Development of Hydrologic Hazard Curves using SEFM for Assessing Hydrologic Risks at Rhinedollar Dam, CA

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1. Introduction

A probabilistic flood hazard assessment was performed to support a quantitative risk analysis for Rhinedollar Dam, a 17-foot high rockfill dam located in the Sierra Nevada Mountains. The Stochastic Event Flood Model (SEFM) was used to develop flood magnitude-frequency relationships for reservoir inflow, outflow, and water surface elevation, which will be used in a Risk Informed Decision Making study for the project.

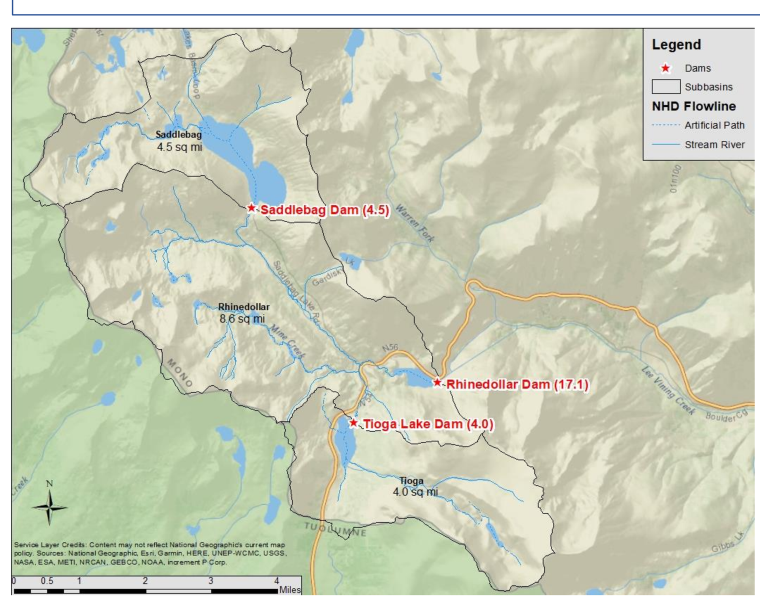
SEFM is a commercially available package from MGS Engineering Consultants, Inc. The basic concept of the SEFM model is to employ a deterministic flood computation model and treat the input parameters as variables instead of fixed values. Monte Carlo sampling procedures are used to allow the hydrometeorological input parameters to vary in accordance with that observed in nature while preserving the natural dependencies that exist between some climatic and hydrologic parameters.

The principal outputs from the analysis are Hydrologic Hazard Curves, which consist of flood magnitude-frequency relationships for reservoir inflow, outflow, and water surface elevation. Additional outputs of interest from the stochastic model included depth-duration-frequency relationships of overtopping, which can be used to assess the potential of eroding the rockfill embankment, and simulation of spillway debris blockage.

2. Rhinedollar Dam Description

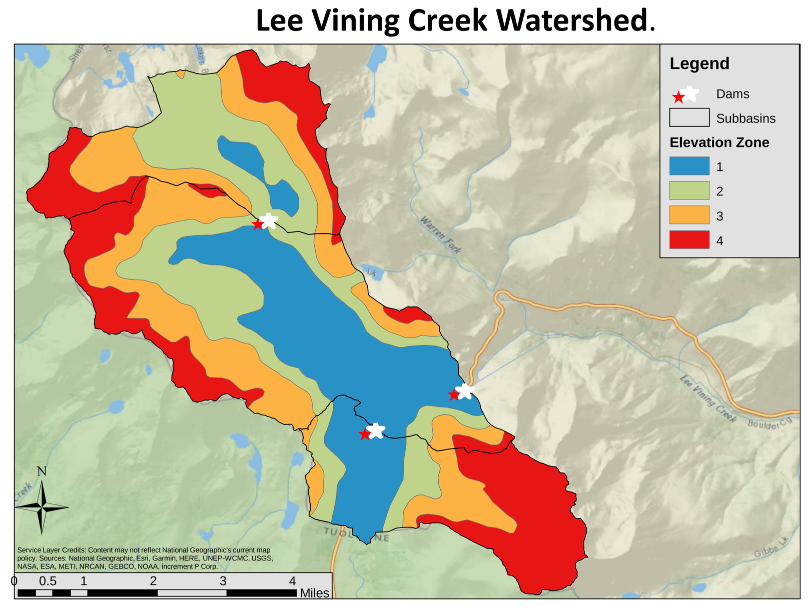
Rhinedollar Dam forms Ellery Lake on Lee Vining Creek on the eastern slope of the Sierra Nevada Mountains in Mono County, California (Figures below). The dam is part of the Lee Vining hydro-electric project and is owned and operated by Southern California Edison (SCE). The dam is a 17-foot high, reinforced concrete-faced rockfill dam. The tributary area is 17.1 mi^2 and includes two upstream dams: Saddlebag Dam (contributing area 4.5 mi^2) and Tioga Lake Dam (contributing area 4.0 mi^2). The watershed ranges in elevation from 9,500 feet at Rhinedollar dam to over 13,000 feet in the headwaters. Significant snowpack is often present from November through May. The local storm and snowpack seasons overlap and snowmelt often contributes to both the local and general storm types.

