Society of Wetland Scientists ~ Western Chapter

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16 April 2003

Ted Rugiel
U.S. Army Corps of Engineers
ATTN: CECW-OR
441 G Street N.W.
Washington D.S. 20314-1000

SUBJECT: **U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers Advance Notice of Proposed Rulemaking EPA Docket # OW-2002-0050; January 15, 2003**

Dear Ms. Downing and Mr. Rugiel:

This letter and the attached comment document are provided as a regional supplement for SWS President Frank Day's comment from the national Society of Wetland Scientists. The intent of this supplement is to amplify upon the relevance of Dr. Day's comments for the importance of isolated wetlands and headwater streams within this Chapter's area of coverage, which includes the states of California, Nevada, and Arizona.

This comment argues for a focus upon wetland functions and values, which are intrinsic ecological properties of wetlands and the benefits that society derives from these wetland properties. The comment also argues for a focus upon "beneficial uses" in relating wetland functions to the waters that are providing the benefits. Beneficial uses describe water-quality elements that are germane to Clean Water Act concerns.

Thank you for providing the opportunity to comment upon this important element of understanding that shapes the regulations that affect a significant component within the landscape of the western states.

Sincerely,

Chad Roberts, Ph.D.
President, Western Chapter
Society of Western Scientists

Western Chapter, Society of Wetland Scientists
Comments Regarding
EPA/Corps Advance Notice of Proposed Rule Making
(68 FR 1991, 15 January 2003)

I. General Comments Regarding Isolated Western Wetlands and Headwater Streams

Aquatic ecosystems are affected by events that occur throughout the landscape, mediated through runoff and changes in hydrology. Small headwaters streams and their tributaries are important elements affecting the physical, biological, and chemical integrity of the waters of the United States. These elements also include seasonal wetlands, which occur extensively in the western United States and provide the wetland functions described below.

These waters fall into two general categories: (1) depressions, swales, playas, and other localized physical features, such as vernal pools, that may in some seasons or under some rainfall conditions lack a direct surface-flow connection to waters that are "navigable," but which are often connected for extended periods to other aquatic ecosystem elements by shallow subsurface flow or by groundwater flow; and (2) ephemeral or intermittent streams, which are often, but not always, located in headwater areas. In both cases, there is a preponderance of evidence that these resources provide ecological functions that benefit the nation's waters at both the site-specific and landscape scales.

Vernal Pools

Vernal pools represent a wetland category that is very important in some western American landscapes, particularly in California. Vernal pools in SWS ~ Western Region states support diverse assemblages of largely endemic and rare species. Although seasonal ponds and pools occur in other regions, the extremes of a short wet season, followed by a long, hot dry season (as well as inter-seasonal variation) have resulted in more than 60 documented endemic species in vernal pools (Baskin 1994). These species are found nowhere except in the vernal pools of California. Consequently, the potential loss of vernal pools in California would constitute an adverse ecological impact at national and international scales.

Species richness in these pools is not correlated with geographic proximity to navigable waters, but with hydroperiod, size, and spatial heterogeneity on the landscape scale. Therefore, the "isolated" nature of these pools is precisely the feature that contributes their ecologically significant role in the bioregion. The seasonal nature of these pools results in relatively unlimited resources being available for pool inhabitants in the short term, internal nutrient recycling, limited predation, and seasonal disturbance that prevents ecological interactions from producing a climax community. The result is a highly specialized, endemic plant and animal community that is found in no other region (King et al. 1996).

Because of the episodic nature of most storm events in the west (particularly in the arid southwest), surface-flow connections between vernal pools (and other seasonal wetlands) and navigable waters may only occur once or a few times in a decade; nevertheless, the persistence of aquatic ecosystem elements may depend on the infrequent periods of hydrological connection. From an ecological standpoint these seasonal wetland elements are critical for the maintenance of the larger aquatic ecosystem's functions. In addition, vernal pools (and other seasonal wetlands) have been documented as providing critical habitat for specific life stages of aquatic-dependent vertebrates, such as amphibians and birds, which are part of the larger regional ecosystem (Whitman 1996).

