Section C

Hydrology

Introduction

This section provides the available river peak flow data for the Russian River and Salmon Creek with analysis of the bed mobility in response reaches of the Willow/Freezeout WAU. The peak flow data is used to show the magnitude of storm events and when they occurred. High river peak flow events are indicative of the largest storms, with large storms typically comes high erosion and sediment transport events. The Russian River peak flow data was the only long-term river flow data available in close proximity to Willow/Freezeout Creeks. The Russian River peak flow data probably does not provide a direct relationship with the peak flows of Willow or Freezeout Creeks. However, for the purpose of showing the timing and magnitude of large storm events of the area, the Russian River and Salmon Creek peak flow data provides insight.

The Willow/Freezeout Creeks WAU does not receive any significant snow accumulations which could contribute to rain-on-snow events. Current research shows possible cumulative effects from increased peak flows from forest harvest in rain-on-snow dominated areas (Harr, 198l). However, in rain dominated areas increases in large stream peak flows (>20 year return interval) from forest harvesting are not found (Ziemer, 1981; Wright et. al., 1990). The Willow/Freezeout Creeks WAU is in a rain dominated area in the temperate coastal zone of Northern California therefore analysis on peak flow hydrologic change was not considered necessary.

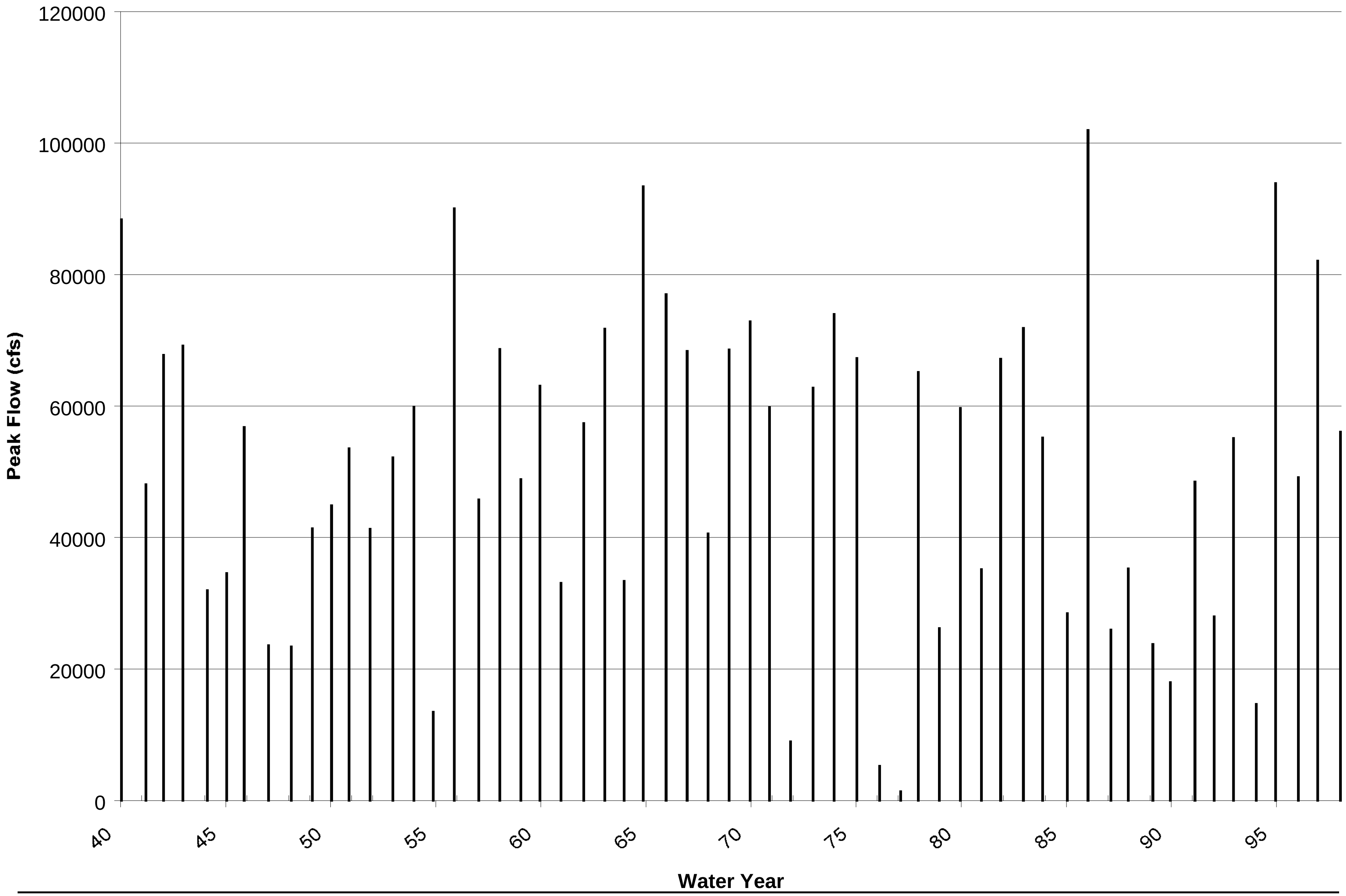
Peak Flows

The peak flow information was taken from the United States Geological Survey (USGS) gage 11467000, Russian River near Guerneville, from water years 1940-1998. Salmon Creek, a creek that drains to the Pacific Ocean close to Willow Creek, peak flow data was taken from the Trihey and Associates report on Willow Creek (1995). All annual peak flows are shown over the period of record for the Russian River near Guerneville (Figure C-1). To estimate the recurrence interval of the flood events of the Russian River near Guerneville the USGS annual peak flow series was used. An extreme value type I distribution (Gumbel, 1958) was fitted to the data. Table C-1 shows the estimated recurrence interval for peak discharges in the basin.

Table C-1. Flood Recurrence for Peak Flows of the Russian River near Guerneville, 1940-1998.

