# Appendix 6-A

# Proposed Watershed Hydrology Water Quality Objective

In response to the 2008 Triennial Review of the *Water Quality Control Plan for the North Coast Region* (Basin Plan), staff developed narrative language for a watershed hydrology water quality objective (watershed hydrology objective) describing the basic characteristics of a hydrologically functional system. Staff from Region 1 (North Coast Region) and Region 2 (San Francisco Bay Region) collaborated on the development of new beneficial uses and water quality objectives to be included in a Stream and Wetland Systems Protection Policy which was to be proposed for adoption to both Boards, including the watershed hydrology objective. As part of the 2011 Triennial Review of the Basin Plan, the North Coast Regional Water Board recognized staffing limitations by ranking the Stream and Wetland System Protection Policy high, but not on the short list. On behalf of both Regions, staff at Region 2 submitted proposed basin plan amendment language and a draft staff report for peer review in 2009.

The TMDL analysis of sediment for the Upper Elk River watershed has found that alterations to the hydrology of the Upper Elk River and the resulting loss of watershed hydrologic function has had a substantial impact on the storage and routing of fine sediment, and has contributed to nuisance flooding conditions. The TMDL, sediment load allocations, and proposed implementation framework all point to the need for implementation actions that specifically address or consider watershed hydrology.

To support this need, staff propose that the Regional Water Board consider reprioritizing the adoption of a water quality objective for watershed hydrology. The objective could be adopted as a site specific objective for the Elk River watershed or as a region-wide objective as originally proposed. The watershed hydrology objective is a means of acknowledging the connection between flow and sediment in Upper Elk River. While the existing water quality objectives for sediment are helpful, an explicit objective describing the connectivity of watershed hydrology and beneficial use support and prevention of nuisance is helpful to guide recovery and protection efforts. The language of a narrative watershed hydrology objective and scientifically-peer reviewed justification for the objective are immediately available. The proposed watershed hydrology objective reads:

> "The hydrologic connectivity between headwaters and estuary, surface water and groundwater, and landscape, floodplain, and stream channel shall be protected to produce the pattern and range of flows necessary to support beneficial uses and a functional ecosystem."
>
> The peer reviewed science associated with the development of this objective is contained in the report titled *Staff Report for Amendments to the Water Quality Control Plans for the North Coast and San Francisco Bay Regions to Protect Stream and Wetland Systems, External Peer Review Draft* (Ho and Livsey, 2009).

Staff proposes that the Regional Water Board consider adopting a watershed hydrology objective either as part of an action taken specific to the Elk River watershed (if a site specific objective) or as part of another related Basin Plan Amendment (if a region wide objective). . With respect to the Upper Elk TMDL, the numeric targets developed and described in Chapter 6 are designed to address the general concepts articulated in the proposed watershed hydrology objective.

With respect to TMDL, the watershed hydrology objective addresses watershed scale disturbances. In Upper Elk River, these disturbances have resulted in alteration of natural stream processes and the degradation of instream and near stream ecosystems. Accordingly, the proposed watershed objective is based upon a watershed approach, rather than focusing on specific pollution or habitat parameters and target the controllable water quality factors that lead to disruption of watershed processes. The watershed hydrology narrative objective articulates the importance of riparian habitat, floodplains, and other hillslope catchments in supporting instream beneficial uses and a functional aquatic ecosystem.

Management-related sediment loads and hydrologic modifications in Upper Elk River have resulted in the exceedence of existing sediment water quality objectives, impairment of beneficial uses, and nuisance conditions related to altered flood frequency and magnitude. But, it is inherently difficult to quantify any individual project's contributions to these exceedences and impairments. This is due to the nature of nonpoint source pollution and the complexity of assessing cumulative effects[1], considering natural variability, delayed erosion, additive effects from multiple projects, and reduced hydraulic and sediment transport capacities. The proposed watershed hydrology objective focuses on maintenance of the pattern and range of hydrologic conditions on a watershed scale that are necessary to support stream processes and functions for beneficial use protection. In many watersheds, it will be the natural pattern and range of flows that is necessary to protect beneficial uses and support ecological function. The watershed hydrology objective is intended to ensure that individual projects and permits are designed and evaluated to support watershed health and avoid adverse cumulative effects.

Table 5.4 presents the proposed watershed hydrology objective and associated goals for stream and wetland functions. This language is derived from the proposed basin plan amendment which was submitted for scientific peer review by Region 2 staff in 2009. The watershed hydrology objective is in narrative form, like many of the other water quality objectives contained in the Basin Plan. As is the case with all objectives, the watershed hydrology objective must be translated to an appropriate scale for use in individual cases. The primary goal of the watershed hydrology objective is to establish a framework for addressing the relationship between water quantity and water quality, recognizing that the

[1] *Cumulative Watershed Effects* (CWEs) are significant, adverse influences on water quality and biological resources that arise from the way watersheds function, and particularly from the ways that disturbances within a watershed can be transmitted and magnified within channels and riparian habitats downstream of disturbed areas (CITATION).

authority to directly control water diversion or extraction lies with other agencies. Nonetheless, adopting the watershed hydrology objective into the Basin Plan would make more clear and transparent the co-relationship between flow and many of the other parameters control of which the Regional Water Board has authority, including but not limited to: sediment, temperature, bio-stimulatory substances, and others.

