RESOURCE INVENTORY

HYDROLOGY

Big Basin Redwoods State Park

June 1998

by

Douglas Rischbieter
Associate State Park Resource Ecologist
Calaveras District

and

Gary Waldron
Associate State Park Resource Ecologist
Northern Service Center

TABLE OF CONTENTS

LIST OF APPENDICES

INTRODUCTION

Big Basin Redwoods State Park encompasses most of the watershed of Waddell Creek and vice versa, thus the description of the hydrology of this park is largely based on what is known about this major Santa Cruz County stream and its tributaries. Big Basin Redwoods State Park also contains portions of about 20 other named streams and/or watersheds (including significant Waddell Creek tributaries) and over a dozen unnamed seasonal streams which drain substantial areas.

Although margins of the Park are situated along ridgetops and small areas on all sides of the unit drain directly to other major Santa Cruz or San Mateo County streams or to the ocean, the features and resources of the Waddell Creek watershed overwhelmingly influence the hydrologic and related resources of the unit. The influence upon downstream areas of the land areas of these boundary regions, which in most cases are relatively tiny compared to the respective watersheds surrounding BBRSP, is usually negligible. Such being the case, ridgetop areas and the hydrology of them are only briefly discussed herein.

Data and information reported in this section were derived from data and reports provided by representatives of several agencies, including the U.S. Geological Survey (USGS), California Department of Water Resources (DWR), State Water Resources Control Board (SWRCB), Department of Fish and Game (DFG), Santa Cruz County Health Services Agency, Big Basin Redwoods State Park and its Santa Cruz District Office. Additional information has been collected and published by Robert O. Briggs, a local resident and retired engineer and hydrologist.

Almost all of Big Basin Redwoods State Park is located within the Central Coast Hydrologic Basin, as defined by DWR (1981). This major hydrologic basin is further subdivided into the Big Basin Hydrologic Unit (HU), the Santa Cruz Hydrologic Area (HA) and the Año Nuevo Hydrologic Area, and additionally into Hydrologic Subareas (HSA). A small portion of the Park, northern ridgetop lands which drain into Pescadero and Butano Creek tributaries, is located in the San Francisco Bay Hydrologic Basin. Table 1 lists hydrologic areal designations.

Surface hydrologic resource field observations of various areas of Big Basin Redwoods State Park took place in March and May 1996 and December 1997 by DPR staff also conducting aquatic resource inventory investigations. The Aquatic Resources section includes a summary of fieldwork sites visited. Additional discussion of some neighboring watersheds and hydrology can be found in the

Castle Rock State Park Resource Inventory, Hydrology Chapter (Rischbieter and Waldron 1997).

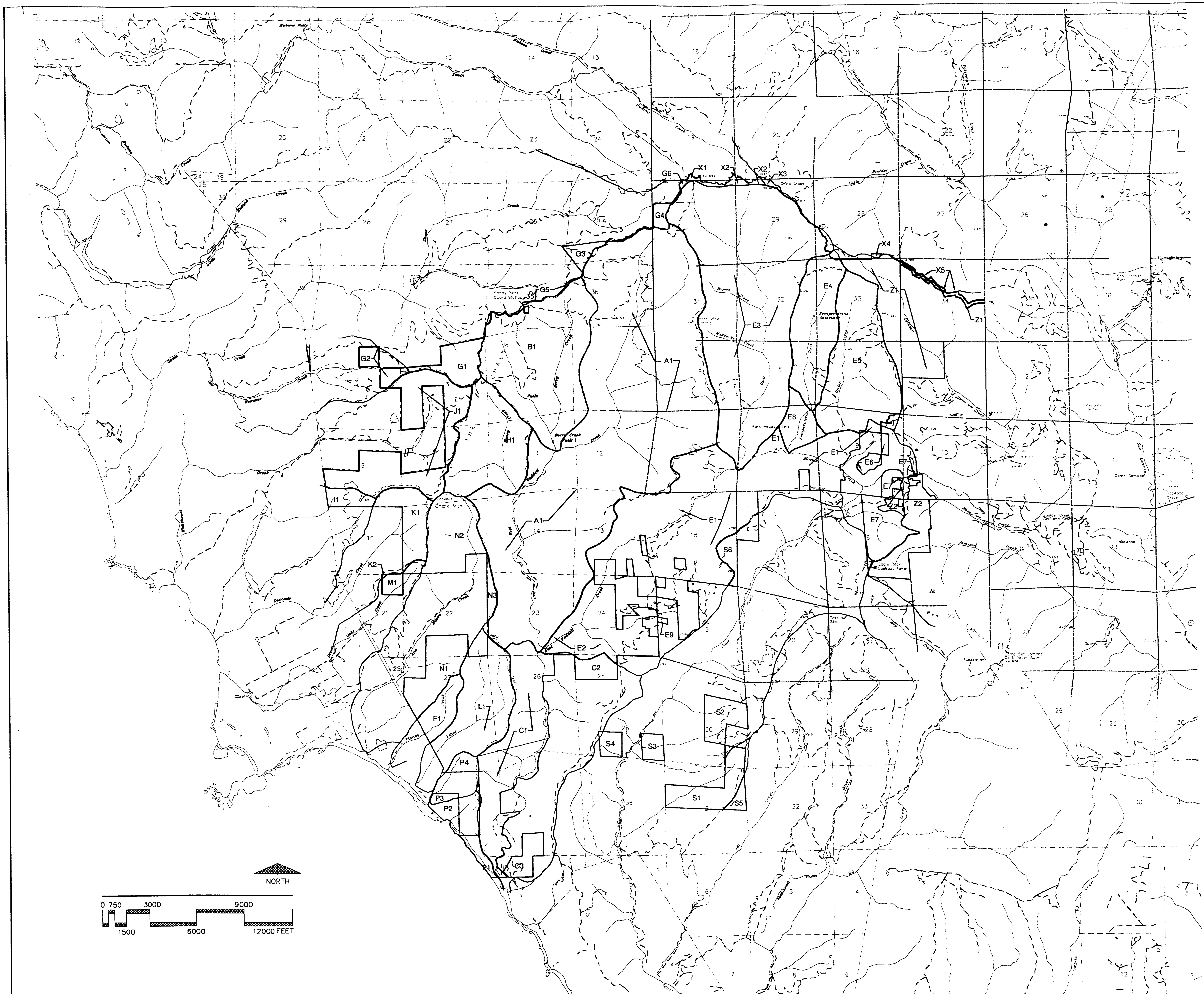
Table 1. Hydrologic areal designation for Big Basin Redwoods State Park watersheds (DWR 1981).

CODE	NAME	DIVISION	ABBREVIATION	COMMENT
T	Central Coast	Hydrologic Basin	(HB)	most of unit
T.04	Big Basin	Hydrologic Unit	(HU)	
T.04.A	Santa Cruz	Hydrologic Area	(HA)	
T.04.A1	Davenport	Hydrologic Sub-Area	(HSA)	most of unit including Waddell Creek
T.04.A2	San Lorenzo		(HSA)	small areas draining eastern ridgetop areas
T.04.B[0]	Año Nuevo		(HA)	no subareas;headwaters of western ocean drainages
E	San Francisco Bay		(HB)	small areas draining northern ridgetops
E.02	San Mateo		(HU)	
E.02.D[0]	Pescadero Creek		(HA)	no subareas

WATERSHED DESCRIPTIONS

Watersheds

Boundaries of the watersheds within Big Basin Redwoods State Park are shown in Figure H-1. The drainage areas of the distinct watersheds within the unit are summarized in Table 2. The areal estimates of the total watersheds were calculated from dot-grid measurements of USGS maps. Watershed areas within the unit were measured from delineations on the DPR base map by DPR Graphic Services using geographic information system (GIS) software.