Recurrence Interval (years)	Peak Discharge (cfs)
1.1	24175
2	47052
10	81777
25	99255
50	112220
100	125091

Figure C-1. Annual Peak Flows for Russian River near Guerneville, CA, 1940-1998.



Using the peak flow record from 1940-1998, the flood of record is 1986 (102,000 cfs) calculated to be a 30 year event for the Russian River (Table C-1). The second highest peak flow of record occurred in 1995 (93900 cfs) and the third highest peak flow was in 1964 (93400). Although is unlikely that these peak flows directly correlate with storm patterns for Willow and Freezeout Creeks. It is very probable that the magnitude of these storms influenced Willow and Freezeout Creeks. Thus some of the largest storms to influence Willow and Freezeout Creeks likely occurred in 1986 and 1995. The Salmon Creek peak flow data record does not have either the 1986 or 1995 peak flows in its record (Appendix C). However, the time period it does cover shows 1982 as the highest flood of record. The 1982 flood for the Russian River was not that impressive in a relative sense, it registers as about a 7-8 year return interval. Yet, locally on the coast the 1982 storm was very large as shown by the Salmon Creek data.

Throughout the last 40-50 years, in the Russian River watershed, there have been numerous large flood events (Figure C-1). These flood events have the capacity to re-shape river or stream channels and transport large sediment loads. The meteorological events that created these large floods also can be assumed to be a major contributor to the erosion and mass wasting delivered to the watercourses in the Willow/Freezeout Creeks WAU.

Hydrologic Change due to Forest Management

Hydrologic change of the size of peak flows, the discharge at low flows, or annual water yield can be affected by forest harvesting. Forest harvesting influences these parameters by: changes in evapotranspiration from removal of vegetation, increased surface run-off from compacted soil surfaces of skid trails and roads, changes in snow accumulation from openings created by vegetation removal, and loss of interception from vegetation removal. The extent or magnitude of the hydrologic change is influenced by the parameter changed, and the physical and geographical characteristics of the watershed where the changes occur.