**Table 4: Proposed Watershed Hydrology Narrative Objective and associated goals for stream and wetland system functions**

| Indicator | Water Quality Objective | Goals for Stream and Wetland System Functions |
|---|---|---|
| Watershed Hydrology | The hydrologic connectivity between headwaters and estuary, surface water and groundwater, and landscape, floodplain, and stream channel shall be protected to produce the pattern and range of flows necessary to support beneficial uses and a functional ecosystem | <u>Runoff flow and volume</u><br>Maintain site runoff and transport characteristics (i.e., timing, magnitude, duration, time of concentration, and discharge pathways of runoff flow) such that post-project flow rates and durations mimic pre-project levels. Where practicable, incorporate measures to restore natural runoff patterns (e.g., enhance soil infiltration capacity and increase the storage of runoff) in watersheds that have been substantially altered from their pre-management conditions.<br><br><u>Hydrologic connectivity</u><br>Maintain lateral, vertical, and longitudinal flow pathways, including connectivity between: stream channels, riparian areas, floodplains, and wetlands; surface water and groundwater; and ocean or estuary-to-headwaters at adequate levels to protect stream and wetland system functions and beneficial uses including the maintenance of, and access to, a diverse range of habitats for aquatic life and wildlife.<br><br><u>Natural flow regime</u><br>Maintain the natural variation of flows and hydrograph characteristics (i.e., timing, magnitude, duration, and time of concentration) such that the range of flows including low, channel forming, and flood flows are of a magnitude and duration to: 1) sustain channel morphology and balance sediment transport; 2) support riparian vegetation community maintenance; 3) provide adequate flows and velocities during low flow months to satisfy aquatic life and wildlife habitat requirements; and 4) maintain seasonal flows that permit the migration or free movement of migratory fish and access to floodplain and off-channel habitat (e.g., sloughs and permanently or seasonally flooded wetlands) for aquatic life. |

## From Peer Review Daft of SWSPP

## Impacts to Hydrology

Various land use activities can affect the hydrologic characteristics of the watershed including adversely impacting the timing, magnitude, duration, and rate of change of runoff and surface water discharges as well as groundwater recharge and baseflows. These adverse changes can result in flooding problems and in turn counterproductive flood control practices which often exacerbate the problem.

### *Changes in Runoff Patterns*

Land use activities can increase runoff volume, peak rates, and durations by changing rainfall infiltration and runoff patterns from their pre-development levels. Specific changes to stream hydrology resulting from urbanization include:

- increased peak discharges
- increased total volume of runoff
- decreased time needed for runoff to reach the stream
- increased frequency and severity of flooding
- greater runoff velocity during storms
- changes in streamflow during dry periods due to reduced level of infiltration in the watershed

In developed areas impervious surfaces (e.g., roofs, roadways, parking lots, sidewalks, and driveways) can dramatically reduce the infiltration capacity leading to increases in total and peak runoff. These increased flows move quickly over paved surfaces and are collected, concentrated, and further accelerated by gutters, curbs, culverts, lined channels, and stormdrain systems. The combination of increased flows and more efficient transport causes a higher, "flashy", more rapidly peaking and falling hydrograph, especially for smaller, more frequent floods (Hollis 1975; Dunne and Leopold 1978; Klein 1979; USEPA 1993; Schueler 1994; State Water Board 1994; Mount 1995; FISRWG 1998).

Channels experience more bankfull flood events each year and are exposed to critical erosive velocities for longer intervals. These changes to the magnitude and duration of flows result in more "effective work" and sediment movement leading to channel incision and bank erosion (Booth 1991; FISRWG 1998). These hydrologic changes result in the peak discharge associated with the bankfull flow (i.e., the 1.5- to 2-year return storm) to increase sharply. Hollis (1975) found that small floods may be increased by a factor of 10 or more depending upon the degree of urbanization, and floods with a return period of 100 years or more may be doubled in size by the extensive urbanization of catchments (~ 30%).

Land use activities that remove vegetation, compact soil, expose dense subsoil, and create steep graded slopes can affect the infiltration and movement of water, thereby altering the timing and magnitude of runoff events (Dunne and Leopold 1978; USEPA 1993; FISRWG 1998). Furthermore, activities that reduce or eliminate the natural storage volume of ephemeral, intermittent, and perennial channels, backwaters, floodplains, and wetlands can reduce the watershed's capacity to retain runoff (USEPA 1993) and flood waters, thus increasing and accelerating runoff (Mount 1995).

Numerous studies have illustrated the hydrologic effects of forest harvesting. Keppeler and Ziemer (1990) analyzed streamflow data for a 21-year period in the Caspar Creek watershed, near Fort Bragg in northern California and found that the removal of forest cover and vegetation from logging operations resulted in a statistically significant increase in streamflow for both the annual period and the low-flow season. Harr et al. (1975) after studying storm hydrographs of six small Oregon Coast Range watersheds following clear-cutting found that average winter peak flows can be increased up to 45% by clear-cutting. Jones and Grant (1996) examined differences in paired peak discharges for 150 to 375 storm events for five basin pairs in the Cascades Range of western Oregon and found that forest harvesting increased peak discharges over the past 50 years by as much as 50% in small basins and 100% in large basins.

