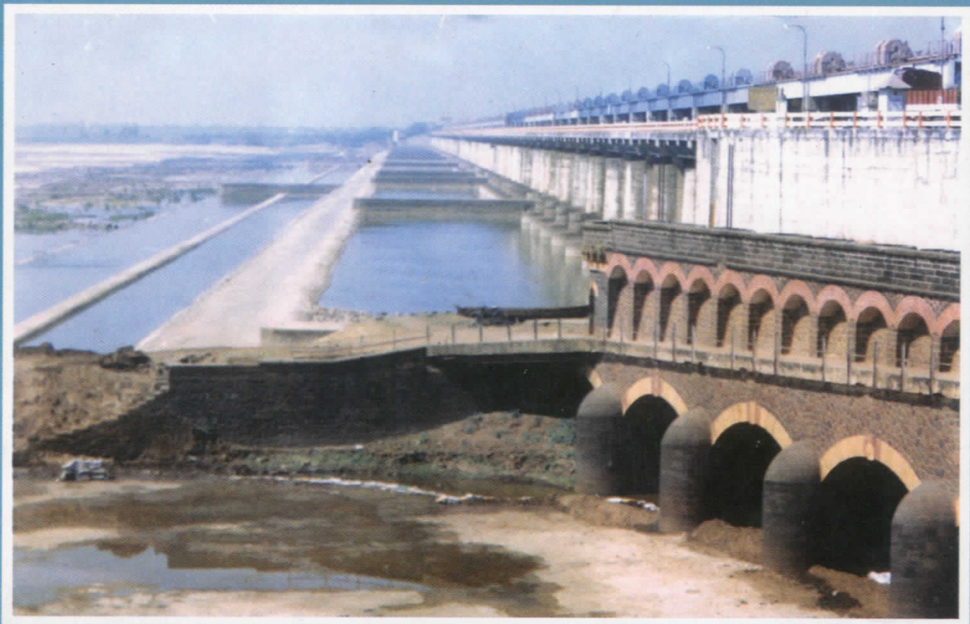
GUIDELINES FOR BENCHMARKING OF IRRIGATION SYSTEMS IN INDIA



Down stream view of Dowlaiswaram arm of the Sir Arthur Cotton's barrage (Andhra Pradesh)

इनसिड - INCID

INDIAN NATIONAL COMMITTEE ON IRRIGATION AND DRAINAGE

NEW DELHI
JUNE, 2002

Grand Anicut (Tamil Nadu)

Aliyar Dam (Tamil Nadu)

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FOREWORD

Presently some parts of India are already experiencing water scarcity conditions. In the coming decades, more areas in the country are likely to face severe water shortages. Irrigation sector being the largest consumer of water, those involved in the sector, namely, experts, professionals and other stake holders will have to strive for higher standards of water use efficiency to save and conserve this precious resource to get optimal outputs. In this regard, Benchmarking process, an important management tool, is proposed to be introduced in irrigation sector in India so as to improve water use efficiency and management of irrigation projects. By using appropriate performance indicators of Benchmarking suitable for various socio-economic and agro-climatic conditions, improvement in water use efficiency and financial viability alongwith adoption of best management practices and environmental sustainability of irrigated agriculture systems could be achieved. It also helps in identifying grey areas in the system and provides direction for improvement therein. Hence Benchmarking process in the water sector has immense potential to improve the services and the efficiency of operations.

With this in view, a Workshop was held at Hyderabad during 4-6 Feb. 2002 to promote Benchmarking in Irrigation Systems in India. About 70 officers from Central and State Governments and experts from World Bank attended the Workshop. The consensus of the Workshop was that Benchmarking is relevant for India. 20 main indicators to assist in the Benchmarking process have also been identified in the Workshop. With the inputs from the Workshop, a set of guidelines have been prepared by INCID to assist in the process of data identifiation, collection, entry, processing and analysis for the irrigation and drainage Benchmarking exercise. Since a number of projects have been identified in the country for the purpose of Benchmarking at the national level Workshop, it is felt that the guidelines would help to ensure consistency in the collection of data etc. so as to ensure comparison of results. I am sure that these guidelines would prove useful to all those concerned with the irrigation and water resoures development projects. With the experience gained in carrying out the Benchmarking of projects in various States, these could be suitably amended. Suggestions for improvement/further addition are most welcome and these would be incorporated in subsequent editions of the Guidelines.

The efforts put in by the officers of the Core Group on Benchmarking constituted by the Ministry of Water Resources, Consultants, officers and staff of INCID in bringing out this publication are appreciated. Special thanks are due to Shri P.L. Diwan, Chairman and Managing Director, WAPCOS (I) Ltd. for his support and providing all infrastructure facilities to INCID Secretariat in publishing this Report.

(SURESH CHANDRA)
Chairman, INCID & CWC

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GUIDELINES FOR BENCHMARKING OF IRRIGATION SYSTEMS IN INDIA

1. Introduction

The average annual flow available in rivers in India is around 1869 BCM. Presently, the national annual average per capita availability is about 1829 cum per year. However, by the year 2050, the estimated annual per capita availability of 1168 cum would take the country at the threshold of water scarce conditions. The situation in certain parts of the country is likely to be critical and it is estimated that by the year 2050, 30% of the geographical area and 16% of population in the country will be under absolute water scarcity condition, with water availability of less than 500 cum per year.

Estimation of water demand and its implications on water quantity and quality is extremely important. Agriculture has the dominant demand and it will continue to predominate for a long time. However, there is considerable scope for rationalisation of its demand and optimisation, of its use. Lower consumption of water in agriculture has a very positive impact on reduction of environmental degradation. For meeting country's need for food grains, the water demand for irrigation for year 2050 has been estimated by the National Commission for Integrated Water Resources Development Plan (NCIWRDP) to be around 628 BCM for low demand and 807 BCM for high demand.