INDEX

A1	Waddell Creek–W. Fork Main
B1	Berry Creek
C1	Waddell Cr. below fork's confluence
C2	Waddell Cr. Misc. parcel
C3	Waddell Cr. Misc. parcel
E1	Waddell Cr. E. Fork Main
E2	Waddell Cr. E. Fork Main
E3	Opal Creek
E4	Sempervirens Creek
E5	Union Creek
E6	Waddell Cr. Eastern Head–waters Parcels
E7	" "
E8	Waddell Cr. Misc.
E9	Waddell Cr. E. Fork isolated parcel
F1	Finney Creek
G1	Gazos Creek Parcels
G2	Old Woman's Creek
G3	Gazos Creek Parcels
G4	Gazos Creek Parcels
G5	Gazos Creek Parcels
G6	Gazos Creek Parcels
H1	Henry's Creek
I1	West Cascade/Reservoir Watershed Headwater Parcel
J1	Whitehouse Cr. Headwaters
K1	Cascade Cr. Headwaters
K2	Cascade Cr. Ridgetop Parcel
L1	Elliott Creek
M1	Green Oaks Creek
N1	Ano Nuevo Cr. East Parcel
N2	Ano Nuevo Creek Headwater Parcel
N3	Ano Nuevo Creek Ridgetop Parcel
P1	Pacific Ocean Trib. #1 (unnamed)
P2	Pacific Ocean Trib. #1 (unnamed)
S1	Scott Cr. West Parcels
S2	Scott Cr. West Parcels
S3	Scott Cr. West Parcels
S4	Scott Cr. West Parcels
S5	Scott Cr. East Parcels
S6	Scott Cr. Headwater Parcels
S7	Scott Cr. Headwater Parcels
X1	Butano Cr. Headwaters
X2	" "
X3	Pescadero Creek Headwater Parcels
X4	" "
X5	" "
Z1	San Lorenzo River Headwaters #1
Z2	San Lorenzo River Headwaters #2

DESIGNED	XXXXX
DRAWN	C. HARRIS
CHECKED	XXXXX
DATE	
REVISIONS	

RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF PARKS AND RECREATION

APPROVED ____________ DATE ________

BIG BASIN REDWOODS STATE PARK

XXXXXXXXXXX

XXXXXXXXXX

DRAWING NO.

SHEET NO. X OF X

Table 2. Summary of Watershed Area Statistics, Big Basin Redwoods State Park.

WATERSHED NAME	TOTAL AREA (acres/mi^2)*	PORTION IN UNIT (acres)	WATERSHED % IN UNIT	UNIT % IN W'SHED
Waddell Cr. (entire)	16,700/26	13,400	80	77.6
Elliot Cr.	640/1	520	81	3.0
Finney Cr.	225/0.35	130	58	0.7
San Lorenzo R.	97,280/152	640	0.66	3.6
Ocean tribs. (~2, unnamed)	300/0.5	160	53	0.9

Other major Creeks, including tributaries, with some BBRSP ownership:

Año Nuevo	1,700/2.65	620	36.5	3.6
Butano	n/a	30	<0.1	0.2
Cascade	~2,000/3+	280	14	1.6
Gazos (includes 66 acres BBRSP in Old Womans Creek watershed)	n/a	310	<1	1.8
Green Oaks	~800/1.25	60	7.5	0.4
Pescadero	40,640/63.5	20	<0.1	0.1
Scott	19,000/30	560	~3	3.2
Whitehouse	1,278/2	560	44	3.2

*Acreages listed from various sources, level of accuracy indicated by number of significant figures.

Waddell Creek

The greater Waddell Creek watershed encompasses almost 17,000 acres (Shapovalov and Taft 1954), of which about 13,400 acres occur in Big Basin Redwoods State Park. The headwaters originate in the relatively steep northern and northeastern margins of the park unit, arising near the 2,200 foot elevation, and form two major forks which typically persist as permanent streams once below 1,000 feet. The Waddell basin west and east forks are formed by the Middle Range and China Grade to the north, the divide between Waddell and Boulder creeks to the east, Chalks Ridge to the west, and the summits of McAbee and Pine Mountain to the south (Harrison 1983). From its mouth at the Pacific Ocean the Waddell Creek watershed stretches about 12 miles inland.

Seasonal headwater areas are steep but within a mile of the ridges the streams' descent moderates from 400 to less than 100 feet per mile (although canyon walls still form a steep V-shaped canyon). The descent to sea level occurs throughout the interior of the park with most of the creek flowing generally south. The West and East branches of Waddell Creek form the main stem about three miles upstream from the mouth; in this confluence area streamside terraces gradually widen until a small floodplain is present in portions of the last mile. The creek crosses under State Route 1 and empties into the Pacific Ocean about a mile south of the Santa Cruz/San Mateo county line. A seasonal lagoon commonly forms behind a wave-formed sandbar during summer and fall. Most of this lagoon, including surrounding marsh and wetlands east of SR1, is also within the Park.

Much of the Waddell Creek watershed can be considered a youthful, V-shaped valley (Harrison, 1983). The principal activity of the streams in this type of watershed is the downcutting of their channels. The capacity for cutting exceeds the load of earth available to the streams over recent geologic time. Waterfalls and gorges are common in this youthful stage.

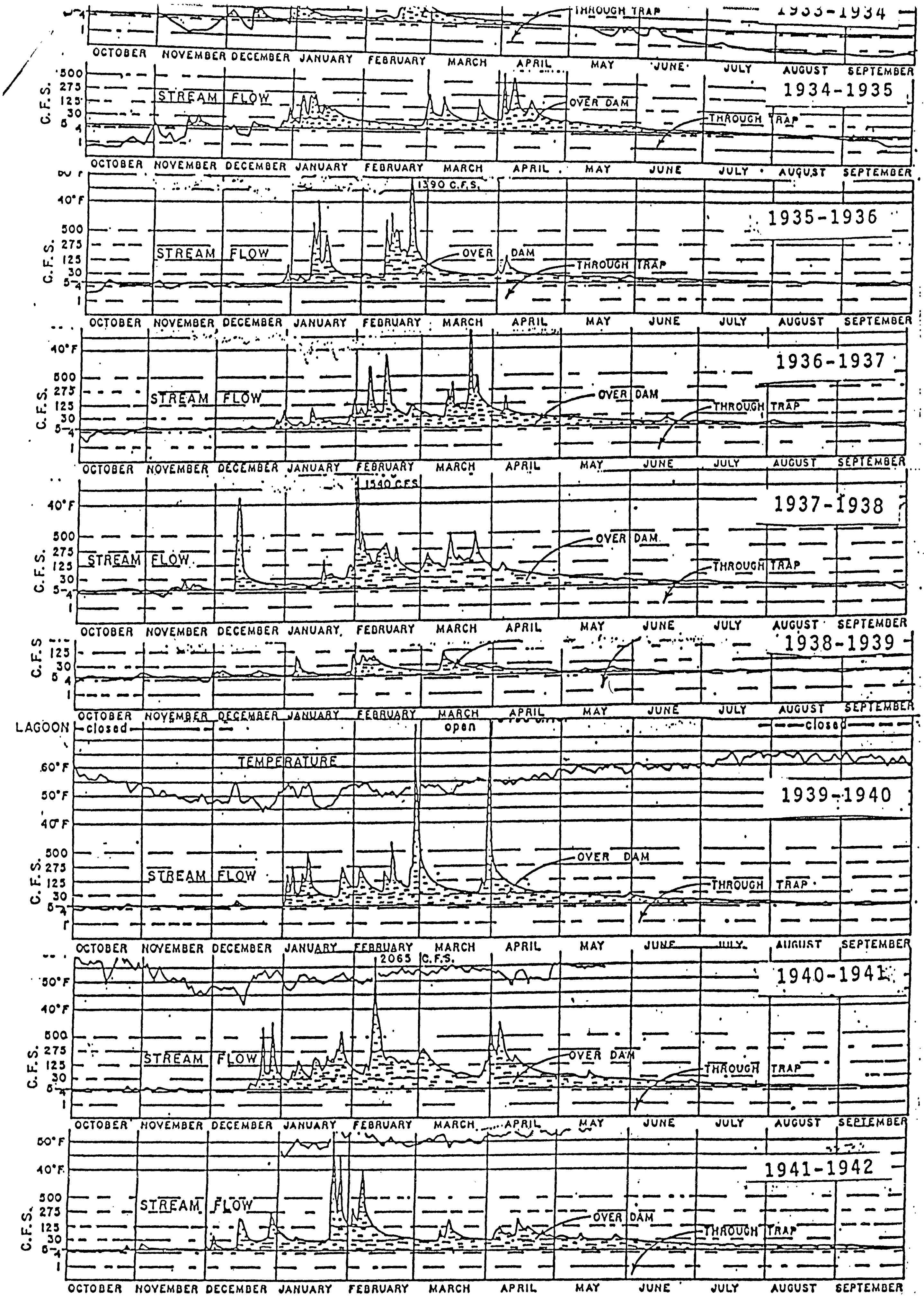
Several waterfalls exist within this watershed within the park unit. The most spectacular falls are along Berry Creek, on West Waddell Creek three miles upstream from its confluence with East Waddell Creek. Golden and Upper Falls are also located on the west fork of the Waddell. Sempervirens Falls is located on Sempervirens Creek, an East Waddell tributary, adjacent to the Sky Meadow Road above Huckleberry Campground.

