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Asset management for irrigation systems

Addressing the issue of serviceability

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Abstract. This paper advocates the need for defining criteria for level of service provision for irrigation networks and outlines a proposed Irrigation Serviceability Matrix to be used in the preparation of asset management plans and investment strategies for irrigation infrastructure. The development of the Irrigation Serviceability Matrix is based on experienced gained in the UK by the privatised water industry where the level of service provision to customers has become a key determinant for investment in infrastructure. The paper describes the evolution of this process within the UK water industry and its application to the irrigation sector.

Key words: asset management, serviceability, irrigation, level of service, Irrigation Serviceability Matrix

Introduction

A major constraint to the effective management and performance assessment of irrigation systems is the lack of clearly defined levels of service provision to water users. Prior to privatisation in 1989 the UK water industry also had limited explicit criteria and limited recognition of the need to define and work towards specified levels of service provision. Some 10 years after privatisation the level of service provision is the driving force for operation, maintenance and investment in infrastructure.

This paper outlines the recent experience with asset management and investment planning within the UK water industry, and details how the issue of level of service provision and serviceability of infrastructure have come to the fore. The approach to the development of an Irrigation Serviceability Matrix, based on the UK water industry experience, is then outlined.

Asset management planning in the UK water industry

The ten water authorities in England and Wales were privatised in 1989. During the run up to privatisation the financial institutions were concerned with regard to the selling price of individual companies. Their concern focused on the following issues:

- Approximately 70% of the industry's assets were buried underground, which meant that investors had no real indication of the condition or performance of these assets
- The extent of the investment required to enhance and maintain the assets to meet the standards set by the European Union and UK government was unknown
- It was not clear how future investment in the assets was to be funded

In addition to these concerns there was concern that a private company might under-invest in the infrastructure and then abandon it, leaving the customers to fund a system in need of significant levels of investment.

These concerns were addressed by the introduction of the Asset Management Plan (AMP) which allowed the asset condition, performance and investment needs to be identified and independently certified. Guidelines for the preparation of asset management plans were produced by the UK's Water Research Centre (WRc), though individual water companies customised the guidelines to suit their own situations (Rumsey & Harris 1990).

The first asset management plans (termed AMP1) were prepared prior to privatisation in 1989 over a period of 12–18 months using statistically based sampling procedures. In this period an investment programme of some £28 billion was identified for a 20-year period for the 10 water companies.

The Operating Licences awarded to the newly privatised companies required them to maintain the AMPs, since they would be used as a key input to the periodic review of price limits undertaken by the industry regulator, the Director General of Water Services (DGWS). The first review was undertaken in 1994 (AMP2), the next review is planned for 1999 (AMP3).

The DGWS has produced guidelines (OFWAT 1992; OFWAT 1995) for the water companies to assist in the preparation of AMPs in order to standardise the data presented and the review procedures. The current major components of asset management planning in England and Wales are:

- Asset condition and performance assessments
- Asset databases or information systems
- Asset planning
- Levels of service (or serviceability levels) set by the DGWS or by the water company
- Asset monitoring
- Investment planning systems (including analysis/scenario assessments)
- Cost estimating (unit cost and/or cost models)
- Demand forecasts
- Capital and operation expenditure forecasts (Capex and Opex)

– Revenue forecasts
– Cash flow forecasts and working capital

As indicated above, the AMPs report on the serviceability levels for customers, operating costs, asset values and sources of revenue. The original AMP has evolved into a comprehensive 20 year Strategic Business Plan for each of the water companies, regulated and monitored by an independent authority on behalf of the customer. Thus:

> Strategic Business Planning in the water industry context is a rolling integrated approach to the planning, management and running of the monopoly business with the objective of ensuring the effective, economic and financially viable long term provision of appropriate quality services to customers and the community. (OFWAT, 1995)

The term “appropriate quality services” encompasses the need to ensure that the products supplied to the customer comply with the statutory requirements (Water Quality Regulations) and that the emissions back into the environment (e.g. the river system) comply with similar legally binding consents.

