EFFICIENCY, EQUITY AND SUSTAINABILITY ASPECTS OF REALLOCATION

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ABSTRACT: In the broadest sense *allocation* is the act of apportioning resources or assets to specific purposes, a critical step in the initial planning and design of federal reservoirs serving multiple objectives—typically including flood control, hydropower, navigation, recreation and water supply. In the intervening decades, relative demands (expressed as society's willingness to pay) on many federal reservoirs have shifted, either among the original purposes or from the original to new purposes. Because reservoir operating rules and priorities can be modified with little or no requirement for physical alteration, re-apportionment or *reallocation* is an attractive adaptive management mechanism for converting existing reservoirs to more beneficial uses as these change over time. Reallocation properly concluded thus potentially conforms to widely-accepted notions of economic efficiency, social equity and sustainability. The authors assess policies, procedures, and practices applied to reallocation of federal multipurpose reservoirs with respect to their accommodation of these basic planning objectives.

INTRODUCTION

Over the past several decades federal water resource development agencies, particularly the U.S. Army Corps of Engineers (USACE), have increasingly come under attack from various sectors over their management of the nation's water resource infrastructure. Profound shifts in economic, environmental and cultural concerns prompting initial construction of multipurpose reservoirs continue to supplant the original uses (purposes) of many of these projects. Federal water projects have in large part become the victims of their own success, as the economic growth induced by rural electrification, waterborne commerce, flood control and water supply they provided has created new environmental problems and demands on water and storage largely unforeseen in their initial formulation.

Reallocation is an adaptive management mechanism better suited to reservoirs than to other types of public works infrastructure such as roads and bridges. This is because the uses to which reservoirs are put can change substantially over time by simply changing the manner in which they are operated, with little or no need for structural modification. The magnitude of the operational shift is normally gaged by the amount of reservoir storage reallocated or redistributed to various purposes, and costs and benefits of reallocation are apportioned based on storage serving individual (separable) and common (joint) uses. When it becomes apparent that demands on federal reservoirs have materially changed, the following questions arise:

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- Which operational changes best contribute to National Economic Development (NED), the primary objective of federal water resource development defined in *Principles and Guidelines* (P&G) (USWRC, 1983) as "...increases in the net value of the national output of goods and services ... following project implementation," implementation denoting either construction of a new project or reallocation of an existing project;

- Whether NED itself constitutes a reasonable objective of federal planning;

- Whether purposes gaining or losing as a result of reallocation should pay for or be compensated for the costs of reallocation, and what should be the basis of payment or reimbursement;

- The limits of federal agency discretionary authority for reallocation, i.e. whether storage originally included for marginalized purposes (purposes no longer producing net NED benefits in excess of their costs of inclusion) requires Congressional authorization to be converted to more beneficial uses, and

- The long-term consequences of failing to reallocate to the most beneficial uses.

Intuitively, the most efficient and fair uses of federal water projects are the most sustainable uses, because demands on water and storage not satisfied by existing infrastructure must be met by other means. Most often the higher demands must be satisfied by new infrastructure (because minor demands are more elastic and easily managed) and a new set of attendant social and environmental costs beyond those already imposed by the original construction and operation of the existing infrastructure. In this context, the authors examine various economic efficiency and fairness aspects of reallocation of existing federal reservoirs, with specific emphasis on the shifting of operational priorities from less vital to more vital uses. A hypothetical case is made in this analysis for reallocation from hydropower to municipal water supply purposes, exemplifying the growth of urban population centers throughout the nation increasingly dependent on federal reservoirs as their principal source of water supply.

FEDERAL POLICY FRAMEWORK FOR REALLOCATION

For federal reservoirs constructed decades ago, water supply—whether or not included among the original purposes—in most instances required no separable facilities or investment to satisfy, because water demands were for the most part conjunctive with other purposes such as hydropower and navigation. This has changed as economic development has created new demands for reliable water supply increasingly in competition with those other purposes. Public awareness of the need for instream flow regimes conducive to ecological diversity is also growing, creating conflicting demands for drought management policies that simultaneously seek to conserve water in storage for drought protection while releasing more water from storage to augment instream flows. Finally, a burgeoning recreation industry has grown around many of the largest federal reservoirs, adding to the direct or incidental contributions to NED by these projects. Reallocation is warranted when the potential NED benefits of water supply and recreation exceed those of hydropower and navigation, particularly when these greater benefits can be realized strictly through operational change, with minor or no physical project alterations. While this situation has undoubtedly arisen

at many federal reservoirs around the nation, and has been conclusively shown to exist in some instances (McMahon, 2001; McMahon et. al., 2001), to date there have been no successful reallocations encompassing *all* current and new purposes at any existing federal reservoir in the United States.

In addition to growing demand for municipal water supply previously described, a combination of social pressures is emerging with the potential to significantly shift the operational priorities of federal dams in the near future between hydropower and water supply. Insurmountable economic, environmental and political obstacles may limit the effectiveness of conservation measures or prevent importation of water, leaving federal reservoirs as the only remaining sources of additional water supply. The march toward deregulation and restructuring of the electric power industry has resulted in a proliferation of non-utility generators and energy traders, the objective of which is consumer savings—reducing the cost of nonfederal alternatives and consequently NED benefits accruing to federal hydropower. With fewer water supply options available and more electric power options available, demand for water supply outstrips demand for hydroelectric power, creating intense pressure on reservoir managers to shift operational priorities from hydropower to water supply and drought protection. And because water scarcity may not be apparent until droughts occur, a timely response to a perceived need for reallocation, particularly when Congressional action is involved, is unlikely. One potential obstacle and cause of superfluous referrals to Congress may be the reliance on *storage* and associated costs in federal policy and agency practice as the measure of the scope of needed operational change.