As the main stream of the Waddell flows through the lower floodplain, it gradually deposits its load of sediment on the inside of bends, causing the stream to meander back and forth. Near the mouth of the creek, one loop was eventually cut off, forming an oxbow lake which has become the freshwater marsh inside the Theodore J. Hoover State Preserve. The whole Waddell valley is still subject to deposition, especially the marsh. In 1970, however, this deposition rate was increased when Silverking Oceanic Farms built a fish weir across the mouth of the marsh as part of its commercial fish hatchery operation. This dam reduced tidal influence and brackishness and created a larger freshwater pond that persisted throughout the year. In 1973, floodwaters washed away the dam and, presumably, the salinity and rate of siltation in the marsh have returned to their earlier levels.

Mean annual discharge from Waddell Creek is a matter of some conjecture in the absence of regular and long-term flow data. A common characteristic of most of California coastal streams is that most of a year's runoff occurs between December and May. Flows change rapidly in response to storm events. During the winter rainy season, Waddell Creek can exhibit a wide range of unregulated flows. There are no gaging stations located on Waddell Creek, however historical data exists for the main stem for the period 1933 to 1942 (Shapovalov and Taft 1954; Figure H-2). Additional data from this lower area have more recently been collected by an adjacent landowner, Mr. Robert Briggs; Appendix HY-V presents some of these data in various forms. A 6.17 square mile area of the San Lorenzo River headwaters was gaged from 1968 to 1992 and had a mean annual discharge of 4,536 ac-ft (Rischbieter and Waldron 1997); this region is adjacent to the headwaters of Waddell Creek but further inland and of different aspect, so precipitation (and presumably discharge) there is lower per unit area than around Waddell Creek.

Rock formations of the watershed (see Geology Chapter) have little long-term storage capacity. During the dry season, usually ranging from May to October, the monthly discharge quickly drops to a small fraction of the wetter months' rates. The baseflow at the end of each dry season closely reflects the total amount of rainfall received during the previous wet season (Hecht and Rusmore 1973; R. Briggs, pers. comm.). While it is known that yield varies extensively and is closely dependent upon annual precipitation, a significant fraction of the precipitation which percolates into the soil leaves the watershed through evapotranspiration and subsurface flow (Dunne and Leopold 1978). By roughly estimating the area under the curves of nine years of hydrographs (Figure H-2) produced by Shapovalov and Taft (1954) it appears that in the 1930s the mean annual discharge was a little over 30,000 ac-ft, however that period of record received average annual rainfall about 20 percent greater than the long-term precipitation average (see Meteorology Chapter). Even so, the discharge estimate value is only about half of the average of mean annual precipitation from two gages in the watershed extrapolated over the area of the watershed, to some degree

Figure H-2. Hydrographs of lower Waddell Creek, 1933-34 to 1942-43 (Shapovalov and Taft 1954, as presented in Briggs 1989).



WADDELL CREEK FLOW RATE FOR 1933 THRU 1942.

Shapovalov and Taft, 1954, Fish Bulletin #98
State of California Department of Fish and Game

illustrating the magnitude of subsurface and evapotranspirative discharges from the drainage basin.

Flow duration curves prepared by Coats (1988; Appendix HY-IV) from data collected in the 70s and 80s are a good illustration how streamflow varies by season and can vary between years. The extremes of high and low flow are further emphasized by actual high and low flow measurements, compiled from several sources, summarized in Table 3. A number of other flow measurements, from various times over several years, have been collected by Mr. Robert Briggs and are presented in Appendix HY-V. Some of these figures show that diurnal variation in flow of Waddell Creek also occurs, dramatically illustrating the influence of evapotranspiration (presumably of riparian plants).

The flow duration curves (Coats 1988; Appendix HY-IV) also raise an interesting issue: the 50 percent-exceedence probability illustrated by the flow duration curves can also be interpreted to suggest that 50 percent-exceedence probability for mean annual discharge is only about 13,000 ac-ft in more recent years. There is evidence that base flow discharge in Waddell Creek has measurably diminished in recent decades, and is continuing to diminish, coincident with and at a rate similar to the vigorous regrowth of vegetation which is occurring following the extensive logging and uncontrolled fires which bared the ground (and allowed for greater runoff) prior to 1930. This trend was identified and extrapolated by Briggs (1989) who illustrates that base flow has been diminishing by about 3 percent per year since the 1930s and suggests that lower Waddell Creek is likely to become intermittent during normal and dry years beginning early in the 21st Century; intermittent flow occurs when discharge slows below 0.2 cfs (R. Briggs, pers. comm.).

The steep headwater areas of Waddell Creek and its major tributaries are drained by several named and unnamed seasonal tributaries. Generally these tributary areas are of mixed evergreen forest with some redwoods present. They are typically seasonal though some springs may occur in the lower areas of some of these watersheds (in close proximity to where they join more permanent streams; rocky slopes and canyons feeding Henry Creek is a good example). Most of the runoff from these areas originates as rain though ridgetop areas are normally subject to several inches of short-lived snow per year (see Meteorology Chapter). The streams rise and fall rapidly during and following a storm, characteristic of watersheds with relatively small drainage area, steep topography, and no water development. Briggs (pers. comm.) reports that later in the rainy season, after watershed lands near saturation, streamflows in lower Waddell Creek take about 3 hours to rise in response to a heavy rain event and about 3 days to recede. The response time is presumably less in the upper watershed.

Not all minor (unnamed) tributaries exhibit flow proportional to the fraction of the watershed they drain. Some variation in flow between drainage areas can be attributed to variations in topography, geology, vegetative cover, and precipitation patterns.

Table 3. Minimum and maximum flow measurements (cubic feet per second; cfs) recorded at Waddell Creek, Santa Cruz County, California (Shapovalov and Taft 1954; Briggs, unpublished data).

DATE	MINIMUM	MAXIMUM
1931	2.6	
1934	0.7	278
1935	2	625
1936	1	1,390
1937	3	1,390
1938	2	1,540
1939	4	114
1940	5	6,460
1941	4	2,065
1942		1,800
1977	0.16	
1988	0.53	
1989	1.27	
1990	1.31	
1991	0.78	
1992	1.14	
1993	1.32	
1994	1.16	

Streams also transport sediment, not just water. Sedimentation occurs in the creeks when there is a decrease in flow velocity after high water stages. The deposited sediments constitute alluvium and can provide rich soil for the redwoods and other associated vegetation. The alluvium also acts as an aquifer, storing water and then releasing it later in the season.

No sediment yield analyses have been done on Waddell Creek but sedimentation has occasionally been perceived to be a problem especially after periodic floods. Such floods and associated storms can cause significant bank erosion and often trigger small landslides on watershed roads. Areas of several larger historic landslides are evident along the creek (see Geology Chapter) and some road crossings and old roads are potential sources of sediment in the future, typical of areas of historic logging activity.

