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JANUARY 2000

US Army Corps
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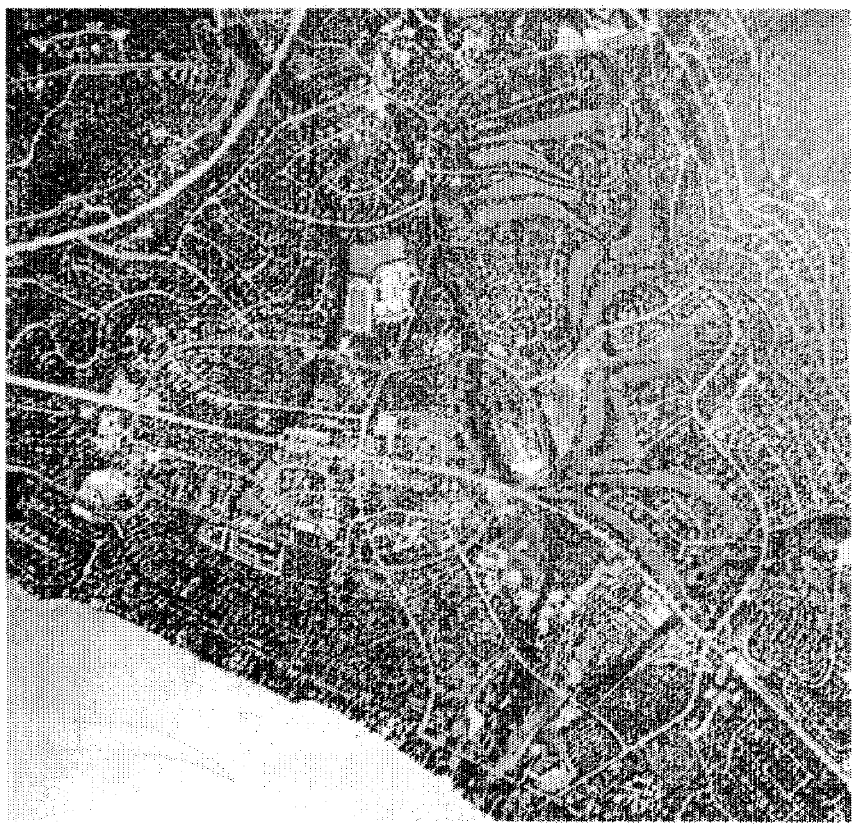
INCLINE VILLAGE
WASHOE COUNTY, NEVADA



FLOOD PLAIN MANAGEMENT SERVICES STUDY

HYDROLOGY REPORT

Volume 1 of 2

JANUARY 2000

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INCLINE VILLAGE
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HYDROLOGY REPORT

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1. PURPOSE

The purpose of this hydrology study is to estimate the 10-, 50-, 100-, and 500-year flows in the eight Incline Village area creeks along the north shore of Lake Tahoe, Nevada, with significant flooding potential. These values along with a detailed hydraulic analysis will be used by the Regional Planning Branch, Planning Division to estimate floodplains for some or all of these potential events. This final product will be submitted to the Tahoe Regional Planning Agency. This study was commissioned to provide a more detailed revision of a 1979 Internal Office Report. The 1979 report, "Lake Tahoe Basin California-Nevada Hydrology for Flood Plain Information Study," relied on a regional hydrologic analysis and only computed flows for some of the streams in the Incline Village area. The report was completed in February of 1979 by the Hydrology Section, Sacramento District. A brief 1991 floodplain analysis performed on several of the creeks in the Incline Village area relied entirely on the hydrology done for the 1979 study. The Tahoe Basin is an environmentally sensitive area under special Presidential mandate to assure the protection of its unique environmental resources.

2. SCOPE

This draft hydrology report presents the results of a HEC-1 model developed for the Incline Village area. The HEC-1 model computes flows for 21 concentration points on nine creeks, representing watersheds which range in size from 0.27 to 6.0 square miles. From west to east, the streams studied are: First Creek, Second Creek, Burnt Cedar Beach Creek, Burnt Cedar Creek, Wood (Rose) Creek, Third Creek, Incline Creek, and Mill Creek. 10-, 50-, 100-, and 500-year flood hydrographs were computed for each control point. Only preliminary hydrologic routings of flows using the Muskingum method were computed. These routings were computed only to assure a stable overall model. As significant flow obstructions are above nearly all the control points, refer to the final floodplain management study report for more accurate hydrographs and more detailed hydraulic analyses and routings.

3. BASIN DESCRIPTION

A. Location and Landmarks

Incline Village is in the Tahoe Basin, which lies between the north-south trending Sierra Nevada Mountains and Carson Ranges. The study area is along the north shore of Lake Tahoe in Washoe County, Nevada, at 120 03' W longitude, 39 17' N latitude. The westernmost watershed boundary in the study area is approximately 300 feet east of the California state line. The study area is accessible from the east and west via State Route (SR) 28, and from the north from SR 431. Several concentration points for the study are located where the streams cross these routes. Figure 1 contains a general location map of the study area.