Compounding the economic pressure previously described, federal water agencies may also be perceived to be out of step with the new world of environmentalism and sustainable economic development. Alteration of instream flows is the most common environmentalist complaint against large dams, rejoined by economists freely chastising P&G as a document committed to outdated economic questions (Zilberman et al., 1994a; 1994b). These are serious charges to federal agencies responsible for a massive infrastructure that engages almost every region and nearly every sector of the American economy. Nonetheless the scope of federal concerns—flood control, municipal and industrial water supply, water quality, agricultural irrigation, navigation, water and environmental quality, and recreation—has always been comprehensive and long-term, characteristic of integrated planning for sustainable water resource development. Consequently the authors argue that relatively modest adjustments and enlightened application of current federal policy are the most effective responses to such criticisms.

Storage reallocation in federal reservoirs in response to growing municipal demand calls into question the incremental approaches to reallocation taken to date. These incremental adjustments, typically reallocating small amounts of hydropower storage to water supply, led to the Water Supply Act of 1958 (WSA58 - P.L.85-500, 1958) and a series of procedural 'rules of thumb' that, while not entirely consistent with the broader P&G framework, preserve most of the elements of the project authorizing legislation and are thus, for practical purposes, 'good enough.' However, incremental reallocations do not invoke the full federal process and an equitable and efficient cost allocation procedure known as the *Separable Costs Remaining Benefits* (SCRB) method (Federal Interagency River Basin Committee, 1950; 1958), and the resulting small inefficiencies and inequities become intolerable when more comprehensive reallocation is required.

Without substantial revision, the simpler procedures implied by WSA58 can eclipse water management practices and prevent adjustment to the highest and best uses when confronting the need for major operational change. The authors contend the answer to this problem lies not in rewriting the rules but in their full application, along with SCRB, to major reallocations, notwithstanding institutional inexperience along these lines. Another reason for not abandoning P&G is that they continue to provide a very useful framework for public works planning nationwide, and have been shown to be largely consistent with sustainable water resource management objectives (USACE-IWR, 1999). By employing the full planning process in lieu of the rules of thumb, therefore, the reallocation process can be substantially improved and the most beneficial and sustainable outcomes assured, fully within the framework of existing federal policy.

Among policies and procedures promulgated to guide incremental reallocations are charges to new water supply users based on the highest of the following four costs:

- Revenues foregone from sale of power, equivalent to original costs of storage
- Benefits foregone by power due to water supply
- Replacement costs of power, equivalent to benefits foregone
- Updated costs of storage reallocated.

The highest of the four costs is normally determined to be power benefits foregone due to water withdrawals or updated replacement costs of storage reallocated from power to water supply, raising the following questions:

- Whether economic efficiency is achieved and the NED objective fulfilled when prior existing purposes are compensated for storage transferred to new, more beneficial uses, or alternatively whether such compensation constitutes a subsidy of one type of NED purpose (power) by another (water supply), in violation of SCRB;
- Whether fairness is achieved in the face of price discrimination, resulting from water supply being assessed at a higher marginal rate (greater than or equal to updated costs of storage) than the rates at which energy and capacity are sold (original costs of storage), and
- Whether storage is in fact the appropriate currency of reallocation, i.e. an accurate measure of public costs of serving one purpose versus another, particularly when purposes are partially conjunctive.

As the need for major reallocations around the nation increases, problems arising out of application of policies designed for incremental reallocations will likely be magnified, with egregiously inequitable or unsustainable outcomes giving rise to political conflicts and litigation. By applying more comprehensive planning and cost allocation procedures to major reallocations in the same manner as in formulating new projects, however, the overall fairness and efficiency criteria established in P&G and SCRB can be achieved

and some of these problems avoided or reduced to manageable proportions. In the process, the authors note a surprising correspondence between the principles that first established the NED objective, the efficiency and fairness criteria of SCRB, and basic principles of microeconomics. It is these fundamental economic principles—originally guiding federal water resource development—that can serve equally well to guide sustainable water resource management in the future, using reallocation as a tool for adapting older projects to newer and more beneficial uses.

ECONOMICS OF REALLOCATION

The cost-sharing mechanism at the core of federal water resource development policy, explicitly articulated in WSA58, is the Separable Costs Remaining Benefits (SCRB) method previously referenced. The stated objective of SCRB—that all purposes share equitably in the benefits of multipurpose development—is based on the premise that most purposes served by large reservoirs are to some degree conjunctive, and that economies and scope of scale are achieved by large dams serving multiple purposes in comparison to smaller dams serving fewer or single purposes. This notion can reasonably be challenged and likewise defended on economic and sustainability grounds (Takeuchi, 1997a; 1997b), to the degree that the cumulative economic and environmental impacts of multipurpose or single-purpose projects can be shown to be better or worse in the long term. While it is true that most purposes are conjunctive to some degree, it is difficult to find much commonality in operating rules meeting, for example reservoir water supply and recreation objectives prioritizing full pools for drought protection, and hydropower, which places a higher priority on power releases drawing down storage during periods of relatively high electric demand. Likewise flood control, seeking to make as much storage space available as possible in advance of floods, competes with most conservation objectives benefitting from storage of additional water in unused flood space as a hedge against droughts.

When all purposes share equitably in the benefits of multipurpose development, proper application of SCRB ensures storage is allocated in a manner preventing cross-subsidy among purposes, and that the costs of participating in the multipurpose projects do not exceed the go-it-alone costs of developing separate projects serving each purpose. The procedure consists of the following three steps:

(1) Each included purpose is first allocated its separable costs, i.e. the costs to add that purpose;

(2) NED benefits limited to least-cost alternative are assigned to each purpose, and

(3) Joint costs, i.e. cost of facilities serving all purposes, are apportioned among all purposes based on remaining benefits (NED benefits minus separable costs).

