California Wetland and Riparian Area Protection Policy

Technical Advisory Team
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Technical Memorandum No. 3: Landscape Framework for Wetlands and Other Aquatic Areas

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1.0 Purpose

This is the third in a series of technical memoranda submitted by the Technical Advisory Team (TAT) to the Policy Development Team (PDT) for the California Wetland and Riparian Area Protection Policy (WRAPP). The first memorandum describes the TAT, including why and how it was formed, its membership, and its workplan. The second memorandum presents the technical wetland definition recommended by the TAT (TAT 2012a). The purpose of this third memorandum is to describe California wetlands in the context of their landscapes and watersheds. It addresses questions about the relationships between wetlands and other landscape features that were raised by the PDT during its review of the TAT's recommended wetland definition. It also provides a general scientific framework for planning, managing, and assessing wetlands in the landscape and watershed contexts.

The TAT reserves the opportunity to revise its memoranda as necessary to make sure they are consistent with the current status of wetland science and that they meet the needs of the PDT for technical information and advice.

2.0 Landscape Framework

2.1 Overview

Wetlands do not exist in isolation. Natural hydrological and ecological processes connect wetlands to nearby and distant areas. Wildlife provide the most far reaching connections. For example, hundreds of species of birds that migrate along the Pacific Flyway connect California wetlands to other U.S. States, western Canada, and Central America (Pacific Flyway Study Committee 1982, Shufford et al. 1998, 2002; Silveira 1998, Page et al. 1999, USDA 2001, Green et al. 2003). Wetlands also support migratory fishes, including steelhead and salmon (Shreffler et al. 1992, Sommer et al. 2005, Jeffres et al. 2008, Hering et al. 2010, USFWS 2010). These fishes connect California wetlands to near-shore ecosystems of the Pacific Ocean (Augerot 2005). Many species of wildlife that migrate to and from California wetlands are protected by U.S. and California State laws and international treaties (e.g., U.S. Endangered Species Act, California Endangered Species Act, California Fish and Game Code §§355-357, 1918 Migratory Bird Treaty Act, 2000 Neotropical Migratory Bird Conservation Act). The TAT recommends that the PDT consider how the WRAPP might support existing efforts to protect anadromous fishes and other migratory wildlife that connect California's wetlands to areas outside the State.

However, this memorandum is focused on the connectivity between wetlands and their immediate landscapes and watersheds. This is because most of the highly valued functions of wetlands (i.e., their beneficial uses as defined by the California Water Quality Control Act) depend on their hydrological and ecological connectivity to nearby areas. For example, flood hazards can be reduced by routing flood waters through wetlands (De Laney 1995, FIFM 1996, Mitsch and Gosselink 2000, Kusler 2011). Flooded wetlands with permeable substrate can help recharge aquifers (van der Kamp and Hayashi 1998, Kent 2000). The quality of urban and agricultural surface runoff can be improved by filtering it through wetlands (Chescheir et al. 1991, Moshiri 1993, Cooper et al. 1997, Lowrance et al. 1997, Kadlec and Wallace 2008). The ability of wetlands to provide breeding habitat for amphibians (e.g., Mazerolle 2005) and drinking water for terrestrial mammals (e.g., Perault and Lomolino 2000) requires corridors for their safe movement between wetlands and other landscape areas (Bennett 2003). The TAT recommends that the PDT incorporate a watershed or comparable landscape focus in the WRAPP to help assure that it addresses the site-specific and cumulative effects of climate, geology, and land use on the distribution, abundance, form, and local functions of wetlands.

The TAT will address the watershed context for wetland assessment in a separate memorandum. At this time, the TAT has developed a framework for identifying and interpreting the functions of wetlands in the local landscape and watershed contexts. The framework is based on a set of criteria intended to preserve the conventional definitions of landscape and watershed while being consistent with the recommended wetland definition (TAT 2010a).

Criteria for Framing Wetlands in the Watershed Context

The framework should support implementation of the Wetland and Riparian Area Protection Policy (WRAPP). To meet this objective, the framework should:

- be consistent with the recommended wetland definition;
- help identify sources and pathways for movements of water, sediment, chemicals, and wildlife into and through wetlands and other areas within watersheds; and
- help assess the cumulative effects of climate change and wetland policies, programs, and projects on the conditions, functions, services, and beneficial uses of wetlands in the watershed context.

2.2 Landscape Moisture Gradients

The criteria for framing wetlands in the watershed context are met by considering wetlands as integral parts of landscape moisture gradients that form within watersheds (Figure 1).

For the purposes of this memorandum, a watershed is defined as all the lands and waters that drain to a common place. This is consistent with most watershed definitions that similarly restate the basic concept that every place has a certain area of land draining to it (e.g., Langbein and Iseri 1960, FISRWG 2001, USEPA 2009). Catchment, catchment area, catchment basin, drainage basin, and drainage area are watershed synonyms.

According to this framework, wetlands are particular areas along landscape moisture gradients (Brinson 1993). The location, extent, and timing of the gradients are controlled by watershed geology and hydrology, as affected by climate and land use (Figure 1). This framework regards landscape moisture gradients as primary pathways of material and energy transfer between wetlands and other landscape areas within watersheds. It emphasizes the role of hydrology in controlling wetland form and function, and therefore helps link wetland protection to watershed management for flood control, water supplies, aquatic habitat, and water quality improvement (Winter 1988, ICCMA 1999, USEPA 2000, Brooks et al. 2004, Thomas and Lamb 2005).

Visualizing wetlands in the context of landscape moisture gradients requires an operational definition of landscapes. Unlike watersheds, landscapes do not have self-evident boundaries. The term, landscape, comes from the Dutch word "landschap" (www.etymonline.com). It originally referred to a tract of land with distinguishing characteristics. Through its usage by Dutch painters and writers in the 16th century, landscape became synonymous with scenery. Landscape came to mean an arrangement of landforms or features, each of which a person could walk around or through, and that could be portrayed together from a single vantage point.

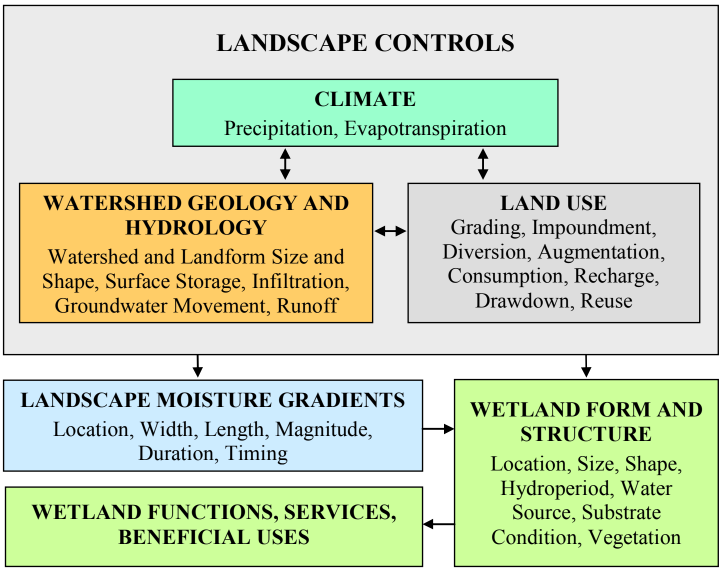

Figure 1: Landscape framework for interpreting wetland functions, services, and beneficial uses in the context of landscape moisture gradients that form within watersheds.

Advances in environmental science and technology have influenced the use and meaning of the landscape concept. Aerial and satellite imagery have elevated our vantage point, expanded our field of view, and increased the geographic scope of landscape analyses. They now range in scope from a few square kilometers to entire continents (Forman and Godron 1986, Forman 1995, International Association for Landscape Ecology 2009).

This memorandum is concerned with landscapes that exist within watersheds. These landscapes usually consist of multiple landforms, such as valleys, alluvial fans, and hillsides, entirely or in part (European Commission 2000, Burel and Baudry 2003). Such landscapes have been intensively studied in terms of their resiliency (Turner et al. 2001), resistance to stress (Forman and Godron 1986), and ecological function (e.g., Naveh and Lieberman 1984, McDonnell et al. 1997, Blaschke 2006, Otte et al. 2007, Vandermeer and Lin 2008, Lovell and Johnston 2009).

