2.3 GEOLOGIC AND HYDROLOGIC VALUES, INCLUDING WATER QUALITY AND FREE FLOWING CONDITION

2.3.1 Geologic and Hydrologic Outstandingly Remarkable Values

The Merced River is the product of geologic and hydrologic processes that continue to shape the landscape. Glaciation and river erosion, coupled with the influence of bedrock fractures, carved pathways that the Merced River continues to follow, creating the river's variable gradients and dramatic changes in water speed and volume. Flows through classic, glacially carved canyons, over sheer cliffs and steep cascades exemplifying stair-step river morphology, through an alluvial landscape in Yosemite Valley, across a well-preserved recessional moraine, and past an exemplary boulder bar in El Portal.

River Segment 1: Merced River above Nevada Fall

The upper Merced River canyon is a textbook example of a rare, U-shaped canyon that was carved by glaciers.

This segment of the Merced River is characterized by a large-scale, U-shaped, glacially carved canyon. The Merced River above Bunnell Cascade highlights the relationship between geology and river course, as exemplified by the sweeping, glacially sculpted granite canyon that cradles the river.

River Segment 2: Yosemite Valley

The "Giant Staircase," which includes Vernal and Nevada falls, is one of the finest examples in the western United States of stair-step river morphology.

This river segment, famous for its glacially carved landforms, is unique in the scale, variety, and sheer grandeur of its celebrated rock and water features. Dropping over the 594-foot Nevada Fall and then the 317-foot Vernal Fall, the Merced River creates what is known as the "Giant Staircase." This exemplary stair-step river morphology is characterized by substantial variability in river hydrology, from quiet pools such as Emerald Pool to the dramatic drops in the waterfalls.

The El Capitan Moraine is an extraordinary example of a recessional moraine.

Yosemite Valley owes much of its form to periodic glaciations, with the rivers of ice following the track of the prehistoric Merced River. When the glaciers retreated, they occasionally paused, dropping their loads of sediment and forming recessional moraines. The best-preserved of these is the exemplary El Capitan Moraine.

The Merced River, from Happy Isles to the west end of Yosemite Valley, provides an outstanding example of a rare, mid-elevation alluvial river.

In Yosemite Valley, the Merced River is alluvial, characterized by a gentle gradient, a robust flood regime with associated large woody debris accumulation, and complex riparian vegetation. There are few examples in the Sierra Nevada of similar river morphology at this scale and elevation (about 4,000 feet).

River Segment 4: El Portal

The boulder bar in El Portal was created by changing river gradients, glacial history, and powerful floods. These elements have resulted in accumulation of extraordinary, large boulders, which are rare in such deposits.

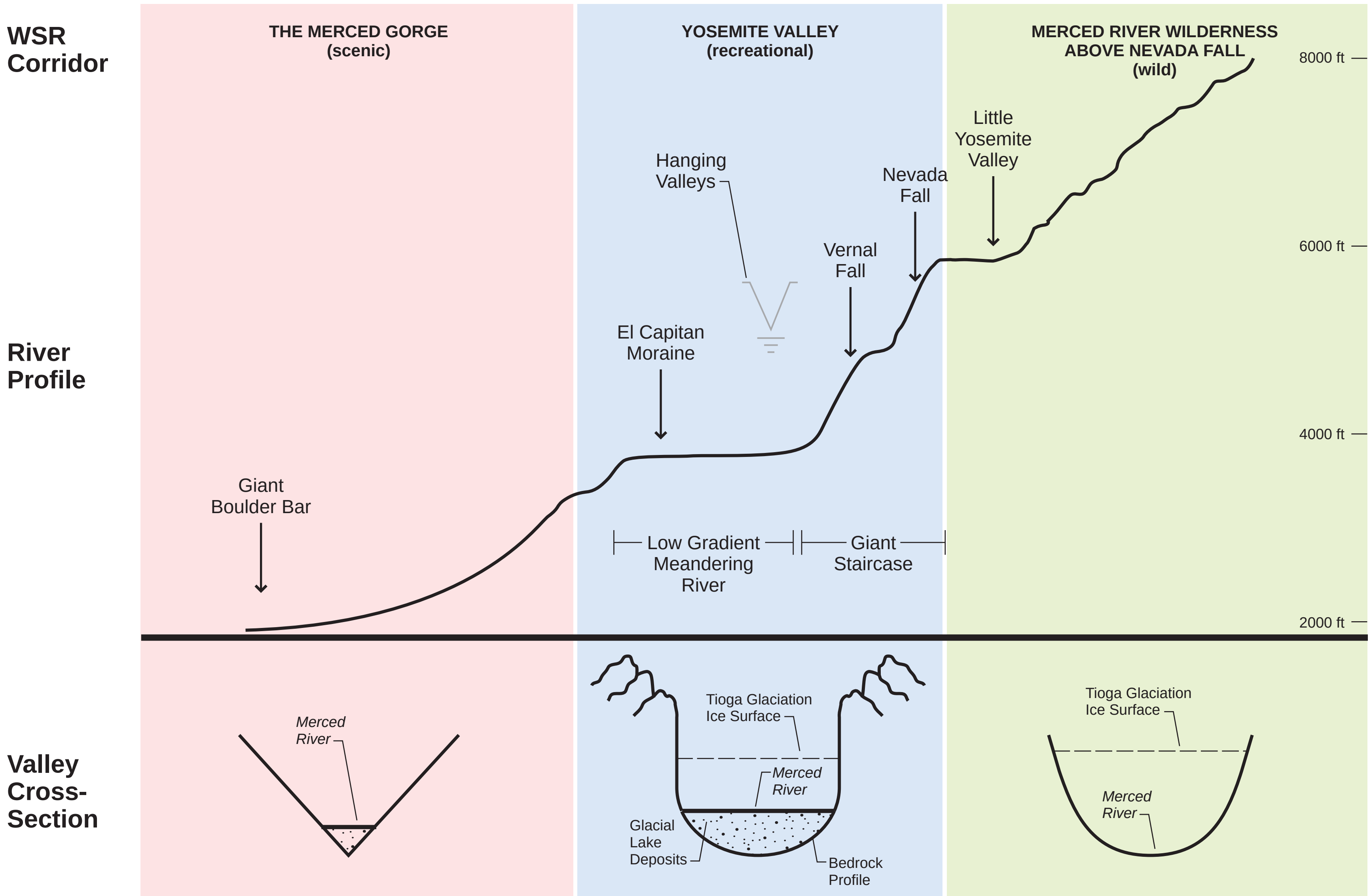
When river gradients decrease, rivers lose the energy needed to transport large sediments and boulders. In such areas, bar-type deposits—such as the large boulder bar at the east end of El Portal—are built up. This rare boulder bar contains massive boulders measuring over a meter in diameter and weighing many tons. It is the combination of boulder availability, steepness of the river in the gorge, major change in gradient and valley width at El Portal, and size of the Merced's peak floods that enables the river to create such a boulder bar. As illustrated by the January 1997 flood, the Merced continues to sort and build this bar, providing evidence in all seasons of the river's potential erosional and depositional ability.

2.3.2 Geologic and Hydrologic ORV Conditions

1& 2) Free-flowing Condition and Water Quality:

The glacial pathways that carved the Merced River and South Fork Merced River valleys form strikingly varied gradients and features. The Merced River begins in a high alpine setting and flows through steep gradients before transitioning to alpine valleys. The river then flows down sheer cliffs in waterfalls and cascades, creating some of the most dramatic views in the world, including Nevada Fall and Vernal Fall. As the river enters Yosemite Valley, its gradient quickly drops and the Merced becomes a gentle, meandering river. Here, in contrast to the dramatic falls and cascades above, the river is characterized by an active floodplain, bank erosion, meandering channel, and channel cutoff. Downstream of Yosemite Valley, the Merced River enters the Gorge where it again becomes a steep, tumbling river. These varied gradients, illustrated in Figure 2.3-1, offer dramatic views and experiences that are found in few other places on earth.

The underpinning features of this relatively unspoiled river that led, in part, to its designation as a Wild and Scenic River, are its free-flowing condition and high water quality. Compared to other rivers in the Sierra Nevada, the Merced River has remained relatively untouched throughout Yosemite National Park. The river has been allowed to undergo natural stream processes that many rivers in more developed areas no longer experience. These processes include erosion, deposition, channel avulsion (i.e., abandonment of an old river channel and the creation of a new one), and regular flooding, which have led to the development of complex channel patterns and valuable riparian and wetland habitat. However, people have sought to control channel erosion and avulsion in Yosemite Valley to support development, which has caused a reduction in these natural processes and the associated habitat niches they create. The upper watersheds of the Merced River and the South Fork Merced River are entirely within designated Wilderness and are protected from development. As a result, water quality in the Merced and South Fork Merced is very high, and these river segments provide excellent habitat for aquatic organisms.



