Evaluating Federal Water Projects: A Critique of Proposed Standards

Water council standards encourage inefficient projects and neglect harmful environmental impacts.

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Water resource development and management in the United States has created 12,000 miles of waterways, irrigated 30 million acres of land (and drained an even larger area), provided water supplies for countless cities and industries, utilized millions of tons of concrete and earth to develop thousands of streams, and harnessed more than 30 million kilowatts. The nation has spent more than $240 billion (at 1970 price levels) on water resource development. More than $72 billion of this amount has been spent under federal auspices, with current federal expenditures budgeted at $3 to $4 billion annually (*1*). Assuming the main objective of these federal expenditures is to contribute to the national welfare, two issues require clarification: the definition of "national welfare"; and the measurement of contributions to that welfare made by water resource development.

The Flood Control Act of 1936 suggests that the basic criterion for evaluating water resource projects is a favorable cost-benefit ratio. The act specifies that "the federal government should be prepared to undertake such investments . . . if the benefits to whomsoever they may accrue exceed the costs." Efforts to produce effective accounting methods for recording costs and benefits include: a National Resources Planning Board Study in 1941; a series of studies by the Inter-Agency Committee on Water Resources—culminating in a handbook of practices for the economic analysis of river basin projects (originally issued in 1950 and revised in 1958); a report by a panel of consultants to the Bureau of the Budget in 1961; and, in the late 1960's, inquiries both by the Senate Committee on Interior and Insular Affairs and the Senate Public Works Committee. Both Senate committees have suggested that the economic analysis of projects should reflect all potential costs and benefits, including all direct and indirect effects.

Most recently, the Water Resources Council (WRC), in proposing "Principles and Standards for Planning Water and Related Land Resources" (*2*), has attempted to improve the inclusiveness and reliability of cost-benefit practices. The WRC has provided a far more comprehensive discussion of economic evaluation issues than any other federal, congressional, or executive effort (*3*). Nevertheless, we question the validity of the concepts behind, and the feasibility of, some of the proposed new procedures.

Our primary objection to the "Principles and Standards" is the erroneous statement of certain fundamental economic principles and the recommended application of certain faulty estimation procedures. In short, the "Principles and Standards" misuses economic methods; economic analyses based on it can only mislead political discussions and decisions.

In order to illustrate these assertions, we discuss those principles and procedures in which we found conceptual errors, fundamental inadequacies, and unrealistic views of agency planning capability. We conclude that the proposed procedures, if accepted in their present form, will bias water resource management in favor of development and against the preservation of the natural environment.

Accounting Stance

Cost-benefit analysis has, until recently, been chiefly concerned with the measurement of the national economic development effects of any given project. The "Principles and Standards" proposes an expansion of the analysis by establishing four accounts by which a project may be evaluated. National economic development remains as one. Regional development, environmental quality, and income redistribution accounts have been added. It is our contention that national economic development effects should continue to be the *primary* criterion in evaluating water resources development, particularly in federal projects using federal funds. We base our judgment on two considerations.

First, the basic purpose of public investments is to correct for private market failures, in order to achieve efficiency in the allocation of resources. To avoid transferring resources through public investment from more productive private activity in one sector of the economy to less productive activity in another, both public and private sector investment must have the same objective—economic efficiency. This coincidence of objectives can be attained only if national economic development, or economic efficiency, is the criterion used to evaluate public investments. By effective use of this criterion, net economic benefits to society from any undertaking can be maximized (*4*).

Second, while there is wide agreement on the definitions and measurement of costs and benefits within the framework of national economic development, there is no such agreement for measuring the effects of the three new accounts proposed by the WRC. The "Principles and Standards" fails to set forth any set of principles on which wide agreement could be reached. More significantly, the document contains no guidelines for integrating the four accounts. As a result, the same benefits can be measured in more than one way and may appear in two or more accounts. Distortions of costs and benefits will be inevitable, especially if the present practice of having the development agencies perform the cost-benefit analysis is retained.

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The fundamental point that the "Principles and Standards" fails to recognize is that the concepts of economic benefits and costs are comprehensive. They include all of the real beneficial and detrimental effects of an undertaking and exclude those effects which represent only income transfers from one group in the country to another. While measurement of all of these effects in terms of willingness to pay is no easy task, conceptually they all belong within the national economic efficiency account. By ignoring this point, the document leads one to count as benefits the gains in the region in which a project is located without considering the cost of these gains, which are achieved at the expense of regional gains elsewhere. Hence, transfers between regions of the country are recorded as benefits in the regional account.