Landscape moisture gradients extend between wet and dry areas involving one or more landforms. In most cases, the moisture originates as precipitation within the watershed, including rain, snow, sleet, hail, frost, dew, and fog drip. Some precipitation is intercepted by vegetation or other land cover and evaporates before reaching the ground. Precipitation that reaches the ground can evaporate, infiltrate, be detained on the land surface, be taken up and transpired or respired by plants and animals, or flow downhill above or below ground (Thornthwaite 1948, Fetter 1994). Some surface runoff occurs when the rate of precipitation exceeds the rate of infiltration. This is called Hortonian overland flow (Horton 1933, 1940) or unsaturated overland flow (Charlton 2007). It commonly occurs where infiltration is naturally or artificially inhibited. Precipitation on saturated substrate causes saturated overland flow (Charlton 2007). This commonly happens in areas with permeable substrate. Surface runoff can be reduced by detention, evapotranspiration, uptake by organisms, and run-on (the infiltration of surface runoff as it flows overland). Water that infiltrates the ground can move downhill through the unsaturated upper substrate or vadose zone as interflow (Beven 1989, Stephens 1996), or it can infiltrate deeper and raise the water table. Underground flow may return to the surface within a channel, wetland, or other aquatic area as groundwater discharge (Flugel and Smith 1998), which is also termed groundwater discharge. Groundwater, interflow, groundwater discharge, surface runoff, and streamflow are intimately related to each other and can be considered as different aspects of a single water source in the hydrologic landscape (Winter et al. 1998, Winter 2001). These processes of water movement through a watershed create and maintain landscape moisture gradients (Figure 2).

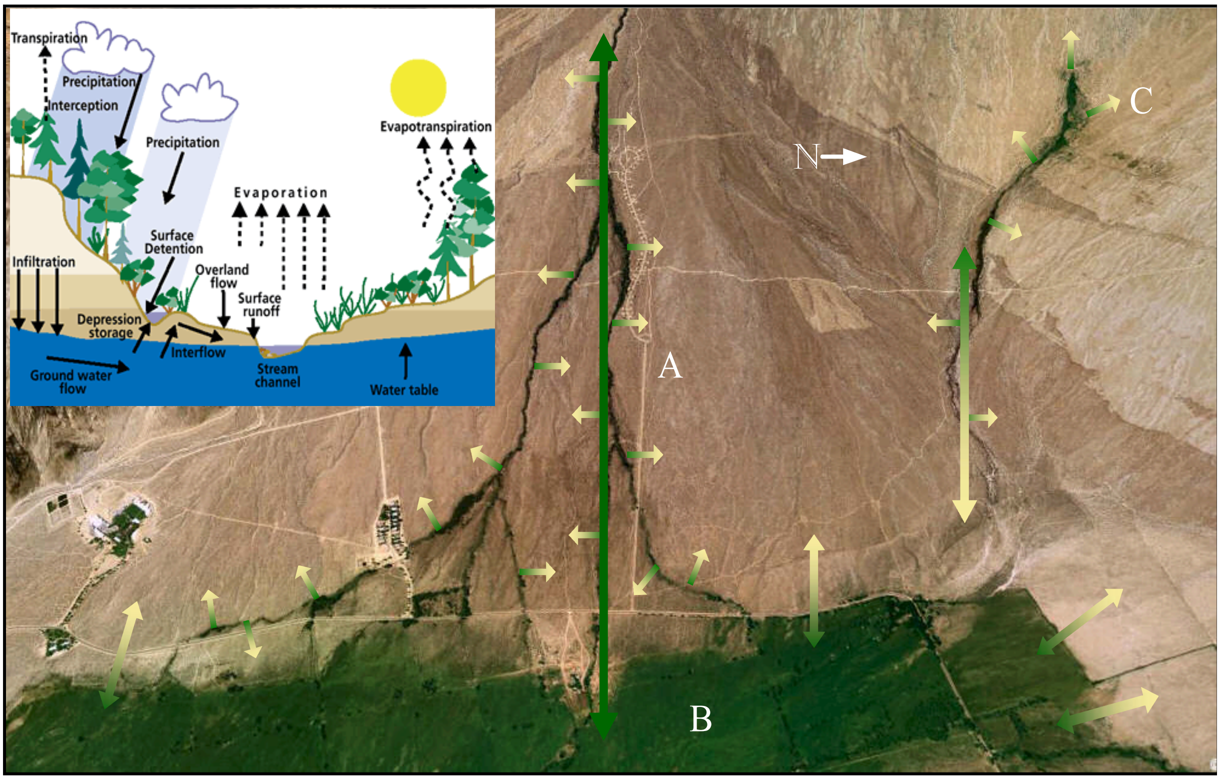

Figure 2: Diagram of hydrological processes of watersheds (inset) and photographic example of landscape moisture gradients extending vertically along drainage networks and horizontally away from them. Photo is centered on an alluvial fan (A) on east side of Sierra Nevada south of Mono Lake. Green areas in photo are wetter. The drainage network on the fan has sufficient flow to support wetlands within its active channels, even as they divide repeatedly toward the fan base. Moisture changes little downstream in these channels leading to a wetland (B) formed by the accumulation of runoff and groundwater discharge at the base of the fan. Gradients extend upslope from the interior of this wetland into the adjacent uplands. The wet channel on the right side of the photo emanates from a spring on the hillside north of the fan (C). Discharge from this spring does not reach the fan base as surface flow; moisture decreases downstream in this channel. Moisture gradients extend laterally away from the wet channels and onto the dry fan surface. The wetland at the base of the fan is contiguous with the in-channel wetlands on the fan, but disconnected from the wetlands in the spring-fed channel. Ditches that capture and direct runoff can be seen in and around the wetland at the base of the fan.

Precipitation is not necessarily the only source of water in a watershed. Water can be unnaturally transferred from one watershed to another to support agriculture, industry, and domestic uses. Such inter-basin transfers can impact the landscape moisture gradients of both the source watersheds and the receiving watersheds by altering their drainage regimes.

A drainage network is a system of hydrologically interconnected channels, seeps, wetlands, lakes, and other aquatic areas that account for the storage and conveyance of surface runoff, interflow, groundwater discharge, and groundwater in a watershed (Dunne and Leopold 1978). The connections can be due to surface or subsurface hydrology (Winter et al 1998, Lewis 1995, Fennessy 1997, Zeeb and Hemond 1998). Drainage networks provide the skeletal structure of landscape moisture gradients (Winter 2001). The gradients extend along the networks and laterally away from the networks (Figure 2). The different kinds of surface runoff and groundwater movement that create and sustain the gradients vary in their relative importance throughout a drainage network.

Not all wetlands or other aquatic areas are hydrologically connected to drainage networks. For example, artificial ponds that get all of their water as direct precipitation, that are sealed to prevent infiltration or leakage, and that are seldom if ever overfilled have essentially no surface or subsurface hydrological connection to their surroundings. Such areas are hydrologically isolated (Winter and LaBaugh 2003, Comer et al. 2006). Wetlands that are completely surrounded by uplands but remain hydrologically connected to their landscapes through groundwater flow are geographically isolated (Tiner et al. 2002, Tiner 2003). Many wetlands are geographically isolated, without evident surface connections to other water bodies, while remaining connected to their landscapes through groundwater. Examples include prairie potholes (LaBaugh et al. 1998, van der Kamp and Hayashi 1998), and other kinds of topographic depressions that intercept groundwater (Wiedemann 1984, Bauder and McMillan 1998, Brooks and Hayashi 2002, Brooks 2005, Ward et al. 2002, Stroh et al. 2008). California vernal pools are hydrologically supported by a combination of surface flow and groundwater flow (Hanes and Stromberg 1998, Bauder 2005, Rains et al. 2006). Such wetlands typically have important hydrological functions in the watershed context (Tiner et al. 2002, McKinney and Charpentier 2008). For example, they can store water that would otherwise enter the network as surface runoff, and thereby reduce downstream flow heights and volumes (Reid 1993; McAllister et al. 2000).

Wetlands that are hydrologically or geographically isolated can nevertheless be interconnected to other landscape areas by ecological processes. For example, wildlife moves to and from wetlands to forage, breed, and take refuge during dispersal or migration (e.g., Batt et al. 1989, Yerkes 2000, Semlitsch 2000, Gibbons 2003, Leibowitz 2003). Wetland plant species are dispersed among such wetlands by wind (Johnson et al. 1981) and by wildlife (Amezaga et al. 2002, Bacles et al. 2006, Chanpen et al 2008). In desert watersheds, isolated springs can be the only sources of water for terrestrial wildlife (Frazier 1977, Shepard 1993, Laudenslayer (http://www.dfg.ca.gov/biogeodata/cwhr/). Although some kinds of wetlands, most notably vernal pools, have distinctive endemic flora and fauna (Hoover 1937, Thorp 1976, King et al. 1996, Liebowitz 2003), there is remarkable similarity in species composition among geographically isolated wetlands of any given kind within large regions of the State. This indicates that the endemic species are able to disperse among widely separated wetlands. While some vernal pools are among the most hydrologically and geographically isolated wetlands in the U.S., they are clearly ecologically connected to each other and to other aquatic areas.