Note: River profile adapted from California Division of Mines and Geology Bulletin 182, 1962
Not to scale

SOURCE: ESA, 2010; CDMG, 1962

Figure 2.3-1
Schematic Longitudinal Profile and Cross-sections along the Merced River

*3) **Geologic Processes***: The rocky cliffs, cascades, and broad valleys along the Merced River represent a nationally significant example of a glaciated landscape. The general Sierran landforms were all well established before glaciation, and the major stream drainages provided the avenues that the glaciers would later follow. The course of the present-day Merced River is determined by the path of glaciers that came and went during the geological epoch known as the Pleistocene (10,000 to 1.8 million years ago) (Table 2.3-1). These glaciers transformed valleys from V-shaped to U-shaped, left hanging valleys along their lower reaches, and deposited thick packages of glacial till—ultimately shaping the iconic landscapes for which Yosemite Valley and the upper Merced River are now known (Figure 2.3-2). Most researchers agree that at least three major glacial advances, or stages, have taken place: the Tioga, the Tahoe, and a much older pre-Tahoe (possibly the Sherwin). The Tioga glaciation is considered to have peaked around 20,000 years BP, but the precise timing of the earlier stages is still a topic of debate.

TABLE 2.3-1: GLACIAL CHRONOLOGY OF YOSEMITE VALLEY

Sierra Glaciation	Age (approximate)	Characteristics/Evidence
Tioga	26,000 to 18,000 years ago	Minimal gullying of flanks Terminal moraine nearly complete except for narrow breaching by axial streams
Tahoe (or Tahoe II)	80,000 to 140,000 years ago	Flanks deeply gullied Termini eroded, mostly removed
Sherwin (“pre-Tahoe”)	800,000 years ago	Scattered erratic boulders and formless bodies of till

BP = Before Present

SOURCE: Glazner and Stock 2010

The Tioga, Tahoe, and pre-Tahoe glaciations affected most of the Sierra Nevada (Table 2.3-1). These glacial processes are not by themselves rare; however, it is the combination and quality of glacial features present along the Merced River that makes its geological and hydrological processes unique and exemplary.

Following the upper Merced River through Yosemite Valley and down the Merced River Gorge, the limits, depths, or even absence of prior glaciers created an extraordinary variety of landscapes from the classic U-shaped valley along the upper Merced River above Nevada Fall to the V-shaped valley that characterizes the Merced River Gorge, as illustrated in Figure 2.3-1.

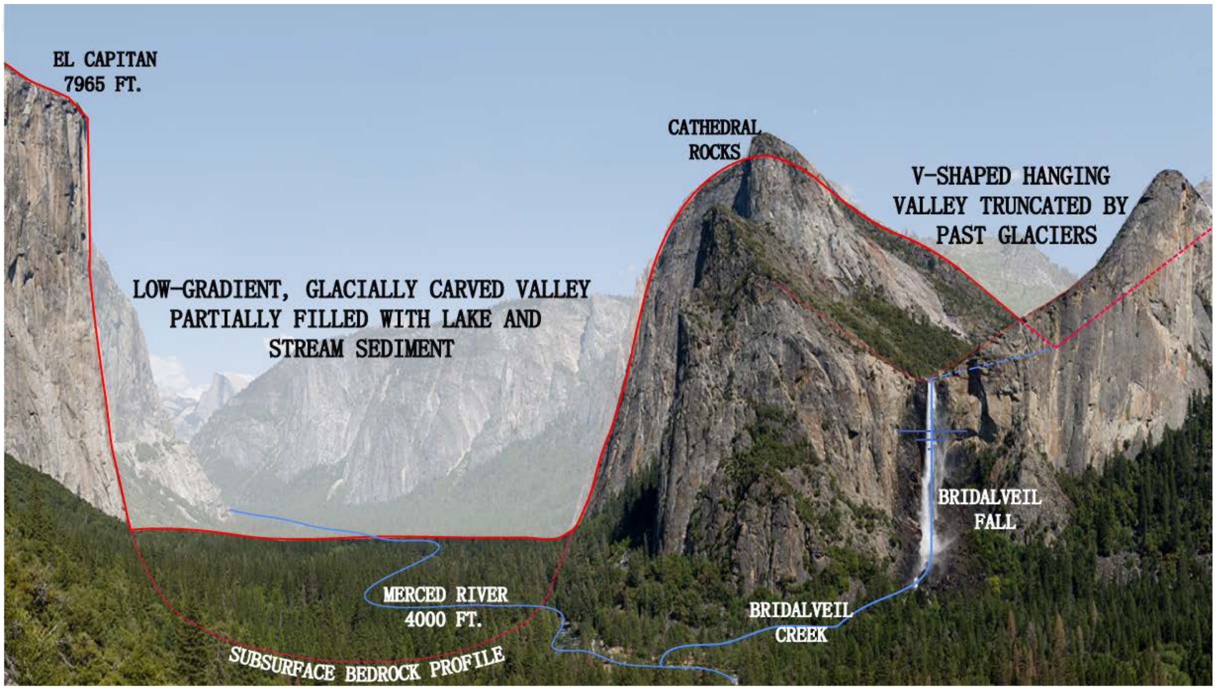
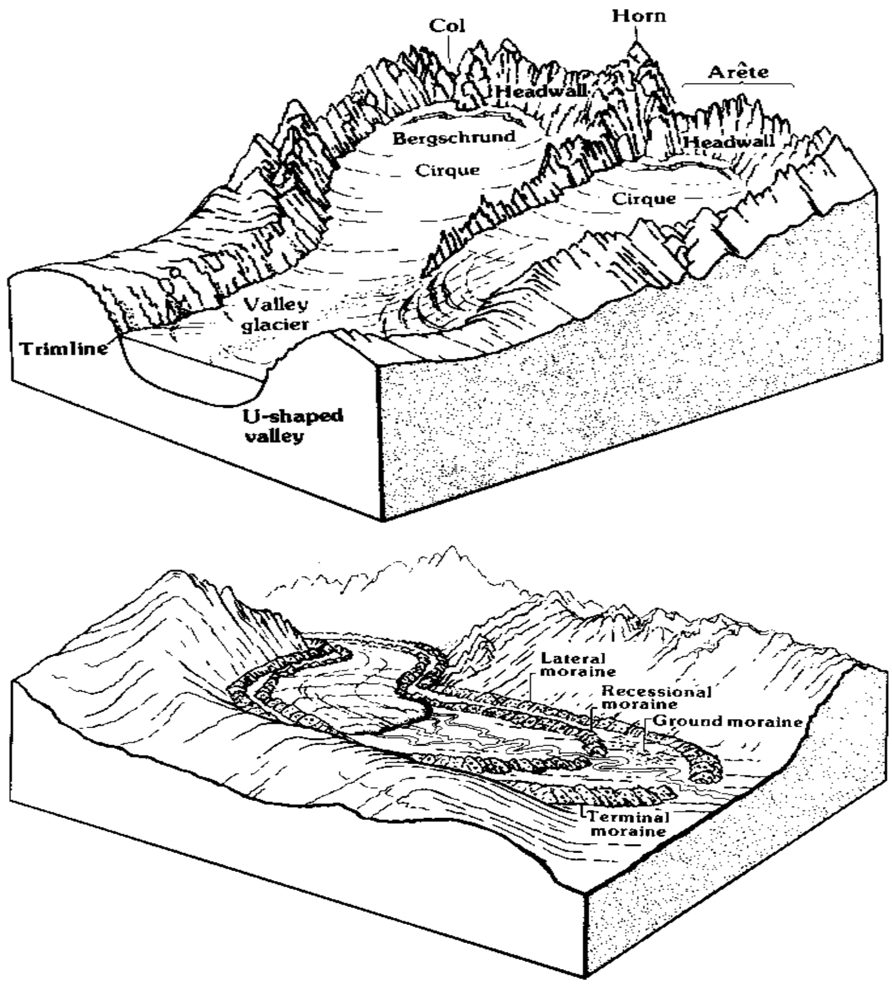


Photo Credit: NPS Panoramic Imaging Project

Figure 2.3-2
Yosemite Valley

François Matthes, who pioneered the study of Yosemite Valley's geology, continued the use of John Muir's term for Yosemite as being the "incomparable valley" largely due to the variety of geologic processes that are evident within the same panoramic views (Matthes 1930). When the Tioga-age glacier retreated from Yosemite Valley, it left behind a moraine across the Merced River. Acting as a natural dam, the Valley floor filled with sediment-laden waters that eventually formed a low-gradient platform along which the Merced River could meander. This system facilitated the development of a rich riparian and meadow complex (Huber 1989). Because the most recent glaciations did not reach the rim of Yosemite Valley, the highest ridges and peaks have been exposed to natural weathering processes, creating the broken spires and irregularly sculpted surface that glaciers would normally polish away (Huber 1989; Glazner and Stock 2010). The valley walls below the glacial trimline exhibit textbook evidence of prior glaciers, such as glacial moraines and steep, polished surfaces (Figure 2.3-3). The type, quality, and variety of geological and hydrological features evident along the Merced River are unparalleled.