Ephemeral or Intermittent Headwater Streams

More than 70 percent of the total stream miles in most watersheds consists of headwater streams. In arid and semi-arid landscapes, such as California, Nevada, and Arizona, these headwater swales and streams (i.e., 0-order and 1st-order streams) are often ephemeral or intermittent (i.e., seasonally "isolated" from most navigable waters). These streams are hydrologically linked to navigable waters (via shallow subsurface flow) and may form surface connections during periods of high flow. Furthermore, in arid landscapes the degree of "isolation" varies on a less-than-annual basis. Surface flow fluctuates at inter-annual, seasonal, and daily time scales, depending on antecedent moisture and meteorological conditions (Dietrich and Dunne 1993). Therefore, determining whether these streams are "isolated" from navigable waters is often arbitrary and represents an artificial distinction that is not often supported by scientific data.

Although headwaters streams are individually small, they collectively exert a disproportionately large influence on the overall ecological integrity of a watershed in mediating runoff and sedimentation, assimilating pollutants, and providing carbon for downstream areas (Rheinhardt et al 1999). From a hydrological perspective, loss of headwater streams may result in a dramatic alteration in downstream hydrology (Poff et al. 1997). From a water-quality perspective headwater streams play a critical role in solute and sediment retention (Dieterich and Anderson 1998). Downstream eutrophication may be strongly influenced by the degree to which headwater streams control nitrogen export to the lower watershed (Peterson et al. 2001). From a biological perspective, allochthonous input to isolated headwater areas provides carbon for downstream areas, and supports many primary consumers and other invertebrates that form the base of aquatic and terrestrial food chains (Richardson 1990; Morse et al. 1993; Whiles and Wallace 1997).

II. Comments Regarding Scientific Basis for Evaluating Wetland Functions in Water Quality Assessments

In the following commentary, information is provided regarding *wetland functions* that have been identified for isolated wetlands in recent literature. This comment then presents a discussion of *beneficial uses* that have been identified for waters of the State of California; nearly all of these beneficial uses also apply to waters of the United States in other western states. The commentary then compares wetland functions identified for isolated wetlands with the identified beneficial uses to indicate in a general way the importance of isolated wetlands and headwater ephemeral or intermittent streams for maintaining water-dependent uses in waters of the United States.

The members of the Western Chapter of the Society of Wetland Scientists suggest that focusing on the benefits provided by wetlands and other aquatic ecosystem elements will help to clarify to society the benefits that the Clean Water Act seeks to address. The authors also consider that these relationships are desirable subjects for research activities by federal regulatory agencies (including supporting similar work at a variety of non-federal research entities) because such research should help to clarify the benefits that regulating wetlands provides to society.

A. Overview of Isolated Wetland Functions

(Source: The following text from Tiner and others 2002 is quoted in full for clarity)

"Wetlands provide a host of functions that benefit ecosystems as well as society (see Mitsch and Gosselink 2000). Many of the functions are synergistic in producing services or materials that are valued by people (Table 1). Wetlands largely operate as a holistic or integrated system within a watershed, waterfowl flyway, or ecoregion (Tiner 1998). Individual wetlands working together provide valued functions and the value of a network of wetlands (e.g., within a watershed or flyway) is greater than the sum of its individual parts. A collection of wetlands on the landscape may be the vital ecological unit for some animals, while others require a combination of wetlands and uplands for survival and reproduction.

Table 1. Major wetland functions and some of their values. (Source: Tiner 1998)

Function	Some Values
Water storage	Flood- and storm-damage protection, water source during dry seasons, groundwater recharge, fish and shellfish habitat, water source for fish and wildlife, recreational boating, fishing, shellfishing, waterfowl hunting, livestock watering, ice skating, nature photography, and aesthetic appreciation
Slow water release	Flood-damage protection, maintenance of stream flows, maintenance of fresh and saltwater balance in estuaries, linkages with watersheds for wildlife and water-based processes, nutrient transport, and recreational boating
Nutrient retention and cycling	Water-quality renovation, peat deposits, increases in plant productivity and aquatic productivity, decreases in eutrophication, pollutant abatement, global cycling of nitrogen, sulfur, methane, and carbon dioxide, reduction of harmful sulfates, production of methane to maintain Earth's protective ozone layer, and mining (peat and limestone)
Sediment retention	Water-quality renovation, reduction of sedimentation of waterways, and pollution abatement (retention of contaminants)
Substrate for plants and animals	Shoreline stabilization, reduction of flood crests and water's erosive potential, plant-biomass productivity, peat deposits, organic export, fish and wildlife habitats (specialized animals, including rare and endangered species), aquatic productivity, trapping, hunting, fishing, nature observation, production of timber and other natural commodities, livestock grazing, scientific study, environmental education, nature photography, and aesthetic appreciation