Landscape moisture gradients change over time. Every California watershed experiences seasonal, annual, and longer-term variability in precipitation. This variability, measured as percent change from long term averages, is lesser in the wetter northwest regions of the State than the drier southeast. However, most of the State is arid or semi-arid (Hancock et al 2004, Hidalgo et al. 2005), meaning that evapotranspiration tends to exceed precipitation. As a result, landscape moisture gradients tend to be very sensitive to the temporal variability in precipitation that typifies most of California. A landscape moisture gradient might expand or become wetter overall during relatively wet periods, and contract or become less wet overall during dry periods.

Landscape moisture gradients also vary within and among watersheds. In wetter watersheds, surface runoff and groundwater discharges tend to increase downstream, and floodplains and terraces (i.e., abandoned floodplains) exhibit increased surface and subsurface hydrological connectivity (Winter et al. 1998, Tockner et al. 2000, Amoros and Bornette 2002, Ward et al. 2002). The wetter watersheds tend to have more wetlands in their lower reaches. For example, low-elevation valleys in the Sierra Nevada and the Northern Coast Ranges were historically perennially wet (WRC 1996, Dull 1999, Grossinger et al. 2007) due to very high water tables and abundant groundwater discharge. In drier watersheds, perennial flow in steep, headwater channels can transition downstream to ephemeral flow across porous, low-gradient, alluvial fans. Wetlands tend to form in the upper and middle reaches of these watersheds, especially in channels where flow becomes seasonal, and along the toes of fans where groundwater discharges are adequate (see Figure 2). However, some large arid watersheds drain to playas in terminal basins and therefore have more wetlands in their lowermost reaches. Landscape moisture gradients that follow topographic slopes do not necessarily get wetter downhill. For example, springs and seeps, cirque lakes, and Sierran glaciers can serve as uphill sources of moisture for gradients that get drier downhill.

Wetlands have internal moisture gradients extending from areas that are wetter longer or wetter more often to areas that tend to be somewhat drier. In sloping wetlands (e.g., wetlands supported by interflow on hillsides), the wetter areas are usually closer to the water source (i.e., closer to the wetter, uphill end of the landscape moisture gradient). In depressional wetlands (e.g., sag ponds, vernal pools, and other wetlands that form in topographic depressions), the wetter areas are topographic lows where precipitation, surface runoff, and groundwater discharges accumulate, or where the ground surface or root zone intercepts groundwater. The moisture gradients within wetlands (like the landscape moisture gradients of which the wetlands are an integral part) are sensitive to changes in water supply. For example, the fringing area of wetland vegetation along a riverbank or lakeshore might narrow during droughts, when river flows decrease and lake levels drop. Conversely, it might widen during very wet years, due to river flooding, rising lake levels, elevated groundwater, and increased groundwater discharges near the river banks and lakeshore. This does not necessarily mean that the wetland, as defined by the TAT, gets smaller or larger, only that the clarity of wetland indicators, including the distribution, abundance, or vigor of wetland vegetation, might vary with changes in water supply (TAT 2010b). Such changes in moisture gradients, as affected by changes in water supply, are reflected

by changes in the distribution and abundance of wetland wildlife (Parker 1982, Nemani and Running 1989, Andersson and Sivertun 1991, Iverson and Anantha 2003).
The spatial and temporal variability in moisture gradients within wetlands and at the landscape scale are major factors driving the evolution of wetland plants and animals in California. In the long term, their protection will require conserving the spatial and temporal environmental gradients along which their evolution can proceed (Noss 1996, Ward 1998, Poiani 2000).

The local variability of moisture gradients within and adjacent to wetlands is also a concern in the identification and delineation of wetlands in the field (TAT 2012b). Wetland boundaries that are delineated during droughts or dry seasons might not mistakenly exclude some wetland areas that are more obvious under wetter conditions.

2.3 Deepwater Areas, Wetlands, Aquatic Support Areas, Uplands, and Channels

Based on the recommended wetland definition (TAT 2012a) and the field indicators recommended by the TAT for identifying and delineating wetlands (TAT 2012b), landscape moisture gradients can be separated into two basic components, aquatic areas and uplands (i.e., non-aquatic areas). The same indicators can be used to distinguish three types of aquatic areas from each other and from uplands. Channels are a type of aquatic area requiring its own set of distinguishing field indicators.

> *Deepwater aquatic areas* are non-wetland areas having an average depth of inundation greater than 2.0 meters during the growing season, or greater than the maximum depth from which rooted vascular vegetation grows to the water surface, whichever is deeper. These areas are too deep to be wetlands. They include, but are not limited to, large lakes, reservoirs, lagoons, deep rivers, and estuarine and marine bays. Areas that are temporarily inundated by deep water can be wetlands if such inundation does not persist throughout most of the growing season. For example, wetlands on floodplains can retain wetland conditions and function as wetlands after being deeply flooded. Deepwater areas are essential to the ecological and economic health of the state. They include the main sources of water for drinking, domestic uses, manufacturing, hydroelectric power generation, irrigation, and aquatic recreation. They are needed for transportation, commerce, and to receive and treat wastewaters. They moderate climate and have intrinsic ecological values.
>
> *Wetland* is an area that, under normal circumstances, (1) is continuously or recurrently inundated with shallow water or saturated within the upper substrate; (2) has anaerobic conditions within the upper substrate caused by such hydrology; and (3) either lacks vegetation or the vegetation is dominated by hydrophytes. Wetlands are among the most important ecosystems in the world (Mitsch and Gosselink 2000). They provide food, water, shelter, and breeding habitat for aquatic and terrestrial wildlife. Many endangered plants and animals depend on wetlands for their survival. People depend on wetlands for food, recreation, shoreline protection, flood control, and groundwater recharge. The water quality services of wetlands include filtering contaminants and treating them through intrinsic biochemical processes.

Aquatic support areas are non-wetland areas exhibiting some but not all the characteristics of wetlands. They can be areas that are changing from wetlands to uplands, or from uplands to wetlands, or they might be areas situated between, and affected by, wetlands and uplands. Most aquatic support areas adjoin wetland areas or deepwater areas, and are hydrologically and/or ecologically connected to them. The hydrological connections might be due to surface runoff, interflow, groundwater discharge, and/or high groundwater. Aquatic support areas and the other aquatic areas to which they are connected tend to integral parts of the same landscape moisture gradients.

Some aquatic support areas do not adjoin wetland or deepwater areas. Such aquatic support areas might be hydrologically or geographically isolated (sensu Winter and LaBaugh 2003, Comer et al. 2006, Tiner et al. 2002, Tiner 2003), but they are unlikely to be ecologically isolated.

Aquatic support areas are ecologically significant. They can provide some of the same kinds of beneficial uses or ecosystem services as wetlands (Castelle et al. 1992). Those that adjoin wetlands or deepwater areas help buffer them from upland stressors (Castelle et al. 1994), increase local biological diversity by providing habitat for ecotypes (Leppig and White 2006), and provide refuge for wetland and terrestrial wildlife during floods, fires, and other disturbances (e.g., Chapman et al. 1996, Sedell et al. 1990, Semlitsch and Bodie 2003). Aquatic support areas provide the geographic linkages or corridors between other aquatic areas and uplands. Many species of wetland plants and animals encounter the limits of their tolerance to environmental factors, such as moisture and temperature, in aquatic support areas. Their ability to survive environmental change can depend on their evolutionary adaptation to conditions at these marginal areas of their habitats (Mayr 1970, Gaston 2003). Aquatic support areas comprise a critically important part of the kinds of environmental gradients highlighted by landscape-scale wildlife conservation theory and plans (e.g., Poiani et al. 2000, Moritz 2002, Huber et al. 2010).

*Channel*s are landscape features with well-defined beds and banks that have been formed by water and which under normal circumstances are maintained by the flow of water, or that are purposefully constructed and maintained to convey water. Unaltered channels can be subterranean for short lengths but are generally surface features. For example, channels can pass under bridges or through culverts and natural tunnels, but buried stormdrains and water pipes are not channels. Channels may be found in wetlands, and they can contain wetlands, deep water aquatic areas, and aquatic support areas. Channels direct the surface runoff of water and the materials carried or moved by surface runoff downhill within watersheds.

Uplands do not exhibit any characteristics of aquatic areas. They comprise the landscape matrix in which aquatic areas form. They are the primary sources of sediment, surface runoff, and associated chemicals that are deposited in aquatic areas or move through them.

The boundaries of deepwater areas, wetlands, aquatic support areas, channels, and uplands can be approximated based on expert interpretation of aerial or other remote imagery. They can be more accurately determined using field indicators (TAT 2012b).