SOURCE: Huber 1989

Figure 2.3-3
Classic Elements of Glacial Landforms

2.3.3 River Segments 1 and 5: Merced River above Nevada Fall and South Fork Merced River above Wawona

These segments of the Merced River contain the most undisturbed riverine conditions in Yosemite National Park. The Merced River and South Fork Merced River watersheds lie entirely within the Yosemite Wilderness, so relatively few changes have been made to the river along these segments. These watersheds contain over 1,000 lakes and ponds, 36 miles of free-flowing river, and extensive high-altitude wetland complexes.

The Merced River above Nevada Fall descends from its headwaters through a glacially carved canyon, dropping from roughly 13,000 feet to 6,000 feet over a distance of 12 miles (Figure 2.3-4). Four tributaries to the Merced River (the Lyell Fork, Triple Peak Fork, Merced Peak Fork, and Red Peak Fork) meet in a low-gradient, glacially carved valley at approximately 7,500 feet. Below Bunnell Cascade, the Merced River enters Little Yosemite Valley, another low-gradient, glacially carved valley. Here, the river meanders across its floodplain, creating oxbow lakes and meander cutoffs. Just above the confluence of Sunrise Creek, a large, centuries-old logjam impounds the river. Logjams, like this one, are important for the development of complex river morphology. They have a profound influence on the formation of floodplain patterns and profiles, creating a diversity of channel forms and aquatic habitats (Montgomery and Abbe 2006). The location of this logjam is shown in Figure 2.3-4.

The headwaters of the South Fork Merced River originate near Triple Divide Peak at an elevation of over 10,500 feet. Upstream from Wawona, tributaries enter the steep-walled canyon of the South Fork from the north and south. Downstream from Wawona, the South Fork once again enters a steep canyon and is largely inaccessible, having no trail crossings in this reach. Chilnualna, Big, Alder, and Bishop Creeks are major tributaries to the South Fork.

Condition at the Time of 1987 Designation

2.3.3.1.1 Free-flowing Condition.

When the Merced River was designated as Wild and Scenic, Segments 1 and 5 had a few small structures, as well as riprap, that minimally impeded flow. Several small footbridges crossed the river in these areas. A small diversion dam above Nevada Fall also impounded flow. Approximately four small, wooden footbridges crossed the Merced River upstream of the Nevada Fall Bridge and created minor constrictions. On the South Fork, the river was largely inaccessible to hikers, so there were no footbridges or impoundments. No sections of the riverbank contained riprap or were otherwise hardened, and the river actively migrated and avulsed over time, creating the geomorphic conditions that contributed to diverse ecological niches. Channel avulsion was especially pronounced in the vicinity of the Little Yosemite Valley logjam.

2.3.3.1.2 **Water Quality**. At the time of designation, water quality in the South Fork Merced River above Wawona was characterized as high, with minor indications of impacts from human activities (NPS 1994). The water was generally found to be low in nutrients, salts, and suspended sediment and high in dissolved oxygen (NPS 1994). Although limited data had been collected for the Merced River above Nevada Fall, the available information indicated that water quality here was high (Clow et al. 1996).

2.3.3.1.3 Geologic Condition (U-shaped Canyon ORV). The segment of the Merced River above Nevada Fall runs through a large-scale, U-shaped, glacially carved canyon (Figure 2.3-5). The Merced River above Bunnell Point highlights the relationship between geology and river course, as exemplified by the sweeping, glacially sculpted granite canyon that cradles the river. At the time of designation, the geologic value of this ORV element (the U-shaped, glacially carved canyon) was unaffected by human activities. Segment 5 does not contain geologic ORVs.

Current Condition

2.3.3.2.1 Free-flowing Condition. No additional structures have been placed in the bed and banks of the river since the time of designation. All structures that existed at the time of designation remain, including the diversion dam above Nevada Fall and several small footbridges.

2.3.3.2.2 Water Quality. Water quality in these two river segments remains high. Nutrient levels in these segments are generally low (Brown and Short 1999). Nitrogen concentrations are higher above

Nevada Fall than in Yosemite Valley, which is consistent with the lower rate of nitrogen assimilation that occurs at higher elevations (Brown and Short 1999).

Several studies have attempted to discern a link between pack stock use and transport of pathogens to receiving waters in River Segment 1 (Derlet and Carlson 2002; Derlet and Carlson 2006; and Derlet et al. 2008). These studies were considered for inclusion in this report, but they lack the scientific rigor necessary for drawing conclusions on water quality impacts from pack stock use in this segment.[28] In contrast, NPS water quality monitoring (using standard water quality monitoring methods) in wilderness sites downstream of more heavily used pack stock sites (Lyell Fork Tuolumne River at Twin Bridges and Tuolumne River below Conness Creek,(outside the Merced River corridor) show low levels of pathogens over multiple samples and multiple years (Clow et al. 2011). Overall, water quality in wilderness areas appears to be excellent. These sites will continue to be monitored as part of the NPS water quality monitoring program.

2.3.3.2.3 Geologic Condition (U-shaped Canyon ORV). The river- and glacier-carved landscapes along the Merced River are the result of varying geologic processes operating over immense spatial and time scales. Since the time of designation, human intervention has not perceptibly modified the ORV elements arising from these geologic processes.

2.3.3.3 Preliminary Management Considerations

The preliminary management considerations associated with the Geologic/Hydrologic ORV in segments 1 and 5:

Water Quality:

- Water quality in these river segments is high. The National Park Service will continue to protect water quality by monitoring and identifying potential pollution sources.

Geology:

- Geologic processes will continue to shape the landscape.

[28] These studies did not use rigorous, published methods for water sample collection and storage, did not define sample locations and dates, and did not employ repeat sampling over time at any one location.