### *Flooding and Channelization*

Urban streams are often extensively modified and channelized in an effort to protect adjacent property from streambank erosion and flooding problems (Mount 1995). Channelization and channel modification (e.g., armoring, lining, etc.) converts streams into deeper, straighter, and often wider waterbodies in an effort to increase flood conveyance and results in fundamental geomorphic and hydrologic transformations to the structure and function of stream and wetland systems (NRC 2002).

Channelization is often counterproductive because it reduces the flood storage within a watershed by restricting high flows to the active channel often constraining flows to a narrow band with floodwalls and levees, thereby preventing detention of floodwater in backwaters and on the adjacent floodplain and increasing the velocity of the stream and elevating flood heights (Mount 1995). These constricted channels can cause water to back up, resulting in localized upstream flooding. Furthermore, rapid passage of floodwaters through "improved" channels can increase flooding downstream by concentrating and synchronizing tributary peaks (Emerson 1971; Dunne and Leopold 1978; Mount 1995). Prestegard et al. (1994) studied the spatial variation in the magnitude of the 1993 floods along the Raccoon River, a tributary to the Mississippi River, and found that extensive channelization produced an increased magnitude of flooding in downstream sites.

### *Groundwater Recharge/Baseflows*

Hydrologic changes to infiltration patterns and runoff can reduce groundwater recharge and lower water tables, since water draining from impervious surfaces is unable to percolate to groundwater at that location. These changes in the watertable can substantially reduce the dry weather baseflows of streams dependent on groundwater. Reductions in baseflow can further decrease groundwater recharge by diminishing the wetted area and the amount of water available for recharge in stream channels (see ***Error! Reference source not found.***) (Dunne and Leopold 1978; Klein 1979; USEPA 1993; State Water Board 1994; FISRWG 1998). A study of hydrographs of six streams on the south shore of Long Island during the last three decades (Simmons and Reynolds 1982) showed that urbanization has reduced the baseflow contribution to total annual stream flow from 95 percent to only 20 percent.

Channelization and channel modification can change groundwater storage by reducing percolation and groundwater recharge, and deepening natural channels can drain adjacent shallow water tables (Dunne and Leopold 1978; USEPA 1993). A lowered watertable can dry up wetlands, stress or kill mature riparian vegetation, and reduce or eliminate seedling survival.

### *Surface Water Diversions*

The State Water Board explains:

> Water diversion has resulted in a significant loss of fish habitat in California. Water withdrawals change the natural hydrologic patterns of streams and can directly result in a loss or reduction in the physical habitat that fish occupy. Flow reduction can exacerbate many of the problems associated with land use practices by reducing the capacity of streams to assimilate pollutants (State Water Board 2007a, p. 1).

### *Hydrology Impacts and Beneficial Uses*

Changes to the hydrologic patterns of stream and wetland systems can impact beneficial uses. For example, increased runoff can impair habitat values by flushing fish and invertebrates out of streams; by increasing water level fluctuations and the velocity of flows entering wetlands; and by causing salinity changes in estuaries and other nearshore marine waters (Klein 1979; USEPA 1993). Increased flooding can be a public safety hazard, result in property damage, and impair habitat, water supplies, navigation, and other beneficial uses (Schueler 1994).

Channelization and the associated ongoing maintenance can directly impair beneficial uses by reducing waterbody area; increasing stream velocity; disrupting riffle and pool sequences, cover, and other structural features; changing substrate characteristics; cutting off nutrient inputs to and from backwaters, riparian areas, and wetlands; dewatering upstream reaches; and reducing aesthetic and recreational value. Reduced overbank flooding associated with channelization can adversely affect the structure and functions of riparian and wetland vegetation communities (Dunne and Leopold 1978; USEPA 1993; Mount 1995; FISRWG 1998). Furthermore, channelization can inhibit the movement corridors for fish and wildlife, and thus isolate and reduce the viability of populations (USEPA 1993; FISRWG 1998).

Reductions in the amount or duration of baseflow can impair habitat quality by eliminating aquatic and riparian habitat area, and reducing the stream flow necessary to support aquatic organisms and wetland and riparian vegetation communities (Klein 1979). A lowered watertable can also impair water supply and other beneficial uses which use groundwater; lead to seawater intrusion into coastal aquifers; and result in aquifer compaction and subsidence (Dunne and Leopold 1978).

## Impacts to Geomorphology

Various land use activities can have dramatic adverse effects on the sediment loads and surface water discharges of a watershed and the stream corridor morphology within it (FISRWG 1998). These land use changes can result in imbalances, channel destabilization, and excessive sediment erosion and deposition problems.

