A Procedure for Planning Irrigation Scheme Rehabilitation

G Cornish
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TDR Project R5832

Report OD/TN 84
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ODA

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Contract

This report describes the work carried out by the Overseas Development Unit (ODU) of HR Wallingford in collaboration with the Directorate General of Water Resources Development, Indonesia.

The work was carried out for the Overseas Development Administration (ODA) of the British Government. The ODA Technology Development and Research theme and project details are as follows:

Theme	Improve availability of water for sustainable food production and rural development
Theme No.	W5
Project	Irrigation Management/Planning and Rehabilitation
Project No.	R5832

Prepared by .... (name) IRRIGATION SPECIALIST (job title)

Approved by .... Section Manager

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Summary

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The Procedure is the final output of a three year project under the UK Overseas Development Administration's TDR programme, to investigate and recommend methods of determining priority needs in irrigation rehabilitation programmes. The work, undertaken jointly by HR Wallingford and the Directorate General of Water Resources Development, Indonesia, was based initially on field investigations at three schemes in Yogyakarta Special Province, and subsequently on a scheme in Central Sulawesi.

The Procedure is aimed at Government, funding agency and consultancy staff who must appraise schemes for rehabilitation. It is intended to help in project identification and formulation, improving the objectivity and consistency of assessment and making the best use of available resources by:

- identifying the factors which lead to schemes performing below expectations
- determining the condition and fitness of scheme components
- establishing priorities for improvement

The performance of an irrigation scheme is influenced by many factors, socio-economic, agronomic, environmental and technical. Factors are often interlinked, so causes and effects may not be readily distinguishable. Physical defects may be more easily identified, but their removal will not necessarily solve problems of under-performance.

Used in the initial stages of project identification, the Procedure should help to determine whether rehabilitation could improve scheme output, or what other measures might be required. If the proposed project continues to look technically and economically feasible, the Procedure may be used further to identify priority works for rehabilitation. Detailed investigation of non-engineering problems is not included in the document.

Section 1 of the document identifies the scope of the Procedure.

Section 2 discusses the performance of schemes. Problems of evaluating performance on the basis of limited data and brief visits to the field are identified.

Section 3 describes the uses and analysis of background data to detect problems.

Section 4 describes the purpose and use of two of the three principal elements of the Procedure :

- Checklist of performance constraints
- Questionnaire for Farmers

The checklist is intended to detect the nature and approximate scale of constraints, both technical and non-technical, on the performance of a system. Underlying causes for apparent constraints should be identified in the process. It should serve as the basis for initial discussions with O&M staff during pre-feasibility investigations and as a guide to further work. The proforma is included in Appendix 1.

The questionnaire (proforma - Appendix 2) is aimed at farmers. It should provide views from field level about the functioning of the system, the needs for technical improvements, general problems faced by farmers and the relative importance of technical and non-technical issues. In conjunction with the checklist it will provide a crosscheck on initial findings.

Section 5 describes function-based **Condition assessment,** the third principal element of the Procedure (Appendix 3). Assessment would be undertaken at feasibility stage if the checklist and questionnaire indicate that there are physical constraints to improved system performance. The process is intended to establish a consistent basis for determining the fitness of an asset for its function.
The priority of works is established by combining the assessed condition of a component of a system with a measure of its strategic importance and the area served, in an overall score and ranking (Section 5.4). The cropped area served by an element is considered to be a rough proxy for its economic value to the system, and it is therefore included in the priority-setting process. As it is difficult to link benefits uniquely to the improvement of individual components of an agricultural system, optimization of the returns to packages of works is not attempted. However, ranked lists of works will form the basis for detailed economic analysis of the costs and benefits of possible alternative programmes of investment.

Computer modelling offers potential for diagnosing hydraulic constraints and for evaluating the effect of different interventions. Notes on the use of modelling are included in Appendix 6.

The experience acquired in Indonesia, which was drawn upon in developing the Procedure, is summarized in a separate report (Cornish 1994). A software program, MARLIN (Maintenance and Rehabilitation of Irrigation Systems), has subsequently been developed at Wallingford to assist with routine use of the condition assessment and ranking procedures in planning scheme maintenance.

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1 Introduction

1.1 Background

In many regions of the world, shortage of water and suitable land increasingly constrain new developments in the irrigated agriculture sector. The major international funding agencies are now largely involved with programmes of rehabilitation rather than with new construction.

Feasibility studies for rehabilitation projects often indicate high rates of return on capital investment, provided that the assumed benefits from intervention are achieved. In practice, performance audits show that returns to rehabilitation are very frequently lower than anticipated. One reason is that projects tend to be formulated around improvements to infrastructure, to remove perceived constraints to performance. However, institutional, social and economic constraints may play a greater role in reducing scheme output than technical factors, the circumstances varying from scheme to scheme. Unfortunately, the relative importance of the various constraints may not be readily apparent.

The International Commission on Irrigation and Drainage (Fasso, 1987) distinguishes between Rehabilitation - the *renovation* of a scheme to meet its original design criteria - and Modernisation - the *improvement* of a scheme to meet new criteria. Intervention projects offer the opportunity to examine the functioning of a scheme and consider whether an upgrading of the design is appropriate. The processes of problem identification and priority - setting, with which the present document is concerned will be common to the two types of project. The decision as to whether to renovate or improve may be taken when the reasons for failing performance have been clearly identified.

HR Wallingford, with the support of the UK Overseas Development Administration (ODA), has undertaken programmes in a number of countries aimed at investigating the deterioration of irrigation systems and diagnozing the causes for declining performance, (Goldsmith and Makin, 1989), Francis, (1988), Brabben and Bolton, (1988), Smailes, (1996). The present document is the principal output of a three year investigation together with the Directorate General of Water Resources Development (DGWRD) in Indonesia to develop improved methods for identifying and formulating rehabilitation needs. Initial work concentrated on an investigation of performance and condition of three schemes, Sapon, Van der Wijck and Papah (Cornish 1994) in Yogjakarta Special Province. In the final year of the project , the Procedure detailed in the present document was developed and applied with DGWRD at Dolago scheme in Central Sulawesi.
It is envisaged that the Procedure will be of use to government, funding agency and consultancy staff, being sufficiently flexible for use at a number of levels. It is hoped that it will help users formulate programmes aimed at the prime causes of scheme underperformance, rather than the renewal of complete systems. In this way, available funds should be used more effectively.

1.2 Need for Rehabilitation - Causes and Effects

Complex linkages can exist between factors affecting performance and their effects. Figure 1 summarizes the interaction between the many possible determinants of performance.

As an example, poor operational control and field water management could lead to excess water in the drains, e+ncouraging weed growth and lack of channel capacity at times of rainfall. The resulting flooding might cause a reduction in cropped area, reduce or reschedule water demand if crops are replanted,

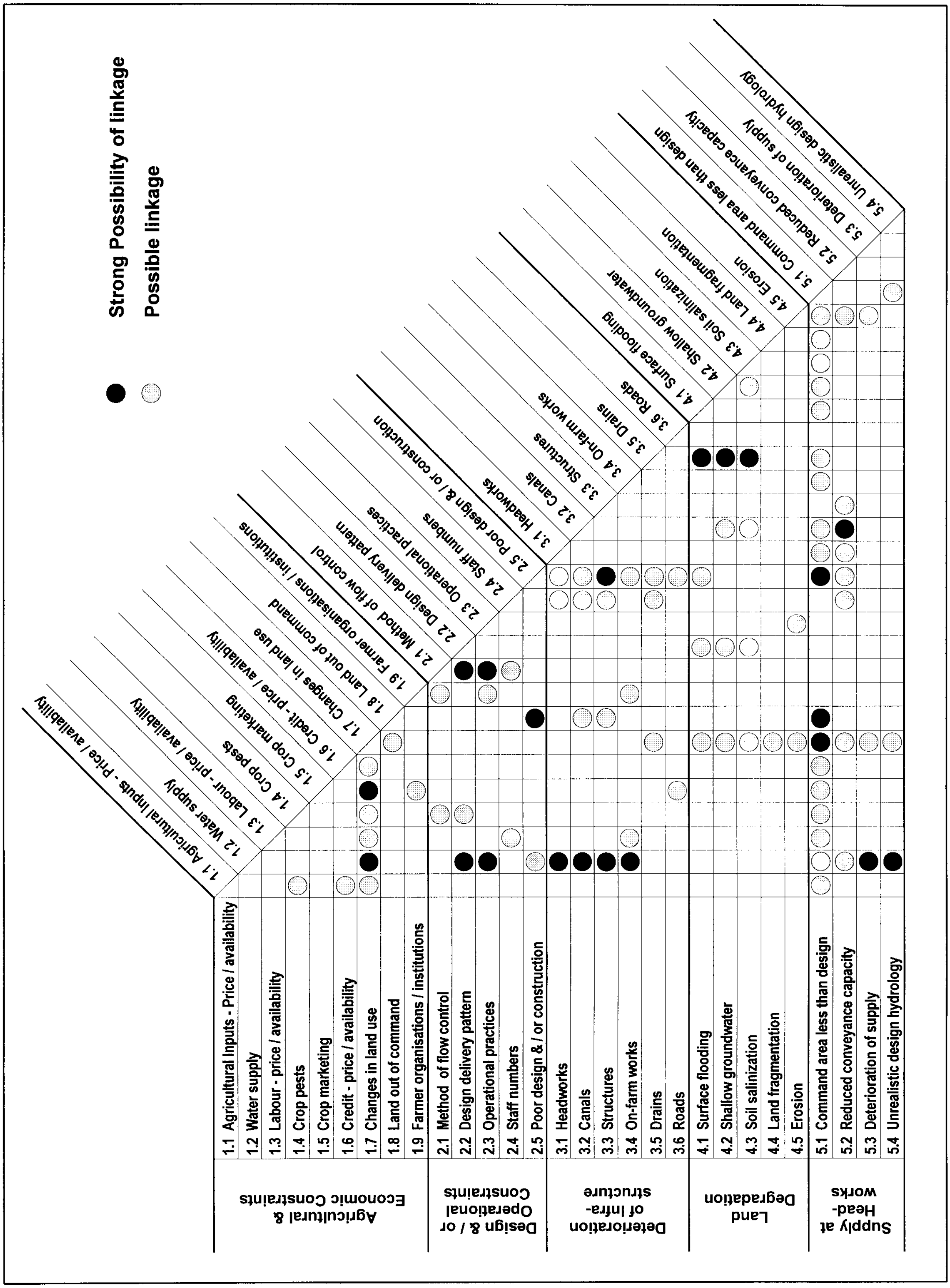

Figure 1 Links between causes and effects

discourage farmers from investing in inputs, reduce yield, worsen problems of water control in the system, and lead to further waste of water.

Again, an external cause such as falling world commodity prices could reduce returns to farming so that farmers leave the land or do not invest in inputs . Crop output falls, water demand falls, channels run part-full, sedimentation and weedgrowth proliferate, water supply becomes erratic, crop yield falls further.

The need for broad-based interventions to achieve sustainable improvements to overall performance is illustrated below:

- Inadequate operational practices may limit improvements to water supply expected from improved infrastructure.
- Trained and motivated operational staff are needed. They must be committed to delivering a specified minimum level of service. Institutional will and government policies are needed to effect such changes.
- Farmers must be willing and able to exploit a better supply. They may need training in water use and maintenance. A formal or informal water user group must exist. Until the water supply is improved, it is unlikely that farmers will cooperate.

Outward indications of underperformance, which may be cited as evidence of a need for rehabilitation, are termed '**perceived defects'** at the head of Figure 2. Perceived defects may be due to a number of linked causes, as indicated above.
'Primary causes' are set out below the perceived defects in Figure 2. They have been grouped into the following broad categories: agricultural/ economic, design and operation, system deterioration, land degradation and headworks supply.

A large number of possible alternative, or complementary, **underlying causes** are shown below the primary causes.

At the bottom of Figure 2 are shown the three diagnostic tools which are contained within the Procedure, which are detailed below. Hydrological analyses are also included as a diagnostic tool. Since standard methods are well-documented elsewhere, they are not further detailed here.

1.3 Aims and Scope of the Procedure

The Procedure is aimed at `pragmatic' physical rehabilitation, (Murray-Rust, 1985). 'Pragmatic' physical rehabilitation relies on diagnosis of the condition of the infrastructure to determine its impact on the water distribution performance of the scheme. The key constraints on scheme performance are identified and may be selectively removed.

The Procedure should help in formulating programmes by:

1) Identifying factors which constrain the performance of individual schemes and thus determining whether rehabilitation will be beneficial and/or what other measures may be needed.
2) Determining the condition of individual scheme elements and their fitness for function.
3) Prioritizing works.

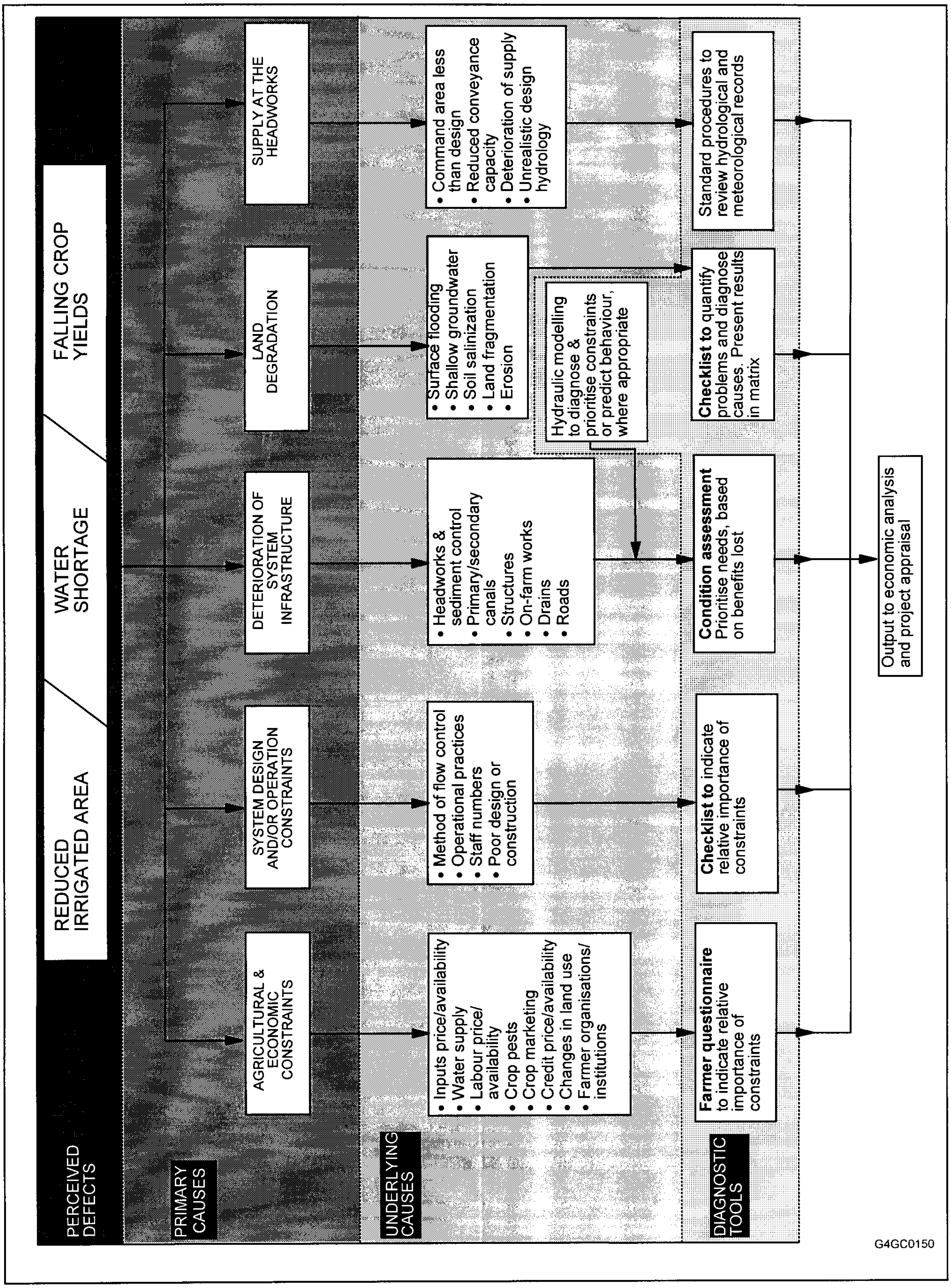

Figure 2 Determinants of performance and diagnostic methods

Action 1) corresponds to the pre-feasibility stage when schemes may be screened and compared on the basis of approximate estimates of technical and economic viability. If the project proceeds to feasibility stage, more detailed information may be required on the constraints to performance of individual projects, so that economic and technical feasibility can be defined. Actions 2) and 3) will follow, providing the detail necessary to plan and cost the project. Note that the Procedure does not cover the investigations required to formulate non-engineering components to the project.

Table 1 summarizes the steps in an investigation. For the present purposes, it is supposed that pre-feasibility and feasibility studies will both be carried out, though the processes may in reality be condensed into one.