The visible differences between uplands and aquatic areas (except channels) are summarized in Table 1. It lists the alternative field conditions that can be differentiated using field indicators for identifying and delineating wetlands based on three criteria: hydrology, substrate, and vegetation (TAT 2012b). The conditions are: (1) continuous or recurrent inundation with shallow water or saturation within the upper substrate (hydrology criterion); (2) anaerobic conditions within the upper substrate (substrate criterion); and (3) vegetation is either lacking (i.e., less than 5% of the substrate is covered by vascular vegetation (vegetation criterion), or if vegetation is present than it is dominated by hydrophytes (vegetation criterion). These criteria can be used to identify the deepwater areas, wetland areas, and aquatic support areas of a landscape moisture gradient. Delineating channels requires a separate set of field indicators that will be addressed by the TAT in a subsequent memorandum.

No single landscape moisture gradient is likely to involve all the conditions described in Table 1. However, at any time of year, each condition in Table 1 is likely to occur in one or more landscape moisture gradients somewhere in the State. Some conditions are likely to be transient. That is, they can represent the conversion of an area from one type to another, as might occur due to changes in water sources or drainage patterns. Aquatic support areas can be transitioning (temporally or spatially) to or from wetlands. Identification and delineation of wetland areas requires training and careful attention to field indicators, especially to differentiate wetland areas from aquatic support areas (TAT 2012b). The boundaries can be feathered or interdigitated due to fine-scale variations in substrate conditions, and small-scale moisture gradients caused by micro-topographic relief (Figure 3).Wetland delineation can be especially challenging during dry seasons or droughts, when the indicators can be difficult to resolve (TAT 2012b).

Figure 3: small-scale substrate moisture gradients among vernal pools that are diffusely dispersed throughout a grassland and savanna matrix across a gently sloping landscape, as evidenced by changes in herbaceous vegetation (i.e., spatial variation in color of ground cover in this photograph); Vina Plain, Butte County, with snow-capped central Sierra Nevada in background.

Table 1: Classification of different areas of a hypothetical landscape moisture gradient based on wetland indicators

deepwater areas — wetlands — aquatic support areas — uplands

Observed Condition	**Wetland Indicators**				**Descriptions of Possible Landscape Patches (examples provided do not comprise an exhaustive list)**
	Wetland hydrology?	Hydric substrate?	At Least 5% vegetated?	Hydrophytes dominant?	
1	**No**	**Yes**	**No**	**No**	Deepwater area lacking vegetation. Could be profundal area of lake, subtidal area of a bay or estuary, etc.
2	**No**	**Yes**	**Yes**	**No**	Deepwater area lacking hydrophytes but not other aquatic vegetation. Could be a clear lake or estuarine bay that supports submerged macroalgae.
3	**No**	**Yes**	**Yes**	**Yes**	Deepwater area with hydrophytes. Might indicate recent increase in water depth. Could be partially drained reservoir recently refilled.
4	**Yes**	**Yes**	**Yes**	**Yes**	Wetland dominated by hydrophytes. Could be tidal marsh, vernal pool, wet meadow, shallow stock pond, etc.
5	**Yes**	**Yes**	**No**	**No**	Wetland lacking vegetation. Could be tidal flat, playa, montane rock pool, or wetland restoration project that does not yet have hydrophytes.
6	**Yes**	**Yes**	**Yes**	**No**	Aquatic support area with hydric substrate and wetland hydrology but dominated by non-hydrophytes. Could be former upland evolving into wetland.
7	**Yes**	**No**	**Yes**	**Yes**	Aquatic support area with wetland hydrology and hydrophytes but lacking hydric substrate. Could be a restoration site that has not yet developed hydric substrate.
8	**Yes**	**No**	**Yes**	**No**	Aquatic support area with wetland hydrology but lacking hydric substrate and dominated by non-wetland plants. Could be recently constructed restoration site that has not yet developed hydric substrate or been colonized by hydrophytes.
9	**Yes**	**No**	**No**	**No**	Aquatic support area with wetland hydrology but lacking hydric substrate and vegetation. Could be a bare rocky shore or a recently inundated area of bare upland yet to form hydric substrate and yet to be colonized by hydrophytes.
10	**No**	**Yes**	**Yes**	**Yes**	Aquatic support area with hydric substrate and hydrophytes but lacking wetland hydrology. Could be area of former wetland with recently altered hydrology.
11	**No**	**No**	**Yes**	**Yes**	Aquatic support area dominated by hydrophytes but lacking wetland hydrology and substrate. Could be former wetland with altered hydrology and substrate but viable hydrophyte seedbed, or area with hydrophytic vegetation intercepting groundwater at depth greater than 50 cm below ground surface.
12	**No**	**Yes**	**Yes**	**No**	Aquatic support area with hydric substrate but lacking wetland hydrology and dominated by non-wetland plants. Could be former wetland colonized by upland vegetation.
13	**No**	**Yes**	**No**	**No**	Aquatic support area with hydric substrate but lacking wetland hydrology and vegetation. Could be desiccated former wetland with unaltered substrate.
14	**No**	**No**	**Yes**	**No**	Upland with enough moisture to support upland vegetation. Could be oak savanna, chaparral, mixed hardwood forest, grasslands, etc.
15	**No**	**No**	**No**	**No**	Upland without enough moisture to support vegetation. Could be bedrock, sand dune, paved area, built structure, etc.

3.0 Illustrations of Landscape Moisture Gradients

Figures 4 to 7 illustrate landscape moisture gradients as discerned through aerial image interpretation and field reconnaissance. The indicators used in remote sensing are generally less resolute than field indicators. Indirect measures of surface water depth to identify deepwater areas are seldom reliable. Wetlands and aquatic support areas can be difficult to differentiate remotely. While the field reconnaissance did not involve strict application of the recommended delineation procedure (TAT 2010b), it confirmed that the illustrations are reasonable representations of landscape moisture gradients.

These examples show that aquatic support areas vary in size, relative to the wetlands or deepwater areas they attend. They can be especially small where the terrain is steep, the substrate is porous, and the water supply regime is relatively constant. For example, a narrow band of aquatic support area with sandy substrate was observed around an intact, high-elevation montane wet meadow (Figure 4). Aquatic support areas can be especially large where the terrain is not steep and moisture gradients expand and contract frequently. For example, a broad aquatic support area is evident upslope from a reservoir that is subject to seasonal cycles of large draw-downs and refills (Figure 5). Aquatic support areas can include previous wetland areas that have been drained or reclaimed but still support residual wetland vegetation (Figure 6). Following a protracted period of reduced flow, aquatic support areas along channels can expand onto floodplains that have been abandoned and colonized by non-wetland vegetation (Figure 7).

These examples also show that large wetland areas are not necessarily associated with deepwater. Some large wetlands are associated with seasonal flooding or elevated groundwater in large valleys having large drainage areas. Reconstructions of historical California landscapes have revealed that valleys with large catchments tended to include large wetland complexes, with perennial ponds and wet meadows surrounded by seasonal wetlands, even in arid climates (Grossinger et al 2007, Stein et al. 2007, Grossinger et al. 2008). The main effect of modern land use on wetland landscapes has apparently been to dewater them through groundwater drawdown and enhanced surface drainage. This accounts for a large part of the significant decline in wetland acreage in California and elsewhere (Dahl 1990).

Wetland reclamation does not usually eliminate the associated landscape moisture gradients. Unless reclamation involves raising the former wetland areas with fill, and unless the surface and subsurface drainage patterns are substantially altered, the landscape moisture gradients tend to persist to some degree. Reclaimed wetlands tend to remain poorly drained unless they are provided with artificial drainage systems. Dewatered wetland areas tend to subside because of wind erosion and the oxidation of organic substrates, exacerbating drainage problems. Wetlands tend to reform in such areas if they are not adequately drained.

By examining landscape moisture gradients in the watershed context, managers can evaluate the possible effects of climate change and alternative watershed management scenarios on the extent and condition of wetlands. By examining wetlands in the context of their landscape moisture gradients, engineers and planners can evaluate the long term feasibility of alternative designs for wetland reclamation or restoration.