### *Causes and Effects of Channel Instability*

Channel instability (i.e., excessive erosion or deposition) can be caused by a variety of factors including increased stream flow, altered sediment regimes, and stream bed and bank armoring. Activities that result in increased surface water discharge and more erosive forces or "effective work" can lead to more sediment movement, channel incision, and bank erosion (Booth 1991; FISRWG 1998). Conversely, land uses such as logging, mining, agricultural and construction practices that result in changes in upland soil erosion can increase the sediment loads entering the stream overwhelming the stream channel's ability to move the sediment. The stream may then aggrade its channel to balance its available energy with the changes in its sediment load.

Activities such as construction and vegetation clearing (e.g., forestry and development) can dramatically increase soil erosion by exposing and destabilizing soils. Vegetation clearing can cause sheet and rill as well as gully erosion, reduced infiltration, increased upland surface runoff, and increased streambank erosion (Dunne and Leopold 1978; FISRWG 1998). These changes in stream flow discharges and sediment loads can cause head cutting, incision and/or widening of the channel, and associated sideslope failures (Dunne and Leopold 1978; Klein 1979; FISRWG 1998; Booth et al. 2002). White and Greer (2002) found that urbanization to the Upper and Lower Los Peñasquitos Creek sub-watersheds increased peak flood flows and dry-season runoff, reduced riparian species diversity, and modified the creek morphology from a broad braided channel to an incised streambed.

Numerous studies have illustrated how various land use activities can increase erosion rates and sediment loads. For example:

- Nelson and Booth (2002) evaluated a watershed-scale sediment budget in the Issaquah Creek watershed of western Washington and reported that human activity, particularly urban development, caused an increase of 50% in the annual sediment yield of the watershed with the main sources coming from landslides (50%), channel-bank erosion (20%) and road-surface erosion (15%).

- Trimble (1997) examined stream channel profiles from 1983 to 1993 in the San Diego Creek watershed and found stream channel erosion contributed two-thirds of the total sediment yield for the watershed. The increase in stream channel erosion was a result of a greater frequency and magnitude of peak stream flow in response to impervious urban surfaces.

- Battany and Grismer (2000) while studying vineyards planted on hillsides in Napa County reported that the extent of soil cover is the dominant factor in erosion rates.

- Research from the Caspar Creek Experimental Watersheds (Keppeler et al. 2003) showed that timber harvesting operations increased peak flows, suspended sediment loads, and erosion in associated stream courses.

- A study of pollen data from the Flynn Creek catchment in northern California (Constantine et al. 2005) showed that logging increased short-term overbank sediment deposition by more than 400 percent above natural levels.

- Amaranthus et al. (1985) examined debris slides over a 20-year period in the Klamath Mountains of southwest Oregon and found an increase in erosion rate associated with logging including rates on roads and landings 100 times those on undisturbed areas, and rates on harvested areas seven times that of undisturbed areas.

The removal of streamside vegetation removes the binding effects of roots upon the soil and causes a reduction in the hydraulic roughness of the bank resulting in increased flow velocities near the bank and streambank erosion (NRC 2002). The increased sediment load can cause channel aggradation and change stream cross sections; reduce channel capacity; increase width/depth ratios; and redirect flows into streambanks and induce bank erosion (Dunne and Leopold 1978; FISRWG 1998). In small streams, increased runoff and erosive forces may also dislodge logs and other channel features that help to define the channel. Loss of vegetation and its associated anchoring root masses can destabilize channel banks and other geomorphic features as well (Booth 1991; FISRWG 1998).

Vegetation conversion, both from changing climate regimes or from activities such as grazing, can dramatically increase the sediment load to the stream and result in channel instabilities. The conversion of hillslopes from coastal sage to grasslands to provide pasturage for cattle is a common occurrence throughout the Southwestern US. Gabet and Dunne (2002) in a study of shallow landslides during the 1997-1998 El Nino in Santa Barbara, California found that the conversion from vegetation with stronger and deeper roots (coastal sage) to vegetation with weaker and shallower roots (grass) caused a pulse of increased landsliding (22.9 failures per square kilometer in the grasslands, compared to 13.2 failures per square meter in the sage). In a separate study, Gabet and Dunne (2003) used a computer model to predict the delivery of sediment from hillslopes in a steep Mediterranean landscape near Santa Barbara, California and provided evidence that approximately 40% more sediment is delivered from grasslands than the sage scrub.

Stream armoring (i.e., the placement of hardscape materials such as riprap and concrete) and channel straightening commonly used for flood control can create an imbalance between water and sediment discharges resulting in the deposition of sediment or the erosion of the stream bed and bank (Brookes 1988; FISRWG 1998; Newson 2002; Fischenich 2003; Florsheim et al. 2008). Channelization attempts to fix the channel form and can cause channel destabilization by changing the balance between the stream flow and sediment load. Destabilization tends to affect entire stream system. For example, channelization can concentrate and synchronize peak flows from tributary streams, causing increased channel erosion both above and below the channelized reach. The eroded sediment is then deposited downstream when the flow slows down, where it may initiate further destabilization (Dunne and Leopold 1978; Brookes 1988; Hydromod TAC

1994; Mount 1995). A study of the Raba River in Poland (Wyzga 2001) illustrated how channelization can lead to downstream incision as a result of increased stream power and a reduction in sediment supply.

