PARTIAL TECHNICAL COMPLETION REPORT

OFFICE OF WATER RESOURCES RESEARCH

PROJECT A-020-ARIZ

"Modeling of Hydrologic Processes and Water Salvage Procedures in Semiarid Regions"

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ABSTRACT

Potential uses or reuses of salvageable waters in the Tucson region were examined, and costs and benefits related to such uses were evaluated. The quality of salvageable waters as determined in exploratory sampling was compared with water quality standards and criteria appropriate for agricultural, recreational and selected industrial uses. A tableau was then constructed which showed the type and estimated cost of conventional water treatment that would be required for each source-to-use combination. Finally, an estimate was made of unit net benefits to be anticipated from salvageable water input to these uses, and the net benefits were applied in several test calculations to illustrate mixed allocations of the various salvaged waters to the selected uses.

INTRODUCTION

The research reported herein was accomplished in partial fulfillment of OWRR Project A-020-ARIZ, "Modeling of Hydrologic Processes and Water Salvage Procedures in Semiarid Regions." The other Partial Technical Completion Reports, already submitted, cover other aspects of the research.

Related Research

An inventory of salvageable water resources in the Tucson region was conducted during 1967-69 under OWRR Project A-011-ARIZ, "Optimizing Salvageable Water Resources in a Semi-Arid Inland Basin". That part of Project A-020-ARIZ reported below has made use of the basic data obtained therein, and the analysis has been carried forward according to Objectives (3) and (4) as quoted below. The detailed analytical procedure and results are to be found in a doctoral dissertation by DeCook (1970), "Economic Feasibility of Selective Adjustments in Use of Salvageable Waters in the Tucson Region, Arizona."

Objectives of Research

The objectives stated as Nos. (3) and (4) in the original research proposal for Project A-020-ARIZ are as follows:

3. To determine potential uses and/or reuses to which the salvageable water resources in the Tucson region may feasibly be adapted; and to formulate sets of water quality criteria for each of the stated uses, appropriately modified to the conditions of a semiarid environ-

ment and to recently enacted statutory and administrative controls in the State of Arizona.

4. To evaluate comparative costs of control and treatment measures needed to upgrade each kind of salvaged water to the levels of quality associated with the criteria for each use; to evaluate benefits derived from application of the several salvageable waters to specific uses; and to combine benefits and costs in one or more analytical models to determine comparative states of the water-use system emanating from alternative combinations of water source, treatment, and use.

RESEARCH PROCEDURES

The initial effort under Objectives (3) and (4) was expanded to the activity-analysis model developed in the dissertation by DeCook (op. cit.).

Conceptual Model

A "water-salvage industry" was conceptualized, for which the inputs are salvageable waters, their quality parameters, and the existing water treatment technology; the principal activity is transformation of water quality by treatment; and the outputs are pollutant removal, water control, and waters of improved quality relative to the set of quality criteria representing specified uses of water.

A measure of effectiveness was designated as a net benefit function, to be determined as the difference between gross social benefit and incremental

social cost for each water-salvage activity. The cost coefficient applied to each water transformation contained elements of fixed plus variable cost for conveyance, storage, treatment, and (in some instances) disposal of water. The requisite cost data were taken from national technical references and modified slightly by local empirical data. The unit benefit attributable to each use of the output product water was determined as follows: (1) Benefits accruing to the water factor in local irrigation uses were derived from a farm-budget analysis based on current cropping patterns in the Tucson region; (2) recreation benefits were determined as an appropriate fraction of a willingness-to-pay demand curve obtained by a direct interview method; and (3) benefits for industrial uses were related to discrete points on local demand curves for cooling water and for mining and milling operations.

Input Data and Analysis

The quantitative and qualitative inventory of salvageable waters in the Tucson region, as compiled in the aforementioned Project A-011-ARIZ, was utilized here for input data. These waters consisted of metropolitan domestic-industrial effluents from the central City and County collection and treatment systems; other (isolated) sources of domestic and industrial effluent; and storm runoff from both urban and rural watersheds. At the 1970 level the aggregate quantity of such waters in the Tucson region was about 35,300 acre-feet per year, and its apparent growth rate projection is in the order of five percent per year during the next 10 to 20 years.

The quality of these waters having been determined from City and County records and by field and laboratory measurements, it was only necessary to specify the quality requirements for the set of water uses in order to determine the treatment method required for each source-to-use combination. The

water quality requirements were based principally on those set out by FWPCA (1968), supplemented by other sources and by local environmental requirements. For the treatment methods thus indicated, unit costs of treatment were compiled as modified from a nationwide study by Smith (1968), and used as a basis for the cost coefficients mentioned earlier.