An interesting problem arises in applying step (2) above to reallocation in cases where no economically feasible or socially/environmentally-acceptable nonfederal alternatives exist, an increasingly common circumstance surrounding large metropolitan areas heavily dependent on federal reservoirs for municipal water supply. This same situation—the scarcity or non-availability of private alternatives—may have applied in past decades to hydropower, reflecting the need for rural electrification in the era in which most of the large federal multipurpose reservoirs were planned and constructed. This condition does not

preclude the application of SCRB in such cases, so long as lost consumer surplus of foregone demand and other water shortage costs are considered in the formulation of the "...least-cost alternative." Moreover, this approach would also allow SCRB to be applied to future sustainable water resource development planning under expanded definitions of NED with more complete measures of social welfare including environmental and non-use values.

Under SCRB, economic efficiency is achieved when the marginal cost of adding new purposes to just equals the marginal gain in NED benefits. Project scope expands, and scale grows to accommodate each added purpose. Under this rule, separable demand for additional scale must exceed cost of supply, and by extension any purpose that later reduces the capacity of the project to serve the existing purposes must demonstrate a greater ability to defray the costs originally assessed to those purposes. In the case of reallocation, whether to serve new purposes or to re-prioritize existing purposes, little or no marginal costs are incurred, so that efficiency is achieved when NED benefits are maximized. Assuming intra- and intergenerational equity are in some measure promoted in the purposes served, the economic efficiency framework provided by SCRB therefore guides reallocation to ensure the most economically beneficial and—by the intuitive definition previously described—most sustainable uses of federal reservoirs.

The link between SCRB and classical notions of economic efficiency can be represented in a series of conceptual supply and demand curves. Hypothetical demand for two project purposes—water supply and hydropower—represented by D_{WS} and D_{HP} respectively, are shown in Figure 1. Up to some level ($Scale^{C/S}$), composite demand D^C for all uses is fully conjunctive—neither use competes with the other. Both D_{WS} and D_{HP} are components of D^C, and are *non-rival* in consumption with each other. That is, the delivery of one service does not interfere with the provision of the other, in much the way an uncongested highway allows drivers free passage without interfering with other drivers. Up to $Scale^{C/S}$, total demand for conjunctive services is the sum of demand for water supply and for hydropower, or $D^C = D_{WS} + D_{HP}$ shown in Figure 1. Beyond $Scale^{C/S}$, water supply demand is wholly satisfied, and hydropower must fully justify any added project scale (additional costs of facilities) on its own. This illustrates a tight correspondence between conjunctive use as described in *Principles and Guidelines* with the various renditions of public goods in welfare economics.

When cost of supply is considered, the optimal project size in conformity with SCRB obeys the engineering efficiency property of lowest average cost of service or expected future services. Figure 2 illustrates this standard property of an average cost curve. Given a chosen project scale (design), the potential exists at very low utilization levels (i.e., highly conjunctive uses of storage) to provide more services at lower average cost, constituting an efficiency improvement analogous to increased resource utilization by seating more people in a stadium or increasing traffic volume on a highway. This potential exists along the downward side of the curve, in the range of increasing returns to scale. Eventually, however, the ability to extract additional services from the same fixed asset crowds the facility. This congestion makes it more expensive, on average, to expand levels of service provided by the project; so the average cost curve *AC* bottoms out and begins to rise. In the case of a multipurpose federal reservoir, 'congestion' may represent either increasing levels of service for a single use or partially disjunctive additional uses of water and storage.