Activities such as dam construction and development (i.e., development that covers soils and routes runoff through stormdrains) can decrease soil erosion and sediment loads below natural levels (Dunne and Leopold 1978; Klein 1979; USEPA 1993; Mount 1995; FISRWG 1998). The decreased sediment load can cause channel incision and/or side-cutting and this effect may be compounded by increased runoff from an altered watershed. Aggradation may occur downstream where the flow slows and deposits the eroded sediment, which may then lead to further bank erosion and flooding problems (Emerson 1971; Dunne and Leopold 1978; Mount 1995; FISRWG 1998).

### *Destabilization: Secondary Effects*

Changes to stream flows and sediment loads can cause channel destabilization, and erosion and deposition problems. These geomorphic changes can have secondary and indirect impacts to stream and wetland system structures and functions. For example:

- Channel aggradation can cause local flooding by diverting flows and decreasing a stream's flow capacity (Mount 1995).
- Channel destabilization can encroach on riparian wetlands and undermine streamside vegetation (State Water Board 1994; FISRWG 1998).
- Channel incision can dewater shallow aquifers adjacent to the channel (Hydromod TAC 1994).
- Channel erosion can threaten property and structures (e.g., bridge abutments and utility crossings), leading to placement engineered "hardscape" materials in critical sections (Dunne and Leopold 1978; USEPA 1993; Mount 1995).
- Aggradation can bury diversion structures and other infrastructure and may require costly sediment removal to maintain flow capacity.

### *Geomorphology Impacts and Beneficial Uses*

Changes to the geomorphic processes of the stream and wetland system can have adverse effects on beneficial uses. For example, channel destabilization and excessive erosion or deposition of sediment can reduce or eliminate habitat, recreation, esthetic values, and other uses by affecting deep pools, pool-riffle ratios, undercut banks, substrate suitability, and other structural features (Klein 1979; Hydromod TAC 1994; Schueler 1994; FISRWG 1998). Secondary effects of channel destabilization can impact the majority of beneficial uses including municipal and domestic water supply, navigation, and groundwater recharge.

## Impacts to Water Quality

Various land use activities can result in the increased loading of pollutants; and a reduced ability of the stream and wetland system to enhance water quality, filter and purify surface water, moderate temperatures, control erosion, and stabilize streambanks.

### *Pollutant Loading*

Urbanization dramatically increases surface runoff during storm events which captures the pollutants associated with urban activity and results in runoff containing moderate to high concentrations of pollutants such as sediment, nutrients, heavy metals, petroleum hydrocarbons, chlorides, oxygen demanding substances, road salts, pathogenic bacteria, viruses, and pesticides (Schueler 1994; State Water Board 1994; FISRWG 1998).

Increases in runoff and erosive forces can create a broader channel with shallower flows and a smaller proportion of shaded water surface. These geomorphic changes and a loss of riparian vegetation can increase maximum water temperatures and daily and seasonal temperature fluctuations by exposing more water surface to the sun (Klein 1979; USEPA 1993; Mount 1995; FISRWG 1998). Shrimpton et al. (2000) in a study in the Torpy River watershed, British Columbia demonstrated that the removal of vegetation increases the diurnal change in temperature and that increase in water temperature are transmitted efficiently downstream. This study demonstrates how the downstream transmission of heat from upstream riparian vegetation removal can lead to cumulative impacts on water quality and harm aquatic species.

### *Reduced Pollutant Removal Capacity*

Land use activities can reduce the ability of the stream and wetland system to remove pollutants through natural processes resulting in greater concentrations of pollutants in receiving waters (Hydromod TAC 1994; FISRWG 1998). Channelization can decrease the natural pollutant removal capacity of stream and wetland systems by reducing instream structural complexity, overbank flow, and turbulent-flow aeration, increasing flow velocity, and by causing changes in the vegetation community (USEPA 1993).

Removal of vegetation adjacent to a waterbody can reduce the removal of nutrients and pollutants from the waterbody and from the overland flow draining to the waterbody (FISRWG 1998). A study of the Caspar Creek watershed in northern California (Dahlgren 1998) showed that nitrate concentrations increased following clearcutting (1.85 kg/ha in the clearcut watershed compared to <0.01 kg/ha in the reference watershed in 1991-1992). The author concluded this post-harvest increase was a result of more leaching from the soil as mineralization (i.e., release of nutrients from organic matter) was enhanced and nutrient uptake by vegetation was greatly reduced.

Disruption of the natural flow regime through regulation and surface water diversion decreases the nitrogen cycling functions of riparian areas by disrupting flow volumes and timing, which are critical to natural biogeochemical processes. Impoundments can lead to streambank erosion, turning riparian areas that were nitrogen sinks into nitrogen sources and alteration of the normal wetting-drying cycle of the floodplain decreases productivity and slows the processes of decomposition and denitrification. A study of the Wisconsin River (Kang and Stanley 2005) demonstrated that levees alter the structure of plant communities and can create soil environments that are less favorable to microbial decomposition, which could inhibit floodplain functions like denitrification.