The ‘Strategic Investment Plan – AMP2’ (OFWAT 1992) was designed to provide the DGWS with sufficient information to determine the ‘K’ profiles for all the water companies for a ten year charging period commencing in April 1995. The ‘K’ factor is the annual average percentage increase in water prices which the water companies will be allowed to charge over and above the rate of inflation. Emphasis was placed on the strategic investment plan being sufficiently robust to enable it to withstand detailed scrutiny.

There were four underlying objectives in the 1995 Strategic Investment Plan:

– To create a database to hold information on the quality and performance of a company’s existing assets. This would be linked with asset cost valuations and collated into long-term asset inventory, providing a summary of a water company’s capital in terms of its assets.
– To provide an auditable calculation of the investment required to *maintain* the performance of the existing assets over time.
– To provide an auditable calculation of the investment required to meet the *growth* in demand over time.
– To provide a document from which the DGWS could monitor the performance and confirm the progress of each water company.

The leading principles governing these objectives were customer involvement, levels of service provision (including obligations, standards and policies) and a long term planning horizon (which was set at 20 years). The AMP2 manual required that each water company could demonstrate that it had undertaken appropriate customer consultation to ensure that its policies were in line with the customers’ wishes and required levels of service.

For the 1999 review (OFWAT 1997) the DGWS has stated three key objectives:

– *To operate an open and transparent process*. For the review the views and aspirations of the four main parties (the paying customers, the Environment Agency (EA), the Drinking Water Inspectorate (DWI) and the water companies) must be taken into account.
– *To operate an effective process*. The process should not hinder the workings of the parties affected (the DGWS, the Secretaries of State, the EA, the DWI and the water companies), rather it should facilitate the carrying out of their duties.
– *To ensure efficient use of data*. The process must allow adequate time for the collection, processing and analysis of data. The results should be published in time for the relevant parties to provide feedback prior to any formal decisions being made by the DGWS.

Serviceability in the UK water industry

In the run up to AMP2 the key driver in determining the required ‘K’ value was the physical condition of the asset, be it a structure, underground asset, or an item of mechanical/electrical plant. In the preparation of AMP3 the condition of the assets is still a key factor, however more attention is being paid to the asset’s serviceability. The issue of the serviceability of assets, as opposed to just its condition (though this affects serviceability), has arisen as water companies have realised that improving the condition of an asset has not necessarily affected its serviceability, and thereby the system’s performance. Money was being invested in the infrastructure but the customer was not necessarily seeing a benefit or return on the investment.

From this concept the ‘Serviceability Matrix’ has developed whereby investment is planned based on improvements to identified infrastructure based on their level of serviceability. Thus investment is now directly linked to the maintenance, or enhancement, of system performance and thus level of service provision to the customer.

An example of a Serviceability Matrix for wastewater treatment works employed by one of the water companies, Southern Water, is presented in Figure 1. There are eighteen different serviceability criteria which take into account the customers’ requirements, where the ‘customer’ is taken as the Environment Agency (EA), the Drinking Water Inspectorate (DWI), the Health and Safety Executive and the paying customer. Thus a paying customer might not complain about the failure of a sludge tank, but they would complain about the resultant odour, hence the Odour Complaints serviceability criteria in the matrix. In a similar manner the other 17 serviceability criteria have evolved based on how the 'customer' would perceive a failure in performance. The serviceability criteria are graded from 1 to 5, with 1 being optimal and 5 complete failure to satisfy the criteria.

Figure 2 shows the procedure for Southern Water's Serviceability Grading which is in three parts:

- Part 1 – Analysis of office data
- Part 2 – Site inspections
- Part 3 – MEA (Modern Equivalent Asset) valuation of the assets

Figure 3 shows the process followed. The TR61 program, which has been produced by WRc Engineering, is a high level planning/costing tool which calculates the MEA values of each site (e.g. pump station) and the equivalent values of the assets allowing for their current condition. The output from the Serviceability Matrix and TR61 enable the costing of improvements to be determined.