B. Topography and Geology

Incline Village lies on a gentle to moderately sloping fan shaped plain with the apex to the north. Except for along the main fork of Third Creek, it is bounded on the west and north by steep to very steep sloped canyon tributaries with narrow valley floors and sharp ridges. The main fork of Third Creek has been scoured by glaciers sufficiently to maintain a more constant grade in the channel for more than a mile above the apex of the fan. The east side of the plain is bounded by hilly to moderately steep canyon tributaries with more rounded ridges and narrow valley floors. Lake elevation is about 6,228 feet, and the plain rises from there to 7,000 feet at the northern apex of the fan. The northern and western bounding ridge lines are between 9,000 and 10,500 feet, those to the east slightly less at 8,500 to 9,300 feet. Stream slopes on the plain itself are generally about 0.05 near the lake, steepening to around 0.1 on the middle elevations of the plain, mostly rising to 0.1 to 0.15 where streams enter the plain.

To the north and east of Incline Village are mostly Mesozoic granodiorites intruded into tightly folded Triassic metasedimentary and metavolcanic rocks. This is overlain in places by late Tertiary Kate Peak formation, consisting of andesitic flows, tuff-breccias and flow breccias. Many slopes on steeper slopes above the fan are covered by colluvial deposits. The fan itself is covered by a layer of Pleistocene to Quaternary glacial outwash, stream deposits and alluvium.

C. Soils

Soils on the fan itself except in the extreme northern and eastern parts are generally moderately well to well drained, coarse loamy sands that are deep to very deep over a pan, are of the Inville - Jabu association, and are in Soil Conservation Service (SCS) hydrologic group C, with some class B and a few small areas of class D. Soils in the northern part of the fan and north of the fan along Third Creek are of the Meeks - Tallac association, are moderately well drained to somewhat excessively well drained gravelly to extremely stony loamy coarse sands that are deep to very deep over a pan and are in hydrologic group B, with smaller portions in groups C and D. Soils immediately along most of the eastern edge of the fan north of SR 28 and most areas immediately adjacent to the western edge south of SR 431 are of the Umpa - Fugawee association, are generally well drained very stony sandy loams that are moderately deep over andesite and andesitic conglomerate, are mostly in hydrologic group C, with small areas in groups B and D. Soils further to the east of the fan and middle elevation ranges to the west of the fan are of the Cagwin - Toem association and are somewhat excessively drained to excessively drained loamy coarse sands and gravelly coarse sands that are deep to very deep over a pan. Lands in the higher elevations to the west of the fan are Rock land - Stony colluvial association that are 50 to 90 percent rock outcrop, cobblestones, stones and boulders.

D. Vegetation

The vegetation in the western and northern portions of the study area consists of mostly forest with some brush and meadows; and mostly brush-range with some patches of forest in the southeastern portion of the study area. The forests are of Sierra Montane type, dominating areas in the more moist western and northern portions of the study area. This community is characterized by Ponderosa Pine at the lower elevations; higher elevations are populated by White Fir, Red Fir and Lodgepole Pines in uplands, and Lodgepole Pine, willows and other riparian species along the streams. Exposed, drier sites in the eastern portions of the study area, especially on south and west facing slopes, are mostly chaparral dominated by Ceanothus and Manzanita with patches of Sierra Montane forest. More moist, protected slopes with northern and eastern facing slopes in the eastern portion are covered by a more even mixture of Sierra Montane Forest and Chaparral.

E. Climate

1. General

The climate in Incline Village consists of warm, mostly dry summers and cold, damp winters. Average temperatures based on data from a gage at 836 McCourry Bl. from 1968 to 1985 are given in table 1.

Table 1
Average Monthly Maximum and Minimum Temperature
(°F)

Incline Village			
Month	Maximum	Minimum	Mean
January	39.4	22.3	30.8
February	42.4	23.7	33.0
March	46.1	25.1	35.6
April	51.7	27.7	39.7
May	65.2	36.3	50.8
June	73.9	43.5	58.7
July	82.2	49.8	66.0
August	80.4	49.5	65.0
September	74.1	44.6	59.4
October	60.7	36.6	48.6
November	47.5	28.6	39.1
December	40.9	23.0	32.0
Annual	58.7	34.3	46.5

2. Precipitation

Normal Annual Precipitation (NAP) ranges from about 21 inches at the mouth of Third Creek to about 55 inches at the top of Tamarack Peak, the highest point at the northern edge of the Third Creek watershed.

At the lower elevations in the village itself, over half of the precipitation falls as snow, mostly in the winter months. Rainfall occurs mostly in Fall, Winter and Spring, with a little less than 10 percent occurring in the Summer. Monthly average, low and high precipitation depths for the years 1968 to 1985 collected at a gage in the village proper at 836 McCourry Bl. from 1968 to 1985 comprise table 2. Table 3 contains the ten highest 1-, 3-, and 6-hour precipitation events, taken from a recording gage at the Mt Rose Highway Maintenance station, located next to SR 431 two miles north of Incline Village, at 7,360 feet.