The Procedure comprises three principal diagnostic tools:

- Checklist of factors potentially limiting scheme performance.
- Questionnaire to obtain farmers' opinions on system constraints and priority needs.
- Condition assessment methods, determining 'fitness for function', which lead to a listing of priority works.

Sections 4.1, 4.2 and 5 respectively describe the use of these elements.

The Procedure identifies where schemes are failing to perform adequately but does not recommend on the standards for improvement. Circumstances change over time; the original design standards may no longer be appropriate. Rehabilitation provides the opportunity to review original assumptions and make changes as necessary.

Initial Investigation (Prefeasibility)
The checklist is intended to detect the nature and approximate scale of constraints, both technical and non-technical, on the performance of a system. Underlying causes for apparent constraints should be identified in the process. It should serve as the basis for discussions with O&M staff and as a guide to further investigations.

The questionnaire is aimed at farmers. It should provide views from field level about the functioning of the system, the needs for technical improvements, general problems faced by farmers and the relative importance of technical and non-technical factors. Used in conjunction with the checklist it provides a crosscheck on initial findings.

Alternative outcomes and actions at the end of the pre-feasibility stage could be:

Finding	Action
No significant problem	End investigation
No major infrastructural problems but substantial problems with institutional, agronomic or socio-economic aspects.	Formulate appropriate project (outside scope of Procedure)
Substantial infrastructural problems(s)	Proceed with more detailed investigation. Focussed institutional support project may also be required.

Table 1   Steps in Investigation

Pre- Feasibility

- Obtain sector and system background data
- Interview operations staff   CHECKLIST
- Check water supply
- Obtain operations data, compare performance with norms

- Stratify scheme for survey   FARMER QUESTIONNAIRE
- Interview farmers
- Visit problem areas
- Rapid inspection of condition
- Rapid hydraulic checks, if appropriate
- Outline costs and benefits

Feasibility

- Interview operations staff
- Hydraulic checks, if appropriate
- Inventory of system & condition   CONDITION ASSESSMENT
- Outline priorities
- Outline programme of works with quantities
- Costs and benefits
- Report feasibility

If rehabilitation appears viable after pre-feasibility investigations , any substantial physical works which would exceed estimates based on a per hectare improvement cost should be identified and costed in. If institutional, agronomic or socio-economic constraints are identified, experts in the individual disciplines should be involved in formulation of complementary actions.

Detailed Investigation (Feasibility)

The condition assessment procedure provides a consistent basis for determining the fitness of an asset to perform its function. It allows a selected set of assets, identified on the basis of priority of need, to be included in a programme of rehabilitation The assessment assigns the asset to one of four categories: Good, Fair, Poor or Very Poor.

Condition assessment would be undertaken only if the checklist and questionnaire indicated that there were physical constraints to improved system performance.

It is assumed that the basic assessment is made by relatively inexperienced staff, (Overseer's Inspection). If needed, more detailed investigation can be made by an engineer (Engineer's Inspection) to bring more experienced technical judgement to bear.

Priority ranking of need is based on three elements: the condition of a component, a function of the area served, and a measure of the functional importance of the component. The ranking method produces priorities which are independent of each other, in other words, there is no direct link to ensure that all components needed to produce an anticipated improvement in performance are ranked together. The user must therefore apply judgement to ensure that a practical programme of works is selected. The economic return to less pressing works will diminish progressively.

Under the condition classification system adopted, classes Good and Fair require only minor work, not urgent at present, which could be addressed under a programme of minor maintenance. Works defined as Poor or Very Poor require imminent actions, provided they satisfy criteria for priority (Section 5.4). Depending on available funding, such works would be suitable for inclusion under a rehabilitation programme or selectively under emergency maintenance. However, the system of prioritization does not demand that such a seemingly arbitrary division between programmes be strictly followed. Works can be selected according to available funding.

For large schemes, the Procedure can be used to confirm the nature and approximate magnitude of problems. If an overall constraint is identified which is principally technical in nature, and the economic returns to rehabilitation appear broadly favourable, the Procedure may be applied further to identify particular elements of the scheme which constrain performance. Priority of need can be established, and selected works included in a programme of rehabilitation.

For sector programmes, less detailed information on individual schemes will probably be available. Preliminary identification of schemes with the more pressing problems could be made on the basis of confirmed information on scheme output and irrigated area. The Procedure would serve initially to identify whether physical rehabilitation were the appropriate response. The preliminary economic case for rehabilitation could be based on standardized development costs per hectare (Section 2.2). After preliminary selection of schemes, the Procedure can be used to identify essential works within individual schemes so that a detailed economic analysis can be made.

By adopting a selective procedure, under which items of work are chosen according to their effect on system performance, the unit costs of rehabilitation might in many cases be reduced without jeopardizing the integrity of systems. The returns to investment by both funding agency and Government would be higher, making scarce local capital available for alternative uses. Governments must, however, commit themselves to effective programmes of maintenance to avoid unchecked deterioration of currently satisfactory elements.

2 Performance of Schemes

2.1 Indicators-General

The costs of a rehabilitation project must be justified either by increasing output by expanding the cultivated area, or by raising yield on the existing command area. In some circumstances, rehabilitation will be necessary to safeguard current levels of output. Irrigated area, yield and cropping intensity are widely seen as primary measures of system performance. Systems may be identified for rehabilitation if the indicators are demonstrably lower than regional /country norms for the crop, soil, and climate. (Section 2.2)

However, outline data on yield and irrigated area do not provide a firm basis for detecting whether rehabilitation is required. High crop yields and areal coverage indicate that the system, including its hydraulic aspects (Section 2.3), is performing satisfactorily. Lower values do not necessarily indicate that the hydraulic performance is unsatisfactory and that the infrastructure therefore needs to be restored. Many other factors may reduce yield and irrigated area, including, for example: a reduction in the water supply at source ; crop losses due to pests and diseases; diminished soil fertility; unseasonable weather conditions; unfavourable crop prices; alternative uses of the land; shortage of labour.

There are other disadvantages to the use of yield and irrigated area as primary parameters of performance. Recorded data are frequently of dubious accuracy. In the case of crop yield, uncertainties are due partly to inaccuracies inherent in the methods used (crop cutting or recall), and partly owing to the use of limited sample sets to produce average values for quite large areas. Variations between samples taken within selected areas may well exceed differences in mean yield between different areas. The Ministry of Agriculture, which is normally responsible for determining crop yields, probably takes samples according to criteria which are unrelated to the water supply system. It is therefore difficult to make meaningful correlations between water supply and yield within localized areas.

Reliable figures on cropped area are notoriously difficult to obtain. Quoted areas are often the nominal commands and therefore show no variation between years. Lands which theoretically lie outside the project may benefit from the project water supply, whilst areas within the project, particularly in the tail regions, may be inadequately served. In such circumstances farmers may draw water from adjacent systems under informal or semi-formal arrangements.

Notwithstanding the difficulties in obtaining accurate information on output, the feasibility or otherwise of rehabilitation will inevitably be judged on that basis.

Supplementary investigations will therefore probably be required at the identification

stage to confirm the output and for cropped area, determine the causes of unsatisfactory production, and locate disadvantaged areas.

2.2 National Performance Norms

Schemes are commonly selected for rehabilitation on the basis that they do not match up to national performance norms which have become established over time. Examples of such norms are :

Aspect	Norm
Agricultural	
Yield	Crop(s) output per ha.
Areal coverage	Actual command compared with design command
Cropping intensity	Annual total cropped area compared with design command
Hydraulic	
System efficiency	Overall water use efficiency
Application efficiency	Farmers' water use efficiency
System level releases	Area irrigated per unit of water, or discharge per unit area
System level seasonal releases	Average depth of water supplied at the headworks per unit of land
Canal seepage	Volume lost in seepage per specified wetted surface area
Tubewell coverage	Area served per installation
Economic	
Development cost	Cost per hectare

Since climate, soils, crop variety and topography can vary widely, even within a region, it is necessary to know the range of conditions for which the national norms were developed, to verify that they are relevant to any individual scheme. In other conditions, the target values of the various parameters may either be unattainable or, on occasions, may be unduly conservative.

National figures for the development costs per unit of land will normally provide a benchmark against which to compare potential benefits from proposed projects.

2.3 Water Supply, Demand, and Hydraulic Indicators

2.3.1 General

A hydraulic system should be able to allocate available supply equitably against demand. In practice, operators and farmers may be accustomed to using the system in ways which lead to uneven distribution or accelerated deterioration. Rehabilitation of the system may be the appropriate response if there are clear physical constraints, but many factors affect the balance between supply and demand. A formal framework can help the assessor to determine the primary causes for observed effects within the limited time available for an investigation. As an example of the possible complexity of the problem, a variety of possible causes for an apparent water shortage in parts of the scheme are indicated in

Section 2.3.2. In some circumstances, the nature of the problem may appear clear. For example, tail end canals may become so weed - grown and silted up that flow clearly cannot pass. The underlying causes might be less clear:

shortage of water at the headworks, inflow of sediment due to catchment development, 'theft' of water by upstream farmers and unsuitable operation, amongst other conditions, might all lead to the observed effects. It might well be necessary to rehabilitate the system, but without other measures the benefits would prove short-lived.

In arid regions, variations in temperatures between years will affect demand to some extent. More importantly, for run-of-river systems, considerable variations in supply are likely. In semi-arid and humid areas, where irrigation is designed to supplement rainfall in one or more seasons, both seasonal demand and supply may vary considerably between years.

Irrigation systems are usually designed to assure adequate supply in 80% of years. Thus, over a long period of operations, some degree of shortage could be expected on average once every 5 years, a very approximate estimate, particularly because the climate in many regions appears to be changing. Since the functioning of the system at any time is affected by climate, judgements about relative scarcity of supply and crop output must obviously be set in the context of recent events.

Field investigations are unlikely to be timed for a period when the system is under stress. It is therefore useful to establish in advance whether the conditions found in the field are broadly typical of longer term performance. At the least, climatic records will serve to establish whether the season to date is 'normal', or significantly wetter or drier than average. Similar procedures will categorize immediately preceeding years/seasons.

2.3.2 Supply and Demand

Overall patterns of supply may be determined from the average depth of water released at headworks level (Section 3.3 shows an example). The volumetric sum of discharges over time divided by the cropped area yields a duty which may be compared with seasonal norms.

A large number of possible alternative factors may affect supply and demand (see Figure 2).

Excess Releases

If the supply at the head of the system consistently exceeds design values or regional norms over a number of seasons, it will be necessary to establish which of the following factors could be responsible:

1) The actual irrigated area is greater than reported. 'Unofficial' areas may be drawing water from the scheme. It may be realistic to accept the *de facto* situation, modifying infrastructure and system operations as necessary.
2) High water use rates owing to poor field management, or light soils.
3) High losses in the conveyance system owing to poor condition of the channel and embankments (linings) or optimistic design assumptions about losses.
4) Poor operational control, water may be lost to drains.

Cause 1) may call for remodelling (modernization). Rehabilitation could address cause 3), and possibly partially improve 4). Problem 2 would require separate, or complementary, solutions.

Reduced Releases

If the releases are apparently low, some or all of the command area may be under-supplied owing to :

5) Insufficient supply at the head of the scheme due to deterioration of the catchment, changing climate, increased upstream abstraction, changing river morphology
6) Poor condition of the headworks structures, blockage or deterioration.
7) Poor control due to inadequate operational procedures, shortage of staff or defective structures.
8) Inadequate conveyance capacity in parts of the canal network due to design/construction faults or progressive deterioration.
9) The cropped area is less than planned (see below).

Rehabilitation could address problems 6), 8), and possibly 7). Other measures would be needed to address the other problems.

Reduced Cropped Area

The cropped area may be less than planned owing to :

5) - 8) above:
9) Land degradation, flooding and salinity.
10) Land out of command.
11) Change in land use caused by poor returns to farming or encroachment by housing/small industry.

In many projects, information on flows will be limited to headworks gate operations, from which discharges and irrigated depths may be deduced. On larger schemes, similar information for key locations further down the network may be routinely kept, but probably not analyzed. Potentially, such processed information should help in determining whether sub- areas of a scheme receive an adequate and equitable supply when required (Section 2.3.3).

External constraints on the water supply clearly need to be detected at the earliest stages of project appraisal.

The technical justification for rehabilitation is an improvement in the performance of components of a system. The point is emphasized because systems may appear superficially run-down and yet may be capable of operating adequately. In older systems, built-in margins of capacity may have developed over the years. Channels may be consistently run above design FSL without obviously jeopardising structural integrity; maintenance over many years may have considerably increased the original section size; standard structures may have spare hydraulic capacity.

The underlying causes for lack of hydraulic capacity at any point in the system may not be obvious. Channel backwater effects, particularly on very flat lands, can extend for many kilometres upstream of the controlling point or reach. (see Section 4.3). Deposition of sediment and weedgrowth occur at points in the scheme where the velocity decreases below some threshold level. The effects will therefore be unevenly spread throughout affected systems. It may be possible to achieve marked improvement in conveyance upstream by detecting and removing a choked section, reach or structure with relatively limited works, rather than completely reforming the entire network of channels. Experience is needed to identify such constraints. Section 4.3 and Appendix 6 discuss ways of detecting problems. The standard procedure for assessing the conditions of reaches (Sections 5.2, 5.3) depends on observations of the channel cross sectional area and adequacy of the water supply.

2.3.3 Hydraulic Indicators

Conventional measures of hydraulic performance, such as **efficiency,** only provide a partial indication of the way the water supply system is performing, and provide no guidance as to the causes for a reduced level of performance. Efficiency is conventionally defined as the ratio between theoretical crop needs and the water supply at some level of the system. At times of water shortage, the efficiency parameter cannot indicate the extent to which the supply meets crop needs. In cases of extreme shortage, the system efficiency could apparently exceed 100%, whilst the effects on the crop would be disastrous. Rehabilitation will probably be called for when greater or lesser parts of the system are suffering water shortage, so efficiency alone will not sufficiently describe hydraulic performance. On many schemes, the efficiency may appear low (high unit water use). The principal reason is not necessarily the condition of the water control and distribution system but may be poor distribution of water by staff and/or farmers. On the other hand, farmers may actually increase overall efficiency by pumping water from drains. If properly interpreted, efficiency remains a useful measure of performance which is universally recognized by irrigation engineers.

<u>Adequacy</u>

There are other measures of a system's ability to deliver water. Most have limited relevance to investigations for rehabilitation where there are likely to be very few data. The most relevant seem to be indicators of supply adequacy, either Relative Water Supply (RWS) or that due to Molden and Gates (1990), shown below:

$$S_p = \frac{\text{Supply}}{\text{Demand}}$$

$$= \frac{(d + ER)}{D_{req}} \qquad (1)$$

where d = supply depth at given level of system
ER = effective rainfall
D_{req} = water requirements at given level of system
S_p = supply indicator

Note 1) D_{req} allows for inevitable losses between given level and crop
2) Effective rainfall determined by a standard method, such as USDA
3) For rice, seepage and percolation term to be included in the denominator

A value of Sp =1 indicates that crop water needs have just been met, in other words, the supply is just adequate. It is most useful to calculate the adequacy indicator at intervals less than a season to identify the scale of inevitable variations, particularly around the time of maximum demand. Oversupply at one period of the season (Sp> 1) will not compensate for shortage at other stages (Sp<1). If Sp is limited to unity, periods of excess supply will be discounted.

Equity

If data on supply at lower levels of the system are available, a number of alternative indicators can be used to determine equity between areas. For simplicity, the coefficient of variation of the supply may be used:

$$Cv = SD/Mean$$

$$= \frac{\sigma}{\bar{x}} = \frac{1}{\bar{x}} \sqrt{\frac{\Sigma\ (x-\bar{x})^2}{n}}$$

$$\approx \frac{W/\sqrt{n}}{\bar{x}} \quad \text{for} \quad (3 \le n \le 12) \qquad (2)$$

where W = range of values (largest-smallest value)

$\bar{x}$ = mean value

n = number of points

σ = standard deviation (SD)

Cv will be zero for perfect equity. A value of 1 will indicate serious inequity. Equity may be judged against the ranges for Cv shown below:

Good	Reasonable	Poor
0.1<	0.1- 0.25	> 0.25

2.4 Preliminary Selection of Schemes

Criteria adopted in Indonesia for initial identification of schemes to be rehabilitated vary slightly between programmes, but generally include items below:

- Schemes exceed a defined minimum irrigated area, (varies between programmes).
- Performance, judged by the following aspects can be improved :
  - cropping intensity
  - cropped area
  - crop yield
- Schemes located in areas designated for irrigated agriculture.
- Water resources are adequate.
- Schemes are economically viable with expected ERR of at least 10% (12%).
- Maps and background data are available.
- Access is good.
- Farmers and water user associations favour the project.