Change in size of peak flows, the highest instantaneous discharge of a hydrologic event, from forest harvest has long been a source of misunderstanding and public concern. The misunderstanding comes from the belief that vegetation removal increases the amount of water available for stream flow thus the peak flow must be increased as well. The first premise of this statement is correct. Annual water yield has been found to increase following forest harvest (Harr et. al., 1979; Keppeler and Ziemer, 1990; Rothacher, 1970). However, the annual water yield increase does not equate to an increase in the peak flow.

Current research shows possible cumulative effects from increased peak flows from forest harvest in rain-on-snow dominated areas (e.g. Harr, 198l). However, in rain dominated areas increases in large stream peak flows (>20 year return) from forest harvesting are not found (Ziemer, 1981; Wright et. al., 1990; Ziemer, 1998). Typically the largest peak flows, in rain dominated watersheds of coastal California, occur during the winter months when soil moisture is at its highest. Evapotranspiration levels during the winter are at the lowest and the intervals between storms are short. Therefore during the winter the water available for stream flow is not strongly affected by vegetation differences and the largest peak flows are not increased. Research conducted in watersheds which have had forest harvesting typically show increased peak flows in the fall, when soil water storage is depleted, but do not discern peak flow increases in the largest winter floods (Ziemer, 1981; Wright et. al., 1990; Rice et. al., 1979; Rothacher, 1973). This is significant when considering that the peak flows of interest for road design, channel formation, and sediment transport are the events with a 50-year recurrence interval, the largest flow events.

Water yield is typically increased following forest harvest. This increase is typically short lived, effects diminish after 5 years (Keppeler and Ziemer, 1990), due to re-growth of vegetation following harvest. Unfortunately the increased water yield is not of great utility to water managers or fishery concerns. This is because the timing of the augmented yield is not when the demand for greater water yield is needed, in the summertime. Secondly, that portion of the flow increase which did increase during the summer diminished rapidly following forest harvest, due to new vegetation demands (Keppeler and Ziemer, 1990).

Low flow is similar to water yield in that summer low flows tend to increase following forest harvest but diminish within 5 years (Keppeler and Ziemer, 1990), due to re-growth of vegetation following harvest. A slight decrease in low flows is observed after 5 years due to the new water demands of the regenerated forest following forest harvest (Keppeler and Ziemer, 1990). The impact of changes of low flows to summertime stream ecology are not known. However, it might be assumed that increased low flow in the summer provides more water for summer fish and macroinvertebrate use and stream temperature reductions. While a decrease in summer low flows would lower the amount of fish and macroinvertebrate habitat and facilitate higher stream temperatures. However, in both scenarios the summer low flow would need to be increased or decreased substantially, something which does not appear to occur.

The Mendocino Redwood Company (MRC) ownership in northern California does not receive any significant snow accumulations which could contribute to rain-on-snow events. The hydrology of the watersheds in the MRC ownership will always be a consideration to the company especially during watershed analysis. However, due to the lack of rain-on-snow event occurence on the MRC ownership no standards for hydrologic change due to forest harvest are considered necessary.

Bed Mobility Analysis

Bed mobility analysis is used to determine whether the bed particles of the streambed (usually represented by D_{50}) are likely to be transported at a given flow. The predicted bed particle size is then compared to the measured particle size to assess whether or not the bed material is likely to be mobilized for the bankfull flow (Version 3.0, Washington Forest Practices Board). The ratio of predicted particle diameter to the actual particle diameter provides a measure of bed mobility potential. Bed mobility is high if the ratio is much greater than 1 and low if the ratio is less than 1.

Uncertainty associated with the use of bedload transport equations is relatively high, differing field conditions can produce a range of results. Even with the greatest care in calculating a predicted D_{50}, there is still considerable margin for error. Because of this a range of values is probably most appropriate for assigning sensitivity ratings. For this analysis high bed mobility potential was assigned to ratios greater than 2, moderate bed mobility potential was assigned to ratios greater than 1 and less than 2, and low bed mobility potential was assigned to ratios less than or equal to 1.

