Changing Perceptions of Watershed Management from a Retrospective Viewpoint

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Abstract.—Watershed management, an ancient concept, was defined in Vedic texts from India that date from 1,000 B.C. This concept has been an integral part of forest and rangeland management in North America throughout the 20th century, but its scope has broadened significantly. Although the Forest Reserve Act of 1891 created the reserves that were to become the core of the National Forest System, it was the Pettigrew Amendment to the 1897 Sundry Civil Appropriations Bill that defined the purpose of the forest reserves. The amendment stated that the reserves could be established only to "...improve and protect the forest within the reservation, or for the purpose of securing favorable conditions of water flows...." Clearly, the interpretation of watershed management within the context of forestry in 1897 was for water supply and flood prevention. By mid-century, forest and watershed management had broadened to encompass recreation, range, wildlife, and fish purposes (Multiple Use Act of 1960). In the latter quarter of the 20th century, legislation, like the National Forest Management Act, National Environmental Protection Act, the Clean Water Act, and the Endangered Species Act, and concepts like ecosystem management have further broadened the goals and importance of watershed management beyond that of water supply production and flood prevention.

Introduction

"Water is the best of all things."
Greek Poet Pindar 522 to 433 B.C.

"We made water everything."
The Koran 632 A.D.

Meinzer (1942) described hydrology and its central concept of the hydrologic cycle as the science that relates to water. He also noted that hydrology is mostly concerned with the course of water from the time it is precipitated on land and flows into the sea or is evaporated. Wisler and Brater (1963) defined hydrology as, "...the science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth." Although the physical processes of the hydrologic cycle have been active since the formation of the earth, rapidly expanding human activities and management of the landscapes have profoundly interacted with hydrology to affect the planet and human habitat. An understanding of hydrology is the key to an endeavor of much greater importance, watershed management.

Watershed management, often thought of as a 20th century development, is rooted in the history of human civilization. Indian texts from Vedic times (1,000 B.C.) indicated an understanding of the hydrologic cycle, the concept upon which the modern science of hydrology is based (Chandra 1990). There is a verse in the Atharva Veda texts from 800 B.C. that can be considered the first definition of watershed management. Atharva Veda verse 19,2.1 states that:

> "...one should take proper managerial action to use and conserve water from mountains, wells, rivers and also rainwater for use in drinking, agriculture, industries..." (Chandra 1990).

Another text directed the king to build canals across mountains to provide water for his subjects for agriculture, industry, and to facilitate navigation; evidence of the first of many government water development projects in the course of human history. Later texts from around 400 B.C. describe the measurement of rainfall. These texts indicate that civilization in the Indian sub-continent had evolved from one at the mercy of climate to one of active water and watershed management.

The development of cities in the Middle East and the Mediterranean Sea basin depended upon the agricultural revolution, and also upon water management (Illich 1986). There is mention in Egyptian texts of well development and extension as early as 2,500 B.C. The Minoan (1700 B.C.) and Mycenaean (1400 B.C.) civilizations of Crete and Greece had a good understanding of water management as indicated by the extensive water facilities they created for their cities (Tainter 1988). Cities like Ninevah and Troy had aqueducts too bring water from 10 to 80 km away in the 7th and 6th centuries B.C. . Rome, founded in 441 B.C., initially used the Tiber River, springs, and wells for its water supply. The first aqueduct supplying Rome was built in 312 B.C. By 97 A.D., Rome was a city of over 1 million people with 9 aqueducts 400 km in length bringing in 450 L / person / day of fresh water. Continued population expansion in Rome necessitated the construction of an additional 5 aqueducts by 300 A.D.

Watershed management and engineering skills declined with the collapse of Rome and the entry of Western European civilization into the Dark Ages. Hundreds of

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years passed before watershed management skills were regenerated. In 1215, King Louis the VI of France promulgated an ordinance The Decree of Waters and Forests in recognition of the interrelationships between water and forests (Kittredge 1948).

