Sustaining Flows of Crucial Watershed Resources

J.E. de Steiguer[1]

Abstract.—Watersheds are the source of a number of resources which are of benefit to society. These resources include water, timber, grazing, recreation, wildlife and others, often described as multiple-use resources. In addition, however, watersheds also produce a number of less tangible resources and uses, which are also socially important. These include amenity, option values, bequest, existence and stewardship values. Watershed resources are usually subject to joint production, that is, the production of one resource is linked to the production of the others. The socially optimal amount of watershed goods and services should not be simply the sustained even flow of commodities, but rather as the flow which maximizes the present net benefits to society. The best way of achieving this maximum is through integrated resources planning on the watershed.

Watershed Resources

Natural Resources

Watersheds are the source of a variety of natural resources that benefit humans (National Research Council 1999). Indeed, the papers presented in these proceedings have discussed these resources in some detail. Chief among these, of course, is water supplies. Watersheds are the principal receiver, collector and conveyer of water for users. The majority of the world's water supplies originate on watersheds. Some watersheds, especially in the world's arid regions, are located at great distances from the towns and cities where end-users reside. Water is important to households where it is essential to human life. Cooking, cleaning, watering of gardens and yards, personal hygiene are all key domestic uses of water. Dependable water supplies are the figurative lifeblood of the world's economies. As such, they are essential to the development of agricultural and industrial economic sectors. The growing demand for irrigation water, and to a lesser extent industrial uses, have been the main forces behind the world's growing demand for water (World Resources Institute 1996). National pressures on freshwater supplies are measured by the so called "water stress index" (World Resources Institute 1996). On the basis of past experience, it is estimate that 1,000 m^3 per capita per year of freshwater is the minimum needed to sustain human health and economic development. By this measure, it is estimated that as much as one-quarter of the world's nations are threatened with inadequate water supplies.

Water quality is another important watershed resource. Not only do the world's watersheds supply simply quantities of water, but also most of our quality water as well. Water quality is dependent upon both natural and anthropogenic factors. However, anthropogenic factors are far more important in terms of the threat posed to human welfare (National Research Council 1999). A major source of anthropogenic pollution in the United States affecting watersheds is non-point source pollution. Important sources of non-point source pollution include croplands, livestock operations, urban development, forestry operations, mining, recreation sites and roads. Improving the quality of water from watersheds is largely a problem of controlling these non-point sources of pollution. Some substantive progress has been made over the last quarter century of the 20th century toward controlling point sources of pollution. However, non-point sources, largely through legal exemptions and political pressure, continue to pose a problem.

Erosion and sediment control are important watershed resource issues which extends beyond merely water quality concerns. Erosion of surface material can affect not only water quality, but other resources as well. Among these would be cropland productivity, aquatic habitats, navigation and recreational uses of water. Sediment-rich waters also usually contain high pollutant loadings.

Flood control is another watershed activity which creates important benefits for society. Engineering projects such as dams, levees and reservoirs, as well as vegetation management, have been the means by which flooding from watersheds has historically been controlled. Indeed, it was the practical need to control flooding which was the earliest motivator of watershed management (National Research Council 1999). For example, in the late 1800s, the French national forestry school at Nancy added to its name and curriculum the study of watershed management largely for the purpose of educating foresters regarding the proper management methods for controlling flooding (de Steiguer 1994).

Hydroelectric power is another resource from watersheds. It is generated largely from reservoirs and dams and is thus an additional benefit associated with flood

[1] *Professor and Chair, Watershed Resources Program, School of Renewable Natural Resources, University of Arizona, Tucson, AZ*

control. Hydroelectric power supplies about 20% of the world's electricity (Miller 1996). It is generally recognized as one of the cheaper types of energy. However, there are several potential environmental problems associated mainly with the dams and reservoirs. Among these are interruption of migrating fish stocks, deprivation of flood plain siltation, and large evaporative losses of water, especially in arid regions.

Navigation is yet another resource coming from watersheds. Rivers emanating from watersheds sometimes are transportation corridors carrying coal, grain and other commodities to the marketplace. Major river arteries such as the Ohio, Missouri, Columbia and the Mississippi are examples of the importance of river travel to national commerce.