By proposing the regional economic development account, the document implies that there is something about such regional gains and losses that cannot be subsumed under the national economic efficiency account. If there is, the new standards must permit discrimination among regions on the basis of redistributive merit. The "Principles and Standards" contains no recognition of the necessity of such indicators of regional merit. And it seems unrealistic to believe that Congress or agency personnel could or would objectively establish such a system of indicators. Without indicators, the implementation of the standards is likely to result in additional economically inefficient projects in all regions. Such a result would reduce the aggregate economic welfare of the nation and perhaps lead to reductions in the economic welfare of citizens in all regions.

The environmental account has been proposed in an attempt to make adverse environmental effects and other indirect effects of water resource projects commensurable with the benefits of these projects. At present, there is no applicable methodology for accurately measuring the economic value of environmental effects and incorporating them into the national efficiency account. Nevertheless, to the extent that such gains and costs represent real effects on welfare, they should be measured and valued as completely as possible and included in the national economic efficiency account.

At one point, the "Principles and Standards" seems to recognize this—it states that all environmental effects should be "quantified and displayed." However, the two sides of the account are unevenly treated. The only effects for which measurement methods are carefully detailed in the document are the possible benefits that would accrue to the environment if a project were constructed. The adverse effects of the project are treated summarily. As a result, any evaluation based on the proposals would tend to be biased toward economic development at the expense of environmental preservation.

The fourth account is designed for evaluating the effects of income redistribution. It has been recommended that this information be presented as a side display. This is a reasonable procedure, but we would emphasize the difficulty of obtaining accurate estimators of the incidence of both benefits and costs. It should be noted that, for social well-being to be accurately reflected, the distributional impacts of the source of funds used to finance the project must be ascertained.

Hence, while all of the impacts of a project cannot be quantified, we judge that all real project effects can be accounted for, at least conceptually, within the national economic development account, which is meant to measure national economic efficiency. Concentration on this account would yield an accurate appraisal of the net effect of a project on national economic welfare. The creation of the new accounts seems redundant and methodologically unsound (*5*). They are open to abuse and will likely lead to a deterioration in the quality of water resource investment decisions.

The Regional Development Account

Efforts to appropriately include regional economic development effects in cost-benefit analyses have always encountered serious problems (*4*). The WRC's recommendation of a separate regional development account does not overcome either the problem of measuring the static secondary effects of a project on a region or of measuring the more dynamic economic growth impacts.

The difficulty in measuring the static secondary effects is two-pronged. First, economic theory has it that, for any project which is not inordinately large relative to the national economy, any secondary benefits in one or more regions will usually be offset by secondary costs imposed on the same or other regions, if the economy is fully employed and smoothly functioning (*6*). Thus, in this situation, any secondary benefit accruing to one region will be offset by an equivalent secondary cost imposed either on that region or some other region—nationally, they even out. Only if the economic effects of a project in one region are given more weight than in another would there be any net regional income gains or losses. Unless someone produces well-defined regional weights, the effect of these secondary benefits and costs on project evaluation will be zero.

Second, if the economy is not operating at full employment or is not flexible and functioning smoothly, the difficulties of estimating these effects are large. This is especially true of the secondary costs, which might be imposed on regions far from the one in which the project is located (*7*). However, methods have been developed for estimating the social costs of project construction when unemployment is present. The point is that these effects are appropriately included in the national economic efficiency account; they are relevant to regional considerations only if well-defined regional weights have been developed and accepted (*6*).

The problem of measuring the dynamic effects of a project on the growth of a region are even more complicated. Indeed, accurate evaluation of these impacts requires a full-scale, dynamic regional model, but, to our knowledge, no such breakthrough has yet been made. Again, these specific effects on the growth of a region are relevant for their national economic growth implications only if the accepted regional weights are applied.

In this context, it is interesting to note that the few studies done on the consequences to regional growth of water resources investments do not suggest that such expenditures are powerful instruments of economic growth. These studies have concluded that:

1) Water does not constitute a barrier to economic development; on the other hand, the presence of large quantities of water does not guarantee rapid growth (*8*).

2) Water resource development projects are likely to be poor instruments for accelerating the economic growth of rural counties (*9*).

3) The correlation between population growth and investment in water resource projects is statistically insignificant (*10*).

