CHAPTER 5

MAINTENANCE POLICY

5.1 Introduction

Maintenance can be defined in general as "any activity that slows the deterioration of a facility, whether caused by use or ageing" or more specifically, "a management response to the deterioration of the physical condition of irrigation systems that threatens to make it impossible to achieve operational targets" (Carruthers & Morrison (undated) p14, from Ostrom *et al.* 1993 and Karunasena 1993).

Maintenance policy covers the following, which are described in turn in this chapter:

- what are the objectives of maintenance?
- what is to be maintained?
- how is maintenance to be executed?
- what is the required institutional set-up? (who will manage and execute maintenance?)
- how much budget is needed?

Maintenance policy as used in this book should be distinguished from the maintenance strategy and the maintenance programme, which are discussed in Chapter 6. Maintenance strategy is the way of implementing the policy. The strategy comprises a number of operations, each with a specified method and frequency (e.g. weeding secondary canals twice per year). The maintenance programme is the time-related schedule for undertaking these operations, with start and finish dates for each constituent task.

5.2 Aims, objectives, performance indicators and targets

This section addresses the question: what are the objectives of maintenance.

5.2.1 Aims of irrigation and irrigation management

The overall aim of irrigation will depend on the specific organisation responsible (for example ARDA or the National Irrigation Board in the case studies described in Chapter 2) or the scheme being considered (e.g. the Chisumbanje or Mwea schemes). Chambers (1988) suggests "optimising human well-being" to encompass the many different possibilities, but for our purposes it is helpful to expand this into the following typical aim for irrigation management:

Optimising human well-being by maximisation of agricultural benefits through the controlled delivery and removal of water, while safeguarding the environment, and by making efficient use of water and other resources.

Benefits may be enhanced by increasing the quantity or improving the quality of agricultural production. In order to do this, attention must focus on ensuring that:-

- the hardware of the system is in order to perform its hydraulic functions to the required standard.
- the distribution of water at the farm level is adequate, timely, equitable and reliable.

Both of these demand effective management of the irrigation system. Effective management therefore embraces

- the condition and serviceability of the hardware or physical assets
- the behaviour issue of irrigation management.

Crucial to both of these considerations is the role and performance of maintenance. Without maintenance, weed growth and siltation cause deterioration in the condition of the system, a reduction in hydraulic performance and a reduction in agricultural benefits.

System deterioration is a function of both age and use. Maintenance is needed to reduce the rate of system deterioration and its attendant costs in order that the net benefits of the system can be maximised. It is useful to think of benefits as including costs of poor performance avoided.

By prolonging and sustaining the life of capital equipment and infrastructure the probability of production loss is reduced. In irrigation the potential for production loss arises from:

- Shortcomings of the system in distributing water in both space and time to crops as required.
- Shortcomings in the timely removal of surplus water in accordance with crop needs.

Both shortcomings may be increased by failure of the system to perform to the target level of service as a result of weed growth or silt build up.

Inadequate maintenance may have the following adverse consequences:

- Production losses caused by failure to effectively deliver and remove water consistent with crop requirements. Both the quantity and quality of crops may be adversely affected.
- External diseconomies of production may be generated. These are unwanted and costly side-effects of production, for example salinity build-up in soils and water logging, often caused by inefficient drainage. They are the unintended consequences of poor maintenance, but such external costs are often ignored when the management or maintenance decisions are being made, and the costs are transferred to the future or to others.
- Introduction of inequities between farmers dependent on the system, manifested by conflicts (for example with respect to availability of water) and arbitrary redistributions of income. Not only may social disharmony result but also the care

of the system may be adversely affected. If the result of unfairness is demoralisation of some individuals the interdependencies inherent in irrigation systems may cause individual neglect to adversely affect the whole scheme.

5.2.2 Objectives for management of irrigation and drainage channels

The focus of this book is on the management of the irrigation and drainage infrastructure which is part of a wider system with the typical aim given above. Objectives will again vary with the situation and the overall aim and perspective, but we consider the following as appropriate objectives for the management of the irrigation and drainage infrastructure:

1. Adequacy and equity of the quantity and timing of water delivery and removal
2. Reliability (i.e. the stability of discharges and predictability of timing) and sustainability (i.e. the risk of breakdown) of water delivery and removal
3. Safeguarding the environment and public health
4. Efficient use of water and other resources

These objectives apply to both operation and maintenance activities. Weed management is usually undertaken as part of channel maintenance work, and is thus related to other activities such as desilting channels. Maintenance is undertaken to sustain the carrying capacity and integrity of the channel, prevent failure by a channel breaching or overtopping, and minimise losses from seepage or evapotranspiration (evapotranspiration losses from reservoirs may be reduced significantly by weed management). Weed growth tends to have a more rapid impact on the discharge capacity of a channel than siltation, and thus requires more frequent maintenance.

