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ASSET MANAGEMENT PROCEDURES FOR IRRIGATION SCHEMES

- Preliminary guidelines for the preparation of an asset management plan for irrigation infrastructure

Institute of Irrigation Studies, University of Southampton, UK
in association with
WRc Engineering, Swindon, UK
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Directorate General of Water Resources Development, Government of Indonesia
Faculty of Agricultural Technology, Gadjah Mada University, Yogyakarta, Indonesia.

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Summary

The report is the result of a six-month project to study Asset Management Planning, a technique derived from the UK water industry, and to examine its potential application to irrigation in developing countries. Central to the work was a four month field trial in Yogyakarta, Indonesia, in which practical procedures were formulated and tested. Experience of this trial enabled the feasibility of applying the methodology to irrigation to be established and aspects requiring further research to be identified.

The approach to the project, the reasoning behind it and its execution are described. There is a review of the origins of Asset Management and a brief examination of the setting within irrigation which concerns the study. More similarities than differences were found between asset management for irrigation and that for the UK water industry. These are summarised together with the implications for transferring the techniques between these two fields of application. Current issues and initiatives in Indonesia are described as a background to the field trial there.

The application of Asset Management to irrigation is described. Procedures are set out and discussed for the production and use of an Asset Management Plan (AMP). Each of the steps is described, with background information, recommendations and examples or illustrations, wherever possible, from the experiences of the trial in Yogyakarta. Aspects for which the requirements are location-specific or which will demand particular attention for other reasons, are identified and discussed.

The report concludes that Asset Management Procedures for Irrigation Schemes are feasible and that the methodology provides a framework for strategic management in the sector. Through the detailed information provided and the references to the trial, practicability is demonstrated and the extent to which the ideas are developed is shown. Resource requirements and the logistics of undertaking the procedures are set out in broad terms. It is recommended that an overall programme for AMP production of nine to eighteen months may realistically be envisaged. The extension of the methodology into other areas is considered briefly and further research needs are identified. Supporting information is given in the Appendices.

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Asset Management Procedures for Irrigation Schemes

CONTENTS

GLOSSARY OF TERMS

Aggregation	The extrapolation of results of sampling, taking due account of stratification and normalisation criteria, to represent all systems together.
Alternative Strategies	Mutually exclusive means to achieving a single set of ultimate goals.
Asset Condition	A measure of the state of deterioration of an asset from its new condition against a defined reference scale. This is assessed independently of the ability of the asset to perform its function (see Asset Serviceability).
Asset Extent	The number of assets which exist, counted under various categories describing assets of similar characteristics and in size bands.
Asset Importance	A measure of the potential influence of an individual asset on system performance due to its position within the system.
Asset Management Plan (AMP)	A comprehensive report on a piece of infrastructure, prepared in accordance with a prescribed format, setting out the nature and extent of the assets concerned, their value and the liabilities associated with each. In order to present this information in a meaningful way, the report will necessarily set out a plausible plan of investment related to the sustained achievement of a satisfactory service to users.
Asset Serviceability	The ability of the asset to perform its function(s). Measured on a scale by reference to appropriate functional definitions.
Asset Stock, Condition and Serviceability Profiles	A report detailing the extent of assets, their size (by band) and MEA value, both 'gross' and 'net' (depreciated - allowing for condition). Condition and Serviceability Profiles are given by reporting the value of assets (by gross MEA) in each condition grade and in each serviceability grade respectively. Provides a clear summary of the current state of the asset stock. (See also 'Modern Equivalent Asset Value' - MEA).
Asset Survey	The inspection of assets in the field to determine (or confirm) their physical attributes, condition and serviceability.
Asset Types and Components Depreciation Categories	The grouping of asset types and components thereof on the basis of similar rates of deterioration from new condition to a degraded state.
Asset Value	The value of an asset based on its replacement cost or MEA (see also 'Modern Equivalent Asset Value'). Reported both as 'gross' and 'net' (depreciated) value.
Band	A continuous range of values from a lower to an upper limit.
Budget Planning and Investment Priorities	The allocating of 'baskets of money' to identified types of investment activity over a short term (5 year) planning horizon but in conformity with the long term strategic business plan arrived at as a result of the financial modelling process.
CAPEX	Capital Expenditure.
Capital Investment Activities Unit Cost Index	A 'look-up table' of unit prices at current rates for rehabilitation, upgrading and extension works (e.g. 'replace gates', 're-line canals', 'repair wingwalls' etc.) related to each asset type and size band. Facilitates the rapid build up of cost estimates for any identified investment need.
Capital Planning	The process of defining the capital investment requirements implied by the preferred investment strategy and established from the financial model. To achieve this it is necessary to know the cost stream, to examine the income stream and to consider the flow of capital.
Components	Each asset comprises a number of component parts. Their identification facilitates condition assessment when different components may be subject to different degrees of deterioration.

Condition	See 'Asset Condition'
Condition Grade	An indicator, on a defined scale from 'Good' to 'Bad', of the state of degradation of an asset from new. See also 'Asset Serviceability'.
Cost Model	A reference data-base for use in the preparation of the AMP and for the comparison of alternative investment strategies in the subsequent financial modelling process. Costs related to each asset type and size are needed to value existing assets (Modern Equivalent Asset); to provide unit costs for system capital investment activities; and to quantify operational costs.
Cost Recovery	The matching of revenue levels to the actual cost of providing the service over the long term.
Daerah Irigasi (DI)	An Indonesian term used to define an irrigation network. The area may range from a few to several thousand hectares. A DI is often characterised as an irrigation network offtaking from a weir or a river.
Demand	The demand placed on the service. The demand may change over time, resulting in changes to the infrastructure requiring additional investment.
Engineering Studies	Studies required to relate system performance to the characteristics of the infrastructure and thus to establish the extent of work needed to maintain and/or improve asset condition and system performance.
Existing Performance	Quantifies the existing performance of the system. The gap between the existing performance and the target (Standards) identifies the performance gap that is to be narrowed through further investment.
Extent	See 'Asset Extent'.
Financial Model	A process of reviewing and refining the provisional ideas presented in the AMP to ensure a realistic investment strategy in terms of funds available including identifying any necessary CAPEX/OPEX trade-offs.
Function	See 'Asset Serviceability'.
Importance Band	See 'Asset Importance'
Investment Activities	The specific activities (e.g. items of construction work) for which the investment is intended to pay and which are essential to achieve the investment objectives.
Investment Benefits	The intended benefits, in terms of improved levels of performance under acknowledged criteria, associated with specific investments.
Irrigation Service	The people, organisation and infrastructure that together provide to users all the services associated with irrigation (including drainage).
Irrigation Service Fee (ISF)	A charge to users of the irrigation service intended to reflect the real costs of its provision.
Modern Equivalent Asset Value (MEA)	The cost, at current prices, of a modern asset of equivalent function, not necessarily replicating the existing asset in precise detail.
Needs Based Budgeting (NBB)	The attempt to allocate annual budget provisions on the basis of clearly identified investment needs rather than on some arbitrary or nominal apportioning measure.
Normalisation	The process of reducing system characteristics, especially costs, to a common unit measure such as cost per unit irrigated area, number of structures per unit irrigated area, etc. Normalised values of quantities or costs can then be used to derive numbers and/or costs for schemes of different sizes.
O&M	Operation and Maintenance.
Operating Costs	The costs of operating (including routine maintenance - see definition) the

	system over the budgeting horizon.
OPEX	Operating Expenditure.
Performance Assessment	A series of stages in which the performance of a system, in terms of 'output measures', is compared with targets and the reasons for differences identified.
Performance Target	See 'Standard(s)'
Policies	Declared intentions against which an organisation expects its achievements to be measured.
Primary Canal	The main supply canal at the top of an irrigation system from its intake to the division into a number of Secondary Canals
Privatisation	The transfer of ownership and management of infrastructure assets and the service they support from the public sector into private hands
Revenue	The income received to pay for the service provided.
Routine Maintenance Costs	Costs associated with regular and frequent activities intended to keep assets operational and in a good state of repair.
Scheme	The complete operation including the infrastructure and all those people and other influences involved in its operation and use. An irrigation scheme includes the 'system', the farmers and operators, the land/soil, the crops, the market etc. (see also 'System').
Secondary Canal	One of a number of secondary canals which convey water from the main Primary Canal of an irrigation system to several 'tertiary' offtakes
Serviceability	See 'Asset Serviceability'.
Serviceability Grade	An indicator of the ability of an asset to perform its function(s) on a defined scale from 'Fully Functional' to 'Ceased to Function'.
Size	A measure associated with each asset type which gives an indication of its scale and hence its monetary value.
Standard(s)	The intended level(s) of performance - i.e. the 'Target(s)'
Strata	See 'Stratification'.
Stratification	The statistical procedure of dividing a diverse collection of systems into groups (termed Strata) having common characteristics from which representative samples can be taken.
System	The infrastructure itself or engineering hardware, separated from other influences (see also 'Scheme').
Technical Level (of an irrigation system)	A classification method used in Indonesia to define the degree of control and measurement of flow which is possible in a system due to its design and construction. Three levels are used: **Technical** - full control and measurement at all divisions/offtakes; **Semi-technical** - full control and measurement at selected points only in the system; **Non-technical** - no measurement of flow within the system and control, if any, using simple structures only.
Tertiary Canal	The canal conveying water from a Secondary Canal offtake to Quartinary Canals and thus to the field.
Tertiary Unit	A grouping of fields, generally totalling between 30 to 150 ha, which are served by a single offtake from the Secondary (or, occasionally, the Primary) Canal. Management and control of water distribution within the Tertiary Unit is usually the responsibility of the water users.
Turnover	The transfer of responsibility for operation and maintenance (of an irrigation system) to a farmer group or Water Users Association.

Part I: Concepts

1. Introduction

1.1 Managing Infrastructure - the Contemporary Challenge

It is a characteristic of modern technological society that, as ‘development’ continues, so dependence upon networks of artificial infrastructure increases. Transportation, telecommunications, energy distribution, water and sewerage systems (for instance) have become essential to the ability of our societies to function ‘normally’. These facilities and the depth of our reliance on them, have grown at an unprecedented rate in recent decades. Invariably they have been accumulated over a long period on a project-by-project basis, the cost of each project being justified by the particular need it satisfied.

As the stock of infrastructure assets thus accumulates, a creeping maintenance liability accrues and this eventually dominates the requirement for resources. Society expects the continuation or improvement of the service to which it has grown accustomed and value for money is demanded. The old ‘project’ approach which served so well for past development is found to be inadequate to the emerging task. New methodologies are needed to provide a clear overview of objectives, options, benefits and competing needs and to resolve these into a comprehensive strategy for investment The institutions responsible for management of the infrastructure may themselves need reform. This phenomenon is quite dramatically illustrated by recent privatisations of public infrastructure in the UK and elsewhere.

The challenge facing irrigation is at least as great as that in other sectors. The following quotation is illustrative (Rabindranath, 1993):

> “Irrigated agriculture is up against an enormous challenge. Global population continues to grow at a tremendous rate... Water is becoming increasingly scarce... The most attractive irrigation sites have already been exploited. Yet, irrigated agriculture will have to deliver average output increases of at least 3.5% per year if future food demands are to be met.”

The era of the Green Revolution saw the large scale development of irrigation schemes. That era of new construction is past. The challenge now is to maintain existing infrastructure and to improve it in terms of water-use efficiency and of cost-effectiveness. This challenge sets the context of the report.

1.2 Structure of the Report

The report is centred on a project set up to study Asset Management Planning, a technique derived from the UK water industry, and to examine its potential application to irrigation. In Part I the concepts are set out. The approach to the project, the reasoning behind it and its execution are described. There is a review of Asset Management and of the setting within irrigation which concerns the study. Current issues and initiatives in Indonesia are described as a background to the field trial there. Part II describes the application of Asset Management to irrigation. Procedures are set out and discussed for the production and use of an Asset Management Plan (AMP). These were devised in the course of the study based on its findings and, importantly, on the experiences of the field trial. The report concludes, in Part III, with reflections on the benefits of the AMP, how these can be mobilised and on some practicalities of implementation. The extension of the methodology into other areas is considered briefly and further research needs are identified. Supporting information is given in the Appendices.

1.3 Background to the Project

The project is a feasibility study led by the Institute of Irrigation Studies with funding from the British Overseas Development Administration (ODA Project R6078). The author worked on the project throughout its six-month programme which included a four-month field trial based in Yogyakarta, Indonesia. Collaborators in Indonesia were funded by the Indonesian Department of Public Works.

The research hypothesis is that Asset Management procedures and techniques developed and used in the water supply and sewerage industry of England and Wales, at the time of privatisation in 1989 and since, can be adapted for application to irrigation in many developing countries. A pressing need exists for a framework which integrates diverse considerations in the approach to investment planning in the irrigation sector. It is proposed that Asset Management can provide exactly such a framework. Thus it has potential benefit for water users, for irrigation managers, funding agencies, tax-payers and for the environment.

1.4 Collaborating Organisations

The following organisations collaborated in the execution of the study:

Institute of Irrigation Studies, University of Southampton, England (Lead).
WRc, Swindon, England.
Mott MacDonald, Cambridge, England.
Department of Public Works, Directorate of Water Resources, Government of Indonesia.
Faculty of Agricultural Technology, University Gadjah Mada, Yogyakarta, Indonesia.

1.5 Project Objectives

The overall aim of the project has been to ascertain the potential for transferring and adapting the methodology concerned and, based upon these findings, to identify longer term research needed to formulate detailed procedures for Asset Management within the irrigation sector in developing countries. Thus the objectives were to:

- study Asset Management procedures in the UK water industry
- consider these in the context of irrigation in developing countries
- formulate ideas for the transfer and adaptation of the methodology
- review these ideas in the light of a trial under real conditions in Indonesia
- prepare provisional guidelines for Asset Management procedures in irrigation
- identify key aspects where further research is required.

1.6 Underlying Aims

It is important at the outset to identify the intended purpose of applying Asset Management to developing country irrigation. The methodology was originated in response to some very specific needs of privatisation in the UK context under social, financial and institutional conditions which, it is recognised, do not prevail in many countries. In the English and Welsh water industry, the objectives of the first Asset Management Plan (AMP1) were (i) to inform potential investors whilst (ii) providing assurances that appropriate levels of investment were intended to be made in unseen underground assets of crucial national importance and that the resulting charges to customers would be reasonable. The introduction of Asset Management into irrigation is seen as having the following aims:

- To help achieve more cost-effective management of the infrastructure.
- To this end, to enable managers to make better-informed investment decisions which have a clear basis of justification and which can be audited or replicated.
- To facilitate turnover of assets from central government control where desired.
- To provide a cost-effective technique for calculating irrigation service charges based on a realistic assessment of the costs of sustaining the supply of water.
- To facilitate comparative performance assessment.

For the purpose of the project the desirability of these objectives is taken as self-evident.

1.7 Work Programme

Work on the project formally commenced on 1st July 1994. The first month was spent studying the origins and techniques of Asset Management in the water industry of England and Wales and then reviewing the needs of irrigation management against this background. Of the four months in Indonesia, the first two weeks or so were occupied in formulating skeletal procedures and in planning their trial. An outline programme for the field trial, as drawn up at that time, is shown in Figure 1.1. The two weeks prior to leaving Indonesia were used to prepare papers and presentations for a workshop held in Yogyakarta at the University Gadjah Mada (UGM).

A meeting of specialists from the collaborating organisations, to review the findings of the field trial and to consider their implications, took place in England early in December. The final month of the project was devoted to writing up the work.

1.8 Field Trial

1.8.1 Nature of the trial

The object of the trial was to use actual conditions prevailing in Indonesia both as a proving ground for the development of practical procedures and as a stimulant to wider thought. The focus of attention had therefore to be on checking the practicability of methods for Asset Management Plan (AMP) production and on exploring potential problems rather than on actually producing an AMP.

	AUGUST				SEPTEMBER				OCTOBER					NOVEMBER			
week commencing	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28
Specialists Visits Bill Kingdom																	
Jim Perry																	
Ian Smout																	
Martin Burton																	
Summary Develop skeletal procedures																	
Cost Model																	
Stratification and Normalisation						⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔⇔								
Database design, Input and Output Forms																	
Select sample DI				⇔													
Collect data																	
Analysis and Confidence limits							⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔	⇔						
Strat / Norm & Conf data sent to UK										⇔.							
Draft Report / Guidelines															⇔	⇔ ⇔ ⇔	
Cost Model (from PRIS / consultants records)																	
”Pie chart” asset value by type across all DIs																	
Extract data on value for each major asset type																	
Estimate figures for all other asset types																	
“Pie chart” rehab costs by rehab activity category																	
Extract rehab costs for each major category																	
Estimate rehab costs for other rehab activities																	
Stratification and Normalisation (from PRIS info)																	
Collect DI stratification data																	
Select strata																	
Demonstrate “sample DI “ selection and clustering						⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔							
Database																	
Design Output Forms																	
Design all Input Forms																	
Database design		⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔												
System Performance Assessment																	
Collect data (1) - from PRIS																	
(2) - from field.																	
Analyse for “Standard” and “Level” of service																	
Asset Valuation (working from Cost Model)																	
Relate value to “size” for each asset type																	
Regression tests to decide on best size measure							⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔								
Apportion each asset value amongst components																	
Asset Survey - Extent, Condition and Serviceability																	
Field trials of Survey Forms																	
Collect asset data																	
Review of System Engineering Study:																	
Acquire and study Report on rehab needs																	
Breakdown rehab costs by time, asset type, imp.																	
Categorise rehabilitation “Activities”																	
Categorise rehabilitation “Benefits”																	
Analysis and Reporting:																	
Statistical observations report (from UK)															⇔		
Gather info. on related work in Indonesia		⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔									
Estimate workload for full AMP								⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔							
Write Reports				⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔ ⇔	⇔ ⇔		
Project Closure Prepare for Workshop																	
Hold Workshop																	
Debriefing meetings																	

Figure 1.1 ASSET MANAGEMENT FOR IRRIGATION - FIELD TRIAL WORK PROGRAMME

The author was assisted by a graduate civil engineer from the Department of Public Works (DPU) and a final year student of agricultural engineering from UGM, each with inputs of about seven weeks (see ‘Acknowledgements’). Senior staff at UGM and DPU and visiting expatriate specialists provided guidance and advice. A number of meetings were held in order to seek the ideas and opinions of others involved locally in irrigation matters (consultants, DPU staff and UGM staff).

1.8.2 Irrigation in Yogyakarta Special Province

Yogyakarta Special Province (Daerah Istimewa Yogyakarta - DIY) lies south of Central Java between the active volcano Mount Merapi to the north and the Indonesian Sea to the south. Its western border is delineated by a line of subsidiary mountains whilst to the east is the elevated karst area of the Wonarsari Plateau. The hydrology of the province is dominated by two major rivers, the Kali Progo to the west and the Kali Opak, which flows below the escarpment of the Wonasari plateau, to the east.

The area recorded as under command in the province is just under 70,000 ha. Most of this lies to the south of the Mataram Canal which transfers flow eastwards from the Kali Progo, via the northern suburbs of Yogyakarta, eventually draining into the Kali Opak. This canal, which is about 30 km long, supplies the Van der Wijck scheme (5000 ha) and allows the flow in several smaller rivers to be supplemented. These in turn feed a large number of small irrigation schemes amounting to a total of about 12,000 ha. Whilst the Mataram Canal serves the left bank of the Kali Progo, the right bank is served by the Kalibawang Canal. This supplies the Kalibawang scheme (1750 ha) and supplements flow to a further 4000 ha or so.

1.8.3 The Sample System - DI Papah

System Daerah Irigasi (DI) Papah serves an area of around 900 ha on the west (right) bank of the Kali Progo. It draws its water from a weir (Bendung Papah) on the Kali Papah, which is one of those rivers whose flow is supplemented from the Kali Progo via a branch of the Kalibawang Canal. The DI had recently been the subject of an engineering study (as part of a ‘Priority Area’ associated with the Sermo Dam Project) as a result of which capital investment had been recommended to ‘improve’ and to ‘extend’ system performance. The consequent construction contract was 15% complete at the commencement of the trial. These facts made selection of the DI attractive for the following reasons:

- The system could be observed largely in its ‘unimproved’ state.
- Since it was dry, its assets could be inspected without causing disruption.
- Insight into the requirements for ‘Engineering Studies’ within the AMP process could be gained from that already completed for this system.

2. Asset Management

This chapter introduces the concept of asset management and sets out its origins in the UK water industry. Essential features of the Asset Management Plan are listed and the role of statistics in compiling the Plan is described. Considering the application of the technique to irrigation, similarities and differences with the UK water industry are noted and the Indonesian context examined.

2.1. Definition

The term 'Asset Management' has its origins in the world of finance and business. Assets are "the entire property of all sorts belonging to a merchant or to a trading association" (Chambers Twentieth Century Dictionary). Whatever the reason for ownership, asset management is intended to maximise the benefits to the owner (i.e. the return on investment) through trading, servicing or extending assets at the most appropriate time. This requires a comprehensive knowledge of the assets and what affects their value.

Applying the term 'asset management' to engineering infrastructure is a relatively new concept. An obvious link lies in businesses regarding their buildings (offices, factories, warehouses etc.) as they would any other asset. The immediate benefits of the approach lie in the clarity which it brings. The focus is essentially on investment efficiency and on the contribution of assets to 'Output Performance' (service to the customer). At the same time, being prepared and presented in a structured manner, it facilitates scrutiny (or 'auditing') at the outset by all interested parties (described as 'stakeholders') be they users, investors, staff members, the government or society as a whole. Thereafter it enables performance monitoring against the same criteria and facilitates comparative performance assessment.

Asset Management, in this context, is defined as a structured and auditable process for planning investment in infrastructure in a sustainable manner, to provide users with a reliable service.

2.2 Origins in the Water Industry of England and Wales

Preparatory to privatisation in 1989 there was an urgent need to quantify the extent, nature, condition and value of the infrastructure whose ownership it was intended to transfer from the public to the private sector. Of this infrastructure (e.g. pipes, sewers, treatment works etc.), referred to as 'the assets', 70% was underground and there was much speculation about its true condition. The requirement was to inform investors of their opening assets and liabilities in a manner that could be independently certified. Simultaneously, the public and the government needed to be assured that assets would not be 'stripped'; that is to say, that the intended investment after privatisation would be adequate to sustain an appropriate standard of service. Furthermore, since the new water companies would each have a geographic monopoly, charges to customers had to be demonstrated to be neither excessive nor subject to temporal fluctuations.

The device developed for this purpose became known as the Asset Management Plan (AMP). This has since evolved to become a comprehensive strategic business plan and indeed was described as such at the time the second AMP was produced (AMP2) in 1994. The first (1989) AMPs were prepared in eighteen months and identified investments, across ten major water and sewerage companies, of some £24 billion. Currently AMPs are prepared on a five year cycle and have a twenty year strategic time horizon. Budget plans (from which consumer charges are derived) are set out for the first five years.

2.3 Essential Features of the Asset Management Plan (AMP)

Asset Management Plans are prepared within a regulatory framework in which charges to customers and standards of service are subject to the scrutiny of the government regulator, known as OFWAT (Office of Water Regulation). They must therefore follow a common format so that companies can be compared with each other and, subsequently, the actual performance of each can be reported and evaluated against that company's plan. The key elements are set out in Table 1.1.

Table 1.1 Key Elements of the Asset Management Plan

Definition of Procedures	The detailed methodology used in producing the AMP set out so that it can be traced and independently audited.
Standards and Policies	Standards are the benchmarks against which achieved performance is to be measured. Policies set out the company's approach to investment decision making.
Existing Performance	The level of service currently provided under each output performance measure against the declared Standard.
Asset Extent, Value, Condition and Serviceability	A report summarising what assets exist under various category headings, their 'Modern Equivalent Asset' value, their current condition and functional serviceability
Long term (20 years) Investment Plans	The investment need identified through engineering studies to rectify performance shortfalls and to extend or improve the service to meet demand.
Programme of planned Activities accounting for the Investment	A schedule of specific works identified in the engineering studies as requiring to be undertaken, showing when it is intended to implement them.
Programme of Performance Benefits accruing from the Investment	A report of how the investment will be rewarded by improvements in performance over time against the declared targets.
Short term (5-year) Expenditure programme	Budgets for the first five years and how these are arrived at.
Operating Costs	A summary of the company's operating costs consistent with its capital expenditure programme.
Revenue Requirements	The implications of the Plan for customer charges.

2.4 Statistics in Asset Management Planning

Although theoretically optional, the use of statistics is seen as central to practical implementation of asset management planning. The methods concerned have been developed and refined in response to the practical needs of the water industry in England and Wales from the time of producing the first AMP in 1989. Each company has complex systems of supply mains and sewers totalling several thousand kilometres. Constraints on time and resources prohibited a comprehensive survey of assets, 70% of which are underground. Estimates of the investment required on all systems had to be prepared from knowledge of some of them. Statistical methods were developed (i) to choose the systems to be investigated and (ii) to estimate the total investment needs from the findings in individual systems.

Two main methods were used by the Water Authorities: Stratified Random Sampling, and the Bayes Linear Estimator (BLE). Of the ten former Water Authorities in England and Wales, one used the BLE for their 1989 AMP while the majority used Stratified Random Sampling. For their second AMP in 1994, approximately half the companies used the BLE, through specially written computer software.

The BLE is a relatively complex tool which makes the best use of good quality information where it exists. However, it requires specialised statistical skills that are not widely available. It is necessary that a statistician be employed to design the statistical aspects of the survey. Stratified Random Sampling is a well known statistical method throughout the world. For this reason, only Stratified Random Sampling has been considered in this study.

2.5 Application to Irrigation - Similarities and Differences

A comparison between the characteristics of irrigation and those of the UK water industry was fundamental to the project. A provisional approach to asset management planning for irrigation systems had to be formulated in planning the field trial and this provided a sharp practical focus for consideration of the key issues. More similarities than differences were found and these are summarised in Table 1.2.

2.6 Asset Management for Irrigation in the Indonesian Context

The irrigation sector in Indonesia has seen a number of specific initiatives taken in response to the changing challenges faced in managing the infrastructure. In October 1987 the Government of Indonesia (GOI) set out new policies, on a 15 year planning horizon, for greater efficiency in operation and maintenance (O&M) of irrigation systems and for the recovery, direct from beneficiaries (i.e. the water users), of O&M costs. The implementation of these policies has been aided by projects promoted by the World Bank (the Irrigation Sub Sector Project, ISSP) and the Asian Development Bank (the Integrated Irrigation Sector Project, IISP) in a number of phases. Some elements of these and related initiatives, which are relevant to the study outlined in this dissertation, are as follows:

(1) Needs based budgeting (NBB)
(2) Irrigation Service Fee (ISF)
(3) Turnover Programme (PIK)
(4) Efficient Operation and Maintenance (EOM)
(5) Programming and Monitoring System (PMS)
(6) Integrated Basin Water Resources Management (WRM)
(7) Project Benefit Monitoring and Evaluation (PBME)
(8) Cost Effective Rehabilitation and Modernisation of Irrigation Schemes research study

The essence of each of these initiatives is briefly summarised in the following sections.

Table 1.2 Comparison between AMP for Irrigation and that for UK Water Industry

Key similarities	Key differences
(i) **Large number of systems and assets.** As with water supply there are a considerable number of systems, and assets within those systems. Consequently it is not cost effective to undertake detailed studies of all systems and assets to obtain an overall investment profile. Some form of sampling and extrapolation is required. (ii) **Assets operate as hydraulically definable systems.** As with the water supply and wastewater functions an irrigation network is an hydraulic system which requires physical assets to convey and control water from a source to the end user. It is therefore appropriate to break the total study into a number of separate, hydraulically definable units on which to undertake sample detailed studies for subsequent extrapolation. (iii)**Assets can be given a condition ranking.** Assets can be inspected and given a condition ranking, thus enabling assessments to be made of investment needed to maintain or enhance overall system condition. (iv)**Assets perform a defined function.** As such their function can be identified and their serviceability quantified, enabling performance ranking. (v) **Cost models can be prepared.** Cost models can be developed to prepare asset valuations (vi)**Long term investment needs must be determined.** These are required in order to plan budgetary allocations for a sustainable service and to set water charges. (vii)**Customer/supplier relationship.** Irrigation has customers who are increasingly involved in decision making on the running of their irrigation systems and on how to pay for the provision of irrigation water. Over time they can be expected to become increasingly discerning and to expect higher standards of service at reduced costs. (viii)**Geographical monopolies.** Both water supply/wastewater and irrigation utilities have geographical monopolies. Use of asset management procedures allows comparison of performance between geographical zones. (ix)**Asset stripping.** Concern over "asset stripping" by farmers of privatised irrigation water companies are relevant. Failure to monitor investment levels and condition profiles of 'turned over' or privatised units may result in government being faced with a significant and unexpected investment after failure of such schemes.	(i) **Influence of management.** In irrigation there is found to be a much greater influence of management on the performance of the systems. In formulating asset management procedures for irrigation it is necessary to separate out clearly the influences of management and of infrastructure (assets) on the overall performance of an irrigation scheme. (ii) **Irrigation performance indicators are not as well defined**. Indicators must reflect the constraints on an irrigation system. Setting appropriate indicators of *infrastructure* performance needs careful thought. The key indicators identified so far relate to *adequacy* and *equity*. In each case the study will need to question whether poor performance on either or both indicators is truly due to the infrastructure (assets). Though not strictly an output performance measure, a further indicator related to asset condition has been proposed as a means to ensure adequate asset maintenance is being carried out over time. (iii)**Discretionary and statutory levels of performance.** It is interesting to note that there are few, if any, statutory levels of service stipulated for the irrigation sector, rather they are discretionary (i.e. not stipulated by law). This makes the determination of appropriate standards of service more difficult. Ideally, they would best be decided through some process of user-consultation or cost-benefit analysis. (iv)**Customer Service Standards.** Customer service standards are formal measures of an agency's performance in responding to queries from the customer. At present, unlike in the UK water industry, this feature is not often found in the irrigation sector. (v) **Access to water.** In a water supply network the use of pressurised, looped, piped systems allows inadequate performance of individual parts of the system to be compensated for by other parts, leading to no noticeable degradation in the overall performance of the system. In a gravity fed irrigation system the malfunction of an asset in the upstream reaches of the system can have a major impact on the downstream users. Assets higher up the system are thus generally more "important" than those at the bottom end of the system. This can be captured through an *importance ranking* and used as one way of presenting the investment need i.e. investment reported by *importance category*. This allows planners to see the effect of different levels of capital expenditure related to the importance of assets needing to be refurbished.