While the "Principles and Standards"

reflects a belief that expenditures on regional development of water resources are important, we would emphasize that water resource agencies alone cannot accomplish such objectives. Regional growth is a complex phenomenon requiring various private, federal, state, and local undertakings, as well as coordination of them.

The Environmental Quality Account

Sound evaluation of water resource developments requires that all of the positive and negative effects of a particular undertaking be quantified and evaluated to the fullest extent possible. Because people value positive environmental effects, they would be willing to pay for the positive effects and willing to pay in order to avoid the negative effects. As such, the evaluation of these effects is no different from other costs and gains and should be included in the economic efficiency evaluation and shown in the national economic development account.

Instead, the WRC has proposed a separate environmental quality account. We are concerned with the relationship of this account to the economic efficiency account and the procedures the WRC has proposed for evaluating environmental effects. In the WRC document, it is stated that both beneficial and adverse environmental effects are to be evaluated, cataloged, and then placed in the same column in the account. The environmental quality account is the only one which requires that both the adverse and the beneficial effects be listed on the same side of the ledger. An introductory note provides the only clue for this procedure: "An environmental impact of a plan cannot be easily labeled as being beneficial or adverse, since that decision will vary with the perceptions of the individual concerned." In our view, this procedure invites the double counting of environmental benefits and the single counting of environmental costs. The reason for this lies in the relationship of the environmental quality account with the national economic development account. Because numerous beneficial environmental effects of projects can be recorded both in physical units (for example, acres of lake and beach frontage provided by a dam) and in monetary units (for example, recreational boating, fishing, and swimming benefits on a new lake), they can be included in both the environmental quality and the national economic development accounts. On the other hand, because many of the adverse environmental effects cannot be either quantified or valued as easily (*11*), they will not appear in the national account and are likely to be described only generally in the environmental quality account. The likelihood of this result is evidenced by the fact that the WRC presents in voluminous detail the beneficial environmental effects that can stem from water undertakings and the procedures for their quantification; it treats the possible adverse effects in but a single sentence.

Finally, the procedures for evaluating environmental effects exclude a major component of environmental impact: the significance of options in the context of irreversible decisions. The possible advantages of preserving the environment are a crucial consideration in those decisions which make it physically or economically impossible to restore the environment to its natural state (*12*). By failing to include the option of preserving a natural environment, a real economic benefit associated with *not* undertaking the project is omitted from the national economic development account. In this case, too, the WRC project evaluation is biased toward development.

This omission is particularly serious in a society with a growing population and changing technology. In such a society, those irreproducible resources in fixed supply can be expected to appreciate in value over time. On the other hand, the values of goods and services for which substitutes exist (and technical improvements are possible) can be expected to decline relatively over time. Since the national environment is irreproducible and has no substitutes, its value is likely to appreciate (*13*).

Benefit Measures

The three approaches recommended in the "Principles and Standards" for calculating the economic benefits attributable to a project are willingness to pay, change in net income, and least-cost alternative. We have reservations about this section of the document, not because three benefit measures are proposed, but because the WRC fails to enunciate the shortcomings of each approach. Furthermore, no guidelines are presented to aid one in deciding which method might best be used to measure benefits in a particular instance.

The willingness-to-pay approach is based on sound economic theory. If applied appropriately, it can yield benefit estimates that indicate the gross contribution to national economic welfare. However, it should be noted that a project which displays willingness-to-pay benefits in excess of real costs may not be the most efficient undertaking. For example, the recreation benefits from improved water quality may exceed the costs of a water treatment facility. However, if that same water quality could be achieved by a less costly, stream-flow augmentation project, the water treatment facility would not be the most efficient undertaking. A less costly way of accomplishing the same objective would exist. While agencies performing cost-benefit analyses may be prohibited from undertaking certain alternatives to accomplish an objective, a valid economic analysis of all the alternatives for accomplishing a set of objectives should not be precluded, even if it meant that the agency should give up the project.

The net income approach measures the benefits of water projects that result in increased production of firms and individuals. It does so by estimating the changes in their net income that are attributable to the project. Under some circumstances, this, too, may be an appropriate means of measuring benefits. Again, however, we add an important caveat: If private investors are to make profitable investments with funds borrowed at the market rate of interest, these investments must earn a return in excess of the market rate of interest. This test keeps businesses from undertaking low-return investments. However, if the net income of a business is increased because it is receiving publicly produced outputs at below their real costs, then it is questionable whether changes in private income are an appropriate measure of efficiency gains.