These can be considered as hydraulic, environmental and efficiency objectives, and these headings are used in the sections below for derivation of focused performance indicators and specific targets for the management of weeds in irrigation and drainage channels. The performance indicator is a measurable indicator of system performance, preferably one which can be easily monitored, e.g. the canal discharge. The target is the target level of the performance indicator, e.g. the scheduled discharge at the time. The level of service is the frequency that the performance meets the target.

5.2.3 Hydraulic targets for channel management

The management of weeds in irrigation and drainage channels can be analysed by using the concepts of hydraulic performance and condition.

5.2.3.1 Hydraulic performance

Objectives 1 and 2 (see Section 5.2.2) require the maintenance of irrigation and drainage channels to meet the following specific targets:

- The channel should be capable of conveying water at a predetermined target discharge, which varies during the year
- The water level at the required discharge should ensure a freeboard between water level and bank top level which equals or exceeds a predetermined target freeboard.

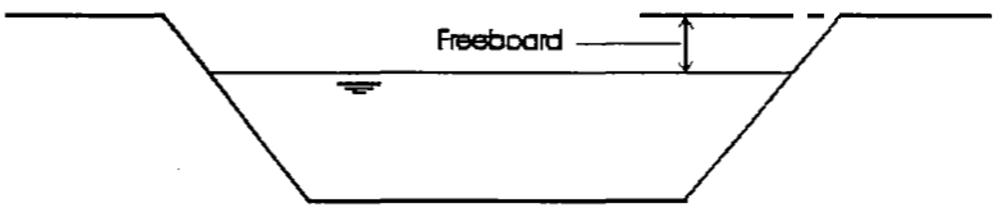

Figure 5.1 Schematic diagram showing canal freeboard

On many schemes the target discharge varies during the year with the irrigation requirements, depending on the crop calendar and climate. An example is given in Fig. 2.4 (Chapter 2) are from Mwea Irrigation Settlement Scheme. The target freeboard however would normally be the same throughout the year, to provide a safety margin against water over-topping the bank.

Thus, hydraulic performance can be represented quantitatively by the delivery performance ratio (DPR) and the freeboard ratio (FBR), defined as follows:

$$DPR = \frac{Actual\,Discharge}{Target\,Discharge}$$

$$FBR = \frac{Actual\,Freeboard}{Target\,Freeboard}$$

where freeboard is the difference between bank top level and water level.

For optimum performance at a particular time, DPR = 1 and FBR ≥ 1, these figures providing the target levels of the performance indicators.

Discharge data are commonly collected at regular intervals, enabling DPR values to be determined for corresponding times.

The actual freeboard at any time will depend on both the actual discharge, and the condition of the channel. Thus at those times of the year when the target discharge is low, a poorer channel condition can be tolerated as it will still pass the current target discharge at the target freeboard, that is optimum performance with DPR = 1 and FBR ≥ 1. Freeboard also varies with distance along each reach of the channel between structures, and will tend to be least at the upstream end of a reach, as the poor condition of a channel causes an increase in water slope. However freeboard is rarely measured, except as the water level at the downstream end of a reach, so FBR is a difficult indicator to determine. An alternative approach would be to set a tolerable failure rate as the target, for example the frequency of overtopping of a canal. This would be easier to monitor. We believe however that the FBR is the key indicator of risk of failure, and greater attention is needed to monitoring actual freeboard levels.

The question then arises: what should be the target freeboard? The design freeboard at design discharge includes allowances for wear and tear of the banks, and rises in water level due to unforeseen circumstances (such as increased discharge or deterioration in canal condition). Reduced freeboards are often observed on canals in practice, and it seems reasonable for the target freeboard at actual operating discharge to be less than the design freeboard at design discharge, which has to take account of the various uncertainties at the design stage.

The target freeboard should be derived from local conditions, taking account of these considerations. In general, a target freeboard of 60% of the design freeboard (with a minimum of 0.20 m) should be satisfactory, depending on local circumstances such as frequency of monitoring freeboard and the acceptable risk of failure. This is based on consideration of the formula often used to calculate freeboard for canals designed using the Lacey equations (in metric units):

Freeboard (design) = $0.2 + 0.235\ Q^{0.33}$;

eliminating the 25% surcharge on discharge and reducing the fixed freeboard by 0.10 m gives a formula for target freeboard of

Freeboard (operating) = $0.1 + 0.15\ Q^{0.33}$.

Trial calculations give values of Freeboard (operating) of about 60% of Freeboard (design). Similar results could be expected with other methods of determining design freeboard.