Source: Adapted from W. Kingdom, WRc, in Project Interim Report No. 1, August 1994

2.6.1 Needs Based Budgeting (NBB)

Annual maintenance budgets were at one time disbursed from central funds to local provincial, section (Cabang Dinas) and sub-section (Ranting Dinas) agencies in proportion to the irrigated area served by systems within the jurisdiction of each. This approach was inadequate in the face of increasing demands for greater efficiency in targeting investment. Needs Based Budgeting changed this by requiring specific needs to be identified by local O&M staff when seeking their budget allocation. However, budget requests calculated in this way have far exceeded the funds made available. Little or no information is provided to enable the balancing of priorities identified by staff in one area against those in another area. Planning horizons are short term or immediate and no meaningful relationship can be made between investments proposed and the benefits which will justify them.

2.6.2 Irrigation Service Fee (ISF)

A programme to introduce a charge to water users which reflects the costs of providing the irrigation service is in course of implementation. Its introduction to a particular area depends upon the existence of an effective Water Users Association (WUA - or P3A in Indonesian) with whom negotiations can take place and who, it is intended, will administer collection of the fee from individual farmers. The underlying concept of the ISF programme is that the beneficiaries, through the WUA, should bear the cost of operating and maintaining the irrigation system which serves them. However, payment is also linked to ability to pay through a complex formula that takes into account harvest yields. The following implications are apparent:

- ISF is calculated based on a scheme's annual Needs Based Budget for O&M.
- ISF can be expected to vary from year to year as maintenance needs vary.
- The level of ISF will be different for each irrigation scheme and these differences could be substantial. Where this occurs on adjacent schemes, neighbouring farmers will experience apparently inequitable charges.
- The 'ability to pay' formula means that a scheme's revenue, as a proportion of its assessed need, will vary. This variation will be subject to the full range of influences in the agricultural system as a whole.

2.6.3 Turnover Programme (PIK)

This involves the transfer of responsibility for irrigation infrastructure from the government agency to Water User Associations. It is also dependent, therefore, upon the prior formation of effective WUAs. Its not clear whether ownership of the assets themselves is actually transferred (i.e. they are removed from the government's inventories); the process was held up for some time because of uncertainty over the legal status of WUAs. The programme aims ultimately to turnover all irrigation schemes serving areas of 500 ha or less: its introduction is being phased by applying it initially to the smallest schemes (e.g. in Yogyakarta province, to schemes of 75 ha or less). Generally the deal includes the implementation of improvement works at government expense prior to turnover taking effect. Progress is therefore dependent upon the availability of funds as well as on the stage of development of WUAs.

2.6.4 Efficient Operation and Maintenance (EOM)

This programme aims to break the cycle of neglect followed by expensive rehabilitation which has apparently been the norm for much of the irrigation infrastructure. Individual schemes (Daerah Irigasi) are brought into the EOM programme through a process of physical improvement to the infrastructure (termed 'Special Maintenance'), changes to organisation and procedures, staff retraining and the establishment of a "realistic O&M budget". The streamlined section office of the irrigation service, responsible for a number of EOM schemes, is termed an Advanced Operations Unit (AOU). A range of thirteen performance indicators has been developed for monitoring the schemes concerned.

2.6.5 Programming and Monitoring System (PMS)

The PMS is a computer based Management Information System currently being implemented under ISSP-II in pilot areas in Central and East Java. Its object is to improve the process of needs-based budgeting and prioritising for maintenance activities (and also to provide operation and hydrological information) based on data generated through operational procedures. It incorporates an asset database which will include detailed information on present condition of each asset and its importance within the system. Summaries from the information systems for each DI will be provided to the Provincial Irrigation Service office (PRIS) as an aid to strategic planning. Data will be entered on desk-top computers at field offices and updated, it is envisaged, on a regular basis whilst information will be fed back to PRIS on dedicated data-links. Implementation rate will therefore be constrained by the expenditure required to introduce the necessary technical hardware and the training of operators. Its effectiveness as an aid to strategic planning will depend upon how the huge amounts of detailed information are to be summarised, interpreted and used and on the quality of that information, its accuracy and how well it is kept up to date.

2.6.6 Integrated Basin Water Resources Management (WRM)

This initiative reflects the GOI's recognition of the place of water as an economic good within an overall programme for sustainable national development. Previous planning was strongly project-oriented largely focusing on irrigation and power development. Ongoing studies recognise the range of river basin uses from the supply of water for consumption, industry, agriculture and power generation, to the disposal of wastes and the extraction of river gravel for example. The objective is principally to achieve efficient and reliable day-to-day management of a basin's surface and groundwater overall. The studies examine, inter alia, the kind of legal and institutional changes necessary to facilitate such an integrated approach. They are also concerned with practical implementation requirements such as the physical accounting and monitoring of water allocations, the issuing of abstraction licences, through the use of geographical information systems (GIS) to record river basin details.

2.6.7 Project Benefit Monitoring and Evaluation (PBME)

This is a methodology for the assessment of irrigation system performance developed for the identification of schemes for rehabilitation and upgrading (R&U) under ADB loan projects and the subsequent monitoring and evaluation of their benefit. The methodology apparently recognises the impracticalities of adopting an approach which is too rigid in its demands for particular types of data and, instead, offers alternative approaches depending on the circumstances. These range from subjective assessments based upon a survey of farmer perceptions and expectations on a sampling basis to an analysis of performance data collected by the provincial irrigation and agricultural services. An Agro-Institutional Profile (AIP) is produced which quantifies the benefits of a scheme in the local context in order to justify the expenditure required.

2.6.8 Cost Effective Rehabilitation and Modernisation of Irrigation Schemes

This is a joint UK/Indonesian collaborative study being carried out by HR Wallingford (funded by the UK Overseas Development Administration) and the Directorate General of Water Resources Development (DGWRD). The aim of the study, which has a three-year programme, is to develop and test a formalised procedure for setting priorities in the rehabilitation and modernisation of irrigation schemes. It involves the identification of under-performing schemes, the diagnosis of causes of performance shortfalls and the relating of specific performance benefits to each proposed corrective action. A number of performance measures are considered for evaluation. The analysis of systems includes the use of a computer-based hydraulic model.

2.6.9 Relevance of Asset Management Planning

With regard to the initiatives set out above, Asset Management provides an integrating framework in which each of the elements described has its place and through which those elements (and others) are related to one another. This must be so by definition since Asset Management is concerned with all aspects of assets and the influences upon them. The technique of Asset Management Planning cannot be thought of as something apart from, or as alternative to, these existing approaches. The great benefit of the technique is its effect of achieving an integrated overview. Indeed, it is this which represents the challenge in devising appropriate procedures.

The following chapters outline such procedures for irrigation and describe the application of the results. Chapter 7, ‘Conclusions’, then returns to the subject of existing practices and Table 7.1 shows how each the above initiatives is related to the AMP.

Part II: Application -

Asset Management Planning for Irrigation

3. Producing the Asset Management Plan

The previous chapter described asset management in outline and set the context of its application to irrigation. This chapter sets out the approach to producing an Asset Management Plan for irrigation as a series of inter-related steps. These steps are illustrated by reference to the field trial in Yogyakarta.

3.1 Introduction

Figure 3.1 shows the principal elements of asset management planning. To these must be added some preliminary steps including those necessary to take advantage of the time and resource savings of using statistical sampling techniques. The steps involved in the process may be summarised as follows:

- defining systems and function;
- stratified random sampling;
- establishing the environmental, legal and development context;
- assessing system performance - achieved levels of service, how these fit with present and future requirements and what infrastructure adjustments are needed;
- studying Management and Operations - a parallel review of the organisation and its procedures;
- doing an Asset Survey - their extent, value and the liabilities they represent;
- building the Cost Model - analysis of historical Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) as a basis for future projections;

Each of these steps is outlined and discussed in the following sections.

3.2 Systems Definition

It is necessary to define at the outset exactly what *primary functions* the service is intended to provide. Appropriate systems can then be identified in this context. For irrigation the following are identified:

- supply of water for irrigation
- removal of water by drainage

Irrigation infrastructure is commonly used for several subsidiary purposes (for example, public use of maintenance access roads; non-irrigation uses of water; waste disposal; flood protection). What constitutes a primary function is a matter of particular circumstances and of policy. The more there are, however, the more complex becomes the analysis. Isolating primary functions is essential not only to provide clarity in system definition but also, ultimately, to assessing performance.

The extent of the infrastructure to be included in the AMP must be defined. It was decided for the field trial in Yogyakarta to consider systems supplying water for irrigation, including primary and secondary canals down to a point 50m beyond each tertiary offtake gate. This is where the irrigation authority's management responsibility ends. Tertiaries were excluded as they are farmer-managed.

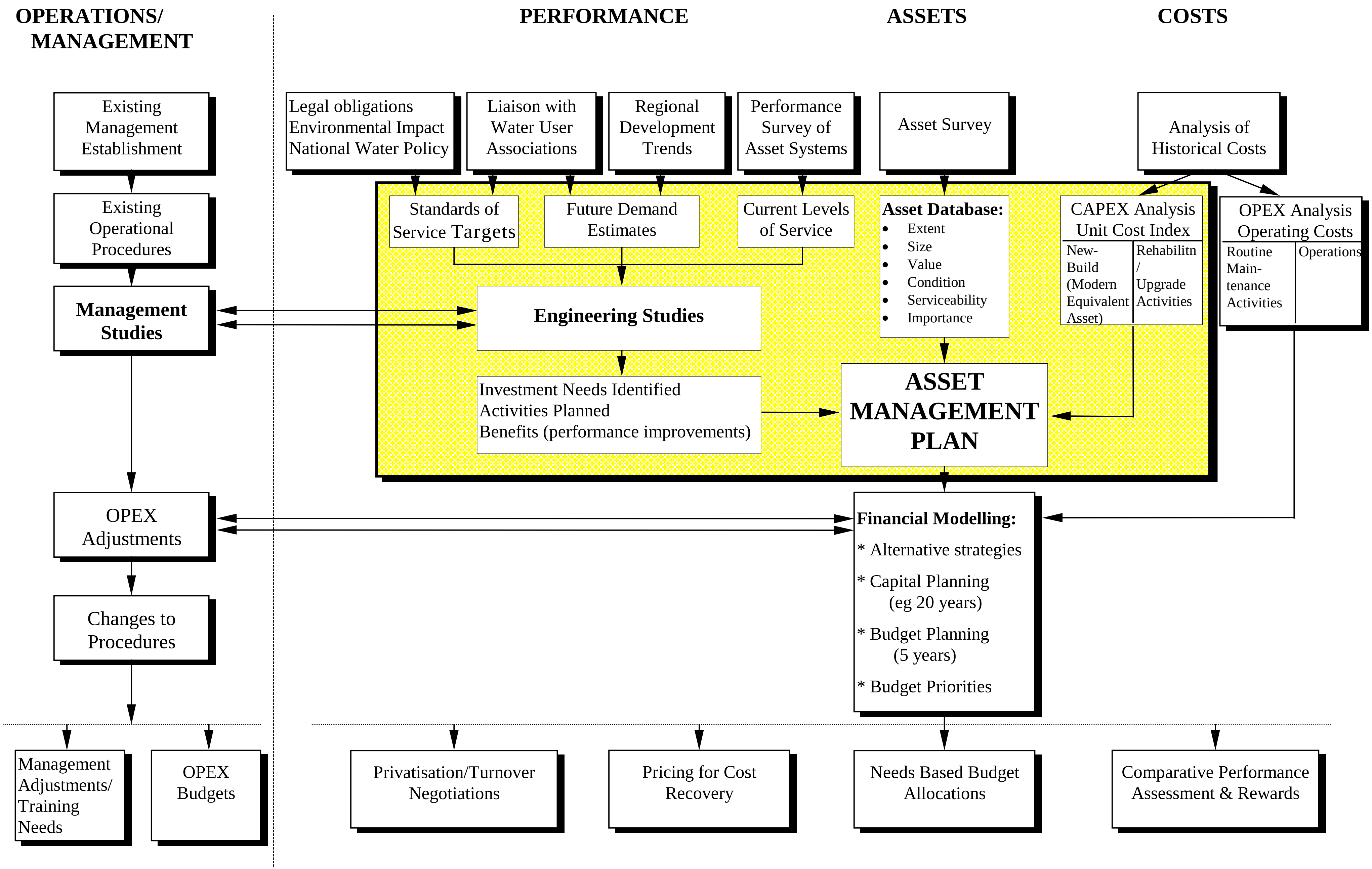


Figure 3.1 Overview of asset management planning for irrigation

3.3 Stratified Random Sampling

Sampling is the process of choosing items from a larger population in a representative way. Random samples are chosen in order to avoid bias in the selection. In this case it is irrigation systems which are to be sampled. The steps required for the AMP are these:

- subdivision of the study area into suitable unit systems;
- grouping the systems ('stratification') according to characteristics related to investment need;
- deciding how many sample systems are needed and selecting them;
- estimating the total investment need from the results of sampling.

These steps are discussed in the following sections.

3.3.1 Subdividing the Study Area

The regional infrastructure must be divided up into individual systems each of which can, for practical purposes, be considered in isolation as more or less independent. For this it is essential to establish an overview of the infrastructure network under consideration using maps and schematic diagrams. The field trial in Yogyakarta demonstrated that it can be surprisingly difficult to obtain such information in a comprehensive and unambiguous form. Here, individual operational units known as Daerah Irigasi (DI) appeared to be suitable for adoption as the unit system required. In all, 1396 DIs were identified in Yogyakarta province, serving areas of less than 75 to over 5000 ha.

Each system delivers water from a source to 'customers' via a number of outlets. Some systems are cross-linked with others. Examples of this occur where systems abstract from the same river at different points along its length and where link canals transfer flow from one river to another. In such situations some 'interference' may arise between 'separate' systems. This effect must be minimised in the course of system definition. In the subsequent analysis, any 'super-systems' (i.e. those parts, such as the link canal example, which feed several of the defined independent systems) must be treated separately.

3.3.2 Stratification

Stratification is the term used for dividing up the members of a set into groups, termed 'strata', having similar characteristics. The benefit of doing this is greater confidence in the estimates obtained from any given number of samples. The characteristics of interest here are those likely to identify systems with similar investment needs. Table 3.1 shows possible criteria. Many factors may be considered as a basis for stratification but their number should be reduced so that there are only a few strata, ideally about five and certainly less than ten. This can be done as follows:

(a) Only factors which are known or can easily be determined for *all* systems should be used.

(b) Factors are preferred that are believed to be closely related to the investment need.

(c) Where two factors are strongly correlated they may be counted as one composite factor.

Table 3.1 Possible Criteria for Stratification of Irrigation Systems

Purpose: To identify

- similar investment requirements in each strata
- similar extent and type of problem*

Typical Elements

Geographical / Topographical

- topography
- sediment load
- soil types
- climate
- water availability; adequacy and reliability

Physical System

- levels of technical sophistication
- size
- age / condition of system
- main construction materials / methods
- source of water supply
- crop type

Management / Ownership

- management type - levels of responsibility and degree of water user participation
- 'customer' satisfaction

Socio-economic

- payment of Irrigation Service Fee
- farmer income levels
- urban or rural
- ownership / land tenure

*Note: where characteristics are common within a region they do not affect stratification.

In the field trial the following data were sought for each DI:

(a) The "technical level" which expresses the degree of flow measurement and control in three classes - 'Technical', 'Semi-technical' and 'Non-technical' (defined in Glossary of Terms).

(b) The topography, either 'flat' or 'steep/undulating'.

(c) The availability of water when needed, expressed as 'good', 'variable' or 'poor'. Unfortunately this could not be used for stratification as data was available only for some systems and it would have required a separate survey to obtain complete data.

(d) The peak flow at the system intake. This is more likely to be subject to error than the irrigated area with which it correlates and data was not available for some systems (no measurement capability). It was therefore not used in this example.

(e) The irrigated area. This is best used for 'normalisation' of investment figures derived from the investigations (see Section 3.3.4) and should not then be used for stratification.

Thus the two factors used to stratify the systems were technical level and topography as shown in Table 3.2. Both factors are related to the types and extent of engineering structures and therefore to the likely investment needs.

Table 3.2 shows that, whilst there are many Non-technical systems, most of the irrigated area is served by Technical and Semi-technical systems. There are a relatively large number of small Technical systems in undulating/steep areas while those in flat terrain generally serve a larger area.

Table 3.2 Stratification of Irrigation Systems (DIs) in Yogyakarta province

Topography	Technical level: Technical	Semi-technical	Non-technical	Total
	(number of systems / % of irrigated area)			
Flat	20 / 24%	110 / 19%	34 / 0.6%	164 / 43.6%
Undulating	159 / 21%	260 / 22%	813 / 13.4%	1232 / 56.4%
Total	179 / 45%	370 / 41%	847 / 14%	1396 / 100%

Roughly equal investigative effort should be directed towards four strata: 'flat-Technical', 'undulating-Technical', 'flat-Semi-technical', and 'undulating-Semi-technical'. Each of these represent roughly equal areas. Rather less effort should be devoted to Non-technical systems in undulating areas, and almost none to Non-technical systems in flat terrain. Since the investigative effort per system is likely to be less for the smaller Non-technical systems, equal numbers of each type of system could be selected.

3.3.3 Deciding which systems to investigate

The number of systems investigated will be a compromise between the desired precision of the investment estimate and the time and resources available. The minimum number of samples from any one stratum to allow the within stratum variability to be estimated is two, whilst at least five are needed for confidence in the estimate of variability. The number of systems for which AMPs were prepared by the English and Welsh Water Authorities in 1989 ranged between 50 and nearly 400 systems. The number of samples varied between 12 and around 60.

For the field trial, an initial estimate of the minimum number of systems to be investigated might be in the range 50 to 70, with 10 or more in each of the 5 main strata, i.e. with flat-Non-technical systems excluded. This would be likely to give reasonable confidence in the estimated total investment need. Having decided how many systems to investigate from each stratum, their selection should be by random numbers in order to ensure that the systems chosen are representative. Detailed investigations can then commence as detailed in Sections 3.5 to 3.7.

3.3.4. Estimating the Total Investment Need

Having conducted detailed investigations on the sample systems, the identified investment needs must be aggregated in order to represent all systems in the study area. To do this, 'normalisation' measures are used along with the strata previously determined. Normalisation measures provide the means to relate characteristics of systems to some common unit of size. Thus characteristics established for a sample can be converted into a general form applicable to all systems. A number of possible normalisation measures are presented in Table 3.3. Typically in irrigation the measure used is *area*, so for example costs are expressed 'per hectare'.

Table 3.3 Possible Normalisation Measures

Relates characteristics to some common units of size. For example: • irrigated area / command area • volume / length of canal • number of structures • number of farms / tertiaries

The stages in the calculation to estimate the total investment need are these:

(i) For each stratum, calculate the stratum mean and variance from the individual sample results. The variance is a measure of the differences between individual samples.

(ii) For each stratum, calculate the stratum total by multiplying by the area served by all systems in the stratum, and its variance.

(iii) Add the stratum totals and their variances to obtain the regional total and its variance.

Detailed formulae are given by Barnett (1974).

3.4 Environmental, Legal and Development Context

It is essential to review the general context within which the irrigation service is to operate in order to establish appropriate and comprehensive Standards of Service, both for the present and over the coming twenty years. Once established, these Standards become the benchmark against which performance will be assessed. This review must therefore be done before detailed investigations of assets and systems can proceed.

3.4.1 Environmental Impact

Heightened awareness by governments and populations of environmental impacts of development projects makes their examination imperative. As an integral part of the water resources development sector, irrigation has a particular significance. Essentially, irrigation will directly affect:

- the location and timing of water availability;
- water quality.

Specific local effects will be many and varied, with several counteracting environmental costs and benefits across a broad range from public health to natural habitats. In setting the Standards of Service criteria for ongoing operation (or improvement, extension or contraction) of an existing irrigation system, it is necessary to focus on net effects which are subject to the influence of managers of the system. Examples might be:

- quantity and quality of "compensation flow" (i.e. that part of the flow not diverted) at the point(s) of abstraction;

- quality and quantity of drainage water discharged into natural water courses (or otherwise disposed of);
- health and safety aspects of public access to irrigation infrastructure (including water quality, contamination risks to downstream users and potential injury);
- direct effects of management practices (e.g. de-silting);
- impact of irrigation on groundwater quality and level.

Those things taken into account will include:

- national environmental legislation and policies;
- international obligations (e.g. Agenda 21 agreement) if not already incorporated in the above;
- discretionary standards (good practices) reflecting local concerns;

3.4.2 Legal Obligations

The obligations placed on the irrigation service by national and regional legislation must be taken into account when setting or reviewing Standards of Service. As governments move towards an integrated water sector, the laws affecting irrigation may be expected to change. So far as possible such changes should be anticipated within the term of the investment plans.

3.4.3 Social Development

There are two aspects of this which affect the setting of Standards:

- the changing perceptions and demands of water users as 'customers';
- the movement of populations from a rural, agricultural base towards an urban, industrial one.

The first of these requires good liaison with water users associations or other customer representative groups to establish their perceptions of need and what, for them, constitutes a good service. This will also help with anticipation of changing farming practices which could lead to significantly altered technical requirements on the irrigation system. Urbanisation and industrialisation could affect the planning of an irrigation system in a number of ways:

- by construction of buildings on land which has been irrigated;
- by making conflicting demands on the available water supplies;
- by polluting irrigation water;
- by secondary effects on the rural population (e.g. greater affluence, reduced dependency on agricultural income) leading to changes in their demands on the irrigation system.

Regional development trends must be studied to ensure such factors are taken into account so far as possible.

3.5 Performance Assessment

3.5.1 Performance Indicators

Irrigation performance assessment is the subject of much discussion at present. Recent publications (such as Murray-Rust and Snellen, 1991; Small and Svendsen, 1992; Bos, Murray-Rust, Merrey, Johnson and Snellen, 1993) should be referred to for a comprehensive treatment. The distinction between different levels at which performance can be measured is usefully summarised in Figure 3.2 (Small and Svendsen's nested systems diagram). It is particularly important to distinguish between the *system* (i.e. the infrastructure: canals, structures etc.) and the *scheme* (which includes agricultural elements - see also Glossary of Terms).

Asset Management planning is concerned with 'output performance measures' (quality of service to the 'customer') at the level of **irrigation system** performance. Key performance measures are related to the supply and distribution of water . These are considered to be:

- adequacy
- timeliness
- equity
- reliability.

Adequacy is a measure of the ability of the system to supply the designed or required quantity of water to a delivery point. In terms strictly of the system infrastructure (i.e. not management or other influences), it is principally a matter of hydraulic capacity. **Timeliness** is a measure of the ability of the system to deliver water at the 'required time' - usually stipulated by the water user and, of course, related to crop irrigation needs. It is principally a matter of system operation. **Equity** is a measure of the ability of the system to provide an equitable distribution of water amongst the many points of delivery. This again is principally a matter of system operation (assuming that the 'adequacy' measure is satisfied throughout the system). It is particularly relevant if water supplies are short. **Reliability** is a measure of the level of confidence that water will be delivered in adequate quantity at the required time. This is related to hydraulic capacity, system operation and to water availability.

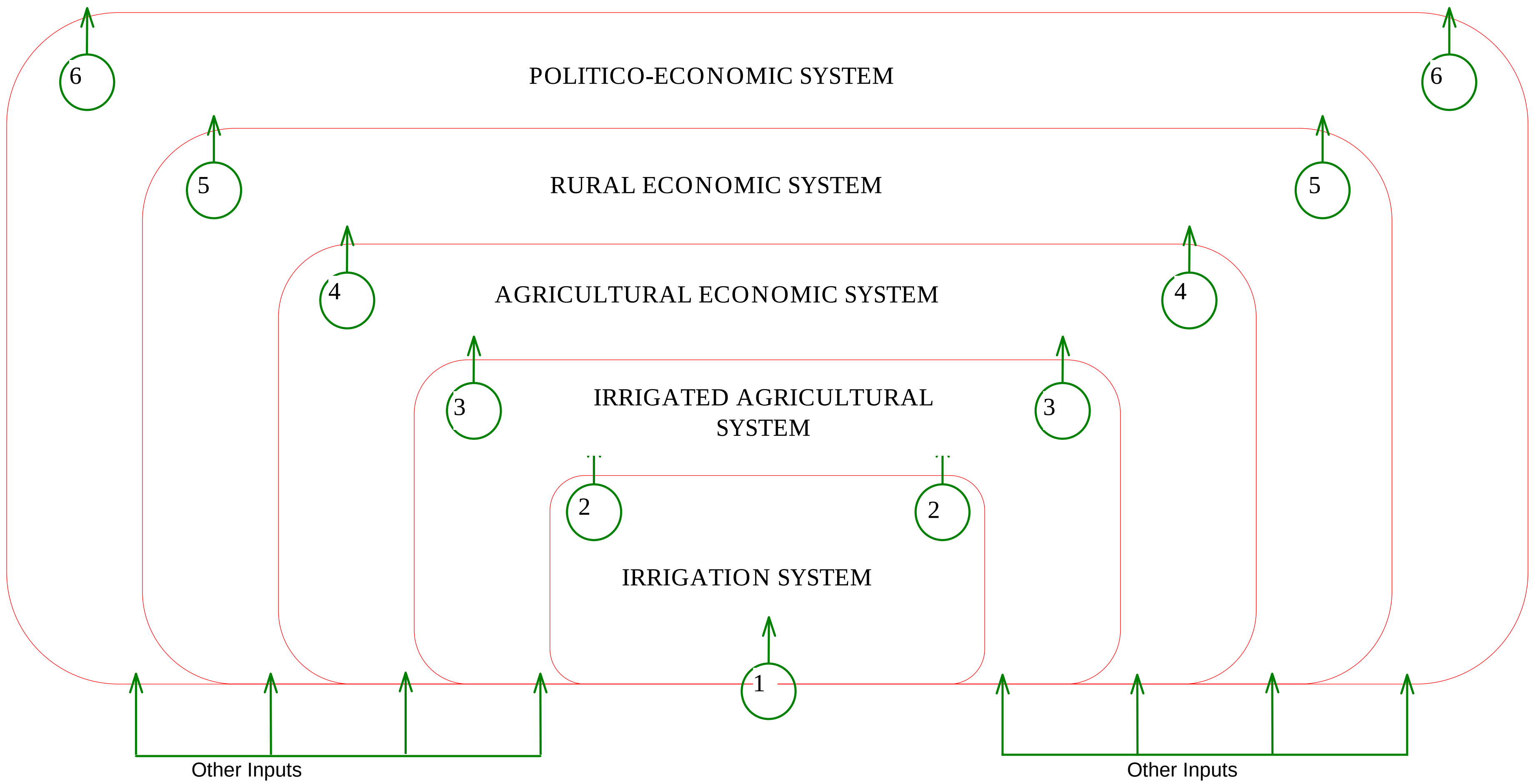
Additional measures of performance may be required to reflect the demands of the environmental, legal and development context, as described in Section 3.4 above.

3.5.2 Performance Assessment for Asset Management Planning

There are considered to be three stages in performance assessment for asset management planning:

Stage 1	System performance assessment using the indicators selected.
Stage 2	Appraisal of a system performance shortfall and its causes.
Stage 3	Quantification of causes of a system performance shortfall and its correction.

These three stages are outlined below.



Key to Inputs/Outputs:

1	Operation of irrigation facilities
2	Supply of water to crops
3	Agricultural production
4	Incomes in the rural sector
5	Rural economic development
6	National development

Figure 3.2 irrigation in the context of nested systems (Small and Svendsen, 1992)

3.5.3 Stage 1 - System Performance Assessment

A short cut to assessing system performance may be to look at the scheme performance. If the scheme is performing well against targets then it may be assumed that the physical system is performing adequately (though Stages 2 and 3 as outlined below may be needed to confirm this). There are various ways in which this initial performance survey might be done. Approaches described below consider:

- crop area planted in comparison to that planned;
- water delivery performance ratio;
- views expressed by Water User Associations.

Appropriate measures must be chosen to reflect local circumstances including the type of data existing and the resources available. The projected future demands on the system must be considered as well as current requirements. Additional measures of performance will be related to environmental, legal and social development criteria.

In the example of the trial on system DI Papah, Yogyakarta, a number of different approaches were tested for the System Performance Assessment. In the first of these the area of crop actually planted by farmers in each tertiary in each season, when compared with that planned or designed, was regarded as an indicator of farmer 'confidence' in the system. For this purpose planted area is relevant rather than harvested area or yield. It was expected that a pattern would emerge where planted area in any given tertiary was consistently slightly higher or rather lower than the plan or design figure. In order to allow for variations in farmers choice of crop, a relative area was calculated based approximately on relative crop water demand.

The second approach compared actual with planned water delivery (Delivery Performance Ratio) at the tertiary offtake. Actual to planned Water Delivery Ratios were also examined at measuring points on the secondary and primary canals. The discharge into the system was compared with its maximum design value to see how closely the system is operated to its theoretical capacity. Given reliable data, these checks should give very 'precise' measures of system performance.

The difficulties experienced in these two approaches lay in the availability of data and in its quality. In some cases less than a full year's data was found. At many tertiaries no measurement of flow is taken because they have no measuring structures. Where figures for crop areas and discharges were available for both 'actual' and 'planned', these were frequently identical which led to doubts as to their authenticity. For crop areas, no design values could be traced.

Another possible approach would be to make spot checks of key parameters on a one-off basis. These would be made under controlled conditions on the day(s) of the survey in preference to relying on uncertain historical data. The confidence in results obtained on such a limited sample would have to be considered. This could not be tried on the sample system because it was drained down.

The third approach tested was to visit Water User Associations and to interview them about the type of problems they faced, their view of system performance and their opinions on the availability and reliability of water. The results of such a survey are, however, difficult to quantify. The design and implementation of a survey of this type is a specialised exercise in its own right which would need careful treatment in order to provide quantitative results suitable for use in the AMP.

3.5.4 Stage 2 - Appraisal of a Performance Shortfall

A performance shortfall may be current or it may relate to some future anticipated requirement. The cause could be due to:

(i) problems with the **system assets**;
(ii) problems with **management** of the system;
(iii) a combination of both the above.

A clear distinction must be drawn between performance shortfalls related to **management** and those related to the **system**. This distinction is crucial. In irrigation, the quality and dedication of management has a vital impact on performance. This is in marked contrast to the assumptions made in the Asset Management procedures developed for the UK water industry. It is quite possible that an irrigation scheme may have a perfectly well functioning system but is nevertheless performing badly due to inadequate management. Conversely, management interventions can and often do offset infrastructure inadequacies of design, construction or maintenance. System and management performance shortfalls must be separately identified. Section 3.6 refers to Management Issues.

The Asset Management Plan itself is concerned with the infrastructure (the system), not its management. The method of appraisal will be tailored to the type of system under investigation. For systems where discharges are theoretically fixed by the design, the study will involve monitoring in sample locations whether or not these discharges are being obtained. In other systems (such as in Indonesia) where water allocations are planned, questions that the study will seek to answer will include:

- Is sufficient data collected to enable water allocations to be planned?
- Is water allocation planning a real or a “paper” exercise?
- Are discharges in the field in accordance with those planned?
- Are the organisational structure and the facilities for operation and maintenance adequate to enable effective system operation?
- Do system operators experience difficulties with passing design or maximum required discharges through the system?

