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A Conceptual Framework for Analysis of Water Resources Management in Asia

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Effective and efficient water resources management to meet the increasing demands for food, energy, and domestic and industrial water is an imperative for Asian countries. As a basis for analyzing Asian water resources management problems, a three-element conceptual framework is presented: (1) water resources management as a system, composed of a set of facilities, operating rules, and incentives applied to water resources through an institutional arrangement; (2) water resources management as a process involving several stages beginning with planning and continuing with design, construction, operation and maintenance; and (3) water resources management as a set of linked activities and tasks required to produce the desired outputs. Using this framework to assess performance it is possible to analyze the linkages among water resources problems, water resources management, and water resources organizations and administrative arrangements. Examples are presented of such linkages as applied to problems of erosion and sedimentation, flooding, salinity, water demand-supply imbalances, and water pollution. Brief analytical summaries of eight critical water resources management problems in Asia are presented, along with an illustration of the complexity of water resources organization and administration, using Thailand as the example.

1. INTRODUCTION

In the decades since World War II, as rapidly increasing populations and production activities have put heavy pressure on available land and water resources, the village-scale pattern of water development and use has been modified in various ways and in different degrees. One common modification has been the supplanting of local facilities to provide irrigation water with large-scale water resources development works, typically involving large dams and multi-purpose projects, often planned on a regional or river basin scale. At the same time, typically few or no changes have been made at the user end of the system, e.g. at the farm level.

Large-scale plans and associated projects and programs have been backed by governments in many countries and have been supported financially by the World Bank, the Asian Development Bank, the US Agency for International Development, and other aid agencies.

As the structural components of such developments were completed and experience gained in their operation, it was found that:

(1) they often did not produce the expected levels of outputs;

(2) serious environmental and social consequences were often encountered that were not anticipated in the planning stage (Farvar and Milton 1972).

In spite of such problems, increased demands for food, energy, and domestic and industrial water require that surface and groundwater resources be put to much more efficient use than at present. The challenge for planners, managers, and policymakers is how to achieve efficient water resources manage-

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ment to meet social and economic goals, while maintaining water resources of high quality, avoiding serious degradation to the physical environment and unacceptable social disruption.

2. CHARACTERIZATION OF WATER RESOURCES PROBLEMS

Various publications on water resources contain lists of water resources problems without any attempt at systematic classification. Problems are identified: (a) in physical terms, e.g. 'flooding', 'erosion and sedimentation'; (b) as unmet human needs, e.g. 'inadequate safe water for human use'; (c) as deficiencies in management or institutions, e.g. 'inefficient use of water for irrigation', 'water use conflicts over rights or priorities'. Table I shows two illustrative lists of this type taken from recent US Water Resources Council and UN Water Conference reports.

As a start toward developing a useful classification, water resources problems are expressed in this paper in terms of their economic and social significance. For example, soil erosion, *per se*, is not defined as the problem. Rather, soil erosion and its associated physical consequences in a specific sub-watershed may reduce the economic return from an area and, by depositing sediment in a reservoir, may reduce the economic return from the operation of the reservoir. Table II shows examples of some water resources problems classified on this basis.

TABLE I
Illustrative List of Water Resources Problems as Conventionally Identified

U.S. Water Resources Council Second National Assessment, 1978[a]	*U.N. Water Conference, 1977*[b]
Inadequate supply	Inadequate safe water supplies
Ground water depletion	Water pollution — sanitation
Surface water pollution	Toxic substances pollution
Ground water contamination	Rural water supply and sanitation
Domestic water supply contamination	Over-extension of irrigation and reclamation
Flooding	Waterlogging and salinity
Erosion and sedimentation	Erosion and sedimentation
Dredge and fill	Ground water depletion
Drainage	Inefficient use of water
Bay, estuary and coastal waters degradation	Expensive water-use technology is using up scarce financial resources
	Water use conflicts on rights and priorities

[a]U.S. Water Resources Council, 1978.
[b]United Nations, 1977.

Expressing water resources problems in relation to economic and social effects, i.e. in relation to final outputs to be achieved as a result of water resources management, is an improvement over simply identifying 'problems' in physical terms, as illustrated in Table I. However, such a procedure is insufficient as an operational tool for diagnosing causes of problems. What is needed is a conceptual framework

TABLE II
Examples of Physical Manifestations of Selected Water Resources Problems and of their Economic and Social Significance

Physical Manifestation	*Economic and Social Significance*
1. *Soil erosion*, involving sheet and gully erosion and landslides, causing loss of on-site productivity of lands, and off-site sedimentation of streams, reservoirs and estuaries.	Often severe economic losses and consequent social disruption[a] because of reduction of on-site and off-site economic value of production.
2. *Severe flooding* of lands adjacent to rivers, with associated damage to agricultural lands and works of man, and changes in river regimen.	Often serious economic losses to agriculture, households, industry, and infrastructure, with consequent social disruption[a].
3. *Waterlogging and salinity*, involving loss of agricultural productivity.	Economic losses and social disruption[a].
4. *Water supply-demand imbalances* involving uneven distribution of water resources in relation to arable land or location of population.	Potential economic and social benefits for rapidly growing population or economic activity are not being realized.
5. *Pollution* of waters may limit direct use for domestic supplies and may impair human and animal health.	Increased water treatment costs or increased health costs and economic losses.