Table 2 Information for investigations

Data/Investigations	Purpose	Details
PRE-FEASIBILITY		
Country norms	Provide baseline comparison for individual projects	Crop yield/ha (high/medium/low inputs) Seasonal output by crop Cropping intensity Rehabilitation costs/ha
Climate	Quantify average, dry and wet historic season to categorize current and past seasons	5 years minimum • ½ monthly rain totals • monthly average evaporation
Nature and location of problems	Identify principal constraints to performance	Questionnaires included in Appendices 1 and 2
Irrigated area, by season	Compare with designated area, also Agricultural department. Check on plan, and in field if possible	5 years' minimum
Terrain	Identify on plan irrigated, deprived areas plus flooded regions and areas supplied from other sources	Outline scheme layout (s) with contours using information from interviews
Crop output/yield by season • rates of input • soil types	Compare with country norms (high/medium/low inputs)	5 years' minimum official data. Check in the field for preceding season(s)
Crop water requirements	Compare with historic seasonal rain and headworks releases	Penman ½ monthly E_{TO}
Headworks releases	Compare with irrigated area and seasonal rains	5 years' ½ monthly records (if available)
Supply source discharges (if available)	Determine whether records confirm questionnaire data	5 years
Discharge at problem sites (if available)	Compare with headworks flows, rain and irrigated area	½ monthly releases, or rapid field checks
Crop prices and farm budgets	Determine incremental benefits in irrigated and areas	Sector studies/feasibility reports
FEASIBILITY		
Detailed condition of scheme	Identify current condition and potential problems	Details in Appendices 3 and 4
Discharges at selected sites (if required)	Confirm nature and location of hydraulic constraints	Measurements at structures or current metering
Prioritize works	Identify most cost-effective works and establish ranking order	Prioritize according to condition, commanded area and importance
Topographic survey of selected components	Quantify work for costing selected items	Details vary according to circumstances
Identify benefits		
Economic feasibility		Standard methodologies

So-called Agro-Institutional Profiles are required for some programmes.

Budgetary norms will limit the scale of the work which may be undertaken.

Under externally-funded rehabilitation programmes in Indonesia, $US 2,500 /ha ($3000/ha) was taken as the upper limit of expenditure in 1990. (Cornish, 1994).
The present procedure is intended to complement existing methods of initial screening by identifying schemes where rehabilitation may not necessarily lead to the required production increases. The Checklist (Section 4.1) and the Farmers Questionnaire (Section 4.2) should help to identify the causes of under-performance without a heavy investment of staff time.

3 Background information

Table 2 shows the needs for information. The following paragraphs provide information to supplement the table.

3.1 Mapping

Maps at a scale of 1:5000 or 1:10000 will be needed. Project O & M staff should indicate whether and where changes have been made to the scheme, to cropped areas and to system layout since the maps were prepared. The maps can be used to identify areas of poor supply, flooding, and alternative sources of water. They may also be used to stratify the scheme for the survey of farmers.

In Indonesia, the requirements are as follows:

Mapping :

- Contours at an interval of 0.5 or 1.0 m
- Villages
- Tertiary block areas
- Areas of irrigated, rainfed and non-agricultural land
- Roads including canal inspection roads
- Benchmarks with levels
- Raingauges and meteorological stations
- Main, secondary and tertiary canals
- Drainage canals
- Location of structures
- Reservoirs, rivers, streams
- Scale and north line

Schematics showing planned command areas at principal points in the canal system may be available.

3.2 Sector and Project

Project reports, sector studies, and government records should provide the following data:

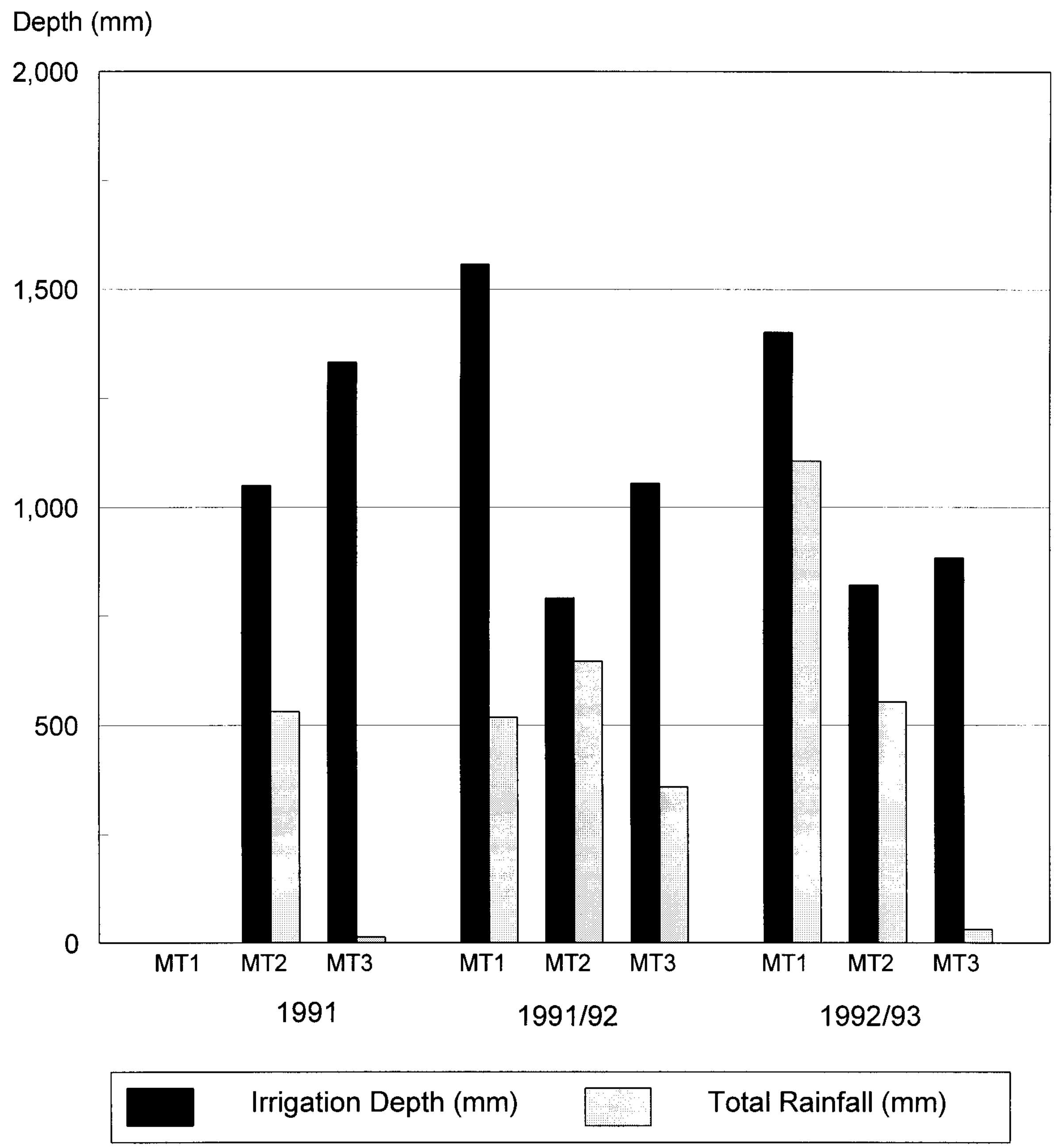

Figure 3 Irrigation supply and rainfall at Sapon headworks 1991 - 1993

Background Information

- Hydrometeorological
  - rainfall
  - evaporation/evapotranspiration
  - dependable river flows
  - historic floods (if available)

- Agronomic/soils
  - soil types
  - planned cropping patterns
  - planned cropping intensities
  - target yields

- Design service area

- Project economics

A minimum of 5, preferably 10 years, information on local rainfall will allow expected mean monthly/seasonal rains to be calculated, as a basis for comparing seasonal water releases and crop needs. Long-term processed rainfall and evaporation data for local stations may be available at national level.

River flow records (run-of-river systems) for a site close to the scheme may not be available. Indications of the pattern of seasonal flows for recent years may be derived from gauging stations elsewhere on the river.

3.3 Analysis of Scheme Operations

Analysis of historic data on scheme operations can help to provide a benchmark for comparing scheme performance with design or expected performance. The scope and scale of analysis will depend upon the data available and the time allowed to the investigating team. Particularly on small schemes, data may be very limited. It is obviously necessary to have a sufficiently long period of record to distinguish between short-term variations and longer-term trends. Five years of data appear a realistic minimum. Experience from work in Indonesia suggests that a rapid analysis of headworks flows, in conjunction with knowledge of rainfall, cropped areas and crop yield should provide a basic technical indicator of overall functioning. The reasons for a given level of performance will remain speculative without further investigation (Section 4).

Analyses of performance were carried out at three schemes in Indonesia (Cornish, 1994). Figure 3 shows the supply at the headworks at Sapon scheme, Indonesia, and the total rainfalls for each of three seasons over a three year period. The recommended cropping pattern was: rice in MT1 and MT2 seasons, 'palowija' cropping in MT3. The table below shows the seasonal water use and effective rainfall compared with design irrigation depth and the ten year mean effective rainfall.

Season	Year						Mean		Expect/ Design	
	1991		1992		1993					
	ER	ID	ER	ID	ER	ID	ER	ID	10 yr mean ER	ID
MT1	820	-	360	1550	750	1410	643	1480	670	1370
MT2	370	1050	450	750	390	800	403	867	380	960
MT3	10	1350	250	1050	20	800	93	1067	100	400

where ID = irrigation depth (mm)
ER= effective rain (mm)

No clear trend in seasonal water use is evident. Releases do not appear to be well-correlated with rainfall, so there is scope for water saving with better management. The irrigation releases for MT1 and MT2 appear close to expected values. Those for MT3 are much higher than expected if the recommended non-rice crops were grown. It appears clear that farmers were growing rice over most of the scheme. The scheme was not being considered for rehabilitation and the figures confirm that there are no significant hydraulic constraints.

Information on flows at lower levels of the system is commonly not available. Where data are available, it must be recognized that processing and analysis will require substantial investment of time, without the assurance that clear trends will be detectable. The process is unlikely to be justified except for the largest schemes. In Indonesia, analysis of water use at points further down the system showed no clear inequities of supply, nor areas where water was obviously short. The conclusion confirmed field investigations and discussions with operating staff.

4 Identifying Problems

4.1 Checklist of Performance Constraints

The checklist included in Appendix 1 lists issues which potentially affect scheme performance. It should indicate, the need for further analysis and specialist studies in e.g. hydrology, agriculture, management and economics.

A question linked to each cause should identify its influence, if any, on water supply, crop yield and/or cropped area. The aim is to ensure review of information from a range of sources before conclusions are drawn.

The questions in the five parts of the checklist can serve as the basis for unstructured interviews with operations staff. The data sheet attached to the checklist can be used to record the comments of staff. Information relating to each factor should be cross-checked wherever possible with data from field inspections and surveys, with operations records, and with interviews at field level.

Problems of water shortage are dealt with in Parts 2, 3, and 4 of the checklist. Water shortage may be due to inadequate supply at the headworks (Part 2) or to problems within the irrigation system. Within the system, shortage may arise from operational problems (Part 3), from poor condition of the infrastructure, (Part 4) or from interactions between the two.

Each factor in the list should be checked in one of three classes Major, Minor or No significance, according to its effect on system performance. To reduce subjectivity, the user should be guided by the following points:

Points to be considered in rating significance of a problem:

- How frequent is it and how long does it last ?
- What is the areal extent of the problem?
- How severe ?
- Will performance deteriorate further if action is not taken?

When interviewing operations staff, the locations, frequency, severity and extent of any problem should be recorded. Area served by adjacent projects or affected by poor supply, by flooding or lack of command can be marked up on a map at the time of questioning to confirm statements. Some questions ask about possible underlying causes. Relevant comments can be included in the `Notes' section of the recording form.

Guidance in assigning responses or observations to the categories `Major' and `Minor' is set out below:

Major significance -	Farmers from around 15% of the command area report a particular factor regularly limits crop yields or area in one or more seasons per year.
AND/OR	Operations staff, field inspection and/or operations records indicate that the factor regularly causes under - supply, reduction in yield or irrigated area on around 15% of the command area.
Minor significance -	Farmers in less than, say, 15% of the command area report a particular factor regularly limits crop yield or area in one or more seasons per year.
AND/OR	Operations staff, field inspection and/or operations records indicate that the factor causes under-supply, reduction in yield or irrigated area on less than 15% of the command area.
No significance -	The factor does not appear to limit performance.

4.2 Farmer Questionnaire

The survey of farmers need not be an onerous procedure requiring experienced interviewers. It is aimed at, and should be limited to, the overall purpose of the Procedure, which is to characterise scheme performance, identify key constraints, and allow priorities to be established.

The interviewer should have already completed the checklist, with which farmers' responses may be compared.

Stratification of the Scheme

Stratification here refers to the identification of sub-groups of farmers within the scheme. The purpose is to define groups of farmers who may hold differing views concerning the performance of the scheme and the actions required to improve the irrigation service. A small number of individuals will be selected from each location to provide information on farming problems and on the performance of the scheme.

For the purposes of the guidelines it is important to acquire information from different areas but it is not considered necessary to interview large numbers of farmers to obtain statistically significant results. The sample size will be determined by the time and resources available.

Stratification may be based on location relative to the canal(s), so as to include head, middle and tail-end farmers. On certain schemes, other criteria may modify the basic pattern:

Criteria to consider in identifying sub-groups of farmers:

- location relative to the head of the scheme or major canal
- topography - include low- lying and upland areas
- different farming systems
- size of holding or type of land tenure
- farmers' income and status
- population density.

On large schemes each canal should be considered a separate sub-group.

As an example of sampling density, farmers were interviewed at 7 locations on a 2500 ha rice-growing scheme in Indonesia (Dolago, Central Sulawesi). Conditions were relatively uniform across the command area.

Use of the Questionnaire

A questionnaire with notes, for use in the field, is given in Appendix 2. The questionnaire can be used as the basis for a structured interview with either a single farmer or a number who obtain their water from the same source. When farmers are interviewed as a group, answers should be cross-checked with different members of the group.

The questionnaire is relatively short and selective. It is designed to assist in the diagnosis of a scheme rather than to provide a broad survey of the socio-economic conditions of farmers. The information obtained by the questionnaire should indicate the effects on farming of a range of factors including water supply, flooding, and agricultural inputs.

Responses from the questionnaire may be checked by supplementary questions, if the investigator possesses background knowledge derived from the checklist and other sources. For example, Part 3 of the questionnaire asks for information on yields in terms of 'good',' average' or 'poor' output. Appropriate values for each range should be known.

Guidelines for Interviewing Farmers

It is important that the interviewer understands the purpose of each question. Questions are intended to find out why the farmer follows a particular course of action or holds a particular view. A list of common responses is provided. However, it is not exhaustive; alternative answers may be recorded in the space provided.

It is essential that the interviewer does not deliberately lead the farmer towards a common or 'expected' reply. If a farmer gives an unusual or unexpected reply it may be checked by phrasing the question differently. The purpose of the interview is clearly to obtain the farmers' views - not those of the interviewer!

- Once a user is familiar with the format of the questionnaire it should require no more than 15 to 20 minutes to interview a single farmer. If farmers are interviewed together, the time required will be greater.
- Before using the questionnaire the interviewer should be familiar with the length and timing of the cropping seasons and their local names, as most of the questions refer to performance on a season - by -season basis.
- Interviews should be carried out at locations defined by logical stratification of the scheme area.
- The interview should be conducted in an informal manner. Where possible, it is preferable to approach and interview farmers in the field rather than rely on more formal, pre-arranged meetings.

Notes for users are provided to clarify the issues involved in each part of the questionnaire. Once the purpose of a question is understood, staff who are familiar with local conditions and practices may wish to re-phrase questions so that they relate more readily to farmers' actual experience. Thus, the material may be considered as a guide - indicating what issues should be considered and providing a format for questions - rather than an inflexible questionnaire.

4.3 Hydraulic Measurements

Backwater

Canal reaches are designed to a uniform depth profile corresponding to the design discharge using a Mannings (Strickler) friction coefficient appropriate to conditions of good maintenance. Cross regulators may be provided to ensure command over offtakes, particularly at lesser discharges.

When the condition of a reach deteriorates owing to obstruction, the deposit of sediment and/or the growth of weeds, its discharge and sediment transport capacity decrease. System operators, under pressure to maintain water supplies, will respond by allowing the full supply level (FSL) to rise above design, thus infringing upon freeboard. The safety or otherwise of such practice will depend on the duration and extent of supercharging, the integrity of the canal banks and the maximum height of FSL above ground.

The extent of the backwater arising from raised water level in one part of the system will depend on the bedslope and the magnitude of the surcharge. For example, a surcharge of 500mm in a canal falling at 1 in 10,000 will have an appreciable effect for some 6km upstream. As another example, the water level in the parent canal may need to be raised, by suitable operation of cross regulators or otherwise, if command is to be retained over lower order canals in poor condition.

The nature and location of a constraint which causes upstream water levels to rise may not be readily apparent, particularly in flat lands. Alternative reasons could be:

- A general problem of sediment deposit/weed growth throughout most of the system.

- Particular reaches where the local hydraulic regime encourages the deposition of sediment and weed growth. The increased normal depth will affect reaches upstream.

- A solid local constriction, occupying more than 33% or so of canal cross section. The obstruction will act as a control and cause supercrical flow immediately downstream.

- Blocked or partially blocked hydraulic structures.