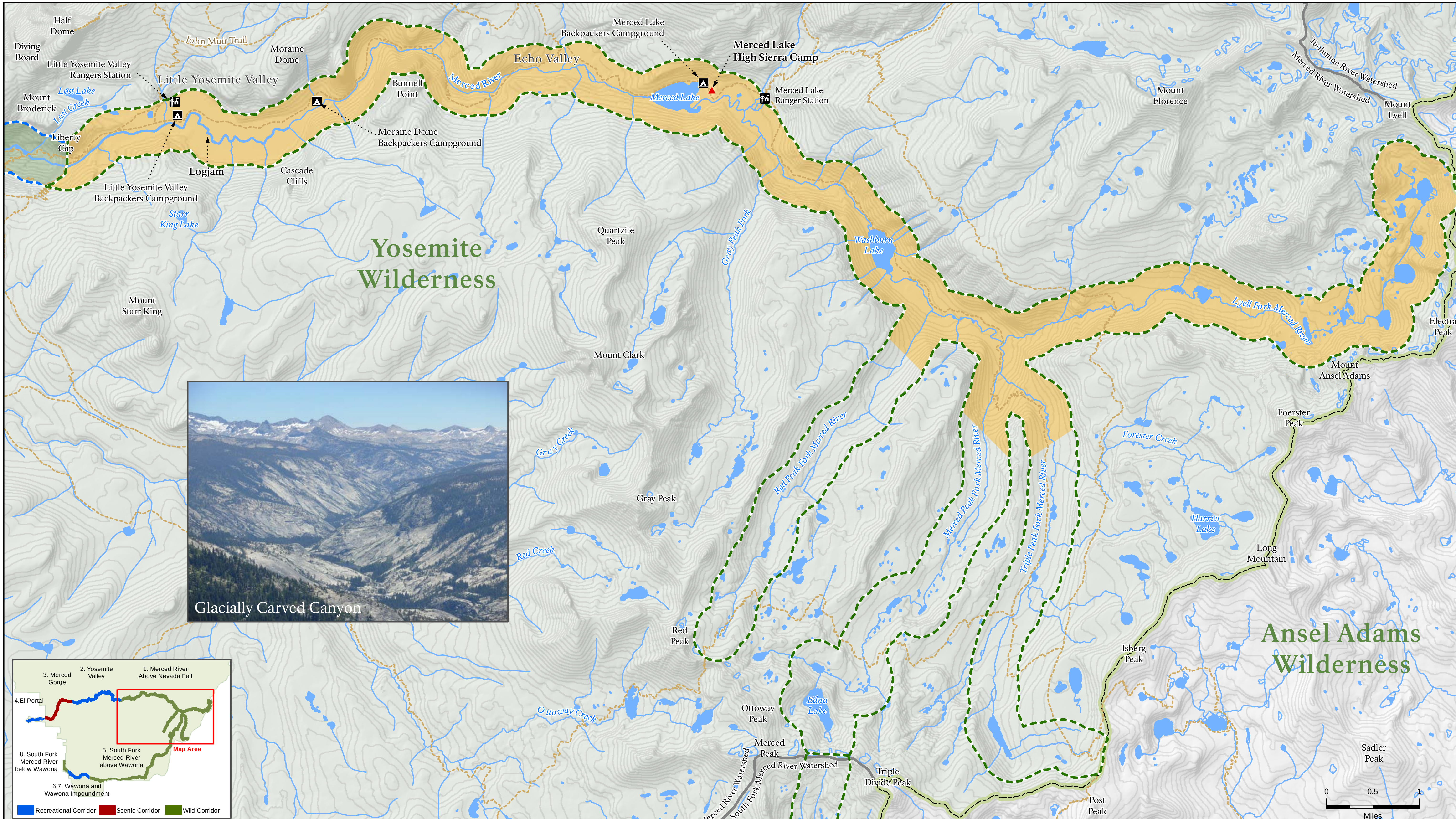


Figure 2.3-4
Geologic/Hydrologic ORV - River Segment 1.
Merced River Above Nevada Fall
Wild WSR Corridor

National Park Service U.S. Department of the Interior

Produced by: Yosemite Planning Division

Projection:	North American Datum 1983, UTM Zone 10
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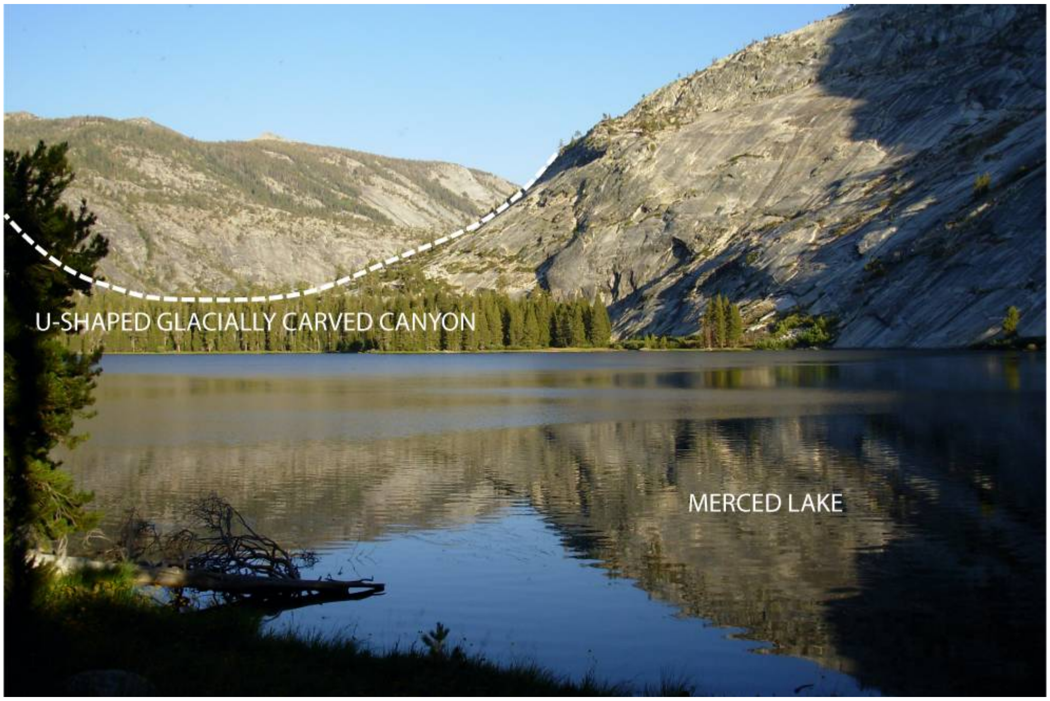

Photo Credit: Mike Yochim

Figure 2.3-5
U-shaped, Glacially Carved Canyon along the Upper Merced River

2.3.4 River Segment 2: Yosemite Valley

The Merced River plunges into Yosemite Valley via Nevada and Vernal Falls, descending from 6,000 feet to the Valley floor (at 4,000 feet) over a distance of two miles. At 594 feet in height, Nevada Fall is one of the largest waterfalls in the United States. Together with the 317-foot-high Vernal Fall, these waterfalls form what is known as the Giant Staircase. As the river crosses the floor of Yosemite Valley, its character changes dramatically in response to the changing geology and gradient of the Valley. Between Nevada Fall and Happy Isles, the river transitions from a granite bedrock channel, to a cascade formed by huge boulders that have fallen from the Valley walls since glacial times, to a step-pool channel formed from smaller talus and woody debris from the surrounding forests. Downstream of Happy Isles, the gradient changes from 2% to less than 1% as the river transitions from a cobble and boulder plane-bed to a riffle-pool morphology in the alluvial sands and gravels of the Valley floor. In its alluvial portion through the east and west Valley, the channel is almost flat as it meanders across the Valley floor. This low gradient is due to the sediment deposited by the river since the last glaciation and the glacial moraine between El Capitan and Cathedral Rocks. The El Capitan recessional moraine rises 58 feet above the Valley floor. Since the last glaciation, this moraine has provided a partial dam that slowed floodwaters causing sedimentation upstream, giving the Valley its characteristic flat floor, and contributing to the development of extensive wet meadows (Milestone 1978).

The Merced River flows across the Valley floor in a series of meanders (Figure 2.3-6). Aerial photos and maps reveal a series of relict meander oxbows that were created and abandoned as the river migrated across the Valley floor. These forms, and the processes that created them, are integral to the free-flowing condition of the Merced River and form a key linkage between the geomorphic processes of the river and the ecology of the Valley floor. Meanders migrate downstream and towards the outer bend over time, eroding a river's outside banks and depositing sediment to form new floodplain[29] on its inside banks. Channel migration across the floodplain supports several ecological processes.

Deposition of new floodplain sediment creates unvegetated banks that undergo vegetation succession. Pioneer species, seedlings, and light-loving species are able to establish, creating new stands of young vegetation in contrast to the older stands of mature shady trees on the outside banks. Madej et al. (1991) and Florsheim (2008) have argued that bank erosion and channel migration are fundamental to maintaining the processes that underpin many of the functions, forms, and landscapes that are valued in the Merced and other river corridors. Preserving and restoring these processes require a long-term, systems-scale approach.

Bank erosion on outside bends creates important habitat areas, such as overhanging banks and undercut tree roots that shelter fish from predation (Florsheim et al. 2008; Sullivan et al. 1987). Over time, bank erosion causes trees to fall into the river, adding nutrients to the base of the food chain and providing hydraulic complexity that creates feeding lanes and shelter for fish and other organisms. In addition, large wood increases flow resistance, reducing overall erosion levels while creating patchworks of local pool scour and sediment deposition that further diversify aquatic habitats. When present in sufficient volume, large wood can block the channel and deflect the stream currents, leading to more dramatic avulsions in the stream channel that create oxbow lakes, abandoned high-flow channels, and wetlands. The combination of gradual migration and occasional, dramatic avulsion creates a diverse combination of habitats on the floodplain.

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[29] As defined in this report, a floodplain is the land adjacent to the river that is inundated periodically during high water. Floodplains contain several geomorphic features that are important to river health, such as oxbows, point bars, meander scrolls, overbank deposits, and logjams. The term "floodplain" is a geomorphic term and does not refer to a regulatory boundary, such as the 100-year floodplain.