A typical output of the Serviceability Matrix is presented in Figure 4. This matrix enables the identification of problem areas and enables priorities to be set if it is necessary to reduce the level of spend to meet an external budgetary target. For example a Grade 5 flow capacity situation might be seen as more important than a Grade 5 flooding problem, and will therefore be addressed first. If a Serviceability Grade of 4 or 5 is given for a particular criteria an engineering study is undertaken to determine the reason for the grading, and the cost of improving the asset(s). The above process requires significant quantities of data, for which a number of databases have been produced and refined over the years (Banyard & Bostock 1998).

Factors to consider in developing an irrigation serviceability matrix

The processes and procedures developed for asset management and investment planning of water supply and sanitation infrastructure can be adapted to the irrigation sector as the fundamental components and processes are similar (IIS 1995; Burton et al 1996).

The focus of Southern Water's AMP3 preparation is the Serviceability Matrix which enables them to check that the company is meeting the required levels of service. By using the information summarised in this matrix they are able to calculate the cost of improvements, hence creating their investment budget based on maintaining or enhancing system performance. The defined levels of service are an effective way of setting the required performance levels.

For irrigation systems to establish a serviceability matrix it is necessary to consider:

- Who is the customer

Grade	Peak Flow 3 dwf	Peak Flow Formula A	Flow to Storm Tank	Sludge Treatment	Site Flooding (all types)	Odour Complaints	Works Config with Consents (3)	Works Config with Consent (3)	Catchment Growth (4)
Grade 1	✓	✓	✓	✓	None	None	✓	✓	✓
Grade 2	N/A	N/A	N/A	N/A	Minor	N/A	N/A	N/A	N/A
Grade 3	N/A	N/A	N/A	Occasional Overtime	Once a Year	Isolated	N/A	N/A	N/A
Grade 4	N/A	N/A	N/A	Excessive Overtime Stockpiling	Twice a Year	District Council Investigating	N/A	N/A	N/A
Grade 5	Overloaded	Overloaded	Overloaded	Overloaded Disposal Non -Complaint	More than Twice a Year	Statutory Notice Received	Main Process Non-Complaint	Storm Process Non-Complaint	Non-Complaint

Grade	Structural Condition	M/E Condition	Statutory H & S	Target Compliant	EA Compliance	Rates of Flow	Nuisance Complaints	Telemetry	Standby Power
Grade 1	Sound	Fully Serviceable	Complies	No Failures	No Failures	Complies	None	Alarm and Monitoring	Fixed
Grade 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Fixed
Grade 3	Minor Defects	Minor Defects	N/A	Isolated Failures Pass LT.	Isolated Failures	N/A	<10	Alarm Only	Mobile
Grade 4	Repair before 2005	Replace Major Elements 2005	N/A	Regular Failures Pass LT.	Regular Failures Pass LT.	Storm Tanks By-passed Prematurely	>10<20	None but Required	Inadequate
Grade 5	Replace major Elements 2002	Replace Major Elements 2002	Non-Complaint	Fails Look Up Table	Fails Look Up Table	Main Process Storms Prematurely	>20	None but Specified in Consent	None but Required by Consent

Notes:
1. Asset is classified by worst grading in boxes outlined in bold
2. LT denotes Look Up Table 1
3. Physical layout, including provision of standby power and telemetry, is consistent with consent
4. Consent is appropriate volumetrically when considered in light of current flows and populations
5. Current rate of flow through Works is consistent with consent requirements

Figure 1. Serviceability matrix for wastewater treatment works (Southern Water).