5.2.3.2 Condition

The weed-related condition of the channel can be represented by its weed succession stage, as described in Chapter 3 (Figure 3.5). Weed clearance changes a channel from a 'poor' to a 'better' hydraulic condition by returning it from a late to an earlier stage of succession. The silt-related condition can be represented similarly, but siltation normally occurs over a longer timescale, requiring less frequent clearance. Desilting operations remove weed, including root material, at the same time as sediment, thereby returning the channel to an earlier stage of succession than would some, if not all weed clearance operations.

Several researchers have studied the effect of weed growth on channel roughness and hence hydraulic performance through laboratory and field studies. This has shown that the commonly used Manning roughness coefficient (n) varies inversely with the flow velocity and hydraulic radius in a vegetated channel, which complicates the analysis (see Section 3.7.1). Also the generalised models from laboratory work use physical measures of weed infestation which are difficult to measure in field conditions, for example the fraction of channel cross section occupied by weed (Kouwen *et al.* 1969) or deflected weed height (Kouwen and Unny 1973). These models have been used for research in Europe (for example in detailed field and modelling work by Querner, (1993)), but our field experience showed that it would be unrealistic to adopt them as the basis for practical procedures to be followed by irrigation staff, particularly where technical skills are limited. Therefore our work is focused on condition categories as described below.

Another possible indicator is the Discharge Capacity Ratio (DCR) of the channel. This represents the discharge which the channel would pass in its current state (current weed infestation and degree of silting) when flowing at the target water level (allowing for the target freeboard), compared to its target discharge capacity (or design discharge of the channel)

$$DCR = \frac{Actual\ Discharge\ Capacity}{Target\ Discharge\ Capacity}$$

The DCR is useful as an indicator of the current condition of the channel, especially as target values could be set easily for different periods of the year, related to the irrigation requirements and irrigation schedule.

Measurement of DCR however requires the channel to be operated at the target water level. Our research showed that channels are often operated at other levels, and it is difficult to derive DCR values from measurements in such cases. What would be possible however is a subjective grading system, with grades being allocated by judgement of field staff from their experience, for example:

Grade	DCR
A	75 to 100%
B	50 to 75%
C	25 to 50%
D	0 to 25%

Estimated DCR grades such as these are coarse and subjective, but may still be sufficiently accurate for monitoring the condition of each channel in a scheme, and programming maintenance work. The DCR reflects the overall condition of the channel, which combines the silt-related condition, the weed-related condition and other factors such as the structural condition of the banks. The weed-related condition of the channel may also be described by its succession stage and standard botanical survey measures (particularly the percentage of plan area covered by each species) as described in Chapter 3.

Box 5.1 The relationship between discharge, freeboard and roughness

Example: A secondary canal is designed for a discharge (Q) of 0.900 m^3/s, with Manning's n = 0.030. The design cross section is bedwidth 1.50 m, water depth 0.75 m, sideslopes 1:1.5.

Assume weed growth causes the roughness n to double to 0.60, then

(1) If the water level remained the same, the discharge would halve to 0.450 m^3/s (DCR = 50%).

(2) If the discharge remained constant, the water level would rise by 0.31 m (assuming n remains constant).

A typical design freeboard, Fb(design), would be 0.50 m for this size of canal, so the water level would be only 0.19 m below the design bank top level, and in danger of overtopping at any particular low point (for example due to inaccurate construction or subsequent wear and tear or damage). The danger will be acute if siltation has raised the bed level, or any unforeseen event occurs such as a blocked gate downstream or closure of an offtake.

(3) If we adopt a target freeboard Fb(operating) = 0.60 x Fb(design)

= 0.60 x 0.50

= 0.30 m

then the maximum discharge will be 0.720 m^3/s (DCR = 80%).

5.2.4 Environmental targets for management of irrigation and drainage channels

The objective of safeguarding the environment and public health when managing weeds can be considered as follows:

- the selected weed management methods should be benign in their effects on the aquatic environment, apart from the target weeds
- weed management practices should minimise risks to the individual.

5.2.4.1 Effects on the aquatic environment

In addition to achieving the hydraulic objectives for a channel, the management adopted should not have an adverse impact on the environment (except for aquatic weeds). The most likely effects are those on the aquatic habitat. Weed management might have an unacceptable effect on such aspects as:

- human use of the water for drinking or bathing
- harvesting of certain species, e.g. fodder for livestock, reeds for basketry or door screens, aquatic plant roots for human consumption
- use of water for irrigating crops
- use of the channel for livestock watering
- fisheries resources
- rare or endangered species known to be present in, or using the channel

Impacts could occur through the misuse of herbicides or through cutting vegetation at inappropriate times. Vegetation left in the channel either after cutting or chemical control will decompose using up oxygen in the water which can have adverse effects on fisheries and other forms of aquatic life, and can produce smells and tainting in the water.