Through detailed analysis of both the management organisation and the physical system, the causes of a performance shortfall can be diagnosed. Where confidence in a system’s infrastructure remains in doubt, more extensive Engineering Studies will be required.

3.5.5 Stage 3 - Engineering Studies

The purpose of undertaking Engineering Studies is to recommend remedial works necessary to adjust the performance of a system to match the prescribed standard of service. To do this, the cause of a system performance shortfall must first be located and confirmed as being infrastructure related rather than due to management. This will involve a combination of fieldwork and desk study and may usefully include hydraulic modelling. The technical solution produced, taken together with information provided in the Cost Model (see Section 3.8), determines the investment required.

The distinction between these Engineering Studies and the Asset Survey is important. The latter is concerned with the assessed condition of individual assets which, important as this is within the AMP, may be of little consequence to the former which considers system performance as a whole. Examples might occur where an individual asset could be bypassed, abandoned or superseded or where it had little influence on the system. Where the system needs to be upgraded, for example due to obsolescence, new technology or future demand changes, the engineering studies will include investigation of different options. The study might examine, for instance, changing control structures from manually operated to automatic. The design, operational and cost implications of such a move would need quantification.

Estimates of anticipated benefits must be prepared, showing how performance indicators are expected to improve over time as a consequence of capital investment in the system. The implications for operating costs of any proposed capital investment must also be quantified. Such analyses are required to inform decisions made during Financial Modelling following preparation of the AMP. General inferences must be drawn from engineering studies carried out on the selected sample systems.

For the sample system in the field trial, DI Papah, engineering studies had been undertaken during the preparation of a project design report for the ‘Rehabilitation and Upgrading’ project which was ongoing. Although the report had served as a basis for justifying the project and for the decision to go ahead with its implementation, the form of the report was unsuitable for the AMP. The following needs of the AMP were not satisfied by the report as it stood:

- It did not relate specific investment activities to specific performance shortfalls. Instead, overall financial costs and benefits were compared.
- It did not enumerate separately the costs of specific investment activities. All activities were aggregated and re-divided into Bill of Quantity items before costs were applied.
- It did not detail benefits in terms of improvements in performance indicators or how these would be distributed over time.

The experience gained from trying to adapt the engineering studies carried out for the trial area demonstrated the particular nature and extent of the data required by the AMP. It is clear that such Engineering Studies will need specific terms of reference to match the requirements of the AMP with those for the location. To understand the variety of such requirements, further research is required.

3.6 Management Issues

3.6.1 The Crucial Role of Management

An overview of the Asset Management Planning process is shown in Figure 3.1. This shows the consideration of management and operation as a parallel activity which interacts with the rest of the process. The Asset Management Plan itself is concerned essentially with the infrastructure (i.e. the engineering hardware) of the system providing the basis of the service. It is important when drawing up the AMP to keep attention focused on the infrastructure and not to allow the effects of system management to confuse the issue (see Section 3.5 - Performance Assessment).

It is a feature of irrigation systems, however, (with the possible exception of the most technologically sophisticated, automated systems) that the influence of management is crucial to the quality of service provided. This sets irrigation apart from many other types of infrastructure and particularly from the UK water industry where the AMP originated. Recognition of this important difference demands that a parallel but integrated study of management issues must therefore be incorporated.

3.6.2 Existing Management Structure

It is important to establish an understanding of the existing management structure both as an aid to conducting and interpreting the AMP generally and as a basis for considering its appropriateness to future needs. The types of questions which will be asked are:

- What is the nominal existing management structure?
- Is it clearly and unambiguously defined?
- How widely is it known and understood by line managers and staff?
- How is authority and responsibility delegated?
- How are goals defined and achievements rewarded?
- What steps are taken to ensure that staff are able to perform as required and that they keep abreast of changing needs and practices?
- What relationship does the formal management structure bear to the day-to-day practice?
- Is the structure rigid or can it readily respond to changing needs?

The answers to these questions will help to determine whether the existing structure is adequately set up to enable true management of the irrigation system(s) concerned or whether it is merely administrative in nature. Administration implies that processes and procedures are followed in a manner which protects individuals from sanction whatever bearing this may have on performance oriented objectives. Management implies that important decisions are routinely taken and implemented at an appropriate level, in response to needs as they arise, in general conformance with the policies of the organisation. Management is achieved through the setting of objectives and targets and the monitoring of performance indicators.

3.6.3 Existing Operational Procedures

These procedures and how they are actually implemented are crucial to the performance of the irrigation system. It is necessary to determine, for example,

- what procedures exist;
- whether they are formally recorded in an unambiguous manner;
- how actively and consistently they are used;
- how helpful they are to staff who operate and maintain the system;
- whether they are appropriate to the current situation and to future needs;
- how relevant they are to achieving the specified performance criteria;
- how frequently they are reviewed against the results of operational performance monitoring and evaluation.

It cannot be assumed, of course, that the findings will be the same across all the sample systems. Each must be independently investigated. Indeed the variability between systems may itself be instructive.

3.6.4 Management Studies

3.6.4.1 The Implementation of the AMP

It is obviously crucial to the success of the whole procedure that the management of the irrigation service will be able to interpret and to implement the Asset Management Plan. This must not be taken as a foregone conclusion. It will depend on the capabilities of individuals, the quality of their briefing and training and the procedural constraints under which they operate. An important aspect of the Management Studies will be to check that an appropriate structure exists with adequate capability.

3.6.4.2 The Influence on System Performance

Liaison and interaction with the Engineering Studies (being conducted under Performance Assessment) is vital at this stage. The Performance Assessment should have established how well the system meets current and projected Standards of Service targets. Adjustments to the infrastructure (‘hardware’) and to management practice (‘software’) will be under consideration to achieve:

- corrections to existing performance shortfalls;
- changes needed to meet new Standards;
- changes needed in response to altered demand;
- greater overall financial efficiency;
- trade-offs between capital (CAPEX) and operational (OPEX) expenditure;
- institutional reforms (e.g. turnover or privatisation).

Clearly the adjustments proposed to the infrastructure and to the management must be co-ordinated and harmonised. The studies conducted under the two headings will inform and stimulate each other.

3.7 Asset Survey

3.7.1 Background

Fundamental to an Asset Management Plan is a knowledge of what assets exist, their value and the liabilities they represent derived from a knowledge of the state of repair of each asset and its life expectancy. It is important to distinguish between the Asset Survey and the Engineering Studies related to system performance assessment as explained in Section 3.5.5. Information derived from the former indicates immediately the scale of the financial commitment represented by the infrastructure system. For example if assets with a value of 'x' dollars have a life expectancy of 'n' years then it is apparent that, for replacement alone, there is an average annual liability of 'x/n' dollars per year. Assuming that some sort of inventory already exists, the task will be to confirm this inventory and to extend it as may be necessary to include all the asset data requirements of the AMP. These are defined in the following sections.

3.7.2 Extent

The unit measure of extent for assets will most commonly be the 'number present' or, for linear assets such as canals, 'length' in kilometres. In order to count them meaningfully assets must be classified by type. The classification method developed for the field trial is shown in Table 3.4.

Table 3.4 Grouping Of Principal Asset Types

Group 1 - WATER CAPTURE River Offtake Weirs. Dams & Impounding Reservoirs. Groundwater Abstraction Wells.	Group 2 - CONVEYANCE Canals. Hydraulic Structures. Supplementary Structures.
Group 3 - OPERATIONS (CONTROL) FACILITIES Head Regulators. Cross Regulators. Measuring Structures.	Group 4 - MANAGEMENT AND GENERAL Access Roads. Offices and Laboratories. Depots and Workshops. Field Officers Quarters. Vehicles and Plant. 'Information Technology' Systems.

Here, asset types are distinguished by *Function* at the first level, with *structural similarity* as the second level. Drop structures and culverts, for example, are thus classified together as hydraulic structures. This approach provides a manageable number of asset types and descriptions. Some irrigation engineers may prefer to extend the typology to identify the irrigation assets more precisely by adding a third level.

3.7.3 Defining Asset Types and Components

A list of asset types and components, based on a reconnaissance of schemes in the Yogyakarta area combined with general experience of irrigation specialists, is shown in Table 3.5. Asset types which are of interest are those into which most investment will be concentrated. Components of assets are defined in order to facilitate condition assessment when different components may be subject to different degrees of deterioration. No more components should be identified than is necessary. An asset's overall condition score can be arrived at by weighting the individual scores of its components and then adding them. The weighting factor suggested for a component is the proportion of its value to that of the asset as a whole.

Table 3.5 Asset types and components used in the trial

Asset Type	Size measures to be recorded	Functions to be assessed	Components to check	Depreciation Life (est.)
Weir	crest length crest height	HYDRAULIC -provide level -pass offtake design flow -pass design flood OPERATIONS -gates -gauges	weir wall dividing walls abutments crest apron sluice gate offtake gate stilling basin superstructure	civil 50 years mechanical and electrical (m&e) 10 years
Head Regulator	total gate width design flow	HYDRAULIC -pass design flow OPERATIONS -control flow -gauges	gate(s) structure notice board shelter	civil 25 years m&e 10 years
Cross Regulator * options -fixed crest -gate(s) -stop logs -flume	total gate width design flow	HYDRAULIC -pass design flow OPERATIONS -control command (level) -gauges	control section* structure notice board u/s wingwalls d/s wingwalls gauge(s) shelter	civil 25 years m&e 10 years
Measuring Structure	total crest width design flow	HYDRAULIC -pass design flow OPERATIONS -measure flow	control section gauges structure u/s w/walls d/s w/walls stilling box	25 years
Canal (linings -earth -masonry -concrete tile -cont. concrete)	design flow length	HYDRAULIC -pass design flow OPERATIONS -n/a	embankment side slopes (note type) bed	civil 25 years m&e 10 years
Hydraulic Structure -aqueduct -culvert -drop struct. -escape struct. (note type)	(depends on structure) design flow length fall	HYDRAULIC -pass design flow OPERATIONS -n/a	conveyance support struct. u/s w/walls d/s w/walls stilling basin	civil 25 years m&e 10 years
Supplementary Structure e.g.: -bridge -cattle dip	(depends on structure) design flow length	HYDRAULIC -pass design flow OPERATIONS -n/a	structure safety other features	civil 25 years m&e 10 years
Access Roads	width length	OPERATIONS -access to system	structure surface drains	civil 25 years

3.7.4 Size and Size Bands

Within each asset category the nature of the asset, its value and the liabilities associated with it, will vary according to its 'size'. In order for classification to be manageable, the use of '*Size bands'* (or ranges of size) is necessary. Definition of the bands will depend on the range of sizes existing in the particular region under consideration and upon the cost-size relationship. The measure of size should be chosen to give a reasonably simple correlation (preferably linear) with value. It should also be an unambiguous measure which can be practically and reliably determined as part of the survey. Measures which are obscure, difficult to check or liable to be in error are impractical.

Table 3.6 Size Measures for typical assets in the Trial Area

Asset type	Size measure	Extent units
Weirs	(crest height)^3 x (crest width)	number existing
Canals	Maximum design flow	length in kilometres
Cross Regulators	Maximum design flow	number existing
Head Regulators	Maximum design flow	number existing
Measuring Structures	Maximum design flow	number existing
Hydraulic Structures	(Maximum design flow)x(length)	number existing
Supplementary Structures:		
- Bridges	(Span)^3	number existing
- Other	Canal Maximum design flow	number existing

For the trial, insufficient information was available to be able to do correlation tests of size measures against value (see discussion of Cost Model). The size measures presented in Table 3.6 were selected on the basis of engineering judgement. In cases where *maximum design flow* is difficult to determine (for example because the design has been subject to several modifications) then the *area served* by the asset may be a more reliable size indicator. This makes the broad assumption that crop water demands per unit area are roughly consistent across the region under consideration. Given that the intention is to place assets in size bands rather than to measure their size precisely, this assumption is reasonable.

Table 3.7 Size Bands for 'Maximum Design Flow' selected in the Trial

Band 1	Band 2	Band 3	Band 4	Band 5
0 - 249 l/s	250 - 749 l/s	750 - 1249 l/s	1250 - 2249 l/s	> 2250 l/s

The definition of size bands also needs to be reasonably straightforward. In the trial the bands shown in Table 3.7 were chosen for 'maximum design flow' to fit well with cost figures located for different sized standard structures (East Java Irrigation Study, Vol. 2, 1981).

3.7.5 Value ('Gross MEA' and 'Net')

The value of the asset depends upon its type and its size and is represented in terms of the 'Modern Equivalent Asset' (MEA) value (that is to say the cost of a modern asset of equivalent function, not necessarily replicating the existing asset in precise detail) at current prices. The gross MEA value is the full amount currently needed to acquire such an asset. The net value takes account of the fact that the asset is not new and assumes that its value depreciates in accordance with a formula (the simplest of which is a straight line relationship between net value and age) until it reaches its 'depreciation life' at which time its value is nil (because it would need to be replaced). This conforms with conventional accounting practice. The establishment in the survey of an asset's type and size enables its gross value to be derived by reference to the Cost Model. Condition information then allows net value to be derived similarly.

3.7.6 Condition and Serviceability

3.7.6.1 General

An important difference between the approach to the asset survey defined here and that more commonly described is that here a distinction is made between the general condition of an asset on the one hand and its ability to perform its function (its '*serviceability*') on the other. As soon as a new asset is put in place it begins to deteriorate. Its condition progressively degrades until it reaches its depreciation life when it will need to be replaced. Thus the *condition* of an asset, taken with its MEA value, can be used to give an indication of the likely cost associated with its restoration.

The serviceability of an asset (that is its ability to perform its function) is often assumed to be directly related to its condition. But this can be a misleading assumption. In practice, assets very often continue to perform their function quite satisfactorily even though their condition is significantly deteriorated. On the other hand there are frequent instances when an asset which is generally in excellent condition is rendered unserviceable by a very minor fault. It is the serviceability therefore which indicates the urgency of the work needed to restore the asset to its fully functional state.

By measuring separately these two indicators, a much clearer picture emerges than is the case when condition and serviceability are treated as one and the same. Condition implies cost whereas serviceability implies urgency. Expenditure priorities are thus much more readily determined and their implementation is more likely to be effective in keeping the assets functional rather than merely maintaining their appearance.

3.7.6.2 Condition Grades

The number of condition grades to be used should be chosen to suit the particular circumstances in which the Asset Management Plan is being created. Due regard must be given to the way in which it is intended to use the information and to the ability of those who will undertake the survey to distinguish between different condition grades. A number of grades between three and six is recommended. The World Bank has a six point scoring system although this rolls together condition and serviceability. The Department of Public Works (DPU) in Indonesia has in some cases used a three point score of 'Good', 'Average' or 'Broken'. In other examples, including that of the UK water industry, a five point system is used although, where the top score is 'new' and the bottom score is 'derelict', these extremes may rarely be selected. There is an argument for having an even number of grades so that a judgement must be made by surveyors as to whether an asset is above or below average condition.

In the trial four condition grades were chosen. These are defined in detail for each asset category under the following broad definitions:

1. **GOOD**: Generally sound with no deformation or damage. Well maintained with little or no signs of deterioration.
2. **FAIR**: Generally sound but with some degradation or damage. Needing maintenance attention.
3. **POOR**: Significant deterioration requiring urgent corrective work.

4. **BAD**: Serious problems requiring partial or complete replacement.

3.7.6.3 Serviceability Grades

The decision on how many serviceability grades to use must be made on the basis of the same sorts of considerations as outlined above for condition grades. It is not necessary that the number of serviceability grades be the same as the number used for condition. It can be argued that serviceability should be reported either as ‘acceptable - i.e. pass’ or ‘unacceptable - i.e. fail’. Indeed a reporting method of this type is used in the UK water industry. However this approach is considered too coarse for irrigation systems in which operations staff are often able to overcome a partial reduction in functionality of an asset in all but the most extreme operational conditions.

Serviceability is measured by reference to two functional criteria applied as appropriate to each asset. These are:

Hydraulic Function: This will normally be ‘to pass the design flow safely’

and:

Operations Function: (where appropriate) ‘to control flow across the required range’
OR ‘to control command (level) across the required range’
AND/OR ‘to allow measurement of flow’

In the trial four serviceability grades were selected. As for condition, these are defined in detail for each asset category under the following broad definitions:

1. **FULLY FUNCTIONAL**: Apparently properly designed and constructed with capacity to pass the design flow safely AND (where appropriate) fully capable of being operated to control flow (OR command) across the desired range AND (where appropriate) facilitating measurement of flow by means of its own components or an adjacent measuring structure. Performance unaffected by silt or debris.

2. **MINOR FUNCTIONAL SHORTCOMINGS**: Normally able to pass the required flows and capable (where appropriate) of being operated to control flow (OR command) in a measured manner but performance likely to be unsatisfactory under extreme conditions of demand or climate. Deficiencies may be due to design or construction inadequacies, insufficient maintenance, measuring devices which are difficult to read or due to the presence of silt and/or debris.

3. **SERIOUSLY REDUCED FUNCTIONALITY**: One or more of the defined functions seriously impaired through deficiencies in design, construction or maintenance, or due to the presence of silt and/or debris. (Likely to have a significant detrimental effect on System Performance.)

4. **CEASED TO FUNCTION**: Complete loss of one or more functions or serious reduction of all functions of the asset for whatever reason.

3.7.7 Importance

The potential influence of an individual asset on system performance is governed by:

- its functional significance and
- its position within the system.

Since the purpose of the AMP is to identify investment need, the functional significance of an asset is of interest only in so far as there is a functional deficiency which needs correction. This is already assessed under 'serviceability'. By recording the positional importance of the asset additionally, a more complete picture is given to aid the targeting of investment funds.

In the trial, the downstream area directly served by the asset, as a proportion of the total system irrigated area, was selected as the simplest measure of positional importance. Additional factors could be considered depending on the asset type but the practical value of introducing more sophisticated importance measures is uncertain and would need further research to be determined. In work done by Davies (1993) and under the Programming and Monitoring System project (PMS - Mott MacDonald 1993), an importance ranking is assigned according to asset type separately from and in addition to recording the area served by each. In their approaches, however, asset 'serviceability' is not measured specifically so the arguments above do not apply to them.

3.7.8 Conducting the Asset Survey

3.7.8.1 Design of Survey Forms

Examples of the forms used for the field trial are given in Appendix A1. The design of these was based on work done previously (Davies, 1993; Mott MacDonald - PMS, 1993) and adapted as required by differences in the information sought. Experience in the field trial suggests that an improved form design would tabulate all assets for a particular reach of canal on a single sheet. This would be easier to handle and save paper (forms as currently developed use one sheet per asset). The same conclusion is apparently being reached under implementation of PMS. The disadvantage will be slightly reduced flexibility where 'unexpected' assets need to be recorded; however, this can be overcome. Further development work on form design is appropriate.

3.7.8.2 Desk Study

As a preliminary to undertaking fieldwork on each sample system, a desk study should be made to establish the availability of relevant information. In particular this should seek:

- a layout of the system - preferably both as a survey drawing and as a schematic - showing the positions of each asset
- the area served by each offtake and thus, by addition, by each asset
- the maximum design flows in each canal and at each offtake
- any history of changes to the design
- records of previous surveys of the system
- reports by operating staff of problems or particular maintenance needs
- results of the System Performance Assessment.

3.7.8.3 Survey Team

A team should be established who will follow through the survey for the system from desk study to completion. The size of the team will depend upon the size of the system and the time and resources available. Members will need to be technically competent, preferably qualified engineers, with experience in irrigation design and operation and in structural assessment. They should communicate effectively with operations staff.

3.7.8.4 Field Work

The survey team should be accompanied on site by a member of the operations staff familiar with the day-to-day running of the part of the system concerned. The survey should begin at the top of the system and work along its length. At least one route should be followed to the 'bottom' of the system (i.e. to the lowest point of interest within the AMP). This practice was followed for the trial where the primary canal (Induk Papah) and one secondary canal (Sekunder Cangkring) were surveyed.

It is preferable that a pair of surveyors work together to follow any section of the system (e.g. a primary or a secondary canal) through from top to bottom. Where branches occur, one branch should be completed before another is started unless there are more than one pair of surveyors in the team. Then each pair may be allocated to different branches.

As the survey progresses any discrepancy between the network as observed and that recorded on the system layout drawings should be carefully recorded. This is not only to aid interpretation of the Asset Survey but also to provide a basis for assessing confidence in the recorded information generally. The experience of the trial demonstrated that it was often difficult to determine the location (by chainage along the canal) of assets since distance markers were absent on many stretches. In these circumstances, particularly where a number of alterations had taken place over the history of the system, it was necessary to be very careful to identify correctly the asset concerned and the area it serves.

3.7.8.5 Creating the Database

The results of the Asset Surveys from the sample systems must be assembled in a manner which facilitates integration and analysis within the AMP. A computer relational database is envisaged, the architecture for which, as developed during the trial, is shown in Appendix A3. Relational databases of this type have been created by Davies (1993) and under the PMS project (Mott MacDonald, 1993).

3.8 Cost Model

3.8.1 Requirements of the Model

3.8.1.1 Purpose

The Cost Model provides a reference data-base for use in the preparation of the AMP and subsequently for financial modelling where alternative investment strategies are compared. Specific purposes of are:

(a) to value existing assets (in terms of the 'Modern Equivalent Asset' value);

(b) to provide unit costs for capital investment activities (as determined from Engineering Studies);

(c) to quantify operational costs (under the headings of (i) system operation and (ii) maintenance).

3.8.1.2 Modern Equivalent Asset (MEA) Value

The Modern Equivalent Asset Value (MEA) is the cost, at current prices, of a modern asset of equivalent function, not necessarily replicating the existing asset in precise detail. The gross MEA Value is the full amount needed to provide such an asset at the current time. The net MEA value allows for the depreciation of asset value over its life. Some relationship between the condition of an asset and its nominal depreciated value needs to be determined for use within the Cost Model.

A Unit Cost Index must developed (or an existing one adapted) in which typical construction costs, represented as gross MEAs, are available for each asset type in each of the size bands applicable. In order to derive these unit costs and to check what size measures are most appropriate for each asset type, it is likely that historical cost data will be collected, analysed and plotted against alternative size measures to find the best correlation. Once this work has been done, estimating asset value or new construction costs becomes a straight-forward matter of taking a figure from the Index.

Where component condition scores are to be weighted by the component's proportional value (see Section 3.7 'Asset Survey'), the information required will be obtained from the Cost Model. The Cost Model must therefore include a breakdown of MEA for each asset type into its component costs.

3.8.1.3 Capital Investment Activities - Unit Cost Index

Capital investment activities are works undertaken to rehabilitate, upgrade, extend or improve existing system infrastructure. They will be determined by Engineering Studies (see Section 3.5.5). Just as for the costs of new construction (MEA value), figures for these activities are best derived from a review of past contracts. In some cases it may be necessary to produce engineer's estimates. Due allowance must be included for the complete or partial removal of an existing asset prior to its replacement.

The unit costs so derived will be used to convert activities, identified as necessary (through Engineering Studies) as the result of a shortfall being found during System Performance Assessment (Section 3.5), into estimates of investment need. An appropriate list of typical activities must be devised and costed. Each activity must be related clearly to the asset type with which it is associated and to the asset size.

3.8.1.4 System Operating Costs

Together with the index of routine maintenance costs described below, this analysis will provide the basis for making adjustments to the OPEX budgets as a result of OPEX/CAPEX trade-offs considered during Financial Modelling. It will summarise the typical costs traditionally associated with the operation of the systems under consideration. It will be broken down into contributory elements (such as 'staff costs', 'equipment', 'transport' etc.) as appropriate to the current operational accounting practices. If these provide inadequate information it may be necessary to re-analyse the historical data or use it as a basis to build up new rates in the form required.

3.8.1.5 Routine Maintenance Costs

These are of interest both to provide reference costs for preparation of the OPEX budget and to enable observation of cost trends. Such trends over time might be correlated for example with deteriorating assets, with particular patterns of capital investment or with changes in maintenance strategies. For meaningful information to be derived, records are needed covering as many years of operation as possible. Where it is proposed to make significant changes to current maintenance practices, or where new types of asset are being introduced requiring a different maintenance regime, then fresh estimates will have to be prepared. Some of the historical data may nonetheless be of value in preparing these.

3.8.2 Sources of Data

The AMP seeks to set out a realistic plan for the coming twenty years. Unless such plans have been prepared previously, the only point of reference for costs will be an analysis of historical activity and expenditure. This, taken in the context of the results of the System Performance Assessment and the Asset Survey, will form a basis for making future projections.

Some historical data will normally be available both for capital expenditure (CAPEX) and for running costs (OPEX). However, re-analysis of this information is likely to be necessary to provide the clear distinctions required by the AMP. In cases where there is a severe shortage of data it may be possible to 'import' information from other regions or sectors to provide a starting point. Such information would need to be interpreted and adjusted for local conditions. On occasions it will be necessary to build up engineers' cost estimates from first principles.

One of the spin-offs of the first AMP in the UK water industry was the establishment of a nation-wide construction unit cost index specifically for water industry related activities. This is updated frequently and published for use by planners and designers throughout the industry. The availability of such information saves time and increases accuracy in the estimation process.

3.8.3 Building the Model

The trial demonstrated that building the model in the required form can be more difficult than might be anticipated. Whilst a large amount of information on unit costs was thought to be available at the outset, much of what was found proved impossible to use without extensive additional analysis. The following list illustrates some of the problems which may be encountered with existing data.

- Contract costs are broken down into Bill of Quantity items which are unrelated to specific activities or to asset types.
- Contracts contain a mixture of rehabilitation/refurbishment, removal of existing assets, new construction and upgrading works which are not readily separated out.
- There is a general lack of data or the data which is available relates to a few specialised contracts in a narrow time span.
- Cost information relates only to a very narrow and unrepresentative range of asset sizes.
- Contracts have been subject to several specification changes and/or claims making it very difficult to relate final costs to work achieved.

Estimating costs for future projects based upon a combination of general contract experience, historical data and engineering judgement is a process familiar to engineers involved in feasibility studies, project planning and contract preparation. Building the Cost Model is fundamentally the same process although more work will be involved to give it the necessary range of asset types and sizes. There is no doubt, therefore, that the Cost Model can be produced but it must be recognised as a specialised activity requiring clear terms of reference to ensure its compatibility with the rest of the AMP.

4. Using the Asset Management Plan

The last chapter examined each of the elements involved in the compilation of an Asset Management Plan. This chapter now describes the presentation and use of the information thus produced, including the assessment of confidence in the results obtained.

4.1 Presentation of the AMP

The detailed form of presentation of the Asset Management Plan must be tailored to the requirements of the commissioning agency. Example output forms are presented in Appendix A2. These have been developed during the trial by adaptation of the principles applied in the UK water industry. They include the elements detailed in the following sections.

4.1.1 Asset Stock, Condition and Serviceability Profile

This is a statement of all the assets which exist, aggregated up from the Asset Surveys on sample systems (as presented in Appendix A2, Output Form 1). Assets are divided by category and size and the number present stated. The total value of assets in each category is quoted both as gross MEA and as net (depreciated) value. Condition and Serviceability Profiles are provided by quoting the summed gross MEA value of all assets assessed to be in each condition grade and in each serviceability grade respectively. An Importance Profile can be similarly provided.

4.1.2 Unit Costs Report for MEA Value and Capital Investment Activities

This is a presentation of information contained in the Cost Model (see Output Form 2, Appendix A2). Costs may be categorised in many different ways according to what is found to be most appropriate and convenient. The factors which define the cost categories are likely to be those having the most significance in determining cost variability. They could include size, location type, ground conditions etc. They might be related to 'stages' of construction work such as 'construct new asset', 'remove existing asset', 'install replacement asset', 'extend asset' etc. The definitions of these factors will emerge from the process of building the Cost Model.

4.1.3 The Investment Programme

This is a report of the total investment estimates for Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) as provisionally programmed by each five-year period for the coming twenty years. This is then subdivided and re-presented as follows (see Output Forms 3a, 3b and 3c in Appendix A2):

- by each Asset Category (this shows where investment is targeted in terms of different asset types)
- by each Importance Band (this shows how the 'importance' of assets affects investment)
- by each Purpose Category; e.g.: - to maintain (preserve) existing performance or
  - to improve/extend existing performance or
  - to maintain (preserve) existing condition

4.1.4 Activities Report

This complements the Investment Programme by stating what work is represented by the investment proposed (see Output Form 4 in Appendix A2). Under each asset category various activities are listed and the amount of work programmed (for example as ‘kilometres of canals relined’ or ‘numbers of gates replaced’) set out for each five year period.

4.1.5 Benefits Report

This relates benefits, in terms of the performance measures used for System Performance Assessment, to the programme of capital investment activities (see Appendix A2, Output Forms 5a and 5b). Where possible it should also show some history to convey an idea of trends. The improvements to be derived from the investment programme are thus clearly declared. They can be used to weigh alternatives, to justify decisions and, subsequently, to monitor achievements.

Although not strictly an output performance measure, maintaining or improving the Asset Condition Profile may be considered an important indicator of satisfactory system management. In this case the projected changes to the Asset Condition Profile, reflecting investment plans for CAPEX and OPEX, can be presented as part of the Benefits Report (as illustrated in Output Form 5c, Appendix A2).

4.1.6 Asset Depreciation Categories

This is a summary statement of the assumptions incorporated into the AMP about the depreciation life of various asset types and their component elements (see Output Form 6 in Appendix A2). The relationship between this and the assumptions in the Cost Model yielding depreciated asset value is an area requiring further consideration and development.

4.2 Confidence Grades

4.2.1 Purpose

All data, at both input and output levels, should be assigned confidence grades in order to demonstrate the robustness of the Plan and the degree of confidence in it. By examining all sources of data and the confidence grade associated with each, an experienced statistician can establish which ones have the greatest impact on overall confidence in any particular output. This allows further studies to be focused on those areas which will provide the best return in terms of boosting overall confidence.

4.2.2 Sources of Variance

COSTS tend to have the widest confidence grades and to dominate overall confidence. They influence valuations, condition and serviceability profiles by value and investment estimates. They are considered to have two separate sources of variance; the variability of a unit cost about the mean and the variability of the calculated mean about the true mean. Where sufficient information is available confidence can be quantified using regression analysis. It should be noted that any error in the calculated unit costs is cumulative and consequently errors in the total estimate are cumulative.

ENGINEERING JUDGEMENT also has a very significant influence on the overall outcome. Errors here may occur in the appropriateness of the chosen solution, its timing or the possibility that the work may not actually be needed at all within the time frame of the AMP. This variance may be high for individual systems but tends to reduce (by mutual cancellation of errors) as these are added together.

CONSISTENCY OF ASSET SURVEY ASSESSMENTS. This is a question of repeatability of judgements made about condition and serviceability by field teams. It depends on the selection and training of the teams and the design of survey forms. Pilot surveys can be conducted comparing the results of several teams assessing the same assets to improve procedures and to quantify confidence.