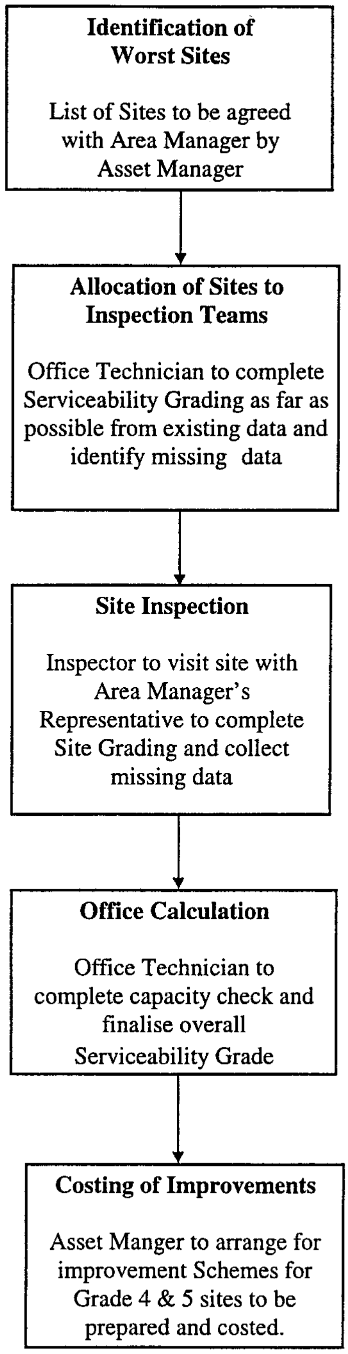

Figure 2. Flow diagram for Serviceability Grading.

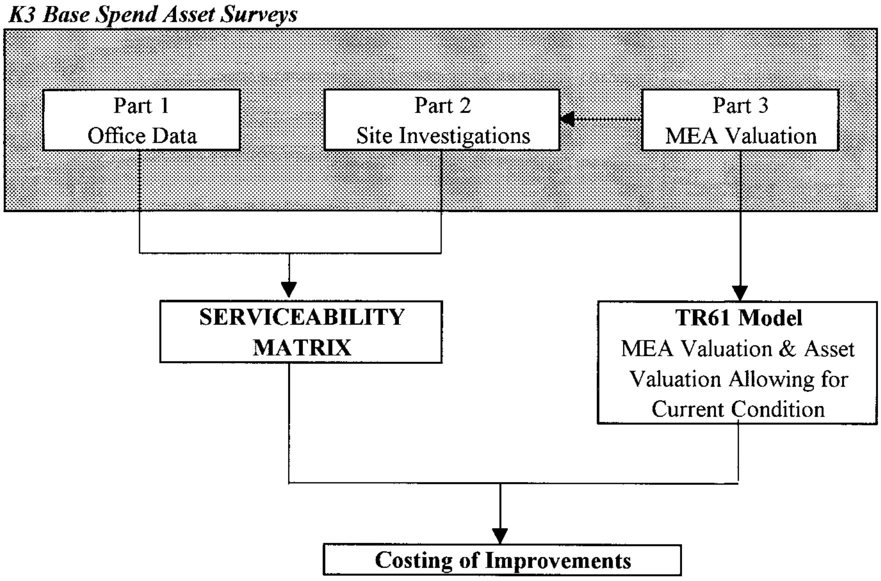

Figure 3. Information flow from asset surveys.

– How serviceability should be measured
– How the performance of the system/asset should be assessed

The Customer The primary customer in an irrigation system is the water user or farmer. In additioni there are the regulatory bodies which might regulate water abstraction, environmental pollution or degradation, and health. In many irrigation schemes the regulatory authorities, and statutory obligations placed on the management of irrigation schemes, are limited in extent. The primary focus is the water user.

Measurement of serviceability When considering the issue of serviceability for irrigation schemes the following questions need to be asked:

– Is the level of service measurable?
– Are the levels of service realistic and achievable?
– How should the levels of service be measured and monitored?

The capacity to deliver a certain level of service is dependent on system design, and the associated infrastructure. Pressurised pipeline systems are able to deliver water on demand to fully match farmers' requirements, whilst proportional distribution systems, such as the Warabandi system, are supply orientated and less flexible in matching farmer' requirements.