The dam is classified as a "high hazard potential" dam under the Federal Energy Regulatory Commission guidelines and is susceptible to overtopping under both the local and general storm Probable Maximum Floods. Population at risk downstream includes a campground and a ranger station which are occupied during the summer and fall.

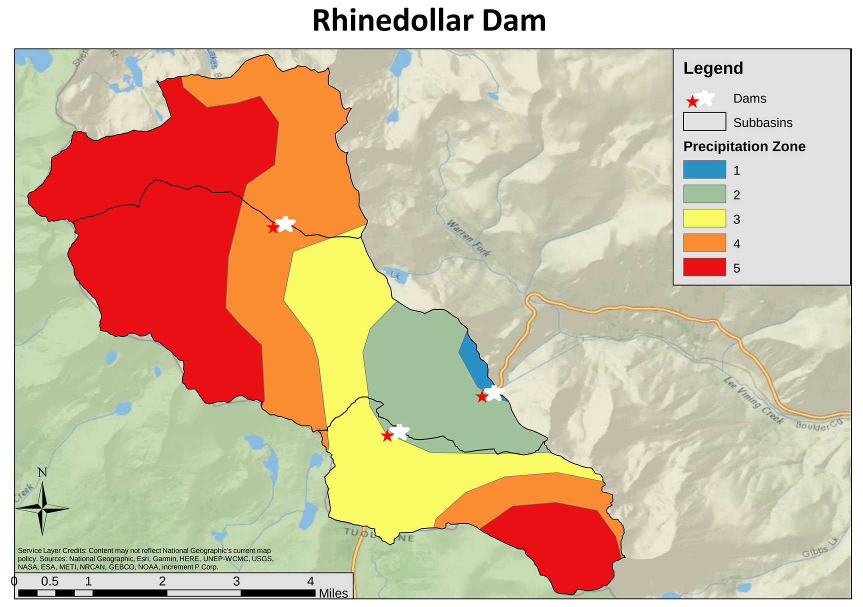


Lee Vining Creek Watershed.

Rhinedollar Dam



Hydrologic Model Elevation Zones



Hydrologic Model Mean Annual Precipitation Zones

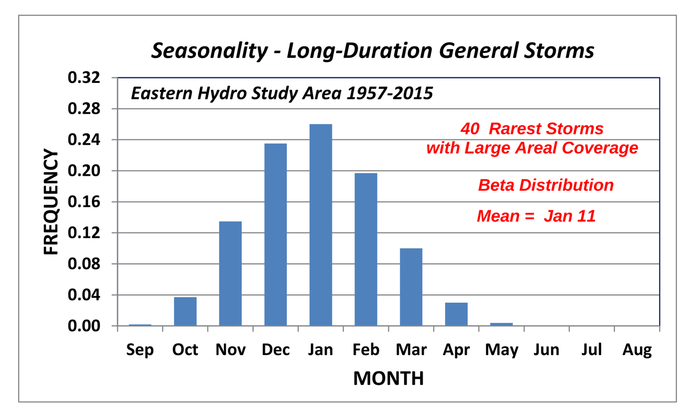
3. Stochastic Event Flood Model (SEFM) Inputs

SEFM Stochastically Samples:

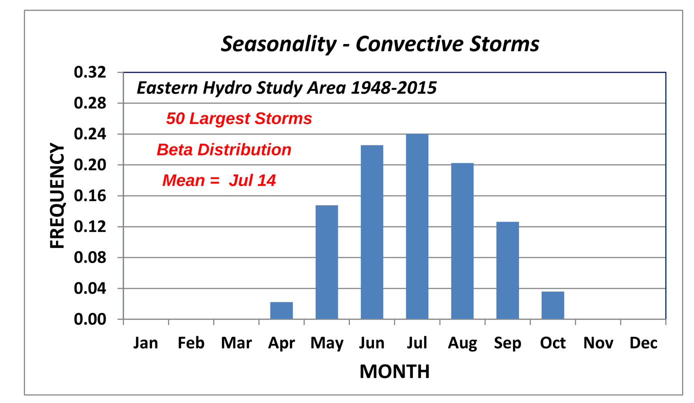
- Month of storm occurrence (seasonality)
- Precipitation volume
- Storm template, Defines storm temporal and spatial distribution
- Watershed Antecedent Conditions, Snowpack, Soil Moisture, etc.