[a]Associated with such factors as forced resettlement and induced unemployment.

for analyzing water resources management in relation to different outputs and in different societal contexts. Below is presented and illustrated the application of one such framework.

3. CONCEPTUAL FRAMEWORK

The conceptual framework for analyzing water resources management has three basic facets.

(1) Water resources management is envisaged as a system, defined as a set of facilities, operating rules, and incentives (economic, regulatory, judicial, social pressure) applied to water and related land resources in their natural state, through an institutional arrangement. Such an arrangement typically involves the working together of both water-related and non-water-related entities, public and private.

The development, operation and maintenance of a water resources management system require inputs of labor, materials, energy, land and management skills. The managed system yields desired outputs, which may be either 'intermediate', e.g. domestic and industrial water supplies, water for irrigation, or 'final', e.g. hydroelectric energy, flood damage reduction. Development, operation and maintenance of the system also generate environmental and social side effects which may be beneficial or harmful, both direct and indirect. The definition of an 'output' or a 'side effect' depends, in part, on how the boundaries of the system are delineated and on the specific purposes for which the system is to be managed. Thus, 'side effects' can be converted into 'outputs' by expanding the geographic and purpose scope of the system. A schematic of a generalized water resources management system is shown in Fig. 1.

Establishing the relevant boundaries of a water resources management system is a crucial step in the analysis. In analyzing a system, the boundaries and outputs are interrelated. For example, if the output of the water resource system in the case of an irrigation project is defined as water delivered at the farm headgate, then the entire agricultural production activity -- including the relevant outputs of food and/or fiber -- lies outside the water resources management system.

The boundary question relates not only to outputs but also to related tasks, geographic scope, and agency jurisdictions. For example, zoning of flood plains and enforcing the zoning represent one means of reducing flood damage. However, the water resources management agency may have no authority to regulate land use in the flood plain. Similarly, management inputs to reduce erosion from forested watersheds in order to reduce adverse effects downstream are not likely to be within the authority of the water resources management agency, but rather are likely to be the responsibility of the forestry ministry.

Regardless of the institutional milieu, if the water resources management system is to be adequately analyzed, all elements of that system must be included within the purview of the analysis.

(2) Water resources management is a process involving various stages beginning with planning, and continuing through to design, construction, operation and maintenance. Although often shown as strictly sequential, as in Fig. 2, in reality these stages are undertaken with considerable overlap in time or even simultaneously. A water resources management agency is frequently engaged in planning, construction and operation all at the same time. For example, one project -- such as a dam and reservoir -- may be in the planning stage, while other projects, such as levees, are being constructed, and still others, such as a set of irrigation water diversion works, are being operated.

(3) Water resources management involves a set of linked activities and tasks. From this viewpoint, management of a water resources system can be subdivided for analytical purposes into a number of specific steps that water resources management agencies or other actors in any given context must perform in order to produce the desired outputs and deal with the side effects of the managed system. These steps can be identified by analyzing the water resources management system as a set of linked activities for which specific management tasks are required. For example, in a typical already-developed surface water irrigation project with reservoir storage, the water must be stored, released from storage, transported via river channel to diversion works or transported by canal directly from the reservoir to the irrigated area, allocated to subsidiary canals, subsequently made available to individual farming units and applied to agricultural lands, and the effluent must be removed from the lands or recycled, and each irrigator must be monitored to insure no application greater than his allotment. Each of these steps is an activity that requires management action.

Given these three facets of water resources

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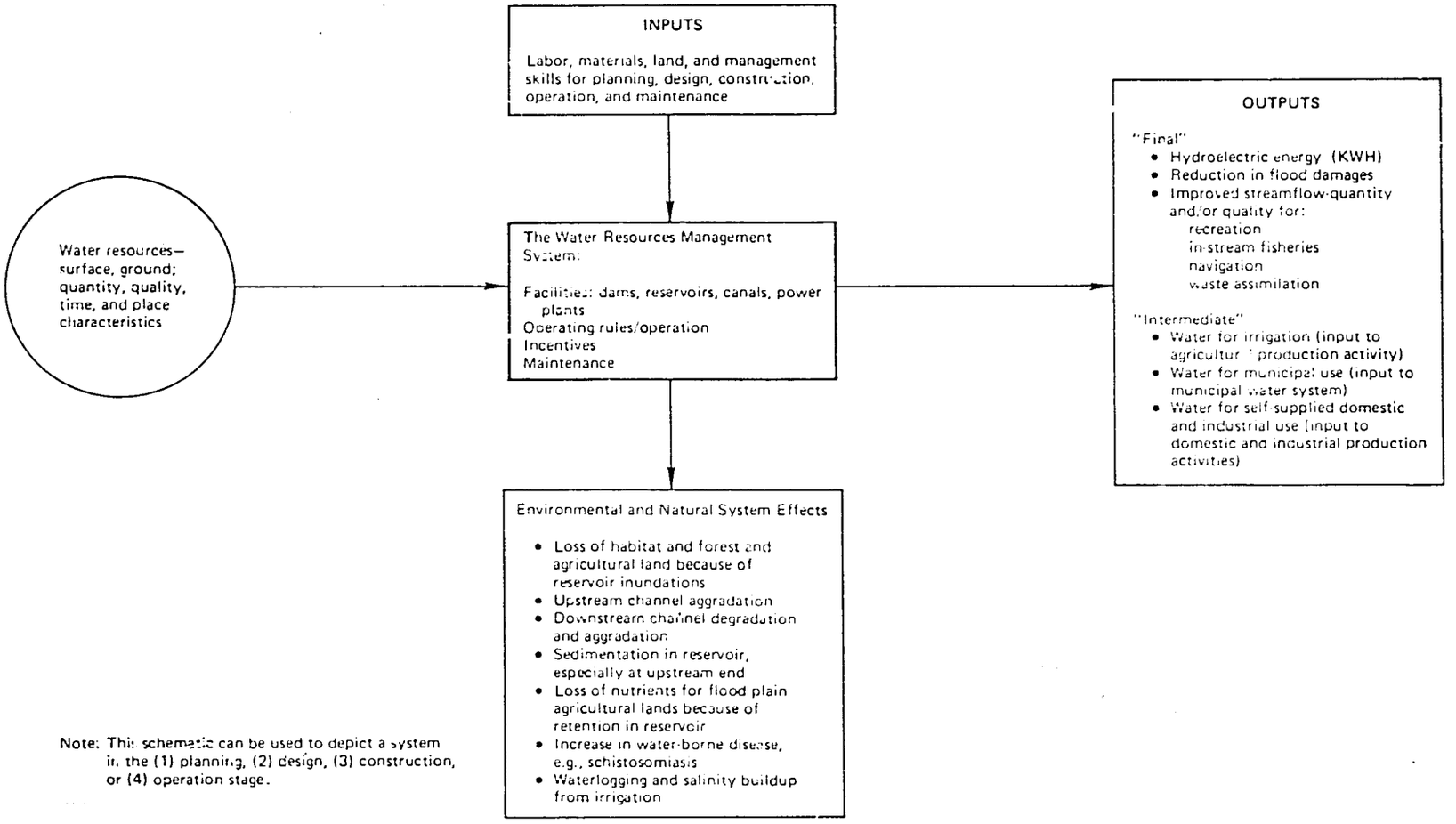