Sedimentation can disrupt riparian forest functions and degrade water quality by reducing the capacity of the system to trap naturally occurring sediment in floodwaters and to filter contaminants and nutrients. A study in Georgia on erosion impacts on riparian processes from unpaved roads and trails subject to vehicle traffic (Lockaby et al. 2005) found that sedimentation rates of 2 mm per year caused decomposition rates, nitrogen mineralization, and microbial biomass carbon and nitrogen to decline significantly.

### *Water Quality Impacts and Beneficial Uses*

Water quality impacts impair many beneficial uses including water supply, recreation, fish and wildlife habitat, and shellfish production (USEPA 1993; State Water Board 1994). Increased water temperature can directly stress aquatic biota and can also affect other parameters associated with habitat quality, such as dissolved oxygen concentration and the rate of chemical reactions.

## Impacts to Biology

Various land use activities can have dramatic impacts to the habitat and populations of aquatic organisms and result in adverse changes in carbon supply, temperature, hydrology, and instream habitat structures (FISRWG 1998).

### *Habitat*

Channelization can cause adverse biological impacts resulting from increases in stream velocity, solar radiation reaching the channel, channel incision, and sediment load; and decreases in pool and riffle habitat complex and other heterogeneous structures and canopy cover (FISRWG 1998; Fischenich 2003; USEPA 2007).

Various land use activities in the stream and wetland system including channelization and the associated ongoing maintenance can reduce the diversity of habitats, destroy wetland and riparian vegetation, and change site features preventing the reestablishment of characteristic species (USEPA 1993). In urban streams, the quantity of LWD found in stream channels is reduced due to the loss of riparian vegetation, increased flows and erosive forces, and channel maintenance practices (Booth et al. 1996 as cited in FISRWG 1998, May et al. 1997). Loss of vegetation directly impairs the quality of aquatic and riparian habitat by reducing cover, structural diversity, and nutrient sources (Hydromod TAC 1994). A study of 16 streams in eastern North America revealed that riparian deforestation causes channel narrowing, which reduces the total amount of stream habitat and ecosystem per unit channel length and reduces the in-stream processing of nutrient and organic matter. Ziemer et al. (1991) using a constructed model of a 10,000-ha coastal watershed such as those found in Oregon and California and found that timber harvesting induced erosion can significantly raise salmon egg mortality compared to rates modeled in undisturbed watersheds.

A lowered water table as a result of hydrologic changes in runoff or groundwater dewatering from channel incision, can dry up wetlands, stress or kill mature riparian vegetation, and thus reduce the input of large woody debris to the channel. The lowered water table can substantially reduce the dry weather baseflows and the depth of flows necessary to support aquatic organisms.

Riparian plants depend on periodic floods for dispersal, creation of heterogeneous site conditions, and transport of nutrients and sediment (FISRWG 1998; Nilsson and Svedmark 2002). The invasion and success of exotic and introduced species in rivers is facilitated by the alteration of flow regimes including the seasonality, timing, and magnitude including the frequency of wet-dry cycles on floodplains (Bunn and Arthington 2002). Regulated rivers have altered species compositions and are often more vulnerable to exotic species invasion with the lower, less variable flows following regulation and damming leading to riparian decline due to water scarcity and diminished hydrochory (dispersal by water) (Nilsson and Svedmark 2002). Exotic flora and fauna can introduce widespread, intense, and continuous stress on native biological communities (FISRWG 1998, p. 3-6).

Projects which fragment habitat and reduce wildlife movement along riparian and other corridors can degrade remaining patches of wetlands and other habitat by changing their physical characteristics and by isolating and exposing small populations of plants and animals, resulting in local or regional extinctions (FISRWG 1998). Removal of vegetation can also fragment and isolate remaining patches of habitat, resulting in decreased habitat value over large areas (FISRWG 1998, Semlitsch 1998; NRC 2001; Hilty and Merenlender 2004).

Urban infrastructure can often be linear in nature (e.g., roads, sewers, and pipelines) and cross stream channels many times resulting in partial or total barriers to upstream fish migration (FISRWG 1998). May et al. (1997) found that the number of stream crossings increases directly in proportion to impervious cover.

Numerous studies have demonstrated the link between land use activities and impacts to the habitats and populations of aquatic organisms. For example:

- Couch (1997) provided evidence that watershed development on 35 major water streams near Atlanta, Georgia Study had a negative impact on the abundance and diversity of fish and macroinvertebrates.

- Jones and Clark (1987) found that watershed urbanization had a major impact on benthic insect communities in northern Virginia streams. The authors did not identify the exact mechanism responsible for the observed degradation but possible causes included increased scour and erosion, decreased baseflow, alterations in trophic relationships, and increased loading of toxic chemicals such as heavy metals, organics, and road salts.

- A study on Hudson River (Limburg and Schmidt 1990) tributaries found that the degree of urbanization has a strong influence on the densities of fish eggs and larvae suggesting that tributary intactness may increase the number of spawning fish.

- Klein (1979) while studying headwater streams in the Piedmont province of Maryland found that macroinvertebrate diversity drops sharply with urbanization and a "generally direct" inverse relationship between the degree of urbanization and the diversity of fish populations.