These effects can impact on the particular channel managed but can also spread on through the system and could be of significance downstream of the area, e.g. herbicides which might get into a river system receiving drainage from the irrigated area.

In a similar way to the setting of performance indicators by which hydraulic objectives can be evaluated, procedures need to be established by which the impact of weed management can be assessed. These could be as simple as designating certain sections of channel as potable water source supply or bathing areas or more complicated, foe example by linking these uses into certain time periods, e.g. the use of certain sections of channel for stock watering over fixed periods of the year. Where herbicides are used, the instructions on the label will specify time periods after application during which the chemical must not be used for irrigation purposes. In the case of a fishery, the permitted concentration of herbicide in the water should not be exceeded by ensuring that the correct dose is applied in the first instance. Regardless of the latter, permission to apply a herbicide must always be sought from the appropriate authority and guidelines/regulations followed.

5.2.4.2 Effects on the individual

The use of cutting tools, machinery and chemicals for weed control all pose a risk to the individual. It is essential to draw up safety guidelines for all these techniques including maintenance of tools, fitting of appropriate safety screens on machines and the type of protective clothing which should be worn. These are usually laid down for machines and herbicides (e.g. MAFF, 1995) but may need to be modified for use in certain locations. In-house safety guidelines will need to be written for most manual weed clearance techniques. These need to recognise the hazards of working along channels (e.g. snakes) and of entering the water (e.g. schistosomiasis).

The guidelines used for weed management need to be compatible and integrated within other health and safety guidelines and regulations as laid down by the irrigation authority.

5.2.4.3 Environmental enhancement

As well as ensuring that environmental objectives are met in terms of minimising adverse impacts and ensuring high standards of health and safety, the opportunity should be taken where possible to enhance the environment from both human and ecological viewpoints. This relates in particular to diseases such as schistosomiasis and malaria.

5.2.4.3.1 Mosquitoes

Malaria is common throughout tropical and subtropical regions and it transmitted by mosquitoes. Other diseases such as dengue fever, yellow fever, filariasis and certain types of encephalitis are also transmitted by mosquitoes. The eggs, larvae and pupae of mosquitoes are aquatic feeding and breathing at the surface of the water, and they can use irrigation and drainage channels so long as the flow is not too great. The larvae are protected from predators by aquatic plants and weed control measures may, therefore, assist in the control of the diseases which they transmit (e.g. Angerelli and Beirne 1982).

Mansonia mosquitoes which are responsible for transmitting rural filariasis and encephalitis, are unique in that both larvae and pupae derive their oxygen by puncturing air chambers in plant stems and roots by means of a specialised air tube. For example, two species of *Mansonia* are reported to be totally dependent on the free-floating aquatic weed *Pistia stratiotes* (Gangstad & Cardarelli 1990). As a consequence *Mansonia* mosquito breeding can be controlled by the elimination of all aquatic vegetation used by the mosquitoes. *Mansonia* numbers are directly proportional to the maintenance of a uniform and constant depth of water. Causing the water level to fluctuate or allowing the water body to dry out is very effective in reducing the numbers of larvae which usually take a considerable time to build up after the channel has refilled (Gangstad & Cardarelli 1990).

5.2.4.3.2 Aquatic snails

There a number of diseases caused by trematode worms that are parasitic in humans and for which aquatic snails provide an intermediate host. These diseases include schistosomiasis (bilharzia), paragonimiasis, clonorchiasis and fasciolopsiais, the former being one of the most important public health problems of the tropics and subtropics. Investigations have shown that there is a positive relationship between schistosomiasis-bearing snails and aquatic vegetation, for example in Egypt (van Schayck 1986) and in Puerto Rico (Ferguson 1980). Aquatic weed control not only removes the habitat for the snails but increases the likelihood of snails being controlled by omnivorous fish (Coates and Redding-Coates 1981).

5.2.4.3.3 Ecological stability

Channel systems in countries such as the Netherlands and England have become important refuges for a wide diversity of aquatic plant and animals species such that some areas have become designated as nature reserves. Consideration should be given to maintaining this diversity in irrigation systems, for example, by limiting management to that which is essential and recognising the importance of processes such as succession in maintaining this diversity. There can be practical advantages to this, following the school of thought which argues that diversity is directly related to stability. A stable irrigation system is much easier to manage than one which fluctuates, for example, in terms of the species which present themselves as problems. Diverse systems are also less likely to be invaded by alien species such as the free-floating aquatic weed *Eichhornia crassipes*. Ecologically sound weed management can also enhance fisheries output, for example, by providing suitable spawning vegetation in secondary channels.