Fig. 1. Schematic of a generalized water resources management system.

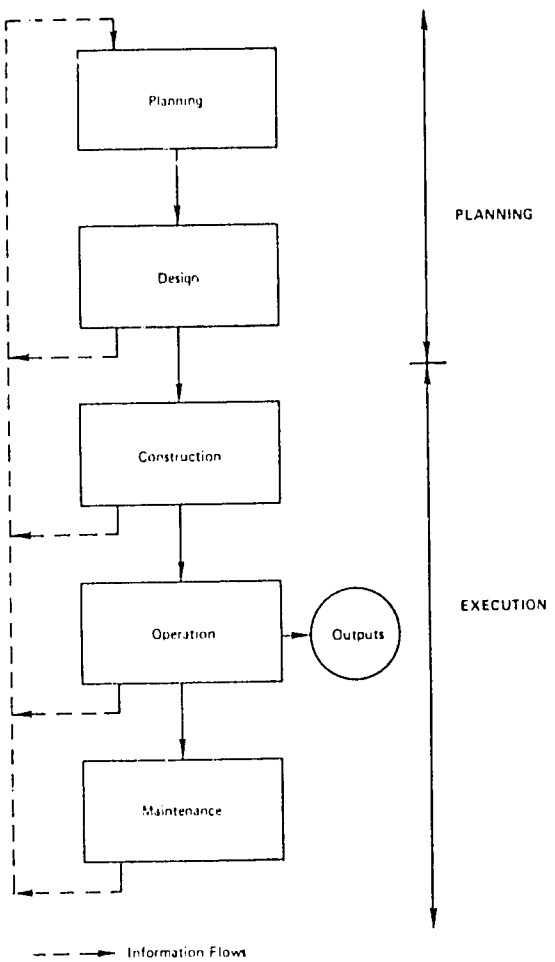

Fig. 2. The five stages of water resources management.

management, it is apparent that performance of the management system can be analyzed at the planning, design, construction, operation, and maintenance stages. Also, certain management deficiencies that could arise at later stages of the sequence can be eliminated or reduced by proper actions at previous stages. In all cases, clear definition of system boundaries is necessary.

To be achievable, management objectives must be defined in specific terms with respect to system outputs, activities and the tasks related thereto. For example, a management objective involving efficient use of water for irrigation in a surface water system would be defined in terms of:

(1) the reservoir management activity, i.e. to store and release water for irrigation;

(2) the watershed management activity, i.e. to maintain the quality of the inflows to the reservoir;

(3) the canal system management activity, i.e. to allocate water to irrigation water users;

(4) the agricultural production activity, i.e. to provide inputs to the irrigation farmer and to install and operate physical measures to reduce residuals discharges from the farms;

(5) the drainage system management activity. These five are illustrated in Fig. 3. The activities and related tasks may be associated with a specific management agency or a set of agencies.

Management performance can also be associated with: (a) the use of resource inputs, in the planning, design, construction, operation, and maintenance stages; (b) the system outputs; and (c) the direct and indirect economic, environmental and social effects of the managed system. For example, problems can arise from the inefficient use of resource inputs in construction, such that the real cost of a project is greater than necessary or construction time is longer than necessary. Also, inefficient and ineffective system planning, design, construction, operation, and maintenance can lead to levels and qualities of outputs that are below those that otherwise could be achieved. In addition, inappropriate construction and operation of a project can lead to serious adverse environmental effects such as increased erosion, sedimentation, and salinity.