Table 2
Average Monthly Precipitation
(inches)

Month	Precipitation		
	High	Low	Mean
January	14.95	0.65	5.02
February	7.00	1.54	3.61
March	6.91	0.46	2.62
April	2.34	0.01	1.29
May	2.49	0.07	0.58
June	2.47	0	0.71
July	2.47	0	0.51
August	2.27	0	0.57
September	1.82	0	0.58
October	2.76	0.10	1.16
November	6.57	0.73	2.26
December	5.57	0.11	3.27
Annual mean			22.05

Table 3
Ranked Largest Annual 1-, 3-, 6-hr Precipitation
(by water year, Oct 1 - Sept 30)

rank	1-hr		2-hr		3-hr		6-hr	
	date	inches	date	Inches	date	inches	date	inches
1	08/20/83	1.3	08/20/83	1.3	01/01/97	1.4	01/01/97	2.6
2	07/31/76	0.9	07/31/76	1.2	02/17/86	1.3	11/13/81	2.0
3	12/24/71	0.8	01/01/97	1.0	08/20/83	1.3	03/08/86	1.8
4	06/24/77	0.7	02/17/86	0.9	11/13/81	1.2	12/12/95	1.7
5	02/18/86*	0.6	11/13/81	0.9	07/31/76	1.2	11/11/83*	1.6
6	06/18/82	0.6	12/24/71	0.9	12/24/71	1.1	07/31/76	1.6
7	09/07/80	0.6	12/11/95	0.8	12/12/95	1.0	11/23/88	1.4
8	09/19/97*	0.5	06/24/77	0.7	11/23/88	0.9	08/20/83	1.3
9	02/04/96*	0.5	01/21/93	0.6	02/14/79	0.9	12/24/71	1.3
10	07/12/90	0.5	11/23/88	0.6	01/21/93	0.9	10/26/91	1.2

* More than one occurrence in the year, latest occurrence listed.

F. Storm Characteristics

Major flood-producing storms over the Incline Village generally are winter rain-on-snow events and summer cloudburst thunderstorms. The largest widespread floods result from major winter storm systems that originate between 30 and 50 degrees north latitude and receive an influx of very moist air at about the latitude of the Hawaiian Islands. This very moist air mass lifts and cools as it moves easterly over the Sierra Nevada Mountain Range, and the moisture condenses and falls as precipitation. The origin point of the moist air influx of storms gives them their common name, "Pineapple Express." Week-long or longer periods of unusually wet weather can also be caused by so-called "Cutoff Low" winter storm systems originating in the Gulf of Alaska. These systems can stall over California or slightly offshore if a split in the jet stream develops and isolates the storm between the forks in the jet. Numerous bands of cloud producing precipitation from the stalled system can then be carried slowly inland at spacings of a few hours to a day apart.

G. Flood Characteristics

Excess rainfall from intense storms drains into the creeks that originate in the mountains above the village. The creeks typically have flood hydrographs with steep rising limbs, high peak flows, and fast recessions. The creeks flow southerly into town and to Lake Tahoe. The latest flood occurred in Incline Village in January 1997. The largest estimated flow for Third Creek is from the August 15, 1965 cloudburst storm. A peak flow estimate of 4,000 cfs was made by Nevada District USGS, based on a field survey. The point of analysis is approximately ½ mile north of SR 431, 0.2 miles north of a major tributary to Third Creek. The drainage area at this point is estimated at 3.4 square miles, which indicates a flow of 1,176 cfs per square mile.

The peak flow of official record on Third Creek at Crystal Bay is 150 cfs, which occurred in 1982. The peak flow of official record on Incline Creek, 179 cfs, happened during a rain-on-snow event on January 2, 1997. Although it is a smaller watershed, Incline Creek has a larger percentage of the watershed at a lower elevation than Third Creek and has a more compact shape than Third Creek. Therefore, should significant snowcover be present throughout the area, Incline Creek should produce a more rapid melting of the snow cover and therefore produce a more peaked response during an intense cloudburst.

H. Streamflow and Precipitation Gages

Few hourly streamflow and climatological gages are installed at the north end of the Tahoe Basin. A precipitation gage with 84 years of nearly complete daily record exists at Tahoe City California along the shore of Lake Tahoe about 10 miles west of Incline Village. An hourly precipitation gage was installed at the Mount Rose Highway Maintenance station in 1971, but has a much less continuous period of record. The station is about 2 miles north of Incline Village and within 1/4 mile of the Third Creek watershed. Stream gages collecting 15 minute data have recently been installed on Third and Incline Creeks. Table 4 shows known peak annual flow at the streamflow gages.

I. Land Use

Nearly all of the moderate to gently sloped areas on the plain have been developed. The lower elevations are devoted to medium to high density residential and light to medium commercial uses. The more steeply sloped areas adjacent to the plain are dedicated to light residential uses. Some light residential development also exists on the lower mountain slopes.

Table 4
Peak Annual Flow (cfs)
(bold text indicates peak of record)

Water Year	First Cr	Wood Cr	Third Cr	Incline Cr
1970	11.0	**16.0**	65.0	87.0
1971	10.0	15.0	110	38.0
1972	**22.0**	7.00	34.0	18.0
1973	9.00	13.0	80.0	40.0
1974	1.00	3.00	80.0	
1975				64.0
1976				
1977				
1978			62.0	
1979			66.0	
1980			74.0	
1981			24.0	
1982			150	
1983			86.0	
1984			78.0	
1985			37.0	
1986			**140**	
1987			31.0	
1988			9.90	6.50
1989			43.0	42.0
1990			20.0	9.00
1991			63.0	23.0
1992			23.0	23.0
1993			67.	40.0
1994			21.0	27.0
1995			122	73.0
1996			116	85.0
1997			108	**179**
1998			83	86

4. HEC-1 MODEL

A. General Considerations

A HEC-1 model of the Incline Village area was created to compute 10-, 50-, 100-, and 500-year flood hydrographs at each of the 24 subareas shown in figure 1. A computation time interval of 5 minutes was selected to assure good definition of the rising limb of the hydrograph on these relatively small watersheds. Preliminary hydrologic routing of the hydrographs done for this report used the Muskingum method, which uses mathematical means to attenuate peaks with downstream travel. The HEC-1 model includes separate precipitation for each event, with infiltration loss rates based on land use and previously measured soil parameters, and unit hydrographs based on S-graph patterns. Initial baseflow was included only on Mill and Incline Creeks to assure proper calculation of flood volumes.