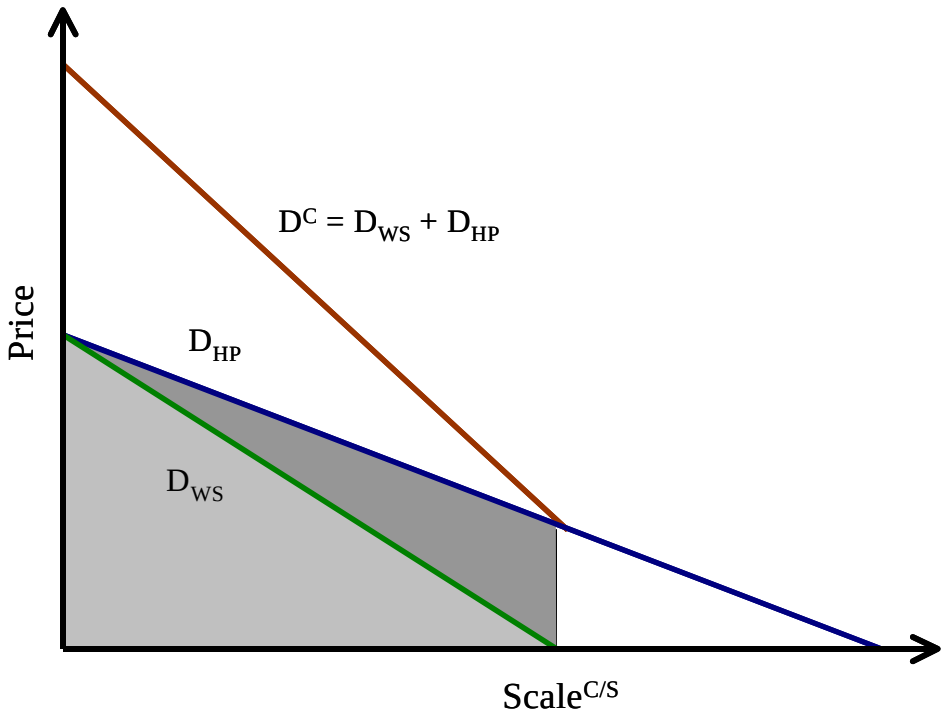

Figure 1: Efficient scale, fully conjunctive demands

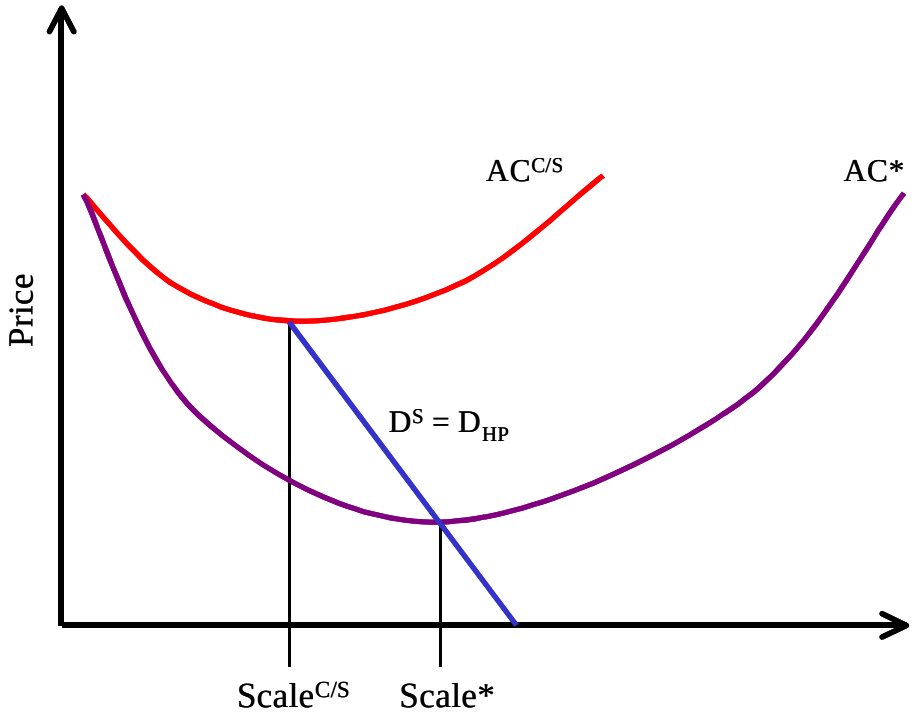

Figure 2: Original average cost curves and efficient scale, single-purpose project

An economically efficient initial allocation or reallocation locates the demand curve (or expected future demands) where the average cost curve intersects demand at its lowest point for the project size.[1] In the SCRB formulation, if it were efficient only to meet conjunctive uses, the optimal scale might occur at $Scale^{C/S}$ (or less) at the bottom of the corresponding $AC^{C/S}$ schedule for the highest-demand use. In this example optimality is achieved at this scale if no other technically feasible *AC* curve lies below the separable demand curve for hydropower $D^S = D_{HP}$. In this case the separable benefits equivalent to demand for hydropower do not justify expanding the project, so that only $Scale^{C/S}$ is efficient. Yet in the more general case, an average cost curve likely exists that will fall below D^S, such as *AC** in Figure 2. In this case, circumstances warrant a larger project than needed to satisfy a single use or fully-conjunctive multiple uses alone. Optimal project scale for multiple disjunctive uses lies at *Scale**, where the composite average cost curve bottoms out at a point intersecting D^S, representing in this case aggregate demand for all conjunctive as well as disjunctive uses.

The goals of efficiency, equity and sustainability are embodied in the SCRB criterion of no purpose subsidizing another, and grounded in microeconomic theory as well. For the economist, the delivery of a good at the lowest point on the average cost curve has a special meaning. By definition, the bottom of the average cost curve intersects the marginal cost (or supply) curve for the dam, so storage initially allocated or later reallocated in accordance with SCRB assures supply equals demand, the basic condition for economic efficiency. The equivalency of SCRB and economic efficiency is highlighted in Figure 3. Economic efficiency and the criterion of no cross-subsidization between purposes reconcile easily to economic efficiency maximizing National Economic Development (NED) benefits. If NED benefits are measured correctly, SCRB leads to an efficient project scale, in either the initial allocation of storage in a new project or reallocation of storage in an existing project. The mechanism for achieving efficiency provided by SCRB is not accidental, and because WSA58 derives from the "Green Book" (Federal Interagency River Basin Committee, 1950; 1958; *Op. Cit.*), the original NED-maximizing and equitable-sharing intent of the legislation is clear, and should take precedence in reallocation over the previously-described highest-of-four-costs criterion.

INCREMENTAL REALLOCATION

While referencing the efficiency and equity provisions of SCRB, these are normally not preserved in applying WSA58 nor in determining compensation for incremental reallocations, primarily from hydropower to water supply. Subsequent analysis shows the deviations in costs allocated to water supply resulting from application of the highest-of-four-costs criterion from those resulting from complete application of SCRB using updated NED benefits may be small, but only because the scale of incremental reallocations contemplated

[1]The envelope theorem assures that an array of *AC*s enveloped within a large, long-run average cost curve touches the enveloping *AC* curve at just one point. In competitive markets with many competitors, each firm will realize the bottom of the long-run AC curve eventually. If there are few suppliers for a congestible good such as water supply provided by a federal dam, then the choice of scale is not necessarily the largest feasible project, a circumstance which in private markets drives oligopoly and monopoly formation. For public projects, the optimal size is a choice variable which, correctly chosen, scales up a project to where the average cost curve bottoms out at the intersection of the composite demand curve for all project outputs.

under WSA58 is also small—less than 15% or 50,000 acre-feet of storage, whichever is less, and with the additional stipulation of no significant impact on power benefits.