SAMPLING ERROR. This is the possibility that samples are not representative. It can be minimised by careful stratification prior to sampling as described in Section 3.3 on 'Stratified Random Sampling'.

Table 4.1 Data ACCURACY bands

Band	Definition
1	Better than or equal to +/-1%
2	Not band 1, but better than or equal to +/-5%
3	Not bands 1 or 2, but better than or equal to +/-10%
4	Not bands 1, 2 or 3, but better than or equal to +/-25%
5	Not bands 1, 2, 3 or 4, but better than or equal to +/-50%
6	Not bands 1, 2, 3, 4 or 5, but better than or equal to +/-100%

Source: UK Office of Water Services - AMP2 Manual

Table 4.2 Data RELIABILITY bands

Band	Description	Definitions	
		Actuals	Forecasts
A	HIGHLY RELIABLE	Data based on sound records, procedures, investigations or analysis which is properly documented and recognised as the best method of assessment	Based on extrapolations of high quality records covering or applicable to more than 100% of the study area, kept and updated for a minimum of five years. The forecast will have been reviewed during the current year
B	RELIABLE	Generally as A but with some minor shortcomings, for example the assessment is old, or some documentation is missing, or some reliance on unconfirmed reports, or some extrapolation	Based on extrapolations of records covering or applicable to more than 50% of the study area, kept and updated for a minimum of five years. The forecast will have been reviewed during the previous two years
C	UNRELIABLE	Data based on extrapolation from a limited sample for which grade A or B data is available	Based on extrapolations of records covering more than 30% of the study area. The forecast will have been reviewed in the previous five years
D	HIGHLY UNRELIABLE	Data based on unconfirmed verbal reports and/or cursory inspections or analysis	Based on forecasts not complying with bands A, B or C

Source: UK Office of Water Services - AMP2 Manual

4.2.3 Recording Confidence Grades

Confidence grades are declared on data forms, as shown in the examples presented in Appendix A2, in the columns marked 'CG'.

Table 4.3 Confidence Grades (CG) for data

Accuracy / Reliability	**A**	**B**	**C**	**D**
<1%	A1	N / A	N / A	N / A
1 - 5%	A2	B2	C2	N / A
5 - 10%	A3	B3	C3	D3
10 - 25%	A4	B4	C4	D4
25 - 50%	N / A	N / A	C5	D5
50 - 100%	N / A	N / A	N / A	D6

Source: UK Office of Water Services - AMP2 Manual

Note: N / A indicates confidence grades that are considered to be incompatible.

The method of assessing and reporting Confidence Grades used for the UK water industry is repeated here for reference. It appears to be suitable for application to irrigation without modification. It uses a combination of two separate measures: ACCURACY of data on the one hand and RELIABILITY on the other, as defined in Tables 4.1 and 4.2 respectively. The accuracy and reliability bands form the matrix of confidence grades given in Table 4.3. Whilst alpha-numeric confidence grades are set out, it is expected that only the quantitative accuracy definitions given in Table 4.1 will be used for statistical combinations of variance.

4.3 Financial Modelling

4.3.1 Purpose

The financial modelling process is one of reviewing and refining the provisional investment programme presented in the AMP. In doing so the information contained within the AMP is used to the full. Specifically, the purpose and boundaries of the financial model are:

(i) to match investment strategy to realistic and achievable revenue projections and

(ii) to examine potential CAPEX/OPEX trade-offs and utilise these to the best advantage.

4.3.2 Process

The AMP contains:

- investment needs identified and quantified
- a provisional expenditure programme over 20 years
- benefits of investment identified and related to the same programme
- an extensive cost database on which to draw in considering alternatives
- a valuation of existing asset stock with condition and serviceability profiles.

Financial modelling considers constraints and priority influences in respect of:

- alternative strategies
- capital planning (20 years)
- budget planning (5 years)
- budget priorities (5 years)
- sources and realistic levels of funding (Irrigation Service Fee, subsidies, etc.).

In practice the process of financial modelling is likely to be a mixture of complementary activities. These will include management workshops in which policies, priorities and constraints are reviewed, rigorous re-examination and numerical analysis of elements of the programme and some subjective assessment. Ultimately a series of management decisions will be made leading to a 'preferred' strategic option. To satisfy the requirements for traceability of the AMP, these processes must take place within a set of pre-defined rules and each stage recorded.

It may be the intention, or an option under consideration, that responsibility for assets within the AMP will be split, with different sources of funding (e.g. government keeps river weirs and intake works but hands over the irrigation system to farmers or to a private company: these two entities may have different sources of funding). The financial model must reflect and facilitate evaluation of such plans.

4.3.3 Alternative Strategies

The investment plans set out in the AMP must be examined to ensure they can be sustained as they stand, without modification, in the light of funding implications and constraints. If they can there may be no reason for making alterations other than, perhaps, to smooth capital requirements. If not then it is necessary to examine alternative strategies based on AMP information. These might include:

- accelerate or delay investment
- alterations to level of service
- review revenue sources and means of collection
- consider OPEX/CAPEX trade-offs.

Decisions which emerge from this process on investment strategy will:

- set policies (for guidance in budget preparation)
- allocate funds for the first five-year plan.

4.3.4 Capital Planning

This is the process of defining the capital investment requirements implied by the preferred investment strategy and established from the financial model. To achieve this it is necessary to know the cost stream, to match this with the income stream and to arrange an appropriate flow of capital. This will be presented as a series of five-year plans, the first of which must also be converted into a budget plan.

Crucial to capital planning is the timing of investment. Investment requirements are built up from the results of examining sample systems, particularly from Engineering Studies and from the Asset Survey. Determining investment timing in each individual sample system is thus important to the whole Plan.

For IMPROVEMENT/EXTENSION expenditure, timing will depend on when funds are available. A spread which minimises the peaks in capital demand is likely to be favoured. Decisions to defer maintenance in order, for example, to create a 'window' for improvement activity, which often tend to occur by default, can in this instance be planned in order to maximise efficiency of capital exploitation, whilst minimising the consequent difficulties.

For MAINTENANCE spend, an algorithm such as that developed by Davies (1993) could be used to simulate the continuing deterioration of assets under different maintenance regimes. A relationship between asset deterioration and time must be assumed and the cost estimated of restoring an asset to new from any given condition grade. The worst case occurs at the end of the asset's 'depreciation life' when the cost of restoration will be the replacement value of the asset (plus the cost of removing the derelict original). As an alternative, curves of rehabilitation costs against maintenance interval could be used to generate a maintenance expenditure profile.

4.3.5 Budget Planning and Investment Priorities

This analysis sets out detailed expenditure policy for the first five years, based on declared priorities. It allocates 'baskets of money' to specific types of activity during the first five years of the plan. It also defines the details of the cash flow (income and expenditure) required to achieve this. The priorities for the period are derived directly from decisions made during the consideration of alternative strategies as set out in Section 4.3.3.

4.3.6 OPEX/CAPEX Trade-offs

Particularly within an irrigation system where the role of operations staff is so crucial to performance, it may often be possible to defer capital expenditure through increased operational activity (and hence OPEX). Conversely, by a piece of capital expenditure, for example automated gates or a new silt trap, operational expenditure may be reduced.

This relationship provides the opportunity, and the need, to make policy decisions affecting short term revenue demands and long term performance improvements. A balance which is unacceptable in the long term may be tolerated or deliberately brought about in the short term in order to make necessary adjustments to investment timing, reflecting constraints on capital.

4.4 Organisational Adjustments

The need for a number of organisational adjustments may arise from the AMP process. Those identified might include:

- organisational and structural changes
- revised O&M procedures
- training
- adjustment of OPEX budgets
- new standards of performance targets.

These are discussed below.

4.4.1 Organisational and structural changes

These may reflect the findings of the Management and Engineering Studies and the policy options selected from the Financial Model. They could range from local adjustments (for example reduced numbers of higher qualified staff needed to complement an investment in automation) to wholesale structural changes upon turnover or privatisation.

4.4.2 Revised O&M procedures

Changes in the infrastructure may require supporting changes in the O&M procedures for the system. When considering infrastructure changes which might improve performance, consideration will need to be given to the feasibility of changing existing O&M practices. The benefits to be gained by improving infrastructure may be lost if complementary changes in supporting ‘software’ are not forthcoming.

4.4.3 Training

Training will be needed to support changes in management and O&M procedures and will need to be targeted at key personnel within the organisation.

4.4.4 Setting of OPEX budgets

The process of carrying out an AMP and investing funds in infrastructure to maintain or improve condition and levels of performance will take account of the level of recurrent budget for operation and maintenance. Levels of CAPEX and OPEX must be complementary, and both are reviewed under the AMP framework. Where decisions have been made which require an increased OPEX budget, this must be protected or levels of service will suffer.

4.4.5 New Standards of Performance Targets

The AMP has its focus on Output Performance measures (service to the ‘customer’) right the way through the process from initial Performance Assessment to final presentation of the Investment Programme and the associated Benefits Report. Thus clearly defined and meaningful targets are set against which staff can implement the plan. These can be used for monitoring progress, for making adjustments as the programme unrolls and as a basis for motivating and rewarding staff effort.

4.5 Applications

4.5.1 Pricing for Cost Recovery

The Asset Management Plan sets out clearly the costs involved in providing the declared level of service over the long term. Capital Planning within the Financial Model will have refined this in a way which aims to smooth the demand for capital and which matches it with revenue. The true costs of providing the service are thus known.

Realistically, the period over which prices will be set will be the five years of the Budget Plan. The aim will normally be to maintain a steady price over the period or to allow a modest price increase with time as measures are seen to be put in place to improve service. In the UK water industry the government regulator (OFWAT) negotiates a price cap, related to inflation, with the water companies based on the Asset Management Plans of each. The negotiations centre around the improvements to quality and service (with particular reference to environmental quality), the rate at which these are to be achieved, the surveyed aspirations of customers and what is considered reasonable as a rate of charge.

However revenue is to be recovered, whether by a full economic Irrigation Service Fee or through subsidy from central funds, the information exists to quantify its level. Furthermore, full justification of that level is provided in the AMP in a way that can be opened to scrutiny and performance targets are declared so that it can be seen how well these are being met.

4.5.2 Needs Based Budget allocations

Needs Based Budgeting has been an innovation in the irrigation sector intended to target available funds more effectively. Budgets are prepared on a detailed, ‘bottom-up’ basis and passed up the line for approval. The problems have been:

- They have had short term or immediate time horizons. The balance of priority between planned preventative actions to avoid stored-up problems versus immediate ‘fire-fighting’ needs is at best unclear.
- Budgets identifying all ‘needs’ can be little better than a ‘wish-list’. Once realistic funding has been applied the resulting priorities can be more or less arbitrary.
- Little or no information is available by which to balance priorities between competing ‘needs’ as assessed in different localities.

The setting of five-year Budget Plans and Budget Priorities based on the AMP is a means for very clear ‘top-down’ guidance to be provided to local managers based on sampled and analysed ‘bottom-up’ information. Needs Based Budgets can then be prepared in a much more positive way as bids to secure funds already known to be allocated to certain types of activity. Where local managers assess a pressing need which is a ‘special case’ in terms of the general priority guidelines, they will prepare, for approval, a justification to show how they propose to divert funds without detrimental effect.

4.5.3 Privatisation and Turnover

The AMP was originally developed for privatisation of the English and Welsh water industry. When the ownership and management of systems is being transferred it is essential to know:

- What are the assets and what liabilities are associated with them?
- What is the service which will continue to be provided and how will it be monitored?
- How can all stakeholders be assured that adequate investment is sustained?
- In a geographic monopoly, how can customers be assured that prices are reasonable?
- Is the privatisation viable or will it require continuing subsidy? If so, to what extent?

The AMP is designed to answer all these questions. Meaningful negotiations require this information as a basis. Financial settlements or enabling works will reflect the agreed plan. Thereafter, monitoring is facilitated.

4.5.4 Comparative Performance Assessment

In texts discussing the performance of irrigation systems (e.g. Bos, Murray-Rust, Merrey, Johnson and Snellen, 1993), comparative performance assessment and related staff rewards are mooted as a means to greater staff motivation. When geographic monopolies are created through privatisation, comparative performance assessment is important as a surrogate for the normal market mechanisms which govern price levels and efficiencies through competition.

The AMP declares clear output performance measures, the standards which it is proposed to meet and how those standards will be met, including the price to customers. It facilitates comparative performance assessment in at least three ways:

- by comparison between plans when these are prepared individually by different regions or companies
- by comparison between actual performance and the plan of the region or company concerned
- by comparison of actual performance between different regions or companies based on the common performance measures declared in their respective plans.

Privatisation is one method of mobilising comparative performance in the motivation and rewarding of staff. Companies must compete with each other to retain their most able staff and this will be reflected in salaries and conditions. The ability of companies to reward staff will be related to their profitability. In the public sector this kind of approach may be simulated or substituted.

Part III: Conclusions

5. Arrangements for Implementation

The ultimate evaluation of any technique such as asset management planning will depend greatly on its resource demands and on related implementation practicalities. This chapter addresses these issues.

5.1 General

The conclusions presented here about resources required to produce an AMP can be broadly indicative only. Quantification of the actual requirements in any specific case of AMP production will depend on the particular circumstances. Influences will include:

- The number of systems under consideration and their irrigated area
- The area of the region over which they are spread and the type of terrain
- The degree of infrastructure problems which exist
- The capabilities and attitudes of managers and staff
- Local availability of suitably qualified specialist staff and the quality of support staff
- The quality and quantity of data available
- The timescale for AMP production
- The logistical arrangements for communications, transport, computer facilities etc.

The experience of the trial in Yogyakarta was valuable in assessing the type of staffing to be envisaged. Being a feasibility study however, the resources available were insufficient to carry out a full AMP. Thus there is as yet no direct experience of staffing a project to produce an AMP for irrigation.

5.2 Tasks

The elements of the AMP project requiring to be staffed may be listed as follows:

AMP Project Management and Co-ordination

- scheduling all other elements
- briefings of senior irrigation service managers and staff
- design of procedures and output format
- terms of reference and co-ordination of specialist inputs
- arranging interaction, feedback and reporting (including meetings, workshops etc.)
- organising and evaluating pilot studies as appropriate
- maintaining logistics support

Preliminaries and Running Requirements

- setting up accommodation, office, transport, communication provisions
- arranging staff movements
- recruiting support staff and equipment
- administration and accounting practices
- project closure

Statistical Design

- overview of study area
- stratification
- sample selection
- aggregation of sample results
- assessment of Confidence Grades

Performance Assessment

- review of environmental, legal and development context
- liaison with water users
- determination of Performance Targets
- assessment of System Performance

Engineering Studies

- investigation of performance shortfalls including hydraulic modelling as required
- examination of alternative investment options including CAPEX/OPEX trade-offs
- development of asset deterioration algorithms
- scheduling of investment activities, benefits and costs

Asset Survey

- computer database design
- design of survey forms
- desk study
- field work
- data entry

Cost Model

- assembly of historical data
- data analysis including regression tests etc.
- selection of size bands, asset value relationships etc.
- scheduling asset values, rehabilitation activity unit costs, operational costs etc.

Management studies

- review of existing management structure and operational procedures
- assessment of capability to implement the AMP
- assessment of management influence on system performance
- proposals for adjustments/training etc.

AMP compilation and presentation

- compiling and cross-referencing of AMP data
- design of standard output format
- processing AMP data to produce output reports

Financial Modelling

- review of the AMP and revenue implications
- consideration of ability of water users to pay
- consideration of alternative strategies
- capital planning
- budget planning

5.3 Staffing

Based on the above task list the following staff requirements are identified. Numbers and commitment will depend upon the scale of the operation as noted above. Some individuals may be able to fulfil more than one role.

Core Staff

All the following must be familiar with AMP procedures. At least one must be an AMP specialist.

- statistician
- irrigation engineer (design and operations experience)
- management specialist (familiar with infrastructure management issues)
- AMP Project Manager

Support Staff

- technical assistants to above (each discipline as required)
- administrative/support staff

Visiting Experts (single short inputs)

- computer database design specialist
- environmental specialist
- sociologist (for design and implementation of Water Users Survey)
- engineering estimator

Local specialist assistance (periodic inputs)

- design engineers/estimators
- survey staff (experienced in irrigation engineering/structural assessment)
- members of irrigation service senior management

5.4 Logistics

5.4.1 Organisation and Work Programming

It is clear from the above that a diverse group of specialists and supporting staff will be involved in an array of related activities. The establishment of an appropriate project organisational structure, which allows flexibility but clearly defines responsibilities, will be important to success. The programming or scheduling of tasks, some of which can run in parallel whereas others must be done in sequence, should be done thoroughly, for example using Critical Path Analysis techniques. Progress must be carefully monitored and co-ordinated across the team as a whole and good communication maintained.

5.4.2 Timescale

This will obviously vary according to the scale of the tasks and the resources (particularly financial) available. However an AMP must be produced over a reasonably short period if its full advantages are to be achieved and it is likely to cover a substantial area. A timescale of between nine months and eighteen months may reasonably be envisaged.

5.4.3 Offices

The AMP project is crucially dependent for its success on close liaison with the irrigation service managers who will eventually implement it and who are the source of vital information and policy. The project should have its offices within those of the irrigation service at the 'lowest' level compatible with maintaining an overview of the study area. Temporary field offices will need to be maintained at sample system locations whilst work is proceeding on the Asset Survey, Performance Assessment (including Engineering Studies) and Management Studies.

5.4.4 Computers

Computers and software will be needed for the databases and potentially for some hydraulic and some financial modelling. Those in field offices must be fully compatible with those at the co-ordinating office and there should be facilities to ensure ease of data-transfer between them.

5.4.5 Transport and Communications

With a substantial area to cover and diverse specialist activity, the AMP project must have good systems of internal and external communication and be adequately served with transportation. Delays or abortive work due to isolation cannot be afforded.

5.4.6 Briefings and Workshops

It is important to the ultimate success of the AMP that good two way interaction is maintained with irrigation service staff and others who are concerned with the operation of the systems concerned. Frequent briefings and workshops should be held during the course of AMP preparation to keep information flowing.

6. Further Considerations

This chapter identifies aspects which are beyond the scope of the current study but which have been revealed by it to be highly relevant to the further development of the topic. Amongst these are the requirements for further research.

6.1 Institutional Context

As discussed in Chapter 1, it was recognised at the outset of the study that Asset Management planning is used in the UK water industry under social, financial and institutional conditions which are quite different from those prevailing in many countries. This is not a fundamental problem as the AMP offers inherent benefits to management effectiveness. However the following observations are pertinent.

- To achieve the full benefits of the AMP, managers of the service will need to have clear responsibility and authority to take and implement decisions in a businesslike manner and they must be positive and active in doing so. The existing institutional arrangements may be found to be unsuited to encouragement of the necessary attitudes and attributes.
- The adoption of a ‘business planning tool’ such as the AMP is indicative of a shift of attitude in the approach to managing infrastructure. It would be surprising if this shift were entirely compatible with the prevailing institutional structures.

It would be inconsistent to set about Asset Management planning without first giving thorough attention to the establishment of compatible institutional reforms as a prerequisite. These will not be successful if they seek only to replicate institutions established elsewhere for they must reflect local cultural and socio-economic circumstances. They are likely to include the following types of change:

- decentralisation of responsibility and authority
- increased accountability based on clearer and simpler performance criteria
- compartmentalisation of roles consistent with the above. For example, environmental standards are the concern of one body whilst social and national strategic considerations are looked after by another (government) regulator; meanwhile, within this framework, the irrigation agency concentrates on providing the service best suited to its customers as efficiently as possible
- water will be increasingly treated as an economic good whose use must be paid for
- the approach to providing the service will be increasingly commercial

There are, of course, serious difficulties to be addressed here. One small example in Indonesia is the relationship between the irrigation agency and the ‘Kuton Royong’ (a village community volunteer labour force) which regularly undertakes maintenance work on parts of canal system because they see it as being in their own interests to do so. An increasingly commercial attitude would interfere with this relationship. Another is the general attitude to the government, in this case in the form of the irrigation agency, as an employer offering long term security and stability to its employees. But these problems exist anyway. Asset Management does not cause them; neither does it avoid them.

6.2 Further Research

This has been a short feasibility study in which the development of procedures through the trial has been exploratory. A number of remaining challenges are acknowledged. Table 6.1 lists some specific areas for further work and explains briefly how these emerged from the trial. Of particular importance are the questions relating to performance indicators and to Engineering Studies. From the work done it is clear that linking performance benefits to specific investment activities and expenditure through Engineering Studies will require special attention. It is known that research work is ongoing (e.g. ODA project 753-620-903 'Cost Effective Rehabilitation and Modernisation of Irrigation Schemes') which may provide valuable information on this key aspect of Asset Management procedures.

The trial did not include management studies or financial modelling since, whilst these are parts of the overall procedures, they are not part of the production of the Asset Management Plan itself. They remain to be investigated although the fundamental requirements are understood and there should be no undue difficulties. Perhaps the most important aspect to examine is that of the options for institutional arrangements needed to complement new planning techniques of the sort that the AMP represents.

6.3 Application to Other Utilities

The principles laid down for the use of asset management planning within the UK water industry and reviewed here for application to irrigation appear to be readily applicable to other sectors of public infrastructure. The technique is particularly well suited to sectors having a large number of 'systems' with broadly similar characteristics, where considerable effort would be required to produce a comprehensive inventory of condition and investment needs. Land transport systems (roads and bridges; railway networks; canal systems etc.) are all examples of this type of infrastructure. The structured approach of the AMP, looking at output performance measures for complete systems of assets as well as recording the state of repair of individual assets, recommends itself in these cases. The practical details involved would need to be studied for each case but there is every reason to think that the technique offers significant advantages. Indeed, it is understood that studies are already underway into the application of asset management planning to road transport systems.

The similarities between the water supply and sewerage industry of the AMP's origins and other pipe-based and cable-based utilities are obviously strong, suggesting that gas, telecommunications and power services could readily benefit from this type of approach. Indeed, when considering other possible sectors for application of the AMP, it is apparent that, of them all, irrigation offers possibly the greatest challenges because of the exceptional degree of operations management influence and the immediacy of its impact on day-to-day system performance. That these difficulties can be overcome for irrigation will be encouraging for applications in other sectors.

Table 6.1 Asset Management Trial - Summary of problems faced and inferences drawn for further work

Activity	Subject	Explanation	Further Actions/Research
Stratification	Defining the unit system size for stratification/sampling	Classification methods of Daerah Irigasi (DI) made them less than satisfactory as independent 'systems'. Overview information (eg. maps) was lacking. The resource savings due to a statistically valid sampling approach will be related to the number of systems and their size.	Solutions will be location specific. Preliminary studies may be needed to establish a regional overview in each case. However, some general studies could be undertaken to examine the problem, to seek common features between locations (if any) and to establish ground rules for this element.
	Establishing strata criteria	The selection of criteria in the trial was done on the basis of what information was available and what characteristics seemed most representative of differences between systems.	Again there will be much about this which is location specific. However, coordinated research covering a number of locations would be valuable and some common criteria would almost certainly be found.
System Performance Assessment	Output Performance Indicators	Data suitable for 'level of service' assessments was lacking in availability or quality. Water Users' perceptions of what constitutes a 'good service' was barely tested. No study was made into Environmental quality indicators.	Detailed research is needed in this crucial and difficult area to link and extend related work (by others) into the specific needs of the AMP.
Engineering Studies	Relating specific investment activities to performance benefits, how these accrue over time, and the costs of each.	Previous studies examined tend to consider overall project costs and benefits without breaking each down into linked elements.	A representative study should be attempted to test the practical difficulties associated with preparation in a form appropriate to the AMP. Terms of Reference (TOR) for such studies need careful consideration and definition.
Cost Model	Net (depreciated) value of assets	A straight-line relationship between asset 'condition' and depreciated value was stated as an assumption for the trial.	Studies of asset lives and associated repair costs under different maintenance regimes should aim to establish whether such a simple expedient can be (or needs to be) improved upon for the practical purposes of the Model.
	Estimating 'depreciation life' for an asset which comprises components with very different rates of deterioration.	It may be appropriate to use the 'depreciation life' of the most significant (cost) component and assume regimes of maintenance investment which keep other components in step. Other approaches might give the Cost Model greater versatility.	This aspect is strongly related to that described in the box above. Algorithms for the costs of repairing (restoring) assets could usefully be developed by examining typical cases and analysing historical maintenance expenditure.
	Unit Costs related to specific assets and/or activities	Existing cost information was found not to be broken down in a way convenient to the required purpose.	Special cost review/estimation exercises are required for each country concerned. Some research for general application may be possible - with local multipliers.
	OPEX/CAPEX relationships	Trade-offs of this type may be instinctively recognised by designers and operators but their quantification is likely to be more difficult.	Comparisons between schemes, with different levels of operational sophistication/automation for example, could yield useful data.
Asset Survey	Correlation of asset value with some measure of size	Relationships could not be studied in the trial because of lack of cost information in a suitable form	Extend Cost Model research to cover this aspect. It is likely that some general conclusions could be drawn
	Definition of asset types	Rationalisation of types is desirable - particularly where assets serving several functions occur as a single structure	Case studies required for specific countries/regions with a review to identify any commonality
	Asset overall 'Condition' score	Weighting of individual component condition scores was proposed by the proportional value of that component.	Further studies are merited of whether this approach yields consistently sensible results and of any alternatives.
	Asset 'Serviceability' score	Where asset serviceability is different for different parts of the system (e.g. a blocked culvert conveying a secondary under a primary canal which is unaffected) but only one score (and one 'area served') is recorded.	The concept of 'serviceability' in this context is innovative and bound to be subject to certain teething troubles. A general review of the approach to 'serviceability' scoring, incorporating this aspect, is appropriate.
	Design of data collection forms	Forms developed during the trial have shortcomings and lead to excessive use of paper	Research into form design - probably based on a tabulated list of assets associated with each canal.
Implementing the AMP	Strategic planning horizons	A twenty year planning horizon with a five year budgeting period has been proposed based on what was used in the UK water sector	Appropriate periods related to depreciation, obsolescence, economic and political considerations etc. may be checked by study.
	Institutional arrangements	Those best suited to effective implementation of the AMP	A comparative institutional analysis is called for.

Table 7.1 Asset Management Planning - Relationship to other Indonesian initiatives and practices*

	Needs Based Budgeting (NBB)	Irrigation Service Fee (ISF)	Turnover/ Privatisation (PIK)	Efficient Operation and Maintenance (EOM)	Programming and Monitoring System (PMS)	Integrated Basin Water Resources Management	Project Benefit Monitoring and Evaluation (PBME)	Cost Effective Rehabilitation and Modernisation	Rehabilitation Projects - Design and Contracts Documents	Advanced Operations Unit Monitoring Indicators	Integrated Urban Development Planning
AMP Inputs											
Historical Costs									◆		
Environmental Impacts						◆					
Future Demand Estimates						◆					◆
Stratification and Normalisation					◆	◆					
Performance Indicators and System Performance Assessment							◆	◆		◆	
Asset Survey					◆						
Engineering Studies								◆	◆		
AMP Outputs											
Investment Needs and Timing	◆	◆	◆	◆							
Planned Activities				◆					◆		
Planned Performance Improvements		◆	◆			◆	◆				
Asset Stock Condition and Serviceability Profile	◆		◆	◆	◆						
Cost Model	◆							◆	◆		
Depreciation Categories	◆				◆						

*Note: See Section 2.6, pages 11 to 15, for summary details of each initiative.

7. Conclusions

It can be concluded from this project that Asset Management Procedures for Irrigation Schemes are feasible and practical. Provisional guidelines, discussed in some detail in Chapters 3 and 4, have been produced in the light of experience of the field trial in Yogyakarta and these demonstrate the extent to which development has taken place. Further research and development, identified and briefly discussed in Chapter 6, is recommended to capitalise on the opportunities represented by the AMP.

The resource requirements and logistics of undertaking these procedures to produce an Asset Management Plan are set out in broad terms in Chapter 5. The quantification of these will depend upon the extent of the area for which the AMP is to be produced and upon other circumstances. Nonetheless an overall programme for AMP production of nine to eighteen months can realistically be envisaged.

Of the individual techniques of Asset Management, it is the use of statistical methods to build a rapid overall picture of the infrastructure, a 'snapshot', that is perhaps the most immediately impressive. This is very attractive in its efficient use of time and resources. It is also seen to be logical and sensible since, no matter how much effort is put into making a condition inventory comprehensive and detailed, it will never be wholly accurate as it will always be out of date as soon as it is published.

Apart from the use of statistics, what is particularly new about these procedures is the integration of their many and various elements into a unified structure. The elements themselves can generally be recognised as modifications and adaptations of existing practices which are already more or less familiar to practitioners as illustrated in Table 7.1. Asset Management procedures are thus seen to provide a genuinely comprehensive "framework" for irrigation infrastructure management. This is the great strength of the methodology. For it is in its *methodology,* at least as much as its *techniques*, where the greatest value of Asset Management lies. It demands that a broad view be taken and provides a context to sharpen the focus on any individual aspect. The task is not so much to ask *whether* the techniques can be applied as to establish *how* existing practices can be improved or extended to integrate them with the philosophy of the AMP. This indeed was how the original AMP was born: this is how it can be reborn within irrigation once the need for it is truly recognised.

Whilst it may be accepted that the introduction of Asset Management Planning will *facilitate* better management, what it clearly cannot do is *guarantee* better management. More than anything else, it is the nature of the managers themselves, their approach to taking and implementing 'active' decisions and the constraints under which they operate which will govern their effectiveness. Just as it was in the English and Welsh water industry at the time of privatisation, so it is the case in Indonesia that, before the benefits of the AMP can be fully realised, some substantial adjustments in management approach will be required. The institutional challenges, discussed briefly in Chapter 6, are not to be underestimated.

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Appendix A1

Examples of Data Collection Proformae

Input Data Table A.
STRATIFICATION AND NORMALISATION DATA (for ALL systems in the AMP)

PARTIAL LIST No. ...... OF	TECHNOLOGY LEVEL:	Tech	semi-tech	non-tech	TOPOGRAPHY TYPE:	Upland	midslope	lowlands

	STRATIFICATION DATA							NORMALISATION DATA					
SYSTEM (DI) NAME	WATER AVAILABILITY (Good/ Variable/ Poor)	SURJAN (MOUNDING) PRESENT (Yes/No)	TOPOGRAPHY FLAT OR UNDULATING ('F' or 'U')	YEARS SINCE LAST MAJOR INVESTMENT (Years)	MANAGEMENT BY (PRIS/ Farmer Group/ Joint)	ISF/ WUA FEE RECOVERY (No Fee/ >80% collected/< 80%)	LOCAL FAMILY INCOME LEVELS(High/ Moderate/ Poor)	COMMAND AREA (ha)	IRRIGATED AREA (ha)	NUMBER OF TERTIARIES (No.)	TOTAL LENGTH OF PRIMARY & SECONDARY CANALS (km)	PEAK SYSTEM INFLOW FROM RIVER (lt/sec)	No. OF STRUCTURES

Input Data Table B.
SYSTEM PERFORMANCE ASSESSMENT: EQUITY - based on 'Cropped Area' data

SYSTEM (DI) :	YEAR: 199...	SEASON:	SHEET ...... OF ......