Serviceability Matrix for 10 Waste Water Treatment Works																		
Sites	**Peak Flow 3 DWF**	**Peak Flow Formula A**	**Flow to Storm Tanks**	**Sludge Treatment**	**Site Flooding**	**Odour Complaints**	**Works Configures with Consent**	**Works Configures with Catchment**	**Catchment Growth**	**Structural Condition**	**M & E Condition**	**Health & Safety**	**Target Compliance**	**Environment Agency Compliance**	**Rates of Flow**	**Nuisance Complaints**	**Telemetry**	**Standby Power**
Site 1	5	x	1	1	5	1	5	1	5	4	3	5	5	4	5	1	3	5
Site 2	5	x	1	1	3	1	5	5	1	3	3	1	5	4	5	1	3	4
Site 3	1	x	1	5	1	5	1	1	1	5	4	1	5	5	1	1	1	1
Site 4	5	x	5	5	1	1	1	5	1	5	5	5	4	4	x	1	3	5
Site 5	5	x	5	1	3	3	1	1	1	3	5	1	5	5	1	1	1	5
Site 6	x	5	x	5	5	1	1	5	1	5	3	1	3	3	5	1	3	4
Site 7	5	x	1	1	1	1	1	1	5	5	5	5	3	1	5	1	1	1
Site 8	x	5	x	5	1	1	1	1	x	5	5	5	x	x	x	1	1	3
Site 9	5	x	5	1	4	1	5	5	5	3	4	5	3	3	5	1	1	3
Site 10	5	x	1	1	1	4	5	1	1	2	5	1	5	5	5	3	1	1

Figure 4. Example of summary table showing serviceability matrix grading for ten waste water treatment works (Southern Water).

When looking at the level of service provision from the farmers' perspective the key criteria in terms of water delivery are that the supply is:

- Adequate
- Timely
- Fair (commonly termed "equitable")
- Reliable
- Affordable
- Efficient (in use of resoures)
- Secure (i.e. will not fail)
- Safe (for crops and possibly human consumption)

Additional criteria for the farmer might be that the supply is convenient and flexible. Serviceability criteria for other concerned parties include:

- Quality of drainage water (levels of salts and agro-chemicals)
- Groundwater levels and waterlogging
- Area prone to flooding
- Occurrence of slow moving or standing water (malaria and schistosomiasis health hazard)
- Safety (from drowning/injury to humans and animals

The ability to deliver the desired level of service will primarily depend on:

- The type of irrigation infrastructure provided
- The performance of the infrastructure
- The management capability

In contrast to piped hydraulic systems such as with water supply and sanitation networks, the water delivery performance of supply orientated open channel irrigation systems are heavily dependent on the quality of management. Issues other than the condition and performance of the infrastructure may predominate in systems where the management procedures are weak.

Performance assessment The performance of the infrastructure, and thus its ability to deliver the desired level of service, depends on the condition of the assets, their hydraulic performance and their location and function within the system.

The *hydraulic performance* of the asset(s) is central to the performance of the system and its ability to provide the defined levels of service.

The *condition* of the asset(s) may or may not affect the hydraulic performance (which is why it is importan to measure the hydraulic performance separately). A gate, though in Condition Grade 4 with a badly rusted plate, may still be able to perform its function of controlling the flow. A new gate (condition Grade 1) which has been (illegally) jammed in the fully open position (to give downstream farmers more water) is not able to perform its required function.

The *importance* of the asset(s) reflects the position, type or function of the asset. The river diversion weir on a gravity fed system is of primary importance to the performance of the scheme, a head regulator controlling supply to a 100 ha tertiary unit at the tail end of the system less so. The following factors influence the determination of asset importance:

- Asset location
- Loss of asset function in relation to system performance
- Cost of replacing the asset
- Risk assessment
  - danger to people and the environment following asset failure
  - extent and cost of damage or loss in the event of asset failure
  - likelihood of failure if not maintained

The *priority* for expenditure on an asset is an important part of the process of asset management. The priority will depend on the asset's performance, condition, importance, impact on serviceability, and cost. Assets can be ranked in terms of the first four criteria with the cost being kept separate until the final decision making stage.