"The following discussion is a brief overview of some of the functions of isolated wetlands. It is not intended to be exhaustive, but is designed to acquaint readers with the potential roles isolated wetlands play.

"<u>Water Storage</u>

"Depressional wetlands, whether isolated or not, store precipitation that could otherwise rapidly flow downstream, creating potential flooding of low-lying areas. Since isolated basins have no natural outlets, all water entering them is retained (including groundwater recharge). This is valuable for flood reduction, since such water does not contribute to local or regional flooding (Carter 1996). When an area contains thousands of isolated depressional wetlands, the surface water storage capacity can be enormous. For example, pothole wetlands in North Dakota's Devils Lake Basin can store as much as 72 percent of the total runoff from a 2-year frequency storm and about 41 percent from a 100-year storm (Ludden et al. 1983). In many cases, this water storage function facilitates an isolated wetland's potential role in groundwater recharge and streamflow maintenance (through contribution to regional groundwater supplies) and at the same time, provides valuable waterfowl and waterbird habitat. The multiple benefits of temporary water storage are considerable.

"By holding water for long periods, isolated wetlands serve as water sources that benefit fish and wildlife, domestic livestock, and people. An abundance of water creates wetland habitats for native fish and wildlife that provide recreational opportunities for many people (e.g., hunting and fishing) and help support local economies. Isolated wetlands within rangeland are often used as watering holes for livestock, while similar wetlands in agricultural settings may serve as sources of irrigation water. These two uses can have adverse effects on wildlife and the habitat quality of these wetlands. The wettest of isolated wetlands may provide fish habitat that may be a valuable resource for local landowners. Recreational fishing and commercial harvest of fish may take place in some isolated wetlands. For example, fathead minnows are caught in Minnesota potholes and sold as baitfish (Hubbard 1988).

"<u>Slow Water Release</u>

"Many wetlands that appear isolated from surface waters are actually vital components of regional water systems, since they contribute to local and regional aquifers (Stone and Lindley Stone 1994). Isolated wetlands hold water until it is removed by evapotranspiration, seepage (percolation contributing to groundwater supplies), irrigation devices, or drainage structures. During extreme high water events, for example, water-filled isolated basins often contribute to groundwater supplies (including regional aquifers) as water enters more permeable adjacent soils and moves downward to underlying aquifers. Such groundwater may flow laterally to contribute to streamflow critical for supporting aquatic life and their respective ecosystems. Playa lakes are major recharge sites in the Southern High Plains (Wood and Osterkamp 1984 as reported in Carter 1996).

"<u>Nutrient Retention and Cycling</u>

"The role of wetlands in nutrient retention and cycling is well known. Wetlands can be sources, sinks, or transformers of chemicals and the range of hydrologies creating and maintaining wetlands has a great impact on biogeochemical processes. Mitsch and Gosselink (2000) reference numerous examples of wetlands serving as sinks for a host of chemicals and summarize various applications of constructed wetlands for wastewater treatment. Two potentially isolated wetland types - ombrotrophic bogs and cypress domes - are cited as natural wetlands that are biogeochemically closed systems which recycle nutrients internally (i.e., intrasystem cycling). These and other isolated wetlands should retain most of the chemicals entering them from surrounding areas and, therefore, appear to serve as sinks for a variety of chemicals. Because of these properties, artificial wetlands are purposely constructed to treat wastewater of various kinds (e.g., municipal wastewater, mine drainage runoff, stormwater and nonsource pollution, landfill leachate, and agricultural wastewater) and improve water quality (Mitsch and Gosselink 2000).