For example, assume that an irrigation project would provide sufficient water for a farmer to grow alfalfa on previously arid land and sell it at the market price. But he can produce this alfalfa at a profit only if he is subsidized and pays for less than his full share of the cost of the irrigation project. Under such circumstances, it is analytically erroneous to equate benefits with profit. In using change in net farm income as a measure of benefits from increased water supply, there are

three important additional factors that must be taken into account: (i) the opportunity costs incurred if least-cost alternative sources of farm output are possible; (ii) the equity effects of subsidizing a farmer from general taxes by not requiring him to pay for the full cost of the water supply; and (iii) the value of the services that are provided by land and water left in their undeveloped state.

The use of changes in net income as a measure of the benefits of flood control protection encounters similar problems. If people react to flood protection by increasing the economic development of the floodplain, the result may be both higher land rents, resulting in higher net income for owners of the former floodplain, and increases in the expected damage of present residents (*14*). A major overstatement of net benefits will occur if the increased net income of landowners is used as the benefit measure and the increased damages suffered by residents of the floodplain (because of induced development) is not included as a cost.

The final benefit concept suggested was the least-cost alternative technique. With this procedure, a project is judged worthwhile if its cost is less than that of any alternative means of achieving the same objective. Again caveats are in order. When no measures of actual benefits are possible, the least-cost technique may have to be applied. By itself, however, least cost is not a sufficient determinant of project acceptability. It is not sufficient to select the least-cost alternative unless it is first established that society values the output of a project by an amount equal to or greater than the cost of that project. For example, if a canal is the least-cost method of transporting a particular good, but society values the transportation of that good by an amount less than the cost of the canal, it is inefficient to build the canal.

Finally, we would note the following, more specific, shortcomings in the WRC's treatment of benefit measures. First, while the WRC does not make clear what measure is to be used for estimating benefits in transportation and navigation, it implies reliance on the legislative mandate of the Transportation Act of 1966. As is now clearly recognized, those measures have no basis in economic logic and are but thinly disguised attempts to undermine efforts to improve the measurement of the real national cost savings generated by navigation projects (*15*).

Second, the procedure recommended for estimating recreation benefits fails to account for the effect of substitute recreation areas on the benefits attributable to a proposed project. If a dam is built in a region having many lakes, but no other source of free-flowing river recreation, two adjustments should be made to the procedures proposed by the WRC. The value of a recreation day for flat-water activities should be considered negligible, or zero, if the neighboring facilities are uncongested. In addition, the value of the free-flowing river recreation that was foregone should reflect the scarcity of adequate substitutes (*16*). The WRC proposal neglects both of these matters. As noted above, to the extent that a water resource project changes a natural environment in an irreversible manner, the loss of present and potential users must be taken explicitly into account (*17*).

Third, the WRC fails to articulate two fundamental assumptions in estimating benefits: (i) the output of a project will not affect the price of goods and services that utilize the project's output as input, and (ii) the project will not affect the cost of goods that would otherwise be produced without it. If the economy is functioning smoothly and the proposed project is not inordinately large, relative to the economy, these assumptions will be correct. However, because exceptions to these two general assumptions may occur under certain circumstances, we recommend that any cost-benefit analysis based on assumptions other than these be required to defend those assumptions.

Finally, the benefits from a project may change over time. For example, the benefits that accrued to U.S. shipping from the protection against German U-boats offered by the Cross-Florida Barge Canal seem less valuable today than they did 30 years ago. Those benefits that depend on technological change should be clearly labeled as such in any analysis. Ignoring the effects of technological change in benefit estimation will typically lead to inflated estimates of benefits and a bias toward development (*15*, pp. 66–92; *17*). If an alternative policy is expected to yield benefits that will increase in value over time, this aspect of evaluation should be included as well. For example, an environmental resource left undeveloped may increase in value as income, leisure time, population, and the number of alternative sites change over time. This aspect of preservation (or development) must be included in any project evaluation, especially if irreversible decisions are involved.