Sempervirens Creek

Sempervirens Creek is of special significance because it is the Waddell Creek tributary providing water supply to the largest developed areas of BBRSP. This watershed is 1465 acres in total area including the major tributary of Union Creek which by itself drains about 807 acres. Sempervirens Creek above the Union Creek confluence drains 516 acres with the remainder (142 acres) below this confluence. Only about 5 acres at the highest point of the Sempervirens Creek watershed (unnamed 2160' peak) is outside BBRSP boundaries, the remaining 1460 acres are within them. Sempervirens Creek is the major tributary to Blooms Creek, the latter being one of two major streams forming East Waddell Creek.

At about elevation 1225' water is stored in Sempervirens Reservoir. Formed by an impervious rolled-earth dam, with a concrete spillway (and chute) and a 12" drain line at the bottom outlet works, this storage reservoir normally provides water to a nearby treatment plant and permanent flow to downstream areas. The 4-acre, steep-sided reservoir stores water from about 230 acres of watershed and has a capacity of 78 ac-ft (Appendix HY-III). This area of watershed is steep and predominantly redwood forest with thick humus; it is not roaded and contains only one steep, wooded trail. Sempervirens Creek and its first major tributary upstream of the reservoir are permanent for several hundred yards though Carroll (1996) reports that a significant fraction of the yield to the reservoir is subsurface and possibly provided by springs fed by the Santa Margarita aquifer (see also Geology Chapter of this Resource Inventory). Colder water temperatures in the northeast corner of the reservoir have been observed and support this theory.

Reservoir operators consider several environmental and water quality issues during operation and maintenance activities at Sempervirens Reservoir but there is no codified or approved Operation Plan. For this reason, reservoir level and downstream releases (flow volume and water quality) vary irregularly. For example, when Sempervirens Reservoir is drawn down for weed control or other maintenance, water does not pass over the spillway. Often, releases from the bottom are avoided because of poor hypolimnetic water quality (anoxic conditions, high hydrogen sulfide concentrations). Whenever there is no outflow from the dam, a short distance of the creek downstream is dry until springs (perhaps seepage) accrete enough volume to restore flow to the channel.

Sempervirens Reservoir was originally about 40' deep but silt accumulation has reduced this to about 33' (Carroll 1996). A delta of silt has accumulated at the inlet; this situation provides a potential laboratory for the measurement of sediment yield from a known acreage over a known period of time and may be representative of the greater Waddell Creek upper watershed.

<u>Opal Creek</u>

Opal Creek is a 4.5-mile-long tributary to Waddell Creek which is of special significance because of its location in the area of BBRSP with the most intense public use and because it and some of its tributaries were once used as part of the Park's water supply. Its 2300-acre watershed is almost entirely within BBRSP and includes the tributaries Rogers, Maddocks, Redwood, and Huckleberry Creeks.

Opal Creek's headwaters and tributaries are steep slopes of redwood forest similar to other watershed areas discussed above, however its lower 2.5 miles are of a low gradient (averaging about 60 feet per mile with some portions almost flat) which is locally atypical. A Park road, and several trails, are in close proximity to much of this lower portion and include several crossings. Water alongside the road often has the appearance of being "stagnant" during summer and fall with base flow of less than 1 cfs. No information specific to the hydrology of Opal Creek is known to be available, but some water quality observations are summarized later in this document.

Opal Creek joins Blooms Creek as East Waddell Creek's two major tributaries. Blooms Creek originates above a flat saddle known as Little Basin and winds through level terrain beside the headwaters of the Scott Creek drainage. Plunging down a narrow boulder-filled canyon to the gentle floodplain on the downthrown side of the Ben Lomond Fault (see Geology Chapter), Blooms Creek also follows a relatively flat path over sandy alluvium and fractured sandstone. Stream gradients increase once it merges with Opal Creek, creating the East Waddell.

Other Waddell Creek Tributaries

A few other Waddell Creek tributaries have not been mentioned above. Some are large enough in size, or because of historical or geographic significance, to bear official names. Other smaller tributaries bear unofficial "local" names, such as "Buck Creek" (the downstreammost mapped West Waddell Creek tributary), or remain unnamed altogether. The latter are invariably steep, headwater areas typically of mixed second-growth redwood forest.

Proceeding north to south, Timms Creek, Kelly Creek, and Last Chance Creek appear on some maps. Timms Creek is the name of one BBRSP trail although the name is apparently only based on that trail's origin at the mouth of Timms Creek; there are no developed trails in that watershed. Kelly Creek is part of the route of the popular Skyline-to-the-Sea Trail. The south fork of Last Chance Creek has steep walls with small waterfalls during the rainy season, but there is no developed access to this stream within the Park.

Finney Creek

Finney Creek drains directly to the Pacific Ocean. The total watershed covers about 225 acres but only the upstreammost 132 acres are within BBRSP. Like adjacent watersheds, the topography is steep and the cover is predominantly pine forest with areas of brush, and redwood forest in the streamside areas. There is no easy access to this watershed except through the Coastways Ranch property off of Highway 1.

Some middle and lower portions of Finney Creek exhibit permanent, though very low, summer flow. Permanent flow is most readily apparent where the stream has cut to bedrock and small pools and seeps persist at the surface. Many other segments of this creek, especially where the substrate is a combination of forest humus and small alluvium, are dry in summer. Many streamside areas here also have thickets of vegetation which do not allow ready access or observation of the stream.

A private diversion works exists on Finney Creek within BBRSP. Though difficult to locate property boundaries in the area, it appears that the diversion (and a corresponding length of pipe) is located about 100 to 300 yards upstream from the BBRSP boundary. According to the Application for appropriative water rights which was filed in 1977, this source and point of diversion has been in use since 1917 under an oral agreement with earlier Park managers.

Elliot Creek

Elliot Creek is another direct Pacific Ocean tributary. Its watershed is situated adjacent to and south of the Finney Creek watershed but is more than twice as large, draining approximately 640 acres. All but the uppermost 40 acres and the lowermost 80 acres are within BBRSP. In aspect, topography, and vegetative cover it is otherwise similar to Finney Creek.

Elliot Creek contains permanent surface flow where it exits BBRSP and downstream from that point. It is not known how far upstream permanent flow persists, but a private diversion dam exists at the lower Park boundary and there is sufficient flow at that point to provide agricultural/irrigation water under an Appropriative Permit during the period April through December. Near its terminus the creek passes through a 5-foot diameter concrete culvert under Highway 1 and shortly thereafter passes over a small waterfall (bedrock face) onto the beach.

Other Headwater Areas

Several significant Santa Cruz and San Mateo County streams have portions of their watershed within BBRSP boundaries. The San Lorenzo River, Scott Creek, Pescadero Creek, Butano Creek, Año Nuevo Creek, Gazos Creek, Green Oaks Creek, Cascade Creek, and Whitehouse Creek all surround the Waddell Creek watershed and originate from the ridges surrounding the Park. However, of this list, the only BBRSP lands which include significant portions of the streams' respective channels are the San Lorenzo River (Boulder Creek and tributary), Scott Creek, and Año Nuevo Creek. All BBRSP properties in the other watersheds are located in areas which are essentially ridgetop, upper slope, or high headwater canyon in relative location. The acreages of these land holdings and their relative size to the greater watershed are listed in Table 2. Little or no additional hydrology information about these streams was collected during this resource inventory; only a brief description is included below.

Scott Creek

The Scott Creek watershed, covering about 30 square miles, is comparable in size to the Waddell Creek watershed. Big Creek and Mill Creek are the largest Scott Creek tributaries in this watershed (there is also a Berry Creek, not to be confused with the Waddell Creek Tributary of the same name).

The eastern BBRSP boundaries include two ridgetop areas at the very head of the Scott Creek watershed totaling about 95 acres, and an additional four disjunct parcels about 3 miles downstream which collectively include about 0.1 miles of Scott Creek and about 2 miles (collectively) of three different unnamed tributaries (Figure H-1). One of the latter parcels includes about 9 acres on the Mill Creek side of the ridge which separates that tributary from the main stem of Scott Creek.