- Booth and Reinelt (1993) summarized physical, chemical, and biological data from a variety of streams and wetlands in King County, western Washington and reported that 10 percent impervious area typically yields demonstrable and probably irreversible, loss of aquatic system functions including measured adverse changes in channel morphology, fish and amphibian populations, vegetation succession, and water chemistry.

- May et al. (1997) examined the effects of urbanization on Puget Sound lowland streams and reported that urbanization resulted in: a large portion of riparian buffers in nonfunctional condition with little mature riparian forest; more common streambank erosion and locally excessive scour and fill; excessive fine sediment and the degradation of streambed habitat including significantly reduced pool area, habitat complexity, and large woody debris quantity; and a rapid decline in the biotic integrity of the benthic macroinvertebrate and salmonid communities.

### *Biology Impacts and Beneficial Uses*

Various activities can impair beneficial uses by destroying habitat or degrading its structural complexity, creating impediments for fish migration, and resulting in water quality effects including temperature, turbidity, and dissolved oxygen levels.

Designation of Beneficial Uses
Under USEPA regulations, states must designate beneficial uses for all waters within their boundaries (40 CFR 131.10). More specifically, USEPA regulations require states to designate "existing beneficial uses," which are defined as "those uses attained in a waterbody on or after November 28, 1975" (40 CFR 131.3(e)).[2] Under the Water Code, the Water Boards also designate and protect "potential beneficial uses" in their Basin Plans.

Water Code Section 13241 requires that each Water Board "establish such water quality objectives in water quality control plans as in its judgment will ensure the reasonable protection of beneficial uses," and, in establishing objectives, directs the Water Boards to consider "past, present, and probable future beneficial uses of water." Therefore, the term "potential beneficial use" as used in the Water Boards' Basin Plans refers to past and probable future uses of water that do not meet the Clean Water Act definition of existing uses, but may be restored or achieved in the future.

Waterbodies may have potential beneficial uses established for any of the following reasons: 1) the use existed prior to November 28, 1975, but is not currently being attained; 2) plans already exist to put the water to that use; 3) conditions make such future use likely; 4) the water has been identified as a potential source of drinking water based on the quality and quantity available (see

[2] Date of promulgation of the first Water Quality Standards Regulation by USEPA (Title 40 CFR 131.3, promulgated November 28, 1975).

*Sources of Drinking Water Policy*, State Water Board Resolution No. 2006-0008); 5) existing water quality does not support these uses, but remedial measures[3] may lead to attainment in the future; or 6) there is insufficient information to support the use as existing, however, the potential for the use exists and upon future review, the potential designation may be re-designated as existing.

Existing uses cannot be removed or modified unless a use requiring more stringent criteria is added (40 CFR 131.10(h) and 131.12(a)(1)). In addition, under 40 CFR 131.10(g) states may remove a designated use which is not an existing use, as defined in Section 131.3, or establish sub-categories of a use if the state can demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met; or
3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by Sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

### *How Other Water Boards Designated FLD and WQE*

In those Regions with the beneficial uses flood peak attenuation/flood water storage, water quality enhancement, and wetland habitat, the designation of these uses to specific waterbodies has been incomplete. Of the three Water Boards that specifically recognize these functions as beneficial uses (i.e., the North Coast, Lahontan, and Los Angeles Water Boards), only the Lahontan Water Board has, as of yet, designated them for waterbodies other than wetlands. The North Coast Water Board's FLD and WQE beneficial uses are defined broadly enough to apply to non-wetland aquatic ecosystems. However, when the North Coast Water Board adopted these uses in 2003, it added them as existing and potential uses of freshwater and saline wetlands but did not designate for any individual hydrologic unit/area/subunit/drainage features. Instead, when field reconnaissance is conducted as part of the wetland regulatory action, the specific beneficial uses of wetlands are identified as existing or potential on an individual basis.

[3] Remedial measures include implementation and effluent limits required under Section 301(b) and 306 of the Clean Water Act, and implementation of cost-effective and reasonable best management practices for nonpoint source control (Clean Water Act Section 131.10(d)).

In contrast, the Lahontan Water Board has also designated its FLD and WQE beneficial uses to some of its floodplain and riparian areas and a few of its streams. Thus, these beneficial uses are primarily designated to wetlands and no Water Board, including the Lahontan Region, has designated them broadly to perennial, intermittent, and ephemeral stream systems, despite the fact that, as described in *Section* ***Error! Reference source not found.****:* ***Error! Reference source not found.***, flood peak attenuation/flood water storage and water quality enhancement are fundamental functions of healthy stream systems as well as healthy wetland systems. The San Francisco Bay Water Board's beneficial use definitions and designations guidance for FLD and WQE reflects the current science on water quality functions provided by stream and wetland systems.