During the Renaissance and subsequent periods, observation, measurement, and experimentation with water resources expanded. The Swiss were leaders in the resurrection of watershed management in Europe. The first watershed protection forests were set aside in 1342 (Kittredge 1948). Between 1535 and 1777, Switzerland set aside 322 forests as watershed reserves and avalanche protection zones. Men of science, such as Leonardo Da Vinci (Italy), Bernard Palissy (France), Edmund Halley (England), rediscovered the philosophical musings on the hydrologic cycle produced by Greek and Roman scholars such as Homer, Plato, Aristotle, Lucretius, Seneca, and Pliny (Chow 1964). French and Italian scientists published treatises between 1801 and 1840 that recognized the relationships between hydrology, vegetation, and climate, and the serious erosional impacts of deforestation. The German naturalist Von Humbolt (1849) made a remark in a publication of his that indicated that the concept of watershed management was well developed again in European scientific circles. He said, "How foolish do men appear destroying the forest cover of the world without regard to consequences, for they rob themselves of wood and water." But as late as 1826, Paris could only supply 3 L / person / day to its population (Illich 1986). London's water supply capacity was only 37 L / person / day by 1936.

In the western hemisphere, early Native American cultures made substantial achievements in watershed management. Between 200 B.C. and 700 A.D., the Huari and Tiahuanaco empires of Peru and Bolivia built extensive irrigation canals and agricultural terracing to create a large artificial agricultural landscape to support their burgeoning populations (Tainter 1988). The Inca civilization that followed these 2 empires had cities of 200,000 people supplied with water by lengthy aqueducts (Kerr 1960). These cities had conveniences, such as subterranean sewerage, drainage systems, indoor running water, and toilets, long before the major cities of Renaissance Europe.

The Mayan culture (1,000 B.C. to 1,000 A.D.) of the Southern Lowlands of Mexico modified their landscapes extensively to provide water for Ramon tree, maize, squash, avocado, cacao, and cotton agriculture (Tainter 1988). Up to 2,500 km^2 of the southern lowlands were modified by canal systems that brought water into agricultural areas during dry seasons. Nearly 180 km of transportation canals were dug to move raw materials and agricultural produce.

The Hohokam culture that occupied areas of the Sonoran Desert in Arizona from 600 to 1200 A.D. was noteworthy among North American native peoples for its development of extensive networks of irrigation canals (Reid and Whittlesey 1997). The River Hohokam living near Phoenix were the first to develop canal systems to irrigate their corn, bean, and squash crops in the arid Sonoran Desert that averaged less than 200 mm of annual precipitation (McGuire 1982). The Hohokam learned to modify their habitat with irrigation canals. These systems contained main canals up to 10 m wide and 2 m deep, smaller secondary canals, and numerous feeder ditches. One network that was 240 km in total length contained 50 main canals, some as long as 26 km. For their low level of technology, the Hohokam were amazing. They were the first to practice watershed management in Arizona. More watershed managers would arrive in the state in the 19th and 20th centuries.

Late 19th Century

> "No one knows the value of water until he is deprived of it"
>
> *David Livingstone 1813 to 1873*

Water deprivation strongly influenced the Mormon view of water and watershed management during their settlement of the Great Salt Lake Valley in Utah. Arriving in 1846, they found a desert landscape next to a salt sea. The Mormons launched into water development projects with a fervor that by the turn of the century would result in 2.4 million ha of irrigated agriculture in several states. The experience of the Mormons would significantly affect the viewpoints and approaches of U.S. Bureau of Reclamation water development programs through much of the 20th Century.

Watershed management in the United States gained a strong foothold with the creation of the national forests. The Forest Reserve Act of 1891 created the reserves that were to become the core of the National Forest System (Steen 1976). During deliberations on the bill before Congress, Secretary of the Interior John W. Noble, at the urging of Bernhard E, Fernow, personally intervened to add Section 24 authorizing the President to create forest reserves. By the end of 1892, President Harrison had added 15 reserves totaling 5.3 million ha, primarily to protect water supplies. In 1896, the forest reserves were up to 8.1 million ha. President Cleveland initiated a land reservation furor by adding another 8.5 million ha in early 1897.

It was the Pettigrew Amendment to the 1897 Sundry Civil Appropriations Bill that defined the purpose of the forest reserves (Steen 1976). The amendment stated that the reserves could be established only to, "...improve and protect the forest within the reservation, or for the purpose of securing favorable conditions of water flows....” By 1897, the interpretation of watershed management within the context of forestry was for water supply and flood prevention.