Despite the fact that productivity in irrigated areas has increased as compared to that of rain fed areas, the increase is still below the world standards and developing countries like China. This is coupled with sub-optimal water management including low irrigation efficiencies. There is scope for considerable improvement in productivity and consequent reduction in the demand for water. Applying the right quantity at the right time and using the right cultivation and irrigation practices can achieve conservation of water on the field. Against the backdrop of such a situation of imminent scarcity and inter-sectoral competition on physical and financial resources, the water resources management has to undergo a paradigm shift and deep introspection.

As a first step along the path towards sustainable water development and management we have to use water efficiently. By using water more efficiently, we in effect create a new source of supply. Each liter conserved can help meet new water demands. Measures to conserve water and use it more efficiently are now most economically and environmentally sound water supply options. Irrigation experts and professionals have to strive for the highest standards of water use efficacy and evolve means to achieve them to tide over the impending menace of water scarcity. It should be our endeavour to achieve the low demand scenario for which it is imperative that considerably higher level of efficiency is effected in irrigation water use.

2. Need for Benchmarking

Fierce competition, globalisation and development of new information and communication technologies have forced us to continuously search for and adopt new processes, structures and tools in order to survive and compete in their respective spheres. The explosion of management tools and techniques in the 1990s to help systems successfully change is evidence of this situation. One among these techniques is benchmarking, which has proved to be valuable in helping individual systems evaluate their competitive position.

Benchmarking is simply the "introspection" since it is a continuous process of measuring one's own performance and practices against the best competitors, and is a sequential exercise of learning from other's experience. It is a fundamental management skill that supports quality and excellence and since the early 1990s has become widely regarded as a skill that should be communicated and utilised in day-to-day private and public business operations. Recent developments are utilising the technique for government operations for example, in municipal and state services, in the developed countries. Benchmarking has also broad applications in problem solving, planning, goal setting, process improvement, innovation, strategy setting, and in various other contexts.

Benchmarking is a continuous process. Opportunities for improvement are identified by conducting an internal assessment and making comparative measurements with best practice organisations to determine the performance gap between current practice and best practice. Selected best practices can then be suitably adopted to fit into the organisation's needs and implemented. The cycle of improvement continues.

Benchmarking as a tool can provide with the criterion for prioritisation for rationally utilising the limited financial resources among different systems. By incorporating *a Fault Tree Analysis* approach as prevalent in *Risk Analysis* the weak spots in the system and the management practices being adopted can be identified for appropriate interventions. In the irrigation sector that would mean more productive and efficient use of the water i.e. 'more crop per drop'. It has successfully been applied in the Water Supply and Sanitation areas in different conditions. Within the irrigation sector Australia is now advanced in the application of the technique to improve the performance of their irrigation systems in a systematic way.

Within the general efforts of reform, benchmarking in the irrigation system is essential. In the irrigation and drainage sector service users are responding to a variety of challenges. Irrigation systems are coping with a vicious cycle that starts with inadequate maintenance, resulting in poor service that causes limited willingness to pay by users. The latter provides insufficient maintenance funds that further reduces the operational efficiency of the system.

The State Irrigation Departments are also responding to a variety of challenges, including:

- increasing competition for water, both within the irrigated agriculture sector, and from other sectors.

- increasing demand on the irrigation sector to produce more food for growing populations. Coupled with the pressure on available water resources, this results in the "more crop per drop" initiative promoted by international agencies such as the International Water Management Institute (IWMI) and the Food and Agriculture Organisation (FAO) of the United Nations.

- growing pressure to effect cost savings whilst increasing the productivity and efficiency of resource use.

- more private sector and users participation leading to more transparent and accountable (to users) management practices.

- increasing interest by the wider community in productive and efficient water resource use and the protection of aquatic environments.

- increasing need for accountability to both government and water users in respect of water resource use and the price paid for water.

By using appropriate performance indicators of benchmarking it is possible not only to improve the water use efficiency and financial viability of the system but also ensure adoption of best management practices and the environmental sustainability in the irrigated agricultural systems. This would also assist in evaluating the efficasy of farmers' participation in irrigation management.

3. Benchmarking Objectives

Objectives set forth for benchmarking are :

a. identifying the best management practices.

b. generating competition among various agencies or the projects, units for distributory networks and or Water Users' Associations (WUAs),

c. prioritising and evaluating rehabilitation and remodeling or modernisation projects,

d. assessing and monitoring the irrigation efficiency.

4. National Workshop on Benchmarking Irrigation Systems

To promote Benchmarking in irrigation sector in India, a Workshop was held at Hyderabad from 4-6 February, 2002 with the participation of officers from Central and State Governments. The objectives of the Workshop were:

- introducing the concepts involved in benchmarking process. These include performance indicators, social indicators and system wide rapid appraisal.

- outlining the different processes and procedures involved in benchmarking approach.

- reviewing current international experiences on performance monitoring and performance indicators in different irrigation projects worldwide.

- developing a benchmarking methodology and adapt the benchmarking methodology to India's different states.

- evolve a work programme to implement benchmarking in India's main states and advocate the use of benchmarking as a tool to enhance the performance of India's irrigation system.

- detailing the implementation plan and programme derived from the Workshop.

- generating sufficient interest in adopting the process and generating partners in the government and state level in different states in India.

The conclusion of the Workshop was that Benchmarking is relevant for India and we should do it, as per capita water availability in coming years will dwindle and hence efficient use of water would be must. Benchmarking would help in appropriate interventions and help in formulation and implementation of policies for improvement of projects. This would result in bringing transparency in Irrigation sector along with many benefits viz. equitable distribution, improvement in irrigation efficiency, help bringing additional area under irrigation lead to diversification of crops, enable putting cap on O&M expenditure, increased productivity per unit of water etc. etc.

20 main indicators to assist in the benchmarking process have also been identified in the Workshop.

5. Purpose of the Guidelines

The purpose of these guidelines is to assist in the process of data identification, collection, entry, processing and analysis for the irrigation and drainage benchmarking exercise. The intention is that they will be used by those responsible for data collection, processing and analysis within the organization.