Scott Creek watershed parcels were not visited during this resource inventory because of difficult access. Most headwater tributaries as small as these, situated high in the watershed, are seasonal streams. The 0.1 mile of Scott Creek within BBRSP lands drains about 2 square miles and thus probably has permanent flow, but it is likely very low; Smith (1994) reported that in 1988 (a dry year) summer flow in Scott Creek was about 0.02 cfs in areas upstream of the Big Creek confluence. However, the portion of the Scott Creek within the Park is about 3.5 miles upstream from Big Creek, so Smith's characterization may not be applicable.

San Lorenzo River

The San Lorenzo River is the largest stream in Santa Cruz County with a total watershed area of over 97,000 acres. Relevant information about the hydrology of this river was the emphasis of the Resource Inventory, Hydrology Chapter, for Castle Rock State Park (Rischbieter and Waldron 1997).

Seasonal headwater portions of the origins of two major San Lorenzo tributaries, Boulder Creek and Hare Creek (a tributary first to Boulder Creek), occur within eastern BBRSP boundary parcels. The narrow corridor of BBRSP land which follows the south side of Highway 236, for two miles west of Waterman Gap, drains to unnamed tributaries of the upper main stem of the San Lorenzo River. There are some trails and roads at the ridgetops (watershed boundary) but otherwise these are all forested, undeveloped areas with no Park facilities.

Not all minor (unnamed) tributaries exhibit flow proportional to the fraction of the watershed they drain. Some variation in flow between drainage areas can be attributed to variations in topography, geology, vegetative cover, and precipitation patterns. As a result of combinations of these factors, the west side of the San Lorenzo Valley is generally more moist and has many more springs than the east side. Also, the west side springs have a fairly steady year-around flow, whereas the east side springs show a greater tendency to dry up in the late summer and early fall. Therefore the west side streams, to which about 640 acres of BBRSP lands are tributary, yield a larger dry-weather (base) flow per square mile of drainage area than the east side streams (County of Santa Cruz 1979).

Año Nuevo Creek

Año Nuevo Creek drains a watershed of about 1,700 acres, of which 620 acres of the northern and eastern areas are within BBRSP's southwestern boundaries. The largest of three discontiguous watershed areas within Park ownership is 335 acres at the highest headwaters immediately southwest of Chalk Mountain. The approximately 0.5 miles of stream in this area, and smaller tributary drainages, are seasonal though permanent flow begins at or shortly downstream from the BBRSP boundary. The remainder of the acreage includes most of the watershed and channel of an unnamed seasonal tributary (250 acres) and a peripheral ridgetop area (35 acres).

Pescadero Creek

The headwater areas of Pescadero Creek, via Little Boulder Creek and other unnamed tributaries, which occur within northern BBRSP boundaries are ridgetop areas without defined drainage channels. Downstream from the unit these streams normally flow year-around. Pescadero Creek provides water for agriculture further downstream, but the relationship of Pescadero Creek hydrology to the small area of the watershed within BBRSP is negligible and further description is beyond the scope of this Resource Inventory.

Whitehouse Creek

The Whitehouse Creek watershed contains about 2,500 acres. The stream stretches for about 5 miles from the headwaters to the mouth, flowing first west and then turning sharply south. The headwaters originate from the west slopes of The Chalks range north of Chalk Mountain. The northwestern BBRSP boundary follows a lengthy, circuitous route around the watershed's eastern slopes and ridges without intercepting any of the stream's major channels or tributaries. In all, 560 acres of this watershed are in the Park.

Outside (downstream) of Park boundaries, the Whitehouse Creek canyon and small valley contains a road, a few dozen private residences, and a Girl Scout camp. However, no information was on file to indicate that there is any development of Whitehouse Creek water for domestic or other use, even though the USGS map shows a small pond half a mile from the mouth. The road follows the upper creek and canyon and provides access from Highway 1 to the BBRSP boundary and fire road along The Chalks ridge.

The upper watershed, within the Park, is steep and brushy. Coats (1988) estimated the mean annual yield from the upper 1,278 acres of this watershed to be about 1,100 ac-ft; thus the runoff from BBRSP lands could be expected to be somewhat less than half that.

Green Oaks Creek

Green Oaks Creek is located immediately north of the relatively narrow Año Nuevo Creek watershed and immediately south of the broad Cascade Creek watershed. It extends a little over 3 miles from its origin at the south end of The Chalks range (elevation 1,200+') to its mouth at the Pacific Ocean; like its neighboring streams it flows generally southwest, except that in its last half mile it turns abruptly northwest at a small reservoir site. Its total watershed area is about 800 acres but only the northern, upstreammost 60 acres are within BBRSP boundaries. This parcel contains a total of about a quarter-mile of seasonal stream channel in two disjunct segments. Upper watershed areas are brushy but forest species occur nearer the channel.

Three small dams and several small ponds exist in the Green Oaks Creek watershed well downstream from BBRSP. Only one dam, at approximately 100' elevation, is listed as being under State jurisdiction (DWR 1993; Appendix HY-III).

Cascade Creek

About 70 acres along part of the west-northwest BBRSP boundary drains into the northern branch of Cascade Creek and the reservoirs downstream there. (None of the three reservoirs are listed as being under the jurisdiction of the State, nor has information been filed with the SWRCB regarding exercise of water rights there.) A little over 200 acres along the western boundary drain into the southern (main) branch of Cascade Creek. Overall, the greater Cascade watershed encompasses about 2,000 acres.

Most of the watershed areas within the Park are steep and brushy, but some mixed forest occurs in the lowlands along the stream. Three headwater, seasonal stream channels are within the larger BBRSP parcel; the smaller parcel contains ridgetop and upper slope land without significant defined channels.

Coats (1988) estimated the mean annual yield of the north branch, an area of about 950 acres upstream of the Highway 1 bridge, to be about 550 ac-ft. On the main branch, the area upstream of the Highway 1 bridge was also estimated to be about 950 acres though yield there was estimated to average 630 ac-ft annually.

Pacific Ocean Direct Tributary Streams

The Park includes lands which drain directly to the Pacific Ocean via some seasonal streams, one in "Wilson Gulch" and several smaller unnamed ones. Wilson Gulch is immediately south of Elliot Creek, and the other "streams" are essentially ravines between Wilson Gulch and the mouth of Waddell Creek.

Wilson Gulch drains a watershed of about 150 acres. The uppermost 43 acres, and about 20 acres bisected by Highway 1 at the mouth, are within BBRSP. This watershed is relatively steep and brushy and is similar in aspect to Elliot Creek and Finney Creek.

The unnamed coastal "streams" south of Wilson Gulch collectively drain an area about the same size as Wilson Gulch but which is not as elongated. Park ownership includes the mouth of the largest seasonal stream and disjunct areas very low in this watershed north and south of the mouth which include portions of the other ravines. Approximately 90 acres of BBRSP in this area contains about 0.1 miles of the largest stream channel; these areas dry up relatively quickly after storms.

Other Watersheds

Several other ridgetop areas of the Park occur within the watersheds of additional streams. About 30 acres along the northern BBRSP boundary drains into Butano Creek and about 300 acres along the northwest boundaries drain into Gazos Creek (including 66 acres draining to Old Womans Creek, a major Gazos tributary). Though these are both important streams of moderate to large size, no significant stream channels are included within the acreages along BBRSP boundaries. Channels in these headwater areas typically exhibit seasonal flow and the portion of the watershed under State ownership is small enough that hydrologic resources are relatively minor.

Groundwater and Springs

The predominant mudstone and sandstone geology of the park's watershed is an important consideration when assessing the hydrologic picture. The rock formations in the basin are of sedimentary origin and are a poor source of groundwater. Water drains quickly and freely through the fissures. The long term storage characteristics of the Waddell and Scott Creek basins are also due to the dense stream network which is incised deeply into the local bedrock. These canyons effectively drain the groundwater; the surface detention capacity of the watershed is low and much of the precipitation (perhaps half) returns to the ocean. It is estimated that in the adjacent Scott Creek watershed forty percent of the precipitation leaves the watershed as surface runoff and eventually reaches the ocean (Creegan and D'Angelo, 1960). Evaporation, transpiration by plants, and groundwater outflow balances the remainder of the water budget.