Sediment and weeds are the most common constraints on channel conveyance capacity, reducing the available waterway area and, in the case of weeds, increasing surface roughness. As an example of the effects on capacity of a medium sized trapezoidal channel; assuming no infringement on freeboard:-

Reduction in Depth (%) 30	Reduction in capacity (%) 35
Increased Mannings Roughness from n = 0.025 to 0.060	Reduction in capacity (%) 58

The cross sections of earth channels which have been operating for some time will no longer appear prismatic. Surface unevenness within the wetted perimeter of a section are not significant *per se*. Limited variation in any individual cross sectional area from the design value (10-20% variation) will also not have much effect on the water level since changes in surface profiles occur gradually on typical bed slopes. Several cross sections in sequence, at say 50m centres, all similarly differing from design, will affect upstream levels. Normally a rise in water level would be expected, but if the downstream channel had been overexcavated during maintenance, the upstream water level could be drawn down.

Local stretches of bank instability may occur where the sideslopes are too steep for the prevailing soil or the canal water level has been drawn down too rapidly. Unless a substantial length is affected, say 50 meters, the effects are likely to be restricted to local changes in water depth and velocity and the section would not act as a control.

Solid local obstructions will also not materially affect upstream levels until the waterway area is so restricted, say 33% of intended section, that critical flow develops through the section. Earthen obstructions, unless massive, are likely to be scoured out as critical flow approaches.

Field Investigations

Field investigations should assess both the structural integrity of system components and their fitness to control and/or convey flows. Judgement needs to be made about current performance and also the likely performance under the maximum required flows. Though the design discharge may in some circumstances be inappropriate, it represents a baseline for comparisons.

Knowledge of canal discharge at the location of a possible constraint will help to detect problems. However, system discharge records are commonly limited to the headworks. It is unlikely that a programme of flow measurements can be undertaken within the timescale of pre-feasibility investigations. It is therefore important to draw heavily upon local knowledge of system operations to identify problem locations. Experienced operators will normally be aware of points in the network which limit releases. At feasibility stage, targetted measurements using standard procedures could be undertaken to answer specific questions about the functioning of the system.

Rapid methods of flow measurement, for example float tracking, can be used to supplement information from operators. They are simplest to undertake in lined canals but can also provide indicative results in unlined canals if the reaches are selected carefully. Reasonable results may be obtained by:

- measuring for at least two minutes
- repeating measurements
- improving the estimate of mean velocity from the surface velocity using a factor dependent on the depth of flow:

Average reach depth (m)	Coefficient
0.3	0.66
0.6	0.68
0.9	0.70
1.2	0.72
1.5	0.74
1.8	0.76
2.7	0.77
3.6	0.78
4.6	0.79
> 6.0	0.80

From Discharge measurements Structures, USBR, 1975

Water level measurements at drops, weirs, flumes or gates can give an accuracy better than 10%.

The discharge, depth and width of the channel at the estimated discharge can be compared with design values at full discharge, and the expected values at partial discharge. Cross regulators need to be opened up, offtakes closed, and conditions allowed to stabilize before investigating. In lined channels it is relatively easy to detect a backwater problem by checking the depth along the reach. The depth will vary if the flow is non - uniform. An engineers level can indicate the water surface slope over a reach. If the slope differs radically from the design bed slope, and the condition of the channel is reasonably similar along its length, there is downstream influence, or conceivably, a discrepancy in construction. The average water surface slope may also be calculated if a level is not available, using Mannings equation with known discharge, measured sections and assumed friction value.

It may be possible to detect backwater effects at cross regulators. Weirs are designed to operate undrowned, with a minimum head difference of at least 60mm, varying with circumstances. Downstream constraint on free flow over the crest should be evident. The effects of a rise in backwater on a gated cross regulator may be less easy to detect. Levels throughout the scheme may have changed over the course of time due to longer term siltation. The designs should indicate the intended head difference across the structure. Operators should be able to indicate progressive problems which force them to raise upstream water levels to get the necessary discharge through the structure.

The magnitude of the discharge at given water levels can be checked in the field and compared with operating rules, where they exist. However, it must be borne in mind that existing structural calibrations may be considerably in error. The effects of a backwater problem will vary with the system. Locations at and below the constraint will suffer shortages, areas upstream may receive excess water owing to increased head at offtakes. Overall, equity of supply will suffer.

Once the origin of a problem is located, decisions may be made as to whether the entire system needs major cleaning/reexcavation or whether localized work will materially improve performance. Experienced judgement and information from operations staff will be needed to estimate the rate at which the problem has developed and the rate at which it could reoccur, if rectified. Recent surveys for maintenance desilting may be available.

Sediment problems may require specialist expertise. Apart from the regime designs of the Indian sub-continent, most canal systems were not designed specifically to transport sediment: designers try to ensure a minimum velocity under design conditions. Sediment excluders/ejectors/extractors may be included at the head of a system drawing from sediment-laden rivers, in an attempt to eliminate the problem. However, fluvial, hydraulic and sediment regimes may have changed radically since scheme implementation, owing to upstream developments, catchment deterioration and climate change. Sediment may also be entering the system below the headworks from subsidiary water sources and from bank erosion. The rate of sediment deposition at any location in the system depends on the suspended sediment size, concentration, settling velocity and the local hydraulic conditions. Improvements resulting from major channel reshaping programmes can be very short-lived if the supply of sediment is not cut off. Delay in taking necessary action can also accelerate the rate of deposition as discharges are progressively reduced.

In large or complex systems with many branches it may not be apparent from field investigations where the principal constraints lie. In these circumstances, properly calibrated hydraulic models can assist both in problem identification and selection of improvements. A model was constructed for one of the schemes in Indonesia to determine whether there were constraints to conveyance of the design discharges. Appendix 6 discusses the experience gained and the potential of modelling.

5 Assessing the Condition of Infrastructure

5.1 General

The US Corp of Army Engineers, under the Repair, Evaluation, Maintenance and Rehabilitation project (REMR), has developed a number of function-based condition indexing procedures to determine the condition of large, multi-function, multi-element structures, (Andersen and Torrey, 1995; Bullock, 1989).

Condition assessment is used extensively in the roads sector to determine the condition of the pavement and ancillary assets over extensive networks. Condition scoring is based on physical measurements of surface and structural deterioration and ride quality, often using sophisticated measurement equipment, (Haas, Cheetham, & Karan 1982; Snaith, 1990).

Surface irrigation schemes typically include a large number of relatively low cost assets, of several different types and functions, spread over a large area. Some irrigation and navigation canal managements have developed condition-indexing procedures. They tend not to relate condition to functioning and may rely on subjective ranking . (Ferguson, 1993; Hogwood, 1995)

The condition-indexing system used in the present Procedure, uses several of the concepts included in the REMR research program. The fitness of an asset to perform its function is assessed by field inspection. However, the assessment method has been adapted for use by relatively unskilled staff (overseers). Since some problems require experienced engineering judgement, a two-stage procedure has been adopted. In the first stage, condition is assessed by relatively unskilled staff using standard forms. (Overseers Inspection). Components which are rated Poor or Very Poor may require a second-stage investigation by engineering staff to confirm condition, identify underlying causes, anticipate progression and define the action to be taken (Engineers Inspection).

Structures of principal importance such as diversion weirs, dams and impounding embankments require formal inspections by experienced engineers. Standard engineering inspection proformas have not been included in the Procedure, but could be prepared by the user, if required.

5.2 Overseer's Inspection

This section describes procedures for determining the condition of infrastructure, condition being judged in terms of hydraulic effectiveness and structural integrity. The final output of the Procedure defines priorities for work. Selected items can be detailed and costed. The method lends itself for use with a computerised asset management system.

The principal elements of an asset are assessed using a standard questionnaire requiring a YES or NO response to each question. The questions are all formulated such that a YES response indicates a defect, a NO response implies no defect. **The overseer is not required to score any of his responses in the field.** However, to help subsequent analysis to put priorities on works, fixed scores (Appendix 4) have been assigned to any 'Yes' response, while 'No' responses all score 100. The condition index (CI) is the score associated with the element in worst condition.

The CI is combined with measures of the percentage command area served and the importance of the asset type, to arrive at an indicator of priority for improvement (Section 5.4). It is a measure of the benefits which would be foregone if the asset were not improved. Priority rehabilitation needs can be rough-costed using averaged repair/renewal costs for assets of that type.

For convenience, structures have been considered to fall into the following types:

Basic structure types for condition assessment:

- Intake
- Gated cross regulator/check
- Gated offtake/ Head regulator
- Drop/chute
- Cross drainage culvert
- Aqueduct/flume
- Syphon
- Flow measurement structure
- Canal reach
- Drain
- Inspection road
- Side weir/escape

It is also clearly essential to regularly inspect structures such as diversion weirs, barrages and embankment dams. However, it is felt that inspections of such structures require experienced engineering judgement based on an Engineer's inspection (see 5.3).

An asset may fail to perform its intended hydraulic functions whilst still structurally sound. It may also fail structurally, with some associated hazard. The scoring is intended to reflect the fitness of the asset for its function.

The assessment scores were developed as set out in the box below:

Derivation of scores:

- The key function, hydraulic or/and structural, of each type of asset was identified - in most cases a single function predominates.
- The principal elements of each type of asset were defined.
- Questions relating to the expected modes of deterioration of each element were formulated.
- The effect of deterioration of each element on overall effectiveness was judged. The allotted score represents remaining percentage effectiveness.

The standardized questions for each type of asset are included in Appendix 3A. Appendix 4 contains the scores assigned to each question, representing the element's hydraulic functioning or structural integrity.

The table below shows how the values for CI correspond to broad descriptions of condition.

Condition Index	Status
100 - 81	**Good** - A YES response returned for a question (s) related to a minor fault. No significant structural deterioration or loss of hydraulic function.
70 - 80	**Fair -** indicates partial loss of function and/or some risk to the integrity of the structure. Action not immediately urgent.
51 - 69	**Poor -** A serious loss of function and/or potentially serious threat to structural integrity. Action needs to be taken to prevent progressive failure.
< 50	**Very poor** - Effective failure.

A general question `Does the overall condition concern you?' is included on all assessment forms. It is intended to allow an overseer to highlight a concern which may not be explicitly covered in the YES/NO question format. It allows for the following situations:

'Overall concern'

- Where the standard assessment questions do not adequately describe deterioration.
- Where an asset is apparently in good condition but it is failing to function as required.
- Where it is apparent that deterioration is in initial stages but may progress rapidly to failure.

The response to the question is not scored.

5.3 Engineer's Inspection

An Engineer's inspection should be undertaken if the overseer responds positively to the question `Does the overall condition concern you?' or where the engineer believes there is a problem.

Engineer's Inspection:

- To confirm the overseer's assessment .
- To identify underlying causes of observed deterioration.
- To estimate progression of actual or potential problems
- To define and plan necessary rehabilitation actions.
- To define requirements for site surveys/investigations.

The inspection should result in an overall classification based on the condition of the worst element.

Standard reporting forms for canal reaches and hydraulic structures, with guidance notes, are included in Annex 3B.

Inspection forms specific to particular structures, such as barrages, diversion weirs and dams, incorporating questions designed to determine the fitness of elements for their function, can be drawn up by individual users.

5.4 Selecting Priorities

Once an inventory of asset condition is prepared, the priority of works is based on the benefit actually, or potentially, foregone. The Priority Index takes account of:

Parameters included in the Index:

- Asset condition, as calculated from the overseer's report.
- A measure of the area served by the asset relative to the total area.
- An indicator reflecting the strategic importance of the asset.

Each asset type is given a strategic importance on a scale of 1 to 4, see table below. The score is intended to reflect the importance of its function, hazard in the event of failure, and relative cost of rebuilding. Appendix 5 contains more details.

Score = 1	Score = 2	Score = 3	Score = 4
Measurement structure	Canal reach Drain Head regulator/ gated offtake Cross regulator Drop/chute Inspection road Escape Bridge	Cross drainage culvert Aqueduct Syphon	Diversion weir* Embankment dam* Barrage* Intake works

* For use with results of Engineer's Inspection (see Section 5.3).

The Priority Index is calculated from the following formula:

$$\text{Priority Index} = (100\text{-CI}) \times \sqrt{(a/A)} \times \text{Is} \qquad (3)$$

Where:

CI = Condition Index
a = The area served by, or dependent on, the asset*
A = Command area of the scheme
Is = Importance score

* Note: Structures such as bridges, inspection roads, escapes, etc are assigned a service area equal to that of the canal reach on which they occur.

Calculation of the Priority Index to produce a ranking of works according to need is most easily done on a customised spreadsheet or an asset management program such as MARLIN (Maintenance and Rehabilitation of Irrigation Networks), currently being developed at Wallingford.

An example showing how the priority system applies to a number of assets is shown in Table 3 following.

Table 3 Example of Priority Ranking

Scheme area = 1500 ha

Asset	Area served (ha)	Importance (1)	Condition Score (2)	Priority Index (3)
Main canal 2+500 - 3+420	1500	2	75 (fair)	50
Sec. Canal 1. 3+000 - 4+000	380	2	40 (v. poor)	60
Sec. Canal 2. 0+000 - 0+850	435	2	55 (poor)	48
MC drain culvert 8+430	1220	3	60 (poor)	108
DC drop 2+690	185	2	75 (poor)	17

(1) **Importance:** See Section 5.4 and Appendix 5

(2) **Condition Score:** Determined by most serious defect recorded by overseer. See scores in Appendix 4

(3) **Priority Index:** = (100 - Cond. Score) x $\sqrt{a/A}$ x Importance

Assets ranked according to Priority index			Priority index
1.	MC drain culvert	8+430	108
2.	Sec canal 1.	3+000 - 4+000	60
3.	Main canal	2+500 - 3+420	50
4.	Sec. Canal 2.	0+000 - 0+850	48
5.	DC drop	2+690	17

The formulation of equation (3) is empirical. The rankings derived from the equation have been checked against expert opinion to ensure that the method produces valid results. The square root function of area is intended to give greater relative weight to assets located towards the tail of main canals, which would otherwise be down-rated relative to assets on large secondary systems (The proportion of total area commanded by any asset is dependent on the level of branching within the canal system. In most systems only a small number of assets will serve more than 20 - 25% of the total command area. Many assets will serve less than 15%).

The resulting ranking order should be regarded as a guide. First hand knowledge of the system may lead to reordering of the priority accorded certain works. In particular, it should be noted that the method produces priorities which are independent of each other. In other words, a need is identified for work on a particular component. In practice, certain groups of items will need to be improved at the same time in order to achieve overall benefit. For example, there is no point in improving downstream works to pass the design discharge if there is an upstream constraint. In particular desilting works should be undertaken from the downstream end of the system working upstream. If the head end of a system is desilted first, sediment will merely resettle locally since the discharge capacity of downstream reaches remains unchanged. Under the method of ranking, upstream works tend to receive a higher priority, in other circumstances there may be reasons why certain items need to receive a higher priority than the ranking list would indicate. So the planner should ensure that he is guided by the above example when selecting programmes of works.

In particular, the use of area served as a proxy for the area disadvantaged, and hence the economic loss, is simplistic for problems connected with backwater. For example, a silted reach or minor could raise upstream water levels, endanger banks and promote inequality of supply throughout the system. Areas upstream might receive an increased supply owing to greater head at the offtakes. Unless waterlogging resulted, economic disadvantage would result predominantly, but not totally, in the downstream area.

Table 3 shows an example of the ranking procedure applied to a number of assets.

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Appendices

Appendix 1

Checklist of possible performance constraints

Appendix 1 Checklist of possible performance constraints

PART 1 AGRICULTURAL AND ECONOMIC FACTORS

PART 2 SYSTEM DESIGN AND OPERATION

PART 3 DETERIORATION OF SYSTEM INFRASTRUCTURE

PART 4 LAND DEGRADATION

PART 5 CONSISTENT UNDER-SUPPLY AT THE HEADWORKS

USER NOTE: Record additional information relating to any question on separate pages. Refer to this in the `Notes' section of the summary table.

PART 1
AGRICULTURAL AND ECONOMIC FACTORS

Information will be obtained using the farmer questionnaire Appendix 2, and from interviews with operations staff and agricultural extension staff.

1.1 Production Inputs - price/availability (Linked to 1.7)
Does the price or availability of agricultural inputs such as:
- fertilizer
- pesticides
- improved seed varieties
- machinery or draught animals

limit their use such that yields are depressed or land is left fallow?

1.2 Inputs - water supply
Do farmers report that the under-supply of irrigation water is a constraint limiting their cropped area or yields in any season?

1.3 Labour - price/availability
Does the cost or availability of labour, at times of peak demand:
- limit the area that farmers cultivate in any season, or
- lead to reduced yields due to inadequate crop husbandry practices such as delayed or limited weed or pest control?

1.4 Future input supply
Is the supply of labour, machinery, water and/or other production inputs sufficient to meet the requirements of any proposed changes in the production system?

1.5 Crop pests
Do crop pests reduce crop yield in any of the cropping seasons?

1.6 Crop marketing (Linked to 1.8)
Have low crop prices, or the absence of an adequate marketing system, caused farmers to reduce the land area that they cultivate, or change their cropping pattern?