6. Selection of Participants in Benchmarking Process

In principle, the decision to join the benchmarking initiative must be taken by the participating organizations themselves. However, benchmarking is a tool of management to improve the performance of service delivery, productivity of agriculture and environmental performance; and as such, certain criteria must be met in order to gain benefits from this activity. Whilst the criteria for selection of participants in the benchmarking initiative must be flexible, it is desirable in the initial stages of the programme to minimize the spread of physical and managerial characteristics of the participating irrigation schemes. Relevant criteria for the selection of participant organisations are :

a) Institutional and Managerial Criteria:

- A government organization, or an organization, which has full authority and control over the management, operation and maintenance of the irrigation and/or drainage system(s).

- Organizations that aim to adopt service-orientated management and improve the quality of water delivery and/or drainage service to water users.

- Clearly identified drivers pushing the need for change and performance enhancement within the water resources or irrigation and drainage sector(s).

- Identified key personnel within the organization with the authority and drive to introduce and implement the benchmarking process.

- Irrigation systems where water supplies are planned, scheduled and monitored.

b) Physical Criteria

- Gravity open channel distribution system consisting of at least main and secondary canals supplying water to individual users or users groups.

- Control structures at primary and secondary canal level.

- Discharge measurement facilities at key locations (either through measuring structures or calibrated sections).

7. Categorization of Schemes

Schemes have to be categorised into similar types so that comparisons may be made between irrigation schemes. There are a variety of ways through which this can be done. Following list is indicative:

- type of control (fixed proportional division, manual control, automatic control);

- type of management (government agency, farmer managed);

- method of allocation and distribution (supply oriented, arranged-demand, on demand);
- climate (humid, arid);
- predominant crop type (rice, non-rice, subsistence/cash cropping)
- water availability (abundant, scarce);
- water source (surface water, groundwater or both);
- socio-economic setting (gross domestic product, degree of industrialization);
- size (major, medium, minor);

In order to group the schemes to be benchmarked salient features of the project/system/sub-system are required as listed in Table 1.

8. Data Collection and Analysis

8.1 Data Requirements

In any system, such as an irrigation network, there are:

- inputs
- processes
- outputs, and
- impacts

In measuring performance we are interested in the efficiency with which we convert inputs to outputs, and the potential impacts that (a) the use of these inputs (resources) might have and (b) that the outputs might have on the wider environment. We are also interested in the efficiency with which the processes convert inputs to outputs.

There are a variety of irrigation domains (or systems) in which we are interested, of which the following three are of primary interest:

- *Service delivery:* This domain includes two areas of service provision: (a) the adequacy with which the organization manages the operation of the irrigation delivery system to satisfy the water required by users (system operation), and (b) the efficiency with which the organization uses resources to provide this service (financial performance).
- *Productive efficiency:* Measures the efficiency with which irrigated agriculture uses water resources in the production of crops and fibre.
- *Environmental performance*: Measures the impacts of irrigated agriculture on land and water resources.

The performance indicators that are proposed for use in the benchmarking exercise are linked to these three domains, and their inputs, processes, outputs and impacts. There are many performance indicators that might be used in this context. For the benchmarking exercise only *key* performance indicators will be used as given in Table 2 and detailed in Appendix A-I. The data required to be collected, for this purpose is given in Table-3.

To ensure consistency in the comparison of results, organizations joining the benchmarking programme will need to collect the data required for the calculation of the benchmarking indicators according to the specifications and protocols provided in Appendix A2 which provides for each indicator the definition, measurement specification and processing needs.

Participating organizations will carry out the primary data processing to convert raw data into the format required for input into the benchmarking spreadsheet. This task must be carried out according to the instruction provided.

The proforma provided for benchmarking contain data in the following categories:

- Summary of benchmarking indicators
- Salient Project Features
- System Performance
- Financial Indicators
- Agricultural Productivity
- Environmental Aspects

Indicator values in the summary worksheet are calculated automatically after the basic data are entered into the appropriate worksheet without user intervention.

Two types of indicators can be considered according to the type of data required:

(a) Indicators based on primary data
(b) Indicators based on secondary data

Some indicators are based on primary data that the organization must collect either as a normal part of its operation or for the specific purpose of benchmarking. Variables such as inflow volumes, revenues collected from water users, and total operation expenditure fall into this category.

Some other indicators rely on the use of secondary data for their calculation. For example, the calculation of evapotranspiration (Et_c) relies on climatic data for the location of the irrigation scheme that must be provided in the format specified by the methodology for calculating Et_c. This type of data may be collected either by the participating organization itself or an external organization. Wherever data are procured from an external organization special attention must be paid to the data processing methodology. This is particularly important when data auditing is necessary to trace possible calculation errors.

8.2 Data Units

In order that the data can be compared across different irrigation systems the data should be presented in the units specified in Appendix A2. Data may be collected and processed locally in different units, but should be converted into the required units before entering into the database.

8.3 Data Processing and Analysis

Much of the data analysis involves compiling ratios of the data collected to produce the value of the required performance indicator. Participating organizations will be responsible for processing the raw data collected in conformance with the protocols outlined in Appendix A2. It is possible that past data collected by such organizations may have been collected in a variety of formats that may not necessarily comply with these specifications. In such cases, it is necessary to ensure that data are processed in a comparable manner.

8.4 Data Audit

There are large volumes of data relevant to the indicators covering water, agriculture, finance etc. Engineers and other professionals working in the field offices generally provide these data. As they are in the lower rungs of the hierarchy, there could be communication gap in understanding the objectivily of the process. Therefore detailed data audit at the system/sub-system level is essential.

9. Comparative Analysis

The essence of the benchmarking process is to provide organizations with the ability to compare their performance in relation to similar organizations or similar processes. The comparative analysis will consist primarily of ranking performance levels for individual indicators both numerically and graphically

10. Program Implementation

Periodic reviews of the programme will be required to ensure that the programme remains flexible and relevant to the benchmarking partners. New performance indicators may need to be added in the future to ensure that emerging issues in irrigation and drainage are reflected in the programme. For example, when a system/sub-system is managed by a Water Users' Association (WUA), indicators relevant to the functioning and effectiveness of the WUA may have to be incorporated.