"<u>Sediment Retention</u>

"Isolated depressional wetlands are sediment traps. Given their landform and landscape position, they should retain all sediments and other particulates entering them. In fact, the volume of many such wetlands is reduced over time due to this process, especially in agricultural areas. Luo and others (1999) reported on sediment deposition in playa wetlands. Most of these sediments are water-borne materials originating from local watersheds. Coarser materials settle out first, so sand content is higher at the margins of playas, while finer particles are carried further and settle out near the center of the basins where clay content is greater.

"**Substrate for Plants and Animals**

"Wetlands provide substrates that support plant growth and colonization by thousands of animals ranging from microscopic invertebrates to large vertebrates. By doing this, wetlands provide habitat for plants and animals. The variety of wetland types is a major contributor to the Nation's biodiversity (see Tiner 1999 for examples of wetland plant communities).

"From an ecological standpoint, isolated wetlands are among the country's most significant biological resources. In some areas, isolation has led to the evolution of endemic species vital for the conservation of biodiversity. In other cases, their isolation and sheer numbers in a given locality have made these wetlands crucial habitats for amphibian breeding and survival (e.g., woodland vernal pools and cypress domes) or for waterfowl and waterbird breeding (e.g., potholes). In arid and semi-arid regions, many isolated wetlands are veritable oases – watering places and habitats vital to many wildlife that use them for breeding, feeding, and resting, or for their primary residence. Many of these wetlands may be small in size, but their value to wildlife is far greater than their size alone would suggest.

"The high density of isolated marshes and wet meadows has made the Prairie Pothole Region, North America's leading waterfowl production area. This region produces half of the continent's waterfowl in an average year (Smith et al. 1964). Forty-one percent of the continent's breeding dabbling ducks use this area (Bellrose 1979). Macroinvertebrates produced by the pothole marshes are a protein-rich food source required by nesting hens (Hubbard 1988).

"Regions with a high density of isolated wetlands may provide a series of "stepping stones" for migrating waterfowl and waterbirds. For example, isolated wetlands east of the Rocky Mountains provide feeding and resting areas for millions of birds that overwinter along the Gulf Coast and migrate to northern breeding grounds. These wetlands produce an abundance of macroinvertebrates and plant life – nourishment required by these species to successfully make the migratory journey essential for maintaining their populations. Playas may be important intermediate stopover sites for migrating shorebirds (Davis and Smith 1998), while Rainwater Basin wetlands are stopover areas for millions of birds. Nearly all of the midcontinental population of greater white-fronted goose (*Anser albifrons*) stage in the Rainwater Basin every year (U.S. Fish and Wildlife Service 1985).

"A high density of small wetlands is also vital for other animals. Semlitsch and Bodie (1998) described the importance of small wetlands to amphibians. The abundance of small isolated wetlands supports a diverse assemblage of amphibian species, produces large numbers of juveniles (necessary to maintain populations), and serves as "stepping stones" to aid in dispersal and recolonization of suitable habitats (Semlitsch 2000). Local populations of wetland-dependent organisms are vulnerable to extinction due to several factors including natural events (e.g., prolonged droughts and changing vegetation), disease, inbreeding, and habitat destruction. A study of wetlands in central Maine by Gibbs (1993) suggests that a high number of small wetlands increases the number of sources of potential colonists for wetlands that have lost populations due to chance extinction. The presence of a high number of small wetlands therefore increases the chances of survival of local populations over time.

"Reducing the number of small wetlands in a given area increases overland migration distances and exposure of migrants (e.g., salamanders) to predators. This may place local populations at the risk of extinction. For example, Semlitsch and Bodie (1998) found that eliminating all natural wetlands less than 10 acres in size (in a South Carolina study area) would increase the nearest-wetland distance from 1,570 feet to 5,443 feet – a distance that would take most amphibian species several generations or more to travel. This type of loss would increase the probability of local population extinction for some amphibians.