Watersheds are the source of many outdoor recreation opportunities which, in turn, provide great public benefits. Dams and reservoirs provide camping, boating, wildlife and fishing possibilities. Wildlife for both consumptive and non-consumptive uses can be found in many watersheds. Whitewater flows are important to rafters, kayakers and canoers. Anglers also take advantage of downstream water flows.

Many of the world's watersheds are covered with forests. Thus, watersheds can also be the source of timber supplies for manufacturing lumber and paper products. The relationship of timber harvesting to water flow, as previously stated, has long been an issue of interest to foresters and other land managers. Care must be taken to balance timber removals with the maintenance of manageable, clean water supplies.

Agriculture and grazing of domestic livestock are still another important possible watershed resources. Arable land exists on many watersheds which produces a variety of crops for human and animal consumption. Whether forested or rangeland, most of the land contained within watershed is also used for livestock grazing.

In addition to those mentioned, there are numerous, locally important resources which come from watersheds. Examples would include crab and oyster fisheries in Chesapeake Bay; cranberry harvests and dairy production on Willapa Bay Watershed, Oregon; and so forth (National Research Council 1999). Clearly, watersheds are the source of numerous resources which are beneficial to the public both in the United States and around the world.

Economic Resources

When discussing resources which come from watersheds, it is often useful to describe them, as we just have, in physical terms as natural resources. However, there is another view, that of the economist, which provides an informative perspective on the topic of watershed resources. And, as we later shall see, the economist's perspective is fundamental in developing a complete strategy for sustaining flows of watershed resources. A common classification system used by economists to describe resources is by their values, as follows: a) use values and b) non-use values. Furthermore, use values can be subdivided into: i) market and ii) non-market values.

A discussion of these resource economic classifications follows:

Use values describes the values derived by an individual from his / her direct consumption, or use, of a resource. Examples of these use values derived from the watershed include essentially any of the resources previously listed: water, timber, hydroelectric power, navigation and so forth. Each of these represents resources which individuals can consume or use directly rather than just contemplate or enjoy in a passive manner.

Market values are those resources, or values, which are traded in cash markets, where buyers and sellers meet and exchange the good or service for money. Production costs of the seller and willingness to pay by the consumer serve, in the market place, to set the price of the good or service in question. Several of the resources previously discussed can be placed into this market value category. Certainly timber, hydroelectric power as well as some forms of water and recreation (e.g., whitewater rafting) are market commodities. These resources are produced and then consumed by users who pay a price which at least approximates their value to consumers.

Non-market values are obtained from the direct use or consumption of resources too. However, there is no payment made to the producer for the resource. This does not mean that they are without value. Rather, only that their value is not reflected in cash transactions. Flood control is an example where no cash market exists for the good (i.e., dams and reservoirs for flood control) in question. (There is, however, a market for another loss prevention measure, flood control insurance.) Perhaps an even better example of non-market values, and one certainly every bit as real to consumers as flood control, is that of resource amenity values. These would be the unpriced values that individuals receive strictly from the passive, aesthetic enjoyment of a resource. It is not at all difficult to find such values coming from watersheds. The public receives amenity values from viewing cold, clear flowing water in streams, from scenic forest vistas, from wildlife observation, from oxygen-laden mountain air and various other non-consumptive uses. Although intangible, these resource values are just as real and meaningful to society as those derived from resource consumption.

The goods and services from which these non-market values are derived are classified as *public goods*. Public goods are those which, if provided by a producer, have the technical characteristics of being both indivisible and fully accessible to all (Tietenberg 1988). Indivisibility means that the resource cannot readily be broken-up into consumable units. For example, a producer cannot easily subdivide or package for consumption (as one might candy bars or gallons of gasoline) a flowing stream or a scenic view. Full accessibility means that use by one person does not exclude another from also using the resource. An example is a scenic view; your viewing does not exclude anyone else's viewing of the same scene at the same time.