Possible relationships between asset performance, condition, importance and priority are presented in Table 1.

The irrigation serviceability matrix

Taking into account the issues raised above, a serviceability matrix consisting of two parts has been formulated:

Matrix A Defines the overall status of the *irrigation system (network)* and its components in relation to providing the defined level of service

Matrix B Defines the status of the *individual assets* in terms of their condition, performance and importance

Matrix A (Figures 5 and 6) is analogous to the water industry's serviceability matrix in that it defines the level of service provision required by sections/areas of the irrigation system, whilst Matrix B (Figure 7) identifies the performance of infrastructure which might influence the level of service provision in those sections/areas. Thus if a serviceability problem is identified in Matrix A, the cause of this problem, if it relates to the performance of the infrastructure, can be traced back to the relevant asset in Matrix B.

Table 1. Possible performance, condition and importance relationships

Performance	Condition	Importance	Explanation of situation	Consequence
Good	Good	High	No problem with asset. Performance and condition are good, indicating that asset is new and in serviceability grade 1 or 2.	Low probability of structural failure.
Good	Good	Low	No problem with asset. Performance and condition are good, indicating that asset is new and in serviceability grade 1 or 2.	Low probability of structural failure.
Good	Poor	High	The situation is hazardous because the asset is close to failure, but its good performance may provide a false sense of security. High priority status because of the importance rating.	High probability of sudden structural failure which could have high direct and indirect cost consequences
Good	Poor	Low	The situation is hazardous because the asset is close to failure, but its good performance may provide a false sense of security. Low priority status because of the importance rating.	High probability of sudden structural failure which could have moderate direct or indirect cost consequences.
Poor	Good	High	High priority status as performance is low and importance is high. Condition is good indicating that performance is affected by something other than condition.	Engineering assessment required to identify the problem causing the poor performance.
Poor	Good	Low	Low priority status since importance is low. Condition is good indicating that performance is affected by something other than condition.	Engineering assessment required to identify the problem causing the poor performance.
Poor	Poor	High	High priority status as performance and condition are poor and importance is high. This indicates that the asset has failed and is in serviceability grade 4 or 5.	High probability of sudden structural failure which could have high direct and indirect cost consequences.
Poor	Poor	Low	Low priority status as importance is low. However, the poor performance and condition indicate that the asset has failed, or is about to fail, and is in serviceability grade 4 or 5.	High probability of sudden structural failure which could have moderate direct or indirect cost consequences.

Grade	Farmers' Requirements								Statutory Requirements	
	Adequacy and Timeliness	**Command**	**Equity of supply**	**Reliability of supply**	**Security of system**	**Water quality**	**Efficiency**	**Waterlogging and Flooding**	**Health and Safety**	**Environment**
Grade 1	Adequate and timely at all times	Target command levels maintained at all times	Water distribution equitable	Fully reliable	No risk of failure	No constraints (to agricultural production)	Efficiency levels match target values	No waterlogging or salinity	Complies	Complies
Grade 2	Generally adequate and timely	Target command levels generally maintained	Distribution generally equitable	Generally reliable	Some risk of failure	Some constraint	Efficiency levels generally adequate	Some waterlogging and/or flooding	N/A	Mild hazard
Grade 3	Adequate and timely on average	Target command levels maintained on average	Distribution equitable on average	Reliable on average	Moderate risk of failure	Moderate constraint	Efficiency levels adequate on average	Moderate waterlogging and/or flooding	N/A	Moderate hazard
Grade 4	Frequently inadequate and/or untimely	Target command levels frequently not maintained	Distribution frequently inequitable	Frequently unreliable	High risk of failure	Serious constraint	Efficiency levels frequently inadequate	Serious waterlogging and/or flooding	N/A	Serious hazard
Grade 5	Completely inadequate and/or untimely	Command levels not maintained.	Water distribution is inequitable	Completely unreliable	Failed or failure imminent	Quality fatal to agricultural production	Efficiency levels unacceptable	Unacceptable incidence of waterlogging or flooding	Non-Compliant	Non-Compliant