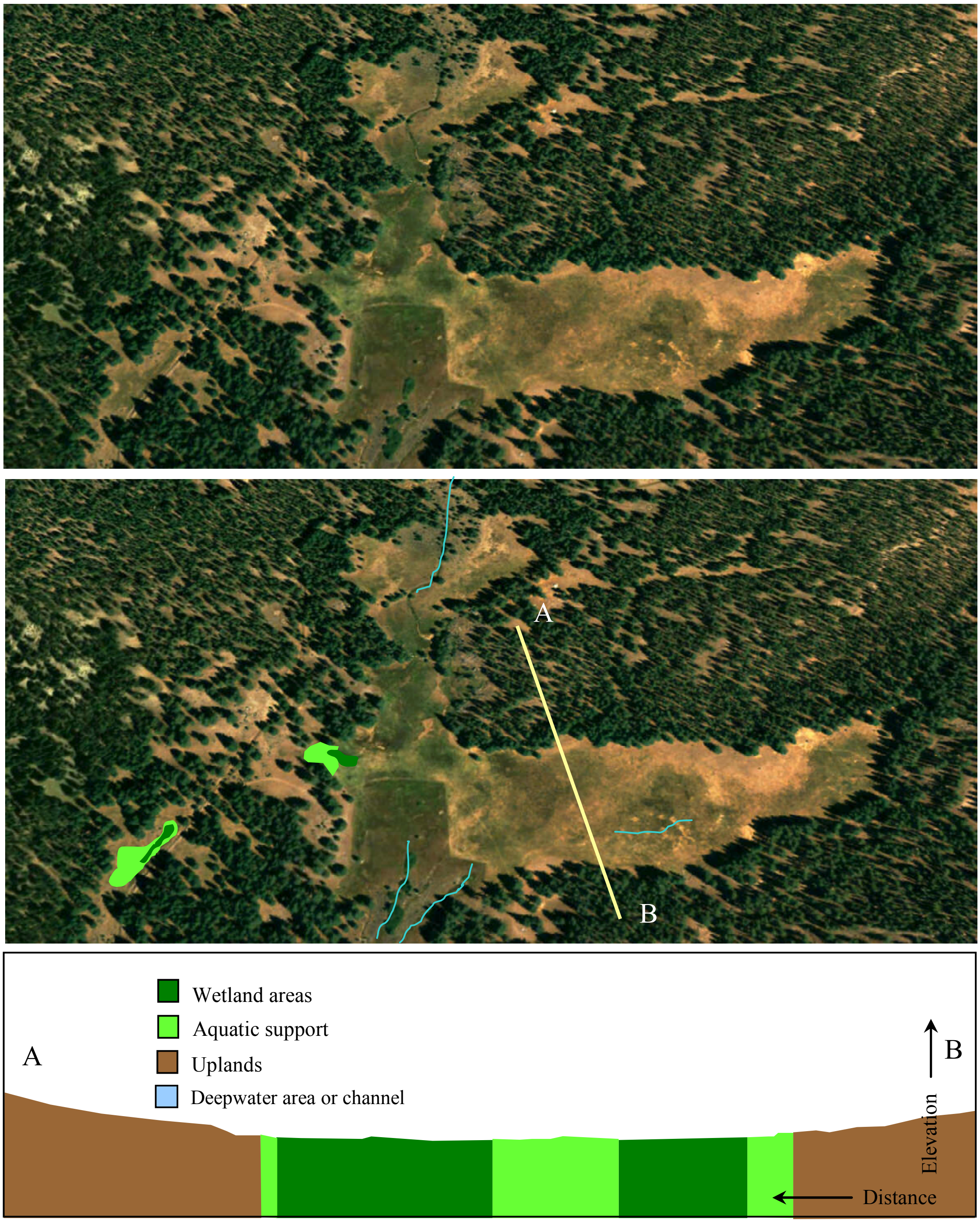

Figure 4: Distribution of wetlands, aquatic support areas, channels, and uplands of a montane wet meadow system, based on photo interpretation. Field-based delineation could yield a different illustration. The water source is seasonal runoff and groundwater discharge from surrounding the watershed. Channels are discontinuous. The bottom graphic shows the arrangement of areas along transect A-B shown in the middle graphic.

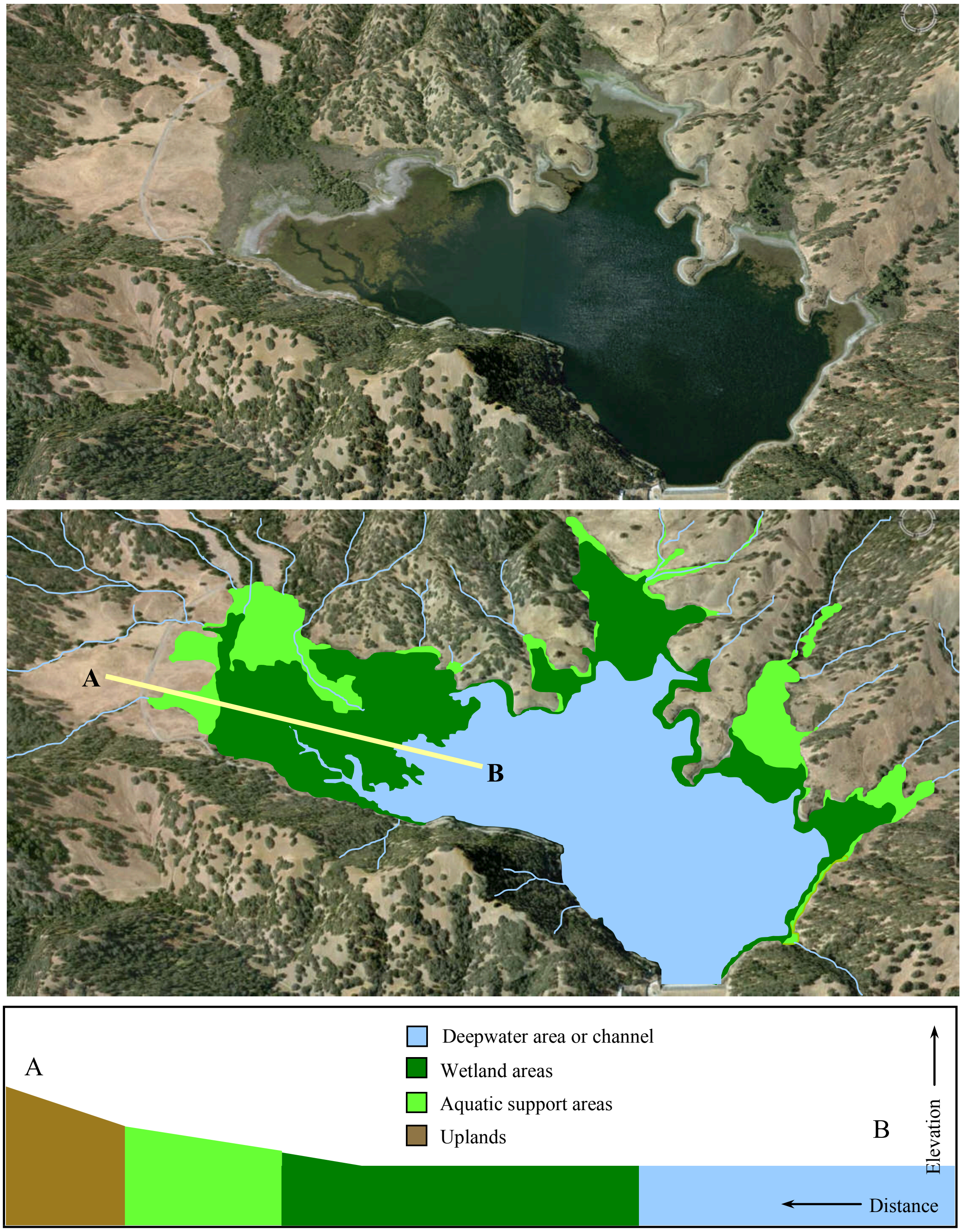

Figure 5: Distribution of deepwater aquatic areas, wetlands, aquatic support areas, channels, and uplands associated with a reservoir, based on photo interpretation. Field-based delineation could yield a different illustration. The water source is runoff and groundwater discharge. The bottom graphic shows the arrangement of the areas along transect A-B shown in the middle