Public goods stand in contrast to private goods. The latter, which comprises consumer goods, are those goods which can be divided for packaging and sale and also can be made exclusive, i.e., available only to paying consumers. There is an incentive for private markets to provide private goods because producers can capture completely the profits from such sales. However, public goods, such as flood control, some forms of outdoor recreation, navigational aides, and amenities where profits cannot be captured, most often are provided to the public by the government to whom the prospects of profit is not a primary motivating factor.

Non-use value is the second categorization of economic values. Included here are resources where the values are derived, not from current use, but from the possibility of use at some future time, and perhaps not even by person currently conveying value to the resource (Fields 1994). The sub-categorizations of non-use values are: *option value* which is the amount a person would be willing to pay to preserve the option of being able to personally use a particular amenity in the future; e*xistence value* is the willingness to pay simply to know that a resource will continue to exist even if the person never uses it; *bequest value* is the willingness to pay in order to maintain resources for use by future generations; *stewardship value* is the value arising not from possible human use, but rather to maintain the health of the environment for the continued use by all living organisms.

The preceding discussion has presented an array of resource values which are often not included in a listing of physical watershed natural resources. Nevertheless, these are real resources with real social values which must be considered when managing watershed resources. Not only economists, but many planners and lawmakers now recognize the relevance of non-market and non-use values to natural resources decisions. Development of methods for determining the money values of these non-market and non-use resources has progressed substantially over the past 25 years. Whereas it is not the intent of this paper to delve into the technical aspects of these non-market valuation methods, the interested reader is referred to works such as Bromley (1995). There one can learn about travel cost, contingent valuation and other methods which have become widely adopted for resource valuation even in court cases involving monetary damages.

Joint Production Processes

Another perspective provided by economics regarding "crucial watershed resources" is that of the watershed resource *production process*. It is possible to view the watershed itself as a complex production facility. The resources of the watershed, when combined with labor and capital, "produce" the array of socially beneficial goods and services we have just discussed. The issue here is the nature of that production facility. Namely, that it is a *joint* production facility which produces, or at least potentially produces, this array of goods and services more or less simultaneously. One fixed area of land, the watershed, produces, at once, clean water, timber, recreation, amenity values and so forth. Quite clearly, with a fixed land base, fixed management budgets and fixed technologies, the production of one item is governed by the production of all the others. This interdependency is referred to as a "joint production process" (Henderson and Quandt 1980)

Joint production is an important consideration for the multiple use management which occurs on most watersheds. Joint production exists because two or more outputs are technically interdependent using some of the same physical production inputs, such as land (Henderson and Quandt 1980) and thus have related production costs (Krutilla and Bowes 1989). An example: Managers of a watershed might want to produce both timber and wildlife from a given area of land. Because the goods are jointly produced, they compete for the same production inputs, in this case, land. When both goods are produced from a fixed land area simultaneously, neither can be produced at their individual maxima. Thus, the two commodities are *substitutes* for one another. Joint production almost always involves such trade-offs. That is, to get more of one resource output, the other resource outputs must be reduced. Joint production is a important economic characteristic to bear in mind when speaking of managing watersheds for sustained flows of resources. Without improvements in production technologies or increases in management budgets for labor and other inputs, more of one resource will almost always mean less of the others.

Sustaining Flows ... Of What?

The notion of sustained flows of resources from the watershed is, in the mind of many natural resource managers, a question of sustained *even* periodic physical resource yields. That is, year after year, decade after decade, the watershed will be managed to produce an equal periodic flow of goods and services. The philosophy of a sustained, even-flow of natural resources seems to have evolved in the United States early in the 20th century from a national concern over timber shortages, and the economically destabilizing effects which might arise from exaggerated supply fluctuations (Krutilla and Bowes 1989). This concern, in turn, stemmed from a general distrust of the private market as a manager of natural resources because of the then rapid harvesting of forestlands. Consequently, the nation turned to public forest management as the solution.

Concern for forest protection, stability and high yields led to the adoption by public managers of some policy rules-of-thumb (Krutilla and Bowes 1989). The first policy is that of maximum sustained yield. Under maximum sustained yield, forests are regenerated and cut at an age so as to produce the maximum biological yield over time. This age is generally regard as the point of culmination of mean annual increment. The second policy was that of even-flow management. Under this policy, current harvest levels were set at a constant level that could be maintained forever. Combining these two principles resulted in the so called “fully regulated forest,” that is, a forest which has a sustained even-flow of harvests over time at the forest’s maximum biological potential.