Discount Rate Policy

While the WRC proposal recognizes that all public investment decisions involve foregoing the possible benefits of displaced private activity—which in recent years, it suggests, has averaged 10 percent—it recommends the use of a rate of 7 percent for evaluating water resource development projects for the next 5 years. The reason offered for this choice of discount rate is that the federal political process desires to transfer income to people in specific regions by subsidizing water resource projects. However, rather than using a rate lower than the opportunity cost of capital for all water resource projects, a more appropriate technique to grant preferential treatment to certain regions would be to establish politically accepted weights and apply them to both benefits received and costs borne by the region. A standardized low-discount rate subsidizes all regions. Unless all water resource projects are to be subsidized in this way, the weighted average of such discount rates should equal 10 percent. In any case, the implicit regional subsidy, or any other reason to subsidize public investments at the expense of superior private investments, should be made explicit by evaluating projects at both the "regional," or preferential, rate and at the 10 percent rate—and then calculating the difference.

Pricing and Cost-Sharing Policies

Economic evaluation of a project considers the costs and benefits generated by an undertaking. Cost-sharing policies determine the incidence of the costs and benefits. It has been demonstrated that evaluation and cost-sharing cannot be separated in proper economic analysis (*18*). Yet the WRC has made no attempt to integrate evaluation, cost-sharing, and pricing procedures in the "Principles and Standards." This omission will encourage the construction of inefficient water resource projects.

Appropriate pricing and cost-sharing policies can encourage both the efficient use of water resources and the proper incidence of project costs. Because the assessment of an appropriate charge

for project outputs will affect the rate at which project services are used—the level of output—price will affect the magnitude of a project's benefits and, hence, its evaluation. The absence of charges will induce excessive use and, hence, waste. On the other hand, excessive charges may result in inefficiently regulated benefits. The ideal pricing structure would equalize marginal social costs and marginal social benefits. In addition to inducing efficient levels of project output, such a pricing structure would serve as a check on excessive claims by beneficiaries and would provide planners with information about the nature of demand.

To attain efficiency, one must be concerned not only with the structure of prices for a project's output, but also with the level of cost-sharing. If local groups are biased by cost-sharing rules to select a project that is beneficial from their standpoint but not from the nation's, a loss in national economic welfare results. For example, flood protection may be provided in many different ways. Suppose the least costly technique for a particular area were a system of floodplain parks; local interests might reject such parks in favor of a more costly solution, such as a reservoir, since local governments are required to pay for the parks but not for the reservoir—and industrial development protected by a dam will yield taxes. Cost-sharing policies should induce local groups to make decisions in the interest of society as a whole.

Currently, the calculated percentage of local cost-sharing differs among techniques. There is little incentive for local interest groups to favor the "least-cost" alternative, as evaluated from the perspective of the nation as a whole. To eliminate this type of bias, the percentage of local cost-sharing should be the same for all techniques, structural or nonstructural, used to accomplish the same objective. This rule should not only be followed within a given agency, but also between agencies (*19*).

Cost-sharing can also influence overall program objectives. Local beneficiaries favor inflated program objectives, as long as they are not held accountable for the costs imposed. To eliminate this kind of cost-sharing bias, local beneficiaries should be required to share the incremental costs of a project in proportion to their share of incremental benefits (*20*).

Historically, it should be noted, water resource management has been based on the management of supply. Through public sector investments, supply has been regularly augmented to meet asserted "requirements." Demand management, through proper cost-sharing and pricing, has not been effectively used—indeed, price is almost never employed to manage use or influence investment, or both. We judge that the failure to use the tools of demand management has contributed more than any other factor to the premature development and overexpansion of water supplies. If properly conceived, demand management could avoid wasting resources on excessively large, and in some cases needless, water resource projects, while maintaining proper use of available supplies (*21*).

Although the issues of pricing and cost-sharing were ignored by the WRC, they have recently been brought to the attention of the public by the National Water Commission (*22*). Established in 1968 to review and make recommendations on the entire spectrum of water resource problems and policies, the National Water Commission has concluded that present cost-sharing policies are grossly inconsistent and lead to inefficiencies and inequities. Based upon the same principles that we have enunciated, the commission has recommended that (*22*, p. 23):

> Insofar as administratively feasible, the users of project services should bear appropriate shares of development and operating costs through systems of pricing or beneficiary charges. These project areas include municipal, industrial, and irrigation water supplies, hydroelectric power, navigation, wastewater collection and treatment, protection from floods and other hazards and various types of outdoor recreation.

The WRC's "Principles and Standards" should not be approved unless the WRC adopts pricing and cost-sharing provisions similar to those recommended by the National Water Commission, since evaluation and cost-sharing cannot be separated in proper economic analysis.