5.2.5 Efficient use of resources for management of irrigation and drainage channels

The objective of efficient use of water and other resources requires systematic monitoring of operation and maintenance with the collection and analysis of appropriate data. The following are proposed as the basis for weed management to contribute to this objective:

- water losses from spillage, evapotranspiration and water control problems should be controlled at an acceptable level;
- the adopted methods for aquatic weed management should be chosen by comparing the use of resources of all possible methods which have similar outcomes.

These are discussed in turn.

5.2.5.1 Control of water losses

Control of water losses is a major concern of irrigation managers, and depends on the operation as well as the maintenance of the system. Inadequate weed control leads to increased losses of water through:

- spillage of water due to reduced channel capacities
- excessive evapotranspiration from weeds in intermediate reservoirs
- leakage through animal holes and inoperable structures.

These losses occur at all levels in the irrigation system, and the key to controlling them is regular measurements of flows in the various types of channels, and analysis to monitor the efficiencies of the channels. Current efficiencies can then be compared from systems world-wide have been collected by Bos and Nugteren (1990). The seepage of water through control structures can be sufficient to sustain aquatic weed populations which would otherwise have been destroyed by drying out of the channel.

5.2.5.2 Selection of efficient maintenance methods

We consider the use of resources by:

- ensuring the maintenance programme is based on the availability and efficient utilisation of physical resources such as labour and equipment (see Chapter 6)
- considering the cost of resources, and hence the cost of the programme: for a given maintenance level the minimum or least cost maintenance programme should be employed, as described in Chapter 7 (see also the Section 5.6).

5.3 Inventory

This section addresses the question: what is to be maintained?

Keeping the irrigation system in good order requires attention to:

- System components such as canals, drains, reservoirs, structures, embankments, access roads and paths.
- Equipment used in the maintenance programmes, including tractors, excavators, specialist buckets and other attachments, cutters, boats, chemicals, chemical applicators and a wide array of tools.
- Equipment needed to maintain the above mentioned assets. These include service and maintenance bays and their support tools.

For systematic maintenance of these assets it is necessary to list and compile summary information in asset registers which are updated regularly.

Although all of these assets are critical to the maintenance process, the concentration in this report is on those components which are critical to the performance of the hydraulic functions of the system. These functions are most imperilled by weed and silt formation and therefore the focus is on control of the water delivery system and the assets required to support that control. Maintenance of other civil works and roads is not central to this focus, but reference could be made to the books by Hindson (1983) and Coukis (1983). For the system components it is necessary to identify the types and sizes of channels to be maintained, and their extent (i.e. length) in order to decide on suitable maintenance methods, institutions and budgets.

5.4 Types and timing of maintenance

This section addresses the question: how is maintenance to be executed?

5.4.1 Maintenance categories

Maintenance can be considered in four categories (based on Sagardoy, 1982 and Burton, 1995):

(1) Routine preventive and minor maintenance
(2) Routine planned maintenance
(3) Special maintenance and emergency repairs

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(1) Routine preventive and minor maintenance
(2) Routine planned maintenance
(3) Special maintenance and emergency repairs
(4) Deferred maintenance

5.4.1.1 Routine preventive and minor maintenance

Routine preventive and minor maintenance is small maintenance work that is done on a regular basis by an individual labourer, without being included in a formal maintenance programme. Such work might include:

- monitoring the presence of problem weeds in channels and elsewhere in the river system,
- selective weeding of problem weeds at early stage within canals and drains from embankments (e.g. trees and bushes likely to cause damage) and from around structures
- frequent light operations to control weeds before flowering or seed set.

This work would normally be done by a water bailiff or gatekeeper, a maintenance labourer, or individual farmers (particularly within the tertiary unit). It may be very effective in reducing weed problems and reducing the amount of planned maintenance required.

5.4.1.2 Routine planned maintenance

Planned maintenance is larger-scale work which is identified as needing to be done, and included in a routine maintenance programme. This work is generally too big for one person to do and will be done by a group of labourers or farmers working together, or by mechanical equipment. The tasks may be undertaken by the irrigation scheme management agency using its own resources of equipment or direct labour; or alternatively the work may be let to a contractor, or done by farmers. Such work might include deweeding or desilting a complete canal or drain using labour-based, mechanised or other methods referred to in Chapter 4.

At Mwea Irrigation Settlement Scheme, weed clearance is scheduled two or three times per year, and desilting once per year, as described in Chapter 2 and detailed in Table 2.4. The maintenance records for 1992, shown in Figures. 5.2 and 5.3, indicate that the peak period for canal maintenance was May to July, and for drain maintenance, July to October. The records show that the allocation of labour and hydraulic machinery is consistent with the reported priorities of the management cycle, together with ongoing year-round activity on both canals and drain; these are related to the other weed clearance operations scheduled during the year and the need to make balanced use of the available resources of labour and hydraulic machinery.