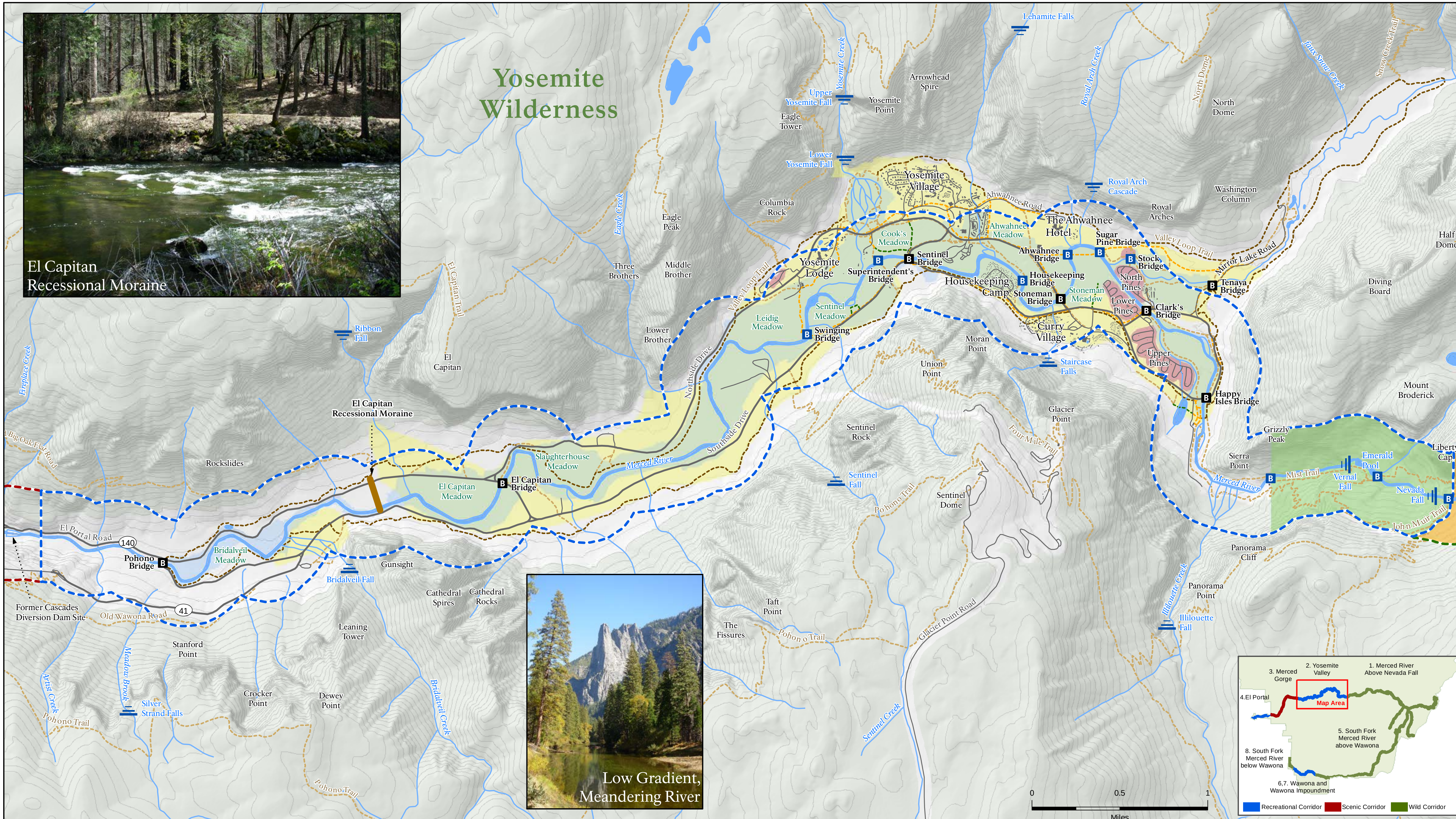

Figure 2.3-6
Geologic/Hydrologic ORV - River Segment 2.
Yosemite Valley
Recreational WSR Corridor

Recreational WSR Corridor Classification
Scenic WSR Corridor Classification
Wild WSR Corridor Classification
Buildings
Campground
100 Year Flood Boundary
Giant Staircase
U-Shaped Glacially Carved Canyon
Low Gradient, Meandering River
Road bridge
Footbridge
Waterfall
Stream/River
Road
Valley Loop Trail
Bike path
Boardwalk
Trail
100' Contour Line

National Park Service U.S. Department of the Interior

Produced by: **Yosemite Planning Division**

Projection:	North American Datum 1983, UTM Zone 10
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Condition at the Time of 1987 Designation

Free-flowing Condition (Mid-elevation Alluvial River ORV).

Although the ORV conditions assessment is based on conditions at the time of Merced Wild and Scenic River designation, it is helpful to describe changes occurring prior to this time so as to understand trends in the river condition. Between Nevada Fall and the Happy Isles Bridge, the river was naturally controlled by bedrock and massive talus boulders that made it more resistant to human impacts than the alluvial reaches downstream. Though the trails through this area were heavily used and there are three river crossings, there was less direct access to the river banks than on the more approachable reaches downstream. The free-flowing condition of the river was largely intact, with only minor constrictions at the Nevada Fall Bridge, the Happy Isles Bridge, the Happy Isles Gaging Station footbridge, and two footbridges on the Mist Trail. From Happy Isles Bridge to Clark's Bridge, the channel had a gradient of 1% and was confined on the right bank by moraines for much of its length. Relatively speaking, this reach was sparsely used by visitors to the park and was generally stable at the time of designation (Madej et al. 1991).

Below Clark's Bridge, the river gradient dropped to 0.16% (Madej et al. 1991) and became a meandering alluvial system. Although the alluvial reach of the Merced River across the flat, heavily visited portion of Yosemite Valley was relatively free-flowing compared to most rivers in California, this segment was the most impacted reach of the river within Yosemite National Park, especially within the east Valley floor between Clark's Bridge and Sentinel Bridge. Between the Euro-American discovery of the Valley in 1851 and the Merced River's designation as Wild and Scenic in 1987, the free-flowing condition of this river segment had been somewhat modified compared to other segments in the park.

In 1879, large boulders were blasted to deepen and widen the river gap through the El Capitan moraine, which lowered the base level of the Merced River by 4 to 5 feet (Milestone 1978). As a result, the extent and frequency of flooding in the upstream meadows were reduced within approximately three to four miles of the moraine (approximately up to Superintendent's Bridge), leading to drier conditions and the loss of wetlands.

Large wood, such as downed trees and logjams, had been removed from the river since the 1870s to reduce flood risk near bridges and to facilitate road construction and river recreation. Current practice within the rafting recreation zone (between Stoneman Bridge and Sentinel Beach Picnic Area) is to move wood to create safe lanes of travel. Outside this zone, wood is manipulated if it directly impacts infrastructure (Roche 2011b). In the 1970s, park policy dictated that the channel should be cleared of wood from Happy Isles to Pohono Bridge (Madej et al. 1991). The removal of large wood has contributed to channel simplification, creating a more homogeneous river. The practice has encouraged faster, more erosive flows and promoted vertical channel erosion (downcutting) rather than point bar creation, lateral migration, and avulsion. It has also removed a source of nutrients, cover, and substrate for aquatic organisms (Montgomery and Piégay 2003). Madej et al. (1994) conducted an inventory of large wood that provides the best picture of wood loading around the time of designation in 1987. They found 12 pieces of wood per kilometer in the upper study reach (between Clarks Bridge and Sentinel Bridge) and 29 pieces/km in the lower reach (comprising the 1.6 miles upstream of El Capitan Bridge). Cardno ENTRIX (2011) repeated this survey in 2010 (discussed below) and found that the level of wood loading reported in 1994 was 7-17% of the levels found in natural systems within the Douglas fir-ponderosa pine forest of the eastern Cascades (Fox and Bolton 2007).

Evidence, such as historical maps and floodplain topography, suggests that the Merced River has always had a high rate of lateral erosion, which may have increased in response to human activities, such as trampling along the banks. Between 1879 and the early 1970s, NPS performed extensive bank stabilization to prevent channel migration near campsites and infrastructure. By 1987, 25% of the Merced River bank had undergone bank revetment (i.e., lined with riprap) between Clark's Bridge and Sentinel Bridge, the area with the greatest infrastructure and human presence. In the west Valley (downstream of Swinging Bridge), only 2% of the channel is riprapped. Riprap—though successful in preventing channel erosion—inhibits the free-flowing condition of the river by preventing natural stream processes, such as lateral migration and point bar formation (Florshiem et al. 2008; Schmetterling et al. 2001). Between 1919 and 1986, visitor trampling along the banks and use of the banks as access points to the river between Clark's Bridge and Sentinel Bridge had damaged riparian vegetation, which allowed banks to widen by an average of 27% along this reach and by over 100% in some locations. At the time of designation, 39% of the Yosemite Valley segment was actively eroding, even though 25% of the eroding channel had been lined with riprap in an effort to control bank erosion. Downstream in the west Valley, 25% of the banks were actively eroding and only 2% were lined with riprap, allowing more natural channel dynamics. Madej et al. (1991) found a strong association between levels of human use around campsites and river access points and the loss of riparian vegetation cover and accelerated bank erosion.