Early 20th Century (1900 to 1930)

> “Whiskey is for drinking, water is for fighting over.”
>
> *Unknown Arizona Cowboy 1901*

The early 20th century was unique in that it experienced the beginnings of watershed management research. The Sperbelgraben and Rappengraben experimental catchments were established in 1903 near Emmental, Switzerland (Penman 1963). This was followed by establishment of the Ota watershed study in Japan in 1908 and the Wagon Wheel Gap study in Colorado, in 1910. This period was also notable for a number of legislative actions that affected watershed management in the United States.

The Reclamation Act of 1902 was passed to increase settlement of large areas of public land in the western United States through public works watershed management projects (Reisner 1986). This approach involved Federal government construction of reservoirs and irrigation canals on a large scale throughout the arid western USA for agricultural and municipal use. The legislation created the Reclamation Service, which floundered repeatedly as a government enterprise until it was transformed into the Bureau of Reclamation in 1923 and received major infusions of public works funds during the 1930s Depression.

The Weeks Law of 1911 recognized the value of vegetation covered watersheds and ended most of the legislative debate caused by Presidential reservations of forest land in the last decade of the 19th Century. This act authorized the President to, “...reserve any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations.” (Kittredge 1948, Steen 1976).

The purpose of the Weeks Law was to protect navigable waterways from the ravages of floods emanating from denuded landscapes (Steen 1976). This law recognized that poorly managed watersheds increased flood flows and produced considerable fluvial and riparian damage. The law encouraged watershed management by designation of forest reserves that were to be managed for their water resource values. However, the most important part of the Weeks Law was scarcely discussed in the heated congressional debates. Section 2 authorized federal matching funds for state forest lands, and their management agencies, within the watersheds of navigable streams. This section created the whole concept of cooperation of the federal government with state agencies for watershed management improvement.

The Clark McNary Act of 1924 added another twist to the watershed management efforts of the federal government (Steen 1976). At that time, the 323.8 million ha of forest standing at time of European settlement had been reduced to less than 56.7 million ha of unlogged stands and 32.8 million ha of barren, logged-over shrubland in poor hydrologic condition. The Clark McNary Act offered incentives to state and private landowners to restore their forests by reforesting their logged-over lands to improve timber production and watershed protection.

Mid 20th Century (1930 to 1970)

> “In the old days, ranchers shot each other for water. Today it is a lot tougher. Bureaucrats are in charge.”
>
> *Will Rogers 1879 to 1935*

The mid 20th century in the United States saw a tremendous amount of activity and investment by federal government agencies in watershed management. The principal agencies that were leaders in watershed management programs were the U.S. Bureau of Reclamation, the Soil Conservation Service, the U.S. Army Corps of Engineers, and the USDA Forest Service.

At this time period, the Forest Service was active in watershed management through its various watershed programs to manage existing forests and to acquire and rehabilitate abandoned and eroded lands. Major watershed management research investments were made at the Coweeta Hydrologic Laboratory (1933) and the San Dimas (1933), Sierra Ancha (1932), Hubbard Brook (1963), Fernow (1934), Fraser (1937), Beaver Creek (1957), and H.J. Andrews (1948) experimental forests.

A major proponent of watershed management by water development in the Western United States was the U.S. Bureau of Reclamation. As recounted by Reisner’s (1986) The Cadillac Desert, this period began with completion of the Hoover Dam on the Colorado River and ended with the filling of Lake Powell behind the Glen Canyon Dam. In between these actions, numerous dams and irrigation developments were completed on every major river system in the Western United States (Colorado, Columbia, Yellowstone-Missouri, Sacramento, etc.). Most of this development (85%) conducted by the Bureau of Reclamation was targeted for agricultural irrigation, with the remainder for municipal water supplies. The dams also provided attenuation of flood peaks and relatively inexpensive electrical power to support urbanization of much of the Western United States. California alone had 1,251 reservoirs constructed by the end of this mid century period (Reisner 1986). Unfortunately, this narrow view of watershed management as water development did not consider ecological impacts to aquatic and riparian biota. There would be a complete rethinking of the values of water development relative to ecological impacts by the end of the century .