The fully regulated forest has intuitive appeal. However, it has been criticized on the grounds that it is devoid of economic rationale. It says nothing about wise investment in lands of varying productivity capability. It says nothing about how the manager should respond to changing temporal patterns of resource demands for timber, water, wildlife, range, recreational and amenity services. Furthermore, the philosophy of sustained, even-flow can result in the sacrifice of consumption in times of plentiful resource stocks and to the uneconomic management of relatively abundant resources (Krutilla and Bowes 1989).

Nowadays, the notion of managing for an even-flow of resources has been largely replaced by that of managing the economic flow of resources. The economic goal of the multiple use problem is the selection of a sequence of management actions to maximize the present value of net benefits from the flow of timber and other resource values over time (Krutilla and Bowes 1989). This notion of maximizing the economic benefits of resources has been embodied in legislation such as the Forest and Rangelands Renewable Resources Planning Act of 1974 as amended by the National Forest Management Act of 1976. These acts provide a mandate to the public land manager to maximize the net benefits from multiple-use, sustained yield management with consideration given to the relative values of all resources while preserving the integrity of the land.

Management prescriptions based on maximization of the present net worth of resource flows are complex. They require large amounts of data and computer analyses. However, public land management agencies have, in fact, developed operational models for maximizing the present value of resource flows. Most notable among these efforts has been the development of the FORPLAN (now SPECTRUM) model by the USDA Forest Service. FORPLAN is a linear programming model which allocates land to various management activities so as to maximize the present net value of the flow of goods and services from the land. FORPLAN has been hailed by some as an important attempt to plan forest and watershed management activities in such a way that will provide the greatest benefit to society. However, others have been critical of FORPLAN saying that, while it has enormous analytical capacity, it “requires massive amounts of data, includes non-use values, e.g., protecting watersheds or improving aesthetics, only as constraints on uses and outputs, and poorly addresses spatial concerns” (Office of Technology Assessment 1992).

Despite the criticism of FORPLAN, the goal of maximizing the present net benefits of resource flows must still be regarded as the correct stance for watershed management. Planners should attempt to quantify and maximize the sustained net economic flow of watershed resources rather than simply providing a sustained, even-flow of goods and services.

The Solution: Integrated Resource Planning

Five Questions

The solution to providing sustained economically efficient flows of crucial watershed resources is through *integrated resource planning*. In saying this, we provide no great surprise. Integrated resources planning has long been recognized as the best means for achieving an economically optimal flow of watershed resources. Rather, our position simply supports and confirms the conventional wisdom in this regard. Furthermore, at least in the United States, the National Environmental Policy Act process must be followed in the development of plans. This is true if a federal agency is involved or if the proposed plan involves the obtaining of federal permits.

Integrated natural resources planning is the process of organizing the different natural resource management activities in a way so as to produce the greatest value of goods and services for society over a given period of time (Loomis 1993). Ideally, a comprehensive plan will include both use and non-use values, as well as both direct and indirect resource effects all of which will be quantified and compared among alternative plans and uses. This, of course, presents a formidable, if not overwhelming, challenge to the watershed manager. However, it must be regarded as an ideal toward which to strive. Indeed, we only compare public land planning of 25 years ago to what is occurring today to see that resource managers have made definite progress toward this ideal.

There are five basic question in the planning process (adapted from Loomis 1993):

1. Who has the planning responsibility and authority?
2. Where are we?
3. Where do we want to be?
4. What alternative actions will best get us there?
5. Did we make it?

These questions provide a reasonable and comprehensive framework to discuss the integrated planning process for natural resources. Thus, in the following sections, we shall discuss the meaning and relevance of each.

Who Has the Planning Responsibility and Authority?

Planning on watersheds often involves a dizzying array of federal, state and local agencies with overlapping and conflicting responsibilities. Also, the planning process can involve a number of federal, state and local laws. In the past, this morass of agencies and laws sometimes led to the development of "super" authorities such as the Tennessee Valley Authority for the administration of the watershed planning process (National Research Council 1999).