The analytical procedure consisted of two main parts, identified as marginal transformations and structural transformations. First with regard to marginal adjustments, two kinds of objectives were sought through the analysis -- a cost minimization strategy for satisfying the constraints of the 1970 conditions as compared to existing 1970 operations, and a net benefit maximization strategy as applied both to observed 1970 conditions and to postulated conditions for optimization. The same solutions were performed for selected future years; the key projection years were 1975, when the major existing contract for municipal effluent will expire, and 1980, estimated as the earliest year in which water imports from the Colorado River conceivably could affect local allocations of salvageable water.

The quantitative solutions for allocation were achieved by a linear programming algorithm, solved with the aid of electronic computer. Linearity in the variables of the objective functions was preserved by selection of points on cost curves and benefit functions, or by a piecewise linearization of these functions, within ranges where linearity would not be violated.

Finally, trial solutions for selected structural transformations in the salvageable water systems were carried out. The first of these postulated construction and operation of a new facility at Randolph Park, where a portion of the sewage flow would be separated from the main collection system, treated, and allocated to local recreational needs. The second solution was set up to evaluate a proposed operational policy for a facility

at Tucson International Airport using mixed industrial effluent and runoff sources for multiple uses. In all cases the transformation resulting from the postulated system modification was evaluated in terms of present value (at any decision time t_o) of all benefits and costs of operating the system through its projected life "with" versus "without" the proposed change, and to make an algebraic summation which expresses the two comparative states of the system.

RESEARCH RESULTS

The inventory of salvageable water resources in the Tucson region disclosed that, of the 35,300 acre-feet per year of such waters that were available at the 1970 level, approximately 32,000 acre-feet consisted of domestic or domestic-industrial wastewaters; 1,200 acre-feet was from discrete sources of industrial cooling and processing effluents; and 2,100 acre-feet was storm runoff. In the matrix containing these water sources and an array of technically feasible water uses, the uses were classified as follows: (1) Irrigation of field and forage crops, cotton, orchard, and produce; (2) recreational uses in terms of fishing and boating and landscape irrigation; (3) industrial uses for cooling and for copper mining and milling; and (4) storage, both surface and subsurface.

Analysis of unit benefits in terms of net returns to water in these various uses showed that irrigation returns ranged from $30 per acre or $6 per acre-foot of water applied for pasture, to $219/ac or about $50/ac-ft for lettuce (spring crop only).

In recreational uses, the derived demand curve and cost analysis indicated that unit net return to water in a 20-acre urban fishing and boating lake would be about $500/ac-ft at maximum intensity of use.

According to national urban recreation standards, at least five such facilities could be supported by the apparent demand in the Tucson region; if these were implemented, approximately 3,000 acre-feet of salvageable water would be utilized and, according to the urban recreation survey conducted in this study, the yield of annual returns over variable costs would be about $1,500,000.

The industrial uses of water considered were copper mining and milling, and power-plant cooling. By reference to an inter-industry analysis, the gross value added per acre-foot of water in the mining sector, adjusted for labor costs, was determined as approximately $1,450/ac-ft, and a similar calculation showed a value of about $950/ac-ft in cooling use.

The available salvaged water supplies, thus categorized and evaluated, were substituted incrementally into the total water supply function for the Tucson region. Calculated examples of allocation of the combined supplies to all the uses indicated that under optimal allocation, the treated municipal-industrial effluent would be used not only for agricultural irrigation but also for recreational and industrial uses. Parameterization indicates that the exact proportionate allocation among uses is very sensitive to the net benefit attributed to water use in the mining industry; additionally, matters of equity such as court decisions can outweigh efficiency criteria and alter constraints, causing profound changes in allocation patterns.

Calculated examples of structural adjustments affecting water allocation, using both separable source and multiple source models, showed that new facilities for the utilization of salvaged waters in the Tucson region can be economically justified (i.e., benefits exceed costs), but that feasibility is highly sensitive to the extent of use of such waters

for urban recreational facilities.

The analytical method illustrated in the study can be applied directly to the existing Tucson region, as the model was tested in terms of actual conditions. In fact, some aspects of this work have been given consideration and incorporated in planning studies, by agencies of the City of Tucson and Pima County.

REFERENCES CITED

DeCook, K. J., Economic Feasibility of Selective Adjustments in Use of Salvageable Waters in the Tucson Region, Arizona, Univ. of Arizona Ph.D. Dissertation, 1970.

Federal Water Pollution Control Administration, Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, 1968a.

Smith, R., Cost of Conventional and Advanced Treatment of Wastewater, Jour. Water. Poll. Control Fed., 40 (9), 1546-1574, September 1968.