Eleven bridges spanned the Merced River between Happy Isles and the Pohono Bridge at the time of designation. All of these bridges constricted flow to some degree, but hydraulic constrictions were especially pronounced at the five arch bridges built in the 1920s (Clark's Bridge, Ahwahnee Bridge, Sugar Pine Bridge, Stoneman Bridge, and Sentinel Bridge) as well as at Housekeeping Bridge. The locations of these bridges are shown in Figure 2.3-6. Milestone (1978) found the average constriction to be almost 50 feet, or 40% of the natural channel width. These bridges created backwaters and excessive sediment deposition upstream, resulting in more rapid scour downstream. Bridges also created hard points that anchored channel migration, preventing channel evolution. Some bridges—for example,Sugar Pine Bridge—created such strong confinement and upstream aggradation that they appear to have accelerated channel avulsions along alternative flow paths that were starting to develop before the bridges were constructed. The effects of some of these bridges were exacerbated by the elevated road causeways leading to them, which intercepted and concentrated floodplain flows at high water.

At the time of designation, the Happy Isles Dam, a 6-foot-high structure spanning the river near Happy Isles, created a barrier to flow though no longer used to produce electricity or divert water.

Water Quality.

At the time of designation, water quality in Yosemite Valley was characterized as high, with minor indications of impacts from human activities. The water was generally found to be low in nutrients, salts, and suspended sediment and high in dissolved oxygen. Occasional concentrations above freshwater criteria were noted for lead, cadmium, and mercury (NPS 1994). Given the proximity of the river to development, these pollutants may have originated as runoff from impervious surfaces (such as parking lots and roads) or leakage from underground tanks or landfills.

Geologic Condition.

Yosemite Valley contains two Geologic ORVs, as described below. The locations of these ORV elements are shown in Figure 2.3-6.

> *The Giant Staircase*. The Giant Staircase, which includes Vernal and Nevada Falls, is one of the finest examples of stair-step river morphology in the country (Figure 2.3-7). The abrupt elevation changes of this feature illustrate the variability of the Merced River's hydrology. The Giant Staircase is a large-scale geologic feature created by the combined actions of past glaciers and local differences in the resistance of the underlying granite rock to erosion. The ORV element had not been perceptibly modified (e.g., alteration of topography via quarrying or blasting) at the time of designation.
>
> *El Capitan Recessional Moraine*. The El Capitan moraine, located in the west Valley, is a textbook example of a recessional moraine (Figure 2.3-8) (Huber 2007; Glazner and Stock 2010). At the time of designation, this ORV element had been slightly modified. In 1879, a guardian of the valley (Galen Clark) blasted large boulders where the Merced River crosses the moraine, thereby lowering its original elevation by 4 to 5 feet along the river corridor (Milestone 1978). At the time of designation, the moraine was largely intact and unaltered when viewed as a large, cross-valley geological/topographical feature. It is the most conspicuous example of a glacial moraine in the valley.

Current Condition

Free-flowing Condition (Mid-level Alluvial River ORV).

Since the Merced Wild and Scenic River designation, localized riverbank restoration projects have been implemented in this segment at Housekeeping Camp, North Pines Campground, Sentinel Bridge, the former Lower River Campground, and the original El Capitan Picnic Area. The El Capitan Picnic Area has been relocated farther from the river as part of these restoration projects. Restoration techniques have included soil decompaction, revegetation, bioengineering stabilization, riprap removal, and installation of fencing to protect restored areas. In addition, the Happy Isles dam, present at the time of designation, was removed. These actions eliminated some impediments to the free-flowing condition of the river; however, the fundamental causes of channellizationremain, including the removal of large wood from the channel, bank revetment, bridge confinement, and continued bank erosion. Through these restoration projects, approximately 1,700 cubic yards of riprap have been removed from the banks of the Merced River, 2,600 feet of biotechnical bank stabilization have been installed, and 15,000 feet of fencing have been installed (numbers estimated from Cardno ENTRIX 2011). The installation of riprap largely ceased in the early 1970s, and no new hardened bank stabilization has been added since the time of designation. Since 1987, the river has undermined riprap in some locations, and bank erosion is occurring behind the lines of riprap.

Large wood continues to be managed, although less aggressively than at the time of designation. The current maintenance practice is to move large wood that threatens boaters from the center of the channel to the edges where possible (Roche 2011a), although this practice is not official park policy. Cardno ENTRIX (2011) repeated the large wood loading study of Madej et al. (1994) and found that in the upper reach wood loading had increased from 19 to 70 pieces per mile, while in the lower reach the load had increased from 47 to 97 pieces per mile. This increase was attributed to a combination of changes in NPS management and bank erosion and wood recruitment resulting from the 1997 flood. Within the Valley, wood loading varies, with the highest levels found in the Happy Isles reach. However, for the Valley as a whole, large wood loading is still below levels found in comparable natural settings, with a level of approximately 26-35% of that found in a similar study of unmanaged watersheds in the eastern Cascades (Cardno ENTRIX 2011).

Hydraulic restrictions due to bridges remain similar to the levels that existed at the time of designation. One bridge (the Happy Isles Gage Bridge) was removed from the channel following the 1997 flood, and Sentinel Bridge was reconstructed immediately upstream of its original location. Anecdotal evidence suggests that deposition upstream of bridges—notably at Sugar Pine Bridge—has continued. This has created conditions that make channel avulsion around the bridge more likely than was the case in 1987. Large scour holes still exist near bridges in the Valley.

This segment has undergone further bank erosion and widening since the time of designation in 1987. Erosion has occurred primarily on the outside of meander bends, with the most significant location being near Sentinel Beach Picnic Area. Channel widening also occurred through erosion of both banks between Swinging Bridge and El Capitan Picnic Area and on the outer bends between El Capitan Picnic Area and El Capitan Meadow (Cardno ENTRIX 2011).

Water Quality.

In recent years, several studies have been conducted on water quality in Yosemite Valley. Water quality remains high, with most water quality constituents measured near natural background levels. Bacteria levels have been higher in the vicinity of Sentinel Bridge and Pohono Bridge than elsewhere in the watershed, but those levels are well below public health limits (Clow et al. 2011). Nutrient concentrations are very low (Brown and Short 1999) and have been near background levels for similar undeveloped areas (Clow et al. 2011). Nitrogen concentrations are lower in Yosemite Valley than in the watershed above Nevada Fall, which is consistent with the effects of atmospherically deposited nitrogen and the lower rate of nitrogen assimilation that occurs at higher elevations. Phosphorus levels are higher in Yosemite Valley than levels above Nevada Fall, reflecting typical patterns of phosphorus weathering due to increased drainage area size (Clow et al. 2011). Dissolved oxygen levels are very high, with most samples near 100% saturation (Brown and Short 1999). Nine to fourteen percent of water quality samples in Yosemite Valley indicate some presence of petroleum hydrocarbons (Peavler et al. 2008), most likely due to stormwater runoff from parking lots and roads; however, concentrations were well below water quality limits.[30] Since the time of designation, NPS has removed over 100 underground tanks, eliminating a potential source of contamination.

2.3.4.2.3 Geologic Condition. The river- and glacier-dependent landscapes along the Merced River—including the Giant Staircase and the El Capitan recessional moraine—are the result of varying geologic processes operating over immense spatial and time scales. The ORV elements created by geologic processes have not been perceptibly modified by human intervention since the time of designation.

[30] The median concentration of samples tested for petroleum hydrocarbons was 0.023 mg/L (Peavler et al. 2008). The water quality action level for California waterbodies is 15 mg/L (California State Water Resources Control Board 2007).