B. Precipitation

1. Temporal Distributions

The temporal precipitation distribution is based on a 6-hour storm, and is nested so that it also includes the maximum 1, 3, and 6 hour precipitation amounts for the respective frequencies for which it is used. The temporal distributions for the return periods are given in tables 5 - 8.

Table 5
10-yr Temporal Storm Precipitation Distribution

15-min period	interval %	15-min period	interval %	15-min period	interval %
1	2	9	5	17	2
2	2	10	5	18	2
3	2	11	5	19	2
4	2	12	5	20	2
5	3	13	5	21	2
6	8	14	5	22	2
7	11	15	3	23	2
8	20	16	2	24	1

Table 6
50-yr Temporal Storm Precipitation Distribution

15-min period	interval %	15-min period	interval %	15-min period	interval %
1	2	9	7	17	3
2	2	10	5	18	3
3	2	11	4	19	2
4	2	12	4	20	2
5	3	13	4	21	2
6	7	14	4	22	2
7	11	15	4	23	2
8	18	16	3	24	2

Table 7
100-yr Temporal Storm Precipitation Distribution

15-min period	interval %	15-min period	interval %	15-min period	interval %
1	2	9	12	17	3
2	2	10	7	18	3
3	2	11	4	19	3
4	3	12	4	20	3
5	1	13	4	21	2
6	3	14	2	22	2
7	11	15	1	23	2
8	21	16	1	24	2

Table 8
500-yr Temporal Storm Precipitation Distribution

15-min period	interval %	15-min period	interval %	15-min period	interval %
1	3	9	6	17	3
2	3	10	3	18	3
3	3	11	6	19	3
4	3	12	6	20	2
5	3	13	6	21	2
6	3	14	6	22	2
7	6	15	6	23	1
8	17	16	3	24	1

2. Precipitation Depth

Precipitation depths for each of the subareas were calculated using precipitation frequency curves computed for a rain gage and were then adjusted for orographic effects using a map of Normal Annual Precipitation (NAP). The frequency curves were developed for 1, 3, 6 hour durations i (P_{FC}) from hourly data gathered at a recording rain gage at the Mt. Rose Highway Maintenance Station. The gage is situated along the Mt. Rose Highway (SR 431) at 7360' elevation, between Fairview Bl. and the view point, about 2 miles north of Incline Village. There is approximately 25 years of hourly data available at the gage, from 1971 through 1997. Points for the 10-, 50-, 100-, and 500-year events for each of the durations were drawn from the respective frequency curves. The NAP for the gage location (NAP_g) and for each subarea j (NAP_{sa}) were estimated from a map drawn from the 1979 Corps Tahoe Floodplain Study, included as figure 2. An area weighted average watershed precipitation (NAP_{ave}) was calculated for each creek from the subarea NAP values. Event precipitation (P_{sa}) for each duration and frequency for each of the respective subareas were then calculated from these initial calculations using the formula:

$$P_{sa} = P_{fci} * \frac{NAP_{saj}}{NAP_g} * \frac{NAP_{saj}}{NAP_{ave}} \qquad [1]$$

Six hour durations were selected for the total storm because it is of sufficient duration to saturate the soil and generate large excess, yet not so long as to reduce the peak flows, as would happen from a longer, less intense storm. This duration would generate the maximum flows that would impact Incline Village for a 100-year event. Table 9 shows the precipitation for all of the subareas. No depth-area reduction was made due to the small size of the watersheds. Third Creek is 6.0 square miles, Incline Creek is 6.7 square miles, all other creeks are less than 3 square miles.

Table 9 Precipitation Depths for
(inches)