- Runoff is Computed for Areas of Common Soil Type, Elevation, and Mean Annual Precip
- The Continuous Holtan Model (or Other Deterministic Model such as HEC-1) was used to develop reservoir inflow hydrographs for each simulation.
- Inflow hydrographs are routed through the dam to calculate reservoir water surface elevation.
- 1000's of simulations are run to develop flood magnitude-frequency relationships (hydrologic loading curves).

Storm Seasonality, Determines Date of Storm Occurrence



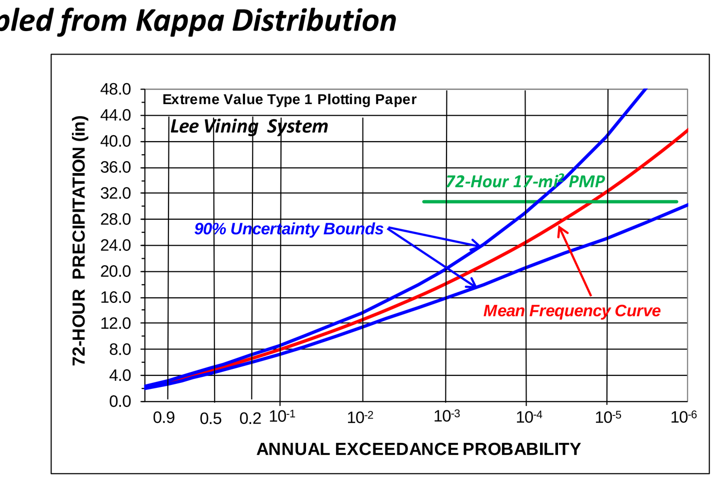
Fall/Winter General Storms



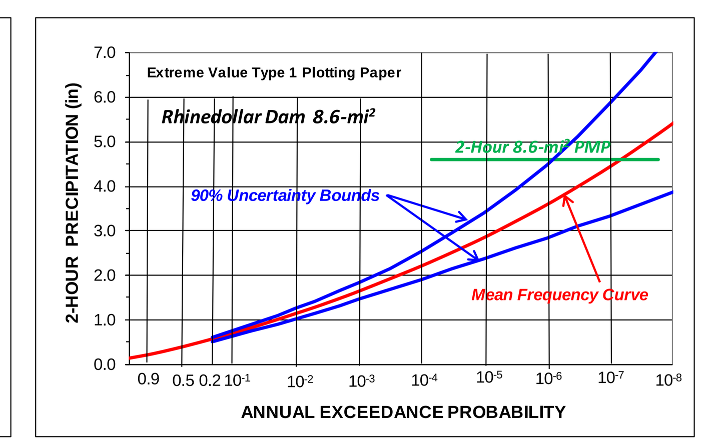
Late Spring-Summer Local Convective Storms

Precipitation Developed from Regional Frequency Analysis using L-Moments

Sampled from Kappa Distribution



Fall/Winter General Storms

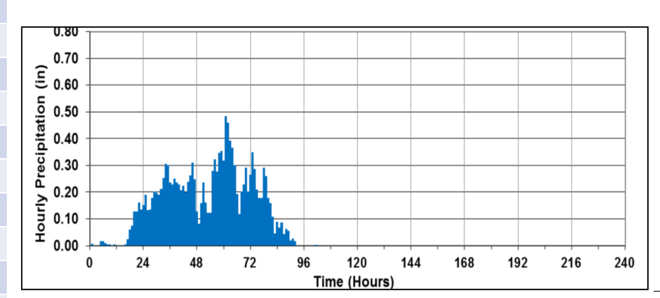


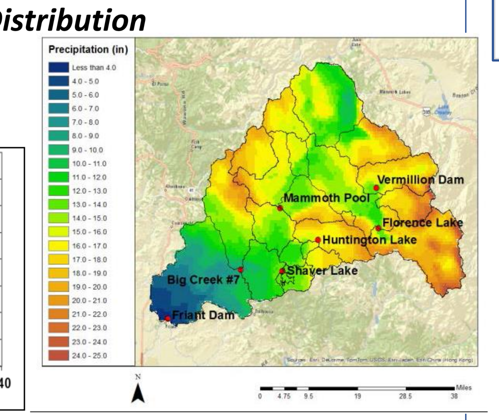
Late Spring-Summer Local Convective Storms