1.7 Price/availability of credit (Linked to 1.1)
Does the cost, or limited availability, of credit to purchase agricultural inputs significantly restrict their use by farmers causing reduced crop yields?

1.8 Changes in land use (Linked to 1.2 and 1.3)
Have areas of land fallen out of production, or are there areas within the command area that have not been developed? Is that land now used for rainfed crop production, is it lying fallow or is it used for non-agricultural purposes such as housing, etc.? Has the change in use come about mainly due to:
- Financial factors
- Failure to carry out land development (land clearance, drainage, construction of tertiary/quaternary systems, etc.)
- Soils not suited to proposed crop types
- Inadequate/unreliable irrigation supply

1.9 Land out of command (Linked to Part 2.7)
Are there areas of land within the existing scheme area that are out of command due to insufficient or poorly sited off-takes, poor canal alignment, or the deterioration of infrastructure?

1.10 Existing organisations/Institutions
Do weaknesses in farmer organisations or other institutions result in reductions in crop yields or cropped area?

1.11 Consultation with Farmers

Proposals for rehabilitation may include changes to existing water allocation practices, either through physical re-modelling (re-alignment of canals and/or drains, land consolidation, construction of new off-takes, etc), or through the promotion of new farmer organisations. Have the effects of such changes on existing water management practices been discussed with the farmers who will be affected, or are procedures established for such consultation to occur?

PART 2
SYSTEM DESIGN AND OPERATION

Information will be obtained from discussions with operations staff, from the observation of structures and water levels in the field, from review of operations manuals, and review of original design criteria and assumptions, where these are available.

To assess the impact of scheme operation on cropping intensity and/or yields, and identify what variations exist between intended and actual practice, the flow control methods and water delivery pattern for which the scheme was originally design, must be defined.

2.1 Method of Flow Control

Different types of flow control structures may be used at different levels of control within the distribution network. Note what structure types are used in the canal distribution network:

Division/offtake structures
- Fixed overflow weir
- Submerged orifice
- Submerged orifice gated

Water Level Control
- No cross regulation
- Fixed cross regulation (weirs)
- Gated cross regulation
- Automated level control

(Record this information on additional pages.)

2.2 Operational practices

Note the design delivery pattern, guided by the following table. Record specific details of intended operational practice where these are available.

At tertiary offtake	In main distribution network
1. Continuous, proportional division (No adjustment)	1. Continuous, fixed discharge. Rotation between canals when supply « demand.
2. Continuous, variable discharge (Control by irrigation agency)	2. Continuous but variable discharge. Rotation between canals when supply « demand.
3. Rotational supply, fixed discharge (Control by irrigation agency)	3. Intermittent throughout network or rotation between canals.
4. Semi on-demand (Farmer requests to irrigation agency)	4. Continuous, variable discharge.
5. On-demand (Farmer control)	

2.2.1 Ask staff to describe actual operational practices. Consider:
- which structures are monitored and adjusted?
- are water levels maintained at design level?
- how frequently are settings changed?
- is rotational supply implemented?

Cross-check key points in discussions with farmers. Record the information on additional pages.

2.2.2 Indicate whether current operating practices limit scheme output. Consider:
a) Differences between design and actual water control practices. Are structures being operated according to design?

b) Headworks and sediment exclusion - are sediment exclusion and/or flushing structures operated effectively to minimise sediment entry?

c) Are canals frequently operated at low discharges causing problems of ponding or sediment deposition?

d) Have any operational procedures led to damage of structures or canals? For example, is canal freeboard regularly infringed at any location? Has rapid canal drawdown caused slumping or damage to lining?

2.3 Design/operation compatibility

Where operational practice differs significantly from design, rehabilitation planning must consider whether original structures, designed for a method of flow control and water delivery which is no longer implemented, should be restored or replaced with structures that allow a different water allocation policy.

2.4 Staff numbers

Compare staff numbers with establishment figures. Are there sufficient staff, with appropriate transport, to control structures and implement water deliver schedules?

Staff grade	Area/chainage served	Target No. on this system	Actual No. on this system

2.5 Variations from design assumptions

Are any factors which differ significantly from original design assumptions affecting operations? Such factors may already be noted in other Parts of the checklist. Check the following factors:

- Irrigated area significantly different from design, (greater or less)
- Significant changes in crop calendar (note what changes)
- Changed river morphology
- Increased sediment load in supply and/or from other sources
- Reduced water supply (Part 5)
- Reduced annual rainfall within the scheme catchment

2.6 Inappropriate design

Are there areas of land within the scheme area that are out of command or receive inadequate water due to insufficient or badly sited off-takes, or poor canal alignment? Has incorrect or inappropriate design of any structure, canal reach or drain resulted in insufficient conveyance capacity or the failure of the structure to function as required? Check the following factors:

- Canal embankment slopes too steep
- Insufficient cross drainage
- Insufficient escape capacity
- High losses in distribution or field systems

PART 3
DETERIORATION OF SYSTEM INFRASTRUCTURE

Detailed information on deterioration of infrastructure, and its likely impact on hydraulic performance, will be obtained using the condition assessment procedure. Early, discussions with operations staff can indicate the location of problems arising from structural deterioration. Where problems are due to faults in original design or construction record this in Part 2.6. Information obtained in this way should be cross-checked through the condition assessment procedure and localised studies of hydraulic performance, where these are required.

3.1 Condition of assets

Does the condition of any component of the irrigation or drainage networks restrict conveyance capacity, threaten structural stability or otherwise lead to reduced water supply or flooding?

Consider each type of asset in turn, as listed on the checklist, to avoid focusing only on the 'worst cases'.

PART 4
LAND DEGRADATION

Information will be obtained from the field, by use of the farmer questionnaire, and in interviews with operations staff and agricultural extension staff.

Use the separate data summary table to record information.

4.1 Surface flooding
Does surface flooding regularly affect any part of the command area causing yields to be depressed or land to be left uncultivated?

4.2 Shallow groundwater table
Does a shallow groundwater table limit the type of crops cultivated or lead to reduced yields or land left fallow in any season?

4.3 Soil Salinization
Is there a build-up of saline or alkali (sodium) salts in the surface soil layers in any part of the command area leading to reduced yields or deterioration of soil structure? Is the severity or areal extent of this problem increasing over time?

4.4 Land fragmentation
Has the sub-division of farm plots resulted in significant loss of irrigable land or reductions in field irrigation efficiencies or has it led to problems for on-farm water management.

4.5 Erosion
Has land erosion within the scheme's command area resulted in a loss of irrigable land through deposition of sediment, gully formation or extensive bank erosion?

4.6 Pollution
Have municipal or industrial pollutants caused land to go out of crop production?

Land Degradation Summary Table

Nature of Degradation	Area influenced (ha)				Underlying cause										
	Perm	Wet Season	Dry Seaso n	Other	1	2	3	4	5	6	7	8	9	10	11
Surface flood															
Shallow Groundwater															
Salinization															
Land fragmentation															
Erosion															
Pollution															
Total Area															

1. Inundation from other water body
2. Seasonal rise in groundwater
3. Inadequate/poorly maintained field drainage
4. Inadequate/poorly maintained main drains
5. Saline irrigation water
6. Shallow saline groundwater
7. Land inheritance customs
8. Highly erodible soil
9. Topography
10. Extensive bank erosion by canals/rivers
11. Urban/industrial waste

PART 5
SUPPLY AT THE HEADWORKS

Information will be obtained from review and analysis of past operations records, review of previous hydrological studies, including original feasibility and design studies, analysis of meteorological records and the observations of operations staff.

5.1 Variation from design discharge
Are actual irrigation releases at the headworks consistently above or below the design value at times of peak requirement?
If flows are close to design values, record this on the summary table and ignore the remainder of this part. Where peak flows do vary from design values, complete all of this part.

5.2 Command area less than design
Is the actual irrigated area less than design? If so, is the reduction in area due to:

- agricultural or economic factors, (see Part 1)
- water shortage due to system deterioration (see Part 3)
- land degradation (see Part 4)
- inadequate supply, (See questions 5.3 & 5.4)

5.3 Reduced conveyance capacity
Releases at the headworks may be reduced because of constraints within the conveyance network. If operations staff are aware of limiting points within the canal system note the location and nature of the constraint in Part 3 of the checklist.

5.4 Deterioration of supply
Do records and/or staff experience show that in the past the supply was reliable and sufficient but is now frequently insufficient? Where it is possible, indicate the probable likely cause:

- Increased abstraction by other users - new irrigation schemes, reservoirs, industrial demand, domestic supply, increases in groundwater pumping, etc.
- Changes in land use in the catchment, and/or changes in rainfall distribution.
- For a river supply. Has the sediment burden in the river increased, therefore requiring more frequent closure of the intake? Does it affect the reliability and adequacy of supply to the scheme?
- Is sediment or other debris blocking the intake structure?
- Changes in river morphology/plan form - aggradation, degradation, channel movement.

5.5 Unrealistic design hydrology
Do records and/or staff experience indicate that ever since the scheme was constructed, the water supply has been insufficient to meet demand in one season or more each year? If not known, record `Cannot be established'.

RECORD SUMMARY SHEET OF POSSIBLE PERFORMANCE CONSTRAINTS

1.	**AGRICULTURAL & ECONOMIC**	SIGNIFICANCE			Notes (Refer to any additional pages used)
		Major	Minor	None	
1.1	Production inputs - price/availability				
1.2	Water supply				
1.3	Labour - price/availability				
1.4	Future input supply				
1.5	Crop pests				
1.6	Crop marketing				
1.7	Credit - price/availability				
1.8	Changes in land use				
1.9	Land out of command				
1.10	Existing organisations/institutions				
1.11	Consultation with farmers				

NOTES

		SIGNIFICANCE			
2.	**SYSTEM DESIGN AND OPERATION**	Major	Minor	None	Notes (Refer to any additional pages used)
2.1	Method of flow control				
2.2	Design delivery pattern				
2.3	Operational practices				
2.4	Design/operations compatibility				
2.5	Staff numbers				
2.6	Variations from design assumptions				
2.7	Inappropriate design				
		SIGNIFICANCE			
3	**DETERIORATION OF SYSTEM INFRASTRUCTURE**	Major	Minor	None	Notes (Refer to any additional pages used)
3.1	Condition of assets				
	Headworks & sediment exclusion				
	Primary canals				
	Secondary canals				
	Head regulators				
	Cross regulators				
	Off-takes				
	Distribution works below offtakes				
	Drains				
	Roads				
	Other structures				

4. LAND DEGRADATION See separate summary matrix in checklist	SIGNIFICANCE			Notes (Refer to any additional pages used)
	Major	Minor	None	
4.1 Surface flooding				
4.2 Shallow groundwater table				
4.3 Soil salinization				
4.4 Land fragmentation				

5. SUPPLY AT THE HEADWORKS	SIGNIFICANCE			Notes (Refer to any additional pages used)
	Major	Minor	None	
5.1 Variation form design discharge				
5.2 Command area less than design				
5.3 Reduced conveyance capacity				
5.4 Deterioration of supply				
5.5 Unrealistic design hydrology				

NOTES

Appendix 2

Questionnaire for Farmers

GUIDANCE NOTES

General
The purpose of the questionnaire is to obtain information on the `normal' or average conditions experienced by farmers in each season. Farmers should therefore be encouraged to consider the situation over the last three or four seasons rather than give a reply that only reflects their most recent experience. It is important to be aware of any abnormal but short lived circumstances which are influencing the current season, and therefore farmers assessment of yield, water supply, or other factors. Abnormally high or low rainfall will influence the current season and this is reported in Part 4. Any other short-lived factors should be noted in the section at the end of the questionnaire.

1. Location and Water source
This part records basic information that ensures that the responses can be linked to an identified area of the scheme.

Where farmers are obtaining the major part of their water from unauthorised off-takes or re-using drainage water there may be problems with the present location of off-takes. Alternatively the development or maintenance of farm channels below existing, authorised off-takes may be inadequate.

Record in the `Notes' section observations on the use of different water sources. Check if different sources are used in different seasons.

2. Cropping Intensity
This part determines if farmers regularly leave potentially irrigable land uncultivated in one season or more in a year, or if there has been a reduction in cropping intensity over time. The questions aim to identify the reasons for land being left fallow or for the change from more to less intensive production, i.e. why, in the past, more land was cultivated and/or more crops were grown per year.

Question 2.1 concerns land which supports an irrigated crop at least once per year but is regularly left idle in a second or third season. Unusual circumstances which led a farmer to leave land fallow can be ignored - we are concerned to identify locations where land is regularly, or routinely, left idle. Question 2.2 examines whether the farmer's current cropping intensity - irrigated cropped area and number of crops per year - has been unchanged over a long time or whether there has been a fall in cropping intensity, with less land area or fewer crops per year being irrigated now than in the past. The important aspect of 2.2 is to determine whether conditions have remained stable over time or have deteriorated.

The farmer may report in question 2.1, that all of his currently irrigable land is cropped in all seasons. Question 2.2 investigates whether in the past he had more irrigable land which may now have changed in use and is no longer irrigated. In this case we are interested to know what has led to this change in land use. Where there has been a change in land use the reason should be recorded in the `Notes' section.

3. Cropping Yields
The question should assess the farmer's level of satisfaction with yield compared to farmers on other parts of the same scheme. If farmers can readily quantify their yield per unit area this may be recorded but quantitative data is not essential. Where farmers report some level of dissatisfaction with yield the cause of the low yield, as perceived by the farmer, should be identified. Tick one or more of the check boxes to indicate the cause of low yield, or where none of these factors apply, note the cause under `other'.

4. Water Supply
Question 4.1 asks for the farmer's evaluation of rainfall in the present and previous seasons. Question 4.2 asks whether the farmer believes there has been a trend for rainfall amounts to fall over the long term. Where rainfall data are available farmers answers can be cross-checked with this.

In question 4.3 the farmer is asked whether he describes the irrigation supply, at the offtake, in each season, as `good' or not. A good supply is one which is reliable and provides adequate water for the full length of a season. Where the farmer states that the irrigation supply is not good, confirm which season is referred to and determine which of the following three descriptions of poor supply lies closest to his or her assessment of the irrigation supply. More than one of these descriptions may apply for any season:

- insufficient all through the season
- insufficient at times of peak demand (land preparation)
- erratic and unpredictable (unreliable)

If the farmer states that the water supply is not good, check to see if the farmer answered that water supply limited yield in Part 3.1.

The second part of question 4.3 asks for the farmer's view on the cause of the poor irrigation supply. The farmer may only have a partial knowledge of the condition of the conveyance and distribution canals and of their operation. However, it is important to obtain the view of the farmer which can subsequently be cross-checked in discussions with operations staff, through review of operations records and through assessment of infrastructure condition.

Where a farmer refers to a specific physical problem in the canal system note what the problem is, as well as ticking the box for `The condition of the main canal system'

5. Flooding

Where a farmer reports that flooding is a problem that prevents him from planting or reduces crop yield determine how frequently the problem occurs and the duration of the flooding, i.e. for how long, on average, the land remained flooded.

Where a farmer reports that flooding causes him to leave land un-planted in a particular season cross-check with the answer to question 2 concerning cropping intensity. Did he refer to flooding when asked if he left land fallow in any season? If not, is this because flooding occurs only occasionally? Record the frequency of damaging floods at 5.4.

Part 5.5 records the farmer's view as to the cause of flooding. As with Part 4, the farmer may not have sufficient knowledge of the scheme to accurately identify the cause of flooding. Information given should be cross-checked. It is possible that the farmer may identify a local constraint which may otherwise be overlooked.

6. Water distribution and structures below the outlet

The purpose of the question is to identify if farmers believe that the condition of canals and structures, at or below tertiary level, leads to a reduction in yields or fallow areas. Where possible the question should be put to several farmers within the block including those most distant from the off-take. It may be necessary to record a summary of the views of several farmers in answering this question.

7. Priorities for change

In the course of the interview with the farmer a large number of potential and actual problems may have been mentioned or discussed in detail. It is possible that a farmer may have stated that something is a problem simply because it has been suggested to him. The purpose of this part is to identify what farmers consider to be the most serious problem that limits their crop production.

QUESTIONNAIRE: FARMERS' VIEWS ON SYSTEM CONSTRAINTS AND REHABILITATION NEEDS

Date: ____________________ Interviewer: _____________________________

Scheme Name:_______________________________

Type of interview: Single farmer ☐ Farmer name: _____________________________
Group of farmers ☐

1. LOCATION & WATER SOURCE

Village name: ______________________

Canal name: ______________________ Tertiary off-take name/s: ________________

Most irrigation water is taken from:

- Authorised off-take ☐
- Unauthorised off-take ☐
- Re-use from drains ☐
- Wells ☐

Notes:____

____

2. CROPPING INTENSITY

2.1 Do you regularly leave land un-planted in one season or more per year?

Yes ☐ No ☐

If 'Yes' , why do you not plant in those seasons?