"Isolated wetlands with fluctuating water levels provide unique habitats for certain species, especially those that are vulnerable to fish predation. Much of the value of woodland vernal pools to amphibians is due to the absence of fish, which cannot survive periodic drawdowns. The presence of fish would eliminate or severely reduce the reproductive success of amphibians that breed in these pools.

"Isolation and periodic drawdowns also promote endemism - the development of unique species. Increased number of species adds to the country's biological richness. Some examples of wetlands that are particularly important in this regard are West Coast vernal pools, desert spring wetlands, and Coastal Plain ponds."

Additional considerations of the relationships among wetland functions may be found in Schneider and Sprecher (2000). The source of this reference (an Army Corps publication focused upon managing Corps facilities) would appear to indicate an adoption by the federal agencies charged with carrying out the Clean Water Act's requirements with the concepts described by Tiner and others (2002) and the understanding of wetland functions in the scientific literature.

B. Beneficial Uses

Water quality is regulated in the State of California by a state law known as the Porter-Cologne Water Quality Act (California Water Code, Division 7). This law was written at the same time and in conjunction with the federal Clean Water Act, and was intended by the State to be the implementing legislation for the Clean Water Act. In consequence, the regulatory framework of the Porter-Cologne Act addresses the requirements of the Clean Water Act.

A primary element of the Porter-Cologne Act is the *beneficial uses* established in the Act. These uses constitute the primary purposes for which water quality is regulated in this state and the purposes to which water may be applied in the state. As will be noted in the following section, the direct and indirect relationships that occur between water quality and isolated wetlands and headwaters streams may be portrayed effectively by focusing comments in the beneficial uses of these waters.

Municipal and Domestic Supply (MUN) - Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Agricultural Supply (AGR) - Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

Industrial Service Supply (IND) - Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.

Industrial Process Supply (PROC) - Uses of water for industrial activities that depend primarily on water quality.

Groundwater Recharge (GWR) - Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Freshwater Replenishment (FRSH) - Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

Navigation (NAV) - Uses of water for shipping, travel, or other transportation by private, military or commercial vessels.

Hydropower Generation (POW) - Uses of water for hydropower generation.

Water Contact Recreation (REC-1) - Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white-water activities, fishing, or use of natural hot springs.

Non-Contact Water Recreation (REC-2) - Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Commercial and Sport Fishing (COMM) - Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Aquaculture (AQUA) - Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Warm Freshwater Habitat (WARM) - Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Cold Freshwater Habitat (COLD) - Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Inland Saline Water Habitat (SAL) - Uses of water that support inland saline water ecosystems including, but not limited to, preservation or enhancement of aquatic saline habitats, vegetation, fish, or wildlife, including invertebrates.

Estuarine Habitat (EST) - Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Marine Habitat (MAR) - Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

Wildlife Habitat (WILD) - Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Preservation of Areas of Special Biological Significance (BIOL) - Includes marine life refuges, ecological reserves and designated areas of special biological significance, such as areas where kelp propagation and maintenance are features of the marine environment requiring special protection.

Rare, Threatened, or Endangered Species (RARE) - Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.

Migration of Aquatic Organisms (MIGR) - Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

Spawning, Reproduction, and/or Early Development (SPWN) - Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Shellfish Harvesting (SHELL) - Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.

C. Wetland Functions and Beneficial Uses

Wetlands and ephemeral/intermittent streams occurring in the parts of watersheds that are remote from traditional navigable waters play important roles in maintaining the physical, biological, and chemical integrity of those watersheds. These roles are mediated through temporary water storage that is associated with infiltration to the subsurface, filtration and sediment/toxicant removal, exported biological productivity, and long-term and short-term habitat provision for aquatic and terrestrial organisms. The relationships among these wetlands and stream elements are summarized in Table 2, with the benefits provided by the wetlands and stream elements expressed in terms of the beneficial uses identified pursuant to the Porter-Cologne Act (used here in a generic sense as indications of beneficial uses that are provided by similar aquatic ecosystem elements in other western states).