TERTIARY		DESIGNED						REQUESTED					PLANNED					ACTUAL					PERFORMANCE RATIOS (on PRA)				
Name (in order from top of system)	Ref. no	R (ha)	S (ha)	P (ha)	B (ha)	PRA (ha)	Inp/ Est	R (ha)	S (ha)	P (ha)	B (ha)	PRA (ha)	R (ha)	S (ha)	P (ha)	B (ha)	PRA (ha)	R (ha)	S (ha)	P (ha)	B (ha)	PRA (ha)	Planned Designed	Planned requested	Actual Designed	Actual requested	Actual Planned
SYSTEM TOTALS																											
																						Mean					
																						Standard Deviation					
																						Coefficient of Variance					

DESIGNED= Original system design (as modified on rehabilitation where appropriate); REQUESTED= As farmers' formal submission to PRIS;

PLANNED= as PRIS approval; ACTUAL= as planted by farmers; PRA= 4xR+2xS+1xP+0xB; R=Rice; S=Sugar cane; P=Polawija; B=Bero (fallow)

Inp= Input from authentic design data; Est= Estimated by "Rule of Thumb" from mid-season Inflow at river offtake weir/PRA duty of 2.5 l/s.ha;

Input Data Table C.
SYSTEM PERFORMANCE ASSESSMENT: ADEQUACY - based on 'Cropped Area' data

SYSTEM (DI) NAME:

POLAWIJA RELATIVE AREA CROPPED	Inp/ Est	YEAR (-3) 199... Season 1	Season 2	Season 3	CG	YEAR (-2) 199... Season 1	Season 2	Season 3	CG	YEAR (-1) 199... Season 1	Season 2	Season 3	CG
DESIGNED (or ESTIMATED)													
REQUESTED													
PLANNED													
STANDARD													
ACTUAL													
ACTUAL/STANDARD													

Note: Season 1 (Wet Season) results disregarded for assessment of Irrigation Water Supply System due to contribution of high rainfall

DISTRIBUTION OF ACTUAL/STANDARD FROM SEASONS 2 AND 3 OVER YEARS (-3) TO (-1):

MEASURE	VALUE
MEAN	
STANDARD DEVIATION	
COEFFICIENT OF VARIATION	
PERFORMANCE BAND (1-4)	

PERFORMANCE BAND DEFINITION		
	MEAN IN RANGE	
STD. DEVIATION IN RANGE		
	1	2
	3	4

ASSET SURVEY

Form C for Canal Sections

C

System Details

Cabang Dinas ____________________

Ranting Dinas ____________________

Name of DI ____________________

DI Reference No. ____________________

Data Collected

By (Name) ________________

On (Date) ___◊___◊___

Asset Details

Asset Ref. No. ________________

Area Served (ha) __________ Canal Name ____________________________

Design Flow (l/s) ______ Reported Age (years): 0-5☐ 5-10☐ 10-20☐ 20+☐

Type of Canal: Primary ☐ Secondary ☐ Supplementary ☐

Topography type: Canal in cut ☐ Canal in fill ☐ Canal on contour ☐

Lined surfaces: Left bank ☐ Right bank ☐ Bed ☐

Lining type: Insitu concrete ☐ Concrete Tile ☐ Masonry ☐ Earth/unlined ☐

Reach distinguished by:

Section change ☐ Lining change ☐ Topography change ☐

Between structures ☐ Other (describe): _________________________

Upstream Location Marker (km) _______ Length of reach (km) ________

Component Condition

	General Condition Grade				Worst Case Local			
	1	2	3	4	1	2	3	4
Left Embankment	☐	☐	☐	☐	☐	☐	☐	☐
Right Embankment	☐	☐	☐	☐	☐	☐	☐	☐
Channel Lining	☐	☐	☐	☐	☐	☐	☐	☐
Channel Cross-section	☐	☐	☐	☐	☐	☐	☐	☐

Asset Serviceability

Overall Serviceability Grade

1	2	3	4
☐	☐	☐	☐

Notes:

<u>ASSET CONDITION AND SERVICEABILITY GRADES</u> - CANALS

COMPONENTS	CONDITION GRADES (implying COST)			
	GRADE 1	GRADE 2	GRADE 3	GRADE 4
Embankments Channel Lining (Note lining type) Channel cross-section	**GOOD**: Structurally sound with no deformation of dimensions or profile. Well maintained with little or no signs of deterioration. Bed clear of weeds and having minor or no silt deposition.	**FAIR**: Generally sound but with some deterioration of structure and/or dimensional deformation. Needing maintenance attention with a review of condition in the medium term. **- OR -** Structural and dimensional condition as (1) but with weeds and/or silt significantly affecting functionality.	**POOR**: Significant deterioration of structure and/or dimensional deformation, requiring urgent corrective work. **- OR -** Structural and dimensional condition worse than (1) with weeds and/or silt significantly affecting functionality.	**BAD**: Serious structural problems causing actual or imminent collapse and requiring partial or complete reconstruction.

<u>General, local worst-case and overall condition scores</u>
Determine scores for general (typical) condition and also for worst case local condition. Where worse case local condition is two or more grades below the general score, then overall condition shall be given as one grade less than the assessed general score. Otherwise the overall condition shall be equal to the assessed general score.

FUNCTIONS	SERVICEABILITY GRADES (implying PRIORITY)			
	GRADE 1	GRADE 2	GRADE 3	GRADE 4
<u>Hydraulic</u>: To pass the design flow safely. **<u>Operations</u>:** Not applicable.	**FULLY FUNCTIONAL**: Apparently properly designed and constructed with capacity to pass the design flow safely and having no deposition or service problems.	**MINOR FUNCTIONAL SHORTCOMINGS**: Normally able to pass the required flows but performance likely to be unsatisfactory under extreme conditions of demand or climate. Deficiencies may be due to design or construction inadequacies, insufficient maintenance or due to the presence of weeds and/or silt.	**SERIOUSLY REDUCED FUNCTIONALITY**: Ability of Asset to pass required flows seriously impaired through deficiencies in design, construction or maintenance, or due to the presence of weeds and/or silt. (Likely to have a significant detrimental effect on System Performance.)	**CEASED TO FUNCTION**: Substantial (or complete) loss of capacity to pass the design flows safely for whatever reason.

ASSET SURVEY

Form HR for Head Regulator

HR

System Details

Cabang Dinas ____________________

Ranting Dinas ____________________

Name of DI ____________________

DI Reference No. ____________________

Data Collected

By (Name) ________________

On (Date) ___◊___◊___

Asset Details

Area Served (ha) __________ Asset Ref. No. ________________

Location (km) __________ Canal Name ____________________________

Offtake from: Headworks ☐ Primary canal ☐ Secondary ☐ Supplementary ☐

Reported Age (years): 0-5☐ 5-10☐ 10-20☐ 20+☐

Channel width at control section (m) ______ Design Flow (l/s) _______

Control section type: Gate(s)☐ Fixed Crest☐ Stop Logs☐ Flume ☐

Component Condition

	General Condition Grade			
	1	**2**	**3**	**4**
Structure	☐	☐	☐	☐
Control Section	☐	☐	☐	☐
Upstream Wingwalls	☐	☐	☐	☐
Downstream Wingwalls	☐	☐	☐	☐
Gauges	☐	☐	☐	☐
Bench Mark	☐	☐	☐	☐
Superstructure	☐	☐	☐	☐
Notice Board	☐	☐	☐	☐

Asset Serviceability

Overall Serviceability Grade

1	2	3	4
☐	☐	☐	☐

Notes:

<u>ASSET CONDITION AND SERVICEABILITY GRADES</u> - HEAD REGULATOR

COMPONENTS	CONDITION GRADES (implying COST)			
	GRADE 1	GRADE 2	GRADE 3	GRADE 4
Structure Upstream Wingwalls Downstream Wingwalls Superstructure Notice Board Control Section (note type)	**GOOD**: Structurally sound with no deformation of dimensions or profile. Well maintained with little or no signs of deterioration. Upstream and downstream bed having only minor, or no, silt deposition and clear of debris.	**FAIR**: Generally sound but with some deterioration of structure and/or dimensional deformation. Needing maintenance attention with a review of condition in the medium term. **- OR -** Structural and dimensional condition as (1) but with silt and/or debris significantly affecting functionality.	**POOR**: Significant deterioration of structure and/or dimensional deformation, requiring urgent corrective work. **- OR -** Structural and dimensional condition worse than (1) with silt and/or debris significantly affecting functionality.	**BAD**: Serious structural problems causing actual or imminent collapse and requiring partial or complete reconstruction.
Gauge(s)	Gauges securely fixed and readable	Gauges generally satisfactory but may be difficult to read under some flow conditions	No proper readable gauge but level mark present from which to measure	No gauge or level mark available **OR** unreadable **OR** unreliable
Bench mark	Bench mark secure, apparently undamaged and readable	Bench mark condition generally as (1) but difficult to read	Bench mark present but of uncertain reliability	Bench mark missing, damaged or unreadable

FUNCTIONS	SERVICEABILITY GRADES (implying PRIORITY)			
	GRADE 1	GRADE 2	GRADE 3	GRADE 4
<u>Hydraulic</u>: To pass the design flow safely. **<u>Operations</u>:** To control flow across the required range AND To allow measurement of flow	**FULLY FUNCTIONAL**: Apparently properly designed and constructed with capacity to pass the design flow safely AND fully capable of being operated to control flow across the desired range AND allowing measurement of flow by means of its own components or an adjacent measuring structure. Performance unaffected by silt or debris.	**MINOR FUNCTIONAL SHORTCOMINGS**: Normally able to pass the required flows and capable of being operated to control flow in a measured manner but performance likely to be unsatisfactory under extreme conditions of demand or climate. Deficiencies may be due to design or construction inadequacies, insufficient maintenance, measuring devices which are difficult to read or due to the presence of silt and/or debris.	**SERIOUSLY REDUCED FUNCTIONALITY**: One or more of the three defined functions seriously impaired through deficiencies in design, construction or maintenance, or due to the presence of weeds and/or silt and/or debris. (Likely to have a significant detrimental effect on System Performance.)	**CEASED TO FUNCTION**: Complete loss of one or more of the three functions or serious reduction of all three for whatever reason.

ASSET SURVEY
Form W for Weirs

W

System Details
Cabang Dinas ____________________
Ranting Dinas ____________________
Name of DI ____________________
DI Reference No. ____________________

Data Collected
By (Name) ________________
On (Date) ___◊___◊___

Asset Details
Area Served (ha) __________ Asset Ref. No. ________________
River Name ____________________________ Design Flow (l/s) ______
Type of Weir: Fixed Crest☐ Step Weir☐ Barrage☐
Crest Height (m) _______ Crest Width (m) _______
Reported Age (years): 0-5☐ 5-10☐ 10-20☐ 20+☐
Location: (latitude ° ' ") _______ (longitude ° ' ") _______

Component Condition

	General Condition Grade 1	2	3	4
Weir Crest/Main Body	☐	☐	☐	☐
Upstream Abutments/Walls	☐	☐	☐	☐
Downstr. Abutments/Walls	☐	☐	☐	☐
Downstream Stilling basin	☐	☐	☐	☐
Offtake structure(s)	☐	☐	☐	☐
Offtake gate(s) + mechanism	☐	☐	☐	☐
Sluice gate(s) + mechanism	☐	☐	☐	☐
Superstructure elements	☐	☐	☐	☐

Asset Serviceability
Overall Serviceability Grade

1	2	3	4
☐	☐	☐	☐

Notes:

Underwater elements assessed by:
Exposing ☐ Reports/estimation ☐

Appendix A2

Examples of Standard Output Forms

Output Table 1.
ASSET STOCK AND CONDITION PROFILE - Irrigation Water Service

ASSET TYPE & DESCRIPTION	'I' or 'C'	EXTENT OF ASSET STOCK BY SIZE BAND								VALUE (MEA)		ASSET CONDITION BY % GROSS MEA					ASSET SERVICEABILITY BY % GROSS MEA					ASSET IMPORTANCE BY % GROSS MEA				
		Units	Band 1	Band 2	Band 3	Band 4	Band 5	Total	CG	GROSS Rp x10^9	NET Rp x10^9	Grade 1	Grade 2	Grade 3	Grade 4	CG	Grade 1	Grade 2	Grade 3	Grade 4	CG	Band 1	Band 2	Band 3	Band 4	CG
Group 1 - WATER CAPTURE																										
River Offtake Weirs.																										
Dams and Impounding Reservoirs.																										
Groundwater Abstraction Wells.																										
Group 2 - CONVEYANCE																										
Canals.																										
Hydraulic Structures.																										
Supplementary Structures.																										
Group 3 - OPERATIONS (CONROL) FACILITIES																										
Head Regulator.																										
Cross Regulator.																										
Measuring Structure.																										
Group 4 - MANAGEMENT AND GENERAL																										
Access Roads.																										
Offices and Laboratories.																										
Depots and Workshops.																										
Field Officers Quarters.																										
Vehicles and Plant.																										
'Information Technology' Systems.																										

Note: Other forms may be developed to cover Drainage and any other identified 'Function' of the Irrigation Service

Output Table 1a.
HUMAN RESOURCE QUALIFICATION & TRAINING PROFILE

STAFF FUNCTIONAL DESCRIPTION	'I' or 'C'	NUMBER OF STAFF BY AGE BAND								ACCUMULATED ANNUAL STAFF COSTS		'HIGHEST QUALIFICATION' BAND BY % SALARY BILL						'MOST RECENT TRAINING' BAND BY % SALARY BILL				
		Units	Band 1	Band 2	Band 3	Band 4	Band 5	Total	CG	SALARIES Rp $x10^9$	TRAINING Rp $x10^9$	Band 1	Band 2	Band 3	Band 4	Band 5	CG	Band 1	Band 2	Band 3	Band 4	CG
Group 1 - STRATEGIC MANAGEMENT																						
Personal budget authority > Rp $x10^9$ per annum																						
Personal budget authority > Rp $x10^8$ pa & < 10^9																						
Group 2 - OPERATIONAL STAFF																						
Field Operations staff																						
Field Maintenance staff																						
Field Operations Management (not incl. in G1)																						
Group 3 - TECHNICAL SUPPORT STAFF																						
Section Office O&M staff																						
Regional Office O&M staff																						
Regional Office Design staff																						
Workshop and Plant operators																						
'Information Technology' support staff																						
Group 4 - ADMINISTRATION & OTHER STAFF																						
Personnel/ Training staff																						
Transport staff																						
Administration & Secretarial staff - Office																						
ditto - Field																						
Accounting staff																						

Output Table 2.
<u>UNIT COSTS: by Modern Equivalent Asset (MEA) Value and by Rehabilitation Activities</u> (Rp x 10^9)

UNIT COST ITEM			NEW CONSTRUCTION MEA VALUE								REHABILITATION COSTS BY ACTIVITY									
River Offtake Weir	'I'	Unit	Upland Rural site	%	Lowland Rural site	%	'Urban' Location	%		%	Repair wetted upstream elements	%	Repair wetted downstream elements	%	Abutment repairs above water level	%	Renew Sluice/ offtake gate(s)	%	Rebuild Weir Wall	%
Fixed crest.																				
Step weir.																				
Barrage.																				
Head/Cross Regulator	'I'	Unit	Remote Location	%	Easy urban access	%		%		%	Re-form control sectn	%	Replace and recalibrate gauges	%	Re-line wetted x-section adj	%	Renew gates	%		%
Fixed weir.																				
Gated regulator.																				
Stop log.																				
Orifice.																				
Measuring Structure	'I'	Unit	Remote Location	%	Easy urban access	%		%		%	Re-form control sectn	%	Replace and recalibrate gauges	%	Re-line wetted x-section adj	%		%		%
Crump weir.																				
Partial flume.																				
Chippoletti.																				
Thompson.																				
Romajn.																				
Canal	'I'	Unit	In rock	%	Firm ground	%	In clay	%	Weak ground	%	Reshaping	%	Lining upgrade	%	Embankment upgrade	%	Sediment removal	%	Weed clearance	%
Cast insitu concrete lining.																				
Concrete tile/slab lining.																				
Masonry lining.																				
Unlined or earth-lined.																				

<u>Notes</u>: Extend for other Asset Types. Confidence Grades ???

Output Table 3a.
INVESTMENT ANALYSIS BY ASSET TYPE & IMPORTANCE- Irrigation Water Service

DESCRIPTION	'I' or 'C'	Units	INVESTMENT - YEARS 1 to 5 Size Band 1	Size Band 2	Size Band 3	Size Band 4	Size Band 5	Total for Years 1 to 5	Var %	5-YEARLY TOTALS YEARS 6 TO 10	Var %	YEARS 11 to 15	Var %	YEARS 16 to 20	Var %
INVESTMENTS BY ASSET TYPE IN EACH PERIOD															
Group 1 - WATER CAPTURE															
River Offtake Weirs.		Rp $x10^9$													
Dams and Impounding Reservoirs.		Rp $x10^9$													
Groundwater Abstraction Wells.		Rp $x10^9$													
Group 2 - CONVEYANCE															
Canals.		Rp $x10^9$													
Hydraulic Structures.		Rp $x10^9$													
Supplementary Structures.		Rp $x10^9$													
.															
Group 3 - OPERATIONS (CONROL) FACILITIES															
Head Regulators.		Rp $x10^9$													
Cross Regulators.		Rp $x10^9$													
Measuring Structures.		Rp $x10^9$													
Group 4 - MANAGEMENT AND GENERAL															
Access Roads.		Rp $x10^9$													
Offices and Laboratories.		Rp $x10^9$													
Depots and Workshops.		Rp $x10^9$													
Field Officers Quarters.		Rp $x10^9$													
Vehicles and Plant.		Rp $x10^9$													
'Information Technology' Systems.		Rp $x10^9$													
INVESTMENT BY ASSET IMPORTANCE BAND															
Importance Band 1.		Rp $x10^9$													
Importance Band 2.		Rp $x10^9$													
Importance Band 3.		Rp $x10^9$													
Importance Band 4.		Rp $x10^9$													
Importance Band 5.		Rp $x10^9$													

Output Table 3b.
INVESTMENT ANALYSIS BY PURPOSE - Irrigation Water Service

CAPEX PURPOSE CATEGORY	'I' or 'C'	Units	INVESTMENT - YEARS 1 to 5										5-YEARLY TOTALS							
			YEAR 1	Var %	YEAR 2	Var %	YEAR 3	Var %	YEAR 4	Var %	YEAR 5	Var %	YEARS 1 TO 5	Var %	YEARS 6 to 10	Var %	YEARS 11 to 15	Var %	YEARS 16 to 20	Var %
Maintain Assets.		$Rpx10^9$																		
Preserve System Performance.		$Rpx10^9$																		
Improve System Performance.		$Rpx10^9$																		
New Development/Growth.		$Rpx10^9$																		
INVESTMENT TOTALS		$Rpx10^9$																		

Output Table 3c.
OPERATIONAL EXPENDITURE ADJUSTMENTS DUE TO INVESTMENT - Irrigation Water Service

OPEX PURPOSE	'I' or 'C'	Units	INVESTMENT - YEARS 1 to 5										5-YEARLY TOTALS							
			YEAR 1	Var %	YEAR 2	Var %	YEAR 3	Var %	YEAR 4	Var %	YEAR 5	Var %	YEARS 1 TO 5	Var %	YEARS 6 to 10	Var %	YEARS 11 to 15	Var %	YEARS 16 to 20	Var %
Growth Related.		$Rpx10^9$																		
OPEX increases due to other CAPEX.		$Rpx10^9$																		
OPEX savings due to CAPEX.		$Rpx10^9$																		
Routine Maintenance Improvements.		$Rpx10^9$																		
OPEX TOTALS		$Rpx10^9$																		

Output Table 4.
ACTIVITIES REPORT - Irrigation Water Service

DESCRIPTION	'I' or 'C'	Units	ANNUAL PROFILE - YEARS 1 to 5										5-YEARLY TOTALS					
			YEAR 1	C G	YEAR 2	C G	YEAR 3	C G	YEAR 4	C G	YEAR 5	C G	YEARS 6 to10	C G	YEARS 11 to 15	C G	YEARS 16 to 20	C G
ASSET STOCK at 1st OCTOBER (each year)																		
Total no. of River Offtake Weirs.																		
Totall length of Primary & Secondary Canals.																		
Total length of Unlined Primary & Secondary Canals.																		
Total length of Canals requiring Rehabilitation.																		
Total no. of Tertiary offtakes served.																		
PLANNED ACTIVITIES DURING EACH PERIOD																		
1.1 RIVER OFFTAKE WEIRS																		
Repair wetted upstream elements.																		
Repair wetted downstream elements.																		
Repairs to Abutments above water level.																		
Renew sluice / offtake gate(s).																		
Rebuild weir wall.																		
2.1 CANALS																		
Reshape Canal.																		
Upgrade Canal Lining.																		
Upgrade Embankments.																		
Remove Sediment.																		
Clear Weeds.																		
2.2 HYDRAULIC & SUPPLEMENTARY STRUCTURES																		
Reconstruct.																		
Hydraulic improvements (eg. Cleaning).																		
Refurbish.																		
3.1 HEAD/CROSS REGULATORS & MEASURING STRUCTURES																		
Reconstruct.																		
Refurbish.																		
4.1 ACCESS ROADS																		
Reconstruct.																		
Resurface.																		
Reinstate verges and drainage.																		

Output Tables 5a, 5b and 5c.

5a: BENEFITS REPORT: WATER DELIVERED/ ADEQUACY - based on “Polawijo Relative Area” Cropped

“Polawijo Relative Area” Cropped	PAST YEARS												TARGET YEARS											
	YEAR (-3)			CG	YEAR (-2)			CG	YEAR (-1)			CG	YEAR +1 to +5			CG	YEAR +6 to +10			CG	YEAR +11 to +20			CG
	S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3	
Total Standard (ha)																								
Total Actual (ha)																								
Difference (ha) - due to assets																								
- for other reasons																								
- Total																								

5b: BENEFITS REPORT: WATER DELIVERED/ EQUITY - based on Coef. of Var. of crop PRA across each system

Σ Coef. of Var. of PRA cropped across all systems	PAST YEARS												TARGET YEARS											
	YEAR (-3)			CG	YEAR (-2)			CG	YEAR (-1)			CG	YEAR +1 to +5			CG	YEAR +6 to +10			CG	YEAR +11 to +20			CG
	S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3	
Standard (less than)																								
Aggregated Actual																								
Total Difference																								
- % due to assets																								
- % for other reasons																								

5c: BENEFITS REPORT: CONDITION PROFILE OF ASSETS - Indicative of maintenance investment activity

% by Gross MEA Value of Assets in each Grade	PAST YEARS				TARGET YEARS					
	5 YEARS AGO	CG	CURRENT YEAR	CG	YEARS +1 to +5	CG	YEARS +6 to +10	CG	YEARS +11 to +20	CG
Condition Grade 1										
Condition Grade 2										
Condition Grade 3										
Condition Grade 4										

Output Table 6.

DEPRECIATION CATEGORIES: ASSUMED ASSET LIVES BY ASSET TYPE

Asset Group	Service(s)	Characteristic	Asset Type Description	'I' or 'C'	Assumed Asset Life (years)
Specialised Operational Assets	Irrigation Water Supply	Structures	River Offtake Weirs Dams and Impounding Reservoirs Groundwater Abstraction Wells Canals Other Hydraulic Structures Head/ Cross Regulators Measuring Structures		
		Plant & Machinery	Pumps Gates Measuring Gauges Instrumentation		
Other Assets with Non-specialised Operational Properties	ALL	Structures	Access Roads Offices and Laboratories Depots and Workshops Field Officers Quarters		
		Plant & Machinery	Bicycles Motor Bicycles Cars and Light Vehicles Trucks Mobile Plant Communications Systems Computer Systems		

Appendix A3

Data Transformation Requirements
and
Database Architecture

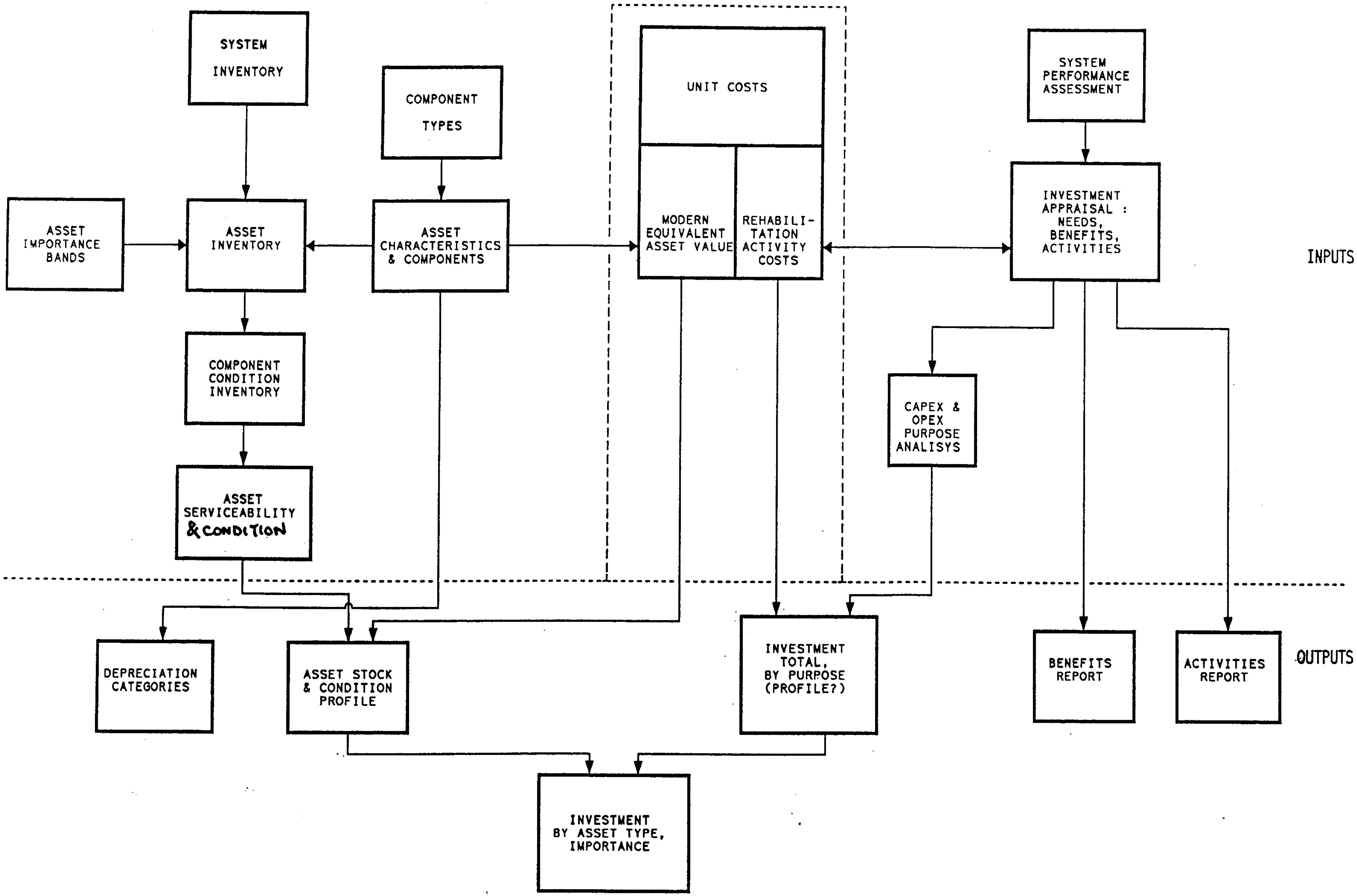
ASSET MANAGEMENT PLAN - DATA TRANSFORMATION

Summary of inputs required at the sample system level which will be used for statistical aggregation in order to develop the output forms for an irrigation Asset Management Plan.