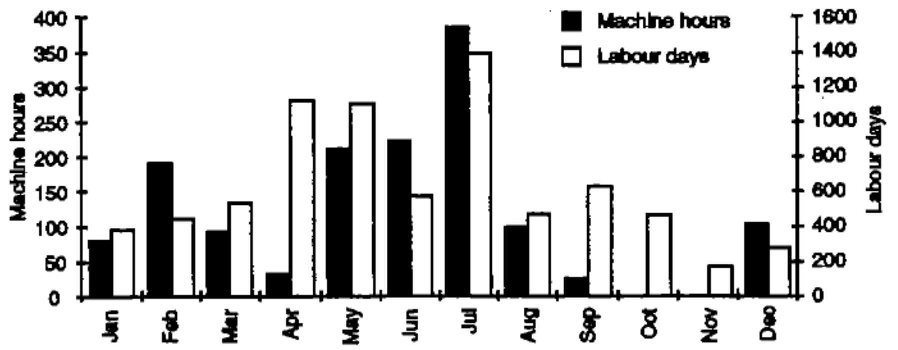


Figure 5.2 Canal Maintenance Inputs at Mwea Irrigation Settlement Scheme, 1992

Figure 5.3 Drain Maintenance Inputs at Mwea Irrigation Settlement Scheme, 1992

Inspection and monitoring of maintenance needs is part of the water bailiff's daily routine. Gatekeepers, pump operators and labourers will also be responsible for identifying and reporting maintenance requirements. Engineers or other operation and maintenance staff can then confirm and quantify the requirements, and their duties should also include formal inspections of the irrigation and drainage systems, and reporting on their condition. This may be carried out at regular intervals during the year, or annually. It is common to have periods of canal closure, one period for inspection, the other, longer one for annual maintenance. Ideally this should be scheduled for a time when there is little need for irrigation and when the weather conditions are most favourable (i.e. avoiding periods when it is too wet or too hot to work). The canal closure and draining down of the system will enable detailed examination of the works below the water line.

5.4.1.3 Special maintenance and emergency repairs

Special or emergency work is carried out as the need arises, following unforeseen problems such as dangerously high water levels in a canal or local flooding. Depending on the nature of the work it may be carried out by the irrigation agency, often with the assistance of the local population, or by groups of farmers.

This work might include unscheduled weed clearance to improve canal capacity and reduce the risk of failure, or temporary repair to canal embankments in the event of overtopping.

By its nature emergency maintenance work has to be carried out quickly. In systems where such needs are common (for instance in high risk flood areas) procedures need to be clearly established beforehand, and agreement reached with farmers and others on such procedures. An effective telecommunication system can be invaluable in such circumstances, for example if a canal breach occurs a message can be radioed to the headworks to close down or reduce the intake discharge.

5.4.1.4 Deferred maintenance

Deferred maintenance is maintenance work that has been identified as needing to be done but which cannot be done straightaway due to limitations of funds, limitations of manpower, or because it is not a serious problem at the present phase of the agricultural cycle, or other tasks have higher priority.

Such work might include any of the examples of planned maintenance given above, such as desilting canals or clearing of weeds from drains. Deferring maintenance may lead to future problems, requiring emergency repairs or rehabilitation of the system.

5.4.2 Implications for maintenance policy

Maintenance may be the *ad hoc* response to failure of system components, i.e. reactive, largely undertaken as special maintenance or emergency repairs. Viewed in this way it is often an element in crisis management. Maintenance will largely be of a corrective nature - putting things right after they have gone wrong. Given the randomness of component failure it is difficult to plan for the future under such a regime, spares may be unavailable or labour may be occupied on say competing agricultural activities. Because of these uncertainties the economic costs are likely to be large due to system failures and equipment downtimes.

Some of these uncertainties and their accompanying costs may be removed (or at least reduced) by a more proactive attitude to maintenance. This attitude anticipates things going wrong unless preventative measures are taken. Taking appropriate measures requires a planned, forward-looking approach to such issues as identifying potential weak and vulnerable links in the system and anticipating the resource requirements to prevent failure.

Planned maintenance involves the programming of work. Identification of specific tasks and maintenance outputs facilitates target setting, monitoring of performance and the provision of incentives for workers. Because of its proactive nature it requires routine inspection, servicing and preventive maintenance, replacement when appropriate and necessary remedial works.