Vegetation type also affects some hydrologic aspects such as runoff potential. Generally speaking, the best deterrent against rapid runoff is a dense cover of deep-rooted plant species. Much of the Waddell Creek watershed is covered by a dense coastal redwood, *Sequoia sempervirens*, forest. Though not deep rooted, redwoods have a well developed horizontal root system and contribute humus to the forest floor. Humus holds moisture within the soil and, as a result, the redwood forest has less water runoff and good recharge capabilities. In contrast, those areas with grassland and chaparral associations shed more runoff and have less recharge capabilities.

Overall, the groundwater resources of Big Basin Redwoods State Park are probably similar to those surrounding the Park. Through 1997, the Department of Water Resources has 21 well-completion reports on file for the 43 sections at and within the boundaries of Big Basin Redwoods State Park (Table 4). There are probably others because such reports are filed for only about 75 percent of completed wells (T. Camoroda, pers. comm.). Only one of the well reports is actually from a site within Park boundaries; this well, drilled at the Rancho del Oso subunit, was capped because its water has unacceptably high concentrations of hydrogen sulfide (E. Osman, pers. comm.).

A spring near the Rancho del Oso subunit has been developed to provide water for Park facilities. This water is of relatively high quality; water quality data from this source is presented in Appendix II. Another spring, Brown House Spring, is located upstream and on the opposite side of Waddell Creek and provides domestic water to several residences (Briggs 1991). Higher in the watershed, Pine Mountain Spring provided potable water to the BBRSP wastewater plant/facilities before the development of Sempervirens Reservoir. Pine Mountain Spring may be used again in the future if needed to meet requirements at the Big Basin wastewater treatment plant (D. Carroll, pers. comm.). Although little additional groundwater information is available from Big Basin, the permanent flow provided by these springs indicates that some high-quality groundwater is available from some water-bearing strata underlying the Park.

Table 4. Well Completion Reports on file for sections in the vicinity of Big Basin Redwoods State Park (T. Camoroda, pers. comm., and J. Gibboney, pers. comm.).

LOCATION	REPORTS ON FILE
T8S, R3W	
Section 27	1
Section 27	1
Section 34	1
Section 35	6
T9S, R3W	
Section 3	2
Section 5	1
Section 9	3
Section 18	1
T9S, R4W	
Section 25	1
Section 34	1
Section 35	2
T8S, R4W	
Section 34	1

CONSTRAINTS

Flood Prone Areas

The narrow floodplains of Quaternary alluvium along Waddell Creek in the southwestern part of Big Basin Redwoods State Park are subject to seasonal flooding. Such flooding also transports large quantities of suspended sediment and bedload and can rearrange stream features (banks, pools, and other habitat types) in a short period of time. These are generally natural events, though habitat damage from some floods is occasionally exacerbated by larger quantities of sediment delivered from areas of slope or bank failure related to roads or other past land uses in the watershed.

There are no developed areas within Big Basin Redwoods State Park subject to severe flood damage, however a "100 year storm" washed out the spillway of Sempervirens Reservoir in 1982. The same storm caused a landslide which destroyed associated water treatment plant. The current plant, built in 1983 to modern specifications, is sited in nearly the same location.

The potential for flood damage was illustrated by the results of earlier attempts to place structures in Waddell Creek. Some remnants of Shapovalov and Taft's (1954) dam are still laying in the creekbed but the functional structure was washed away years ago. The fish wier of Silverking Oceanic Farms, built across the mouth of the marsh, washed away in 1973. Existing streamside structures are limited to bridges, culverts, and some private water lines and pumps.

Some culverts under the road adjacent to lower (main stem) and West Waddell Creek are of insufficient size to pass combined high flow, sediment, and debris from large storm events. Debris and sediment are accumulating on the upstream (southeast) side of the culverts and elevating streambeds there. Thus, the road along Waddell Creek is prone to occasional washout.

Other streams adjacent to Big Basin Redwoods State Park, such as Pescadero Creek and the San Lorenzo River, occasionally have flooded developed areas downstrean. However, Park ownership of areas within watersheds other than Waddell Creek is relatively minor and generally confined to only the highest headwater areas. Thus, present land use at Big Basin Redwoods State Park probably has no significant relationship to threat of future floods to other downstream areas.

Surface Water Quality

Surface water quality apparently varies among different sources in Big Basin Redwoods State Park but is generally good within Park watersheds. During periods of high flows, turbid surface water is common in Big Basin Redwoods State Park. Such turbidity has no significant impact, from a water quality standpoint, to park resources. Otherwise, during much of the year, water quality in the Park's streams is reasonably good.

The water supply developed from Sempervirens Reservoir is of good quality and is periodically tested. Chlorine is tested daily by DPR staff; bacteriological testing is done monthly by a lab under contract to DPR. Recent Title 22 water quality test results (annual test by laboratory) for treated water produced from Sempervirens Reservoir, Rancho del Oso Spring, and Sempervirens Nature Center "well" are included in Appendix HY-I; these data illustrate the mineral compostion and other chemical characteristics of these water sources.

The park staff routinely perform water quality tests in conjunction with water and wastewater treatment facilities. Tests for water quality are rated by presence of coliforms and streptococci, both indicators of sewage-contaminated water. In fresh water, streptococci do not live as long as coliforms, thus indicating more recent pollution. For water contact sports, the Santa Cruz County Health Department has set a maximum safe limit of 200 fecal coliforms per 100 milliliters of water. Almost every test made in the Waddell resulted in the water meeting these limits. Howerver, with the exception of some samples taken from springs, the water does not meet accepted requirements for untreated drinking water (4 fecal coliforms/100 milliliters).

Relatively high counts of fecal coliform and streptococci have been found in the upper tributaries of Blooms Creek, which lie outside the park. A significant location of leachfield seepage was mapped as early as 1956 near one of these tributaries, the north fork of Union Creek, along the Shadowbrook Trail. This conditions is probably caused by seepage of effluents from houses near the streams; the leachfield of Residence #14 is near the seepage area. Waters near this seepage have been posted to prohibit human contact. The lower portions of Bloom Creek in the park show less contamination. The coliform count then rises again as the creek passes through the campground.

The headwaters of Opal Creek lie almost entirely within BBRSP boundaries where there are no private buildings or camping. Bacteria counts are very low near the stream's source and slowly increase downstream. Coliform concentrations increase near the campgrounds. Low gradient areas upstream from Park Headquarters often have the apperance of being "stagnant" in Summer and Fall, but late-season dissolved oxygen measurements taken during hot weather in October 1996 were all about 8 parts-per-million (Carroll, pers. comm.), near saturation.

The sewage treatment plant discharges effluents into East Waddell Creek just below the confluence of Bloom and Opal Creeks. Tests are made above and below the outfall; in the past bacteria counts have sometimes been lower downstream from the discharge than upstream (resulting from the use of chlorine in sewage treatment). On February 28, 1981 use of chlorine reduced the fecal coliform number from 95/100 to 0/100 milliliters (Harrison, 1983). However, excess residual chlorine can "sterilize" the creek water and harm beneficial aquatic organisms.

On the other hand, sewage adds a large and variable supply of nutrients to the waters of East Waddell Creek which may have a substantial effect on the living organisms in the stream. In winter, high concentrations of phosphates and nitrates in the effluent are readily diluted by the greater quantity of creek water. However, more tests are needed during the summer to determine how well the concentrations are diluted when stream water is low and the sewage flow relatively high. During the early part of the twentieth century, cases of polio and typhoid in the lower reaches of the Waddell were attributed to drinking water contaminated by discharge of raw sewage from the park (Mclean, 1971).