The median grain diameter at which the streambed is entrained can be calculated by:

$$D_{50} = \rho_w \, g \, R \, S/(\rho_w - \rho_s) \, 0.047 \, g$$

where ρ_w is the density of water, ρ_s is the density of the grain particle material (assumed to be 2.65 g cm^{-3}), g is the acceleration of gravity, 0.047 is a constant defining the critical shear stress (i.e. Shield's number)(Dietrich, pers. comm.), R is the hydraulic radius, and S is channel slope. The hydraulic radius was approximated by bankfull depth, which was observed during the stream channel assessment. The D_{50} value calculated from this equation is compared to the actual observed D_{50} of the different locations for determination of bed mobility potential. The results of the bed mobility potential calculations are presented in Table C-2.

Table C-2. Bankfull Discharge Bed Mobility Potential for Channel Segments of the Willow/Freezeout Creeks WAU.

Stream Name	Segment ID#	Observed D50 (mm)	Predicted D50 (mm)	Predicted/ Observed Ratio	Bed Mobility Potential
Willow Creek	SW1	52	36	0.7	Low
Willow Creek	SW2	34	43	1.3	Moderate
Willow Creek	SW2(2)	36	141	3.9	High
Willow Creek	SW3	35	51	1.5	Moderate
North Fork Willow Creek	SW20	31	69	2.2	High
Willow Creek	SW23	51	154	3.0	High
Freezeout Creek	SF1 and 2	106	415	3.9	High
Freezeout Creek	SF10	79	190	2.4	High

* - see Section E -Stream Channel Condition module for channel segment locations.

Bed mobility tends to be directly proportional to scour, and thus provides an index of scour potential of the bed (Version 3.0, Washington Forest Practices Board). Bed mobility also tends to be directly proportional to sediment supply, and may reflect large supplies of sediments supplied either naturally or from accelerated erosion in the watershed. Low bed mobility may indicate that the channel bed is inherently stable and not subject to scour; on the other hand, it can also mean large floods have scoured the channel of finer materials.

Several stream segments show high bed mobility. Segment SW2(2) has a low width to depth ratio therefore the bankfull discharge is deeper and more apt to produce a higher predicted D50. However, there is a high amount of stored gravel deposits in the channel and banks of this area and it likely that the high bed mobility is a function of the high sediment supply available to the channel. The two segments along Freezeout Creek both have high predicted D50s yet low observed D50 making it rank as a high bed mobility potential. These segments have very high gradients that typically show a tendency toward a larger D50. However, the confounding factor is when a high amount of friction or drag is introduced in the channel, thus slowing water velocities and the ability to transport smaller sediment sizes. This is the case in the case of the Freezeout segments. Both channels are stable with large wood debris dams storing sediment, and creating drag on the flow regime thus lowering the segments D50. In the case of the Freezeout Creek segments a high bed mobility is expected given the high gradient and frequent wood accumulations in the channel. Segment SW20, North Fork of Willow Creek also is predicted to have high bed mobility likely due to high sediment supply being routed through the segment.

Stream channel segments that show low or moderate bed mobility potential are assumed to have beds that are well armored and not influenced by small changes in peak discharges or sediment supply. The remaining response reaches analyzed for bed mobility with low and moderate bed mobility potential are better interpreted in the Stream Channel Condition module of this report. The low potential sites could still have problems with scour potential or changes in sediment supply and transport. Also low bed mobility might occasionally occur in a channel recovering from previous high sediment impacts. The interactions between sediment supply, present and past channel conditions, and bed mobility all must be considered.