Table 1
Salient features of the project/system/sub-system*

Code	Item	Possible options
Location		
D1	State	–
D2	District	
D3	Name of the Project/Scheme	–
D4	Name of System/Sub-System	
D5	River/Basin/Sub-Basin	
D6	Latitude/Longitude	
Climate and soils		
D7	Climate	Arid Semi-arid Humid Humid tropics
D8	Average annual rainfall (mm)	–
D9	Average annual reference crop potential evapotranspiration, Et_c (mm)	–
D10	Peak daily reference crop potential evapotranspiration, Et_c (mm/day)	
D11	Predominant soil type(s) and percentage of total area of each type	Clay Clay loam Loam Silty clay loam Sand
Institutional		
D12	Year first operational	
D13	Type of management	Government agency Water Users Association/ Federation of WUAs

- Considering that the records connected with works, personnel employed etc. are maintained at the level of an Irrigation Section, the System/Sub-System adopted should be at least at the jurisdictional level of a Section.

Code	Item	Possible options
D14	Agency functions (to indicate the extent the Agency controls the system/sub-system)	Irrigation and drainage service Water resources management Reservoir management Flood control Domestic water supply Fisheries Other
D15	Type of revenue collection	Tax on irrigated area Charge on crop type and area Charge on volume of water delivered- charge per irrigation Charge based on number of waterings per season
D16	Agency entrusted with Revenue Collection	Irrigation Department Revenue Department WUA Others
D17	Land ownership	Government Private
Socio-economic		
D18	Gross Domestic Product (GDP)	
D19	Farming system	Cash crop Food grains crop Mixed cash/Food grains crop
D20	Marketing	Government marketing board Private traders Local market Regional/national market
D21	Pricing	Government controlled prices Local market prices
Water source and availability		
D22	Water source	Storage on river Run-of-the river including barrage/anicut Groundwater Conjunctive use of surface and groundwater
D23	Water availability	Abundant Sufficient Water scarcity

Code	Item	Possible options
D24	Number and duration of irrigation season(s)	Number of seasons Number of months per season: Season 1: Season 2: Season 3:
Size		
D25	Commanded (irrigation) area (ha)	–
D26	Total number of water users supplied	–
D27	Average farm size (ha)	–
D28	Average annual irrigated area (ha) Out of the above by Surface water (ha) Groundwater (ha) In case of conjunctive use, please give weightage for the waterings from each source.	–
D29	Average annual cropping intensity (%)	–
Infrastructure – Irrigation		
D30	Method of water abstraction	Gravity diversion Pumped diversion Groundwater
D31	Water delivery infrastructure (length and %)	Lined channel Unlined Pipelines
D32	Location and type of water control equipment	Control structure at intake of the system/sub-system Type: None Fixed proportional division Gated - manual operation Gated - automatic local control
D33	Discharge measurement facilities, location and type	Location: None Type: Flow meter Fixed weir or flume Calibrated sections Calibrated gates

Code	Item	Possible options
	Infrastructure – Drainage	
D34	Area serviced by surface drains (ha)	–
D35	Type of surface drain	Constructed Natural
D36	Length of surface drain (km)	Natural Open Closed
D37	Area serviced by sub-surface drainage (ha)	
D38	Number of groundwater level measurement sites	
Water allocation and distribution		
D39	Type of water distribution	Supply oriented On-demand Arranged-demand
D40	Frequency of irrigation scheduling at the intake of the system/sub-system	Daily Weekly Twice monthly Monthly Seasonal None
D41	Predominant on-farm irrigation practice	Surface – furrow, basin, border, flood, furrow-in-basin; Drip/trickle Sub-surface
Cropping		
D42	Main crops each season with percentages of total command area	–

Table 2
Main Performance indicators for Benchmarking

Domain	Performance indicator
I. System Performance	1. Water delivery capacity Index 2. Total annual volume of irrigation water supplied/delivered (m^3/year) 3. Field application efficiency 4. Annual Relative Irrigation Supply Index 5. Annual irrigation water supply per unit command area (Cum/ha) 6. Annual irrigation water supply per unit irrigated area (Cum/ha)
II. Agricultural Productivity	7. Output per unit command area (Rs/ha) 8. Output per unit irrigated area - Tons/ha cropwise, Rs/ha 9. Output per unit irrigation supply (Rs/cum) 10. Output per unit crop water demand (Rs/cum)
III. Financial Aspects	11. Cost recovery ratio 12. Total O&M cost per unit area (Rs/ha) 13. Total cost per person employed on O&M Works (Rs/person) 14. Revenue collection performance 15. Revenue per unit volume of irrigation water supplied (Rs/cum) 16. Maintenance cost to revenue ratio 17. Staff numbers for O&M per unit area (persons/ha) 18. Total O&M cost per unit of water supplied (Rs./cum)
IV. Environmental Aspects	19 (a) Average depth to watertable (m) 19 (b) Land Damage Index 20 (a) Water quality: Ph/Salinity/Alkalinity Index 20 (b) Salt balance (tonnes)

Table 3
Data requirements pertaining to the system/sub-system

1. Current canal capacity of the system/sub-system at the diversion point.
2. Designed Peak irrigation water demand for a month/fortnight
3. Total daily measured water at the intake of the system/sub-system..
4. Total daily measured water delivery to the field head
5. Total daily measured water used by evapo-transpiration (for different crops if available)
6. Total daily measured rainfall over irrigated area.
7. Total command area serviced by the irrigation system/sub-system.
8. Total annual irrigated crop area
9. Total annual tonnage of each crop
10. Market price/Minimum Support Price (MSP) for the crops.
11. Total volume of water consumed by the crops (ETc). For rice crop, percolation losses need to be included.
12. Total revenue collected from water users
13. Total management, operation and maintenance (MOM) cost excluding capital expenditure and depreciation/renewals.
14. Total cost of MOM personnel
15. Total number of MOM personnel employed
16. Total revenue due during the year
17. Periodic measurements of depth to water table
18. Waterlogged area in the command area after introduction of irrigation
19. Salinity/alkalinity affected area in the command area after introduction of irrigation
20. Electrical conductivity of periodically collected irrigation water samples in mmhos/cum
21. Electrical conductivity of periodically collected drainage water samples in mmhos/cum
22. Total daily measured drainage water outflow from the irrigation system
23. Periodic measurement of salt content of irrigation water
24. Periodic measurement of salt content of drainage water