The concentration of bacteria in the East Waddell decreases downstream from the sewage plant and from the lower end of the campgrounds. Bacterial concentration in the undeveloped West Waddell also decreases towards the mouth. This may indicate that downstream the creek is being charged with groundwater, thus diluting the concentration of the bacteria. Tests show that the concentration of bacteria may increase again in the Waddell before it reaches the marsh. This is most likely attributed to livestock on surrounding lands.

More algae and aquatic plants are found in the water below the sewage plant than above it. Three factors affect these levels: sunlight, nutrients and geology. The creek is shaded by redwoods above the sewage plant; downstream it is relatively recently logged, burned and surrounded by deciduous trees, thus allowing more sunlight to reach the creek water. In addition, nutrients are supplied by sewage effluents and possibly leached from logged areas which are more susceptible to erosion.

The occurrence of sea water intrusion has not been reported in the groundwater basin of lower Waddell Creek near the ocean.

However, it has occurred in nearby Scott Creek, the next major drainage to the south of the park unit (Phillips 1976).

Many areas of BBRSP are surrounded by undeveloped land. However, in the few places where there are private residences, they typically use septic systems for wastewater disposal. Thus, the potential exists for impacts to nearby water quality whenever these systems, many of them decades old, fail to operate properly. Impacts to water quality would be most noticeable, and significant, during periods of low streamflow when relatively little dilution would occur.

Seismic activity has been documented to affect surface water quality and quantity. Studies following the 1989 Loma Prieta earthquake documented some of these phenomena in springs, wells, and streams in several local watersheds and are discussed below.

Groundwater Quality

Groundwater quality in the vicinity of BBSRP is highly dependent on the composition of the water-bearing rock where the respective well is sited. Because of the highly-fractured, jumbled nature of subsurface rock in this geologically-active area (see Geology Chapter), even wells in close proximity to each other can produce water varying greatly in mineral content and potability. One well drilled years ago at Rancho del Oso, now capped and buried, yielded unusable water high in hydrogen sulfide (E. Osman, pers. comm.). Very nearby on private property in the Waddell valley, a well yields high-quality water similar in chemical nature to a well drilled on the relatively distant Cascade Ranch (R. Briggs, pers. comm.).

Two springs not far from the two well sites produce water of measureably different chemical composition. "Brown House Spring" produces water used by at a local private residence and the chemical compostion was measured by Briggs (1991). The most recently available water quality data for potable water produced from a spring at Rancho del Oso is presented in Appendix HY-II; these data illustrate the mineral compostion and other characteristics of this water source. For comparison, Table 5 lists selected water quality data from these two otherwise similar sources.

Quality and quantity of groundwater yield in many local areas changed quickly and dramatically following the 1989 Loma Prieta earthquake. Briggs (1991) studied some effects on surface waters in the Waddell valley which illustrates some of the influences of this quake on groundwater; Brown House Spring first increased in flow and then went dry for almost 2 years. In other nearby watersheds, discharges of gelatinous materials were observed in about 30 percent of springs and headwater streams which experienced short-term increased flow (from 4 to 20 times base flow) immediately following the earthquake. These water quality impacts persisted for up to eight months. Similar water quality impacts occurred to numerous private wells, some of which also went dry following drops in the water table of over 100 feet in the months following the earthquake. Such declines in the water table, which occurred at some homeowners' wells on ridgetops along the headwaters of the San Lorenzo River and appear to be permanent, required construction of new wells to substantially deeper strata (Rojstaczer and Wolf 1994; S. Wolf, pers. comm.).

Table 5. Comparison of selected chemical characteristics of water from Brown House Spring and Rancho del Oso spring.

PARAMETER	BROWN HOUSE	RANCHO del OSO
pH	7.1	7.2
Conductance	630	820
Total Hardness	160	310
Total Alkalinity	230	200
Calcium	45	28
Magnesium	23	37
Sulfate	60	150
Chloride	40	80
Sodium	71	56
Total Iron	1.4	3200

Water Supply

Three sources of water have been developed and are currently used within BBRSP. Water from Sempervirens Reservoir serves the headquarters area including residences and the campgrounds. A spring has been developed to supply Park facilities and the Ranger residence at Rancho del Oso. The Sempervirens Nature Center uses water from a shallow well. All three sources have historically been adequate to meet typical demand, even during drought conditions, although the latter requires some conservation measures during summer. The other two are considered adequate to meet the unit's general needs through the foreseeable future; however, California law requires that the Big Basin wastewater treatment plant obtain its potable water from source outside its discharge watershed (current source is within watershed), so the development of another supply source is being considered.

Sempervirens Reservoir stores about 78 acre-feet of water (DWR 1993) although water in storage is rarely required to meet demand. Inflow to the reservoir from Sempervirens Creek and other springs is permanent and usually adequate to meet withdrawals to the treatment plant; about 11 million gallons (34 ac-ft) are treated for delivery each year. Variation of typical monthly demand from this source is summarized in Table 6.

Table 6. Typical monthly production (gallons) from three potable water sources in Big Basin Redwoods State Park.

MONTH	Big Basin	Nature Center	Rancho del Oso
JAN	520,000	7,200	10,000
FEB	550,000	9,000	9,000
MAR	755,000	12,000	20,000
APR	950,000	14,000	20,000
MAY	1,130,000	28,000	30,000
JUN	1,225,000	25,000	13,000
JUL	1,430,000	25,000	18,000
AUG	1,122,000	20,000	18,000
SEP	1,136,000	20,000	10,000
OCT	810,000	19,000	10,000
NOV	580,000	12,000	10,000
DEC	460,000	12,000	10,000
TOTALS	10,668,000	203,000	178,000

Water from Rancho del Oso Spring is considered "groundwater under the influence of surface water". Water is collected in an infiltration gallery and concrete springbox, treated with chlorine and ozone for potability, and stored in a 10,000 gallon concrete tank. Recent (typical) production totals are summarized in Table 6.

Water from the Sempervirens Nature Center "spring" is also groundwater under the influence of surface water. The collection device is a simple 24" corrugated metal pipe, with holes drilled into it, sunk vertically eleven feet below the ground surface in a excavation backfilled with 2" drain rock. It is in essence a shallow well, and water drawn from it is treated with chlorine and ozone for potability and stored in two 5,000 gallon plastic tanks. Recent (typical) production totals are summarized in Table 6. This source serves the Nature Center and two residences but during dry summers is not quite adequate to support the Center's lush garden (Carroll, pers. comm.).

Other sources of water supplied BBRSP in past years before construction of Sempervirens Reservoir in 1952 and an associated water treatment plant in 1962 (Carroll 1996). The first reported system was piped "from a stump" in Maddocks Creek in 1905 and stored in redwood tanks. From 1914 until about 1962 water from Craig Springs, now within Castle Rock State Park, was piped through Waterman Gap to Big Basin for various purposes including domestic use, dust control, and fire protection. These sources and others, including Pine Mountain Spring (which supplied the wastewater plant) and Opal Creek (which was primarily used as a supplement during periods of shortage), were abandoned after the completion of the 100 gpm Permuitt precipitator water treatment plant in 1962. Additional details of the history of water development in Big Basin can be found in the Big Basin Watershed Sanitary Survey (Carroll 1996).

There are no conventional wells within BBRSP boundaries. However, several private wells exist on the east ridge of the Waddell Creek watershed (Briggs 1991) and one resident living along lower Waddell Creek drilled a well in the early 1980s to supplement domestic water normally obtained from a distant spring (R. Briggs, pers. comm.). Also, other local residents in remote and rural adjacent areas, such as the San Lorenzo River and Pescadero Creek watersheds, often rely on wells for domestic water. Most of these wells serve only a single household and many exhibit a remarkable variety of water quality and quantity even though they may be in close proximity to one another (S. Wolf, pers. comm.). Local wells may be prone to failure following seismic activity as occurred following the 1989 earthquake (S. Wolf, pers. comm.; Briggs 1991; Rojstaczer and Wolf 1994).

There is little or no industrial water use in the immediate vicinity of BBRSP. Agricultural use of surface water does occur in many local watersheds, however, most notably on farmed terraces and fertile alluvial areas along SR 1.