- Lack of water ☐
- Land is flooded ☐
- Poor supply of other inputs - labour, seed, fertilizer, pesticides ☐
- Prefer to spend time in other activities ☐
- High risk of pest attack ☐
- Other ____

2.2 Have you been able to irrigate more land or plant more crops per year in the past?

Yes ☐ No ☐

If 'Yes', what has caused the change:

- Lack of water ☐
- Land is flooded ☐
- Less land available (land use changed) ☐
- Poor supply of other inputs - labour, seed, fertilizer, pesticides ☐
- No need/desire to work for another crop ☐
- Prefer to spend time in other activities ☐
- Other ____

Notes:____

3. CROPPING - YIELDS

3.1 Do farmers think their yields are normally:

	Good	Average	Poor
First Season (month of harvest ___________)	☐	☐	☐
Second Season (month of harvest __________)	☐	☐	☐

If yields are poor then what, in the farmers' opinion, is the cause?

- Water supply ☐
- Seed type ☐
- Time of planting ☐
- Soil fertility ☐
- Weeds ☐
- Crop pests ☐
- Drainage ☐
- Other____

Notes:____

4. WATER SUPPLY

4.1 Was/is the rainfall amount:

	More than average	Average	Less than average
Present season	☐	☐	☐
Last season	☐	☐	☐

4.2 Was the rainfall higher in the past?

Yes ☐ No ☐

4.3 Is the irrigation supply normally good, i.e. enough water and a regular supply?

	Yes	No
in First Season	☐	☐
in Second Season	☐	☐

If the supply is not good, do farmers describe the supply as:

	First Season	2nd. Season
insufficient all through the season	☐	☐
insufficient at times of peak demand (land prep)	☐	☐
erratic and unpredictable (unreliable)	☐	☐

If the supply is not good then what, in the farmers' opinion, is the cause?

	First Season	2nd. Season
Not enough water in the river or reservoir	☐	☐
Bad control/operation of the main canal system	☐	☐
Other farmers take too much water	☐	☐
The condition of the main canal system	☐	☐
Distribution/control of water below the tertiary off-take	☐	☐
Other ______________________		

Notes:____

____

____

5. FLOODING

5.1 Does flooding around this area ever prevent planting or cause damage to crops?

Yes ☐ No ☐

If 'Yes', then:

5.2. In which month or months is flooding a problem?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5.3 For how long is the land flooded? ______________________

5.4 Does flooding prevent cropping or reduce yield:

Every year ☐
Most years ☐
Occasionally ☐

5.5 Farmers think the cause is:

blocked drains ☐
No drains ☐
Other ______________________

Notes:____

____

____

6. ON-FARM STRUCTURES AND WATER DISTRIBUTION

6.1 Does the off-take from the main system, or the canal and structures below it, cause problems of water supply for any farmers in the block?

Yes ☐ No ☐

If yes, describe the problem ____

7. **PRIORITIES FOR CHANGE**

7.1 What is the most serious problem that limits crop production in:

First Season? ______________________________

Second Season? ______________________________

8. **NOTES**

Note any unusual and short term constraints influencing production or farmer perceptions at the time of carrying out the interview of farmers.

Appendix 3A

Condition assessment - Overseer's inspection

STRUCTURE TYPE: **INTAKE (or HEAD REGULATOR)**

		YES	NO	UNASSESSED
1.	Are any of the gates missing?	☐	☐	■
2.	Is it difficult to fully open or close any of the gates?	☐	☐	■
3.	Is any gate seriously corroded or rotting?	☐	☐	■
4.	Are there serious cracks or movement in any part of the structure?	☐	☐	■
5.	Is any part of the structure blocked by sediment?	☐	☐	☐
6.	Is seepage occurring around the structure?	☐	☐	☐
7.	Is the d/s apron seriously damaged or undercut?	☐	☐	☐
8.	Is it difficult to read the u/s or d/s gauge boards?	☐	☐	■
9.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Missing Gate**
   Only answer YES if a gate has been removed from the structure. Where a gate is broken but still present, answer NO to this question and YES to question 2.

2. **Gate operation**
   Answer YES when the condition of the lift mechanism, missing components or other factors make it impossible to effectively operate a gate. If a gate is missing, answer YES to question 1 and NO to this question.

3. **Gate Condition**
   Answer YES where corrosion or rotting has reduced the strength or water tightness of any gate. Disregard minor patches of surface corrosion or minor deterioration of any gate.

4. **Cracks/damage and movement**
   Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotational movement may be visible. Disregard shallow, surface cracks or minor damage that does not affect function.

5. **Blockage**
   Answer YES where sediment accumulation is seriously reducing the open area for water to pass through. Disregard blockage by floating vegetation or other debris that could be quickly pulled away.

5. **Seepage**
   Answer YES if there is washout of fine soil particles, very wet areas of fill or other evidence of water flowing around the structure.

6. **D/s Apron**
   Answer YES where the apron, or other bed protection, is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this appears stable and does not threaten the stability of the structure. Answer NOT KNOWN, if you cannot see the apron or gain reliable information from the operator.

7. **Gauge Boards**
   Answer NO when gauge boards have not been installed.

8. **Overall condition**

Answer YES, if:

- There is a serious fault or deterioration or failure to function that is not covered by any other question.

OR

- Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **GATED CROSS REGULATOR**

		YES	NO	UNASSESSED
1.	Are any of the gates missing?	☐	☐	■
2.	Is it difficult to fully open or close any gate?	☐	☐	■
3.	Is any gate seriously corroded or rotting?	☐	☐	■
4.	Are there serious cracks or movement in any part of the structure?	☐	☐	■
5.	Is leakage occurring around the structure?	☐	☐	■
6.	Is the d/s apron seriously damaged or undercut?	☐	☐	☐
7.	Is it difficult to read the u/s or d/s gauge boards?	☐	☐	■
8.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Missing Gate**
   Only answer YES if a gate has been removed from the structure. Where a gate is broken but still present, answer NO to this question and YES to question 2.

2. **Gate operation**
   Answer YES when the condition of the lift mechanism, missing components or other factors make it impossible to effectively operate a gate. If a gate is missing, answer YES to question 1 and NO to this question.

3. **Gate Condition**
   Answer YES where corrosion or rotting has reduced the strength or water tightness of any gate. Disregard minor patches of surface corrosion or minor deterioration of any gate.

4. **Cracks/damage and movement**
   Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotational movement may be visible. Disregard shallow, surface cracks or minor damage that does not affect function.

5. **Leakage**
   Answer YES if you can see washout of fine soil particles, very wet areas or other evidence of water flowing around the structure.

6. **D/s Apron**
   Answer YES where the apron, or other bed protection, is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this is now stable and does not threaten the stability of the structure. Answer UNASSESSED, if you cannot see the apron or gain reliable information from the operator.

7. **Gauge Boards**
   Answer NO when gauge boards have not been installed.

8. **Overall condition**
   Answer YES, if:
   - There is a serious fault or deterioration or failure to function that is not covered by any other question.

   OR
   - Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **CANAL REACH**

		YES	NO	UNASSESSED
1.	Is the canal partially blocked at any location by illegal weirs or debris?	☐	☐	■
2.	Is there serious siltation at any location?	☐	☐	■
3.	Is there serious weed growth at any location?	☐	☐	■
4.	Do farmers and/or staff report the canal capacity restricts water supply?	☐	☐	■
5.	Where the reach is in fill, has the water level been dangerously near the canal top at any point?	☐	☐	■
6.	Are there problems of serious bank slippage or erosion?	☐	☐	■
7.	If lined - Is there important damage to lining?	☐	☐	■
8.	Are there any unauthorised off-takes?	☐	☐	■
9.	Is seepage a problem in the reach?	☐	☐	☐
10.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Illegal weirs or debris**
   Answer YES where farmers have placed material in the reach to raise the water level or where a land slip or accumulation of rubbish appears to reduce the conveyance capacity of the reach.

2. **Sediment**
   Disregard minor and localised accumulation of sediment which does not reduce the conveyance capacity of the canal or cause a reduction in the freeboard. If you are uncertain, answer YES.

3. **Weed**
   Disregard small areas of weed which do not appear to restrict the conveyance capacity of the canal or cause a reduction in the freeboard. If you are uncertain, answer YES.

4. **Conveyance capacity**
   Ask farmers or staff if they believe that water supply is limited because of a problem in THIS reach. If so, answer YES.

5. **Freeboard**
   Answer YES where: There is sometimes a risk of overtopping that might result in washout of an embankment and serious structural damage. Disregard minor low points where the canal is in cut.
   OR,
   The condition is not yet dangerous but deterioration of the canal freeboard is continuing and may become dangerous before the next inspection.

6. **Bank slippage or erosion**
   Answer YES if slippage or erosion threatens to block the canal or, where the canal is in fill, weaken the embankment. Disregard minor erosion of the channel section unless it threatens the integrity of the reach.

7. **Lining damage**
   Disregard isolated damaged panels or masonry. Answer YES where more than 1 in 10 of the lining panels or 10% of the surface within the reach is seriously damaged.

8. **Unauthorised off-takes**
Look for deliberate cuts or submerged pipes etc. in the canal bank.

9. **Seepage**
Look for standing water, washout of fine particles from the embankment, flowing water emerging from the toe of the embankment, reeds or salt deposits on ground lying close to the canal embankment. If any of these is widespread answer YES.

10. **Overall condition**
Answer YES, if:
●There is a serious fault or deterioration or failure to function that is not covered by any other question.
OR
● Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **INSPECTION ROAD**

		YES	NO	UNASSESSED
1.	Does limited track width prevent vehicle access at any point?	☐	☐	■
2.	Do surface unevenness and pot holes make driving difficult?	☐	☐	■
3.	Are cross drainage culverts seriously damaged or exposed at any point?	☐	☐	■
4.	Are sides slopes seriously eroded or showing signs of serious slippage?	☐	☐	■
5.	Is access difficult at any time of year?	☐	☐	☐
6.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Road width**
Answer YES, if the width prevents necessary maintenance vehicles/plant from using the road.

2. **Surface condition**
Answer YES, where the surface condition limits driving speed to less than 15 km/hr over at least 1 km. Minor isolated holes or surface deterioration to be disregarded.

3. **Cross drains**
Answer YES if a culvert is:
   - exposed and vulnerable to damage from traffic using the road

   OR
   - substantially damaged and/or settling

   OR
   - substantially blocked or causing serious flooding

4. **Side slopes**
Answer YES, where erosion or slippage is likely to weaken an embankment or cause a slip that will block the road. Disregard isolated, minor problems unless they may develop into a serious problem before the next inspection.

5. **Year round access**
Answer YES if the road can frequently not be used by vehicles during the wet season.

6. **Overall condition**
Answer YES, if:
   - There is a serious fault or deterioration or failure to function that is not covered by any other question.

   OR
   - Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **FLOW MEASUREMENT STRUCTURE**

		YES	NO	UNASSESSED
1.	Are there silt, weeds or rubbish within 5m u/s or d/s of the structure?	☐	☐	■
2.	Is the measurement structure drowned?	☐	☐	■
3.	Is there serious damage to any part of the structure?	☐	☐	■
4.	Is leakage occurring around the structure?	☐	☐	■
5.	Is the d/s apron seriously damaged or undercut?	☐	☐	☐
6.	Is it difficult to read the u/s or d/s gauge boards?	☐	☐	■
7.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Channel obstruction**
Answer YES where silt or debris influence the flow of water through the measurement structure causing a serious disturbance of the flow. Ignore weed growth that can be simply cleared.

2. **Drowned structure**
A `drowned ' measurement structure is one where the water level d/s of the structure affects the level u/s. Structures require a minimum head differential for accurate measurement:

For broad crested weirs and flumes	H(d/s)/H(u/s) must be $\leq$ 0.6
For sharp crested weirs	H(d/s) must be below crest

3. **Structural damage**
Look for any damage that influences flow measurement or the stability of the structure. Common examples will be damage to a weir crest or other control section, serious cracks or structural movement.

4. **Leakage**
Answer YES if there is/are washout of fine soil particles, very wet areas of fill or other evidence of water flowing around the structure.

5. **D/s Apron**
Answer YES where the apron, or other bed protection, is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this is now stable and does not threaten the stability of the structure. Answer UNASSESSED, if you cannot see the apron or gain reliable information from the operator.

6. **Gauge boards**
Answer YES if any gauge boards are missing or cannot be read.

7. **Overall condition**
Answer YES, if:
●There is a serious fault or deterioration or failure to function that is not covered by any other question.
OR
● Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **GATED OFFTAKE**

		YES	NO	UNASSESSED
1.	Are any of the gates missing?	☐	☐	■
2.	Is it difficult to fully open or close any of the gates?	☐	☐	■
3.	Is any gate seriously corroded or rotting?	☐	☐	■
4.	Are there serious cracks or movement in any part of the structure?	☐	☐	■
5.	Is any part of the structure blocked by sediment?	☐	☐	☐
6.	Is seepage occurring around the structure?	☐	☐	■
7.	Is the d/s apron seriously damaged or undercut?	☐	☐	☐
8.	Is it difficult to read the u/s or d/s gauge board?	☐	☐	■
9.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Missing Gate**
   Only answer YES if a gate has been removed from the structure. Where a gate is broken but still present, answer NO to this question and YES to question 2.

2. **Gate operation**
   Answer YES when the condition of the lift mechanism, missing components or other factors make it impossible to effectively operate a gate. If a gate is missing, answer YES to question 1 and NO to this question.

3. **Gate Condition**
   Answer YES where corrosion or rotting has reduced the strength or water tightness of any gate. Disregard minor patches of surface corrosion or minor deterioration of any gate.

4. **Cracks/damage and movement**
   Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotational movement may be visible. Disregard shallow, surface cracks or minor damage that does not affect function.

5. **Blockage**
   Answer YES where sediment accumulation is seriously reducing the open area for water to pass through. Disregard blockage by floating vegetation or other debris that could be quickly pulled away.

6. **Seepage**
   Answer YES if there is/are washout of fine soil particles, very wet areas of fill or other evidence of water flowing around the structure.

7. **D/s Apron**
   Answer YES where the apron, or other bed protection, is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this is now stable and does not threaten the stability of the structure. Answer UNASSESSED, if you cannot see the apron or gain reliable information from the operator.

8. **Gauge Boards**
   Answer NO when gauge boards have not been installed.

9. **Overall condition**
Answer YES, if:
- There is a serious fault or deterioration or failure to function that is not covered by any other question.

OR

- Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **DRAIN**

		YES	NO	UNASSESSED
1.	Is the flow seriously limited at any location by silt, weeds or debris?	☐	☐	■
2.	Are there any signs that water has overtopped the drain?	☐	☐	■
3.	Is there evidence of waterlogging (salts, mud, reeds) in this area?	☐	☐	■
4.	Is there serious bank slippage at any location?	☐	☐	■
5.	Are any structures in this reach seriously deteriorated?	☐	☐	■
6.	Does the overall condition concern you?	☐	☐	■

NOTES :

1. **Channel obstruction**
Answer YES if silt, weed or debris limits flow in the drain so that localised flooding or waterlogging of land occur frequently.

2. **Overtopping**
Look for the high water mark in the drain or for debris caught on the banks or in adjacent vegetation.

3. **Waterlogging**
If necessary, ask farmers if problems of waterlogging, due to inadequate drainage, are common.

4. **Bank slippage**
Answer YES where slippage threatens to restrict flow capacity of the drain. Disregard minor slides if they are now stable.

5. **Drainage structures**
Answer YES only where damage to a structure threatens the correct functioning of the drain.

6. **Overall condition**
Answer YES, if:
●There is a serious fault or deterioration or failure to function that is not covered by any other question.
OR
● Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **DROP/CHUTE**

		YES	NO	UNASSESSED
1.	Are there serious cracks or movement in any part of the structure?	☐	☐	■
2.	Is leakage occurring around the structure?	☐	☐	■
3.	Is the d/s structure - stilling basin/apron - seriously damaged or undercut?	☐	☐	☐
4.	Is the d/s bed or channel section seriously eroded?	☐	☐	■
5.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Cracks/damage and movement**
   Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotational movement may be visible. Disregard shallow, surface cracks or minor damage that does not affect function.

2. **Leakage**
   Answer YES if there is/are washout of fine soil particles, very wet areas of fill or other evidence of water flowing around the structure.

3. **D/s protection**
   Answer YES where the apron, or other bed protection, is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this is now stable and does not threaten the stability of the structure. Answer NOT KNOWN, if you cannot see the apron or gain reliable information from the operator.

4. **D/s bed & channel**
   Answer YES if erosion of the bed or banks threatens the stability of the drop structure or the canal reach. Disregard minor scour or bank erosion if this appears to be stable. Answer UNASSESSED if you cannot see the bed or channel section or gain reliable information from the operator.

5. **Overall condition**
   Answer YES, if:
   - There is a serious fault or deterioration or failure to function that is not covered by any other question.

   OR
   - Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **CROSS DRAINAGE CULVERT**

		YES	NO	UNASSESSED
1.	Are there serious cracks or movement in any part of the structure?	☐	☐	■
2.	Is the canal visibly leaking into the culvert?	☐	☐	■
3.	Do farmers or staff say the culvert fails to effectively carry peak flow?	☐	☐	■
4.	Does the culvert appear blocked?	☐	☐	■
5.	Is there serious erosion around the entry or exit of the culvert?	☐	☐	■
6.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Cracks/damage and movement**
   Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotational movement may be visible. Disregard shallow, surface cracks or minor damage that does not affect function.