The Dust Bowl of the Great Plains in the early 1930s was the impetus for the Soil Conservation Act of 1935 that created the Soil Conservation Service. The mission of the Soil Conservation Service (now the Natural Resources Conservation Service) was to provide for the control and prevention of soil erosion at a national scale (Steiner 1987). The objectives of its soil-based watershed management programs were, from the beginning, to preserve natural resources, control floods, prevent reservoir impairment, maintain river and harbor navigability, and protect public health and lands. The Flood Control Act of 1936 mandated the Soil Conservation Service to conduct watershed management programs on upstream areas to reduce flooding. The Watershed Protection and Flood Prevention Act of 1954 created the small watershed restoration and management program that worked with both private and public landowners to maintain or improve soil productivity conditions and reduce destructive flood flows (Held and Clawson 1965). A decade after implementation, the small watershed program (headwater catchments smaller than 101,000 ha) included 2,088 projects on 60.7 million ha.

The Flood Control Act of 1936, which asserted federal responsibility for flood control on navigable rivers and their tributaries, dramatically initiated involvement of the U.S. Army Corps of Engineers in the watershed management arena (Leopold and Maddock 1954). The act stated that watershed improvement is in the best interest of the country, and that flood control is a proper federal function. The approach of the Corps to watershed management was through large structure engineering to control floods and erosion on the downstream portions of large watersheds. The Corps of Engineers program often conflicted with that of the Soil Conservation Service due to a lack of definition of the boundary between the responsibilities of each agency within individual watersheds.

Stoddart and Smith's (1943) treatise on range management defined that profession as the science and art of planning and directing the use of rangeland vegetation to obtain the maximum sustained livestock production while conserving the multiple resources of the landscape. They recognized that the inherent nature of range management is watershed management when they stated that, "One of the most important but at the same time least realized functions of natural vegetation is the protection of the watersheds and the conservation of soil and water."

Stoddart and Smith (1943) commented that at mid century about 85% of the streamflow in the Western United States was from lands that were 79% actively managed rangelands. They pointed out very clearly at the beginning of their text that a prerequisite of good range management is maintenance of good range vegetation conditions to ensure optimum multiple use of watersheds. Indeed, they believed that the most important function of range management is the protection of watersheds that are used for water supply.

Kittredge (1948) substantive milestone work on forest influences used the 1944 Society of American Foresters definition of watershed management (SAF 1944). He stated that watershed management is, "...the administration and regulation of the aggregate resources of a drainage basin for the production of water and the control of erosion, streamflow, and floods." This definition has a heavy commodity (water supply) and protection of human values (erosion control, flood protection, etc.) emphasis. Kittredge (1948) elaborated on the definition by outlining 4 phases of watershed management. He identified these phases as resource recognition (surveying, location, etc.), restoration (correction of unstable conditions), protection (guarding from disturbance and maintenance of existing conditions), and improvement (practices to increase water yield). Although this definition incorporated concepts (restoration and protection) that would grow in importance in the latter part of the century, the emphasis was clearly on the commodity of water.

Francois (1950) commented on the objectives of forest watershed protection and management policies in a United Nations report on forest policies in Europe. He recognized the values of non-commodity products when he stated that forest management policy should, "...provide for the protective, productive, and accessory (recreation, aesthetics, and wildlife habitat) of the forest, as well as for changing demands for wood and the other products and benefits of forest land." Pavari (1962) expanded on the thoughts of Francois (1950) concerning the relationships between forestry and watershed management by saying that, "The objective today is not only to establish forests of proper size and character to protect the soil, the climate, and the water resources of a country and to meet the nation's requirements for wood, water, and other products; it is also to secure the fullest use of all lands in the general interest of the country."

Colman (1953) produced a major synthesis of the effects of vegetation management on hydrologic processes and water yield. His approach to watershed management focused on the importance of manipulating vegetation to alter hydrologic processes and to achieve watershed management goals. He stated that:

> "The need for control over water yield arises because of the development of population

> centers, industry, and agriculture. All of these need protection against floods, and all need water of proper quality delivered in sufficient quantity at the right time."

The International Glossary of Hydrology (WMO/ UNESCO 1969) presented a very simple definition of watershed management. It states that watershed management is the, "...planned use of drainage basins in accordance with pre-determined objectives."