From the above, it follows that in analyzing water resources management performance, it is essential to analyze the linkage among: (1) water resources problems, both as conventionally perceived in the literature and as redefined in this analysis; (2) water resources management, as characterized above; and (3) organizations and administrative arrangements. These linkages are portrayed in Fig. 4. For example, a water resources problem, defined as a reduction in value of agricultural output caused by increased levels of waterlogging and salinity, may be traced to inadequate water resources management identified by determining that the drainage system was poorly maintained. This inadequacy in management may in turn be traced to an inadequate assignment of administrative responsibility for maintenance of drainage works.

Examples of the application of the problem–management–organization linkage to some types of water resources problems are shown in Table III. In that table, water resources problems, such as erosion

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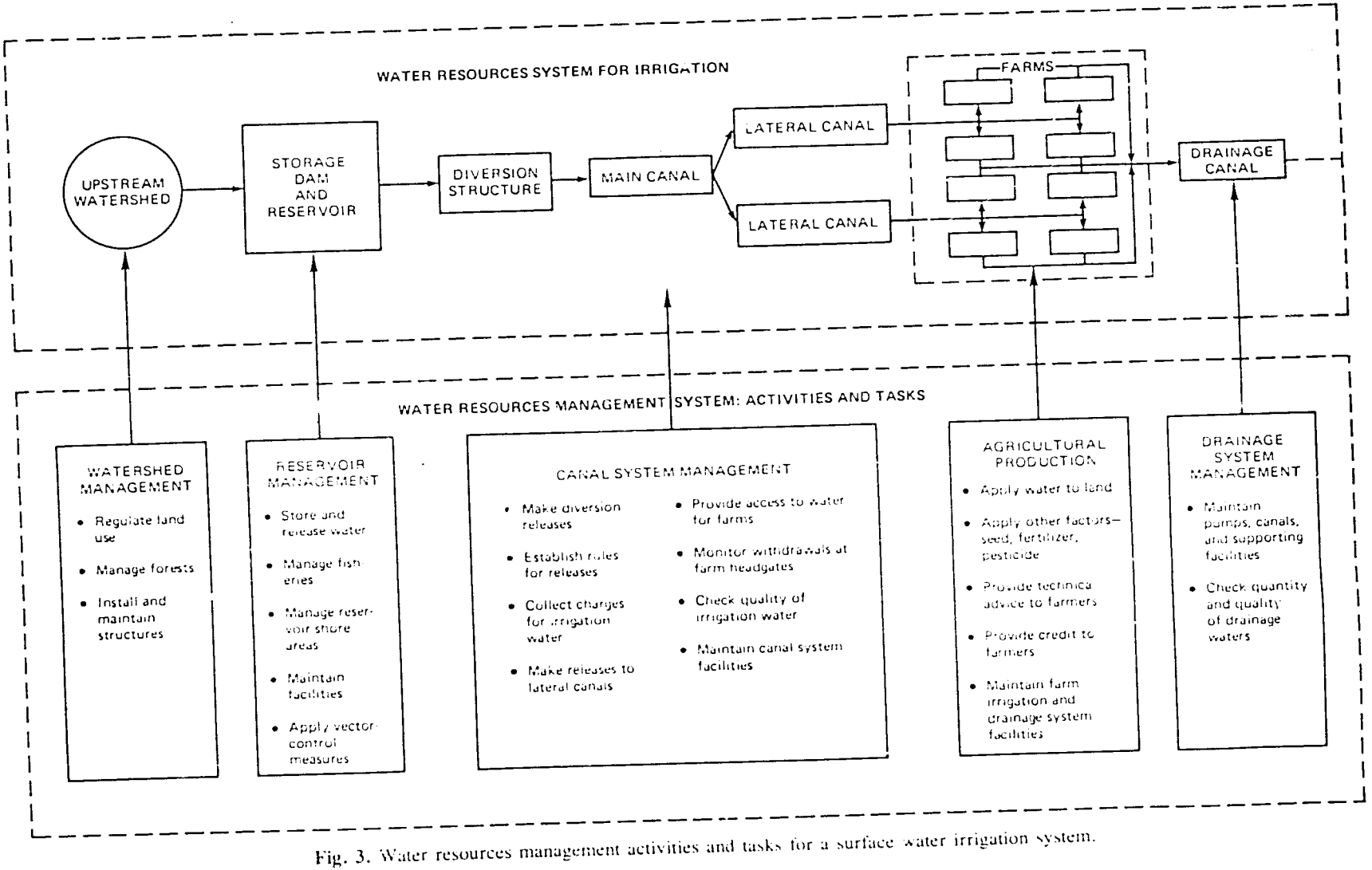

Fig. 3. Water resources management activities and tasks for a surface water irrigation system.