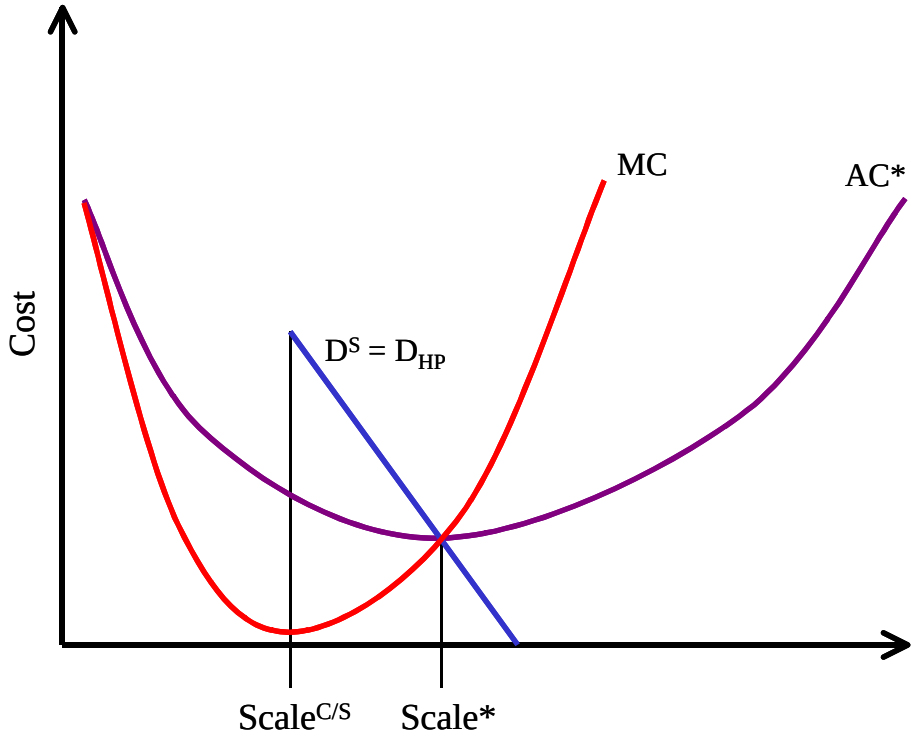

Figure 3: Original marginal and average cost curves and efficient scale, single-purpose project

Inefficiencies arise in applying the highest-cost recovery criterion because the water supply purpose is not charged the lowest average cost for multiple uses (*AC** in Figure 2), but rather the highest average cost $AC^{C/S}$ of that increment of storage formally allocated to power. The implications of this outcome are as follows:

- Inequitable price discrimination occurs, in that a higher marginal price of allocated storage is assessed against the last added user (water supply) in comparison to the first (hydropower), and

- Inefficient overpricing of storage may result in charges for water exceeding go-it-alone costs, violating the basic SCRB premise of economies of scope and scale.

Normally in incremental reallocations of the type contemplated by WSA58, these diseconomies do not rise to a level that non-participation in the federal project becomes a feasible option, nor would it be cost-effective in such cases to engage in full-scale planning studies. Nonetheless, application of WSA58 in disregard of the overarching principles of SCRB to reallocations involving larger shares of project storage—increasingly seen as preferable to building new reservoirs to meet growing water demands—potentially leads to highly inefficient, inequitable, and unsustainable outcomes.

It is becoming apparent that, in the decades since many of the federal multipurpose reservoirs were constructed, relative demands on water and storage have shifted to a substantial degree. Whether this shift has occurred among original purposes or from original to new purposes, application of SCRB serves equally well to guide reallocation of project costs if necessary, and the establishment of new operational priorities. The equity question arising out of reallocation—whether existing purposes are entitled to any compensation by new or encroaching purposes—must ultimately be answered by the relevance of the NED objective itself to sustainable water resource development.

REFORMULATION: TOTAL REALLOCATION

Assuming a hypothetical federal project was efficiently designed from the start and a small reallocation occurs, costs based on the updated cost of storage criterion should be very close to efficiency. As shown in Figure 3, the original allocation of storage is determined by the nexus of the average cost, marginal cost, and demand curves, so small excursions along any path in future minor reallocations will not deviate too far from the optimum. Problems arise, however, when more vital uses of water and storage prompt massive reallocation affecting all project purposes, resulting in substantial differences between economic demand and supply margins, and engineering cost averages. These problems cannot be avoided by inaction, however, because failure to reallocate leads to the far more serious and unsustainable outcome of an existing project becoming economically obsolete—a candidate for deauthorization or decommissioning. Figure 4 illustrates a conceptual shift in demand such that the relative primacy of water supply D_{WS} and power D_{HP} purposes are reversed (in comparison to Figure 1), prompting a total reallocation from hydropower to water supply. In this example, the impact of the reallocation on hydropower can range from full loss of NED benefits ($D^S = D_{HP}$ limited by replacement costs goes to zero) assuming water supply is fully disjunctive with hydropower, to partial NED benefits foregone due to reallocation ($D'^S > 0$) assuming partial conjunctivity.

