set to allow incremental improvements within the resources available rather than the frequently unattainable leap to the ultimate goal.

Standards also provide protection for professionals. If engineers choose an unorthodox solution to a specific problem and there is a failure that leads to disaster, they carry the burden of responsibility, but if they adhere to the accepted design conventions they avoid criticism. Both expatriate and national engineers are particularly sensitive about this issue, and their attitude, however understandable, has been a significant obstacle to the development of low-cost water supplies in Africa (Pacey, 1977).

D. Information Flow

Irrigation project planning, design, and construction, whether by country or international institution, has been a demanding task. Very few, if any, systems operate close to their target design in water efficiency. Frequently systems serve less than half of the command area for which they were designed. A major effort is still being undertaken around the world to improve the design and performance of the agricultural production aspect of irrigation systems. With intense pressure to improve the performance, it is not surprising that many engineers and planners have not thought about the possibility of multiple uses of the systems they are designing. The single most important task, providing water for crops, completely dominates all the thinking in the planning and design stage.

Along with sensitizing the engineers and planners to the potential for non-agricultural uses, additional staff with expertise in sanitation, health, water supply, sociology, etc. must be provided to the planning team when required.

There is also recognition of a significant time lag between the acceptance of research findings and their utilization by engineers in design. An example is seen in the water quantity vs. quality issue. Health experts now nearly all agree that in many communities with poor water supplies, increasing the quantity of the water has immense benefits even if the quality cannot be improved. Until this information is translated into standards, it will not be available for use in designing.

E. Departmentalization

It was observed that trees, inspection roads along canals, and other structures that are a direct benefit to the irrigation department are generally better maintained than the facilities that are important to only the irrigator. Unless the operation and maintenance technology, as well as the cost, are within the capability of the users, and unless they perceive the benefits to be worth the cost and effort, non-agricultural uses seldom materialize.

Since the mandate for drinking water, health, and sanitation concerns are always with other than the irrigation agency, joint or integrated projects are necessary if water from the irrigation system is to be formally used for domestic purposes. Departmental rivalry and "turf protection" are obstacles to the communication and cooperation that must exist in joint projects.

On a higher level, the donor agencies have internal communication and rivalry problems. Annis (1980) pointed out that in Guatemala, USAID designed both small-scale irrigation systems and drinking water systems on the same floor of the same building and each group was almost entirely unaware of the other. The technology was very similar but the end use put them into different groups within the agency. In the Guatemala case, the objective of water delivery in the two projects was compatible for joining, but in many cases they conflict. As Bradly (1977) points out, "all too frequently, when advice is sought by a planner or engineer, the medical authorities may be less than helpful. Too often their advice may tend to resemble that given to the man about to be married, 'don't', and this may be economically and, even more, politically unacceptable." Departmentalization along professional disciplines may be a major reason that planning of non-agricultural uses of irrigation systems has lagged behind the policy changes that suggest inclusion.

F. Water Laws

In gravity irrigation systems such as the Gal Oya, where there is already a conflict over water for agricultural requirements, domestic needs greatly complicate the situation. A combination of technical (wells) and organizational (water user association) solutions are being pursued.

Water disputes are well known and cross farm, district, regional, and international boundaries. Where water is scarce, there are usually priorities on its use. Irrigation frequently takes second place to water source development for domestic use in developed countries but the situation is not so clear for developing countries. No legal restrictions against using irrigation systems for other than agricultural purposes were found in the review, but priorities are an important issue. If a drinking water system is built with initial excess capacity, there is frequently reluctance to use the excess for irrigation. Rights to water are usually established by use and there is fear that in later need, the water may not be redirected for domestic use. The reverse, however, should not be true except in very small irrigation schemes. Except for cases where groundwater recharge is important for wells used domestically, the quantity of water withdrawn for non-agricultural uses ha^ been a very small fraction of the total irrigation water.

The need and desirability of water laws to ensure access to irrigation water for non-agricultural purposes must be studied on a country-by-country basis.

VIII. IMPLICATIONS FOR POLICY

The degree of planning and design for non-agricultural uses of irrigation systems in ancient times is uncertain. That systems built even centuries ago are still being used for such purposes today is clear, but one cannot generalize that the bureaucracies that constructed the ancient schemes were concerned about the convenience or impact of water access by people and animals. In many cases it is more likely that populations adapted to the changed environment of a new irrigation scheme rather than the system being planned for improvement of their well-being.

Even as awareness of health issues related to water supply and sanitation grew in the later stages of the colonial period, little evidence is found that it influenced the planning or design of irrigation systems. Exceptions are found in the way the colonialists protected the reservoirs which supplied water for their own domestic needs (McJunkin, 1975). As already noted, the religious needs were carefully incorporated into the irrigation systems in India. This was certainly for political rather than health reasons, however.