Although the mid 20th century in the United States is noted for the great water development projects of the Bureau of Reclamation, this period also saw the rise of a land ethic and a consideration for ecological consequences in watershed management (Leopold 1949). Aldo Leopold's concept of land ethics took watershed management beyond the economic, commodity driven approach to watershed resources. He noted that:

> "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land."

He further stated that:

> "In short, a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such."

The key point of his message was that, "Conservation is a state of harmony between men and land." Leopold bemoaned the fact that conservation was moving ahead at a snail's pace. What he was asking for was a monumental change in our approach to land (watershed) management. Leopold noted that, "No important change in ethics was ever accomplished without an internal change in our intellectual emphasis, loyalties, affections, and convictions." He challenged land managers to move from a purely economic, commodity paradigm to one of holistic ecosystem management.

On June 12, 1960, President Eisenhower signed into law the Multiple-Use Sustained Yield Act. For the first time, the 5 major uses of watersheds (wood, water, wildlife, range, and recreation) were specifically mentioned in one federal law (Steen 1976). The Multiple-Use Act contained the concept that national forest management did not have a resource priority, instead of all resource uses should be managed for their sustainability. Four decades later we still struggle to incorporate those concepts into action on the ground. However, the Multiple-Use Act did broaden the objectives of watershed management.

Ogrosky and Mockus (1964), in a paper on agricultural hydrology that appeared in V.T. Chow's 1964 Manual of Hydrology, defined watershed management as, "Management of a small watershed to conserve soil and water resources that the land be used within its capabilities and treated according to its needs." In another paper in Chow's 1964 volume, Dixon (1964) referred to watershed management as, "...the conservation and improvement of the soil, sediment abatement, runoff retardation, forest and grassland improvement, and protection of water supplies." Both of these definitions focused on the physical aspects of watershed management without biological or ecological considerations.

In the late 1960s, Dortignac (1967), head of the Water Resource Branch, USDA Forest Service, stated that the discipline of watershed management was on the threshold of great opportunity in land management, since the water supply inadequacies previously only a problem in arid and semi-arid regions of the United States had suddenly arrived on the doorstep of the humid eastern United States. He believed that watershed management on forests, shrublands, and untilled grasslands could make a substantial contribution to improving water supplies. Dortignac said that:

> "Watershed management can play an important role under the present increasing population pressures and the public demand for greater productivity and multiple use of forest and related lands. Scientific prescriptions that utilize the wood, forage, wildlife, and recreation resources as well as improve water yields and control, maintain, or improve soil stability provide the means." (Dortignac 1967).

Dortignac's views of watershed management were affected by the multiple use philosophy of the mid century and the importance of water as a commodity. However, his views reflected a holistic view of the discipline. He considered that practice watershed management was of greater importance than reactive management to repair or mitigate human mistakes.

Late 20th Century (1970 to 2000)

> "If we solve every other problem in the Middle East but do not satisfactorily resolve the water problem, our region will explode."
>
> *Yitzhak Rabin 1922 to 1995*

John Bullein (1562) noted that, "Water is a very good servant, but it is a cruel master." (Mencken 1966). At the end of the 20th century, water has become increasingly cruel to the human inhabitants of the planet. Although no water wars have broken out in the 20th century, human suffering at the hand of this cruel master is continuing to increase. United Nations estimates indicate that 9,500 children die each day due to lack of water or water pollution (Simon 1998). Others place the child death rate at 2 to 4 times that figure because of water-borne diseases like malaria, diarrhea, and schistosomiasis. As Clarke (1991) points out, 51% of the countries in the world have low to very low fresh water availability (<5,000 m^3/person/year). Because of simple watershed management errors, ecological disaster has occurred in the Aral Sea area of the Russian Federation (Aronson 1998). Stream diversions for cotton agriculture starting in the 1950s prevented the world's 4th largest lake from keeping up with 33 to 36 km^3 of annual evaporation. The result has been shrinkage of this body of water to half its former size, isolation of coastal villages and destruction of the pre-diversion local economy, extinction of 20 fish species, and a 30- to 60-fold increase in human kidney, liver, arthritic, and bronchial diseases.