Nowadays, however, the super authority approach has been largely replaced by the "partnership" approach to planning (National Research Council 1999). Using this method, the principal agencies seek to involve not only the federal, state and local agencies with interest in, and possibly jurisdiction over, some of the elements of watershed planning. They also involve private landowners, watershed associations, soil and water conservation districts and state natural resource and game and fish agencies. By involving broad public participation, the agencies are more likely to be in compliance with the public involvement portions of NEPA. Furthermore, they are much more likely to achieve acceptance of the final plans once they are completed.

Where Are We Now?

The second step in planning, determining "where are we now," calls for an inventory. This inventory requires an enumeration of the physical resources on the watershed, such as the amount of timber; volume and flow rate of streams; current water quality; wildlife censuses; etc. Maps must be developed, perhaps as part of a geographic information system. Acreages and quantities of resources must also be determined. Also, the inventory must also include the assets and resources of the agency such as personnel, budgets, equipment, and so on (Loomis 1993).

The data collected at this stage of the planning process, can help to determine the direction of the next stages in the planning process. For example, shall we continue in recreation management or shall we consider more intensive timber management? Also, the resources of the watershed and those of the agency will serve as constraints on any future plans. The agency can only produce within the possibilities afforded by the resources it has at its disposal.

Where Do We Want to Be?

The third step of the planning process is that of determining where the agency and the public wants to be, in terms of the productive possibilities of the watershed, at some time in the future. Some federal agencies, such as the USDA Forest Service, develop plans with a 5 to 15 year time horizon. Other decisions, such as construction of a dam and reservoir, can require a much longer planning horizon. This step usually requires that "scoping" sessions take place in order to identify alternative futures for the watershed. Increasingly, it has been recognized that the planning agencies must be required to draw upon input from the public for this stage of the process. As we have said, plans that do not involve the public will not be in compliance with the National Environmental Policy Act nor will they likely be accepted by the public.

What Actions Will Best Get Us There?

This the fourth step of the planning process is the most demanding. Here, a principle action must be proposed, but then alternative actions must be proposed and explored as well. Indeed, one of the actions considered must be "no action."

This planning step will certainly involve the collection of research data. It will perhaps even require the establishment of watershed experiments to determine the response of the various resources to specific land management treatments. We will recall, that these responses are in the form of trade-offs due to the joint nature of the production process. Once the joint response of resources to treatments has been determined, estimates of the costs of various actions must be made as well as the benefits of outputs. Perhaps even optimization methods such as linear programming will be employed to determine the most economically efficient watershed management alternatives. Once the planning alternatives have been evaluated, the most desirable course of action will be chosen and implemented.

Did We Make It?

The final stage of the planning process is to address the question "did we make it?" This is the time for monitoring the plan which was implemented. In a sense, the planning process has gone full circle with this step. Inventories are again required to determined precisely what the management actions have achieved in terms of resource outputs. Also, this is the time for corrective measures to redirect actions that may not be achieving their targeted outputs. The monitoring step is, in fact, an on-going process which continues throughout the planning process.

Conclusion

When sustaining the flows of crucial watershed resources, watershed managers must recognize that the "crucial resources" involve not only those tangible, commodity resources such as clean water, timber, recreation and the like. Crucial resources also include intangibles such as amenity, option, bequest, existence and stewardship values. These latter values have increasingly been recognized as having significant economic value to society.

Furthermore, managers should replace even-flow production criteria with the more relevant objective of maximizing the net social benefits from watershed production. The maximization of net benefits criteria insures that watershed management best serves the economic needs of society. Significant progress has been made in recent years toward the quantification of resources benefits. Furthermore, mathematical optimization methods for selecting the best production strategies have been in use for planning on public lands for about the past 25 years.

The planning process requires input from other agencies and the public, inventorying and mapping of current resources, choosing production targets, selecting alternative courses of management action, implementing the optimal management strategy and, finally, monitoring the results. Planning for the sustained yield of watershed resources is a complex process. It is also, quite likely, the most important function of the watershed manager.

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