In the early years of development assistance that followed independence of many countries, the major emphasis was on increased productivity. In the late 1960's concern about quality of life began to erode the preoccupation with gross national product. This is emphasized by Burton (1979:1):

> ...the purpose of development had more to do with morals and politics than with economics. In developing countries people began to question the purposes of struggling hard to increase the national product if large segments of the population remained largely unaffected and saw no benefit from the development effort. Encouraged by changes of attitude and policy in the development banks, developing country governments no longer found the idea satisfactory that the benefits of investment in directly productive investment would eventually "trickle down" to the poorest and most inaccessible of their populations. The idea began to be promoted that development should be for all the people, and that some programs should be directed specifically towards the poorer regions of the country and segments of the population, so that all should receive some early benefit of development and thereby be drawn more actively into the process of social and economic change and modernization.

This sentiment is also echoed in the guidelines for the preparation of feasibility studies of rural development projects for FAO and The World Bank (FAO/World Bank, 1975). The new orientation, however, has not been initiated in the planning and design process for irrigation systems. Although all aspects of projects--on-farm development, access roads, farm inputs--are usually investigated in project feasibility studies, the quality-of-life issues such as ease in access to water, health impact, etc. are not included in the FAO/IBRD (1970) guideline currently used in preparation of feasibility studies.

Negative environmental impact, including health aspects, are routinely assessed through environmental impact studies, as the project is planned. Such studies provide an important check on the potential intervention proposed and have frequently required modification of plans. Since these studies are usually carried out late in the planning stage, they represent a significant cost in time and money as plans are redrawn. USAID has recently initiated a trial program for small rural development projects where a manual of environmental considerations will be used by the planners in an effort to reduce the environmental conflicts (USAID, 1980). This manual of environmental design considerations uses appropriate technology guidelines and places special emphasis on social and public health considerations. This approach recognizes and encourages multi uses of irrigation water as long as the uses are limited to plants, animals, and fish. It stops short of formalizing the planning and safer design for domestic needs that have informally been incorporated since the beginning of irrigation history.

The stated development policy of lending and aid agencies, to provide benefits directly to people, is compatible and at least partially fulfilled by the non-agricultural uses of irrigation systems. Implementation of this policy will require a movement toward the resolution of the issues stated in the preceeding section. First it will require a change in the accessibility of irrigation systems for other uses. Presently only hydraulic and agricultural production factors are considered in the planning and design of systems. Emphasis and priority must also be given in the design phase to non-agricultural uses. This should not be done by shifting the already overtaxed efforts of planners and engineers that are trying to improve the rather poor performance of many irrigation systems but by adding persons to the design team with interest and expertise in the non-agricultural uses. Second is the requirement to shift from the current no-risk approach to planning and design to one of incremental improvements.

VIII. RECOMMENDATIONS

A possible starting point for expanding and improving the non-agricultural uses of irrigation systems could be along the following lines of action:

A. Action Research

1. Documentation of present experience

A thorough in-country investigation should be made of the present non-agricultural uses of the existing irrigation systems. Several countries should be selected for the initial study that would represent different climatic and cultural environments. All agencies and institutions involved in irrigation planning, design, and operation should be contacted. This investigation should:

(a) Review the literature, planning and design papers;

(b) Collect information from agency personnel on both official policy about multi uses and what actually happens in the field;

(c) Make field observations of the informal uses of systems, including the degree of utilization, level at which decisions are made about use, users relationships and proximity to the system, and the users status in the community;

(d) Identify methods and designs incorporated into the use of the system and make scale drawings and cost estimates where appropriate;

(e) Estimate the water quantity used and health impact.

2. Collection of planning and design information

A methodology should be developed and tested for rapid and complete assessment of a community's needs that could be met by the irrigation system. It should particularly focus on the factors that relate to hygiene and health such as: endemic diseases, sanitary habits, religious and cultural practices. It should identify factors that may concern or conflict with goals of improved health. It should evaluate the present water supply sources and possible alternatives, both for acceptability to the people and the cost of improvement. It should also document the complementary needs of health education and sanitation facilities.

3. Pilot project

The literature indicates that very little concerted development effort has been made to adapt existing technology to utilize irrigation systems for domestic water needs. A project should be undertaken that will:

(a) Categorize the need for methods, devices, and design to facilitate irrigation system usage;

(b) Evaluate the designs that are observed in the field;

(c) Adapt existing technology into practical designs for incremental levels of improvement in access, quality, cost, and convenience of irrigation system usage;

(d) Field test the designs in pilot projects where they will be monitored and modified to improve operation;

(e) Use the experience gained in building and operating the pilot projects to recommend:
- design standards;
- planning and design considerations to be included in handbooks and manuals;
- training that will be a part of irrigation engineering programs.

B. Increase Sensitivity

A program should be undertaken that will increase awareness about the present use of irrigation systems for non-agricultural purposes. The objective should be to sensitize the following groups to the water-related needs that could be met by the use of irrigation systems:

(1) Field personnel.

(2) Government leaders and irrigation policy makers including those in lending body and aid agencies.

(3) Irrigation consultants and contractors.

Pilot projects should be undertaken in many countries for demonstrating the potential uses to a wide audience, including government officials. As these projects are observed and documented, modifications can be made in educational programs that train irrigation engineers and managers. Policy changes can be reflected to irrigation consultants and contractors through appropriate inclusions in the terms of reference of projects.

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