2.3.4.3 Preliminary Management Considerations

The preliminary management considerations associated with the Geologic/Hydrologic ORV in segment 2 :

Free flow :

- Several bridges are causing upstream deposition and downstream scour as well as creating the potential for flooding and uncontrolled channel avulsions. Table 2.3-2 describes the level of concern associated with each bridge as identified in an earlier study of this segment (Madej et. al. 1991).
- Large wood removal can affect channel migration and avulsion as well as many aquatic biological processes.
- Extensive bank hardening affects the free-flowing condition of the Merced River and artificially maintains the river in its existing shape.
- Trampling of riparian vegetation in the East Valley contributes to bank erosion, channel widening, loss of shade, increased water temperature, and other biological issues.
- Bank erosion is particularly focused near campsites and points where recreational users access the river.

Water Quality:

- Water quality in this river segment is high. The National Park Service will continue to protect water quality by monitoring and identifying potential pollution sources.

Geology ORV:

- Geologic processes will continue to shape the landscape.

Photo Credit: Mike Yochim

Figure 2.3-7
The Giant Staircase along the Merced River

Photo Credit: Mike Yochim

Figure 2.3-8
The El Capitan Recessional Moraine

2.3.5 River Segment 3: Merced Gorge

Once the Merced River flows out of Yosemite Valley, it enters the Merced Gorge, dropping about 2,000 feet over a distance of six miles. This segment is largely undeveloped, except for El Portal Road – which parallels the Gorge for its entire length – as well as other small facilities. These facilities include the electrical switching station, the Cascades Picnic Area, Arch Rock Entrance Station, and associated facilities. The Merced Gorge is characterized by steep boulder-cascades and large step-pools.

Condition at the Time of 1987 Designation

Free-flowing Condition.

At the time of designation, the Cascades Diversion Dam, a 17-foot-high structure about 1 mile downstream of Pohono Bridge, impeded the free-flowing condition of the river. This structure was previously used for small-scale electricity generation. This segment was otherwise free of impoundments that would impede flow or otherwise alter the free-flowing condition of the river.

Water Quality.

Limited water quality data were collected in the Merced Gorge, but the data indicated that water quality characteristics at the time of designation were similar to those in the Merced River in Yosemite Valley.

Geologic Condition.

There are no identified Geologic ORVs in this river segment.

Current Condition

Free-flowing Condition.

Cascades Diversion Dam was removed in 2004, restoring free-flowing conditions to this segment. Removal of the dam was followed by native vegetation planting and removal of an abandoned transformer.

During the 1997 flood, El Portal Road suffered significant damage when the Merced River eroded the road's embankments. After the flood, about 7.5 miles of the roadway were reinforced with riprap. There are no structures or other impediments in this segment that affect the free-flowing condition of the river.

Water Quality.

Water quality in the Merced Gorge is exceptionally high. Nutrient concentrations are very low (Brown and Short 1999) and have been found to be near the background levels in similar undeveloped areas (Clow et al. 2011). Dissolved oxygen levels are very high, with most samples near 100% saturation (Brown and Short 1999).

Preliminary Management Considerations

The preliminary management considerations associated with the Geologic/Hydrologic ORV in segment 3:
Free-flowing condition:

- Management considerations focus on maintaining the free-flowing condition of the river in this segment. This includes designing future embankment protection with the natural processes of the river in mind.

2.3.6 River Segment 4: El Portal

Through El Portal, the Merced River begins to lower in gradient and begins to deposit coarse boulders and cobbles that have been transported from upstream. As a result, the morphology of the river transitions rapidly from steep boulder cascades to step pools and from step-pools to a pool-riffle system. Here, the river begins to meander across boulder bars and riffles and becomes more longitudinally dynamic than in the Merced Gorge.

Condition at the Time of 1987 Designation

Free-flowing Condition.

The Merced River near El Portal was confined by Foresta Road and associated abutments and revetment, which encroached into the historical channel bed in places. In El Portal, a small deflection bar was located on the left bank of the Merced River, just downstream from the El Portal Road (Highway 140) bridge (Figure 2.3-9). This approximately 300-foot-long deflection bar was built to protect the Trailer Court area from flooding by pushing floodwaters away to the river's right. The road berm had also cut off the floodplain and a historical meander, creating Odgers' Pond near El Portal. These constrictions somewhat increased flow velocities and reduced channel complexity, active floodplain inundation, and backwater habitat.

Other modifications to the river in this segment included several remnant rock diversions and the Greenmeyer Sand Pit, which was used to mine sand from the Merced River for park operational needs until 1997. In the course of developing the area, fill was added to secondary channels and the floodplain, including large boulders along the river to build a worksite and protect the site from flooding. A small concrete diversion structure just upstream of the area was used to divert flows and sediment to the work area. This operation impacted the free-flowing condition of the Merced River because it substantially constricted high flows..

Bridges on the Merced River near El Portal included the El Portal Road Bridge and the Foresta Road Bridge. Neither of these bridges created significant impoundments that affected the free-flowing condition of the river.

Water Quality.

At the time of designation, water quality in the Merced River in this segment was characterized as high, with minor indications of impacts from human activities. The water was generally found to be low in nutrients, salts, and suspended sediment and high in dissolved oxygen (NPS 1994). Elevated levels of nutrients and metals were measured below the El Portal Wastewater Treatment Plant, but water quality was still within established limits.

Geologic Condition.

When river gradients drop, rivers lose the energy needed to transport larger sediments and boulders. In such areas, bar-type deposits, such as the large boulder bar at the east end of El Portal, are built up. This is no ordinary boulder bar, however, for it contains massive boulders over a meter in diameter and weighing many tons. It is the combination of boulder availability, the steepness of the river in the gorge, the major change in gradient at El Portal, and the size of the Merced's peak floods that enables the river to build such a boulder bar.

Current Condition

Free-flowing Condition.

The condition of the river remains about the same as conditions at the time of designation. The river is still confined by roads and revetment, which in places encroach into the historical channel bed. The small deflection bar built to protect the Trailer Court still exists, as do the El Portal Road berm, remnant rock diversions, and the footprint of the Greenemeyer sand pit, which all continue to act as impediments to free flowing condition of the river.

Water Quality.

Water quality in this segment is considered to be high. Bacteria levels are generally low, and dissolved oxygen is near saturation (Peavler et al. 2008). Nutrient concentrations are slightly elevated near the El Portal Wastewater Treatment Plant, especially during periods of low streamflow (Peavler et al. 2008; Clow et al. 2011).

Geologic Condition.

As illustrated by the January 1997 flood, the Merced continues to sort and build this bar, providing evidence in all seasons of its potential power.

2.3.6.3 Preliminary Management Considerations

The preliminary management considerations associated with the Geologic/Hydrologic ORV in segment 4:

Free-flowing conditions for segment 4:

- Extensive riprap associated with California State Highway 140 and the Trailer Court affects river functions.

Water Quality for segments 4 (and 6, 7 and 8):

- Water quality in these river segments is high. The National Park Service will continue to protect water quality by monitoring and identifying potential pollution sources

2.3.6.4 El Portal Boulder Bar

This boulder bar is located on the Merced River across from and just upstream of the El Portal General Store (Figure 2.3-9). The boulder bar is an exposed mid-channel bar composed of large boulders and cobbles.

Condition at the Time of 1987 Designation. The boulder bar along the Merced River in El Portal is a dynamic geomorphic feature that results from the pronounced change in river gradient that occurs just downstream of the park boundary. Aerial photographs (digital orthophoto quarter quads) dating from 1993 show that the boulder bar was present at that time, and therefore almost certainly was present in 1987 at the time of Wild and Scenic designation. Aerial photographs dating from 1997 and thereafter clearly show that the boulder bar was extensively modified during the 1997 flood; the river channel migrated south by tens of meters, the southern riverbank was eroded, and the boulder bar surface experienced erosion and deposition of boulders. Boulder bars are dynamic geomorphic features that are modified frequently over geologic timescales by high-discharge flood events. The 1997 flood on the Merced River was the most recent flood to have modified the boulder bar, but earlier floods (for example, winter floods in 1964, 1955, 1950, and 1937) probably also modified the boulder bar.

Current Condition. The boulder bar became prominent after the 1997 flood, when either vegetation was removed by the high velocity of flow from that storm or large boulders were transported from upstream. In high energy rivers, such as the Merced River, bars tend to go through cycles of deposition, colonization by vegetation leading to semi-stable “islands,” and removal of vegetation during floods. Once vegetation is removed, the bar becomes less stable and the channel often avulses into a former abandoned course or cuts a new channel across the bar. The 1997 flood likely stripped the vegetation and fine sediment off the bar, exposing the underlying boulders and potentially depositing new boulders. The excavation and deposition reactivated the bar, leading to an avulsion in the main channel from the north side of the floodplain to the south side. Because of this increase in sinuosity in the avulsed reach, the channel now impinges more acutely onto the north bank (alongside El Portal Road) where the channel returns to its former north side course.