2. **Leakage into culvert**
   Answer YES if there is obvious and important loss of water from the canal into the culvert. Disregard minor seepage.

3. **Culvert capacity**
   Answer YES If farmers report that the drain frequently floods on the u/s side of the culvert.

4. **Blockage**
   Answer YES, where more than one quarter of the open area appears blocked. Disregard small quantities of sediment or weed in the bottom of the culvert.

5. **Erosion**
   Answer YES if erosion is occurring that could lead to undercutting of the structure.

6. **Overall condition**
   Answer YES, if:
   ●There is a serious fault or deterioration or failure to function that is not covered by any other question.
   OR
   ● Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **AQUEDUCT / FLUME**

		YES	NO	UNASSESSED
1.	Are there serious cracks or movement in any part of the structure?	☐	☐	■
2.	Is there any serious separation of the backfill & structure?	☐	☐	■
3.	Does the aqueduct leak at the union with u/s or d/s reach?	☐	☐	■
4.	Are there important leaks from the aqueduct itself?	☐	☐	■
5.	Is there evidence of overtopping in the aqueduct or immediately u/s?	☐	☐	■
6.	Is there evidence of serious damage, to supporting piers and/or superstructure?	☐	☐	■
7.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Cracks**
   Disregard shallow, surface cracks. Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure.

2. **Separation from Backfill**
   Report YES where gaps can allow seepage.

3. **Aqueduct/canal**
   Answer YES if there is any leakage, resulting in a serious loss of water or erosion of the foundation slab.

4. **Leakage**
   Disregard minor leakage from construction joints, but answer YES where there are important leaks from expansion/contraction joint fillers.

5. **Overtopping**
   Check the high water line or consult local farmers.

6. **Damage to piers/Superstructure**
   Look for exposure/corrosion of reinforcing bars, split masonry or settlement of any pier which can crack the aqueduct.

7. **Overall condition**
   Answer YES, if:
   - There is a serious fault or deterioration or failure to function that is not covered by any other question.
   OR
   - Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **SYPHON**

		YES	NO	UNASSESSED
1.	Are there serious cracks or movement in any part of the structure ?	☐	☐	■
2.	Is there any serious separation of the backfill & structure?	☐	☐	■
3.	Are there signs of leakage from the syphon?	☐	☐	☐
4.	Is there, or has there been overtopping immediately u/s of syphon?	☐	☐	■
5.	Is the syphon blocked or partially blocked?	☐	☐	☐
6.	Is there serious erosion in the d/s transition section?	☐	☐	■
7.	Is there serious erosion or settlement in the section which the syphon crosses?	☐	☐	■
8.	Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Cracks**
   Disregard shallow, surface cracks. Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure.

2. **Separation from Backfill**
   Report YES where gaps can allow seepage.

3. **Leakage from syphon**
   Look for damp patches in soil or seepage from soil surface at low points

4. **Overtopping u/s of syphon**
   Look at the level of the high water line.

5. **Blockage**
   It is not possible to inspect the syphon itself. Blockage will be indicated by high u/s water levels.

6. **Erosion in d/s transition**
   Answer YES if erosion of the bed or banks threatens the stability of the structure or the canal reach. Disregard minor scour or bank erosion if this appears to be stable.

7. **Erosion of channel/drain**
   Answer YES if the barrel of the syphon is exposed where the channel or roadway crosses. Where the syphon crosses a drainage line answer YES if erosion of the drain bed threatens the stability of any part of the syphon.

8. **Overall condition**
   Answer YES, if:
   - There is a serious fault or deterioration or failure to function that is not covered by any other question.

   OR
   - Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

STRUCTURE TYPE: **SIDE WEIR/ESCAPE**

	YES	NO	UNASSESSED
1. Is any part of the structure blocked?	☐	☐	■
2. Are there serious cracks or movement in any part of the structure?	☐	☐	■
3. Is seepage occurring around the structure?	☐	☐	■
4. Is there serious separation of the backfill & structure?	☐	☐	■
5. Is the d/s protection seriously damaged or undercut?	☐	☐	■
6. Does the overall condition concern you?	☐	☐	■

NOTES:

1. **Blockage**
   Answer YES if the blockage prevents water passing over the weir at the design crest level or would prevent the safe discharge of water d/s of the weir.

2. **Cracks/damage and movement**
   Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotational movement may be visible. Disregard shallow, surface cracks or minor damage that does not affect function.

3. **Seepage**
   Answer YES if there is/are washout of fine soil particles, very wet areas of fill or other evidence of water flowing around the structure.

4. **Separation from Backfill**
   Report YES where where gaps can allow seepage.

5. **D/s protection**
   Answer YES where the d/s protection, is breaking up or unstable because of serious undercutting. Disregard minor erosion if this is now stable and does not threaten the stability of the structure.

6. **Overall condition**
   Answer YES, if:
   ●There is a serious fault or deterioration or failure to function that is not covered by any other question.
   OR
   ● Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

Example of Field Data Collection forms:

CANAL REACH

Assessor:	**Date:**	**Canal:**

Canal Reach: u/s station						
Canal Reach: d/s station						
1. Is the canal partially blocked at any location by illegal weirs or debris?						
2. Is there serious siltation at any location?						
3. Is there serious weed growth at any location?						
4. Do farmers and/or staff report the reach capacity restricts water supply?						
5. Where the reach is in fill, has the water level been dangerously near the canal top at any point?						
6. Are there problems of serious bank slippage or gullies?						
7. If lined - Is there important damage to lining?						
8. Are there any unauthorised offtakes?						
9. Is seepage a problem in the reach?						
10. Does the overall condition concern you?						

GATED OFFTAKE

Assessor:	**Date:**	**Canal:**

Offtake ID						
Station						
1. Are any of the gates missing?						
2. Is it difficult to fully open or close any of the gates?						
3. Is any gate seriously corroded or rotting?						
4. Are there serious cracks or movement in any part of the structure?						
5. Is any part of the structure blocked by sediment?						
6. Is seepage occurring around the structure?						
7. Is the d/s apron seriously damaged or undercut?						
8. Is it difficult to read the u/s or d/s gauge board?						
9. Does the overall condition concern you?						

Appendix 3B

Condition assessment - Engineer's inspection

ENGINEERING INSPECTION - CANAL REACH page 1

Canal Name: ____________________ Reach ID ______________________

Design Parameters:

Discharge	____________	Flow depth	______________________
Bed width	____________	Freeboard	______________________
Bed slope	____________		

A. Hydraulic functions:

	Value	Percentage of design (125- 80%)	(79 - 70%)	(69 - 50%)	(<50%)
Estimated discharge	_____	☐	☐	☐	☐
Average depth	_____	☐	☐	☐	☐
Average clear bed width	_____	☐	☐	☐	☐

	Yes*	No	Don't know*
Do d/s conditions create backwater problems?	☐	☐	☐

*Describe d/s condition at section D

B. Channel condition:	Good (None/minimal)	Fair (Minor)	Poor (Serious)	Very Poor (Very serious)
Siltation	☐	☐	☐	☐
Weeds	☐	☐	☐	☐
Freeboard	☐	☐	☐	☐
C. Bank condition:				
Slips	☐	☐	☐	☐
Erosion	☐	☐	☐	☐
Seepage	☐	☐	☐	☐
If lined:				
Primary purpose - structural	☐	☐	☐	☐
Primary purpose - seepage reduction	☐	☐	☐	☐

Condition summary:

Most serious defect ____

Overall classification Good / Fair / Poor / Very poor

ENGINEERING INSPECTION - CANAL REACH page 2

D. Notes on Sections A and B :

F. Is any condition expected to become Poor or Very Poor within 12 months, if not already so?

G. **Required action:**

- None ☐
- Repair ☐
- Demolish & rebuild ☐
- Demolish & redesign ☐

Define scope of detailed site survey/investigations, if these are required:

Rough estimate of quantities/materials required:

GUIDANCE NOTES FOR ENGINEERING ASSESSMENT OF CANAL REACHES

1. REACH FUNCTIONS

I. Convey maximum design discharge without infringement of design freeboard, without drowning u/s control or measurement structures and without hazard of structural failure.

ii. Maintain level vs discharge relationship such that all off-takes on the reach can abstract their design proportion of the available flow.

iii. Maintain a stable channel section (neither bed/bank erosion or deposition) under normal, operating flows.

iv. Convey water without undue seepage loss and without unauthorised abstraction.

2. POTENTIAL MODES OF FAILURE

2.1 Channel degradation:

a) Blockage, caused by:
- Earth slips or other debris
- Sediment accumulation
- Weed growth

b) Bank erosion, caused by:
- Rainfall
- Canal flow
- Human or animal traffic
- Cross drainage flows

c) Reduced freeboard, caused by:
- Bank erosion
- Increased channel roughness
- Reduced cross-sectional area

d) Failure of side drains

2.2 Structural failure:

a) Slippage
- Surface
- Deep seated

b) Lining damage

c) Seepage
- Minor and stable
- Progressive seepage failure

Based on this summary of functions and possible mechanisms of functional or structural failure, guidance for the classification of each factor is presented in the following tables.

GUIDANCE NOTES: Condition of elements

Factor: Discharge capacity

GOOD	No more than 10% reduction in discharge below design capacity when running at FSL. Reduced capacity therefore has little effect on adequacy of d/s supply except at times of peak demand.
FAIR	Discharge capacity reduced by between 10% and 25% when running at FSL. Reduced capacity has a moderate effect on the adequacy of d/s supply.
POOR	Discharge capacity reduced by between 25% and 50% when running at FSL. Reduced capacity has a serious effect on the adequacy of d/s supply.
VERY POOR	Discharge capacity reduced by more than 50% when running at FSL. Reduced capacity results in serious yield loss or failure to crop in some d/s areas.

Factor: Sediment/weeds/other blockages

GOOD	Any sediment, weed or other blockage is insufficient to cause reduction of freeboard here or in u/s reaches when flowing at FSD.
FAIR	Channel cross-section, whether caused by sediment, weeds, or debris in any combination, is reduced by no more than 30% over any sustained length of the reach.
POOR	Channel cross-section, whether caused by sediment, weeds, or debris in any combination, is reduced by between 30% and 50% over a sustained length of the reach.
VERY POOR	Channel cross-section, whether caused by sediment, weeds, or debris in any combination, is reduced by more than 50% over a sustained length of the reach.

Factor: Freeboard

GOOD	Freeboard at normal design Q is equal to or greater than design
FAIR	Freeboard at design discharge is reduced by up to 25% over localized area.
POOR	Freeboard at design Q reduced by between 25% and 50% at any point. **Or** Freeboard reduced by up to 25% over a major part of the reach.
VERY POOR	Freeboard reduced at any point so design discharge cannot pass without risk of overtopping. (Freeboard reduced by >50% at any point.)

Factor: Slippage

GOOD	No slips or signs of surface cracks. No heave at slope toe. No slumping or deep seated movement either in up-slope terrain (cut) or in embankments
FAIR	Minor surface cracks. No heave at slope toe. No slumping or deep seated movement either in up-slope terrain (cut) or in embankments
POOR	Occasional surface slumping of embankments due to over-steep slopes. May contribute to minor sedimentation but no risk of sudden blockage through sliding. Banks not weakened and no immediate risk of structural failure
VERY POOR	Actual or threatened failure of banks, including: ● deep-seated slips, including upslope collapse in cut areas, especially after rainfall, or saturated embankments in fill areas. ● Tension cracks in embankment surface or heave at embankment toe may indicate potential failures.

Factor: Erosion

GOOD	No erosion, either within the channel, on upslope terrain (cut) or on the external face of embankments.
FAIR	Minor surface erosion under rainfall, on upslope terrain (cut) or on the external face of embankments. Minor local scour at hydraulic structures which does not threaten undermining.
POOR	Frequent areas of bank erosion, including major runnelling under rainfall. Cannot be restored to condition by minor maintenance/ turfing. Progressive bed erosion around hydraulic structures may lead to structural undermining. Design bank top width may be reduced locally, but no immediate danger of bank failure.
VERY POOR	Widespread areas of bank erosion, either major runnelling under rainfall or around hydraulic structures. Immediate danger of structural undermining. Bank top width and cross section dangerously reduced.

Factor: Seepage

GOOD	No evidence of seepage from embankment.
FAIR	Minor canals: Limited occasional areas of seepage from embankment. Conveyance canals: No evidence of seepage
POOR	Minor canals: frequent breaches causing visible loss. Conveyance canals: stable, minor seepage/up-welling visible at bank toe.
VERY POOR	Minor canals: frequent breaches seriously diminish channel flow. Conveyance canals: seepage/up-welling at bank toe visibly increasing over time. Seepage may threaten stability of slopes (cut) or embankments.

Factor: Lining damage -
Lining purpose, structural

GOOD	Insitu concrete lining - No significant damage - penetrating cracks, settlement or heave - in any lining panel. Masonry/block lining - Very few isolated instances of damaged or missing blocks may occur. No evidence of washout behind lining at any point. No apparent risk of progressive failure.
FAIR	Insitu concrete lining - An Isolated, few occurrences of penetrating cracks, settlement or heave. Masonry/block lining - minor occurrence of individual damaged/missing blocks or masonry. **and/or** Isolated occurrence of minor washout behind lining. No apparent risk of progressive failure.
POOR	Insitu concrete lining - Frequent, isolated cases of penetrating cracks, settlement or heave, (no more than 20% of panels show damage). No single area of extensive damage. Masonry/block lining - Frequent occurrence of individual damaged/missing blocks or masonry **and/or** Frequent occurrence of washout behind lining. A risk of progressive failure from existing weak points is apparent .
VERY POOR	Insitu concrete lining - Very frequent occurrence of penetrating cracks, settlement or heave, (more than 20% of panels show damage). Or a single extensive area of damage. Masonry/block lining - Very frequent occurrence of individual damaged/missing blocks or masonry. Or a single extensive area of damage. **and/or** Serious erosion and risk of bank failure is evident.

Factor: Lining damage -
Lining purpose, seepage reduction

GOOD	Insitu concrete lining - Panels to line and level. No evidence of sub-grade erosion. Rare occurrence of hairline cracking only. Joints appear sound, material firmly held in place. No vegetative growth. Masonry block lining - Panels to line and level - no evidence of sub-grade erosion. Very occasional isolated blocks missing but no danger of progressive loss.
FAIR	Insitu concrete lining - Panels to line and level. Occasional points where erosion or settlement of sub-grade may be occurring. Minor cracking, up to 1mm wide, may affect one panel in 20. Joint material generally sound, some joints may require re-sealing. no vegetative growth in joints. Masonry block lining - Panels to line and level. Occasional points where erosion or settlement of sub-grade may be occurring. Small areas of bricks/blocks missing - not more than 0.5m^2 on main system. Joint generally sound but some minor shear cracking. No cracks greater than 1mm wide.
POOR	Insitu concrete lining - Occasional panels deviate from line and level. approximately one panel in 20 clearly damaged, back erosion and/or bank settlement occurring at such points. Cracks up to 5mm wide randomly distributed over the lining. Frequent joint failures. Clear danger of progressive failure. Masonry block lining - Lining clearly deviates from line and level. Areas of bricks/blocks missing - up to 1.0m^2 on main system. Frequent joint failures. Clear danger of progressive failure.
VERY POOR	Insitu concrete lining - Line and level lost over groups of panels. Panels collapsed, sub-grade erosion and/or settlement at these points. Other panels cracked, progressive failure occurring. Masonry block lining - line and level lost over tens of metres. Major holes in the lining occur frequently. Bonding lost over virtually full cross section in many places. progressive failure occurring.

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For hydraulic structures complete Sections A and B.
For non-hydraulic structures, e.g. bridges, roads etc. omit Section A

Structure type ___________________ Structure ID ______________________

A. Hydraulic functions:

	Good	Fair	Poor	Very Poor
Conveyance capacity	☐	☐	☐	☐
Where relevant: Control of discharge/level	☐	☐	☐	☐
Discharge measurement	☐	☐	☐	☐
Water tightness	☐	☐	☐	☐

B. Structural condition:

	Good (None/minimal)	Fair (Minor)	Poor (Serious)	Very Poor (V. serious)
Movement - (settlement displacement/heave/rotation)	☐	☐	☐	☐
Scour damage to structure	☐	☐	☐	☐
Scour damage to channel	☐	☐	☐	☐
Joint condition	☐	☐	☐	☐
Condition of structural elements (Cracking, etc.)	☐	☐	☐	☐
Surface condition (Spalling, rust, damaged coatings)	☐	☐	☐	☐
Stability of slopes/retained soil	☐	☐	☐	☐

Condition summary:
Most serious defect ______________________________

Overall classification Good / Fair / Poor / Very poor

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C. Notes on sections A & B:

D. Is any condition expected to become Poor or Very Poor within 12 months if not already so?

G. **Required action:**

- None ☐
- Repair ☐
- Demolish & rebuild ☐
- Demolish & redesign ☐

Define scope of detailed site survey/investigations, if these are required:

Rough estimate of quantities/materials required:

Factor: Conveyance capacity

GOOD	No more than 5% reduction in conveyance capacity at FSL. Flow can be distributed evenly across full width of structure.
FAIR	Conveyance capacity reduced by between 5 and 15% at FSL. Flow can be distributed evenly across full width of structure.
POOR	Conveyance capacity reduced by between 15 and 30% at FSL. Part of the open area may not function correctly.
VERY POOR	Conveyance capacity reduced by more than 30% at FSL. Part of the open area may not function correctly.