The obstacles to total reallocation are formidable; none have yet occurred in the United States. One obstacle may be the storage metric itself and a perceived need for compensation paradoxically arising out of misconceptions surrounding SCRB. While storage is the fixed asset ostensibly allocated, bought and sold by federal agencies under either SCRB or WSA58, the real demand is for a service—the operation of a federal project or system of projects to ensure a particular set of demands is met and priorities observed. Furthermore, the federal objective in reallocation remains the same as in original project formulation—contribution to NED—and any compensation necessarily shifts NED benefits among purposes and thus constitutes a cross-subsidy, in violation of SCRB. While storage may provide a meaningful basis for original allocation or even reallocation among fully disjunctive purposes, measurement of storage required by multiple partially conjunctive uses is highly problematical. With multiple competing and complementary uses engendering complex and conditional operating rules, the problem of accounting for the storage and separable costs appropriately allocated to each can become intractable. The common practice of allocating storage to water supply based solely on the fraction of yield represented by water withdrawals is ill-suited to realloctions involving (1) nonconsumptive uses of water, such as recreation, power, navigation, water quality, or habitat protection; (2) water utilities withdrawing water from downstream rivers rather than directly from storage (and returning water at multiple locations above and below reservoirs); and (3) interdependent uses with each affecting the timing or quantity of water available to others.

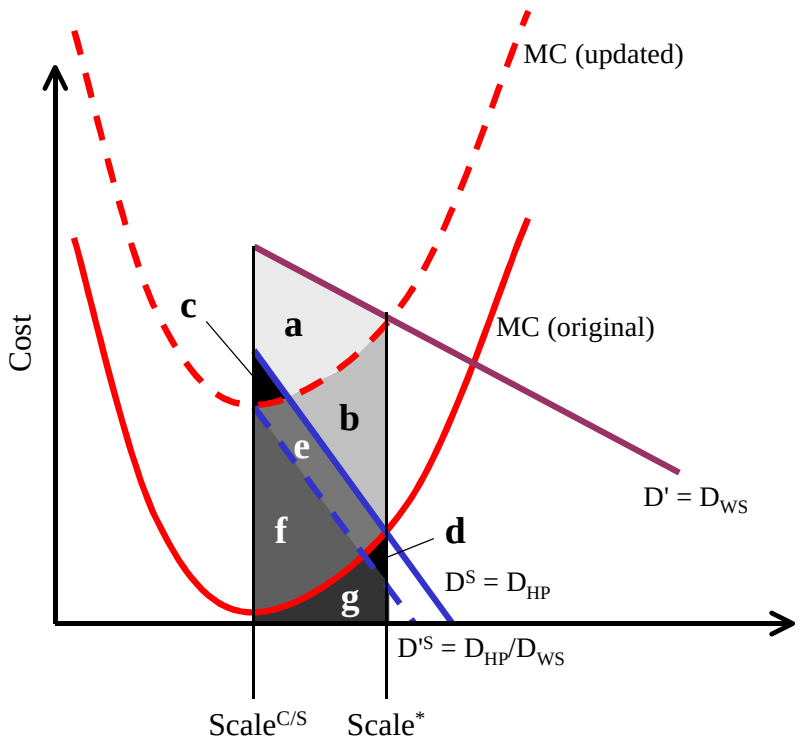

Figure 4: Original and updated cost and demand curves, total reallocation

STORAGE AS THE MEASURE OF REALLOCATION

Further examination of Figure 4 discloses constraints imposed by use of storage as a measure of reallocation scope and scale, and by extension the problems associated with compensation for reallocation. The most basic constraint is the fact that project scale is fixed by the original design, and as shown in Figure 4, the higher demand curve *D'* (water supply in this case) no longer intersects the original marginal cost curve at the original project scale *Scale**. The opportunity costs of inaction (not reallocating) are the NED water supply benefits foregone, represented by areas ***a*** + ***b*** in Figure 4. The costs of not reallocating are magnified when power benefits are devalued due to factors exogenous to water supply, so that the new power demand curve D'^{S} falls below the marginal storage cost curve at the current allocation (*Scale**), and power demand shrinks by areas ***c*** + ***d*** + ***e***. Application of SCRB in this case with updated benefits and costs would reveal that the continued commitment of project storage and facilities to power is no longer justified (because power demand falls well below updated costs of storage at *Scale**), and that power has become a *marginalized* purpose. This outcome is egregiously unsustainable outcome, rendering the federal project in effect an enormously expensive memorial to obsolescence in terms of the foregone opportunity costs of more beneficial uses. Without the federal project, the more vital demands for water must be satisfied by alternative means likely to incur substantially higher energy, material, and environmental costs in comparison to simply changing the operating rules of an existing federal reservoir.

Beyond the economic and sustainability problems encountered using storage as a surrogate for reallocation scope, the engineering problem of distributing storage—in single reservoirs or reservoir systems—among multiple competing and complementary uses of water is formidable. Only rule-based storage accounting systems that track storage depletion in real time against sequential simulation results using pre-specified comprehensive operating rules are suitable for this purpose. While the basic components of storage accounting systems are well documented and widely used for operational planning and storage yield analysis throughout the United States (USACE, 1997), they have yet to be applied for simultaneous determination of separable storage requirements for multiple purposes. The measure most commonly used of storage required to be reallocated to water supply storage is that portion of conservation storage equivalent to the ratio of water withdrawn directly from a reservoir to its yield, following the rationale that direct reservoir withdrawals reduce water available for power generation on a 1:1 basis. By focusing exclusively on a single type of explicit demand in this very simplistic way (the method does not extend to water withdrawn downstream of reservoirs, for example, which may be wholly or partially conjunctive with power releases), this approach fails to assure all project operating objectives can be met through the critical period, i.e. the period of the most adverse hydrologic and demand circumstances, delineated by reservoir emptying and refilling.