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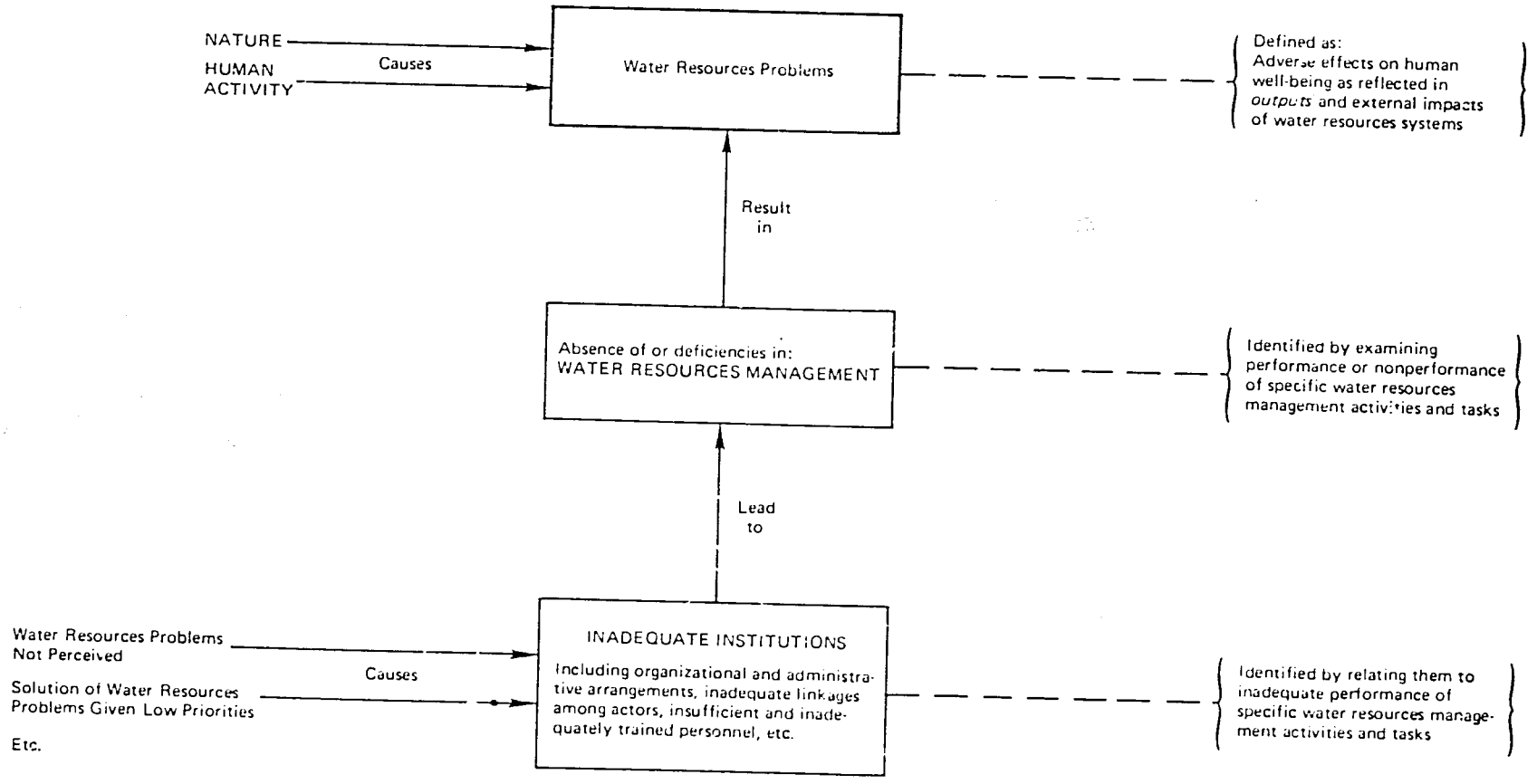

Fig. 4. Linkage of water resources problems, water resources management and water resources management institutions.

TABLE III
Linkage of Water Resources Problems, Water Resources Management, and Organization and Administration

Water Resources Problem Expressed in Output Terms	*Direct and Indirect Physical Manifestations*	*Implications for Water Resources Management*	*Implications for Organization and Administration*
Erosion and Sedimentation Economic losses to agricultural and fishery production and hydroelectric energy generation because of premature loss of reservoir storage capacity.	Increased rates of reservoir sedimentation, caused by erosion of watershed lands, in turn caused by improper agricultural and grazing practices, timber cutting, and road construction.	Implies the absence of or deficiencies in watershed management that includes: (1) effective controls on both private and public use of public lands, (2) protection and restoration programs on forest, grazing and agricultural lands, and (3) technical and financial aid to private landowners.	The primary water resources management agency rarely has responsibility for watershed management; in fact, no single agency typically has this responsibility. For some types of land use, e.g., agriculture, no agency may be able to exert effective control. With a number of agencies nominally responsible, there may be no effective leadership and no coordinating mechanism.
Flooding Economic losses to agriculture, households, industry, and infrastructure, because of inundation and force of flood waters.	Increased flood peaks caused by loss of forest cover, diminished infiltration capacity of land, aggradation of stream beds due to increased sediment loads, and increased occupancy of flood plains.	Implies the absence of or deficiencies in watershed management, as above, and in flood plain management programs, including controls over land use, flood proofing and flood warning systems.	The primary water resources management agency, which has responsibility for building and operating flood damage reduction facilities rarely has responsibility for watershed management, or for flood plain management measures such as land use controls and flood proofing.
Salinity Economic losses to agriculture, forestry, and to domestic and industrial water users because of limitations on uses of highly saline water.	Excessive use of water for irrigation, and/or excessive leakage from unlined canals. Inadequate drainage facilities for irrigation projects. Excessive pumping of groundwater or reduction of surface water flows in coastal areas can cause saline water infiltration from the sea.	Implies the absence of or deficiencies in management of irrigation water by farmers, or excessive groundwater pumping in coastal aquifers.	Irrigation agencies often have no responsibility for controlling waterlogging and salinity buildup on farm lands. No single water resources management agency may have full responsibility for controlling excessive groundwater pumping.
Water Demand-Supply Imbalances Economic development opportunities can be limited by inadequate and uncertain supplies of precipitation and runoff.	Variability of precipitation and runoff from year to year causes uncertainty in supplies. Drought years may bring extreme reduction in agricultural production. The wet–dry season phenomenon limits agricultural production without external supplies.	Implies difficult management problems at the river basin, irrigation district, and farm levels in attempts to adjust to variability.	Responsibility for water resources development may be unassigned or may be scattered among a number of different agencies.
Water Pollution Economic losses to agriculture, fisheries, industry and households, plus threats to public health, from biological and chemical pollution of streams, lakes, and estuaries.	Biological pollution caused by inadequate disposal of human and animal wastes in both rural and urban settings. Chemical pollution from agricultural fertilizers and pesticides, and chemical wastes, including toxics, from industries and urban areas.	Implies the absence or inadequacy of programs of basic sanitation in rural areas, and wastewater collection and treatment in urban areas. Improper use of fertilizers and pesticides in agriculture.	No agency has full responsibility to handle water pollution problems. Authority to control some types of pollution may be unassigned. Water resources management agencies may have no responsibility for pollution control.