OUTPUT FORM		DATA INPUTS		OTHER INPUTS		
ITEM	INPUT SOURCES	REF.	ITEM	REF.	ITEM	SOURCE
ASSET STOCK						
Asset extent	1+2+3+A+B	1	Asset + Reference	A	Asset Types	Definition
Gross value by asset type	Asset extent +C	2	Asset Type	B	Size bands	Definition
Nett value by asset type	From condition profile (see below)	3	Size (or size band)	C	Cost models (for value)	Studies
Condition profile by asset type by value	Gross value +5+D+E+F	4	Areas 1&2 (for importance)	D	Components for each asset type	Definition
Serviceability profile by asset type by value	Gross value +6+G+H+I	5	Condition of components	E	% asset value in each component	Studies
Importance profile by asset type by value	Gross value +4+J	6	Service grade of functions	F	Condition grades	Definition
UNIT COSTS						
Unit cost tables	C+K	7	Total investment	G	Functions of each asset type.	Definition
INVESTMENT ESTIMATES						
Investment - Total	7 (drawing on C+K+9)	8	Investment by purpose	H	Serviceability grades	Definition
Investment - by Purpose Classification	8+L (with total for 8 =7)	9	Activities by Category	I	Function aggregation rules	Definition
Investment - by Asset Type	7 split by type defined in A	10	Benefits	J	Importance rules	Definition
Investment - by Importance	7 split by type defined in J			K	Cost Models (for rehabilitation)	Studies
Investment - Profile	7+ “rules” including use of input O			L	Purpose classifications	Definition
BENEFITS REPORT						
Benefits list	10+N			M	Activity categories	Definition
ACTIVITY REPORT						
Activities list	9+M			N	Benefit classifications	Definition
DEPRECIATION CATEGORIES						
Assumed asset life by asset type	A+O			O	Asset lives	Definition

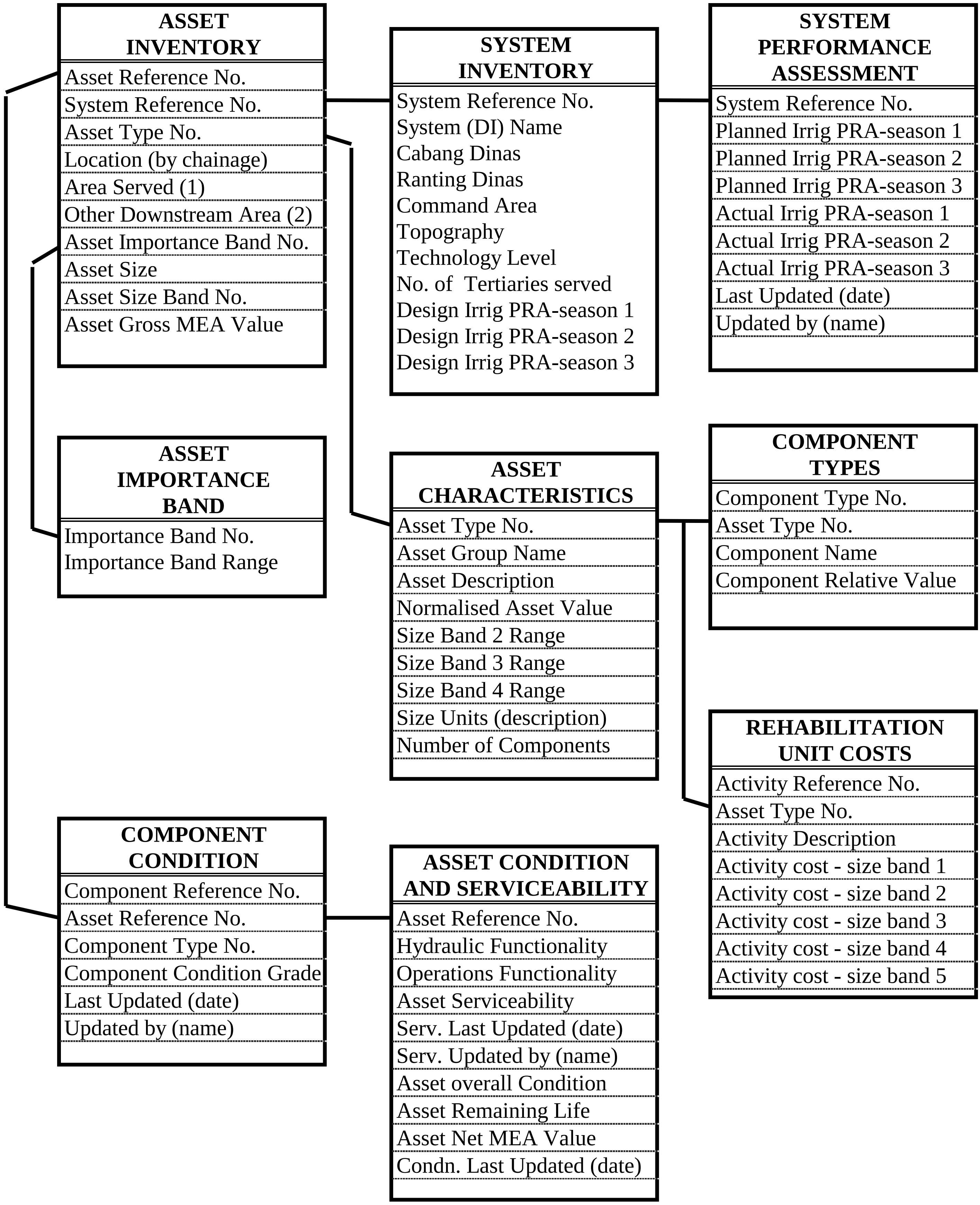
Notes:

1. Wherever a ‘definition’ is stated this will be trialled in the field and in consultation with local staff
2. Confidence grades will be attached to all the ‘data’ and to any other inputs where confidence grades are appropriate e.g. cost models



ASSET MANAGEMENT PLAN - DATA TRANSFORMATION

ASSET MANAGEMENT PLAN - RELATIONAL DATABASE DESIGN



ASSET MANAGEMENT PLAN - INPUTS AND OUTPUTS

Inputs to the AMP that need to be collected are:

<u>Asset Survey - Extent, Size, Importance, Condition and Serviceability</u>

- the *number* of assets in the system by each *type* (eg. Weir; Measuring-structure; Cross-regulator etc)
- a measure of the *Size* of each asset by *size band*
- the *Importance* of each asset (eg. by area served)
- the *Condition* (1-4) of each asset by an aggregation of its *components* (NOT its *Serviceability*)
- the *Serviceability* (1-4) of each asset by its *Hydraulic capacity* and its *Operability* (NOT its *Condition*)

<u>System Performance Assessment</u>

- a measure of *Level of Service* achieved against a *Standard* (by *Reliability*, *Adequacy* and *Equity* Performance Indicators based on "cropped area".

<u>System Performance Survey</u>

- a field survey of the reasons for *System* failure to perform
- rehabilitation needs assessment

<u>Cost Model</u>

- a breakdown of rehabilitation costs by *Activity categories*
- a breakdown of asset value by *Asset type*
- the relationship between asset value and *Asset size*
- a proportional disaggregation the value of each asset to its various *Components*

Outputs required from the AMP (which dictate the form of data presentation) are:

<u>Asset Stock</u>

- *extent* of assets by *category* and *size band* and their *value*, both gross and nett modern equivalent asset (MEA)

<u>Investment Estimates (OPEX - operating and CAPEX - capital)</u>

- total investment in five year period bands
- total investment in five year period bands by purpose category (ie. for *maintenance* or for *improvement*)
- investment by each *asset type* category
- investment by each *asset importance* category

<u>Activity Report</u>

- list rehab/improvement activities by category (eg. canal relining; weed removal etc)
- ditto by five year period bands
- activities by each *asset importance* category

<u>Benefits Report</u>

- total benefit in terms of system performance measures
- ditto by five year period bands

<u>Depreciation Categories</u>

- assumed *asset life* by each *asset type* category

<u>Unit Costs</u>

- unit costs for key activities

	COMPONENTS OF THE ASSET MANAGEMENT PLAN (AMP)								
WHAT THEY ARE AND WHY WE WANT THEM	ASSET EXTENT	ASSET VALUE	ASSET CONDITION	ASSET SERVICE-ABILITY	ASSET IMPORTANCE	INVESTMENT NEEDS	INVESTMENT PURPOSE	INVESTMENT ACTIVITIES	INVESTMENT BENEFITS
1. What do we mean ?	What is the extent of the asset stock	What is the current replacement cost of the assets (gross) and what is their depreciated value (net)	This is a statement of the overall physical condition of the assets reported under asset stock	This is a statement of how well each asset is performing its required function under the two headings of Hydraulic and Operational functionality	This is a statement of how important assets are in terms of their impact on other parts of the system. e.g. an asset at the top end of the system is generally more important than one at the bottom end because fewer hectares depend on the latter's correct operation	The amount of money needed to be spent over the planning period to achieve the benefits that will arise (and which have been defined)	For what purpose is the investment being made	What tasks are going to be undertaken as a result of the investment i.e. the level of physical activity	What is the benefit that will arise as the result of making any investment
2. Why is it important ?	This is essentially good housekeeping i.e. you ought to know what you own and operate. It is also a prerequisite to the valuation exercise and could help in defining what you are handing over or even privatising	It is important for financial modelling e.g. to set up an opening balance sheet for an irrigation company and determine the depreciation component of the P&L account. It may also be important to determine rates of return on investment if the companies were privatised	It is important because it will help define investment needed for maintenance of assets and the timing thereof (when linked to average asset life). It can also be used to define the net asset valuation. Finally it can be monitored over time to ensure that assets are not being stripped.	It is important because it will help define investment needed to maintain the functionality of assets. It too can be monitored over time to ensure that assets are not being stripped.	It is important because we could undertake scenario analyses with respect to investment in different importance bands. If money was constrained we could investigate how to spend it in relation to the importance of the assets being refurbished/ maintained	It helps set budgets for future years	It is important to know whether money is being spent on maintenance or improvements. You could envisage a time when 'improvement' expenditure would be paid for by those that benefit from the improvement.	Important in order to get a feel for what is going to be undertaken. The full extent of the activities may be a limiting factor on the investment at a any time. Also can be used as a secondary measure of performance (although it is an input rather than an output measure)	Benefits are an output from the investment (=input). It is important to measure both the inputs and the outputs
3. How is it measured?	We measure it under a set of ASSET CATEGORIES and in different SIZE BANDS	We measure it at current prices in local currency. Usually this will be achieved using cost models.	It is measured by reference to a standard set of condition grade definitions, allocated to each asset and then normalised by reference to asset value.	Measured by reference to a standard set of serviceability grade definitions under each of HYDRAULIC and OPERATIONAL functionality. As part of the trial rules will have to be developed for how to combine these.	System of measurement being investigated as part of the trial.	Measure it in a range of ways to suit the needs of the planners. This can be at the top level i.e. total only , or at lower levels e.g. by asset category or importance. It will be presented as a total and over each time horizon.	Measured under MAINTENANCE or IMPROVEMENT headings at the moment using the rule of 'Prime Purpose' ie what is the main/prime reason for making that investment and then ignoring secondary benefits that may arise under other purpose headings	Measured under a range of activity categories to be defined during the trial	Improvements in adequacy, equity and condition indicators

Appendix A4

Examples of Data Collected in the Field Trial

Input Data Table A.

STRATIFICATION AND NORMALISATION DATA (for ALL system in the AMP)

Partial I No. _7_ of ___	Technology Level :	Technical	Semi-Tech. X	Non-Tech.		Topography Type :	Flat As shown	Steep/Undulating

SYSTEM (DI)			STRATIFICATION DATA							NORMALISATION DATA						
Name	ref. no.	Cabang Dinas Name	Water Availability	Surjan (Mounding) Present	Topography Undulating or Flat	Years Since Last Major Investment	Management By	ISF/WUA Fee Recovery	Local Family Income Level	Command Area (ha)	Irrigated Area (ha)	No. of Tertiaries	Total Length of Prim. & Sec. Canal (km)	Peak System Inflow from River (m3/sec)	No. of Structures Measuring Instrument	Other Structures
Tambak I	14	Bantul	Var	No	Flat	>5	Joint				138		4.648	205	0	19
Sumberan	15	Bantul	Good	No	Flat	>5	Joint				142		3.397	159	1	21
Kenalan	16	Bantul	Var	No	Flat	>5	Joint				261		3.629	93	13	31
Tengah	17	Bantul	Good	No	Flat	>5	Joint				187		5.865	210	12	19
Tanjung	18	Bantul	Var	No	Flat	>5	Joint				776		16.182	1028	48	112
Bayen	19	Bantul	Var	No	Flat	>5	Joint				128		1.32	144	14	21
Merdico	20	Bantul	Var	No	Flat	>5	Joint				571		7.601	1110	19	48
Gamping	22	Bantul	Var	No	Flat	>5	Joint				530		9.727	604	12	29
Kadisono	23	Bantul	Var	No	Flat	<=5	Joint				530		7.803	813	1	23
Ewon	24	Bantul	Var	No	Flat	<=5	Joint				550		6.585	711	1	17
Dadapan	25	Bantul	Var	No	Und	>5	Joint				52		0	77	1	0
Kucir	26	Bantul	Good	No	Und	>5	Joint				100		1.432	150	1	25
Bangeran	29	Bantul	Var	No	Und	>5	Joint				31		0	21	0	0
Mrican	30	Bantul	Var	No	Und	>5	Joint				144		1.825	125	1	15
Grembul	4	Kulon Progo	Var	No	Und	>5	WUA				31		0	35	1	3
Penkol	5	Kulon Progo	Var	No	Und	>5	WUA				34		0	100	1	1
Penjalin	14	Kulon Progo	Var	No	Und	>5	Joint				380		8.423	956	1	93
Jelog	15	Kulon Progo	Var	No	Und	>5	WUA				94		0	113	1	1
Munggang	16	Kulon Progo	Var	No	Und	<=5	Joint				205		3.337	0	0	33
Papah	17	Kulon Progo	Var	No	Und	<=5	Joint				925	24	11.605	1187	6	122
Drigul	18	Kulon Progo	Var	No	Und	>5	Joint				101		0	0	0	4
Niten	20	Kulon Progo	Var	No	Und	>5	Joint				129		1.573	180	2	25
Pengung	21	Kulon Progo	Var	No	Und	>5	WUA				32		0	80	0	1
Ciki	22	Kulon Progo	Var	No	Und	>5	Joint				40		0	100	0	1
Banjaran	23	Kulon Progo	Var	No	Und	>5	WUA				29		0	135	1	1
Sumitro	24	Kulon Progo	Var	No	Und	>5	Joint				447		5.307	407	3	42
Plelen	26	Kulon Progo	Var	No	Und	>5	Joint				114		4.382	300	7	53
Klampok	27	Kulon Progo	Var	No	Und	>5	WUA				56		0	0	0	1
Bogor	28	Kulon Progo	Var	No	Und	>5	WUA				85		0	0	1	1
Simo	78	Gunung Kidul		No	Und	<=5	Joint				1247	68	17.78	1400	6	128

SYSTEM PERFORMANCE ASSESSMENT - WATER DELIVERY

PRIMARY AND SECONDARY CANALS - System DI Papah

Canal Name		Primary Papah	Secondary Cangkring	Secondary Kongklangan	Kenteng Kiri	Kenteng Kanan
Jun-93	1-15	252.53	121.20	111.73	0.00	0.00
	16-30	0.00	0.00	0.00	0.00	0.00
Jul-93	1-15	299.00	163.53	151.67	0.00	0.00
	16-31	251.50	192.94	55.00	0.00	0.00
Aug-93	1-15	80.07	0.00	0.00	0.00	0.00
	16-31	131.19	0.00	0.00	0.00	0.00
Sep-93	1-15	601.93	150.60	265.73	117.20	82.20
	16-30	903.40	372.67	369.93	129.60	114.67
Oct-93	1-15	955.67	376.07	455.73	249.60	195.47
	16-31	1,249.06	480.88	572.20	166.13	117.73
Nov-93	1-15	1,409.00	570.40	612.13	118.53	192.60
	16-30	1,264.00	547.20	526.27	169.27	124.07
Dec-93	1-15	1,046.33	445.47	463.67	165.47	113.87
	16-31	992.93	385.19	435.56	160.75	135.81
Jan-94	1-15	774.69	336.00	339.87	71.80	51.40
	16-31	890.87	317.88	329.25	10.56	0.00
Feb-94	1-15	1,067.40	459.60	457.60	65.27	82.67
	16-31	942.69	388.00	367.38	77.31	120.47
Mar-94	1-15	717.07	259.07	295.87	70.67	52.47
	16-31	1,153.06	491.25	503.50	129.13	93.13
Apr-94	1-15	1,200.73	418.00	439.53	116.60	89.73
	16-30	1,119.87	468.33	498.80	135.73	85.80
May-94	1-15	1,135.27	281.00	422.80	141.40	114.93
	16-31	845.31	289.81	349.13	75.25	64.00
Max. flow in the year (l/s)		1,409.00	570.40	612.13	249.60	195.47
Max. Design flow (l/s)		1,530.00	670.00	830.00	250.00	250.00
Ratio Actual/Design		0.92	0.85	0.74	1.00	0.78

No.	Tertiary	Jun 1, 1993			Jun 2, 1993			Jul 1, 1993			Jul 2, 1993			Ags 1, 1993			Ags 2, 1993		
	Name	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio
1	Wora-wari	0.73	3.56	0.21	0.00	3.56	0.00	4.07	3.56	1.14	0.73	3.56	0.21	0.00	0.00	1.00	0.00	0.00	1.00
2	Blimbing	2.00	22.00	0.09	0.00	22.00	0.00	0.00	19.68	0.00	0.00	19.68	0.00	0.00	0.00	1.00	0.00	0.00	1.00
3	Semen	9.33	15.00	0.62	0.00	15.00	0.00	0.00	17.00	0.00	0.00	17.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
4	Gendingan	0.00	14.28	0.00	0.00	14.28	0.00	0.00	14.27	0.00	0.00	14.27	0.00	0.00	0.00	1.00	0.00	0.00	1.00
5	Gunung Duk		10.50			10.50			11.00			11.00			0.00			0.00	
6	Patuk	0.00	5.25	0.00	0.00	5.25	0.00	0.00	5.25	0.00	0.00	5.25	0.00	0.00	0.00	1.00	0.00	0.00	1.00
7	Ngentakre	0.00	25.00	0.00	0.00	25.00	0.00	0.00	25.62	0.00	0.00	25.62	0.00	0.00	0.00	1.00	0.00	0.00	1.00
8	Klipuh								12.50			12.50			0.00			0.00	
9	Kemendur	23.13	11.25	2.06	0.00	11.25	0.00	0.00	11.25	0.00	0.00	11.25	0.00	0.00	0.00	1.00	0.00	0.00	1.00
10	Pergiwatu	0.00	30.28	0.00	0.00	30.28	0.00	0.00	32.77	0.00	0.00	32.77	0.00	0.00	0.00	1.00	0.00	0.00	1.00
11	Sempu		9.50			9.50			9.50			9.50			0.00			0.00	
12	Kenteng	0.00	4.75	0.00	0.00	4.75	0.00	0.00	4.75	0.00	0.00	4.75	0.00	0.00	0.00	1.00	0.00	0.00	1.00
13	Karongan		12.25			12.25			12.25			12.25			0.00			0.00	
14	Milir	0.00	6.50	0.00	0.00	6.50	0.00	0.00	6.50	0.00	0.00	6.50	0.00	0.00	0.00	1.00	0.00	0.00	1.00
15	Cumetuk		13.75			13.75			11.25			11.25			0.00			0.00	
16	Papah Kar	0.00	10.25	0.00	0.00	10.25	0.00	0.00	10.25	0.00	0.00	10.25	0.00	0.00	0.00	1.00	4.07	0.00	1.00
17	Drigul		11.25			11.25			28.00			28.00			0.00			0.00	

No.	Tertiary	Sep 1, 1993			Sep 2, 1993			Okt 1, 1993			Okt 2, 1993			Nov 1, 1993			Nov, 2 1993		
	Name	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio
1	Wora-wari	17.20	18.27	0.94	29.80	18.27	1.63	29.13	19.90	1.46	13.25	15.43	0.86	19.40	14.71	1.32	12.40	14.71	0.84
2	Blimbing	21.33	98.43	0.22	44.80	98.43	0.46	19.07	109.18	0.17	49.19	85.75	0.57	49.40	80.67	0.61	61.00	80.67	0.76
3	Semen	13.53	95.62	0.14	36.33	95.62	0.38	30.07	95.62	0.31	32.88	72.25	0.46	38.33	72.25	0.53	48.53	72.25	0.67
4	Gendingan	37.87	75.93	0.50	64.40	25.93	2.48	90.60	80.00	1.13	84.19	61.43	1.37	107.33	53.25	2.02	53.27	53.25	1.00
5	Gunung Duk		61.87			61.87			61.87			46.75			41.43			41.43	
6	Patuk	11.33	29.52	0.38	12.80	29.52	0.43	21.60	29.52	0.73	27.50	22.31	1.23	18.40	18.06	1.02	13.07	18.06	0.72
7	Ngentakre	21.27	126.52	0.17	72.80	126.56	0.58	59.33	142.81	0.42	111.75	142.81	0.78	92.60	127.50	0.73	110.00	127.50	0.86
8	Klipuh		70.31			70.31			70.31			70.31			53.12			53.12	
9	Kemendur	33.33	63.27	0.53	67.27	63.27	1.06	99.53	63.27	1.57	105.31	47.81	2.20	78.13	47.81	1.63	25.53	47.81	0.53
10	Pergiwatu	0.00	172.96	0.00	0.00	172.96	0.00	0.00	183.52	0.00	0.00	141.25	0.00	0.00	136.53	0.00	0.00	136.53	0.00
11	Sempu		53.43			53.43			53.43			53.43			38.25			38.25	
12	Kenteng	10.00	26.71	0.37	19.93	26.71	0.75	43.13	26.71	1.61	15.31	26.71	0.57	33.87	21.25	1.59	29.20	21.25	1.37
13	Karongan		68.90			68.90			68.90			52.06			52.06			52.06	
14	Milir	22.13	36.56	0.61	12.60	36.56	0.34	0.00	36.56	0.00	0.00	27.62	0.00	66.27	27.62	2.40	25.87	27.62	0.94
15	Cumetuk		63.27			63.27			63.27			63.27			47.81			47.81	
16	Papah Kar	64.53	36.56	1.77	92.07	36.56	2.52	115.93	56.06	2.07	73.25	47.12	1.55	51.13	38.42	1.33	80.47	38.42	2.09
17	Drigul		157.50			157.50			157.50			119.00			128.56			128.56	

No.	Tertiary	Des 1, 1993			Des 2, 1993			Jan 1, 1994			Jan 2, 1994			Feb 1, 1994			Feb 2, 1994		
	Name	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio
1	Wora-wari	9.07	14.71	0.62	5.69	14.71	0.39	4.60	19.18	0.24	1.06	19.18	0.06	6.80	14.71	0.46	10.92	14.71	0.74
2	Blimbing	58.93	80.67	0.73	19.44	80.67	0.24	4.67	104.68	0.04	34.06	104.68	0.33	55.00	80.61	0.68	29.54	80.67	0.37
3	Semen	43.93	72.25	0.61	19.50	72.25	0.27	2.00	95.62	0.02	27.00	95.62	0.28	47.93	72.25	0.66	22.54	72.25	0.31
4	Gendingan	36.13	53.25	0.68	17.63	53.25	0.33	99.47	9.00	11.05	36.60	9.00	4.07	75.33	53.25	1.41	82.77	53.25	1.55
5	Gunung Duk		41.43			41.43			54.84			54.84			41.43			41.43	
6	Patuk	13.07	18.06	0.72	4.00	18.06	0.22	0.00	23.90	0.00	13.87	23.90	0.58	25.33	18.06	1.40	14.31	18.06	0.79
7	Ngentakre	116.33	127.50	0.91	79.25	127.50	0.62	191.40	28.68	6.67	106.60	28.68	3.72	141.20	127.50	1.11	115.62	127.50	0.91
8	Klipuh		53.12			53.12			70.31			70.31			53.12			53.12	
9	Kemendur	29.00	47.81	0.61	0.00	47.81	0.00	0.00	63.27	0.00	21.73	63.27	0.34	141.20	47.81	2.95	43.08	47.81	0.90
10	Pergiwatu	0.00	136.53	0.00	0.00	136.53	0.00	0.00	178.81	0.00	0.00	178.81	0.00	50.93	136.53	0.37	77.31	136.53	0.57
11	Sempu		38.25			38.25			57.65			57.65			43.56			43.56	0.00
12	Kenteng	23.27	21.25	1.09	16.56	21.25	0.78	11.20	28.12	0.40	0.00	28.12	0.00	13.87	21.25	0.65	27.54	21.25	1.30
13	Karongan		52.06			52.06			68.90			68.90			52.06			52.06	
14	Milir	23.53	27.62	0.85	28.94	27.62	1.05	0.00	36.56	0.00	0.00	36.56	0.00	0.00	27.62	0.00	0.00	27.62	0.00
15	Cumetuk		47.81			47.81			63.27			63.27			47.81			47.81	
16	Papah Kar	38.88	38.42	1.01	33.88	38.42	0.88	10.80	47.30	0.23	20.07	47.36	0.42	18.80	38.42	0.49	48.46	38.42	1.26
17	Drigul		128.56			128.56			170.15			170.15			128.56			128.56	

No.	Tertiary	Mar 1, 1994			Mar 2, 1994			Apr 1, 1994			Apr 2, 1994			Mei 1, 1994			Mei, 2 1994		
	Name	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio	Actual	Planned	Ratio
1	Wora-wari	2.13	14.71	0.15	14.50	14.71	0.99	12.67	14.12	0.90	20.40	14.12	1.44		3.56			3.56	
2	Blimbing	21.40	80.67	0.27	22.06	80.67	0.27	38.60	76.56	0.50	45.87	76.56	0.60		19.69			19.69	
3	Semen	12.87	72.25	0.18	14.88	72.25	0.21	23.53	72.25	0.33	27.20	72.25	0.38		17.00			17.00	
4	Gendingan	32.20	53.25	0.60	35.19	53.25	0.66	43.27	51.77	0.84	35.87	51.77	0.69		12.78			12.78	
5	Gunung Duk		41.43			41.43			41.43			41.43			9.75			9.75	
6	Patuk	13.07	18.06	0.72	13.00	18.06	0.72	14.93	18.06	0.83	8.80	18.06	0.49		4.25			4.25	
7	Ngentakre	60.33	127.50	0.47	103.69	127.50	0.81	105.07	130.62	0.80	166.80	130.62	1.28		98.13			98.13	
8	Klipuh		53.12			53.12			53.12			53.12			53.13			53.13	
9	Kemendur	22.87	47.81	0.48	61.00	47.81	1.28	60.27	47.81	1.26	67.73	47.81	1.42		11.25			11.25	
10	Pergiwatu	79.07	136.53	0.58	129.13	136.53	0.95	131.93	132.71	0.99	135.73	132.71	1.02		2.03			2.03	
11	Sempu		43.56			43.56			43.56			43.56			43.56			43.56	
12	Kenteng	6.07	21.25	0.29	18.88	21.25	0.89	25.00	21.25	1.18	8.13	21.25	0.38		0.00			0.00	
13	Karongan		52.06			52.06			52.06			52.06			0.00			0.00	
14	Milir	0.00	27.62	0.00	0.00	27.62	0.00	0.00	27.62	0.00	0.00	27.62	0.00		0.00			0.00	
15	Cumetuk		47.81			47.81			47.81			47.81			47.80			0.00	
16	Papah Kar	18.00	38.42	0.47	46.50	38.42	1.21	40.20	31.37	1.28	42.07	31.37	1.34		3.75			10.25	
17	Drigul		128.56			128.56			128.56			128.56			128.56			0.00	

ACTUAL WATER DELIVERY (l/s) - Tertiaries with measurement

No.	Tertiary	Jun-93		Jul-93		Aug-93		Sep-93		Oct-93		Nov-93		Dec-93		Jan-94		Feb-94		Mar-94		Apr-94		May-94	
	Name	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	Wora-wari	0.73	0.00	4.07	0.73	0.00	0.00	17.20	29.80	29.13	13.25	19.40	12.40	9.07	5.69	4.60	1.06	6.80	10.92	2.13	14.50	12.67	20.40		
2	Blimbing	2.00	0.00	0.00	0.00	0.00	0.00	21.33	44.80	19.07	49.19	49.40	61.00	58.93	19.44	4.67	34.06	55.00	29.54	21.40	22.06	38.60	45.87		
3	Semen	9.33	0.00	0.00	0.00	0.00	0.00	13.53	36.33	30.07	32.88	38.33	48.53	43.93	19.50	2.00	27.00	47.93	22.54	12.87	14.88	23.53	27.20		
4	Gendingan	0.00	0.00	0.00	0.00	0.00	0.00	37.87	64.40	90.60	84.19	107.33	53.27	36.13	17.63	99.47	36.60	75.33	82.77	32.20	35.19	43.27	35.87		
5	Patuk	0.00	0.00	0.00	0.00	0.00	0.00	11.33	12.80	21.60	27.50	18.40	13.07	13.07	4.00	0.00	13.87	25.33	14.31	13.07	13.00	14.93	8.80		
6	Ngentakrej	0.00	0.00	0.00	0.00	0.00	0.00	21.27	72.80	59.33	111.75	92.60	110.00	116.33	79.25	191.40	106.60	141.20	115.62	60.33	103.69	105.07	166.80		
7	Kemendun	23.13	0.00	0.00	0.00	0.00	0.00	33.33	67.27	99.53	105.31	78.13	25.53	29.00	0.00	0.00	21.73	141.20	43.08	22.87	61.00	60.27	67.73		
8	Pergiwatu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.93	77.31	79.07	129.13	131.93	135.73		
9	Kenteng	0.00	0.00	0.00	0.00	0.00	0.00	10.00	19.93	43.13	15.31	33.87	29.20	23.27	16.56	11.20	0.00	13.87	27.54	6.07	18.88	25.00	8.13		
10	Milir	0.00	0.00	0.00	0.00	0.00	0.00	22.13	0.00	0.00	0.00	66.27	25.87	23.53	28.94	0.00	0.00	0.00	0.00						
11	Papah Kar	0.00	0.00	0.00	0.00	0.00	0.00	64.53	92.07	115.93	73.25	51.13	80.47	38.88	33.88	10.80	20.07	18.80	48.46	18.00	46.50	40.20	42.07		
Total Actual (recorded)		35.20	0.00	4.07	0.73	0.00	0.00	252.53	440.20	508.40	512.63	554.87	459.33	392.14	224.88	324.13	260.99	576.40	472.08	268.00	458.81	495.47	558.60	0.00	0.00

PLANNED WATER DELIVERY (l/s) - Tertiaries with measurement

No.	Tertiary	Jun-93		Jul-93		Aug-93		Sep-93		Oct-93		Nov-93		Dec-93		Jan-94		Feb-94		Mar-94		Apr-94		May-94	
	Name	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	Wora-wari	3.56	3.56	3.56	3.56	0.00	0.00	18.27	18.27	19.90	15.43	14.71	14.71	14.71	14.71	19.18	19.18	14.71	14.71	14.71	14.71	14.12	14.12	3.56	3.56
2	Blimbing	22.00	22.00	19.68	19.68	0.00	0.00	98.43	98.43	109.18	85.75	80.67	80.67	80.67	80.67	104.68	104.68	80.61	80.67	80.67	80.67	76.56	76.56	19.69	19.69
3	Semen	15.00	15.00	17.00	17.00	0.00	0.00	95.62	95.62	95.62	72.25	72.25	72.25	72.25	72.25	95.62	95.62	72.25	72.25	72.25	72.25	72.25	72.25	17.00	17.00
4	Gendingan	14.28	14.28	14.27	14.27	0.00	0.00	75.93	25.93	80.00	61.43	53.25	53.25	53.25	53.25	9.00	9.00	53.25	53.25	53.25	53.25	51.77	51.77	12.78	12.78
5	Patuk	5.25	5.25	5.25	5.25	0.00	0.00	29.52	29.52	29.52	22.31	18.06	18.06	18.06	18.06	23.90	23.90	18.06	18.06	18.06	18.06	18.06	18.06	4.25	4.25
6	Ngentakrej	25.00	25.00	25.62	25.62	0.00	0.00	126.52	126.56	142.81	142.81	127.50	127.50	127.50	127.50	28.68	28.68	127.50	127.50	127.50	127.50	130.62	130.62	98.13	98.13
7	Kemendun	11.25	11.25	11.25	11.25	0.00	0.00	63.27	63.27	63.27	47.81	47.81	47.81	47.81	47.81	63.27	63.27	47.81	47.81	47.81	47.81	47.81	47.81	11.25	11.25
8	Pergiwatu	30.28	30.28	32.77	32.77	0.00	0.00	172.96	172.96	183.52	141.25	136.53	136.53	136.53	136.53	178.81	178.81	136.53	136.53	136.53	136.53	132.71	132.71	2.03	2.03
9	Kenteng	4.75	4.75	4.75	4.75	0.00	0.00	26.71	26.71	26.71	26.71	21.25	21.25	21.25	21.25	28.12	28.12	21.25	21.25	21.25	21.25	21.25	21.25	0.00	0.00
10	Milir	6.50	6.50	6.50	6.50	0.00	0.00	36.56	36.56	36.56	27.62	27.62	27.62	27.62	27.62	36.56	36.56	27.62	27.62	27.62	27.62	27.62	27.62	0.00	0.00
11	Papah Kar	10.25	10.25	10.25	10.25	0.00	0.00	36.56	36.56	56.06	47.12	38.42	38.42	38.42	38.42	47.30	47.36	38.42	38.42	38.42	38.42	31.37	31.37	3.75	10.25
SUB-TOTALS for Tertiaries with measurement																									
Sub-Total Planned		148.12	148.12	150.90	150.90	0.00	0.00	780.35	730.39	843.15	690.49	638.07	638.07	638.07	638.07	635.12	635.18	638.01	638.07	638.07	638.07	624.14	624.14	172.44	178.94
Sub-Total Actual		35.20	0.00	4.07	0.73	0.00	0.00	252.53	440.20	508.40	512.63	554.87	459.33	392.14	224.88	324.13	260.99	576.40	472.08	268.00	458.81	495.47	558.60	0.00	0.00
Actual/Planned Ratios		0.24	0.00	0.03	0.00	1.00	1.00	0.32	0.60	0.60	0.74	0.87	0.72	0.61	0.35	0.51	0.41	0.90	0.74	0.42	0.72	0.79	0.89		