Table 2. Wetland Functions of Headwaters Wetlands and Streams and Related Beneficial Uses

Function	Related Beneficial Uses Provided by Headwaters Wetlands and Ephemeral/Intermittent Streams
Water storage	Municipal and Domestic Supply (MUN); Agricultural Supply (AGR); Groundwater Recharge (GWR); Freshwater Replenishment (FRSH)
Slow water release	Municipal and Domestic Supply (MUN); Agricultural Supply (AGR); Groundwater Recharge (GWR); Freshwater Replenishment (FRSH); Water Contact Recreation (REC-1); Non-Contact Water Recreation (REC-2); Warm Freshwater Habitat (WARM); Cold Freshwater Habitat (COLD); Inland Saline Water Habitat (SAL); Migration of Aquatic Organisms (MIGR); Spawning, Reproduction and/or Early Development (SPWN)
Nutrient retention and cycling	Warm Freshwater Habitat (WARM); Cold Freshwater Habitat

Function	Related Beneficial Uses Provided by Headwaters Wetlands and Ephemeral/Intermittent Streams
	(COLD); Inland Saline Water Habitat (SAL); Wildlife Habitat (WILD); Preservation of Areas of Special Biological Significance (BIOL); Rare, Threatened, or Endangered Species (RARE)
Sediment/toxicant retention	Municipal and Domestic Supply (MUN); Agricultural Supply (AGR); Industrial Process Supply (PROC); Water Contact Recreation (REC-1); Non-Contact Water Recreation (REC-2)
Substrate for plants and animals	Freshwater Replenishment (FRSH); Warm Freshwater Habitat (WARM); Cold Freshwater Habitat (COLD); Inland Saline Water Habitat (SAL); Wildlife Habitat (WILD); Preservation of Areas of Special Biological Significance (BIOL); Rare, Threatened, or Endangered Species (RARE); Migration of Aquatic Organisms (MIGR); Spawning, Reproduction and/or Early Development (SPWN)

Many of the benefits provided for the identified beneficial uses are *indirect*. The positions of these wetlands and stream elements in the most remote parts of watersheds allow the wetlands and streams to affect water quality and hydrological processes where the effects are environmentally beneficial, while contributing to reducing potential cumulative effects on the same water quality and hydrological processes that occur downstream. The absence of the benefits in the headwaters could be associated with potentially significant adverse effects lower in the watersheds.

Many of the benefits are, however, provided directly and at the locations of the headwaters wetlands and streams, particularly those related to habitat uses. For these uses the headwaters wetlands and streams form parts of an interconnected habitat matrix that extends from traditionally navigable waters to the most remote parts of the watersheds.

D. Conclusion

The information summarized above indicates that wetlands and stream elements that may only be present for limited periods play important roles in the aquatic ecosystem processes in the western United States, particularly in California. Maintaining the physical, biological, and chemical integrity of these watersheds requires that these remote wetland and stream elements be considered as essential elements of these aquatic ecosystems.

III. References

Adamus, P. R., Stockwell, L. T., Clairain, E. J., Jr., Morrow, M. E., Rozas, L. P., and Smith, R. D. 1991. Wetland evaluation technique (WET) Vol. 1: Literature review and evaluation rationale, Technical Report WRP-DE-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Carter, V. 1996. Wetland hydrology, water quality, and associated functions. In: J.D. Fretwell, J.S. Williams, and P.J. Redman (compilers). National Water Summary on Wetland Resources. U.S. Geological Survey, Reston, VA. Water-Supply Paper 2425, pp. 35-48.

Baskin, Y. 1994. California's Ephemeral Vernal Pools May be a Good Model for Speciation. *BioScience*, 44:384-388.

Bellrose, F.C. 1979. Species distribution, habitats, and characteristics of breeding dabbling ducks in North America. In: T.A. Bookhout (editor). Waterfowl and Wetlands – An Integrated Review. Proceedings of a symposium, 39th Midwest Fish and Wildlife Conference (December 5, 1977), Madison, WI. LaCrosse Printing Company, Inc., LaCrosse, WI.

Davis, C.A. and L.M. Smith. 1998. Behavior of migrant shorebirds in playas of the Southern High Plains, Texas. The Condor 100: 266-276.

Dieterich, M. and N.H. Anderson. 1998. Dynamics of Abiotic Parameters, Solute Removal and Sediment Retention in Summer-Dry Headwater Streams of Western Oregon. *Hydrobiologia*, 379:1-15.