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and sedimentation, flooding, and water pollution are expressed in output terms, such as economic losses from reduced productivity. For each type of problem, (1) the direct and indirect physical effects, and (2) the implications for water resources management and organization and administration are indicated.

This framework can be summarized as: relating outputs from water resources management systems to activities and tasks required to produce the outputs and to mitigate the adverse side effects of producing them, and then to the 'actors' (government agencies, private associations, individuals) responsible for carrying out the activities and tasks. Two important advantages flow from use of this framework. First, the analyst is able to identify required tasks that are not being performed by any actor, and is able to pinpoint inadequate management performance in specific terms. Second, the framework helps the analyst to trace and identify underlying causes of water resources problems through the output–task–actor chain.

4. CURRENT WATER RESOURCES MANAGEMENT IN ASIA

With the conceptual framework described above as a base, a preliminary examination of water resources management in Asia was undertaken. Deficiencies rather than strengths in management were emphasized because an understanding of deficiencies is necessary before specific actions can be taken to improve water resources management. The review consisted of discussions with individuals with experience in water resources management in Asia and an extensive search of the literature. The following generalizations about the current status of water resources management in Asia are the result of that review. The order of listing does not indicate the order of importance.

(1) With respect to the major stages of water resources management there is over emphasis on planning and underemphasis on implementation. This deficiency takes at least two forms. First, in formulating plans emphasis is placed on planning for facilities, e.g., water control structures, at the expense of planning for: (a) other means for producing outputs; (b) incentive systems to induce desired behavior; and (c) appropriate institutional arrangements, including organizational and administrative entities to carry out the tasks of water resources management (Carruthers and Clayton, 1977; United Nations, 1980; Jayaraman, 1982). Second, in the implementation stage emphasis is placed on construction of physical facilities with little thought to the operation and maintenance of those facilities (Carruthers, 1981; Kellar *et al.*, 1981; Howe and Dixon, 1983). One factor leading to inadequate operation and maintenance is the choice of inappropriate technology (Bower, 1977).

(2) The water resources management system is often defined too narrowly to include only the physical control of water. Irrigation agriculture is a good example of this limitation (Lazaro, *et al.*, 1977; Coward, 1980). To be efficient water resources management for irrigation must have regard for the ultimate outputs in terms of food and fiber produced by the agricultural system (Maheswaran, 1979). Three subsystems are involved:

(a) the water control subsystem, involving efficient collection and distribution of irrigation water to, and efficient removal of drainage water from, the farms;

(b) the agricultural production subsystem, involving the efficient combining of water, seeds, fertilizers, energy, machines, labor and management for production of food and fiber; and

(c) the agricultural marketing subsystem, involving the efficient collection and transport of produced food and fiber to markets and to processing.

Typically, water resources management has emphasized only the water control subsystem; only recently has increasing attention been given to the agricultural production subsystem (Sherman, 1978; Taylor, 1980; Asian Productivity Commission, 1980; Singh, 1981; Lenton, 1982). The agricultural marketing subsystem has as yet received little attention by water resources managers. It is recognized of course that this subsystem is rarely under the jurisdiction of the water resources management agency.

(3) Water resources management is often defined too narrowly in terms of the range of measures considered for producing the outputs that are desired. For example, a water resources management system may consist primarily of physical facilities such as dams, canals, power plants, wastewater treatment plants to the exclusion of many other essential measures, such as economic incentives, regulations, technical assistance, credit, land use zoning etc. Thus, a water resources management system to reduce flood damage may consist solely of a reservoir and the associated operating rules. Such a system would exclude such relevant possibilities as flood

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proofing, flood warning networks, evacuation and resettlement plans, and flood plain zoning (Prasad, 1976; Wiener, 1977).

(4) The planning activity, and therefore water resources management as a whole, is often too narrow in scope in that primary emphasis is placed on the engineering, economic, and financial data and analyses required to obtain approval of the project by donor agencies. Inadequate attention is given to the direct and indirect environmental quality and social effects of projects. Although donor agency and country requirements for preparation of environmental impact statements as a part of the planning process have led to some improvement, water resources planning and operation still give inadequate treatment to these important aspects (Lahiri, 1976; Rogers, 1977; Taylor, 1980; Asian Development Bank, 1980; Negi, 1982).