Box 5.2 Benefits of maintenance planning

1. The principle benefit is that planned maintenance fosters and promotes a culture of caring for the smooth and efficient operation of all aspects of the system. It elevates the idea of system performance.
2. Maintenance can be phased through time to be compatible with the hydraulic requirements of the agricultural year if it is planned rather than a response to failures. The sequence of the agricultural cycle is critical in maintenance planning.
3. In the case of maintenance equipment higher utilisation levels may be achieved as downtimes are reduced. Higher productivity manifests itself in reduced costs. In the case of infrastructure better hydraulic performance may improve crop quantity and quality resulting in higher system benefits.
4. Systematic maintenance may reduce the incidence and costs associated with the aforementioned external diseconomies of production for example, salinity problems caused by poor drainage or excessive water use through over-topping.
5. Requirements of spare parts, tools and skills can be estimated and stocks of each maintained and employed at adequate levels. Elimination of wastage through holding surplus spares of redundant materials may be accomplished. A more systematic inventory policy may reduce the financial penalties of delayed receipt of spares.

Although it may be argued that planned maintenance is expensive in terms of resources and organisation, with sound institutional arrangements these expenses could be financed from the improved system working and the consequent additions to net revenue. It may equally be argued that without planned maintenance the potential economic losses are also considerable from system breakdown, more expensive repairs and poorer performance.

5.5 Maintenance management

This section addresses the questions: what is the required institutional set-up? And who will manage and execute maintenance?

The institutional model that we work from has three levels

- senior management of the irrigation agency, such as the Board of Directors of a company or parastatal or the Directorate of a government Department of Irrigation
- management and staff of each irrigation scheme
- farmers, both as individuals and groups, possibly organised in water user associations.

In addition central agency staff may be involved (for example, in procurement) and some work may be undertaken by contractors. An important issue is the split of responsibilities between the various levels and organisations.

Senior management of the agency will be concerned with maintenance policy. The planning and implementation of the maintenance programme will be the responsibility of scheme management and/or the farmers.

Economies of scale in the provision and maintenance of mechanical equipment require major maintenance tasks to be controlled and executed at the scheme (or agency) level. Economies of scale arise from the spreading of fixed costs (e.g. maintenance depots, equipment and staff); a related issue is the indivisibility of mechanical plant - it cannot be divided into farmer size units and for example the minimum size of excavator may be much larger than an individual farmer could afford or need. Also better terms for the purchase of inputs, for example fuel and lubricants, spares and loans may be obtained by large scale purchase.

Moreover, the complexity and the interdependencies in irrigation systems require an overseeing authority at least for the maintenance of higher order components of the system. Synchronising maintenance timings to the deployment of capital equipment and labour are obvious examples of the need for a supervisory agency. There are other reasons which relate to the economist's point of view that a maintenance service has the characteristic of a collective or public good. These are goods which once provided are consumed by all - even those who do not pay. Markets do not function for these goods and markets fail to allocate them. In the absence of some element of compulsion they will not be provided or will be provided at sub-optimal levels. Other examples, include street lighting, swamp drainage for malaria control and refuse removal. Collective action is needed to provide the public good at an efficient level and this requires a body such as the scheme management to levy compulsory payments and to supply maintenance at least at the primary and secondary levels.

Maintenance of smaller channels is commonly left to farmers perhaps with supervision by the scheme management. However, the interdependencies in systems at the lower levels demand that checks on maintenance quality are made and that sanctions can be imposed on poor maintenance provision. At the farmer level the incentives may be perverse in that poor maintenance may even confer benefits for the offender (i.e. they may get more water) while the costs are imposed on a neighbour downstream (i.e. they may get less water). Thus an overseeing authority must be able to deploy incentives and sanctions to ensure that such perversities are overcome. This may be accomplished, for example, by making a private benefit to the farmer conditional upon a satisfactory level of maintenance. Hence, free or subsidised seeds, tools or technical advice may be contingent on passing a maintenance quality check.

The scheme management should also have the function of arbitrator in the event of disputes between neighbours. These may occur for example when a tertiary channel is bordered by the land of two farmers who fail to agree on a division of maintenance responsibilities.

5.6 Maintenance budget levels

This section is concerned with the question: how much budget should be allowed?

From an economic perspective, maintenance expenditures are viewed as investment expenditures rather than as consumption expenditures. Money and resources are used to assure a return through the increase in net benefits that the well-maintained system provides.