Appendix A1

Performance indicators - Definitions & Data Specifications

I System Performance

Indicator	**Definition**	**Data specifications**
1. Water delivery capacity Index	Canal capacity to deliver water at system head Peak irrigation water requirement	*Canal capacity to deliver water at system head:* Actual discharge capacity of system/sub-system at diversion point. *Designed Peak irrigation water requirement:* The peak crop irrigation water requirement for a monthly/fortnightly period expressed as a flow rate at the head of the irrigation system/ sub-system.
2. Total annual volume of irrigation water delivery (cum/year)	Total volume of water delivered to water users over the year or season. Water users in this context are the recipients of irrigation service and these may include single irrigators or groups or irrigators organized into water user groups.	Measured at the interface between the irrigation agency and water users.
3. Field Application efficiency	Water used by crops by evapotranspiration Water delivered at field head	Total volume of water used by the crops worked out from evapotranspiration values Total annual volume of water made available at the field worked out from daily measurements.
4. Annual relative irrigation supply Index	Total annual volume of irrigation water supplied Total annual volume of irrigation water supplied For paddy rice, percolation losses must be included.	Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) worked out from daily measurements to the system/sub-system. Total annual volume of crop irrigation demand is equal to total annual volume of irrigation water required by the crop less effective rainfall.
5. Annual irrigation water supply per unit command area (cum/ha)	Total annual volume of irrigation water inflow Total command area serviced by the system/sub-system	*Total annual volume of irrigation water inflow:* Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) into the system/sub-system. *Total command area serviced by the system/sub-system:* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.

Indicator	Definition	Data specifications
6. Annual irrigation water supply per unit irrigated area (cum/ha)	$\frac{\text{Total annual volume of irrigation water inflow}}{\text{Total annual irrigated crop area}}$	*Total annual volume of irrigation water inflow:* Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) into the system/sub-system. *Total annual irrigated crop area:* The total irrigated area cropped during the year.

II. Agricultural productivity

Indicator	Definition	Data specifications
7. Output per unit serviced area (Rs./ha)	$\frac{\text{Total annual value of agricultural production}}{\text{Total command area serviced by the system/sub-system}}$	*Total annual value of agricultural production:* Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) *Total command area serviced by the system/sub-system:* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
8. Output per unit irrigated area (Rs./ha)	$\frac{\text{Total annual value of agricultural production}}{\text{Total annual irrigated crop area}}$	*Total annual value of agricultural production:* Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) *Total annual irrigated crop area of the system/sub-system:* The total irrigated area cropped during the year.
9. Output per unit irrigation supply (Rs./cum)	$\frac{\text{Total annual value of agricultural production}}{\text{Total annual volume of irrigation water inflow}}$	*Total annual value of agricultural production:*. Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) *Total annual volume of irrigation water inflow into the system/sub-system*: Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) worked out from daily measurements.

Indicator	Definition	Data specifications
10. Output per unit crop water demand (Rs./cum)	Total annual value of agricultural production Total annual volume of water consumed by the crops	*Total annual value of agricultural production:* Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) *Total annual volume of water consumed by the crops:* Total volume of water consumed by the crop to meet evapotranspiration demand. For rice crops this excludes deep percolation losses.

III Financial indicators

Indicator	Definition	Data specifications
11. Cost recovery ratio	Gross revenue collected Total MOM cost	*Gross revenue collected:* Total revenues collected from payment of services by water users during the year. *Total MOM cost:* Total management, operation and maintenance cost of providing the irrigation and drainage service excluding capital expenditure and depreciation/renewals. The O&M cost of Head works, main canal, etc. will be added on pro-rata basis to the actual O&M cost of system/sub-system.
12. Total O&M cost per unit area (Rs./ha)	Total MOM cost Total command area serviced by the system/sub-system	*Total MOM cost:* *Total command area serviced by the system/sub-system:* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
13. Total cost per person employed on water delivery (Rs./person)	Total cost of personnel engaged in I&D service Total number of personnel engaged in I&D service	*Total cost of personal engaged in I&D service:* Total cost of personnel employed in the provision of the irrigation and drainage service in the system/sub-system. *Total number of personnel engaged in I&D service:* Total number of personnel employed in the provision of the irrigation and drainage service in the system/sub-system.

Indicator	Definition	Data specifications
14. Revenue collection performance	Gross revenue collected Gross revenue invoiced	*Gross revenue collected:*. Total revenues collected from payment of services by water users during the year. *Gross revenue invoiced:* Total revenue due for collection from water users for provision of irrigation and drainage services during the year.
15. Average revenue per cubic metre of irrigation water supplied (Rs/cum)	Gross revenue collected Total annual volume of irrigation water delivery	*Gross revenue collected:* Total revenues collected from payment of services by water users. *Total annual volume of irrigation water delivery:* Total volume of water delivered to water users over the year or season. Water users in this context are the recipients of irrigation service and these may include single irrigators or groups or irrigators organized into water user groups.
16. Maintenance cost to revenue ratio	Maintenance cost Gross revenue collected	*Maintenance cost:* Total expenditure on system maintenance *Gross revenue collected:* Total revenues collected from payment of services by water users during the year.
17. Staffing numbers per unit area (Persons/ha)	Total number of personnel engaged in I&D service Total command area serviced by the system/sub-system	*Total number of personnel engaged in I&D service:* Total number of personnel employed in the provision of the irrigation and drainage service in the system/sub-system. *Total command area serviced by the system:* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
18. Total O&M Cost per unit of water supplied (Rs./cum)	Total MOM Cost Total Water supplied	

III. Environmental Aspects

Indicator	Definition	Data specifications
19 (a) Land damage index	$\frac{\text{Waterlogged + saline/alkaline affected area}}{\text{Total CCA}}$	Since some waterlogged area may also be saline/ alkaline affected area, double accounting should be avoided.
19 (b) Average depth to watertable (m)	Average annual depth of watertable calculated from watertable observations over the irrigation area.	
20 (a) Water quality: Ph/Salinity/ Alkalinity.	Ph/Salinity/Alkalinity of the irrigation supply and drainage water.	
20 (b) Salt balance (tonnes)	Differences in the volume of incoming salt and outgoing salt.	