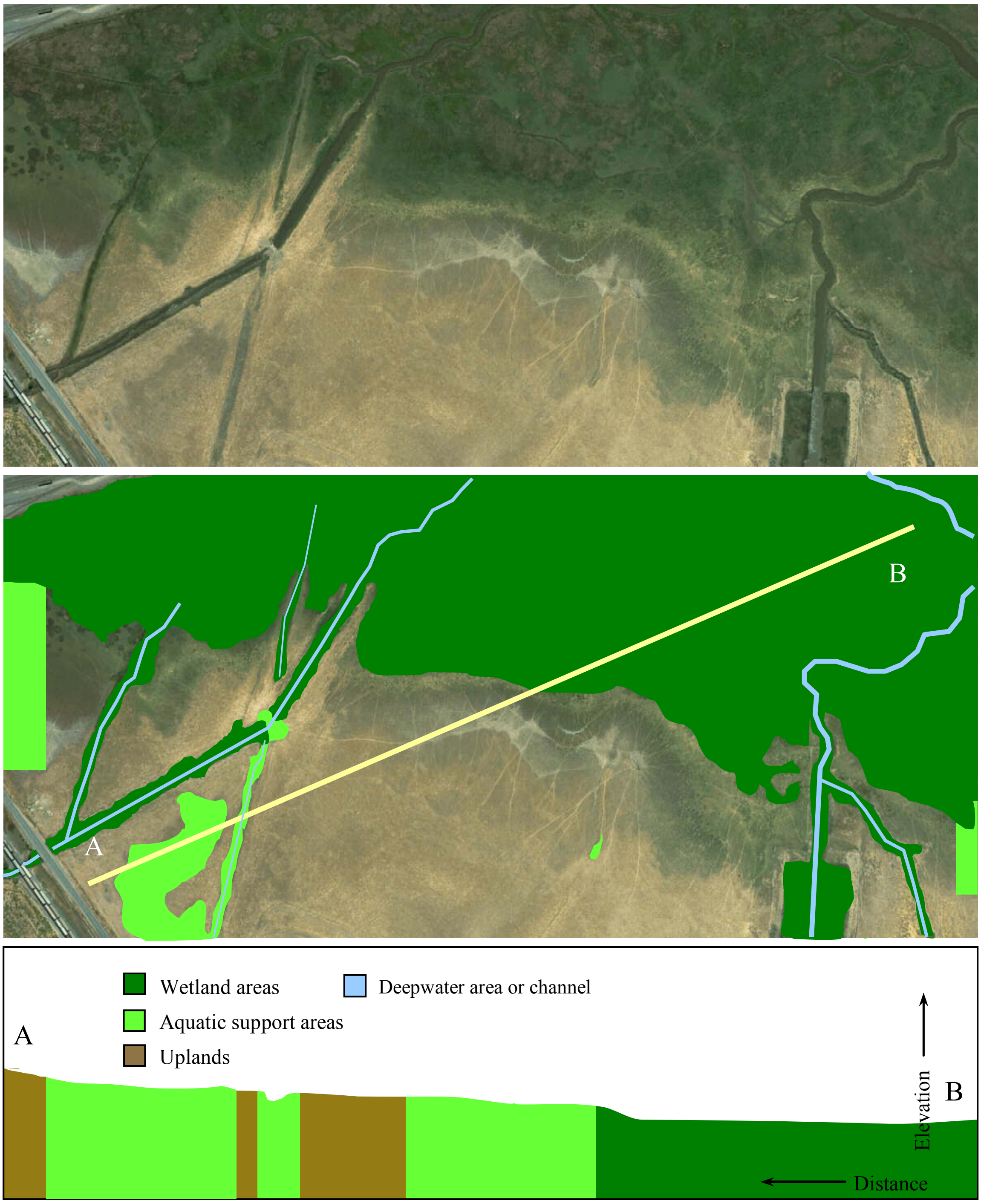

Figure 6: Distribution of wetlands, aquatic support areas, channels, and uplands in an estuarine landscape, based on photo interpretation. Field-based delineation could yield a different illustration. This landscape includes areas of former tidal wetlands converted to pasture but having residual wetland vegetation. The bottom graphic shows the arrangement of the areas along transect A-B shown in the middle graphic.

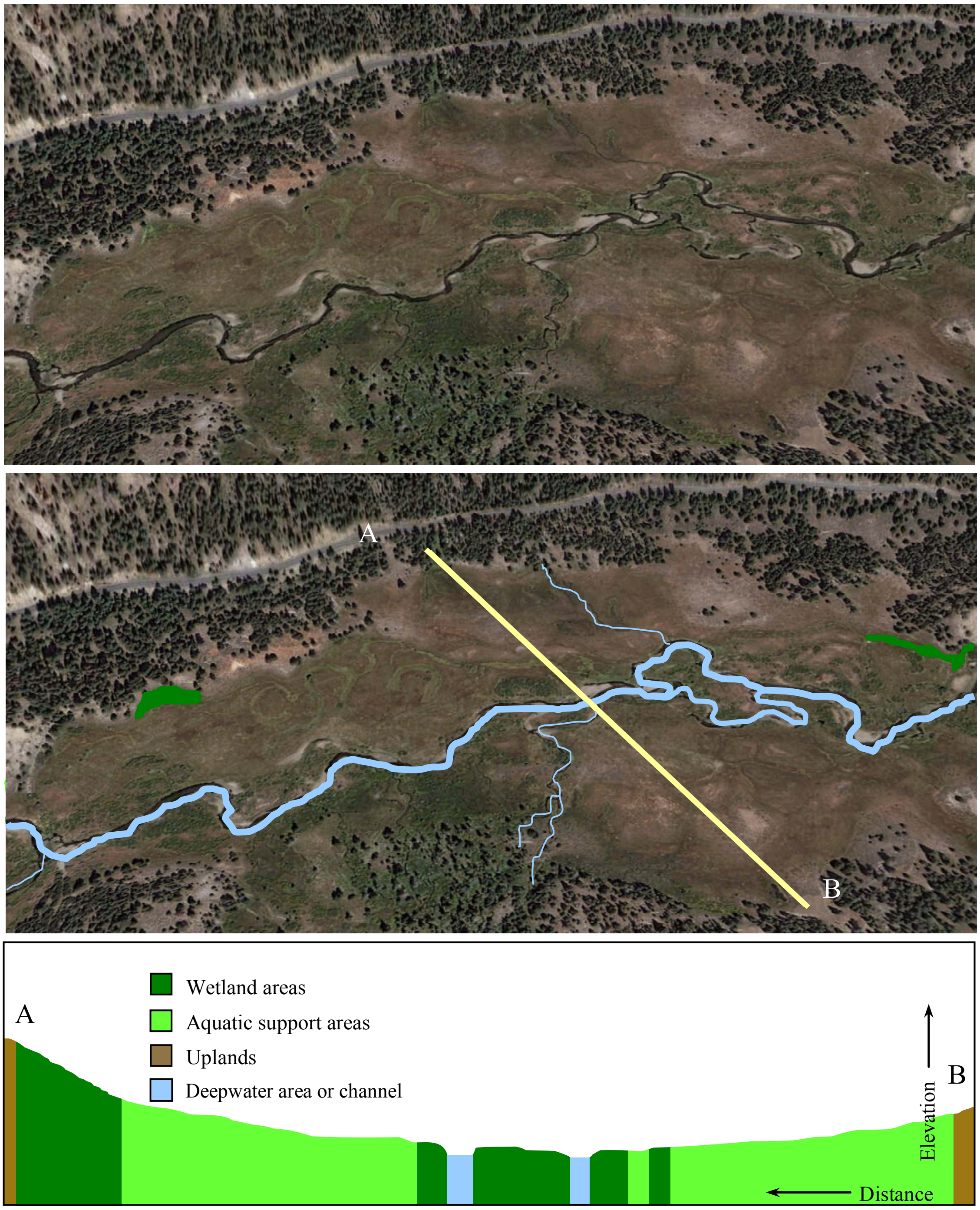

Figure 7: Distribution of wetlands, aquatic support areas, channels, and uplands in a montane valley, based on photo interpretation. Field-based delineation could yield a different illustration. The water source is flooding and groundwater discharge. The bottom graphic shows the arrangement of the areas along transect A-B shown in the middle graphic.

4.0 Riparian Areas

This discussion of riparian areas is limited to a brief consideration of their spatial relationships to wetlands and other aquatic areas of landscape moisture gradients. The TAT intends to dedicate a separate technical memorandum to a more comprehensive discussion of riparian areas, including their formative processes, intrinsic functions and services, and how they might be mapped.

The TAT has tentatively adopted the riparian definition provided by the National Research Council (see Glossary), with one essential clarification: the TAT specifies that all aquatic areas, including wetlands, have riparian areas. While this is implied by the NRC definition, it is explicitly stated by the TAT.

The TAT does not assume that riparian areas are defined by plant species specifically adapted to riparian conditions. Instead, in keeping with the NRC definition, the TAT assumes that riparian areas are defined by spatial gradients in biophysical and ecological processes that do not necessarily depend on any particular plant species or assemblage of species.

Riparian areas can be envisioned as sets of functions extending along landscape moisture gradients, across the boundaries between aquatic areas, and sometimes extending through the aquatic areas into uplands (Figure 8). Different riparian functions can extend different distances (Keller and Swanson 1979, Benda and Sias 1998, Naiman et al. 2000, FPAC 2000, WFPB 2004, Collins et al. 2006). As illustrated in Figure 8 below, the erosion control and shading functions might be restricted to the immediate margins of aquatic areas, whereas the groundwater recharge function might extend along the entire landscape moisture gradient and into the adjoining upland. For example, if the deepwater area is a river, then the broad zone of recharge might result from major overbank flooding, where the wetland and aquatic support areas represent floodplains. Or, the recharge zone could be due to a tributary infiltrating its fan, where the fan apex is part of the upland, the fan surface includes the aquatic support areas, and the wetland area forms between the fan and the river, due to groundwater discharge.