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Hydrology Module
Appendix

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# US GEOLOGICAL SURVEY
# PEAK FLOW DATA
#
# Station name  : Russian R Nr Guerneville Ca
# Station number: 11467000
# latitude (ddmmss)............................ 383031
# longitude (dddmmss).......................... 1225536
# state code................................... 06
# county....................................... Sonoma
# hydrologic unit code......................... 18010110
# basin name................................... Russian
# drainage area (square miles)................. 1338
# contributing drainage area (square miles).....
# gage datum (feet above NGVD)................. 20.14
# base discharge (cubic ft/sec)................ 23000
# Gage heights are given in feet above gage datum elevation.
# Discharge is listed in the table in cubic feet per second.
#
# Peak flow data were retrieved from the
# National Water Data Storage and Retrieval System (WATSTORE).
#
# Format of table is as follows.
# Lines starting with the # character are comment lines describing the data
# included in this file.  The next line is a row of tab-delimited column
# names.  The next line is a row of tab-delimited data type codes that
# describe the width and type of data in each column.  All following lines
# are rows of tab-delimited data values.
#
# ----Water Years Retrieved----
# 1940 - 1998
Type      Station    Date      Water     Date      Discharge
1s        15s        10d       Year      10d       6n
        3  11467000        40      1940        40     88400
        3  11467000        41      1941        41     48100
        3  11467000        42      1942        42     67800
        3  11467000        43      1943        43     69200
        3  11467000        44      1944        44     32000
        3  11467000        45      1945        45     34600
        3  11467000        45      1946        45     56800
        3  11467000        47      1947        47     23600
        3  11467000        48      1948        48     23400
        3  11467000        49      1949        49     41400
        3  11467000        50      1950        50     44900
        3  11467000        50      1951        50     53600
        3  11467000        51      1952        51     41300
        3  11467000        53      1953        53     52200
        3  11467000        54      1954        54     59900
        3  11467000        54      1955        54     13500
        3  11467000        55      1956        55     90100
        3  11467000        57      1957        57     45800
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3	11467000	58	1958	58	68700
3	11467000	59	1959	59	48900
3	11467000	60	1960	60	63100
3	11467000	61	1961	61	33100
3	11467000	62	1962	62	57400
3	11467000	63	1963	63	71800
3	11467000	64	1964	64	33400
3	11467000	64	1965	64	93400
3	11467000	66	1966	66	77000
3	11467000	67	1967	67	68400
3	11467000	68	1968	68	40600
3	11467000	69	1969	69	68600
3	11467000	70	1970	70	72900
3	11467000	70	1971	70	59800
3	11467000	71	1972	71	8990
3	11467000	73	1973	73	62800
3	11467000	74	1974	74	74000
3	11467000	75	1975	75	67300
3	11467000	76	1976	76	5260
3	11467000	77	1977	77	1370
3	11467000	78	1978	78	65200
3	11467000	79	1979	79	26200
3	11467000	80	1980	80	59700
3	11467000	81	1981	81	35200
3	11467000	81	1982	81	67200
3	11467000	83	1983	83	71900
3	11467000	83	1984	83	55200
3	11467000	85	1985	85	28500
3	11467000	86	1986	86	102000
3	11467000	87	1987	87	26000
3	11467000	88	1988	88	35300
3	11467000	89	1989	89	23800
3	11467000	90	1990	90	18000
3	11467000	91	1991	91	48500
3	11467000	92	1992	92	28000
3	11467000	93	1993	93	55100
3	11467000	94	1994	94	14700
3	11467000	95	1995	95	93900
3	11467000	96	1996	96	49200
3	11467000	97	1997	97	82100
3	11467000	98	1998	98	56100

SALMON CREEK (15.7 mi2): Recurrence interval for annual maximum flood

Water Year	Q (cfs)	Rank (M)	Recurrence Interval T= N+1/M	Notes
1963	1430	11	1.45	Bankfull discharge**
1964	1220	12	1.33	
1965	1540	10	1.60	
1966	1960	4	4.00	
1967	1760	7	2.29	
1968	1370	13	1.23	
1969	1650	9	1.78	
1970	1790	6	2.67	
1971	1380	12	1.33	
1972	537	15	1.07	
1973	2260	3	5.33	
1974	1760	7	2.29	
1975	1950	5	3.20	
1982	7400	1	16.00	actual recurrence interval is probably longer*
1983	6020	2	8.00	actual recurrence interval is probably longer*

Footnotes:

*short period of record and recurrence interval definition probably lead to underestimation of return periods for these floods.

**The 1.5 year flood under the annual maximum series usually corresponds to "bankfull discharge".