Protocols for Data Collection and Processing

Ref. To Indicator *No.1*	**Canal capacity to deliver water at system head**
Definition	Actual discharge capacity of main canal at diversion point of the system/sub-system.
Measurement specifications	*Location:* Discharge capacity must be determined at the system/sub-system head assuming canal freeboard according to canal design specifications. If not yet available, it can be determined using any accepted flow measuring technique including: flow metering, measuring flumes and control sections. *Frequency* Needs to be determined at the start of the irrigation season.
Processing	
Units	Expressed in cubic metres per second (cumecs)

Ref. To Indicator *No.1*	**Peak irrigation water requirement**
Definition	The peak crop irrigation water requirement for a monthly period expressed as a flow rate at the head of the irrigation System/Sub-System.
Measurement specifications	*Location:* The calculation is based on the designed maximum monthly crop water requirement in the system/sub-system. The field, distribution and main system conveyance efficiency must be used to index this value to the head of the system/sub-system. *Frequency:* Calculated each season.
Processing	The maximum monthly crop water requirement should be available from the calculation of crop water requirements for the entire system/sub-system.
Units	Expressed in cubic metres per second (cumecs).

Ref. To Indicator *No.2*	**Total annual volume of irrigation water delivery**
Definition	Total vc lume of water delivered to water users over the year or season. Water users in this context describe are the recipients of irrigation service, these may include single irrigators or groups or irrigators organized into water user groups.
Measurement Specifications	*Location:* Measurement should occur at the point of interface between the irrigation provider and the water user(s). *Frequency:* The magnitude and frequency of fluctuation in discharge will determine the desired frequency of measurement. Discharge should be monitored at least twice daily to ensure sufficient accuracy. The best accuracy can be obtained from continuous monitoring of discharge by electronic monitoring devices.
Processing	Daily average discharges must be converted into daily delivery volume using the actual delivery time. The total volume of water delivered is the aggregate result of daily volume of supply.
Units	Expressed in cubic metres (cum)

Ref. To Indicator *No.4*	**Total annual volume of crop irrigation demand**
Definition	Total annual volume of irrigation water required by the crop less effective rainfall. For paddy rice, percolation losses must be included.
Measurement specifications	*Location:* Crop evapotranspiration will be calculated using the FAO CROPWAT model for the net area planted to each crop in the irrigated command area. Estimation of effective rainfall may prove to be difficult in some circumstances. There are a variety of methods included in CROPWAT for estimating effective rainfall (Dastane, 1974). The use of the USDA-SCS model is recommended. *Frequency:* The preferred Et_c calculation period is daily. In situations where daily data are not available the shortest possible interval is to be used. The calculation of Et_c will include the entire growing season from planting to harvest.
Processing	The total annual volume of water consumed by all crops grown in the system is the weighted sum of the water consumed by individual crops as follows: $VET_{Net} = \square(Etc_i - R_e)A_i$ where: VET_{Net} = Total volume of water consumed by crops less effective rainfall (cum) i = Crop type Etc_i = Evapotranspiration from crop *i* from planting to harvest (cum) R_e = Effective rainfall over crop area from planting to harvest (cum) A_i = Area planted to crop i. (ha) For rice crops the average percolation rate will be multiplied by the crop area and growth period to obtain the total percolation volume.
Units	Expressed in cubic metres (cum).

Ref. To Indicator *No.5*	**Total annual volume of irrigation water inflow**
Definition	Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage to the system/sub-system).
Measurement specifications	*Location:* Inflow will be measured at the diversion point in case of gravity diversions or at the pump delivery of groundwater or river pumps. In situations where there are additional inflows and/or diversions for any purpose other than irrigation, e.g. urban supply, industrial supply, etc. a mass balance of the net inflow for irrigation must be carried out. Inflows from drainage recovery must be deducted from the inflow amount whereas catchment inflows must be included as irrigation diversions. *Frequency:* The magnitude and frequency of fluctuation in discharge will determine the desired frequency of measurement. Discharge should normally be monitored at least twice daily to ensure sufficient accuracy. The best accuracy can be obtained from continuous monitoring of discharge by electronic monitoring devices.
Processing	Daily average discharges must be converted into daily delivery using the actual delivery time. The total volume of water delivered is the aggregate result of daily volume of supply converted into daily volume.
Units	Expressed in cubic metres (cum).

Ref. To Indicator *No.5*	**Total command area serviced by the system/sub-system**
Definition	The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated by the system/sub-system.
Measurement specifications	This area is usually derived from the design drawings for the irrigation system. Over time areas may go out of production due to a variety of factors, including construction of houses, buildings, drainage channels, etc. Adjustments should be made to the command area to allow for this reduction in irrigable area.
Processing	The command areas for each tertiary unit are measured and aggregated up for the whole system/sub-system.
Units	Expressed in hectares (ha).

Ref. To Indicator *No.6*	**Total annual irrigated crop area**
Definition	The total irrigated area cropped during the year in the system/sub-system.
Measurement specifications	This value is the result of the total area nominally commanded by the system multiplied by a cropping intensity factor to take into account the actual intensity of land utilization during the year.
Processing	The area cultivated in each cropping season is the aggregate of the areas planted to each individual crop. The annual irrigated area is the aggregate value of the each season's cropped area. These data are usually collected by the irrigation and drainage organization for operation and accounting purpose and/or by other related agencies that compile production statistics.
Units	Expressed in hectares (ha).
Example	For instance, if the area commanded by the irrigation system is 10,000 ha and the areas cultivated during the year are: wet season 8,000 ha, and dry season 6,000 ha, the total area irrigated by the system is 14,000 ha. The cropping intensity is 1.4.