(5) In the operation and maintenance stage, the major emphasis of water resources management agencies is given to water control and conveyance works, such as the reservoir, diversion dam, and main canals, (B, C, and D, respectively) in the irrigation system portrayed in Fig. 5. Little attention is given to management of the watershed upstream from the reservoirs, A in Fig. 5, in spite of the fact that the construction of the dam and reservoir itself stimulates development of the watershed, often with consequent increased erosion rates and pollution loads (Rogers, 1977; Negi, 1982; American Society of Agronomy – Soil Science Society of America, 1982). Also, inadequate attention is often given by water resources management agencies to the problems of operation and maintenance of irrigation works at the farm level, E in Fig. 5 (Lazaro *et al.*, 1977; Kandiah, 1978; Taylor and Wickham, 1979; Asian Productivity Commission, 1980; Carruthers, 1981). All too often, it is assumed that farmers will be able to do an effective job without technical advice and associated financial and equipment inputs. Finally, inadequate

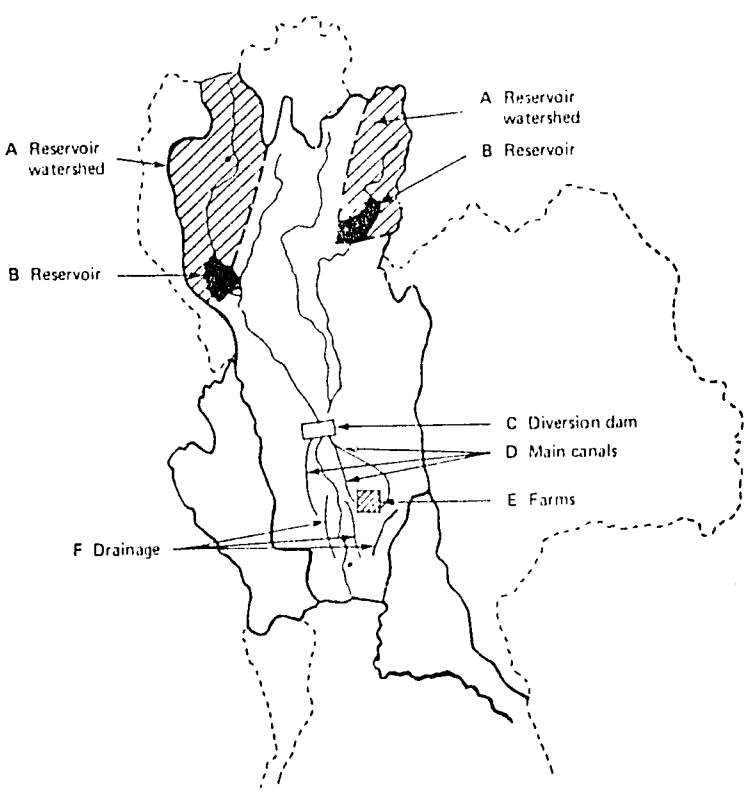

Fig. 5. Major physical facilities in a surface water irrigation system.

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TABLE IV

Water Resources Management Activities Related to Irrigated Agricultural Production in Thailand with the Public or Private Agencies Responsible for those Activities, 1982

RESPONSIBLE AGENCY / ACTIVITY AND TASK	MINISTRY OF AGRICULTURE AND COOPERATIVES								MINISTRY OF INTERIOR							MINISTRY OF COMMUNICATIONS			MINISTRY OF INDUSTRY			MIN. OF PUB. HLTH.		MIN. OF SCI./TECH.		STATE ENTERPRISES																
	The Royal Irrigation Department	Department of Livestock Development	The Royal Forest Department	Department of Agricultural Tech.	The Cooperative Promotion Dept.	The Land Development Department	Office of Land Consolidation	Office of Agricultural Land Reform	The Local Administration Department	Department of Lands	Department of Public Welfare	Department of Public Works	Department of Town and Country Plng	Office of Accelerated Rural Dev.	Office of Policy and Planning	The Harbour Dept.	The Department of Highways	The Meteorological Department	Department of Mineral Resources	Department of Industrial Works	Department of Industrial Promotion	Department of Comm. Dease Control	Department of Health	Department of National Energy Adm.	Office of National Energy Board	The Marketing Org. for Farms	Prov. Water Works Authority	Metropolitan Water Works Authority	The Bank for Agr. Agr. Coops	Electricity Gen. Authority of Thai.	Dairy Promotion Org. of Thailand	Th. Fish Marketing Organization	The Forest Industry Organization	Office of the P.M. Bureau of Budget	Office of NESDB	Ministry of Defense	Ministry of Education	Ministry of Commerce	Water Users Assns.	Farm Cooperatives	Farm Suppliers, Merchants	Farmers
PLANNING																																										
Basic Surveys	●	●				●												●	●									●		●						●	●					
Analysis	●																													●												
Formulation	●																													●												
Env. Impact	●																								●					●					●							
Assessment	●																													●												
Evaluation	●																								●					●												
Review/Appr.	●																													●												
DESIGN																																										
Det. Plans	●																													●												
Specific.	●																													●												
Budgeting	●																													●				●								
Scheduling	●														●															●												
CONSTRUCTION																																										
Bids	●											●															●			●												
Work Supervision	●											●															●			●				●								
Disbursement	●														●															●												
Approval	●																																									
OPERATION																																										
Watershed Mgt.			●																														●									
Reservoir Mgt.	●																													●												
Control Gate	●																																									
Water Releases	●																													●												
MAINTENANCE																																										
Cleaning/Main	●																																									●
Cleaning/Laterals	●																																						●	●		
Repair/Main	●																																									
Repair/Laterals	●																																						●	●		●
Dredging	●											●																														
NON-IRRIGATION																																										
Hydroelectric																														●												
Fishing																																	●									
Recreation																																										
Disease Control											●											●	●																			
FARM PRODUCTION																																										
Inputs				●		●	●	●																																●		
Credit					●																								●					●					●			
Extension				●					●																																	
Weather Forecast.																		●																			●						
MARKETING																																										
Processing				●					●																	●														●	●	●
Transportation				●																						●														●	●	●
Pricing																										●												●		●	●	●
Storage				●																						●												●		●	●	●