10 Storm Temporal Patterns Developed from Historic Record

Selected at Random, Equally Likely. Scaled by Precipitation Sampled from Kappa Distribution

Storm Date	72-Hour Precip (inches)
Dec 18-27, 1955	7.35
Feb 3-12, 1962	5.75
Jan 29 - Feb 7, 1963	10.77
Dec 1-11, 1966	5.71
Jan 18-27,1969	5.64
Jan 8-18, 1980	8.76
Feb 12-21, 1986	8.16
Dec 29, 1996 - Jan 7	7.23
Nov 6-16, 2002	3.51
Dec 15-24, 2010	6.54

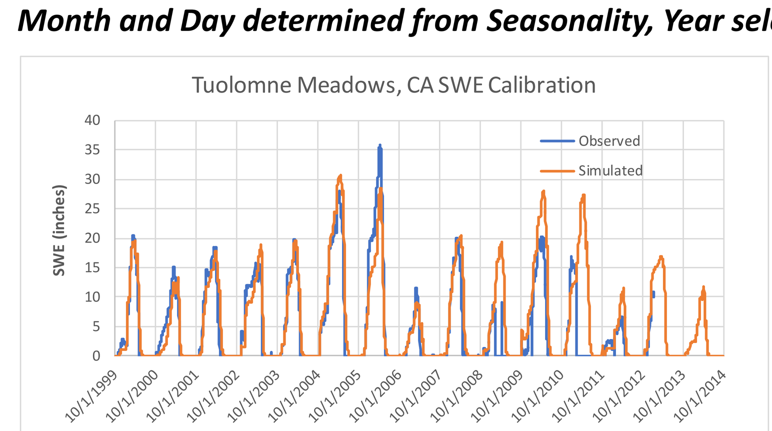




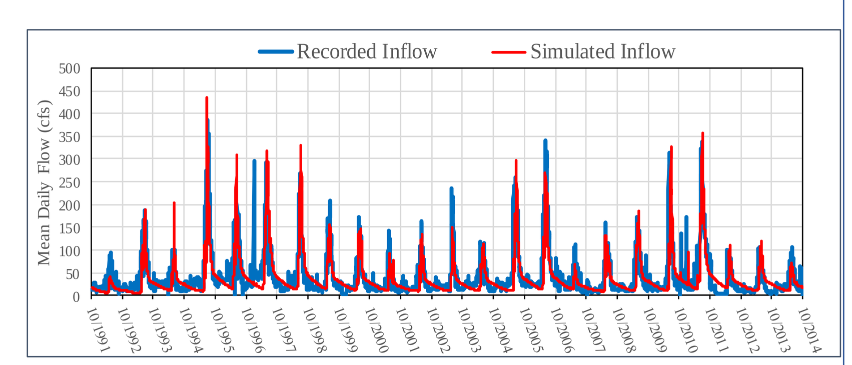
Example General Storm Temporal and Spatial Distributions

Continuous Holtan Model Used to Simulate 23-Year, Daily Antecedent Condition Series

Month and Day determined from Seasonality, Year selected equally likely from Antecedent Series



Simulated and Recorded Snow Water Equivalent (Daily)



Simulated and Recorded Streamflow (Daily)

4. Flood-Frequency Results

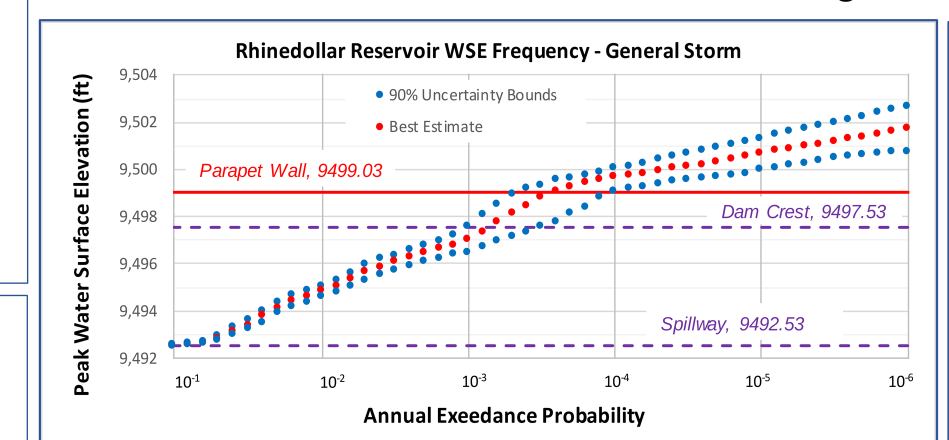
180,000 computer simulations were performed (30,000 for each storm type and upper and lower bounds of the precipitation frequency values) to develop magnitude-frequency relationships for the flood characteristics of peak inflow, maximum reservoir release, runoff volume, and maximum reservoir level.