## Watershed Hydrology

Watershed Hydrology refers to the ways in which atmospheric, surface and subsurface phenomena are connected through the hydrologic cycle including the role of groundwater in maintaining wetlands and stream baseflows. Watershed Hydrology targets maintaining the connections between floodplains, headwaters, and other tributary streams and wetlands to support the ecological functioning of a watershed as a whole, including the availability of diverse habitat niches. Watershed Hydrology includes maintaining a natural flow regime characterized by periodic fluctuations of high and low flows that disturb, create, and enhance habitat elements, with flow magnitude, frequency, duration, timing, and rate of change mirroring natural levels. It articulates the connection between rainfall and flooding and the role of infiltration in moderating surface runoff, storm flows, and erosive forces. Watershed Hydrology addresses maintaining the natural pattern and range of flows and avoiding disruptions to each end of the hydrologic spectrum—baseflows and high erosive flows.

The natural level of hydrologic connectivity in the watershed helps maintain the pattern and range of flows (i.e., surface and subsurface flow frequency, timing, magnitude, and duration) necessary to support stream and wetland system beneficial uses (see *Section* ***Error! Reference source not found.****:* ***Error! Reference source not found.***). Natural flood processes in streams create disturbance and temporal and spatial heterogeneity that affect stream communities, increases habitat diversity, and provide for a variety of water quality functions. Maintaining this natural flow regime is essential because aquatic biota are adapted to predictable seasonal floods, wet-dry season fluctuations, and high magnitude infrequent flood events, and their life cycle stages, including breeding, rearing, migration, dispersal, and establishment, depend on these seasonal and interannual events. Poff et al. (1997) write:

> The timing, or predictability, of flow events is critical ecologically because the life cycles of many aquatic and riparian species are timed to either avoid or exploit flows of variable magnitudes. For example, the natural timing of high or low streamflows provides environmental cues to initiating life cycle transitions in fish, such as spawning, egg hatching, rearing, movement onto the floodplain for feeding or reproduction, or migration upstream or downstream.

Water stored in aquifers and hyporheic zones during high flow events maintain baseflows during drier periods of the year when stream levels drop below water tables. The volume and sustainability of streamflow from headwaters to downstream reaches commonly depends on these groundwater contributions. Groundwater recharge and hyporheic flows from streams to subsurface areas sustain a variety of plant and animal communities, including riparian vegetation and aquatic invertebrates, in floodplains and hyporheic zones.

Periodic inundation and drought within the river-floodplain system promotes the lateral exchange of organic matter and nutrients between the stream channel and floodplain. In addition, maintenance of channel-forming flows is critical to the proper functioning of these watershed services and an alteration in the timing of bankfull flows could result in sedimentation, loss or degradation of habitat, and increased flooding.

However, human land uses in watersheds may adversely impact hydrologic connectivity through activities such as water diversions and groundwater pumping, hydromodification (e.g., stream channelization and dams), floodplain encroachment, draining and filling of wetlands, and alteration of surface runoff and infiltration patterns (e.g., due to impervious surfaces, roadside ditches, and stormwater outfalls) (see *Section 0: Impacts to Hydrology*). The natural flows of many streams have been modified either by the presence of permanent or temporary dams or by the diversion or withdrawal of surface water in significant amounts. In highly modified watersheds, such as the Klamath River, the result can be a steep reduction in summer baseflows and a shift in the timing of peak flows. Baseflows that have been reduced over time might result in the stranding of summertime aquatic organisms within separate pools. Similarly, they might result in elevated water temperatures and/or reduced dissolved oxygen incompatible with the support of cold water fisheries. Another noted phenomena is:

> In regulated rivers of northern California, the seasonal shifting of scouring flows from winter to summer indirectly reduces the growth rate of juvenile steelhead trout (Oncorhynchus *mykiss*) by increasing the relative abundance of predator-resistant invertebrates that divert energy away from the food chain leading to trout. In unregulated rivers, high winter flows reduce these predator-resistant insects and favor species that are more palatable to fish (Poff et al. 1997).

Poff et al. (1997) also write “for many riverine species, completion of the life cycle requires an array of different habitat types, whose availability over time is regulated by the flow regime.” This is notably true of salmonid species whose life cycle requirements have evolved to maximize use of North Coast and San Francisco Bay Region stream habitats. Poff et al. (1997) further note that “in the absence of high flushing flows, species with life stages that are sensitive to sedimentation, such as the eggs and larvae of many invertebrates and fish, can suffer high mortality rates.” Changes to the hydrologic patterns of stream and wetland systems impact beneficial uses. For example, increased runoff can impair habitat values by flushing fish and invertebrates out of streams; increasing water level fluctuations and the velocity of flows entering wetlands; and causing salinity changes in estuaries and other nearshore marine waters. Increased flooding can impair habitat, water supplies, navigation, and other beneficial uses.

**Watershed Hydrology** The hydrologic connectivity between headwaters and estuary, surface water and ground water, and landscape, floodplain, and stream channel shall be protected to produce the pattern and range of flows necessary to support beneficial uses and a functional ecosystem.

The implementation plan for the Policy evaluates a permit applicant's potential impacts on the Watershed Hydrology water quality objective through consideration of environmental factors such as the alteration of site runoff flow and volume, and the maintenance of hydrologic connectivity and natural flow regime (see Section **Error! Reference source not found.**).