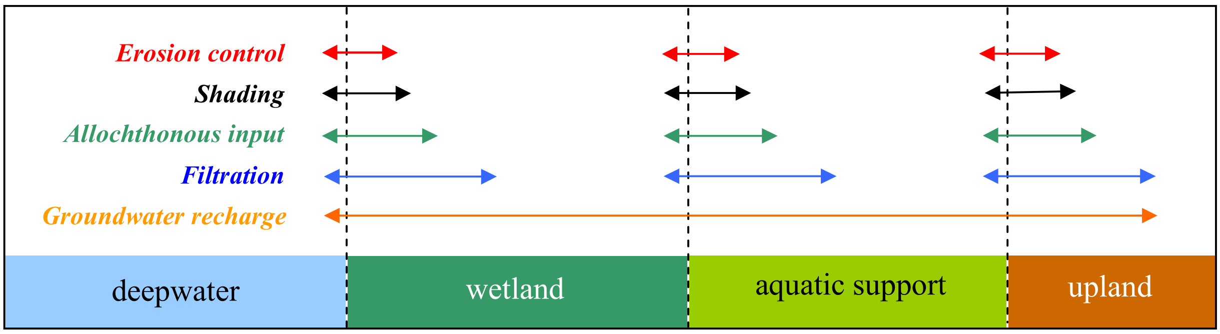

Figure 8: Schematic diagram of riparian extent (colored arrows) for a variety of riparian functions, illustrating three key riparian concepts: (1) some amount of riparian area is associated with each element of every landscape moisture gradient (i.e., deepwater areas, wetlands, aquatic support areas); (2) the extent of any riparian area (i.e., the length of an arrow representing riparian extent along a moisture gradient) varies with riparian function; and (3) riparian functions, and hence riparian areas, can extend into uplands. For any function, riparian extent can depend on many factors not represented in this diagram, including topography, soil permeability, climate, land use, and plant community structure. Not all riparian functions are represented in this diagram.

5.0 Glossary

Allochthonous refers to material found in a wetland or other aquatic area that originates elsewhere. For example, sediment from a hillside or woody debris from a riparian forest that enters a stream or pond is regarded as allochthonous.

Anaerobic conditions occur in substrates in which oxygen in the soil solution is depleted and aerobic bacteria (oxygen-requiring bacteria, as well as fungi) rapidly die off or enter resting stages. Under these conditions, anaerobic or facultatively anaerobic bacteria begin to flourish; these microorganisms can use a variety of molecules other than oxygen as the terminal electron acceptor in cell respiration (i.e., the microorganisms chemically reduce those molecules). Anaerobic conditions occur in substrate zones that are saturated or close enough to saturation that maintenance of air diffusion from the surface is precluded. Anaerobic conditions are associated with chemically reducing conditions, and typically lead to or exhibit well-characterized indicators in the substrate.

Aquatic area is a general term for any area in a landscape exhibiting physical, chemical, and/or biological conditions resulting from the presence of standing or flowing surface water and/or shallow groundwater. Aquatic areas include deepwater areas of estuaries and lakes; wetlands; aquatic support areas; stream and river channels; and other water features in the landscape.

Aquatic support areas are non-wetland areas exhibiting some but not all the characteristics of wetlands. They can be areas that are changing from wetlands to uplands, or from uplands to wetlands, or they might be areas situated between, and affected by, wetlands and uplands.

Beneficial uses define the resources, services, and qualities of wetland areas and other waters of the State of California that are the ultimate goals of protecting and achieving high water quality. Beneficial uses serve as a basis for establishing water quality objectives and discharge prohibitions to attain these goals.

*Channel*s are landscape features with well-defined beds and banks that have been formed by water and which under normal circumstances are maintained by the flow of water, or that are purposefully constructed and maintained to convey water. Channels can be subterranean for short lengths but are generally surface features. For example, channels can pass under bridges or through culverts and natural tunnels, but buried stormdrains and water pipes are not channels. Channels may be found in wetlands, and they can contain wetlands, deepwater aquatic areas, and aquatic support areas.

Connectivity is a concept that reflects the relative ease with which materials and/or energy can move through a landscape (Forman 1995); movements of matter and energy are easier in landscapes with higher connectivity. There are many kinds of connectivity. It can be ecological, as represented by the movements of wildlife, and physical, as represented by the movement of water. In general, connectivity increases with the amount of shared edge among different patch types, or the percent of patch boundaries within a landscape that adjoin its matrix (Fuller and Sarkar 2006, Saura and Pascual-Hortal 2007). For example, channel density (the total length of drainage channels per unit area of a watershed) is a common measure of hydrologic connectivity.

Corridors are elongate patches that differ from adjacent patches on both sides (Forman 1995). Wildlife dispersal and migration often are facilitated along corridors. Streams and their riparian areas comprise some of the most ecologically effective corridors (Thomas 1974, Rosenberg et al. 1997, Jongman and Kamphorst 2002, Hilty et al. 2006).

Deepwater aquatic areas are non-wetland areas having an average depth of inundation greater than 2.0 meters during the growing season, or greater than the maximum depth from which rooted vascular vegetation grows to the water surface, whichever is deeper. These areas are too deep to be wetlands. They include, but are not limited to, large lakes, reservoirs, lagoons, deep rivers, and estuarine and marine bays. Areas that are temporarily inundated by deep water can be wetlands if such inundation does not persist throughout most of the growing season. For example, wetlands on floodplains can retain wetland conditions and function as wetlands after being deeply flooded. See *Surface water*.

Dominance in wetland vegetation refers to the relative abundance of plant species as explained in the USACE delineation manual (Environmental Laboratory 1987). The "50/20 rule" of the USACE manual is the recommended method for measuring dominance. It states that for each height stratum in the plant community, dominant species are those that (when ranked in descending order of abundance and cumulatively totaled) immediately exceed 50% of the dominance measure for the stratum (typically ground surface coverage), plus any additional species that individually comprise 20% or more of the total dominance measure for the stratum (USACE 2008).

Drainage network is a system of interconnected water sources, storage areas, and conveyance channels that moves water and the materials it transports downhill within a watershed.

Duration refers to the length of time that an area is continuously saturated or inundated by water. It is the period available for the formation of anaerobic substrate conditions. It does not refer to the presence or lack of seasonal occurrences of inundation or saturation, but to the length of time an area is continuously saturated or covered (inundated) by water. The USACE delineation methodology includes specific reference to a duration of inundation or saturation sufficient to cause anaerobic conditions in the soil and to support hydrophytes. The TAT-recommended delineation methodology also incorporates this factor. For both methodologies, the recommended duration of saturation is the identified USACE standard of 14 days (USACE 2008, 2010).

Ecological Service is an ecological process or function that has value to people. For example, the wetland process of storing flood waters serves society by reducing flood risks, and the wetland process of recharging aquifers serves society by helping to maintain groundwater supplies.

Fragmentation is a process by which the number of landscape patches of one kind is increased, and the distance between the patches might also be increased (Noss and Csuti 1994, Forman 1995). Fragmentation is one of several interrelated processes that change the overall connectivity of a landscape. Others processes include *perforation* and/or *dissection* of the matrix, *shrinkage* of remnant patches, and *attrition* of patches. In the context of conservation biology, fragmentation is often described as the amalgamation of all of these processes, leading to an overall reduction in the area of the prior matrix and an increase in the average distance between patches, such that the overall connectivity in that landscape is decreased (Wilcove et al. 1986, Turner et al.1991).

Functions are what wetlands do as physical or ecological systems. For example, wetlands store flood waters, recharge aquifers, protect shorelines from erosion, filter pollutants from water, and support native biological diversity.

Growing Season is the annual period during which hydrophytes can generate new tissue above or below ground. It generally corresponds to the period when daily minimum soil temperature at 30 centimeters below the surface is higher than biologic zero (5º C or 41º F). In colder or mountainous regions of California, the growing season can be approximated as the period when daily maximum air temperature is above 28º F (-2.2º C).

Hydric conditions are established if the upper substrate is saturated long enough to create anaerobic conditions. For the purposes of this definition, the minimum duration of such saturation is 14 consecutive days during the growing season. However, the minimum duration required to develop anaerobic conditions in the upper substrate is known to vary with soil temperature, soil pH, and other environmental factors, and scientific evidence indicates that in some California environments the chemical transformation to anaerobic conditions in the upper substrate may occur in fewer than 14 days (TAT 2012b).

Hydroperiod is the temporal aspect of inundation and/or upper substrate saturation of a given area. It can be continuous or recurrent.

> *Continuous Hydroperiod* describes hydrological conditions on the land surface or in the upper substrate that are perennial or that tend to persist for at least twelve months.
>
> *Recurrent Hydroperiod* describes hydrological conditions on the land surface or in the upper substrate of a given area that persist for less than twelve months. A recurrent hydroperiod may be periodic and sustained, such as a regular inundation by tidewater, or episodic and intermittent, such as the inundation of an arid-region streambed by floodwaters. In order for the recurrent hydroperiod to support the development of anaerobic conditions, the substrate must become, and remain, saturated for a duration ≥14 days during an annual cycle. The TAT-recommended methodology for identifying and delineating wetland areas incorporates the recurrence frequency defined by the USACE as "normal conditions," a decadal recurrence frequency of 50%; the recurring substrate saturation must occur in at least half the years over the course of a decade. See *Duration*.