The World Bank uses the watershed management approach in assessing the environmental benefits of development projects (Brooks et al. 1992). This organization believes that this approach is the key to identifying the linkages between landscape improvements, productivity increases, and attainment of true natural resource sustainability. Their definition of watershed management is that it:

> "...is the process of guiding and organizing the use of the land and other resources on a watershed to provide desired goods and services without harming soil and water resources. The interrelationships among land use, soil, and water, and the linkages between uplands and downstream areas are recognized in this concept."

The World Bank recognizes that, as part of the watershed management approach, people are affected by the interaction of water with other resources, and they influence the nature and magnitude of those interactions. They recognize that the impacts of water resource interactions follow watershed boundaries, not political ones, but that political externalities have to be factored into watershed management analyses, and that costs and benefits must be distributed among political units, communities, and individuals.

In 1990, most European countries began the process for developing management guidelines and criteria to ensure conservation and sustainable management of forests (Helsinki Process 1994). Criterion Five of Helsinki Process is to, "Maintain and develop the role of forests in water supply and protection against erosion." A parallel, but independent, effort was initiated by Canada and joined by other countries with temperate or boreal forests. The Canadian effort came up with similar criteria for measuring the sustainability of forest management (Montreal Process 1995). Criterion 4 of the Montreal Process is very similar. This criterion includes the conservation of soil and water resources and the protective and productive functions of forests. Since the chemical, physical, and biological characteristics of aquatic systems and their watersheds are excellent indicators of the condition and sustainability of the lands around them (Breckenridge et al. 1995), key conditions of soil and water resources were selected as indicators of sustainability.

Eight out of 67 indicators selected in the Montreal Process and endorsed by the 10 nations that drafted the Santiago Declaration in 1995 pertain to soil, watershed condition, and the quantity and quality of water resources. Briefly, they are: (1) area and percent of forest with significant soil erosion, (2) area and percent of forest managed primarily for protective functions, (3) percent of stream length in forested catchments in which stream flow and timing has significantly deviated from the historic range, (4) area and percent of forest with significantly diminished soil organic matter and/or changes in other soil chemical properties, (5) area and percent of forest with significant soil compaction or change in soil physical properties resulting from human activities, (6) percent of water bodies with significant variance of biological diversity from the historic range of variability, (7) percent of water bodies with significant variation in water quality from the historic range of variability, and (8) area and percent of forest land experiencing significant accumulation of persistent toxic substances. The USDA Forest Service has adopted these water and soil indicators of the Santiago Declaration on sustainability as guidance for its land management activities.

Brooks et al. 1997, in their text on hydrology and watershed management, expanded on the definition proposed by the World Bank (Brooks et al. 1992). They noted that their perspective is different from traditional ones because it recognizes the importance of land productivity as an integral component of watershed management. They defined watershed management as:

> "...the process of organizing and guiding land and other resource use on a watershed to provide desired goods and services without adversely affecting soil and water resources. Embedded in the concept of watershed management is the recognition of the interrelationships among land use, soil, and water, and the linkages between uplands and downstream areas."

Brooks et al. (1997) emphasized that by having a good perspective of a how a watershed functions and a clear understanding of the linkages between the uplands and downstream areas, watershed managers should be able to design long-term, sustainable solutions to human natural resource problems and avoid the disasters that can cause human suffering due to a lack of water or water pollution.

Reimold (1998) has a short but thorough definition of watershed management that also reflects thinking on the discipline at the end of the 20th Century. He states that, "Effective management of a watershed depends on a comprehensive human understanding of the components of watersheds and their interactions." Reimold's definition incorporates the holistic approach to the watershed as an ecosystem, not just physical processes. He commented on why, at the end of this century, "...comprehensive human understanding..." still does not exist. He paraphrased Aldo Leopold by saying, "Humans do not seem to be able to understand a system that they did not build; instead they seemingly must partially destroy and rebuild the system before its use and limitations are understood and appreciated."

In the waning years of the 20th century, major debates continue in the Western United States about how to undo some of the ecological consequences caused by extensive water development in the mid century period by breaching major dams on the Snake, Columbia, and Colorado Rivers. The main factor fueling these arguments is consideration for plant and animal species covered under the Threatened and Endangered Species Act. It will be interesting to note if this debate carries on into the 21st Century with any sort of credence and forcefulness.