The Public's Role

The "Principles and Standards" does not consider the public's role in planning water resource projects. Moreover, we fear that the standards may so complicate evaluation procedures as to preclude public discussion, debate, and participation in the decision-making process.

Public debate and discussion is desirable both at the planning level in the region or locality, and at the national level, where the trade-offs among objectives are discussed. Fully representative public involvement in this process is the nation's best guarantee of a balanced evaluation of water resource expenditures. By prescribing analytical techniques that exceed the limits of economic methods, as well as the capabilities of agencies required to perform the computations, the WRC is likely to obscure the issues, which must ultimately be settled politically. We believe that quantification of project information should be pushed as far as possible, both in terms of methods and practice. However, to implement procedures that confound both those who must follow them and the public and its representatives is useless.

Conclusions

The essence of economic evaluation is a double-entry system, in which the social benefits generated by an activity are measured and appropriately set off against social costs. The "Principles and Standards" is inadequate in its prescription of benefit estimation techniques and virtually ignores certain significant opportunity costs—especially those related to the deleterious environmental effects attributable to a project. In addition, the explicit judgments made in the "Principles and Standards" adjust the economic parameters in the direction of inefficient choices. We refer, for example, to the unjustifiably low interest rate. Similarly, implicit judgments necessary to implement the environmental, regional development, and equity accounts are left to agency planning personnel without the aid of adequate guidelines. Finally, by not considering cost-sharing and pricing policies as an integral part of the evaluation process, the "Principles and Standards" is not likely to encourage efficient and equitable programs. The cumulative effect of all these deficiencies would bias public decisions toward excessively large land and water resource development programs.

References

1. G. White, *Strategies of American Water Management* (Univ. of Michigan Press, Ann Arbor, 1969).
2. *Fed. Reg.* **36** (No. 245), part II, p. 24144.
3. See Federal Inter-Agency River Basin Committee, subcommittee on benefits and costs, *Proposed Practices for Economic Analysis of River Basin Projects* (Government Printing Office, Washington, D.C., 1950); U.S. Congress, *Senate Document 97* (Government Printing Office, Washington, D.C., 1962).
4. O. Eckstein, *Water-Resources Development*:

The Economics of Project Evaluation (Harvard Univ. Press, Cambridge, Mass., 1959).
5. A. M. Freeman III and R. H. Haveman, *Water Resour. Res.* **6** (No. 6) 1533 (1970).
6. R. H. Haveman and J. V. Krutilla, *Unemployment, Idle Capacity and the Evaluation of Public Expenditures* (Johns Hopkins Press, Baltimore, 1968).
7. C. Howe and W. Easter, *Interbasin Transfers of Water* (Johns Hopkins Press, Baltimore, 1971).
8. C. Howe, *South. Econ. J.* **34** (No. 4), 477 (1968).
9. P. T. Cox, C. S. Grover, B. Siskin, *Water Resour. Res.* **7** (No. 1), 32 (1971).
10. J. Carson and C. Cicchetti, "An analysis of the relationships between population growth and investment in water resources projects," unpublished paper based upon *Water Resources Policy and Population Change*, prepared for National Water Commission, contract NWC 71-016, October 1971, by Rivkin/Carson, Inc.
11. M. Farvar and J. Milton, Eds., *The Careless Technology* (Natural History Press, New York, 1972).
12. See B. Weisbrod, *Quart. J. Econ.* **78** (No. 3), 471 (1964); C. Cicchetti and A. M. Freeman III, *ibid.* **85** (No. 3), 528 (1971).
13. J. Krutilla, *Amer. Econ. Rev.* **57** (No. 4), 777 (1967).
14. ———, *Water Resour. Res.* **2** (No. 2), 183 (1966).
15. R. Haveman, *The Economic Performance of Government Investments* (Johns Hopkins Press, Baltimore, 1972), pp. 38–65.
16. J. L. Knetsch, *Natur. Resour. J.* **11** (No. 4), 624 (1971).
17. See J. V. Krutilla and C. J. Cicchetti, *ibid.* **12** (No. 1), 1 (1972).
18. J. Krutilla, *ibid.* **6** (No. 1), 60 (1966).
19. R. K. Davis and S. H. Hanke, *Water Resour. Res.*, in press.
20. H. E. Marshall and V. I. Broussalian, *Report No. 10 666* (National Bureau of Standards, Washington, D.C., 1971).
21. S. H. Hanke and R. K. Davis, *J. Amer. Water Works Assoc.* **63** (No. 9), 555 (1971).
22. *Review Draft, Proposed Report of the National Water Commission* (National Water Commission, Washington, D.C., 1972).