Note: 1. The above serviceability classifications are preliminary, further refinements of the descriptions are required
2. N/A - Not applicable

Figure 5. Proposed irrigation serviceability Matrix A criteria and classifications.

Canal Command	Farmers' Requirements								Statutory Requirements	
	Adequacy and Timeliness	**Command**	**Equity**	**Reliability**	**Security**	**Water Quality**	**Efficiency**	**Waterlogging and Flooding**	**Health and Safety**	**Environment**
Main Canal	1	1	N/A	1	3	1	1	1	1	1
M1/C1	4	4	3	4	5	1	3	2	1	3
M1/C4	1	1	1	2	1	1	2	1	1	1
M1/C4.2	1	1	1	2	1	1	2	1	1	1
M1/C6	1	2	1	2	1	1	1	1	1	1
M2/C1	2	2	2	2	3	1	2	1	1	1
M2/C2	2	2	2	2	3	1	3	2	1	1
M2/C2.1	3	3	2	2	2	1	2	1	1	1
M2/C4	2	3	4	4	2	1	3	3	1	1

Note: The asset situation in the highlighted sections are displayed in Serviceability Matrix B

Figure 6. Example of a completed irrigation serviceability Matrix A form.

Canal section	Asset number	Description	Performance	Condition	Importance	Priority Index	Colour Code*	Estimated cost (£)
M1/C1	1101	Head regulator	1	3	1			-
M1/C1	1102	Tertiary offtake M1/C1/1	2	2	3	-		-
M1/C1	1103	Tertiary offtake M1/C1/2	1	4	3	002	BLUE	1,200
M1/C1	1104	Cross regulator	5	5	2	001	RED	5,237
M1/C1	1105	Tertiary offtake M1/C1/3	1	3	3	-		-
M2/C4	2401	Head regulator	1	2	1	-		-
M2/C4	2402	Tertiary offtake M2/C4/1	1	2	3	-		-
M2/C4	2403	Tertiary offtake M2/C4/2	2	4	3	003	BLUE	2580
M2/C4	2404	Tertiary offtake M2/C4/3	1	3	3	-		-
M2/C4	2405	Tertiary offtake M2/C4/4	5	2	3	004	YELLOW	3200
M2/C4	2406	Cross regulator	2	2	2	-		-

Note: 1. The entries are indicative only
2. In the database the row is colour coded and this column is not required

KEY TO COLOUR CODING

Asset failure	Performance	Condition	Description
RED	1,2,3,4,5	4,5	Asset has, or is about to, completely fail, and must be repaired/replaced

Warning Indicator	Performance	Condition	Description
BLUE	1,2	4	High risk of asset failure. Low perception of risk due to high performance of asset

Problem Indicator	Performance	Condition	Problem
YELLOW	4,5	1,2	Problem with asset. Engineering assessment to determine nature and extent of problem e.g. inadequate canal capacity.

Figure 7. Irrigation serviceability Matrix B.

Matrix A is completed by monitoring performance of the irrigation system using repeat performance indicators such as Relative Water Supply and Delivery Performance Ratio, amongst others (Bos 1997; Murray-Rust & Snellen 1993; Molden & Gates 1990; Rao 1993). The focus is on performance measures and indicators which facilitate performance assessment of the irrigation system (network), and the impact of the system performance on the scheme (GICC 1998). A screening procedure is required to determine whether the failure in provision of the desired level of service is due to management or to the performance of the infrastructure.

As shown in Figure 6 performance is assessed against the serviceability for individual command areas of the irrigation system, Matrix B is then used to focus on specific assets which are responsible for such performance.