PLANNED WATER DELIVERY (l/s) - Tertiaries without measurement

No.	Tertiary	Jun-93		Jul-93		Aug-93		Sep-93		Oct-93		Nov-93		Dec-93		Jan-94		Feb-94		Mar-94		Apr-94		May-94	
	Name	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	Gunung Du	10.50	10.50	11.00	11.00	0.00	0.00	61.87	61.87	61.87	46.75	41.43	41.43	41.43	41.43	54.84	54.84	41.43	41.43	41.43	41.43	41.43	41.43	9.75	9.75
2	Klipuh	12.50	12.50	12.50	12.50	0.00	0.00	70.31	70.31	70.31	70.31	53.12	53.12	53.12	53.12	70.31	70.31	53.12	53.12	53.12	53.12	53.12	53.12	53.13	53.13
3	Karongan	12.25	12.25	12.25	12.25	0.00	0.00	68.90	68.90	68.90	52.06	52.06	52.06	52.06	52.06	68.90	68.90	52.06	52.06	52.06	52.06	52.06	52.06	0.00	0.00
4	Cumetuk	13.75	13.75	11.25	11.25	0.00	0.00	63.27	63.27	63.27	63.27	47.81	47.81	47.81	47.81	63.27	63.27	47.81	47.81	47.81	47.81	47.81	47.81	47.80	0.00
5	Sempu	9.50	9.50	9.50	9.50	0.00	0.00	53.43	53.43	53.43	53.43	38.25	38.25	38.25	38.25	57.65	57.65	43.56	43.56	43.56	43.56	43.56	43.56	43.56	43.56
6	Drigul	11.25	11.25	28.00	28.00	0.00	0.00	157.50	157.50	157.50	119.00	128.56	128.56	128.56	128.56	170.15	170.15	128.56	128.56	128.56	128.56	128.56	128.56	128.56	0.00
Sub-Total Planned (Tertiaries with no measurement)		69.75	69.75	84.50	84.50	0.00	0.00	475.28	475.28	475.28	404.82	361.23	361.23	361.23	361.23	485.12	485.12	366.54	366.54	366.54	366.54	366.54	366.54	282.80	106.44

SYSTEM TOTALS	Jun-93		Jul-93		Aug-93		Sep-93		Oct-93		Nov-93		Dec-93		Jan-93		Feb-93		Mar-93		Apr-93		May-93	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Total Planned	217.87	217.87	235.40	235.40	0.00	0.00	1255.63	1205.67	1318.43	1095.31	999.30	999.30	999.30	999.30	1120.24	1120.30	1004.55	1004.61	1004.61	1004.61	990.68	990.68	455.24	285.38
Actual System Inflow at Weir	252.00	0.00	323.00	256.00	80.00	135.00	677.00	1013.00	1085.00	1359.00	1514.00	1403.00	1400.00	1700.00	1634.00	1502.00	1348.00	1626.00	1566.00	1285.00	1784.00	1494.00	1157.00	867.00
Actual Inflow-Planned Use Ratio	1.16	0.00	1.37	1.09			0.54	0.84	0.82	1.24	1.52	1.40	1.40	1.70	1.46	1.34	1.34	1.62	1.56	1.28	1.80	1.51	2.54	3.04

Note : Ratio disregards delivery losses

Design max. inflow to System	1800 l/s
No. of periods (from 24) in the year that	0

System DI Papah - Performance Assessment - Water Delivery

PERFORMANCE ASSESSMENT - System DI Papah
ACTUAL-PLANNED RATIOS
WATER DELIVERY

No.	Tertiary	Jun-93		Jul-93		Aug-93		Sep-93		Oct-93		Nov-93		Dec-93		Jan-94		Feb-94		Mar-94		Apr-94		May-94		Mean	Coef.
	Name	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2		Varn.
1	Papah Ka	0.00	0.00	0.00	0.00	1.00	1.00	1.77	2.52	2.07	1.55	1.33	2.09	1.01	0.88	0.23	0.42	0.49	1.26	0.47	1.21	1.28	1.34			1.00	0.54
2	Wora-war	0.21	0.00	1.14	0.21	1.00	1.00	0.94	1.63	1.46	0.86	1.32	0.84	0.62	0.39	0.24	0.06	0.46	0.74	0.15	0.99	0.90	1.44			0.75	0.24
3	Blimbing	0.09	0.00	0.00	0.00	1.00	1.00	0.22	0.46	0.17	0.57	0.61	0.76	0.73	0.24	0.04	0.33	0.68	0.37	0.27	0.27	0.50	0.60			0.41	0.10
4	Semen	0.62	0.00	0.00	0.00	1.00	1.00	0.14	0.38	0.31	0.46	0.53	0.67	0.61	0.27	0.02	0.28	0.66	0.31	0.18	0.21	0.33	0.38			0.38	0.09
5	Gendinga	0.00	0.00	0.00	0.00	1.00	1.00	0.50	2.48	1.13	1.37	2.02	1.00	0.68	0.33	11.05	4.07	1.41	1.55	0.60	0.66	0.84	0.69			1.47	5.46
6	Gunung Duk																										
7	Patuk	0.00	0.00	0.00	0.00	1.00	1.00	0.38	0.43	0.73	1.23	1.02	0.72	0.72	0.22	0.00	0.58	1.40	0.79	0.72	0.72	0.83	0.49			0.59	0.18
8	Ngentakr	0.00	0.00	0.00	0.00	1.00	1.00	0.17	0.58	0.42	0.78	0.73	0.86	0.91	0.62	6.67	3.72	1.11	0.91	0.47	0.81	0.80	1.28			1.04	2.17
9	Klipuh																										
10	Kemendu	2.06	0.00	0.00	0.00	1.00	1.00	0.53	1.06	1.57	2.20	1.63	0.53	0.61	0.00	0.00	0.34	2.95	0.90	0.48	1.28	1.26	1.42			0.95	0.65
11	Kenteng	0.00	0.00	0.00	0.00	1.00	1.00	0.37	0.75	1.61	0.57	1.59	1.37	1.09	0.78	0.40	0.00	0.65	1.30	0.29	0.89	1.18	0.38			0.69	0.29
12	Karongan																										
13	Milir	0.00	0.00	0.00	0.00	1.00	1.00	0.61	0.34	0.00	0.00	2.40	0.94	0.85	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.37	0.38
14	Cumetuk																										
15	Pergiwatu	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.57	0.58	0.95	0.99	1.02			0.29	0.18
16	Sempu																										
17	Drigul																										
Mean		0.27	0.00	0.10	0.02	1.00	1.00	0.51	0.97	0.86	0.87	1.20	0.89	0.71	0.43	1.70	0.89	0.93	0.79	0.38	0.73	0.81	0.82				
Coef. of Variance		0.40	0.33	0.17	0.33	0.00	0.08	0.24	0.78	0.50	0.51	0.45	0.35	0.08	0.32	12.34	2.14	0.58	0.32	0.08	0.29	0.15	0.34				

Mean of 'means' column	0.72	
Mean of 'coef. varn.' column		0.93

SYSTEM PERFORMANCE ASSESSMENT SYSTEM : DI PAPAH YEAR : 1992/1993 SEASON : MT3

Based on Crop Area data

Tertiary Name	ref. no.	Designed R (ha)	Designed P (ha)	Designed S (ha)	Designed B (ha)	Designed PRA		Requested R (ha)	Requested P (ha)	Requested S (ha)	Requested B (ha)	Requested PRA	Planned R (ha)	Planned P (ha)	Planned S (ha)	Planned B (ha)	Planned PRA	Actual R (ha)	Actual P (ha)	Actual S (ha)	Actual B (ha)	Actual PRA	Performance Ratio Planned/Designed	Planned/Requested	Actual/Designed	Actual/Requested	Actual/Planned
Wora-wari								0	15	0	0	15	0	15	0	0	15	0	13	2	0	17		1.00		1.13	1.13
Blimbing								0	74	14	0	102	0	74	14	0	102	0	70	14	0	98		1.00		0.96	0.96
Semen								0	66	0	0	66	0	68	0	0	68	0	68	0	0	68		1.03		1.03	1.00
Gendingan								0	45	5	0	55	0	45	5	0	55	0	54	5	0	64		1.00		1.16	1.16
Gunung Duk								0	36	0	0	36	0	36	0	0	36	0	44	0	0	44		1.00		1.22	1.22
Paten								0	22	0	0	22	0	22	0	0	22	0	21	0	0	21		1.00		0.95	0.95
Ngentakrejo								0	64	0	0	64	0	64	0	0	64	0	90	20	0	130		1.00		2.03	2.03
Klipuh								0	50	0	0	50	0	50	0	0	50	0	50	0	0	50		1.00		1.00	1.00
Drigul								0	94	0	0	94	0	94	0	0	94	0	112	0	0	112		1.00		1.19	1.19
Kemendung								0	50	0	0	50	0	50	0	0	50	0	45	0	0	45		1.00		0.90	0.90
Kenteng Kulon								0	21	0	0	21	0	21	0	0	21	0	19	0	0	19		1.00		0.90	0.90
Pergiwatu								0	113	13	0	139	0	113	9	0	131	0	123	13	0	149		0.94		1.07	1.14
Sempu								0	38	0	0	38	0	38	0	0	38	0	38	0	0	38		1.00		1.00	1.00
Karongan								0	49	0	0	49	0	49	0	0	49	0	49	0	0	49		1.00		1.00	1.00
Cemetuk								0	14	0	0	14	0	40	0	0	40	0	45	0	0	45		2.86		3.21	1.13
Milir								0	31	0	0	31	0	31	0	0	31	0	26	0	0	26		1.00		0.84	0.84
Papah Kanan								0	34	22	0	78	0	34	22	0	78	0	26	24	0	74		1.00		0.95	0.95
SYSTEM TOTALS												924					944					1049		1.02		1.14	1.11
																		Mean						1.11		1.21	1.09
																		Standard Deviation						0.45		0.58	0.27
																		Coef. of Variance						0.20		0.34	0.07

SYSTEM PERFORMANCE ASSESSMENT SYSTEM : DI PAPAH YEAR : 1992/1993 SEASON : MT1 SHEET 2 OF 3

Based on Crop Area data

Tertiary Name	ref. no.	Designed R (ha)	Designed P (ha)	Designed S (ha)	Designed B (ha)	Designed PRA		Requested R (ha)	Requested P (ha)	Requested S (ha)	Requested B (ha)	Requested PRA	Planned R (ha)	Planned P (ha)	Planned S (ha)	Planned B (ha)	Planned PRA	Actual R (ha)	Actual P (ha)	Actual S (ha)	Actual B (ha)	Actual PRA	Performance Ratio Planned/Designed	Planned/Requested	Actual/Designed	Actual/Requested	Actual/Planned
Wora-wari								13	0	0	0	52	13	0	0	0	52	13	0	2	0	56		1.00		1.08	1.08
Blimbing								79	0	14	0	344	79	0	14	0	344	70	0	14	0	308		1.00		0.90	0.90
Semen								59	0	0	0	236	59	0	0	0	236	68	0	0	0	272		1.00		1.15	1.15
Gendingan								54	0	5	0	226	54	0	5	0	226	54	0	5	0	226		1.00		1.00	1.00
Gunung Duk								39	0	5	0	166	39	0	5	0	166	44	0	0	0	176		1.00		1.06	1.06
Paten								21	0	0	0	84	21	0	0	0	84	21	0	0	0	84		1.00		1.00	1.00
Ngentakrejo								100	0	0	0	400	100	0	0	0	400	90	0	20	0	400		1.00		1.00	1.00
Klipuh								60	0	0	0	240	60	0	0	0	240	50	0	0	0	200		1.00		0.83	0.83
Drigul								112	0	0	0	448	112	0	0	0	448	112	0	0	0	448		1.00		1.00	1.00
Kemendung								45	0	0	0	180	45	0	0	0	180	45	0	0	0	180		1.00		1.00	1.00
Kenteng Kulon								19	0	0	0	76	19	0	0	0	76	19	0	0	0	76		1.00		1.00	1.00
Pergiwatu								119	0	9	0	494	117	0	9	0	486	123	0	12	0	516		0.98		1.04	1.06
Sempu								38	0	0	0	152	38	0	0	0	152	38	0	0	0	152		1.00		1.00	1.00
Karongan								49	0	0	0	196	49	0	0	0	196	49	0	0	0	196		1.00		1.00	1.00
Cemetuk								45	0	0	0	180	45	0	0	0	180	45	0	0	0	180		1.00		1.00	1.00
Milir								26	0	0	0	104	26	0	0	0	104	26	0	0	0	104		1.00		1.00	1.00
Papah Kanan								26	0	24	0	152	26	0	24	0	152	26	0	24	0	152		1.00		1.00	1.00
SYSTEM TOTALS												3730					3722					3726		1.00		1.00	1.00
																		Mean						1.00		1.00	1.00
																		Standard Deviation						0.00		0.07	0.07
																		Coef. of Variance						0.00		0.00	0.00

SYSTEM PERFORMANCE ASSESSMENT SYSTEM : DI PAPAH YEAR : 1992/1993 SEASON : MT2 SHEET 3 OF 3

Based on Crop Area data

Tertiary		Designed						Requested					Planned					Actual					Performance Ratio				
Name	ref. no.	R (ha)	P (ha)	S (ha)	B (ha)	PRA		R (ha)	P (ha)	S (ha)	B (ha)	PRA	R (ha)	P (ha)	S (ha)	B (ha)	PRA	R (ha)	S (ha)	O (ha)	B (ha)	PRA	Planned / Designed	Planned / Requested	Actual / Designed	Actual / Requested	Actual / Planned
Wora-wari								13	0	0	0	52	13	0	0	0	52	13	0	2	0	56		1.00		1.08	1.08
Blimbing								79	0	14	0	344	79	0	14	0	344	70	0	14	0	308		1.00		0.90	0.90
Semen								59	0	0	0	236	59	0	0	0	236	68	0	0	0	272		1.00		1.15	1.15
Gendingan								54	0	5	0	226	54	0	5	0	226	48	0	5	0	202		1.00		0.89	0.89
Gunung Duk								39	0	5	0	166	39	0	5	0	166	39	0	0	0	156		1.00		0.94	0.94
Paten								21	0	0	0	84	21	0	0	0	84	17	0	0	0	68		1.00		0.81	0.81
Ngentakrejo								100	0	0	0	400	110	0	0	0	440	120	0	20	0	520		1.10		1.30	1.18
Klipuh								60	0	0	0	240	60	0	0	0	240	50	0	0	0	200		1.00		0.83	0.83
Drigul								112	0	0	0	448	112	0	0	0	448	112	0	0	0	448		1.00		1.00	1.00
Kemendung								45	0	0	0	180	45	0	0	0	180	45	0	0	0	180		1.00		1.00	1.00
Kenteng Kulon								19	0	0	0	76	19	0	0	0	76	20	0	0	0	80		1.00		1.05	1.05
Pergiwatu								119	0	9	0	494	117	0	9	0	486	123	0	13	0	518		0.98		1.05	1.07
Sempu								38	0	0	0	152	38	0	0	0	152	41	0	0	0	164		1.00		1.08	1.08
Karongan								49	0	0	0	196	49	0	0	0	196	49	0	0	0	196		1.00		1.00	1.00
Cemetuk								45	0	0	0	180	45	0	0	0	180	45	0	0	0	180		1.00		1.00	1.00
Milir								26	0	0	0	104	26	0	0	0	104	26	0	0	0	104		1.00		1.00	1.00
Papah Kanan								26	0	24	0	152	26	0	24	0	152	26	0	24	0	152		1.00		1.00	1.00
SYSTEM TOTALS												3730					3762					3804		1.01		1.02	1.01
																		Mean						1.00		1.00	1.00
																		Standard Deviation						0.02		0.12	0.10
																		Coef. of Variance						0.00		0.01	0.01

PLANNED IRRIGATED AREA
System: DI Papah YEAR : 1990/1991

No.	Tertiary Name	Total Irrigated Area Recorded (ha)	Total Planned Irrigated Area (ha) Season MT1	Season MT2	Season MT3
1	Wora-wari	15.00	15.00	15.00	15.00
2	Blimbing	83.00	83.00	83.00	83.00
3	Semen	66.00	66.00	66.00	66.00
4	Gendingan	50.30	50.30	50.30	50.30
5	Kalikutuk	36.25	36.25	36.25	36.25
6	Klampok	10.10	10.10	10.10	10.10
7	Cangkring	4.95	4.95	4.95	4.95
8	Paten	11.50	11.50	11.50	11.50
9	Kemendung	44.50	44.50	44.50	44.50
10	Gletak	30.30	30.30	30.30	30.30
11	Wiyu	25.30	25.30	25.30	25.30
12	Kenteng Wetan	39.65	39.65	39.65	39.65
13	Pergiwatu	173.50	173.50	173.50	173.50
14	Sempu	36.10	36.10	36.10	36.10
15	Kenteng Kulon	20.50	20.50	20.50	20.50
16	Karongan Kiri	3.00	3.00	3.00	3.00
17	Karongan Kanan	43.00	43.00	43.00	43.00
18	Karangasem	22.00	22.00	22.00	22.00
19	Ngramang	2.85	2.85	2.85	2.85
20	Milir	23.00	23.00	23.00	23.00
21	Cemetuk	6.50	11.50	11.50	11.50
22	Klipuh Kiri	40.00	40.00	40.00	40.00
23	Klipuh Kanan	60.00	60.00	60.00	60.00
24	Drigul	94.00	94.00	94.00	94.00
	TOTAL	941.30	946.30	946.30	946.30

PLANNED IRRIGATED AREA
System: DI Papah YEAR : 1991/1992

No.	Tertiary Name	Total Irrigated Area Recorded (ha)	Total Planned Irrigated Area (ha) Season MT1	Season MT2	Season MT3
1	Wora-wari	15.00	15.00	15.00	15.00
2	Blimbing	88.00	88.00	88.00	88.00
3	Semen	68.00	68.00	68.00	68.00
4	Gendingan	50.30	50.30	50.30	50.30
5	Kalikutuk	36.25	36.25	36.25	36.25
6	Klampok	10.10	10.10	10.10	10.10
7	Cangkring	27.10	27.10	27.10	27.10
8	Paten	11.50	11.50	11.50	11.50
9	Kemendung	50.00	50.00	50.00	50.00
10	Gletak	28.60	28.60	28.60	28.60
11	Wiyu	27.05	27.05	27.05	27.05
12	Kenteng Wetan	27.15	27.15	27.15	27.15
13	Pergiwatu	126.00	126.00	126.00	126.00
14	Sempu	38.00	38.00	38.00	38.00
15	Kenteng Kulon	18.40	18.40	18.40	18.40
16	Karongan Kiri	3.00	3.00	3.00	3.00
17	Karongan Kanan	46.05	46.05	46.05	46.05
18	Karangasem	24.00	24.00	24.00	24.00
19	Ngramang	4.85	4.85	4.85	4.85
20	Milir	13.50	13.50	13.50	13.50
21	Cemetuk	31.25	31.25	31.25	31.25
22	Klipuh Kiri	37.20	37.20	37.20	37.20
23	Klipuh Kanan	50.00	50.00	50.00	50.00
24	Drigul	94.00	94.00	94.00	94.00
	TOTAL	925.30	925.30	925.30	925.30

PLANNED IRRIGATED AREA
System: DI Papah YEAR : 1992/1993

No.	Tertiary Name	Total Irrigated Area Recorded (ha)	Total Planned Irrigated Area (ha) Season MT1	Season MT2	Season MT3
1	Wora-wari	15.00	15.00	15.00	15.00
2	Blimbing	88.00	88.00	88.00	88.00
3	Semen	68.00	68.00	68.00	68.00
4	Gendingan	50.00	50.00	50.00	50.00
5	Kalikutuk	36.00	36.00	36.00	36.00
6	Klampok	10.00	10.00	10.00	10.00
7	Paten	12.00	12.00	12.00	12.00
8	Cangkring	64.00	64.00	64.00	64.00
9	Klipuh Kanan	50.00	50.00	50.00	50.00
10	Drigul	94.00	94.00	94.00	94.00
11	Kemendung	50.00	50.00	50.00	50.00
12	Wiyu	27.00	27.00	27.00	27.00
13	Kenteng Wetan	27.00	27.00	27.00	27.00
14	Pergiwatu	126.00	126.00	126.00	126.00
15	Sempu	38.00	38.00	38.00	38.00
16	Kenteng Kulon	21.00	21.00	21.00	21.00
17	Karongan	49.00	49.00	49.00	49.00
18	Karangasem	26.00	26.00	26.00	26.00
19	Cemetuk	14.00	14.00	14.00	14.00
20	Milir	31.00	31.00	31.00	31.00
21	Papah Kanan	29.00	29.00	29.00	29.00
	TOTAL	925.00	925.00	925.00	925.00

PLANNED IRRIGATED AREA
System: DI Papah YEAR : 1993/1994

No.	Tertiary Name	Total Irrigated Area Recorded (ha)	Total Planned Irrigated Area (ha) Season MT1	Season MT2	Season MT3
1	Wora-wari	15	15	15	15
2	Blimbing	93	93	93	93
3	Semen	59	59	59	59
4	Gendingan	59	59	59	59
5	Gunung Duk	44	44	44	44
6	Paten	21	21	21	21
7	Ngentakrejo	100	100	100	100
8	Klipuh	60	60	60	60
9	Kemendung	45	45	45	45
10	Pergiwatu	126	126	126	126
11	Sempu	38	38	38	38
12	Kenteng Kulon	19	19	19	19
13	Karongan	49	49	49	49
14	Milir	26	26	26	26
15	Cumetuk	45	45	45	45
16	Papah Kanan	50	50	50	50
17	Drigul	112	112	112	112
	TOTAL	961.00	961.00	961.00	961.00

PLANNED IRRIGATED AREA
System: DI Papah YEAR : 1994/1995

No.	Tertiary Name	Total Irrigated Area Recorded (ha)	Total Planned Irrigated Area (ha) Season MT1	Season MT2	Season MT3
1	Wora-wari	15	15	15	15
2	Blimbing	84	84	84	84
3	Semen	68	68	68	68
4	Gendingan	53	53	53	53
5	Gunung Duk	39	39	39	39
6	Paten	17	17	17	17
7	Ngentakrejo	140	140	140	140
8	Klipuh	50	50	50	50
9	Kemendung	121	121	121	121
10	Pergiwatu	45	45	45	45
11	Sempu	20	20	20	20
12	Kenteng Kulon	136	136	136	136
13	Karongan	41	41	41	36
14	Milir	49	47	49	49
15	Cumetuk	45	45	45	45
16	Papah Kanan	26	26	26	26
17	Drigul	50	50	50	50
	TOTAL	999.00	997.00	999.00	994.00

Appendix A5

Research paper

(Submitted to the journal of the Institution of Water and Environmental Management, February 1995)

Strategic investment planning for irrigation - The "Asset Management" approach

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Keywords: privatisation, turnover, investment planning, financial modelling, asset management, performance assessment, rehabilitation, asset survey, pricing for cost recovery, maintenance, level of service, accountability.

Abstract : Asset management planning provides a structured and auditable process for planning long term investment in infrastructure. The irrigation sector has a pressing need for an efficient means to facilitate strategic investment decisions based upon a clear overview of objectives, options, costs, benefits and competing needs. This paper describes research carried out in Indonesia to assess the feasibility of transferring asset management planning procedures developed for the United Kingdom water industry to the irrigation sector. The 6-month study found notable similarities and some differences between the two applications. Modified procedures were developed accordingly and tested in field trials. It is concluded that there are significant opportunities for the application of the approach as developed in the UK using statistically based sampling procedures. From the experience of the study and the field trials the approach is found to be highly relevant and practicable.

1 Introduction

There is a need, in all societies, to invest in public infrastructure such as roads, water supply networks, irrigation and drainage systems following their initial construction. In recent years the level of investment in such infrastructure has become a major issue as governments in both developed and developing countries come to terms with the sums of money involved. Pricing for cost recovery, demand and customer orientation, cost and operational efficiency are currently key issues. It is estimated by the World Bank (1994) that potential annual gains worldwide from eliminating mispricing and inefficiency in infrastructure provision amount to US$ 55 billion. This represents nearly 10 percent of total government revenues in developing countries, 60 percent of annual infrastructure investment and approximately five times the annual development finance for infrastructure.

In some countries, such as the United Kingdom, some public infrastructure has been privatised, in others government agencies are looking to ways to better manage their infrastructure in order to avoid the repetitive cycle of system deterioration, rehabilitation and deterioration which result from under-investment. It is in this context, the determination of adequate levels of investment, that asset management planning has a role to play. Asset management planning can be defined as:

> "A structured and auditable process for planning investment in infrastructure to provide users with a sustainable and defined level of service."

Asset management planning identifies asset stock (in irrigation the canals, drains, structures) and quantifies its condition and its performance (Rumsey and Harris,1990). The latter is considered both in terms of the performance of the individual asset and the overall system (of which it is a part). From the assessment of asset condition and level of performance estimates can be made for the investment required to either:

(i) maintain existing system performance;

(ii) enhance or extend system performance;

(iii) maintain asset condition profile

From these estimates investment plans can be prepared, both in the long term (20-25 years) and the short term (5 years). It should be noted that the process is applicable whether the utility is in the public or the private sector, and whether the intention is to run a profit-making enterprise or to determine the real cost of the service (which may, or may not be, subsidised).

2 Development of asset management planning procedures for irrigation systems

This paper outlines research carried out to develop procedures for asset management planning for irrigation systems based on asset management planning procedures developed for the UK water industry in the run-up to privatisation in 1989. The research was carried out between July and December 1994 by the Institute of Irrigation Studies, University of Southampton, in association with WRc (formerly the UK Government's Water Research Centre), Swindon; Mott Macdonald, Cambridge, UK; the Faculty of Agricultural Technology, Gadjah Mada University, Yogyakarta; and the Directorate General of Water Resources Development (DGWRD), Department of Public Works, Indonesia. The study was funded through a research contract with the United Kingdom Overseas Development Administration (ODA).

The objectives of the research were:

(i) To study the development and current procedures of asset management in the UK water industry;

(ii) To assess the applicability of UK asset management procedures to the developing country irrigation scenario;

(iii) To formulate a strategy for application of asset management procedures and techniques to the irrigation sector;

(iv) To carry out, on a trial basis, identified asset management planning procedures for selected irrigation scheme(s);

(v) To review the application of the trial procedures, and, where required, identify areas for further study and research;

(vi) To prepare outline recommendations in the form of guidelines for implementation of asset management planning procedures in developing country irrigation.

Preliminary work for this research had commenced in July 1993 with a study based in East Java, Indonesia (Davies, 1993). Though addressing and solving some of the issues related to asset management planning for irrigation this study identified particular areas that the 1994 study needed to investigate further.

3 UK water industry asset management planning procedures

The approach adopted for this research was to apply asset management procedures as recently developed for the UK water industry. A brief outline of the historical development of these procedures is provided below.

In the run up to privatisation of the UK water industry in 1989 the investment community was concerned over the ability to sell the water companies on the free market at a sensible price. Their concern centred on:

- the need for investors to have a clear understanding about the condition and performance of the assets of the industry (some 70% of which are buried);

- the extent of investment needed by the industry to maintain assets and meet new performance requirements; and

- how investment was to be funded.

Newspaper photographs of buses falling into collapsed sewers provided a graphic illustration of what potential investors could be buying into.

There was therefore a requirement for some form of plan that addressed these concerns. This plan would need to be independently certified to provide comfort to both the government and investors that what was contained within them was fair and reasonable. In addition there was concern in the public mind that the privatised water companies would run down the assets ('asset stripping') through under-investment, and might, at some time in the future, 'run off' leaving the customer to fund a major improvement programme. It was important therefore that asset condition could be both *measured* and *monitored* to ensure that sufficient investment was being made by the companies on asset maintenance and that the plans for this were transparent and capable of being audited.

Thus the concept of the *Asset Management Plan (AMP)* was born - a plan that would allow asset condition, performance and investment needs to be quantified and independently certified.

There was a need to ensure some degree of consistency between the companies in the preparation of the asset management plans. A framework for the preparation of an underground[1] asset management plan was therefore prepared (WRc/WAA/WCA/DoE/WO,1988) by WRc jointly for the Government and the water utility trade associations (the Water Services and Water Company Associations).

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[1] At privatisation the AMPs focused entirely on underground assets, it being considered that above ground assets, being visible and with well established performance measures, would be relatively straightforward in respect of quantifying investment needs. Since then, above ground assets have been included.

The framework identified six stages to the plan as presented in Table 1 below.

Table 1 Six stages of an Asset Management Plan

1. Devise *procedures* for preparing the AMP and keeping it up to date. These must be *traceable and repeatable*.

2. Prepare a statement of the Utility's relevant *standards and policies.*

3. Identify various *functions* of the Utility and prepare a *list of systems* under each heading. Each system will comprise a number of assets.

4. Collect information on *performance* and *condition* of the principal components of each system. This may be done by sampling (Note that *performance* information relates to a *system* whereas *condition* information relates to *individual* assets).

5. Estimate *long term investment* covering a 20-year planning period to meet *shortfalls of performance and condition* and to *provide for expansion and improvement.*

6. Prepare *short term programme of expenditure* for 5 years.

Source: Adapted from WRc/WAA/WCA/DoE/WO (1988)

Stage 2 is particularly important in that it introduces the idea of standard of service provision to customers as a key driving force in determining investment needs. This was a major step forward in terms of changing the ethos of the water utility from the provider of services as determined by the priorities of management and government to the provider of service to the customer. The actual level of service provided to the customer is compared to the standard and the shortfall identified. Investment to improve levels of service can be identified and subsequent improvements monitored.