NEWS AND COMMENT

Radiation Spill at Hanford: The Anatomy of an Accident

For most of the 7000 workers at the Atomic Energy Commission's vast Hanford Reservation—and for most of the 26,000 citizens of Richland, Washington, Hanford's residential appendage—nuclear energy long ago lost its aura of mystery. They grew up with the atom in a way most Americans did not; they learned to live near, if not exactly to love, potentially hazardous sources of radiation, and they learned to take for granted the strange jargon and paraphernalia of the business—"radwaste," the film badges, the head-to-toe coveralls, the scintillation counters. If nuclear energy meant a mushroom cloud to most Americans, it meant a way of life to those at Hanford.

Nestled in a crook of the Columbia River in a dry, almost empty corner of south-central Washington, the 570-square-mile reservation was the site of one of the three "atomic cities" that the Army built for the Manhattan project. During the war and for 25 years thereafter, great complexes of production reactors and chemical plants (there are nine reactors, all but one of which has been mothballed) turned out tens of thousands of kilograms of plutonium for the nation's swollen stockpiles of nuclear weapons. In the process, the chemical plants also turned out more than 70 million gallons of intensely radioactive liquid waste. The AEC has been slowly evaporating the waste down into solid cakes of salt and storing the cakes in steel tanks; 42 million gallons of the waste are still in liquid form, however. Either way, it remains an exotic legacy of the postwar arms buildup that will have to be guarded for centuries until radioactive decay renders it harmless.

The waste is also an aspect of nuclear energy that Hanfordians have learned to live with quite well. Perhaps because of this necessary accommodation with the atom, and perhaps because spills of radioactive waste are not all that unusual at Hanford, officials of the Atlantic Richfield Hanford Company—the AEC contractor in day-to-day charge of all this nuclear garbage—evinced no signs of urgency in June as hints appeared of yet another spill.

In fact, they kept the bad news to themselves for an entire working day. Having confirmed at a 9 a.m. meeting on Friday 8 June that some of the waste was missing, ARHCO officials waited until 4:25 that afternoon before telephoning the AEC's Richland office and relaying the news: One of the oldest and largest of 151 underground tanks of "high-level" waste was leaking.

No one knew how long tank 106-T had been leaking, or how much of its caustic, boiling contents had seeped into the sandy soil near the center of the reservation. As a matter of fact, no one was certain how much liquid had been in the tank in the first place. Nevertheless, the AEC was advised that emergency pumping operations would begin late that night to salvage what remained in the 533,000-gallon tank.

It was only around noon on Saturday 9 June that federal authorities and ARHCO technicians began to grasp the magnitude of the problem. Picking through what recent records they could find of the leaking tank's contents (a month later, some records were still missing), technicians calculated that the seepage had begun "on or about" 20 April. For 51 days thereafter, roughly 2500 gallons of liquid waste had dribbled out of the steel-and-concrete tank each day; the total loss is estimated at 115,000 gallons, containing 40,000 curies of cesium-137; 14,000 curies of strontium-90, 4 curies of plutonium, and smaller amounts of assorted fission by-products.

The AEC has methodically and deliberately disposed of far larger amounts of radioactivity in Hanford's soil over the past 25 years, and quite safely, it insists. Other high-level waste tanks have also leaked. Between August 1958, and this June, an estimated 422,000 gallons containing more than half a million curies seeped out of 15 other tanks, all of which have since been "retired." But the leak in 106-T was something different. It was the largest single accidental release of radioactive waste in the commission's history, and easily its most embarrassing incident since Project Baneberry, a weapons test that went awry in Nevada in 1970, sending a puff of fallout all the way to the Canadian border.

Not surprisingly, Hanford's big leak has blossomed into one of the AEC's worst public relations disasters in years. Environmental groups have filed a flurry of lawsuits seeking to stop the flow of wastes from Hanford's two chemical reprocessing plants, and the spill has brought out a rash of frightening headlines up and down the West Coast. On the morning of 5 July, for instance, 22 days after the AEC at Richland issued a press release describing the accident, readers of the Los Angeles *Times* awoke to a six-