21st Century

> "Water, like energy in the late 1970s, will probably become the most critical natural resource issue facing most parts of the world by the start of the next century."
>
> *Financial Times, London*

After this retrospective look at the changing perceptions of watershed management to date, I would like to briefly peer into the crystal ball of the 21st century. Making predictions is easy, but looking ahead with clarity is another matter. Lacking a Palladian glass ball, I will refer to the comments of others for the future definition and roles of watershed management.

Faculty of the University of Arizona Watershed Resources Program in the School of Renewable Natural Resources drafted a definition of watershed management and a future vision statement for their program that clearly states what the profession is about and where it needs to go in the 21st century (Cortner 1999). Their definition is a reflection of the one offered by Brooks et al. 1997. It stated:

> "Watershed management is a holistic approach to managing the biological, physical, and social elements in a landscape defined by watershed boundaries. It is the art and science of manipulating land and other resources on a watershed to provide goods and services to society without adversely affecting soil and water resources. Watershed Management relies heavily on the science of watershed (forest / range / wildland / land use) hydrology, a branch of hydrology, that addresses the effects of vegetation and land management on water quality, erosion, and sedimentation. Embedded in both watershed hydrology and management is the acknowledgment of the linkages between uplands and downstream areas and interrelationships among land use, soil and water. With increasing awareness that land management decisions can not be made in isolation, the principles of watershed management are being used as the basis for many environmental and natural resource management decisions."

The University of Arizona watershed management definition document goes highlighted the interdisciplinary nature of watershed management training, knowledge, and experience. The document notes that the profession's uniqueness is its integration of ecology and hydrology to solve land management problems and conflicts. Watershed management in the 21st Century must shift its traditional wildland focus to include urban fringe or urbanized areas to keep pace with society's needs. In the future, watershed management professionals must become more involved in land use planning and public education to maximize the effectiveness and social impact of their discipline.

Faculty of the University of Arizona Watershed Resources Program further stated that the goal of watershed management is to:

> "...evaluate the effect of current and future land use conditions on the soil and water resources, and assess the potential social and ecological impacts. Watershed management must also be capable of providing solutions to watershed problems, such as plans for water augmentation or watershed restoration."

They concluded that the profession encompasses a wide range of expertise. What links everyone together is the common goal of solving watershed management problems, not the specific areas of expertise.

Albert Rango (1995), Chief of the Hydrology Laboratory, USDA Agricultural Research Service, Beltsville, Maryland, presented a paper on the future of watershed management at an American Society of Civil Engineers symposium on Watershed Management Planning in the 21st century. His definition of watershed management is more narrow than that proposed by the University of Arizona Watershed Management program. Rango broadened the definition found in the International Glossary of Hydrology (WMO / UNESCO 1969) to be, "...the optimization of the quantity, quality, and timing of runoff through planned use of a drainage basin." Rango (1995) believed that watershed management would continue as an identifiable discipline into the 21st century because the demand, scarcity, and price of water will continue to increase. He identified the early 21st century as the beginning of the era of Global Hydrology for watershed management. In this era, worldwide emphasis will be on large-area assessments using modeling, remote sensing, and watershed management expertise. Large-area assessments are already happening in some countries (e.g., Interior Columbia Basin Ecosystem Management Project in the United States and the Eastern Anatolia Project in Turkey). As a parting comment, Rango (1995) recommended expanding the area of interest and training of watershed management from mainly forests, rangelands and other wildlands to include agricultural and urbanized areas. He also reiterated that watershed management technology transfer efforts must be expanded nationally and internationally to allow developing countries desperately in need of water information to easily access recent research results.

In a June 1999 address to Western United States water officials at the University of Colorado, Secretary of the Interior Bruce Babbitt stated, "In the coming century, water policy must be made in the context of the entire watershed." (Associated Press 1999). He went on to say that, "Water is a natural resource with no fixed address, and any water use inevitably affects many other uses, both upstream and downstream." Babbitt believes that water can no longer be managed, as it has been in the past, as a separate entity or commodity. Water must be managed within the holistic concept of watershed management. He further remarked that, "The big task of the coming century will be to restore rivers, wetlands, and fisheries." (McKinnon 1999).

Accomplishing this task will require approaching the problem from a watershed management viewpoint.