Hydrophytes, or hydric plant species, are plants adapted to inundated or saturated substrates (see *hydric substrate conditions*). The currently adopted list of California hydrophytes is available in Reed (1988a) (Region 10), which classifies hydrophytes into five groups based on the probability of their occurrence in wetland areas: Obligate Wetland (OBL ≥99% frequency of occurrence in wetland areas), Facultative Wetland (FACW = 67–99%), Facultative (FAC = 34–66%), Facultative Upland (FACU = 1–33%), and Obligate Upland (UPL = <1%). Most wetland plant communities are dominated by OBL, FACW, and/or FAC species, yet some are characterized during dry seasons by FACU species or may become non-vegetated. Obligate hydrophytes nearly always occur in wetland areas, while FACW species typically are found in wetland areas, FAC species are common in wetland areas and in uplands, and FACU species occur mostly in uplands. This definition may be reviewed in the context of future supplements and other revisions to the USACE wetland delineation manual or guidance documents. It should be noted that many plant species that may be encountered during field delineations are not included in the hydrophyte lists, and species ratings reported in the lists may not always reflect the ecological amplitudes and wetland affinities of individual plants or plant populations in the wild.

Indicators are identifiable but not necessarily quantitative characteristics used to determine whether or not a site satisfies the criteria of the wetland definition. Wetland indicators are used to identify and delineate wetland areas from other aquatic areas and from non-aquatic areas (i.e., uplands).

Inundation is a condition in which water from any source continuously or recurrently covers a land surface. Inundation may include (a) *ponding*, a situation in which water stands in a closed depression, where the water is removed only by infiltration, evaporation, or transpiration; or (b) *flooding*, a condition in which the substrate surface is temporarily covered with flowing water from any source, such as overflowing streams or rivers, surface runoff from adjacent slopes, groundwater groundwater discharge, inflow from high tides, or any combination of such sources.

Landscape generally refers to a set of visible, physical geographic features, including landforms, aquatic areas, vegetation, land uses, and built structures that can be viewed together in a single scene. In the context of landscape ecology, landscape refers to a mosaic of patches that recurs over a broad region of the earth's surface (Forman 1995).

Landscape Matrix is the land cover type in which landscape patches such as aquatic areas are embedded (Forman 1995). The landscape matrix characteristically is the cover type that demonstrates the greatest areal coverage, has the greatest intrinsic connectivity, and controls the overall dynamics of the landscape. During landscape conversions, the matrix is replaced through processes often collectively referred to as fragmentation.

Landscape Moisture Gradients are spatial continua in land surface moisture created by precipitation, surface runoff, groundwater discharge, and other groundwater movements.

Normal circumstances are the hydrologic, substrate, and vegetation conditions that are present in the absence of altered circumstances. Normal circumstances include natural seasonal and inter-annual variations in hydrology, substrate, and vegetation conditions. Natural, purposeful, or inadvertent conversion of a non-wetland area into a wetland area, or conversion of a non-channel area into a channel can cause new normal circumstances. See *Altered Circumstances*. This definition incorporates much of the meaning of normal circumstances as defined by the USACE, which states that normal circumstances are the soil and hydrologic conditions that are normally present, without regard to whether the vegetation has been removed. The determination of whether or not normal circumstances exist in a disturbed area involves an evaluation of the extent and relative permanence of the physical alteration of hydrology and hydrophytic vegetation and consideration of the purpose and cause of the physical alterations to hydrology and vegetation (based on Regulatory Guidance Letter 90-7, 26 September 1990).

Riparian Areas are areas through which surface and subsurface hydrology interconnect aquatic areas and connect them with their adjacent uplands (Brinson et al. 2002). They are distinguished by gradients in biophysical conditions, ecological processes, and biota. They can include wetlands, aquatic support areas, and portions of uplands that significantly influence the conditions or processes of aquatic areas.

Surface runoff is the surface water flow that occurs when the substrate is infiltrated to full capacity or when the rate at which water is added to the substrate surface exceeds the rate infiltration.

Groundwater discharge is groundwater that returns to the substrate surface. This should not be confused with irrigation return flow or other land use groundwater discharge, which consists of water that has been used for irrigation or another land use but not consumed or evaporated by those uses and subsequently flows to another landscape area away from those uses.

Saturated refers to a condition in the upper substrate in which all pores are filled with water, except for a small volume of micropores (pores <0.08 mm in diameter, which retain water after drainage of gravitational water) that have trapped air. This may include a small part of the capillary fringe above the water table (i.e., the tension saturated zone) in which substrate water content is approximately equal to that below the water table, but normally the capillary fringe is not saturated. Soil at field capacity (which indicates a condition 2-3 days after saturation when free drainage due to gravity can occur, where water is held in the soil micropores against the force of gravity and the macropores [pores 0.08 to 5+ mm in diameter] are mostly air-filled) is not considered to be saturated above the water table. This definition may be reviewed in the context of future supplements, the adoption by the USACE of National Technical Committee on Hydric Soils (NTCHS) standards for hydric soils (NRCS 2006), and other revisions to the USACE wetland delineation manual.

Surface water is the freestanding or moving water above the ground surface.

> *Deep surface water* – For all landscapes, deep surface water is either (A) deeper than 2 meters during the growing season; or (B) deeper than the greatest depth from which rooted vascular vegetation grows to the water surface, whichever is deeper. Areas temporarily inundated by deep surface water can be wetlands if such inundation does not persist throughout most of the growing season. For example, floodplain areas that are temporarily deeply inundated due to natural flooding or water management can retain wetland conditions and subsequently function as wetlands.
>
> *Shallow surface water* – For all tidal landscapes, shallow surface water is any portion of the tidal prism that is bounded by the local Mean Lower Low Water (MLLW) datum and the local maximum tide height as adjusted for the current tidal epoch. For landscapes that are not tidal, shallow surface water is either (A) any water having depth equal to or less than 2 meters for at least 14 consecutive days during the growing season; or (B) the greatest depth from which rooted vascular vegetation grows to the water surface, whichever is deeper.

Uplands are non-wetland areas that lack any field-based indicators of wetlands or other aquatic conditions. Uplands are generally well-drained and occur above (i.e., up-slope) from nearby aquatic areas. Wetlands can be surrounded by uplands, however. For example, some natural seeps and constructed stockponds lack aboveground hydrological connection to other aquatic areas. In the watershed context, uplands comprise the landscape matrix in which aquatic areas form. They are the primary sources of sediment, surface runoff, and associated chemicals that are deposited in aquatic areas or move through them.

Upper substrate is the portion of substrate-extending downward from the substrate surface to a depth of 50 centimeters (20 inches). In non-vegetated as well as vegetated wetlands, this is the portion of substrate within which relevant anaerobic chemical conditions develop. In vegetated wetlands, this is also the portion of substrate that includes the major portion of the root zone. The "major portion of root zone" is interpreted by the USACE to be the zone containing >50% of the living root mass of the dominant wetland species. The depth of the upper substrate that influences wetland indicators will vary, depending on vegetation, substrate texture, depths to impermeable layers, and substrate chemistry. The USACE 1987 manual identifies the major portion of the root zone as typically 30 cm (12 in) deep; for the purposes of this definition, the upper substrate includes the zone extending downward from the substrate surface to a depth of 50 cm (20 in), as indicated in the regional supplements. However, the USACE methodology requires that hydrology observations consider that saturation must occur within the majority of the dominant wetland-species root zone, and in porous soils the upper substrate may extend to depths greater than 50 cm.

Vegetation consists of rooted macrophytes, parts of which may be emergent, submerged, or floating, including monocots, dicots, and ferns. An area is vegetated if at least 5% of it is covered by vegetation. The area exhibits wetland vegetation if the dominant vegetation is hydrophytic.

Water table refers to the top of the groundwater, below which is the zone of saturation in the substrate. It is the level in the substrate at which the pore-water potential is zero compared to atmospheric pressure, and to which water will rise in an open borehole or well.

Watershed is defined as all the lands and waters that drain to a common place. Catchment, catchment area, catchment basin, drainage basin, and drainage area are watershed synonyms.

Wetland is an that, under normal circumstances, (1) has continuous or recurrent saturation of the upper substrate caused by groundwater or shallow surface water or both; (2) the duration of such saturation is sufficient to cause anaerobic conditions in the upper substrate and; (3) lacks vegetation or the vegetation is dominated by hydrophytes.

Wetland criteria (sometimes alternatively identified as *wetland factors*) are aspects of wetland condition verified by the observation of indicators. The wetland criteria used to define, identify, and delineate wetland areas are hydrology, substrate, and vegetation. See also *Indicators*.

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