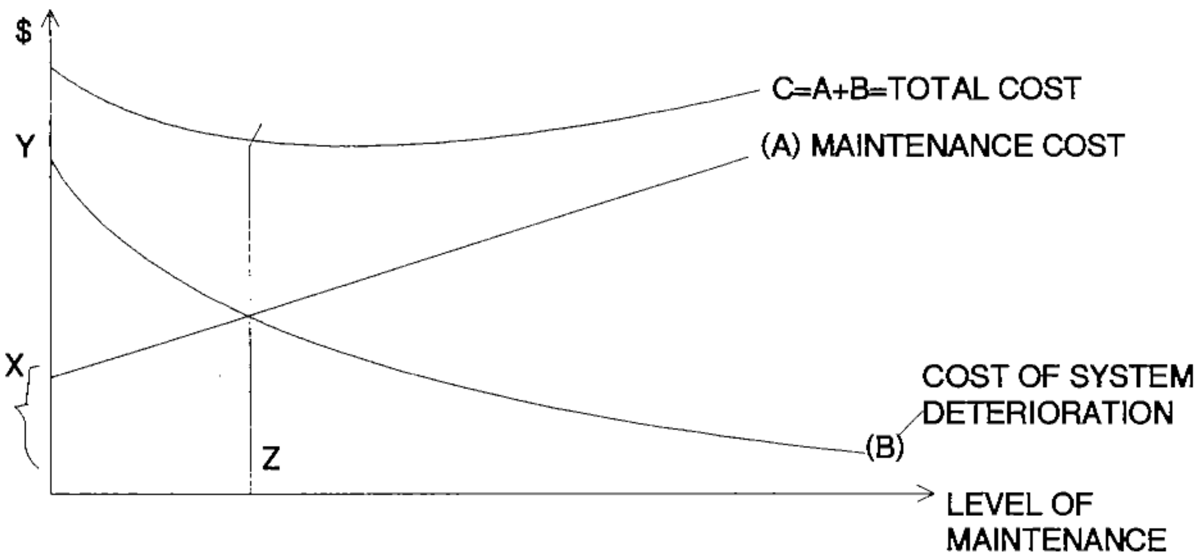
The relevant judgement for management is whether the incremental maintenance expenditures needed for a level of maintenance are more than recovered by the benefits which ensue in the form of avoided deterioration costs (see Box 5.3). In making this judgement it is important to realise that maintenance is forward looking. Expenditures that have been made in the past and which are now sunk costs are irrelevant for current decisions. Thus, an expenditure incurred 10 years ago for the acquisition, say of a hydraulic excavator, has no significance for today's decision as to which is the least cost method of removing silt. The issue is whether future incurred costs provide sufficient benefits to justify their future expenditure.

Operationally, it is difficult, if not impossible, to estimate the money value of benefits in the form of avoided reductions in the quantities and qualities of crops which inadequate maintenance would cause. The calculation is complicated because neglect of maintenance only increases the probability of losses but does not make them certain. External events may compensate for poor maintenance, for example, more plentiful rain than usual or the introduction of less water dependent crop varieties.

Because benefits are location and crop specific and their monetary estimation requires a large amount of information, it is suggested here that a more workable way to proceed is to examine alternative maintenance programmes and to calculate the minimum cost strategy for attaining a given level of system performance. The latter is deemed to be a standard of weed and silt clearance sufficient to reduce the risk of economic losses to acceptable levels. The mechanics of this calculation and examples are provided in Chapter 7.

Box 5.3 The idea of optimum maintenance provision

From economic principles the maintenance budget should be set according to the benefits obtained from maintenance, and the diagram seeks to show the principles which govern the idea of optimum maintenance. The vertical axis provides an indication of costs measured in money. The horizontal axis shows the level of maintenance. In the case of a stretch of canal it presents the amount of clearance.



The amount of X could be viewed as the minimum expenditure without which the irrigation system would completely fail to function. As clearance effort increases, timely and sufficient quantities of water reach and leave the crops. Additional clearance requires resources - labour and excavator time - and so Curve A rises from left to right. Failure to maintain the system resulting in complete collapse would impose economic costs equal to Y amount. As clearance effort increases the expected cost of system deterioration costs include financial losses due to lower crop yields and perhaps reduced quality. In addition the economic costs of wasted water should be included. Although many irrigation authorities do not pay for water or pay a price below cost, the economic value of this water is not zero but the Average Incremental Cost of its production.

The vertical sum of Curves A and B yields the Total Cost Curve C. It is tempting to say a perfectly maintained system should have zero deterioration but this could only be achieved at exorbitant cost.

Taking both maintenance costs and the avoided costs of deterioration (the benefits) it can be seen that the economic optimum degree of clearance is at the minimum of Curve C at level Z.

In practice the curves are difficult to define due to lack of data, particularly on the cost of system deterioration. The important point to note is that there is an optimum level of maintenance which is usually neither the minimum to prevent collapse of the system, nor the amount which enables maximum performance, unaffected by deterioration in the condition of the system. Without the data, managers have to make a judgement of this optimum level of maintenance, by asking questions like “is it worth doing any extra maintenance work?”.

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