COSTS OF REALLOCATION

Assuming the NED objective of federal water resource development previously described applies to reallocated or reformulated existing projects as well as new projects, the basis of costs allocated to the added purpose(s) is crucial to the 'success' of reallocation. Application of SCRB to reformulation of existing projects assures some measure of success, but SCRB has never been applied in the U.S. to an incremental reallocation. In the case of reallocation of conservation storage from power to water supply, NED benefits are maximized by assessing water supply only the power revenues foregone due to water supply and/or other factors—area ***d*** in Figure 4. The NED benefits of reallocation—or alternatively the opportunity costs of not reallocating—are equivalent at a minimum to areas ***a + b*** in Figure 4, and areas ***c + d + e*** in addition in cases where power has already been devalued by exogenous factors prior to reallocation. Assessment for revenues foregone also assures the debt repayment schedule is maintained and is revenue-neutral to the federal treasury, because total revenues from power and water supply exactly equal original power revenues. Other bases for compensation are inefficient and inequitable for the following reasons:

- Compensation based on power benefits foregone or the equivalent power replacement costs (areas ***c + d + e*** in Figure 4) inappropriately shifts NED benefits from the added purpose (water supply) to the original purpose (hydropower), a cross-subsidization violating the fundamental economic efficiency and equity tenets of SCRB;

- Compensation based on replacement costs of power is equivalent to power benefits foregone, and

- Assessing water supply the higher *updated* costs of storage as opposed to the *original* (sunk) costs of storage substantially and unnecessarily diminishes the NED benefits provided by the project, by an amount equivalent to areas ***b + e + f*** in Figure 4, potentially exceeding the go-it-alone costs for

a separate single-purpose water supply project, in violation of the stated SCRB objective that all purposes share equitably in the benefits of multipurpose development. This practice is also inequitable, in that a higher standard (updated costs of storage) is applied the new purpose than to the original purpose (original costs of storage).

Implicit in the foregoing discussion of repayment options is the compensation principle of federal planning, supplanting rights or interests perceived by individual purposes in the management of federal reservoirs. While Pareto economic efficiency is achieved when none can be made better of without making others worse off, the compensation principle holds that a federal project (*project* including reallocation) is justified when with-project gains are sufficiently large that the nation as a whole is better off, so that everyone could in theory be made better off by some redistribution of goods or income following project implementation (Greeley-Polhemus Group, 1991). Absent severe local repercussions, there is no compelling federal interest in such a redistribution actually occurring, because with-project gains are measured by NED (public) benefits. In the case of reallocation from power to water supply, for example, neither NED nor fairness objectives are advanced by water supply compensating power, because the users of both services are the same—the public.

While the aforementioned diseconomies of incremental reallocation may not seriously deter the most beneficial uses of federal reservoirs where demands have not significantly change since original construction, the risks of ignoring the overall planning principles articulated in the NED objective and SCRB become unacceptable as competition for water resources and pressure for reformulation of existing projects intensify. The nature of these risks is summarized as follows:

- Price discrimination (overcharging one use in comparison to another) conveys inaccurate information on the relative scarcity and economic and/or intrinsic value of resources, with unintended consequences likely to be detrimental in the long term to sustainable water resource management.

- Cross-subsidies among purposes occurring as a result of over- or under-pricing of public facilities serving them breed conflict and attempts to redress by legislation or litigation, processes not necessarily compatible with federal planning objectives and procedures and therefore unlikely to produce efficient, equitable or sustainable outcomes.

- Prospects for efficient and sustainable solutions to growing demands for water diminish when options for alternative uses of existing resources (i.e. reallocation of federal reservoirs) are deferred or foreclosed. Discouraging or preventing reallocation by erecting price barriers or imposing unequal performance standards on new and original purposes fuels pressure by states and municipalities to develop new water projects without the federal strings attached. Construction of new projects considerably increases the economic and environmental costs in comparison to re-operation of existing projects, and is therefore a less sustainable means of supplying vital uses of water.

When current demands on water and storage in federal reservoirs are greatly out of kilter from those contemplated in the original design, de-facto accommodations sometimes occur in the form of amended water control procedures. While an explicit responsibility of federal water resource development agencies, policies

and procedures governing water control planning (USACE, 1987; 1996) leave prioritization among project purposes largely to intuition—neither updating of NED benefits nor re-application of SCRB is mandated. Moreover, statutory agency authorities and funding are generally inadequate for full-scale studies in support of water control management or reallocation planning. While environmental review is arguably addressed by statute (P.L. 91-190, 1970) and policy (USACE, 1988), the following two critical elements are typically missing from water control management and incremental reallocation:

- Determination of NED benefits of alternative operational plans, and

- Determination of long-term opportunity costs of alternative operational plans.

Operator knowledge and intuition are indispensable, but the scope of operational planning and decisionmaking without this information is unlikely to include sustainable water resource management.

PLANNING FOR SUSTAINABILITY

Ultimately the case for reallocation as a sustainable development strategy hinges on the measure to which the NED objective itself and the planning framework provided by the P&G conform with basic notions of sustainability. A definition of sustainability applicable to water resource management—and to reallocation as an adaptive management strategy—recently formulated by an American Society of Civil Engineers (ASCE, 1998) Task Committee serves as a suitable starting point:

> "Sustainable water resource systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity."

This definition captures the essential economic, environmental and intergenerational equity aspects of sustainability. It suggests, in the absence of a unifying scientific theory, that sustainability can be described by integrating well-established welfare economics concepts bearing some resemblance to the NED objective of federal planning (Loucks, 1997; McMahon, 2001 *Op. Cit.*). These are briefly described as follows:

- Efficiency - maximizing current and discounted future welfare:

$$Max \sum_y W(k,y)/(1+r)^y$$

- Survivability - assuring future welfare always exceeds minimum subsistence level::

$$W(k,y) \geq W_{min}$$

- Sustainability - maximizing cumulative improvement (or minimizing cumulative decline) in welfare over time:

$$Max \Sigma_y \{W(k,y+1) - W(k,y)\}$$
s.t.
$$W(k,y) \geq W_{min} \text{ (survivability)}$$

where $W(k,y)$ is welfare resulting from decision k in period y, and r is the social discount rate or cost of funds.