Dietrich, W.E, and T. Dunne. 1993. The Channel Head, in *Channel Network Hydrology*, K. Beven and M.J. Kirkby (eds.). John Wiley and Sons, New York, pp. 175-221.

Hubbard, D.E. 1988. Glaciated Prairie Wetland Functions and Values: A Synthesis of the Literature. U.S. Fish and Wildlife Service, Washington, D.C. Biol. Rep. 88 (43).

King, J.L., M.A. Simovich, and R.C. Brusca. 1996. Species Richness, Endemism, and Ecology of Crustacean Assemblages in Northern California Vernal Pools. *Hydrobiologia*, 328:85-116.

Ludden, A.P., D.L. Frink, and D.H. Johnson. 1983. Water storage capacity of natural wetland depressions in the Devils Lake basin of North Dakota. J. Soil and Water Conserv. 38: 45-48.

Luo, H-R, L.M. Smith, D.A. Haukos, and B.L. Allen. 1999. Sources of recently deposited sediments in playa wetlands. Wetlands 19(1): 176-181.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands, Third Edition. John Wiley & Sons, Inc., New York, NY.

Morse, J.C., B.P. Stark, and W.P. McCafferty. 1993. Southern Appalachian Streams at Risk: Implications for Mayflies, Stoneflies, Caddisflies, and other Aquatic Biota. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 3:293-303.

Peterson, B.J., W.M. Woheim, P.L. Mulholland, J.R. Webster, J.L. Meyer, J.L. Tank, E. Marti, W.B. Bowden, W.M. Valett, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton, S. Gregory, and D.D. Morrall. 2001. Control of Nitrogen Export from Watersheds by Headwater Streams. *Science* 292:86-90.

Poff, N.L., J.D. Allan, and M.B. Bain. 1997. The Natural Flow Regime. *BioScience*, 47:769-784.

Rheinhardt, R., M. Rheinhardt, M. Brinson and K. Fraser. 1999. Application of reference data for assessing and restoring headwater ecosystems. *Restoration Ecology* 7:241-251.

Richardson, W.B. 1990. A Comparison of Detritus Processing Between Permanent and Intermittent Headwater Streams. *Journal of Freshwater Ecology*, 5:341-357.

Schneider, C., and Sprecher, S. W. 2000. Wetlands management handbook, ERDC/EL SR-00-16, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Semlitsch, R.D. and J.R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12: 1129-1133.

Smith, A.G., J.H. Stoudt, and J.B. Gollop. 1964. Prairie potholes and marshes. In: J.P. Linduska (editor). Waterfowl Tomorrow. U.S. Fish and Wildlife Service, Washington, D.C. pp. 39-50.

Stone, A.W. and A.J. Lindley Stone. 1994. Wetlands and Ground Water in the United States. The American Ground Water Trust, Dublin, OH.

Tiner, R.W. 1998. In Search of Swampland: A Wetland Sourcebook and Field Guide. Rutgers University Press, New Brunswick, NJ.

Tiner, R.W., H. C. Bergquist, G. P. DeAlessio, and M. J. Starr. 2002. Geographically Isolated Wetlands: A Preliminary Assessment of their Characteristics and Status in Selected Areas of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Northeast Region, Hadley, MA.

U.S. Fish and Wildlife Service. 1985. Rainwater Basin Fact Sheet. Ecological Services, Grand Island, NE.

Whiles, M.R. and Wallace, J.B. 1997. Leaf Litter Decomposition and Macroinvertebrate Communities in Headwater Streams Draining Pine and Hardwood Catchments. *Hydrobiologia*, 353:107-119.

Whitman, C.W. 1996. Ecology, Conservation, and Management of Vernal Pool Ecosystems: Proceedings form a 1996 Conference. California Native Plant Society, Sacramento, California.

Wood, W.W. and W.R. Osterkamp. 1984. Recharge to the Ogallala aquifer from Playa Lake Basin on the Llano Estacado. In: G.A. Wetstone (editor). Ogallala Aquifer Symposium II, Lubbock, TX. Proceedings, pp. 337-349.