There are ten proposed Irrigation Serviceability Criteria for irrigation schemes, as outlined below:

Adequacy and Timeliness:	This criteria covers the adequacy and timeliness of irrigation water supply and the variability of delivery of water supply from the target. The prime variables used for this criteria are rate, frequency and duration of supply and demand, over time.
Command:	Maintaining command is a central function of canal control structures, failure to achieve command has a direct impact on system performance. The performance indicator is the actual water level compared to the design value, over time.
Equity:	Measure of the fairness of access to, or distribution of, water. Failure to achieve this level of service will adversely affect fee payment and can lead to undesirable consequences as farmers take their own action to remedy perceived unfairness.
Reliability:	Reliability of irrigation water supply can be actual or perceived, based on recent or long past events and circumstances. It is a powerful factor in farmers' decision making, affecting choice of cropping patterns, farmer behaviour, relationships between farmers and system managers. Can be measured using variables of rate, frequency and duration, and through determination of opinions/perceptions of farmers.
Security:	This criteria needs to be assessed using risk analysis to determine the potential for failure of the system, or parts of the system. Canals in fill are potentially more hazardous than canals in cut, cross drainage culverts on contour canals pose a threat to the system if they become blocked.
Water Quality:	The occurrence of salts or pollutants in irrigation water supplies may be undesirable depending on the particular conditions of crops and soils within the scheme.

Efficiency:	This criteria measures the efficiency of resource use related to the abstraction and conveyance of irrigation water. As well as the traditional measure of conveyance efficiency, it takes account of other efficiencies of resource use, such as the cost of pumping, or labour required to operate the system.
Waterlogging and Flooding:	Farmers wish to avoid waterlogging and flooding of the land. Variables used to measure performance in relation to this criteria are the level of the water table, areas affected by waterlogging or flooding, and the duration for which affected.
Health and Safety:	Assessments need to be made of potential health and safety hazards associated with the irrigation system. Stagnant or slow moving water can be health hazards in areas prone to malaria and/or schistosoiasis, whilst absence of trash screens on siphon underpasses and culverts are a safety hazard to humans and animals alike.
Environment:	Irrigation can have adverse impacts on the environment, these should be monitored and remedial action taken when defined thresholds are exceeded. Hazards can include discharge of drainage water with high salt or agro-chemical content.

It should be noted that variability is a common theme for criteria such as adequacy and timeliness, command, equity and reliability. Each of these criteria thus has to be assessed using a specific performance indicator and a measure of its attainment against the target value over time. The variability is the measure of the deviation from the target value(s) over time and can be measured using standard statistical measures.

Matrix B can be completed through inspection of the irrigation network and individual assets. Performance tests and inspections will be central to the completion of Matrix B, including, for example, tests to see if a given canal section can pass the design or peak required discharge. Criteria need to be established for quantifying the condition of the assets and their facets (components). For this condition grading charts or tables are required for elements of the assets, such as, for example, concrete. In a similar manner criteria and gradings need to be established for asset performance and for the importance of the assets.

Conclusions

The paper has outlined the development of the concept of an Irrigation Serviceability Matrix for identifying asset performance in relation to the impact on the provision of stated levels of service to the customer. The development of the serviceability matrix has focused attention on the absence of universally accepted criteria and specifications for level of service provision for irrigation systems.

From experience gained in the UK water industry over the last 10 years since privatisation the focus for asset management and investment planning has moved away from asset condition towards asset serviceability. This approach ensures that investment is targeted at activities which will result in the maintenance or enhancement of system performance, and thus enhanced service provision to the customer. This approach maintains the customer at the forefront of the process of asset management.

The Irrigation Serviceability Matrix described herein has been developed from recent research work carried out into asset management and investment planning, and is preliminary in nature. Further work is required, and planned, to better define the serviceability criteria and the classifications and boundaries for the gradings for each of these criteria.

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