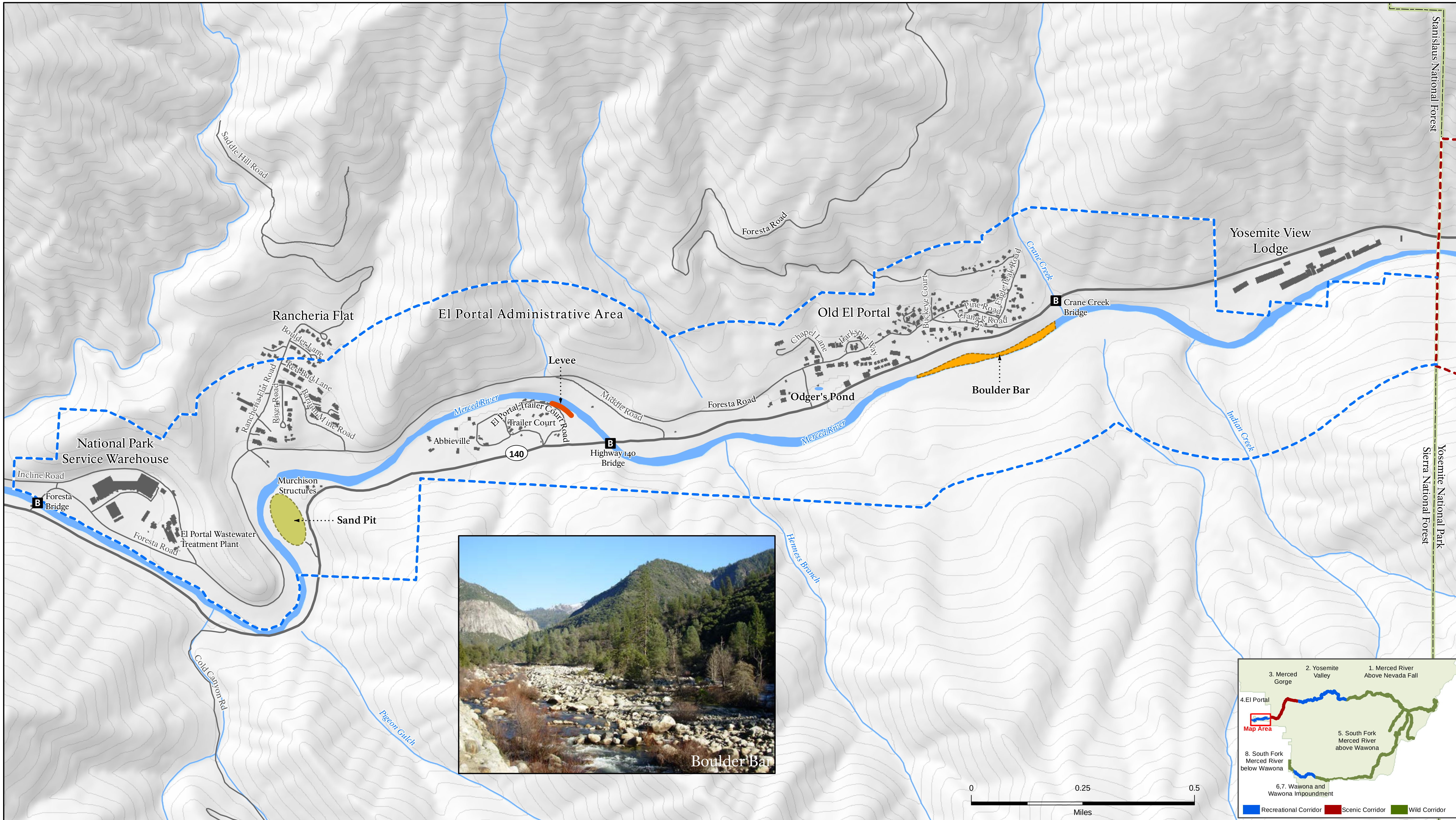

Figure 2.3-9

Geologic/Hydrologic ORV - River Segment 4. El Portal Recreational WSR Corridor

- Recreational WSR Corridor Classification
- Scenic WSR Corridor Classification
- Building
- Yosemite National Park Boundary
- Highway 140
- Road
- Stream/River
- 100' Contour Line
- B Road Bridge

National Park Service U.S. Department of the Interior

Produced by: **Yosemite Planning Division**

Projection:	North American Datum 1983, UTM Zone 10
Date:	6/2/11
File:	Figure 2.3-9

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2.3.6.4.1 Preliminary Management Considerations

There are no preliminary management considerations related to the El Portal boulder bar.

2.3.7 River Segments 6, 7, 8: Wawona Impoundment, Wawona, and South Fork Merced River below Wawona

In the Wawona area, the South Fork Merced River transitions out of its steep canyon and enters a large floodplain meadow, which is part of an alluvial valley. In this area the river morphology transitions from step-pools and boulder cascades to a meandering river with substantial gravel bars. This area is the most accessible area of the South Fork, with the highest levels of visitor use occurring at the developed Wawona area. Development in this area includes employee housing, approximately 300 privately-owned residences, as well as the Wawona Hotel. Other developed areas in this segment include the Wawona Golf Course, the Pioneer Yosemite History Center, the Wawona Stable, the store and gift shop, the Wawona Post Office, and the Wawona Campground.

2.3.7.1 Condition at the Time of 1987 Designation

2.3.7.1.1 Free-flowing Condition.

In the Wawona area, a small impoundment at the intake of Wawona's surface water supply was located near the end of Forest Drive. By the time of designation, the pool had filled with small cobbles, sands, and other sediments; however, this impoundment was not a major source of sediment and did not act as a significant barrier to river flow and dynamics. In 1987, NPS implemented the *Wawona Water Conservation Plan*, which set the rate of diversion from the Wawona water intake at 0.59 cubic feet per second (cfs) (NPS 1987), and water was diverted for domestic and irrigation uses. To protect instream flows for aquatic habitat, the plan enacted mandatory water conservation whenever the river reached flows of less than 6 cfs. At flows of less than 6 cfs, diversions were limited to 10% of the river flow. No other diversions took place on the South Fork Merced River.

Bridges on the South Fork Merced included the Swinging Bridge, just upstream of Wawona; the historic Wawona Covered Bridge, a timber-framed covered bridge; and the South Fork Bridge (Wawona Road). At the time of designation, the South Fork Bridge was a narrow, somewhat hazardous bridge. The unreinforced masonry cobble abutments and piers impeded the flow of the South Fork Merced and created local scour holes.

2.3.7.1.2 Water Quality.

At the time of designation, water quality in the Merced River near these four river segments was characterized as high, with minor indications of impacts from human activities. The water was generally found to be low in nutrients, salts, and suspended sediment and high in dissolved oxygen (NPS 1994).

2.3.7.1.3 Geologic Condition.

There are no identified Geologic ORVs in these river segments.

2.3.7.2 Current Condition

2.3.7.2.1 Free-flowing Condition.

The 1997 flood caused additional scour at the South Fork Bridge, and concern regarding the bridge's stability led NPS to replace it. The South Fork Bridge was closed, and a temporary bridge was used between 1998 and 2006 while a new bridge was studied and constructed. The former South Fork Bridge and the temporary bridge have been demolished, and the new South Fork Bridge is now in place. As established in the Wild and Scenic River Act Section 7 determination process, this new bridge was evaluated for direct and adverse effects on the river and was found not to represent a significant impediment to the free-flowing condition of the river during most flow conditions. No other structures have been placed in the river since the time of designation.

2.3.7.2.2 Water Quality.

Water quality in these segments is considered to be high. Bacteria levels are generally low, and dissolved oxygen is near saturation (Peavler et al. 2008). Nutrient concentrations are slightly elevated near the Wawona Wastewater Treatment Plant, especially during periods of low streamflow (Peavler et al. 2008; Clow et al. 2011).

Elevated phosphorus levels were detected on the South Fork Merced River downstream from the Wawona Campground and may be due to excessive erosion at the campground. The presence of hydrocarbons was found in 11% of water quality samples in Wawona (Peavler et al. 2008).

2.3.7.3 Preliminary Management Considerations

The preliminary management considerations associated with the Geologic/Hydrologic ORV in segments 6, 7, and 8:

Water Quality for segments 6, 7 and 8 (and 4):

- Water quality in these river segments is high. The National Park Service will continue to protect water quality by monitoring and identifying potential pollution sources.

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