		10-yr			50-yr			100-yr			500-yr	
Subarea	1-hr	3-hr	6-hr	1-hr	3-hr	6-hr	1-hr	3-hr	6-hr	1- hr	3-hr	6-hr
First Cr	1.10	1.39	2.08	1.56	1.88	2.86	1.74	2.07	3.19	2.18	2.53	3.93
Second Cr	1.13	1.43	2.13	1.60	1.93	2.94	1.79	2.12	3.27	2.24	2.60	4.04
Burnt Cedar Beach Cr	0.84	1.06	1.59	1.19	1.44	2.18	1.33	1.58	2.43	1.67	1.93	3.00
Burnt Cedar Cr	0.77	0.97	1.44	1.08	1.31	1.99	1.21	1.44	2.21	1.52	1.76	2.73
Wood Cr ab SR 431	1.33	1.68	2.50	1.88	2.27	3.45	2.10	2.49	3.84	2.63	3.05	4.74
Wood Cr at SR 28	0.49	0.62	0.93	0.70	0.84	1.28	0.78	0.93	1.43	0.98	1.13	1.76
Wood Cr at Mouth	0.44	0.55	0.82	0.62	0.74	1.13	0.69	0.82	1.26	0.86	1.00	1.56
Third Cr ab Ophir Diversion	2.19	2.77	4.12	3.09	3.74	5.68	3.46	4.11	6.33	4.34	5.03	7.81
Third Cr Ginny Lake	1.96	2.48	3.69	2.77	3.35	5.09	3.10	3.68	5.67	3.89	4.51	7.00
Third Cr Incline Lake	1.54	1.95	2.90	2.18	2.63	4.00	2.44	2.89	4.46	3.06	3.54	5.50
Third Cr ab SR 431	1.42	1.79	2.66	2.00	2.41	3.67	2.23	2.65	4.09	2.80	3.25	5.04
Third Cr at Village Blvd	0.63	0.79	1.18	0.89	1.07	1.63	0.99	1.18	1.82	1.24	1.44	2.24
Third Cr at SR 28	0.44	0.55	0.82	0.62	0.74	1.13	0.69	0.82	1.26	0.86	1.00	1.56
WF Third Cr ab Village Blvd	0.81	1.02	1.52	1.14	1.38	2.09	1.28	1.51	2.33	1.60	1.85	2.88
WF Third Cr at SR 28	0.42	0.53	0.79	0.59	0.72	1.09	0.66	0.79	1.21	0.83	0.96	1.50
Third Cr at Mouth	0.37	0.47	0.70	0.52	0.63	0.96	0.58	0.69	1.07	0.73	0.85	1.32
WF Incline Cr ab Village Blvd	1.04	1.32	1.96	1.47	1.78	2.70	1.65	1.95	3.01	2.06	2.39	3.71
WF Incline Cr at SR 28	0.71	0.89	1.33	1.00	1.21	1.83	1.12	1.32	2.04	1.40	1.62	2.52
Incline Cr ab Ski Way	1.23	1.56	2.32	1.74	2.11	3.20	1.95	2.31	3.56	2.44	2.83	4.40
Incline Cr at SR 28	0.52	0.66	0.98	0.73	0.89	1.35	0.82	0.97	1.50	1.03	1.19	1.85
Incline Cr at Mouth	0.48	0.60	0.90	0.67	0.81	1.24	0.75	0.89	1.38	0.94	1.09	1.70
Mill Cr ab Dam	1.05	1.33	1.98	1.48	1.79	2.72	1.66	1.97	3.04	2.08	2.41	3.75
Mill Cr at SR 28	0.63	0.80	1.19	0.89	1.07	1.63	0.99	1.18	1.82	1.25	1.45	2.24
Mill Cr at Mouth	0.58	0.99	1.09	0.82	0.99	1.50	0.91	1.08	1.67	1.14	1.33	2.06

C. Loss Rates

The SCS curve number method was used to calculate loss rates for all areas, using the protocol in the USDA National Engineering Handbook, Chapter 4, Section 9. Hydrologic soil groups (e.g. A, B, C, D) are those mapped in the 1974 (latest) soil survey completed by the Soil Conservation Service (now Natural Resource Conservation Service) in cooperation with other agencies. Curve numbers (CN) for forested, un-developed areas were calculated using equations developed for western forests and published by Branson et al, reported therein as originally derived from unpublished USFS data. The equations for hydrologic soil groups B, C, and D are computed using equation 2:

$$CN = E - F * X \qquad [2]$$

Where E is the base curve number, F is a correction factor, and X is the fractional groundcover density. Branson and Gifford give the applicable range of X for this equation as between 10 and 80 percent cover density. Coefficients for equation 2 are given in table 10.

Table 10
Curve Number Equation Coefficients

Hydrologic Soil Group	E	F
Group B soil	71.5	0.229
Group C soil	81.5	0.229
Group D soil	87	0.21

Equation 2 modifies the base curve number value to account for individual deviations in infiltration capacities due to variations in forest cover density. Analysis of available aerial photography led to the conclusion that most forested areas were approximately 80 percent forest cover density. However, many areas near ridges and other rocky areas exhibited a significantly lower cover density. The forest cover density for these areas was estimated at 50 percent. Curve number values for developed lands were drawn from the USDA National Engineering Handbook. These curve number values for individual land covers and soil types are given in table 11. Adopted curve numbers for the subareas were calculated as areally weighted averages of the applicable curve numbers in table 11. These adopted curve number values used for different hydrologic soil groups and vegetation/land use classes are in table 12.

Table 11
Curve Numbers for Individual Soil and Land Cover Classes

Vegetation - land cover density/imperviousness	Curve numbers by hydrologic soil class		
	B	C	D
Conifer forest - 80% cover density	53.18	63.18	70.20
Conifer forest - 50% cover density	60.05	70.05	76.50
Light density urban - (15-18% impervious)	75	82	86
Medium density urban - (21-27% impervious)	77	84	86
High density urban - (50-75% impervious)	79	86	90

Table 12. Adopted Watershed Curve Numbers.