The above framework was subsequently implemented by all the water companies of England and Wales with the results being used to:

- Provide input to the prospectuses of the water companies
- Allow price "caps" (limits) to be set by the government regulator
- Allow monitoring of performance once privatised.
- Allow asset condition to be monitored over time

The asset management plans were prepared in some 18 months and resulted in the identification of over £24 billion of investment during the subsequent 10 year period by the 10 major water and sewage companies.

It is important to note that the AMP procedures outlined above (which are based on statistical sampling) allow the identification of total investment needs and timing of expenditure over the plan period. They do not, therefore, identify where to spend the money in terms of specific schemes. The annual disbursement of monies allocated each year under the AMP requires detailed planning and prioritisation according to the actual investment requirements at that time. What can be said, however, is that the total sums of money budgeted for over the planning horizon (20 years, in four 5-year programmes), as determined by the AMP, should be adequate to fund all the activities necessary to achieve the outputs identified. In practice, many individual projects incorporated into the AMP, particularly in its first 5-year plan, will already have been identified under existing investment procedures, and will already be well advanced in either the planning or implementation phase.

Since privatisation in 1989 the AMP process has been further developed and enhanced. The plans now include, very sensibly, consideration of *all assets* (not just the underground ones) in terms of condition and performance (WRc,1990). In addition the plans report on level of service provision to customers, asset values, operating costs and sources of revenue. What had started as an asset management plan for underground assets has now become a comprehensive 20 year *Strategic Business Plan* for each water company.

The Strategic Business Plan is monitored by the water industry regulator, OFWAT, which publishes annual reports outlining how customers' standards of service (measured using a "basket" of performance indicators) have changed during the last year in response to the investment programme. These reports are public domain information and are used to "shame" poor performers into doing better next time. The information is also available to the financial markets and, in theory, the results influence the company's share price and market value. Companies thus have a real incentive to improve performance. Typical examples taken from OFWAT reports are presented in Tables 2 and 3 below, from which it is possible to see the change in performance over time, and to compare performance between different water companies. As well as improving levels of service "Companies have greatly improved the information which they collect on what they achieve, as opposed to what they spend. This is in keeping with a regime based on performance and incentives" (I C R Byatt, Director General, OFWAT, OFWAT Report on Information for Regulation, Volume 1, 1995).

Table 2 Company performance 1990-91 to 1994-95

Indicator	Description	1990-91 %	1991-92 %	1992-93 %	1993-94 %	1994-95 %
DG1	Population at risk of water shortage	24	20	12	12	12
DG2	Population at risk of low pressure	1.85	1.69	1.26	1.02	0.81
DG3	Properties subject to unplanned supply interruptions of 12 hours or more	0.42	0.20	0.38	0.35	0.26
DG4	Population subject to hosepipe bans	41	14	9	0	3
DG5	Properties at risk of sewer flooding	0.13	0.11	0.09	0.08	0.09
DG6	Billing queries not responded to within 20 days	3.84	3.25	3.99	3.30	1.16
DG7	Written complaints not responded to within 20 days	8.82	5.86	8.61	12.78	1.02

Source: Table 1, OFWAT Report "1994-95 Report on Levels of Service for Water Industry in England and Wales."

Table 3 Examples of water delivered unit costs 1991-92 to 1994-95

Company	Year	Cost of operations (pence / m3)	Capital maintenance (pence / m3)	Return on capital (pence / m3)	Cost to customers (pence / m3)
Anglian	1991-92	32	16	15	64
	1992-93	35	19	18	72
	1993-94	46	20	7	73
	1994-95	33	15	24	71
Thames	1991-92	29	6	8	43
	1992-93	30	6	10	46
	1993-94	30	8	10	49
	1994-95	27	9	11	47

Source: Table 4a, OFWAT Report "1994-95 Report on the Cost of Water Delivered and Sewage Collected"

4 Asset management for irrigation

From the study it was found that there were certain similarities and differences between the requirements for asset management procedures for UK water supply and wastewater systems and developing country irrigation systems. The key similarities between the two cases were:

- there are a large number of systems and assets
- assets operate as hydraulically definable systems
- assets can be given a condition ranking
- individual assets perform defined functions
- cost models can be prepared
- there is a requirement to plan investment in the long term
- systems have to provide a service to customers
- systems are geographical monopolies
- there is concern over "asset stripping" in turned over or privatised systems

The key differences between the two cases were found to be:

- management plays a far more significant role in irrigation performance than is the case with water supply/wastewater.
- irrigation performance indicators are not easily, nor well, defined
- there are few statutory levels of performance laid down for irrigation
- in irrigation standards of customer service are often not defined
- in water supply pressurised, looped pipe systems can compensate for malfunction of parts of the system. In gravity fed, open channel irrigation malfunction of assets in the upper reaches can have a significant impact on performance downstream.

The issue of whether the irrigation system is in the public or private sector, and whether, if in the private sector, it should operate on a profit or non-profit making basis was not found to be of significance. The asset management planning process outlined herein facilitates the determination of realistic levels of investment required to sustain the cost effective delivery of the irrigation service. Whether additional charges are levied on the figures so obtained, or to whom the irrigation service fees are paid, does not affect the validity of the asset management planning process. In fact the process of asset management planning has importance in the turnover or privatisation of irrigation schemes, as it provides a mechanism for assessment of value, viability and investment planning. Many of the issues addressed by the recent International Conference on Irrigation Management Transfer, held in Wuhan, China in September 1994, can be addressed through asset management planning.

Though there are differences, it was found, through analysis of the two types of application and the field trials, that asset management procedures developed for the UK water industry can be applied, with modifications, to asset management planning for irrigation. As a consequence a framework was developed for asset management planning for irrigation (Figure 1), the components of which are discussed in turn in the following sections.

(i) Defining system functions

The primary function or functions that the service is intended to provide need to be defined. For an irrigation system the primary function might be defined as " to supply irrigation water in adequate quantity and quality and at the time required to suit crop needs". For the complementary drainage system the primary function might be defined as " to remove excess water from the land surface and soil profile in adequate quantity and time to match crop drainage needs."

(ii) Identifying the Planning Unit

For the purposes of the asset management planning procedures described herein it is necessary to identify "Planning Units", for which samples can be taken and statistically analyzed. Such Planning Units should be representative of the systems as a whole. Planning Units could be whole systems (as in the trial case in Indonesia), or parts thereof such as secondary canals. The systems could be divided up into several categories of Planning Units, for instance the diversion weirs on the rivers could be one category, the primary canal system and below another.

The selection of the Planning Units is central to the preparation of the AMP to ensure that the samples are truly representative and that information obtained from the sampled areas can be aggregated up to provide an accurate picture of all systems. The involvement of a statistician can never be too early in the preparation of an AMP.

(iii) Stratification and Normalisation

Having decided on the Planning Unit it is necessary to "stratify" or group them. The purpose of this stratification is to divide Planning Units into similar investment types with similar characteristics. Once systems are grouped into strata representative samples can be taken for statistical analysis. Grouping could be based, amongst others, on one or more of the following:

- general topography (steep,flat)
- scheme cropping pattern
- level of technical sophistication (fully developed, partially developed, etc)
- age
- management/ownership (agency, agency/farmer, farmer)
- average farmer income levels

"Normalisation measures" provide the means to relate characteristics of systems to some common unit of size. Typical normalisation measures are area or discharge. Thus it is possible to convert investment estimates for one size of scheme to another using the normalisation measures.

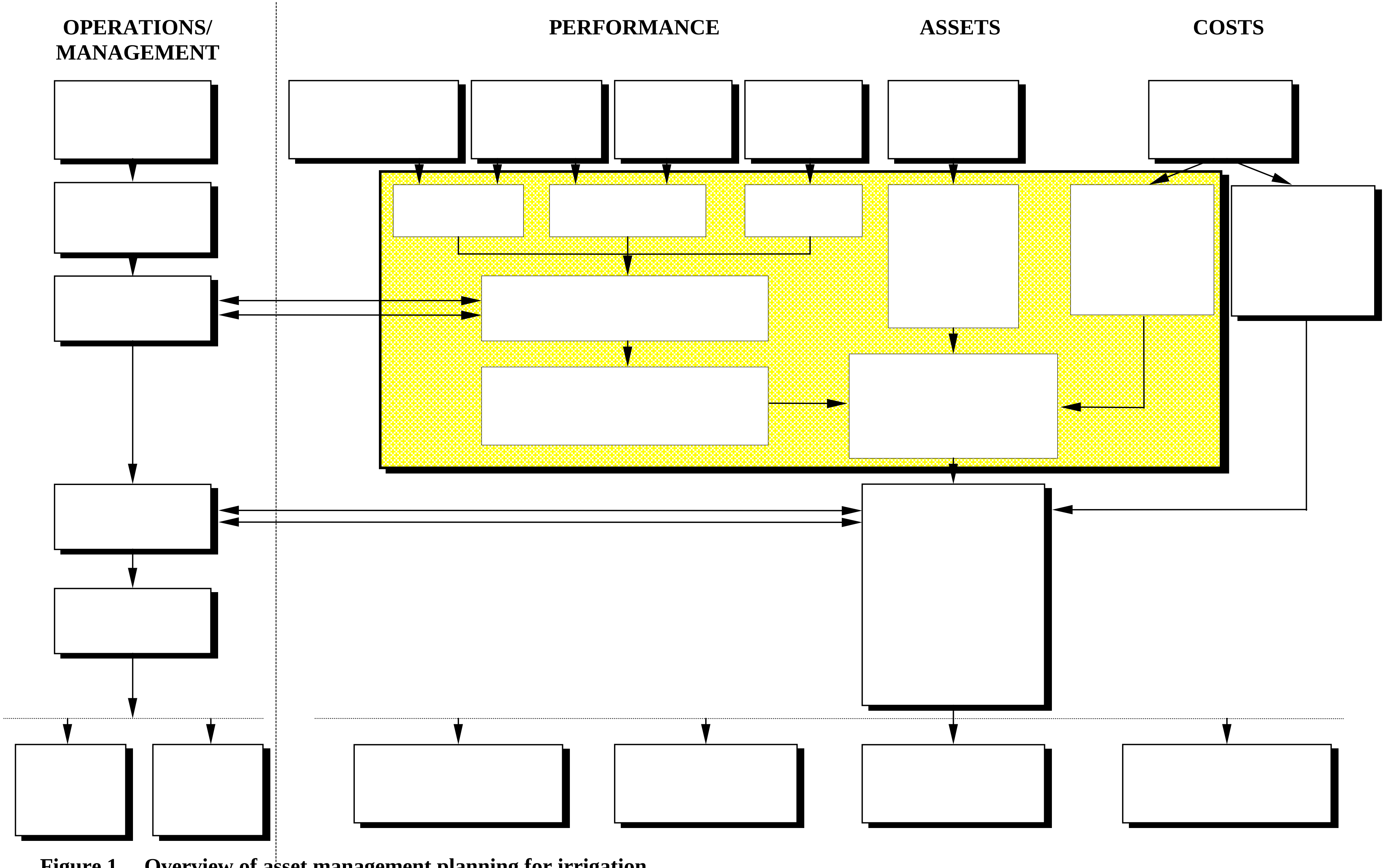


Figure 1 Overview of asset management planning for irrigation

(iv) Carrying out the Asset Survey

The Asset Survey is a central feature of the asset management planning process. The survey aims to plug gaps in the information required to prepare an AMP. Typically, at the preparation of a first AMP, those gaps could be quite extensive. Over time, however, more and more information will become available and surveys will continue to fill these gaps, update information and improve the accuracy of information.

As sample (rather than all) systems are taken it is possible to carry out the Asset Survey in detail without overtaxing the available resources of skilled manpower, time and money. The survey serves to determine:

- the **category** of components of the system (canal, head regulator, etc).
- the **extent** of the assets that exist (how many and in what categories).
- the **size** of the asset (these are grouped into Size Bands).
- the "**importance**" of the asset. The importance relates to the impact that malfunction of the asset might have on the system as a whole. The head regulator at the river intake is thus more "important" than a secondary canal head regulator lower down the system.
- the **value** of the assets in each size band. The value is based on the Modern Equivalent Asset (MEA), that is the cost of replacing the structure at today's costs.
- the **components** of each asset (e.g. gates and masonry as components of a head regulator structure). Different components of an asset may deteriorate at different rates.
- the **condition** of the asset and its components. The condition will affect the level of investment required. **Condition Grades** are used to categorise condition.
- the **serviceability** of the asset, that is, how well it performs its function. An asset may be in a poor condition (masonry damaged) but performing its function satisfactorily (gates operating and passing design discharge). For irrigation serviceability of structures is divided into **Hydraulic Function** (ability to pass design discharge) and **Operations Function**(ability to control flow across a specified range, ability to provide command level,etc). **Serviceability Grades** are used to categorise serviceability.

(v) Assessing scheme performance

This is one of the most difficult elements of the asset management planning process for irrigation. By comparison performance assessment for water supply systems are relatively straightforward. For irrigation a clear distinction needs to be made between the performance of the **scheme** (that is the irrigation and drainage network, the fields, the crops, the farmers, etc) and that of the **system** (just the irrigation and drainage network alone). Asset management planning is concerned with the performance of the system, the principle performance measures are design, or maximum required, discharge, and command. Other common scheme performance indicators such as crop production, crop yield, etc are not of direct interest for asset management planning (though improvement in system performance will be quantified in terms of these variables). Small and Svendsen (1992) recognise the distinction between different "systems" (using terms of "irrigation system" and "irrigated agriculture system") and provide a useful framework for performance assessment at all levels. Murray-Rust and Snellen (1991) do not make such a clear cut distinction between scheme and system performance.

A key feature of the asset management planning process is to specify the **required** level of service and to then determine the performance shortfall by measuring the **current** levels which are, or could be, provided by the assets (assuming there are no management constraints).

(vi) Engineering Studies

Engineering Studies are a central part of the asset management process. Their primary requirements are to:

a. Identify and quantify causes of **system** performance shortfall (if any)

b. Quantify likely consequences (benefits and costs) of investment strategies aimed at improving performance levels.

c. Quantify changes (over time) in values of performance indicators as a consequence of capital investment.

Further studies related to the needs of the Financial Model may be required, such as, for instance, an economic and financial analysis to determine the ability of the water users (farmers) to pay for the planned levels of service.

The number and location of the Engineering Studies will be determined in consultation with the AMP statistician to ensure that the results will provide information that can be aggregated in a statistically valid way.

It must be emphasised that the Engineering Studies and the Asset Survey have different aims and outputs, and in this respect they complement each other.

(vii) Building Cost Models

The purpose of Cost Models is to:

- facilitate valuation of existing assets (in terms of their MEA)
- provide unit costs for capital investment activities
- quantify operational costs into (a) Operation and (b) Maintenance.

The values for the Modern Equivalent Asset (MEA) may come from existing data, or may need to be generated as part of the Engineering Studies. Unit costs will be needed to convert investment activities (such as replacing secondary canal head regulator gates) identified by the Engineering Studies into expenditure. The recurrent budget required for system operation and maintenance (OPEX, as opposed to capital investment, CAPEX) will need to be quantified. Trade-offs between CAPEX and OPEX expenditure may need to be considered, if so the opportunities for these will need to be determined under the Engineering Studies.

(viii) Assembling and Presenting the AMP

The process of producing the Asset Management Plan (AMP) is one of data transformation of the various inputs from diverse sources (as described above) into a set of interrelated outputs. The various outputs from the processing within the AMP are presented in Table 4 below. These outputs from the AMP are then used in the Financial Model.

Table 4 AMP outputs

Output	Description
Asset Stock Condition and Serviceability Profiles.	Report outlining the total number of each asset type, the sub-totals in each size band, the MEA value, total depreciated value and profiles by MEA value of asset condition, serviceability and importance.
Asset Types and Components Depreciation Categories.	Report on the depreciation lives of the various asset types and components.
Investment Timing and Purpose Analysis.	A provisional programme of capital investment for the first 5-year plan and each subsequent 5-year band to 20 years. Also identifies purpose of investment as either (i) maintain system performance (ii) improve or extend system performance or (iii) maintain asset condition profile.
Investment by Asset Type and Importance Band.	Report relating investment plans, in financial terms, to specific asset types and their importance band.
Investment Activities.	Report showing long term investment programme broadly defined into the most significant types of work which will be undertaken (such as "replace gate", "repair downstream protection".)
Investment Benefits.	Report detailing the anticipated benefits gained over time from the investment programme in terms of improvements in performance indicators. Forms a key aspect of the Financial Model.

(ix) Running the Financial Model

The financial modelling process is one of reviewing and refining the provisional ideas presented in the AMP. This is the part of the process through which the key strategic management decisions can be taken. Specifically, the purpose and boundaries of the financial model are:

(i) to come up with a realistic investment strategy in terms of the funds available; and

(ii) to identify CAPEX/OPEX tradeoffs (Capital against Operating expenditure decisions).

In running the Financial Model the data collected for, and collated in, the AMP are used to the full. From the AMP we have:

- investment needs identified
- a provisional expenditure programme over 20 years
- benefits of investment identified and related to the same programme
- a database on which to draw in considering alternatives

Using the above as a base to work from, the Financial Model considers constraints and priority influences in respect of:

a. Alternative strategies
b. Capital planning (20 years)
c. Budget planning and investment priorities (5 years)
d. Sources and realistic levels of funding (Irrigation Service Fee, subsidies, etc).

a. Alternative Strategies. A fundamental question which needs to be explored is whether the investment plans provisionally set out in the AMP can be sustained as they stand without modification. If they cannot then consideration needs to be given to alternatives, such as:

- Accelerating or delaying investment
- Altering the level of service to be provided

- Finding alternative sources of revenue
- Considering alternative CAPEX/OPEX trade-offs

The decisions arising from consideration of alternative strategies will:

- set policies (for guidance in budget preparation)
- allocate funds and priorities for the first 5-year plan

b. Capital Planning. This is the process of defining the capital investment requirements arising from the preferred investment programme. It is necessary to know the cost and income stream and the flow of capital in 5-year periods over the 20 years. The first 5-year plan is converted into a budget plan.

c. Budget Planning and Investment Priorities. This analysis sets out a detailed expenditure policy for the first 5 years, based on declared priorities. It allocates "baskets of money" to specific types of activity, and defines the cash flow (income and expenditure) required to achieve this level of investment.

d. Sources of Funding. As part of the financial modelling process the pricing structure for provision of the service needs to be considered and the charge rate to the consumers set. The level of this "Service Fee" will depend on, inter alia:

- obligatory standards (eg.legislation, minimum flow levels for pollution control, etc)
- the desired level of service to be provided to the customer given the ability and/or willingness of the water users to pay (based, for example, on a 'customer survey' or socio-economic appraisal)
- the current level of service (in comparison with the desired level of service)
- the level of investment to be made in the system
- tradeoffs made between CAPEX and OPEX expenditure

In the Financial Model careful attention will need to be paid to the level set for the service fee. The cost stream should be relatively stable such that customers are not met with widely fluctuating fee levels. In the case of the recently completed AMP2 for the UK water industry the level of fee set for water charges was a major issue in the investment planning proposals prepared by the water companies.

(x) Pricing for Cost Recovery

By planning the level of investment required over time the AMP sets target income levels to fund investment. This income can come from a variety of sources; in the case of water supply it is usually from the customers, whilst in irrigation in developing countries it is often paid by government. Within many countries, however, moves are being made to charge users for irrigation water supplies through the levy of an Irrigation Service Fee. As discussed above the setting of this fee level is a sensitive issue and in the case of irrigated agriculture the ability to pay needs to be carefully studied (ADB/IIMI,1986; Small, 1987). Such studies should form part of the Engineering Studies outlined above.

5 Experiences of the trials

Two trials of the application of asset management procedures to irrigation were undertaken in Indonesia, one in East Java Province in 1993 and one in Yogyakarta Province in 1994. Findings from the first study (Davies, 1993) were incorporated and refined in the second study (IIS,1995a), and a preliminary set of guidelines produced for asset management planning for irrigation (IIS,1995b).

The first study and trial was undertaken as part of the World Bank funded Operation and Maintenance Turnover Component of the Second Irrigation Sub-Sector Project (ISSP-II). The second study and trial took place in Yogyakarta Province, and was selected because of its proximity to Gadjah Mada University and because of its relatively small size as a province. It was envisaged that a province was a realistic size of administrative unit on which to base an asset management plan.

The stages of AMP production and the requirements of each stage have been set out above, the sections below briefly outline some of the practical difficulties experienced in developing and following through the asset management planning process. The details provided mainly refer to the second, more comprehensive, trial.

(i) Stratification

In order to stratify systems into groups with like characteristics it is necessary to gain a comprehensive overview of all systems operated in the area concerned. This proved to be more difficult than might have been supposed. Data did exist, however, and could be collected and analyzed in an appropriate way although it was not always consistent. Parts of the procedure require the grading of data 'accuracy' and 'reliability' and these scores are the basis of statistically derived confidence limits. Some reliance had to be placed on the assessments of operations staff who know the area (for example about whether a system was on "flat" or "steep/undulating" terrain) but this is quite acceptable as a source of some data. Ultimately it proved possible to undertake stratification in a manner which made operational sense and satisfied the statistical requirements.

(ii) Sample system

Sample systems for detailed examination (performance assessment and asset survey) would normally be selected randomly from the strata groups identified. Sufficient work was done to demonstrate the procedure and establish its feasibility. For the next stages of the trial, however, a single system, Daerah Irigasi (D.I.) Papah, was selected as a contract had just been let for a series of upgrading, extension and deferred maintenance tasks aimed at improving system performance. This meant that it could be inspected extensively in its 'deficient' state without disruption to service. Furthermore "Engineering Studies" had already been undertaken in justification of the ongoing works and were available for inspection.

(iii) Performance indicators

A great deal of thought and discussion went into the theoretical selection of appropriate performance indicators. In practice, of course, the choice is limited to data which are available or which can be collected. Following adoption of Asset Management Planning, steps could be taken to improve quality of data over time thus narrowing confidence limits and adding clarity. In the trial the following approaches to measuring system performance were tested:

- crop area planted in comparison to that planned as a measure of farmer confidence in the service
- Water Delivery Performance Ratio (Actual discharge/Target discharge)
- interviews with Water User Associations (PPPA) about their experiences of the service and any associated problems

In Yogyakarta Province data on crop area and type within each tertiary unit is collected each 15 days, data on river and canal discharges is, in theory, collected each day. Data from the previous 15-day period is used to plan the target water allocations for the coming 15-day period. Thus the performance indicators chosen for the AMP were consistent with current practices.

These approaches could be regarded as alternatives or as complementary depending upon the amount and consistency of data available. In practice, the difficulties in the first two approaches lay in the availability and quality of data (even though the indicators had been chosen with this in mind) whilst in the third approach the problem is one of converting the qualitative results of wide ranging interviews into an appropriate quantitative scoring systems. It is recognised that there is nothing fundamentally new about these problems and that they can be overcome. Sufficient was undertaken in the trial to demonstrate that performance indicators of the form required by the AMP can be selected for irrigation and can be measured. However the authors feel that the detailed approach to this aspect should be the subject of a preliminary study for each country intending to use Asset Management Planning since requirements and practices vary widely from one country to another.

(iv) Cost Model

The trial found that data exists from past project estimates and priced contract documents to enable the compilation of a Cost Model. The form of presentation of the information is often unsuitable for use without 'unscrambling' however. Work was undertaken in the trial to clarify practical difficulties in compiling the Cost Model which proved, as expected, to be largely to do with gathering and analysing data. The attractions and range of uses of such a cost database, once compiled, were appreciated by irrigation agency officials - reflecting the experience in the UK where the development of a water-industry-specific cost database had its origins in the requirement to produce the original AMP.

(v) Engineering Studies

The requirement to undertake Engineering Studies is well understood by irrigation agencies and has long been the bread-and-butter of consulting engineers. As explained above, an existing report on D.I. Papah was used in the trial as a means to identify potential difficulties. In essence the report addressed the requirement of the AMP but, as it stood, the form of its output was not fully suited to preparation of an AMP in the following respects:

- It did not relate specific investment activities to specific performance shortfalls. Instead, overall financial costs and benefits were compared.

- It did not enumerate separately the costs of specific investment activities. All activities were aggregated and re-divided into Bill of Quantity items before costs were applied.

- It did not detail benefits in terms of improvements in performance indicators or how there would be distributed over time.

It was found that specific terms of reference for Engineering Studies for the AMP were required, and that further research was required in this particular area. Interestingly research work along these lines is being carried out by the Overseas Development Unit of HR Wallingford (1994) in Yogyakarta Province.

(vi) Asset Survey

A set of survey forms and grading classifications were developed for principal elements of 'asset systems' (i.e. Weirs, Canals, Head and Cross Regulators, Measuring Structures etc.). These were tested by the research team and irrigation service staff carrying out asset surveys. Lessons were learnt and amendments made in relation to the layout, clarity of 'condition' and serviceability' descriptors and about the logistics of survey planning and organisation.

(vii) Data Transformation and Presentation

The detailed form of presentation of the Asset Management Plan must be tailored to the requirements of the commissioning agency. A suite of input and output proformae were developed equivalent to those required and used in the UK water industry but reflecting the needs of irrigation (IIS,1995b). The process of data transformation was designed in a manner suitable for a computer database.

In the first study a spreadsheet program was used to compile, analyze and present the data. Whilst more time than was available is required to develop a more sophisticated program the spreadsheet model did allow comparison of different investment strategies (Figure 2). With a "Very Poor" specified level of service the investment comes later in the planning period (in this case 10 years) as investment is deferred. Eventually investment has to be made if the system is to function at all. With a "Very Good" proposed standard of service the investment profile is weighted towards the early stages of the planning horizon. Interestingly, in this example, the average annual budget requirement are similar in both cases. From this analysis the average annual income (the "Irrigation Service Fee") needed to support this level of investment can be determined (approximately Rupiahs 18,000 (US$8) per ha).

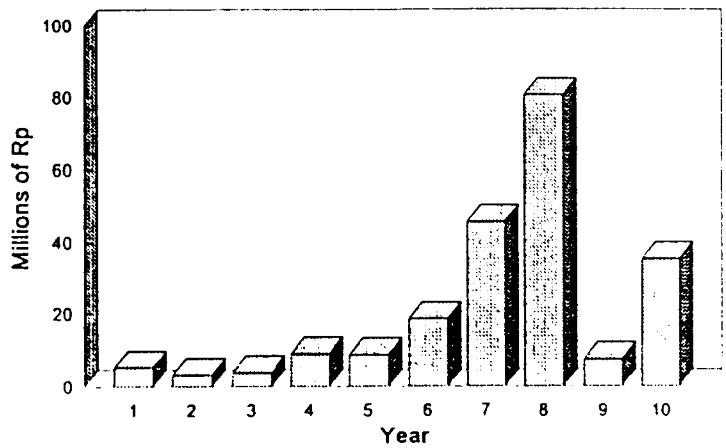
Figure 2 Examples of investment profiles for different specifications of standard of service

Asset Management Program

DI Penewon
Long-Term Budget Forecast

Proposed Standard of Service	Very Poor
Interest Rate	10%
Ave. Annual Budget Requirement	17,927,043 Rp 18,425 Rp per hectare

Year	Budget
1	5,185,983 Rp
2	3,276,833 Rp
3	3,894,688 Rp
4	8,932,750 Rp
5	8,658,000 Rp
6	18,642,727 Rp
7	45,628,847 Rp
8	80,512,987 Rp
9	7,402,333 Rp
10	35,510,000 Rp

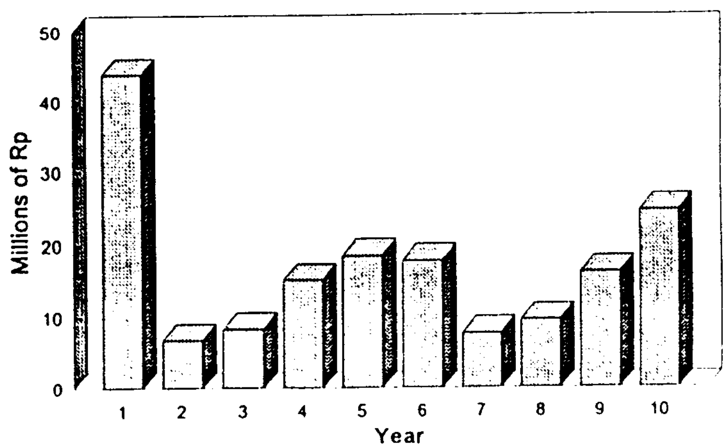


Asset Management Program

DI Penewon
Long-Term Budget Forecast

Proposed Standard of Service	Very Good
Interest Rate	10%
Ave. Annual Budget Requirement	17,676,010 Rp 18,167 Rp per hectare

Year	Budget
1	43,878,989 Rp
2	6,913,067 Rp
3	8,378,683 Rp
4	15,167,333 Rp
5	18,491,167 Rp
6	17,828,483 Rp
7	7,784,900 Rp
8	9,573,117 Rp
9	16,212,800 Rp
10	24,567,258 Rp



6 Conclusions

The major conclusion drawn from the study is that asset management planning, as developed for the UK water industry, can be applied, with modifications, to the irrigation sector in developing countries. By the nature of the approach (using statistical sampling methods) its applicability is limited to those countries with an extensive irrigation network. This approach makes best use of available resources of skilled manpower, time and money by concentrating efforts on in-depth analysis of selected sample areas. The key to the process lies in the approach adopted to statistical sampling. Great care is required to identify the criteria for stratification and normalisation in order that the sampled areas are representative of the system or systems as a whole.

A key issue in the asset management planning process for irrigation was found to be the influence that operational management has on performance. It is essential that management constraints are identified and their impact on system performance understood. The performance assessment needs to concentrate on the system, though measures of scheme performance (such as crop production and its spatial distribution) may be used as proxies for system performance. As has been the case in the UK, it was found that the process of preparing the AMP for the irrigation system focused attention on, and clarified, the actual and desired level of service provision to customers.

Finally it is believed that asset management planning as outlined herein provides an excellent framework for the "business" of managing irrigation systems. The process has application whether the system is in the public or private sector. The question of what institutional arrangements would best suit the provision of the service is a separate one - although, clearly, for it to be effective, conditions must prevail in which managers have at their command both the resources and the authority to carry out the plan. Through the process of asset management planning many of the current issues in irrigation are addressed and resolved within a systematic framework. These include cost recovery and the setting of an irrigation service fee; performance assessment and stipulation of performance targets; irrigation turnover and privatisation; stipulation of levels of service; maintenance management and sustainable development. The key issue is that these initiatives are brought together in a logical framework which addresses the whole process rather than individual parts.

The process results in a Strategic Business Plan in which investment levels are set for the system to provide stipulated levels of service to customers which will facilitate specified levels of output from the irrigation scheme as a whole. Through the process of preparation of the AMP, data is collected against which subsequent performance can be measured and assessed. The system is "transparent" and auditable. It has much to recommend it.

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