Ref. To Indicator *No.8*	**Total annual agricultural production**
Definition	Total annual tonnage of agricultural production by crop type in the system/sub-system.
Measurement Specifications	Total tonnage of utilizable production obtained from each crop.
Processing	Records normally compiled by the irrigation and drainage organization or related agricultural organizations are adequate for this purpose.
Units	Expressed in metric tonnes (t).

Ref. To Indicator *No.8*	**Total annual value of agricultural production**
Definition	Total annual value of agricultural production received by producers in the system/sub-system.
Measurement Specifications	The total value of agricultural production received by producers is determined at local (domestic) market prices or Minimum Support Price (MSP).
Processing	Worked out from the yield of crop, area planted for the crop and local price of the crop.
Units	Expressed in Rupees.

Ref. To Indicator *No.10*	**Total annual volume of water consumed by the crops**
Definition	Total annual volume of water used by the crop to meet evapotranspiration demand. For rice, percolation losses must be included.
Measurement specifications	*Location:* Crop evapotranspiration (Et_c) will be calculated using the FAO CROPWAT model for the net area planted to each crop in the irrigated command area. *Frequency:* The preferred Et_c calculation period is daily. In situations where daily data are not available the shortest possible interval is to be used. The calculation of Et_c will include the entire growing season from planting to harvest.
Processing	The total annual volume of water consumed by all crops grown in the system is the weighted sum of the water consumed by individual crops as follows: $VEt_c = \sum_{crops} Etc_i x A_i$ Where: Vet_c = Total volume of water consumed by crops (cum) Et_{ci} = Evapotranspiration from crop i, from planting to harvest (cum) A_i = Area planted to crop i. For rice crops the average percolation rate will be multiplied by the crop area and growth period to obtain the total percolation volume.
Units	Expressed in cubic metres (cum)

Ref. To Indicator *No.12*	**Total MOM cost**
Definition	Total management, operation and maintenance cost of providing the irrigation and drainage service excluding capital expenditure and depreciation/renewals.
Measurement specifications	This item includes all costs involved in the provision of the irrigation and drainage service. Typically these include: Bulk water fee Staff cost Operation cost (e.g. electricity for operation of plant and equipment and water supply) Maintenance cost Overheads (include administrative expenses of the project worked out on pro-rata basis, insurance, taxes, etc.)
Processing	A single annual value is required for this item. All costs items must be aggregated annually according to the financial calendar of the organization.
Units	Expressed in Rupees

Ref. To Indicator *No.13*	**Total cost of personnel engaged in I&D service**
Definition	Total cost of personnel employed in the provision of the irrigation and drainage service in the system/sub-system.
Measurement Specifications	This item includes the cost of all personnel employed by the organization including contractors and contract employees engaged in the administration, management and operation.
Processing	A single annual value is required for this item. All personnel cost items must be aggregated annually according to the financial calendar of the organization.
Units	Expressed in Rupees.

Ref. To Indicator *No.13*	**Total number of personnel engaged in I&D service**
Definition	Total number of personnel employed in the provision of the irrigation and drainage service in the system/sub-system.
Measurement Specifications	This item includes all personnel employed by the service provider including contract employees engaged in the management, operation and maintenance. It must be expressed in Equivalent Full Time (EFT) units.
Processing	A single annual value is required for this item. All personnel must be aggregated annually according to the financial calendar of the organization and expressed in EFT units.
Units	Expressed in Equivalent Full Time units. The time of part-time or seasonally employed personnel should be converted to the equivalent full time employment based on the proportion of full time worked.
Example	Full time weekly hours: 48 hours EFT = 1.0 Employee working 24 hrs part-time per week EFT = 0.5

Ref. To Indicator *No.14*	**Gross revenue collected**
Definition	Total revenues collected from payment of services by water users in the system/ sub-system.
Measurement Specifications	This item includes all the revenues (cash and in-kind) received by the irrigation or drainage service provider as payment for water supply and disposal, and other services using the agency's infrastructure. Where drainage charges are levied separately these must be included in the calculation.
Processing	A single annual value is required for this item. Where services are charged on a different basis, e.g. seasonal, bi-annually, etc. the partial figures must be aggregated annually according to the financial calendar of the organization. Payment made in kind must be converted into monetary terms, either using local market prices for the in-kind commodity, or at rates stipulated in the service agreement.
Units	Expressed in Rupees.

Ref. To Indicator *No.14*	**Gross revenue invoiced**
Definition	Total revenue due for collection from water users for provision of irrigation and drainage services for the system/sub-system.
Measurement Specifications	This item includes all fees levied (cash and in-kind) by the service provider in payment for water supply and other services provided by the irrigation and drainage infrastructure. Where drainage charges are levied separately these must be included in the calculation.
Processing	A single annual value is required for this item. Where services are charged on a different basis, e.g. seasonal, bi-annually, etc. the partial figures must be aggregated annually according to the financial calendar of the organization. Payment to be made in kind must be converted into monetary terms, either using local market prices for the in-kind commodity, or at rates stipulated in the service agreement.
Units	Expressed in Rupees