Subarea	CN
First Cr	65.14
Second Cr	69.79
Burnt Cedar Beach Cr	74.31
Burnt Cedar Cr	79.74
Wood Cr ab SR 431	68.67
Wood Cr at SR 28	82.01
Wood Cr at Mouth	85.14
Third Cr ab Ophir Diversion	61.84
Third Cr Ginny Lake	69.60
Third Cr Incline Lake	62.30
Third Cr at SR 431	69.44
Third Cr at Village Blvd	75.22
Third Cr at SR 28	80.68
WF Third Cr ab Village Blvd	72.23
WF Third Cr at SR 28	83.73
Third Cr at Mouth	83.58
WF Incline Cr ab Village Blvd	64.74
WF Incline Cr at SR 28	70.58
Incline Cr ab Ski Way	66.58
Incline Cr at SR 28	79.59
Incline Cr at Mouth	83.17
Mill Cr ab Reservoir	66.32
Mill Cr at SR 28	74.12
Mill Cr at Mouth	74.43

D. Unit Hydrographs

The 5-minute unit hydrograph developed for each subarea of the HEC-1 model converts excess rainfall into runoff. A S-graph provided the pattern for constructing unit hydrographs. The DOS based computer program developed by the Corps, UHG.EXE, computed the hydrographs using an established pattern S-graph and five basin parameters: drainage area (DA), length of the longest channel from outlet to uppermost discernible channel (L), distance from the outlet to the point opposite the longest channel that is closest to the basin centroid (LCA), total elevation change of the main stream (DELTAH), and a basin drainage efficiency parameter (NBAR). NBAR values of 0.03 and 0.04 were selected for valley floor areas, values of 0.05 for watersheds of mixed valley and foothill/mountain subareas, and 0.07 for mountainous subareas. Testing of pattern S-graphs for mountainous watersheds of the Truckee River Basin, South Fork American River, and Martis Creek watersheds revealed that the Truckee River, Truckee Meadows Average Mountain pattern (sgr47.dat) produced hydrograph shapes on average most similar to available short term storm hydrographs from USGS gages on Third and Incline

Creeks. This method computes the time distribution of runoff as a ratio of lag time. Figure 3 shows the Truckee River, Truckee Meadows Average Mountain S-graph plotted as a percentage of lag time. UHG.EXE also calculates basin lag (LAG) in hours.

Table 13 shows the unit hydrograph parameters. Figures 4 to 27 are the computed 5-minute unit hydrographs for each of the subareas.

Table 13
Unit Hydrograph Parameters

Subarea	DA (sq. mi.)	L (mi.)	LCA (mi.)	DELTAH (feet)	NBAR	LAG (hrs)
First Cr	1.72	2.35	1.72	2712	0.07	0.77
Second Cr	1.03	2.75	1.78	2612	0.07	0.85
Burnt Cedar Beach Cr	0.43	0.76	0.66	452	0.05	0.30
Burnt Cedar Cr	0.27	1.14	0.76	452	0.04	0.31
Wood Cr ab SR 431	1.70	2.59	1.61	2300	0.07	0.81
Wood Cr at SR 28	0.19	0.87	0.38	360	0.04	0.23
Wood Cr at Mouth	0.08	0.53	0.36	192	0.03	0.15
Third Cr ab Ophir Diversion	1.03	1.80	1.17	1140	0.07	0.67
Third Cr Ginny Lake	1.01	1.25	0.76	760	0.07	0.52
Third Cr Incline Lake	0.46	0.57	0.38	280	0.03	0.15
Third Cr at SR 431	1.78	2.31	1.29	1290	0.07	0.78
Third Cr at Village Blvd	0.07	0.76	0.38	380	0.04	0.21
Third Cr at SR 28	0.38	1.14	0.78	375	0.03	0.24
WF Third Cr ab Village Blvd	0.84	1.40	1.14	885	0.05	0.44
WF Third Cr at SR 28	0.15	0.66	0.42	367	0.04	0.21
Third Cr at Mouth	0.16	0.76	0.45	142	0.03	0.20
WF Incline Cr ab Village Blvd	1.03	1.91	1.25	1550	0.05	0.48
WF Incline Cr at SR 28	0.93	1.61	1.42	960	0.05	0.50
Incline Cr ab Ski Way	4.20	3.60	2.12	2080	0.07	1.10
Incline Cr at SR 28	0.25	0.57	0.38	275	0.05	0.25
Incline Cr at Mouth	0.26	0.68	0.45	117	0.03	0.19
Mill Cr ab Reservoir	1.26	1.04	0.78	1200	0.07	0.44
Mill Cr at SR 28	0.06	0.28	0.28	252	0.05	0.19
Mill Cr at Mouth	0.70	1.21	0.57	1492	0.05	0.30

5. RESULTS

The Incline Village HEC-1 model computed the 10-, 50-, 100-, and 500-year flood hydrographs for each of the subareas using the precipitation, loss rates, and unit hydrographs described above. Tables 14-18 lists the predicted peak flow, 6, and 24 hour volumes for the 10-, 50-, 100-, and 500-yr events. Figures 28 to 52 are the computed 10-, 50-, 100-, and 500-year flood hydrographs for each of the subareas. Some entries in tables 14-18 represent flow combinations, routings or reservoir regulation effects that were necessary to calculate for inputs to the hydraulic routing which is be performed using this hydrologic analysis.