operation and maintenance of the irrigation 'return flow' drainage system (F in Fig. 5) — if, indeed, one has been provided — is all too common, often with significant adverse waterlogging and salinization effects at the lower ends of irrigation areas and on downstream lands (Howe and Dixon, 1983).

(6) All water resources management systems rely for success on the co-operation of water users or people affected by water — e.g. farmers using irrigation, domestic and industrial water users, fishermen, residents of flood plains. Yet, water resources management agencies often fail to seek and obtain the understanding, support, and participation of the people affected, in planning, designing, building, operating, and maintaining water resources management systems (Takahashi, 1977; Taylor, 1980; Botrall, 1981; Carruthers and Clark, 1981). This deficiency in management is often reflected in failure to achieve planned outputs of projects, increased costs in design and construction of project elements, rapid deterioration of project facilities caused by inadequate maintenance, and increased adverse environmental and social effects of projects (Kandiah, 1978; Takase and Wickham, 1980; Bromley *et al.*, 1980; Lenton, 1982). Failure to consider the situation and behavior of users of water leads to: (a) failure to take into account the effects of their internal water use patterns on the larger system, e.g. recirculation of water could lead to less reservoir capacity required than otherwise; and (b) failure to consider the implementation of incentives needed to induce changes in user behavior.

(7) Rarely is there enforcement of regulations limiting wastewater discharges from municipalities and from industrial activities. This has often led to major deterioration of water quality in surface and groundwater bodies.

(8) Rarely is there a recognition of the physical, economic, technologic, and ecologic linkages among water supply, wastewater modification, and air quality management and solid residuals management. The result is deterioration of one or more of the environmental media. Of course, *recognition* of the linkages is of little use in and of itself. What is required is the development of explicit linkages between the water resources management agency and the agencies having responsibility for air quality and solid residuals management.

These points imply that multiple linkages should exist among water resources management agencies and between other agencies providing needed non-water inputs, such as credit banks and extension agencies, and agencies mitigating adverse side effects such as environmental quality and health agencies. Only occasionally has the need for such linkages been recognized and rarely have such linkages been actually developed (Rosenfield and Bower, 1978).

5. THE ROLE OF INSTITUTIONS

There are many reasons for inadequacies in water resources management, depending upon the particular situation at the particular time in the particular country in question. However, both review of the literature and discussions with experts have made clear the great importance of institutions, including the organizational and administrative aspects, both formal and informal (Reidinger, 1974; Wade, 1975; Takahashi, 1977; Bottrall, 1979; Maheswaran, 1979; Taylor and Wickham, 1979; Takase and Wickham, 1980; Bromley *et al.*, 1980; Coward, 1980).

A typical situation encountered in many Asian countries is the fragmentation of water resources management activities among many sectoral agencies, with both policy and management centralized in the provincial or national capital. This fragmentation is illustrated for Thailand in Table IV. The fragmented management structure in Thailand, involving 42 separate agencies and nine ministries, makes it very difficult to achieve the integration which is required for efficient and effective water resources management. It is a major factor in the inadequate attention given, for example, to: (1) implementation, because planning is more readily done at the central level than implementation; (2) upstream watershed management; (3) maintenance and operation of irrigation works at the farm level and water supply and wastewater treatment facilities at the municipal level; and (4) consideration and execution of a wide range of possible measures to achieve outputs, such as integrating flood warning networks, flood proofing, evacuation and return, levees, and reservoirs.

6. CONCLUDING COMMENTS

The first proposition put forth in this paper is that items conventionally defined as water resources problems, for example, waterlogging, pollution, and sedimentation, are actually symptoms or manifes-

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tations of inadequacies in the institutional arrangement for water resources management. These institutional inadequacies are the basic problems in water resources management. The second proposition is that, in order to identify these inadequacies, a conceptual framework which relates outputs of water resource management systems (1) to the tasks needed to produce the outputs, and (2) to the actors responsible for the tasks, will be a useful analytical tool.

The typical institutional environment for water resources management consists of many governmental agencies at various levels in the governmental structure, with often ill-defined and overlapping responsibilities (and for some essential tasks no responsibilities), plus many nongovernmental actors. To penetrate this environment in order to apply the conceptual framework described above will be difficult and will require analysts who are sensitive to cultural nuances. But the payoffs in terms of substantial insights for improving water resources management can be large.

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