Diversions of surface water by private parties from points within or very near BBRSP boundaries occur from Waddell Creek, Elliot Creek, and Finney Creek. As presently used and configured, these diversions have negligible impact on the hydrologic and aquatic resources of BBRSP.

Water from Waddell Creek is currently diverted under riparian rights for domestic use and to irrigate about 10 acres of private farmland about one mile upstream from the mouth of the creek. This diversion is pumped through a 4" pipe and totals about 6 ac-ft/year (R. Briggs, pers. comm.). A substantially larger diversion under appropriative rights (Application 6813, License 01912) was used to irrigate 220 acres of row crops in southern San Mateo County from 1931 until 1992. This latter diversion of 1.8 cfs, allowed between May 1 and October 30, constituted a significant fraction of summer and fall flow and was controversial because of occasionally significant impacts to aquatic life downstream. Initiated by Theodore Hoover and William Steel, these appropriative rights are now owned by the California Coastal Conservancy but are not being used. Pumps and other equipment associated with this diversion were removed in 1997.

In a somewhat unusual arrangement, water is appropriated from Finney Creek within BBRSP for domestic use and stockwatering on the Coastways Ranch (Application 25395, License 11542). The license allows diversion of up to 2,000 gallons per day but the actual diversion rate is usually substantially less (T. Hudson, pers. comm.); the maximum diversion allowed under the License is 1 ac-ft/year. Diversion is from a modified small bedrock pool in the face of a 10'-15' high steeply-sloping cascading waterfall and through a 1" pipe to three redwood tanks several hundred yards downstream on Coastways Ranch property.

Coastways Ranch also appropriates water from Elliot Creek at the approximate location of the BBRSP boundary (Application 12474, License 04955). The maximum diversion allowed is 0.25 cfs (30 ac-ft/year maximum) between April and December with storage allowed in April and May; this water is used primarily to irrigate about 61 acres of various crops with some reported domestic use and stockwatering. The diversion works consists of a broad flashboard dam which spans about 40' and is up to 5' high during the diversion season if all boards are in. An older defunct diversion dam, undermined by the creek which is now entrenched 20' into the terrace at this point, exists about 100' downstream from the current point of diversion.

Several small dams exist on Green Oaks Creek and on tributaries to Cascade and Año Nuevo Creeks. These dams are downstream from BBRSP boundaries and are primarily used for storage of irrigation water. Two of these dams are listed as being under the jurisdiction of the State of California (DWR 1993) and summary information can be found in Appendix HY-III. Small portions of the watershed of each reservoir occurs in BBRSP but the significance of water yield from State Park lands to the water supply of these facilities has not been determined.

RECOMMENDATIONS

The hydrologic information presented in this inventory has been pieced together from separate studies and extrapolated from data for nearby sites. It is believed to be as good a summary as possible given the dispersed and remote areas, disjunct ownership, and diverse information sources. However, information on surface water quantity, quality, and erosion rates are all lacking to some degree. A better assessment of the hydrologic conditions within the park would require broad data collection at more locations, over a longer period of time, and at frequent intervals. The effects of erosion, visitor use (trails, campgrounds, etc.), sewage treatment and fire (including prescribed burning) on water quality could be evaluated more reliably, for management decision-making, in the presence of a comprehensive monitoring program.

Several examples of monitoring are probably of higher priority. Regular measurement of Waddell basin discharge is necessary to document the apparent trend of diminishing base flow. Water flowing into the park unit from outside of park boundaries should be monitored for excessive siltation and pollutants from human habitation and land use. A reasonable index of natural sediment yield from local watersheds may be calculable from a study of accumulated silt at the inlet of Sempervirens Reservoir. Water quality and flow monitoring downstream from Sempervirens Reservoir is necessary to help develop a Reservoir Operation Plan.

There are also undocumented reports of illegal diversions from streams of remote, disjunct BBRSP parcels. Remote parcels along Scott Creek (V. Roth, pers. comm.) and populated neighboring areas such as along Whitehouse Creek may warrant closer scrutiny in the future.

ACKNOWLEDGMENTS

Several individuals contributed their valuable personal time and knowledge during development this Hydrology Resource Inventory. Mr. Robert O. Briggs and his wife Ann have collected a lifetime of information about the behavior of Waddell Creek and were graciously cooperative in providing that information as well as reviewing a draft of this document. The data displayed in Appendix HY-V were wholly produced by Mr. Briggs, efforts for which the Department of Parks and Recreation are grateful.

Mr. Tim Hudson of Coastways Ranch provided access to BBRSP land in the vicinity of Finney and Elliot Creeks, areas easily accessible only via private property. He also provided current information about water use from those streams.

Daniel Carroll of BBRSP maintenance staff contributed his vast knowledge of water treatment and wastewater systems and operations at the Park. He and his staff provided water quality information and other details about the history and nature of the upper watershed.

Other DPR staff also assisted by providing local orientation and arranging site visits to areas addressed in this and related Resource Inventory documents. Rangers Steve Oka, Les Clark and Gary Strachan assisted in this manner and also provided important information during this hydrology investigation.

REFERENCES

Briggs, R. O. 1989. Forecast of reduction in summertime flow rate of Waddell Creek due to tree cover growth. Draft paper provided to the California Department of Parks and Recreation, Resource Management Division, Sacramento, CA. Rancho del Oso, Davenport, CA.

_____. 1991. Effects of Loma Prieta earthquake on surface waters in Waddell Valley. Water Resources Bulletin 27(6):991-999. American Water Resources Association.

_____. Unpublished data. Discharge measurements from Waddell Creek (various dates).

Briggs, Robert O. Personal communication. Private resident, retired engineer and hydrologist. Rancho del Oso, Davenport, CA.

Camoroda, Tony. Personal communication. California Department of Water Resources, San Joaquin District, Fresno, CA.

Carroll, Daniel. Personal communication. California Department of Parks and Recreation, Big Basin State Park.

California Department of Water Resources. 1993. Dams under the jurisdiction of the State of California. Bulletin 17. Sacramento, CA.

_____. 1981. Index to sources of hydrologic data. Bulletin 230-81. Sacramento, CA. 696 pp. and map.

_____. 1975. California's Ground Water. Bulletin 118. Sacramento, CA. 135 pp.

Coats, Robert. 1988. Letter to the California Coastal Conservancy, July 20, 1988. Philip Williams & Associates. San Francisco, CA.

County of Santa Cruz. 1979. San Lorenzo River Management Plan. Santa Cruz, CA.

Creegan, . and . D'Angelo. 1960.

Curry, R.A., B.A. Emery, and T.G. Kidwell. 1994. Sources and magnitudes of increased streamflow in the Santa Cruz Mountains for the 1990 water year after the earthquake.

Gibboney, Jim. Personal communication. California Department of Water Resources, Central District, Sacramento, CA.

Harrison, . 1983.

Hecht, . and . Rusmore. 1973.

Mclean, . 1971.

Osman, Eric. Personal communication. California Department of Parks and Recreation, Big Basin State Park.

Phillips, . 1976.

Wolf, Stephen. Personal communication. United States Geological Survey, Menlo Park, CA.

Rischbieter, D. and G. Waldron. 1997. Resource Inventory: Hydrology - Castle Rock State Park. California Department of Parks and Recreation, Northern Service Center. Sacramento, CA. 21 pp. plus appendices.

Rojstacer, S. and S. Wolf. 1994. Hydrologic changes associated with the earthquake in the San Lorenzo and Pescadero drainage basins.

Roth, Victor. Personal communication. California Department of Parks and Recreation, Santa Cruz District.

Shapovalov, L. and A. C. Taft. 1954. The life histories of the steelhead rainbow trout and silver salmon. Fish Bulletin No. 98, California Department of Fish and Game, Sacramento, CA.

Smith, Jerry J. 1994. Status of steelhead in Central California. Summary report with select circulation, San Jose State University, Department of Biological Sciences. San Jose, CA.

United States Geological Survey (USGS). 1983. Water Resources Data California: water year 1995, Volume 2. USDI Geological Survey, Sacramento, CA.