Leadership from the federal government of the United States in watershed management policy for the 21st century is eminent. The U.S. Departments of Agriculture and Interior are currently working on a draft Unified Federal Policy (UFP) with other Federal agencies, states, tribes, and other interested stakeholders. The intent of the UFP is, "...to enhance watershed management for protection of water quality and the aquatic ecosystem health on Federal lands." (Kennedy 1999). This policy , a breakthrough for watershed management as a science and profession in the 21st century, will certainly answer some of the key concerns raised by Rango (1995). Among other things, the UFP is committed to the concept of watershed management, to use watersheds as the management unit for soil and water resources, and to incorporate science in development of management programs. Regarding watershed management, the draft UFP states that:

> (1) "Stream characteristics are a result of the condition of the lands that drain them", (2) "Watershed assessments are necessary to determine existing and potential conditions", (3) "Assessments are used to define management programs for maintenance and improvement of watershed condition", (4) "Resources are focused on identified priority watersheds", (5) "Monitoring is used to measure success of land management prescription", (6) "Watershed management programs must include all owners", and (7) Good watershed conditions are essential for long-term productivity and sustainability of forest and rangeland health."

The original timetable for release of the UFP was December 1999, that may be delayed by the political debates being waged between the Administration and Congress.

The need for cooperation, not rivalry, in international watershed management in the 21st century will become more acute. The English word rival derives from the Latin word that means someone who shares the same stream. However, the English word rival implies that the sharing inherent in the Latin word is really competition. There are 200 basins worldwide that are each shared by at least 2 countries (Simon 1998). Dr. Wally N'Dow, Head of the United Nations Center For Human Settlements, stated in a 1996 interview with Robin Wright of the Los Angeles Times that was quoted by Simon (1998) that:

> "In the past 50 years nations have gone to war over oil. In the next 50 years, we are going to go to war over water. The crisis point is going to be 15 to 20 years from now."

By 2020, over 35 countries in water-short regions are expected to have severe water scarcity problems due to declines in available freshwater per capita. An Associated Press (1995) article quoted in Simon (1998) contained a very telling statement from Ismail Serageldin, World Bank Vice President for Environmentally Sustainable Development. He pointedly noted that:

> "We are warning the world that there is a huge problem (water) looming out there.... The experts all agree on the need to do something

fast. The main problem is the lack of political will to carry out these recommendation."

To avoid ending this paper on a dark note, I will throw out a challenge. Professionals in watershed management need to exhibit leadership and energize the public and the politicians of the 21st century to ensure that future use of water resources is done in the spirit of cooperation and not competition. The importance of watershed management must be clearly identified, widely articulated, and holistically conducted to meet the biological, physical, and social needs of all nations, not just a few powerful ones. Watershed management professionals must examine and answer the 3 questions posed Rango (1995) related to the future of the discipline, training of the next generation of specialists, and the important watershed science areas of emphasis.

Summary

"It always rains after a dry spell."
Marshall Trimble, Arizona Cowboy Folklorist

Over the span of the 20th century, the perception of what constitutes watershed management has grown considerably. At the beginning of the century, watershed management was mostly concerned about the development and maintenance of water supplies. At the end of the century, it is probably best defined in the words of R.J Reimold (1998), "Effective management of a watershed depends on a comprehensive human understanding of the components of watersheds and their interactions." Reimold's (1998) definition also reflects the thinking on the discipline at the end of the 20th century that watershed management incorporates the holistic approach to a watershed as an ecosystem, and not just manipulation of physical processes. The goal of watershed management is to assess the effects of current and future land uses on soil and water resources, determine the potential social and ecological impacts, and provide solutions to watershed problems.

As Rango (1995) pointed out, the increase in the world's human population (now at 6 billion) will cause the demand, scarcity, and price of water to expand on a global scale into the foreseeable future. His forecast is that, in this era of Global Hydrology for watershed management, worldwide emphasis will be placed on large-area assessments using modeling, remote sensing, and watershed management expertise. The technological tools are in place. The key to the future success of these endeavors lies in watershed management expertise and the actions of watershed management professionals.

Acknowledgments

The author wishes to thank Dr. Peter Ffolliott, University of Arizona, and Mr. Keith McLaughlin, USDA Forest Service, for their technical reviews of this paper.

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