Examination of the above relationships reveals the following:

- Economic efficiency is neither necessary nor sufficient for sustainability, due to the present-weighted bias introduced by discounting future welfare.

- Survivability is a necessary but not sufficient condition for sustainability.

- The proposed sustainability measure is unbiased.[2]

The previously-cited (IWR, 1999, *Op. Cit.*) framework existing within the P&G coupled with the NED welfare-maximizing objective of federal planning provide the basic underpinnings of sustainable water resource development, provided heretofore non-monetized or externalized environmental and social effects can be more fully integrated into NED. Recent advances in environmental and non-use valuation and decision support techniques now make this possible. The problem of accommodating sustainable development principles in federal water resource development has been characterized (Loucks, 2000) as "...not so much a different planning paradigm [as] an extended set of evaluation factors—different criteria and weights on objectives to reflect a perceived shift in public preferences." The existing P&G/NED framework appears highly adaptable to this problem, and reallocation contributing to NED in an expansive sense thus constitutes sustainable water resource management.

CONCLUSIONS

A substantial backlog has prompted recent calls for economic review of Congressionally-approved but unfunded new federal water projects, and more ominously for wholesale revision of federal water resource development policies and procedures, including the P&G. The foregoing summary of federal water

[2]By not discounting future welfare, the proposed sustainability metric is *unbiased* with respect to intergenerational equity. Positive discounting reflects aversion to risk, weighting present over future welfare in decisionmaking and assuming appreciation of resources over time. Negative discounting, on the other hand, accommodates entropic degradation and depreciation of resources over time, reducing the efficiency of economy-environment interactions and rendering human activities overall thermodynamically more costly to future generations. (Georgescu-Roegen, 1971; Rifkin, 1989).

policy and the opportunities it provides for reformulating both new and existing projects indicates potential risks as well as opportunities occasioned by policy review, some of which are described as follows:

- Project implementation and funding decisions may be improved more by economic review applying new techniques for environmental valuation and integrating an expanded set of environmental, social and temporal concerns in NED effects accounting, than by simply updating the cost and benefit categories traditionally considered.

- Because the P&G and the NED federal planning objective are largely consistent with widely- held notions of economic efficiency and equity, and provide a useful starting point for sustainable water resource development, wholesale revisions of this planning framework are precipitous and potentially pose unacceptable risks by (1) dismantling a cohesive, principled framework for integrated resource management in the long term, potentially foreclosing opportunities for future reallocation, and (2) replacing it with fragmented jurisdictions and processes fueling conflict and litigation, leading to unsustainable outcomes involving significant externalities (shifting of environmental and social costs) or irreversible environmental harm.

Taken together, the P&G, the compensation principle, and SCRB are well-grounded in theory and application in public works planning throughout the nation, and appear highly adaptable to sustainable water resource planning and management. However, the best opportunities to adapt are afforded by existing multipurpose reservoirs needing reallocation, on the grounds that the need is more immediate and costs of implementation substantially less than for future projects. Because the planning process encompassing reformulation has never been fully applied to reallocation, and the potential for incorporating environmental and non-use values in NED has only recently existed, shortcomings historically observed in planning more likely reflect failures of implementation and process than failures of policy itself. As opposed to revamping policy, attempts to improve the planning and implementation processes—whether directed at reallocation of existing projects or formulation of new projects—should be made. The following research and development needs present themselves:

- A nationwide reallocation needs survey, identifying existing federal reservoirs on which demands have changed to the point reformulation/reallocation among original purposes or adding new purposes is warranted; primary candidates are projects meeting water demands for which no viable non-federal alternatives exist, e.g. municipal water principally supplied by federal reservoirs.

- Identification of federal and non-federal cost-sharing mechanisms for full NED effects accounting and application of SCRB to reallocation.

- Increased use of environmental and non-use valuation techniques in NED effects accounting.

- Estimation of potential cost savings achieved by applying full federal planning guidelines to operations, maintenance and rehabilitation funding decisions, reducing unnecessary or counterproductive

expenditures on facility improvements dedicated to marginalized purposes (i.e. unusable generating capacity additions/rehabilitations).

- Review and clarification of agency discretionary authority for reallocation for flexibility in implementing reallocation without Congressional referral.

- Development of periodic review or other adaptive management mechanisms to ensure federal multipurpose reservoirs are put to their most beneficial uses as defined by the needs of society in the present and in the future.

In summary, the authors echo assertions that the underlying principles guiding federal planning are sound and provide a useful starting point for sustainable water resource planning and management in the long term. The transition to a sustainable development planning paradigm is better achieved by adjusting the processes by which projects are reviewed and reallocation or reformulation is implemented, as opposed to wholesale revision of the principles themselves. Only when the tools provided and boundaries set by the current guidelines are fully explored can attempts to streamline public policy be successful.

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NOTATION

The following symbols are used in this paper:

AC	=	average cost
D^C	=	composite demand or willingness to pay for multiple services
D^S	=	demand for service
D_{HP}	=	demand for hydropower
D_{WS}	=	demand for municipal water supply
D_{HP}/D_{WS}	=	demand for hydropower after meeting demand for water supply
MC	=	marginal cost
r	=	social discount rate or cost of funds
$Scale^*$	=	efficient scale or storage allocation, partially and non-conjunctive demands
$Scale^{C/S}$	=	efficient scale or storage allocation, fully conjunctive demands

$W(k,y)$	=	welfare resulting from decision k in period y
W_{min}	=	minimum welfare for survival