Table 14
Predicted 10-yr 6-hr Storm Flows

Subarea	10-yr peak flow	10-yr 6-hr volume	10-yr 1 day volume
First Cr	52 cfs	15 AF	15 AF
Second Cr	93 cfs	26 AF	27 AF
Burnt Cedar Beach Cr	20 cfs	4 AF	4 AF
Burnt Cedar Cr	16 cfs	4 AF	4 AF
Wood Cr ab SR 431	134 cfs	37 AF	38 AF
Wood Cr at SR 28	5 cfs	1 AF	1 AF
Wood Cr at mouth	2 cfs	0 AF	0 AF
Third Cr ab Ophir diversion	194 cfs	51 AF	62 AF
Third Cr bl Ophir diversion [1]	144 cfs	34 AF	43 AF
Third Cr Ginny Lk	234 cfs	61 AF	73 AF
Third Cr bl Incline diversion [1, 2]	257 cfs	61 AF	71 AF
Third Cr Incline Lake	45 cfs	9 AF	9 AF
Third Cr Incline Lake outflow [1, 2, 3]	12 cfs	6 AF	17 AF
Third Cr at SR 431	178 cfs	48 AF	50 AF
Third Cr at Village Bl	1 cfs	0 AF	0 AF
Third Cr at SR 28	4 cfs	1 AF	1 AF
WF Third Cr ab Village Bl	24 cfs	6 AF	6 AF
WF Third Cr at SR 28	3 cfs	1 AF	1 AF
Third Cr at mouth	2 cfs	0 AF	0 AF
WF Incline Cr ab Village Bl	27 cfs	7 AF	7 AF
WF Incline Cr at SR 28	11 cfs	3 AF	3 AF
Incline Cr ab Ski Way	193 cfs	60 AF	63 AF
Incline Cr at SR 28	5 cfs	1 AF	1 AF
Incline Cr at mouth	7 cfs	1 AF	1 AF
Mill Cr ab reservoir	49 cfs	13 AF	17 AF
Mill Cr reservoir outflow [3]	5 cfs	2 AF	10 AF
Mill Cr at SR 28	1 cfs	0 AF	0 AF
Mill Cr at mouth	7 cfs	2 AF	2 AF

Notes:
1 Flow reflects a roughly approximated upstream diversion
2 Combined flow given uses unverified approximate hydrologic routings upstream.
3 Flow has significant regulation, estimated regulated flow given.

Table 15
Predicted 50-yr 6- Storm Flows

Subarea	50-yr peak flow	50-yr 6-hr volume	50-yr 1 day volume
First Cr	137 cfs	41 AF	42 AF
Second Cr	193 cfs	61 AF	64 AF
Burnt Cedar Beach Cr	36 cfs	10 AF	11 AF
Burnt Cedar Cr	29 cfs	8 AF	8 AF
Wood Cr ab SR 431	255 cfs	82 AF	84 AF
Wood Cr at SR 28	9 cfs	2 AF	2 AF
Wood Cr at Mouth	4 cfs	1 AF	1 AF
Third Cr ab Ophir Diversion	322 cfs	103 AF	120 AF
Third Cr bl Ophir Diversion [1]	272 cfs	82 AF	95 AF
Third Cr Ginny Lk	419 cfs	113 AF	135 AF
Third Cr bl Incline Diversion [1,2]	481 cfs	137 AF	156 AF
Third Cr Incline Lake	81 cfs	22 AF	22 AF
Third Cr Incline Lake Outflow [1,2,3]	81 cfs	28 AF	53 AF
Third Cr at SR 431	318 cfs	102 AF	105 AF
Third Cr at Village Blvd	3 cfs	1 AF	1 AF
Third Cr at SR 28	11 cfs	3 AF	3 AF
WF Third Cr ab Village Blvd	53 cfs	15 AF	16 AF
WF Third Cr at SR 28	6 cfs	2 AF	2 AF
Third Cr at Mouth	4 cfs	1 AF	1 AF
WF Incline Cr ab Village Blvd	72 cfs	20 AF	21 AF
WF Incline Cr at SR 28	35 cfs	10 AF	10 AF
Incline Cr ab Ski Way	448 cfs	147 AF	154 AF
Incline Cr at SR 28	10 cfs	3 AF	3 AF
Incline Cr at Mouth	16 cfs	4 AF	4 AF
Mill Cr ab Reservoir	106 cfs	31 AF	37 AF
Mill Cr Reservoir Outflow [3]	38 cfs	6 AF	13 AF
Mill Cr at SR 28	2 cfs	1 AF	1 AF
Mill Cr at Mouth	22 cfs	6 AF	6 AF

Notes:
1 Flow reflects a roughly approximated upstream diversion
2 Combined flow given uses unverified approximate hydrologic routings upstream.
3 Flow has significant regulation, estimated regulated flow given.

Table 16
Predicted 100-yr 6-hr Storm Flows

Subarea	100-yr peak flow	100-yr 6-hr volume	100-yr 1 day volume
First Cr	176 cfs	55 AF	57 AF
Second Cr	262 cfs	79 AF	81 AF
Burnt Cedar Beach Cr	65 cfs	14 AF	14 AF
Burnt Cedar Cr	53 cfs	10 AF	10 AF
Wood Cr ab SR 431	358 cfs	103 AF	107 AF
Wood Cr at SR 28	16 cfs	3 AF	3 AF
Wood Cr at Mouth	8 cfs	1 AF	1 AF
Third Cr ab Ophir Diversion	513 cfs	127 AF	154 AF
Third Cr bl Ophir Diversion [1]	463 cfs	106 AF	125 AF
Third Cr Ginny Lk	675 cfs	137 AF	172 AF
Third Cr bl Incline Diversion [1,2]	888 cfs	180 AF	209 AF
Third Cr Incline Lake	167 cfs	29 AF	29 AF
Third Cr Incline Lake Outflow [1,2,3]	109 cfs	39 AF	70 AF
Third Cr at SR 431	465 cfs	128 AF	132 AF
Third Cr at Village Blvd	5 cfs	1 AF	1 AF
Third Cr at SR 28	16 cfs	4 AF	4 AF
WF Third Cr ab Village Blvd	77 cfs	20 AF	21 AF
WF Third Cr at SR 28	10 cfs	2 AF	2 AF
Third Cr at Mouth	6 cfs	1 AF	1 AF
WF Incline Cr ab Village Blvd	96 cfs	28 AF	28 AF
WF Incline Cr at SR 28	45 cfs	13 AF	14 AF
Incline Cr ab Ski Way	562 cfs	189 AF	198 AF
Incline Cr at SR 28	17 cfs	4 AF	4 AF
Incline Cr at Mouth	20 cfs	5 AF	5 AF
Mill Cr ab Reservoir	151 cfs	41 AF	50 AF
Mill Cr Reservoir Outflow [3]	95 cfs	16 AF	25 AF
Mill Cr at SR 28	4 cfs	1 AF	1 AF
Mill Cr at Mouth	30 cfs	8 AF	8 AF