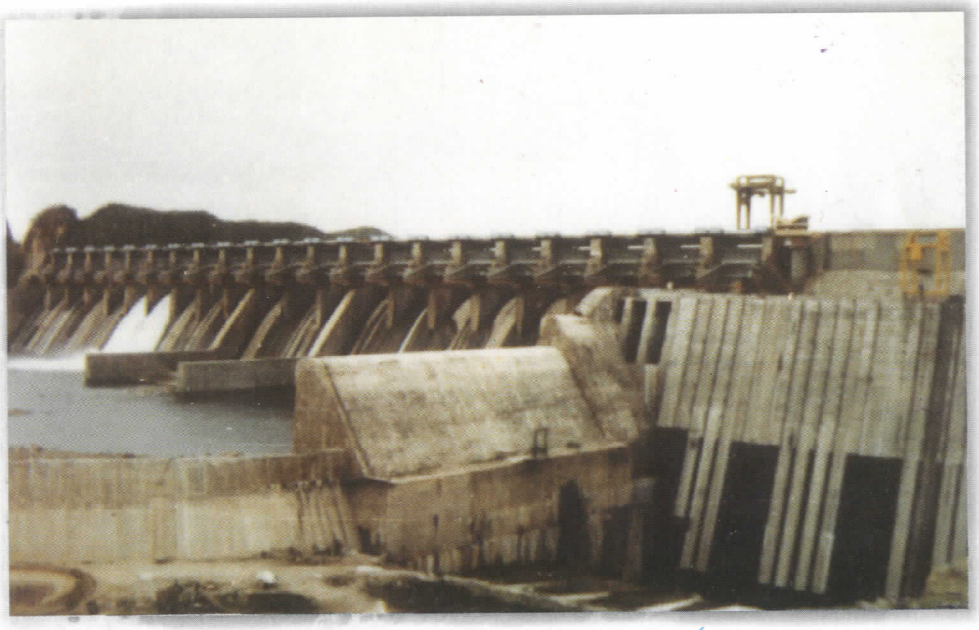
Ref. To Indicator *No.16*	**Maintenance cost**
Definition	Total expenditure on system maintenance
Measurement Specifications	This item includes all the costs associated with maintenance of the irrigation and drainage infrastructure either carried out by the organization or by external contractors. It should not include major repairs or rehabilitation work.
Processing	A single annual value is required for this item. All maintenance costs items must be aggregated annually according to the financial calendar of the organization.
Units	Expressed in Rupees.

Ref. To Indicator *No.19(b)*	**Average depth to watertable**
Definition	Average annual depth of watertable calculated from watertable observations over the irrigation area in the system/sub-system.
Measurement Specifications	*Location:* Watertable depth must be monitored by a network of piezometers distributed over the commanded area of the System/Sub-System in sufficient density to enable the delineation of contour lines of watertable depth. The installation of piezometers must follow the standard guidelines described in FAO Irrigation and Drainage Paper No.38 Drainage Design Factors. *Frequency:* Watertable levels are typically monitored on a monthly basis.
Processing	Individual readings will be average over the 12-month period to produce a single value required for this item.
Units	Expressed in metres (m).

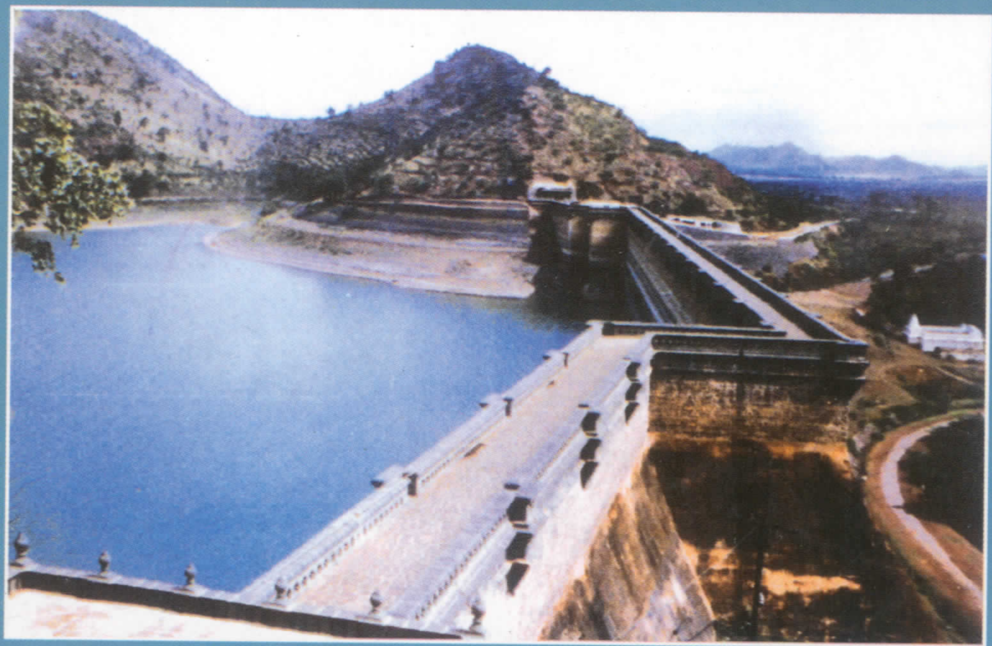
Ref. To Indicator *No.20(a)*	**Water quality: Salinity/Alkalinity**
Definition	Salinity/Alkalinity of the ir rigation supply and drainage water.
Measurement Specifications	*Location:* The salinity/alkalinity of irrigation inflow will be measured at the intake of the system/sub-system. In situations where there are additional inflows these should be monitored separately. The salinity/alkalinity of drainage water will be measured at the point where drainage flows leave the irrigation scheme or just before entering a receiving body of water, e.g. river, lake, etc. *Frequency:* The magnitude and frequency of fluctuation in discharge will determine the desired frequency of measurement. Weekly or monthly readings are typically used.
Processing	A single value of the parameters is necessary each year. Weekly or monthly readings must be converted into weighted average according to the volume of irrigation supply water or drainage water occurring during the measuring period.
Units	Expressed in micro mhos per centimetre (mmhos/cm).

Ref. To Indicator *No.20 (b)*	**Salt balance**
Definition	Differences in the volume of incoming salt and outgoing salt.
Measurement Specifications	*Incoming salt:* Total amount of salt entering the irrigation area of the system/sub-system through the water supply system. The salinity of irrigation inflow will be measured at the diversion point in the case of gravity diversions or at the pump delivery of groundwater or river pumps. In situations where there are additional inflows these should be monitored separately. *Outgoing salt:* The total amount of salt that leaves the irrigation area through the irrigation supply and drainage system. The salinity of drainage water will be measured at the point where drainage flows leave the irrigation scheme or just before entering a receiving body of water, e.g. river, lake, etc. Additional salt outgoings may occur where irrigation water leaves the system through outfalls or is diverted for other uses.
Processing	The annual incoming and outgoing amounts of salt will be the aggregate of the individual readings collected for each individual period. This may vary in length according to water quality practices although daily readings are preferred.
Units	Expressed in metric tonnes (t).

Hirakud Dam (Orissa)



Kadam Dam (Gujarat)



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