Factor: Control of discharge/level

GOOD	All gates fully operational. No damage to any fixed control surface. No blockage of any part of the structure
FAIR	All gates fully operational. No damage to any fixed control surface. Accumulation of sediment or debris may affect the control of discharge or level.
POOR	All gates in place. Sub-standard condition of one or more gates limits control of discharge or level. **Or** Fixed control surfaces damaged. Performance of system is affected.
VERY POOR	One or more gates missing or not working. **Or** Fixed control surfaces badly damaged. Structure cannot provide control of level or discharge. Structure is effectively non-functional.

Factor: Discharge measurement

GOOD	Level gauge/s present and correctly sited, clear of drawdown and turbulence. Structure approach, control section and exit in good repair and free from obstruction. Structure is not drowned under any operating conditions.
FAIR	Level gauge/s present and correctly sited, clear of drawdown and turbulence. Structure approach, control section and exit in good repair. Channel obstruction u/s of structure distorts flow profile through the control section. Structure is not drowned under any operating conditions.
POOR	Gauge/s missing/illegible or sited in zone of drawdown or turbulence. **and/or** Minor structural damage to control surface - crest, throat etc. Structure partially drowned.
VERY POOR	Control surface seriously damaged. Structure drowned under normal operating conditions.

Factor: Water tightness/Leakage

GOOD	No meaningful leakage.
FAIR	Minor leakage estimated at < 1% of design discharge of structure.
POOR	Leakage estimated at up to 5% of design discharge. This water may be re-used elsewhere.
VERY POOR	Serious leakage - > 5% of design discharge of structure. Affects water available in system and/or threatens erosion.

Factor: Movement

GOOD	No settlement or heave/rotation or displacement under load, including temperature stress. All joints appear sound. No structural cracking.
FAIR	Minor movement apparent from small structural cracks or minor joint displacement. structure remains basically sound, remedial work may be needed to avoid progressive movement and damage.
POOR	Movement in any plan is clearly apparent. Proper functioning of the structure already impaired. Early action needed to avoid progressive failure.
VERY POOR	Movement in any plane has seriously disrupted proper functioning of the structure. Full depth structural cracks of 5mm width or more. (Hydraulic structure) Rotation and displacement of joints mean that structure cannot retain water.

Factor: Scour at structure

GOOD	No meaningful damage to bed or banks adjacent to structure apparent on de-watering.
FAIR	Progressive erosion to bed or banks adjacent to structure. No structural damage has yet occurred but it may occur if remedial action is not taken.
POOR	Erosion to bed or banks has begun to seriously undermine the structure. Progressive failure is threatened.
VERY POOR	Structure actually or virtually ceased to function as intended. Extensive damage to structural elements.

Factor: Scour in channel

GOOD	no meaningful damage to bed or banks apparent on de-watering.
FAIR	Erosion to bed or banks does not affect conveyance. Bank stability not impaired to date but undercutting is threatened.
POOR	Erosion to bed or banks causing instability to side slopes.
VERY POOR	Progressive erosion to bed or banks causing extensive slips, threatening sudden blockage in sections of cut or bank failure in sections of fill. Excess sediment being deposited in reaches downstream.

Factor: Joint condition

GOOD	Joints appear sound throughout their length. Sealant or filler securely in place. No leakage, observed or expected.
FAIR	Minor defects. Joints generally sound but localised areas where sealant or filler is eroded or damaged. No obvious leakage path.
POOR	Sealant or filler lost or substantially damaged in several places. Joint will allow leakage (hydraulic structures), entry of water, dirt and debris (bridge decks etc).
VERY POOR	Sealant or filler lost over most of the joint length. Joint will be completely ineffective in preventing leakage (hydraulic structures), or entry of water, dirt and debris (bridge decks etc)

Factor: Structural elements

GOOD	Element(s) are sound. No signs of structural cracking, damage or distress.
FAIR	Element(s) are generally sound. Minor damage may have been sustained. Element(s) still fit to perform function within the immediate future.
POOR	Element(s) appear distressed. Structural cracks and/or damage. Performance is, or will shortly be, adversely affected.
VERY POOR	Elements no longer fit for function.

Note: Identify affected elements on the proforma.

Factor: Surface condition

GOOD	Surface sound. No evidence of deterioration under external or internal erosive/corrosive agents.
FAIR	Surface substantially sound. A few areas showing localised defects. Slow deterioration likely.
POOR	Surface noticeably defective:- spalling, cracking or rusting. Structural integrity of the structure at risk.
VERY POOR	Severe surface deterioration. Progressive or sudden failure of the element under external or internal agents is imminent.

Factor: Stability of slopes/retained soils

GOOD	Soil mass stable. No cracking, deformation or movement.
FAIR	Soil mass stable. Minor surface cracking and/or deformation, not extending into body of soil.
POOR	Soil mass marginally stable. Cracking and/or deterioration affecting body of soil. Evidence of minor movement and/or seepage.
VERY POOR	Soil mass unstable, cracking and/or deterioration affecting body of soil. Clear evidence of significant movement with/without seepage. Slip planes may be visible.

Appendix 4

Condition assessment scores

Appendix 4 Condition assessment scores

Ratings :	> 80 = Good	51 - 70 = Poor
	71 - 80 = Fair	≤ 50 = V. Poor

<u>Note</u> Questions correspond to those in the Overseers Inspection forms - Appendix 3A. Scores/Class are used in subsequent analysis to determine priorities, and have been set on the basis of reasonable engineering judgement.

STRUCTURE TYPE : **INTAKE / HEAD REGULATOR**	Hydraulic	Structural	Class	% Effective
1. Are any of the gates missing?	•		V. Poor	40
2. Is it difficult to fully open or close any of the gates?	•		V. Poor	45
3. Is any gate seriously corroded or rotting?		•	Poor	70
4. Are there serious cracks or movement in any part of the structure?		•	Poor	60
5. Is any part of the structure blocked by sediment?	•		Fair	75
6. Is seepage occurring around the structure?		•	Poor	60
7. Is the d/s apron seriously damaged or undercut?		•	V. Poor	40
8. Is it difficult to read the u/s or d/s gauge board?	•		Good	90

STRUCTURE TYPE : **GATED CROSS REGULATOR**	Hydraulic	Structural	Class	% Effective
1. Are any of the gates missing?	•		V. Poor	45
2. Is it difficult to fully open or close any of the gates?	•		V. Poor	45
3. Is any gate seriously corroded or rotting?		•	Poor	70
4. Are there serious cracks or movement in any part of the structure?		•	Poor	60
5. Is leakage occurring around the structure?		•	Poor	60
6. Is the d/s apron seriously damaged or undercut?		•	V. Poor	40
7. Is it difficult to read the u/s or d/s gauge boards?	•		Good	90

STRUCTURE TYPE : **CANAL REACH**	Hydraulic	Structural	Class	% Effective
1. Is the canal partially blocked at any location by illegal weirs or debris?	•		Good	85
2. Is there serious siltation at any location?	•		Poor	55
3. Is there serious weed growth at any location?	•		Poor	55
4. Do farmers and/or staff report the canal capacity restricts water supply?	•		Poor	60
5. Where the reach is in fill, has the water level been dangerously near the canal top at any point?		•	V. Poor	40
6. Are there problems of serious bank slippage or erosion?		•	V. Poor	45
7. If lined - Is there important damage to lining?		•	Poor	55
8. Are there any unauthorised offtakes?	•		Good	90
9. Is seepage a problem in the reach?		•	Poor	60

STRUCTURE TYPE : **INSPECTION ROAD**	Structural	Class	% Effective
1. Does limited track width prevent vehicle access at any point?	•	V. Poor	45
2. Do surface unevenness and pot holes making driving difficult?	•	Fair	75
3. Are cross drainage culverts seriously damaged or exposed at any point?	•	Poor	60
4. Are sides slopes seriously eroded or showing signs of serious slippage?	•	Poor	55
5. Is access difficult at any time of year?	•	Poor	60

STRUCTURE TYPE : **FLOW MEASUREMENT STRUCTURES**	Hydraulic	Structural	Class	% Effective
1. Are there silt, weeds or rubbish within 5m u/s or d/s of the structure?	•		Fair	75
2. Is the measurement structure drowned?	•		V. Poor	50
3. Is there serious damage to any part of the structure?		•	Poor	55
4. Is leakage occurring around the structure?		•	Poor	55
5. Is the d/s apron seriously damaged or undercut?		•	Poor	55
6. Is it difficult to read the u/s or d/s gauge boards?	•		Fair	75

STRUCTURE TYPE : **GATED OFFTAKE**	Hydraulic	Structural	Class	% Effective
1. Are any of the gates missing?	•		V. Poor	40
2. Is it difficult to fully open or close any of the gates?	•		V. Poor	45
3. Is any gate seriously corroded or rotting?		•	Poor	70
4. Are there serious cracks or movement in any part of the structure?		•	Poor	60
5. Is any part of the structure blocked by sediment?	•		Fair	75
6. Is seepage occurring around the structure?		•	Poor	60
7. Is the d/s apron seriously damaged or undercut?		•	V. Poor	40
8. Is it difficult to read the u/s or d/s gauge board?	•		Good	90

STRUCTURE TYPE :**DRAIN**	Hydraulic	Structural	Class	% Effective
1. Is the flow seriously limited at any location by silt, weeds or debris?	•		V. Poor	50
2. Are there any signs that water has overtopped the drain?	•		Fair	75
3. Is there evidence of waterlogging (salts, mud, reeds) in the area?	•		Poor	55
4. Is there serious bank slippage at any location?		•	Poor	60
5. Are any structures associated with this drain reach seriously deteriorated?		•	Fair	75

STRUCTURE TYPE : **DROP/CHUTE**	Hydraulic	Structural	Class	% Effective
1. Are there serious cracks or movement in any part of the structure?		•	Poor	60
2. Is leakage occurring around the structure?		•	Poor	60
3. Is the d/s apron seriously damaged or undercut?		•	V. Poor	40
4. Is the d/s bed or channel section eroded?		•	Fair	75

STRUCTURE TYPE : **CROSS DRAINAGE CULVERT**	Hydraulic	Structural	Class	% Effective
1. Are there serious cracks or movement in any part of the structure?		•	V. Poor	40
2. Is the canal visibly leaking into the culvert?	•		Fair	75
3. Do farmers/staff say the culvert fails to effectively carry peak flows?	•		Poor	55
4. Does the culvert appear to be blocked?	•		V. Poor	45
5. Is there serious erosion around the entry or exit of the culvert?		•	Poor	50

STRUCTURE TYPE : **AQUEDUCT / FLUME**	Hydraulic	Structural	Class	% Effective
1. Are there serious cracks or movement in any part of the structure?		•	V. Poor	40
2. Is there any serious separation of the backfill and structure?		•	Fair	75
3. Does the aqueduct leak at the union with u/s or d/s reach?		•	Poor	65
4. Are there important leaks from the aqueduct itself?		•	Poor	70
5. Is there evidence of overtopping in the aqueduct or immediately u/s?	•		V. Poor	50
6. Is there evidence of serious damage to supporting piers and/or super structure?		•	Poor	55

STRUCTURE TYPE : **SYPHON**	Hydraulic	Structural	Class	% Effective
1. Are there serious cracks or movement in any part of the structure?		•	V. Poor	45
2. Is there any serious separation of the backfill and structure?		•	Poor	60
3. Are there signs of leakage from the syphon?		•	Poor	65
4. Is there, or has there been, overtopping immediately u/s of siphon?	•		Poor	60
5. Is the syphon blocked or partially blocked?	•		Poor	65
6. Is there serious erosion in the d/s transition section?		•	Fair	75
7. Is there serious erosion or settlement in the section which the syphon crosses?		•	V. Poor	45

STRUCTURE TYPE : **SIDE WEIR / ESCAPE**	Hydraulic	Structural	Class	% Effective
1. Is any part of the structure blocked?	•		V. Poor	45
2. Are there serious cracks or movement in any part of the structure?		•	V. Poor	50
3. Is seepage occurring around the structure?		•	Poor	55
4. Is there any serious separation of the backfill and structure?		•	Fair	75
5. Is the d/s protection seriously damaged or undercut?		•	Poor	50

Appendix 5

Relative importance of different assets

Appendix 5   Relative importance of different assets

The strategic importance of a given type of asset to the overall functioning of the scheme is based on consideration of the following three components:

Function - The significance of the asset to proper functioning of the system. Considers the effect of removing that type of asset from a system. The notion of area served is **not** included in this assessment.

Hazard - The potential impact on the integrity of the system should the asset fail. This does **not** consider the risk to life and limb. It anticipates the most likely type of failures - a slow deterioration, which has low hazard, or sudden, catastrophic failure and high hazard. For example, a cross regulator in a canal system is unlikely to fail suddenly or dangerously. An aqueduct has a much higher associated risk or hazard.

Worth - An approximate measure of the relative cost of repairing or replacing the asset. Comparisons based on the the intrinsic cost of components sized for similar locations in a scheme.

Each type of asset was rated in one of three categories corresponding to each of the above criteria:

Function	**Hazard**	**Worth**
Essential	High	High
Important	Medium	Medium
Minor	Low	Low

Assets were then grouped into four classes of importance:

Importance Scores (classes)

1	**2**	**3**	**4**
Measurement structures	Canal reach Drain Head regulator Cross regulator Drop/chute Inspection road Side weir Bridges	Scour sluice Cross drainage culvert Aqueduct Syphon Sediment trap	Diversion weir Embankment dam Intake works Barrage

Appendix 6

Hydraulic modelling as an aid to diagnosis

Appendix 6 Hydraulic modelling as an aid to diagnosis

In applying computer models to design, the designer will normally set the principal system parameters uniformly over large parts of the system. In contrast, in order to simulate the hydraulic behaviour of an existing system, it is necessary to correctly represent parameters varying from place to place in the system.

Thus, to provide a useful tool in system diagnosis, hydraulic models require detailed information on field conditions. Users would probably be designers rather than systems managers.

Design information on the system will be introduced initially, and the model run to check and establish reference water levels. Survey information can then be used to run the model for prevailing system conditions. Reasonable judgements on channel roughness values may be made using standard texts, such as Ven Te Chow (1959). Once the user is satisfied that the model is correctly calibrated, identified constraints causing a rise in water level can be successively removed and the model re-run to assess the effectiveness of the action. It is thus possible to arrive at a priority of actions.

There is little point in conducting highly detailed surveys, involving cross sections at close centres, if uncertainties in the values of other parameters, such as the friction coefficient, mean that average estimated values must be used. It may be possible to approximate by using design profiles for much of the system and conducting detailed surveys over localised areas of particular significance. The following observations are intended to assist in determining the intensity of survey.

- Once a system of earthen channels has been operating for some time the cross section may no longer appear prismatic. Surface unevenness within the wetted perimeter of a section are not significant *per se*. Limited variation of any individual cross sectional area from the design value (10-20% variation) will also not have much effect on the water level since changes in surface profiles occur gradually on shallow slopes.

- A possible exception could be a section in hard ground which has been under-excavated to the extent of some 33% or more of the intended value. In this case, the section is likely to form a ‘choke’, causing critical flow and afflux upstream.

- Several cross-sections in sequence, all similarly differing from design, (sections assumed at, say 50m centres) will affect upstream water levels. Normally, a rise in water level would be expected, but if the downstream channels had been over-excavated during maintenance, the upstream water level could be drawn down.

In the type of systems indicated above, hydraulic modelling can assist by:

- establishing the location and effect of constraints in the system

- simulating the response of the system to alternative interventions

- predicting the response of the system if conditions were to worsen in specified ways and no corrective action were taken

A model can assist with problems of weed growth, sedimentation, seepage loss, malfunctioning or damaged structures. It could also be used to determine, for example, the effect of modification to canal cross sections; lining; and the construction of cross regulators.

It is difficult to accurately predict the time needed to set up a model, as it will depend on the information already available, the size of the scheme and the ease of use of the software. As an example, a scheme of 2000 ha in Indonesia was modelled in 2 weeks by a new user who had received a week’s preliminary training in the software of a model that was then current and was familiar with the scheme. Existing design data were used throughout. A further week was spent in the field to compare the preliminary model output with the observed behaviour of the system. Once the model was established and calibrated, several simulations were performed in a single day.

In this case it was found that there were no material constraints to flow within the system.

More recent models running seasonal simulations at, say, weekly time steps, can be set up and calibrated in a few days.

The method seems most appropriate for :-

- large multi-branched systems on flat terrain where large sums will be needed for rehabilitation.
- systems affected by severe problems which do not show material improvement even just after maintenance.
- systems where topographic surveys of canals are routinely carried out in connection with annual maintenance programmes.

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