Notes:
1 Flow reflects a roughly approximated upstream diversion
2 Combined flow given uses unverified approximate hydrologic routings upstream.
3 Flow has significant regulation, estimated regulated flow given.

Table 17
Predicted 500-yr 6-hr Storm Flows

Subarea	500-yr peak flow	500-yr 6-hr volume	500-yr 1 day volume
First Cr	363 cfs	91 AF	94 AF
Second Cr	468 cfs	123 AF	128 AF
Burnt Cedar Beach Cr	100 cfs	22 AF	22 AF
Burnt Cedar Cr	67 cfs	15 AF	16 AF
Wood Cr ab SR 431	602 cfs	158 AF	163 AF
Wood Cr at SR 28	25 cfs	5 AF	5 AF
Wood Cr at Mouth	10 cfs	2 AF	2 AF
Third Cr ab Ophir Diversion	734 cfs	187 AF	226 AF
Third Cr bl Ophir Diversion [1]	685 cfs	166 AF	191 AF
Third Cr Ginny Lk	764 cfs	194 AF	235 AF
Third Cr bl Incline Diversion [1, 2]	1193 cfs	283 AF	321 AF
Third Cr Incline Lake	214 cfs	45 AF	46 AF
Third Cr Incline Lake Outflow [1, 2, 3]	186 cfs	63 AF	102 AF
Third Cr at SR 431	732 cfs	191 AF	198 AF
Third Cr at Village Blvd	10 cfs	2 AF	2 AF
Third Cr at SR 28	35 cfs	7 AF	7 AF
WF Third Cr ab Village Blvd	155 cfs	34 AF	35 AF
WF Third Cr at SR 28	17 cfs	3 AF	3 AF
Third Cr at Mouth	13 cfs	2 AF	3 AF
WF Incline Cr ab Village Blvd	214 cfs	47 AF	49 AF
WF Incline Cr at SR 28	111 cfs	24 AF	25 AF
Incline Cr ab Ski Way	1057 cfs	303 AF	316 AF
Incline Cr at SR 28	31 cfs	6 AF	6 AF
Incline Cr at Mouth	40 cfs	7 AF	7 AF
Mill Cr ab Reservoir	301 cfs	67 AF	83 AF
Mill Cr Reservoir Outflow [3]	8 cfs	2 AF	2 AF
Mill Cr at SR 28	76 cfs	15 AF	16 AF
Mill Cr at Mouth			

Notes:
1 Flow reflects a roughly approximated upstream diversion
2 Combined flow given uses unverified approximate hydrologic routings upstream.
3 Flow has significant regulation, estimated regulated flow given.

6. REASONABLENESS OF RESULTS

A comparison with other, less detailed studies of the flood flows of the area indicate that these results are in the mid-range of all studies. Table 18 compares the 100 year results for all studies for which data was available.

Table 18
Comparison of 100-yr Peak Flows from Various Sources
(cfs)

Creek	Current HEC-1	USACE 1979	W & B 1970
First Cr	176	275	758
Second Cr	162	275	1,080
Burnt Cedar Beach Cr	65	60	N/A
Burnt Cedar Cr	53	38	N/A
Wood Cr	368 [1]	350	894
Third Cr	1,333 [1,2,3]	1,040	2,560
Incline Cr	698 [1]	1,150	2,750
Mill Cr	117 [1,2]	350	N/A

Notes:
1 Combined flow given uses unverified approximate hydrologic routings upstream.
2 Flow has significant regulation, estimated regulated flow given.
3 Flow reflects a roughly approximated upstream diversion

Table 18 is a comparison of results from the HEC-1 model, the 1979 Corps study, and a study by John Webster Brown, a private engineering firm.

Figure 53 is a comparison plot of the 100-year 6-hr cubic feet per square mile (csm) value for each subarea. The figure shows that the computed gage and model csm values are widely scattered. The cause of the scatter is presumed to be due to the scaling of storm precipitation according to the NAP, which varies more than 100 percent within the study area, from 22 inches at the lake shore to 55 inches at the northern edge of Third Creek. The computed 100- year flood hydrographs are reasonable, as are the computed 10-, 50-, and 500-year flood hydrographs. The computed 10-, 50-, 100-, and 500-year flood hydrographs should be used to determine the 10-, 50-, 100-, and 500-year floodplains in the Incline Village area.

7. SELECTED REFERENCES

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