Each simulation contained a set of climatic and storm parameters that were selected through Monte Carlo procedures based on the historical record and collectively preserved dependencies between the hydrometeorological input parameters. Execution of the watershed hydrologic model and reservoir routing of the inflow floods yielded the annual maxima flood characteristics of interest shown in the table and figures below.

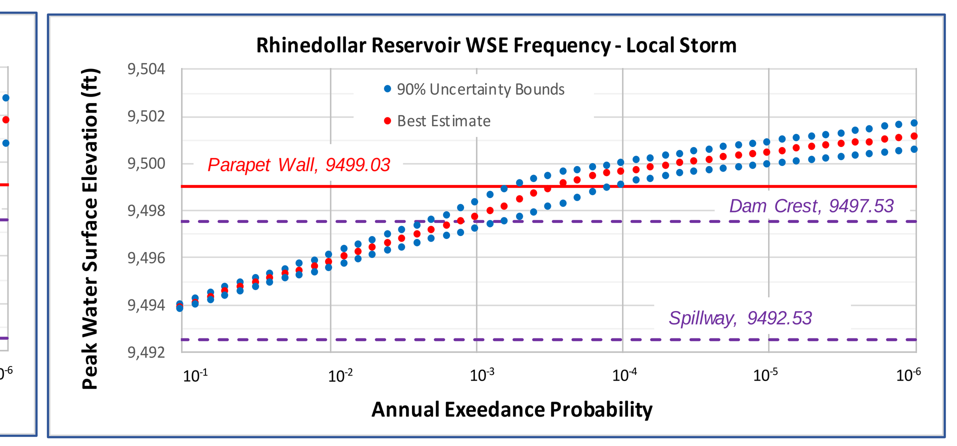
Rhinedollar Dam Probability of Overtopping Parapet Wall

	Local Storm		General Storm	
	AEP	Return Period (yr)	AEP	Return Period (yr)
Upper Bound	5.6E-04	1,800	4.6E-04	2,200
Best Estimate	2.7E-04	3,700	2.6E-04	3,800
Lower Bound	1.1E-04	9,200	1.0E-04	9,800

Rhinedollar Dam Elevation Magnitude-Frequency Relationships

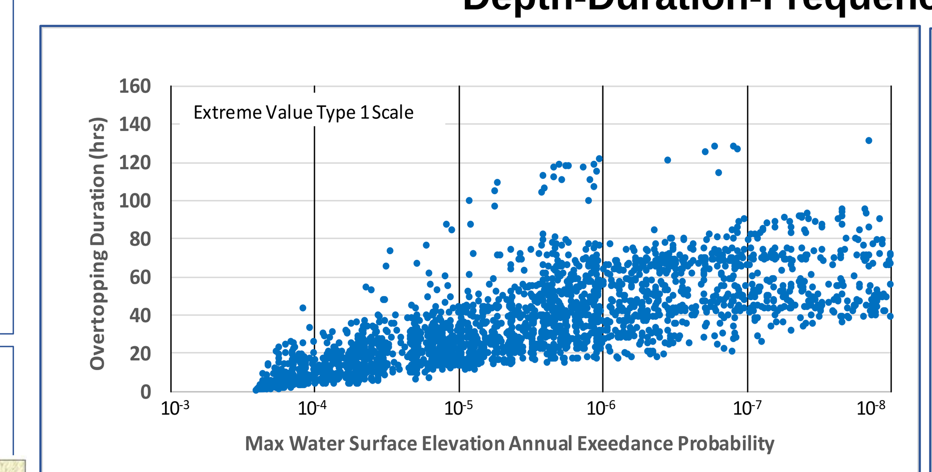


General Storm Elevation Magnitude-Frequency

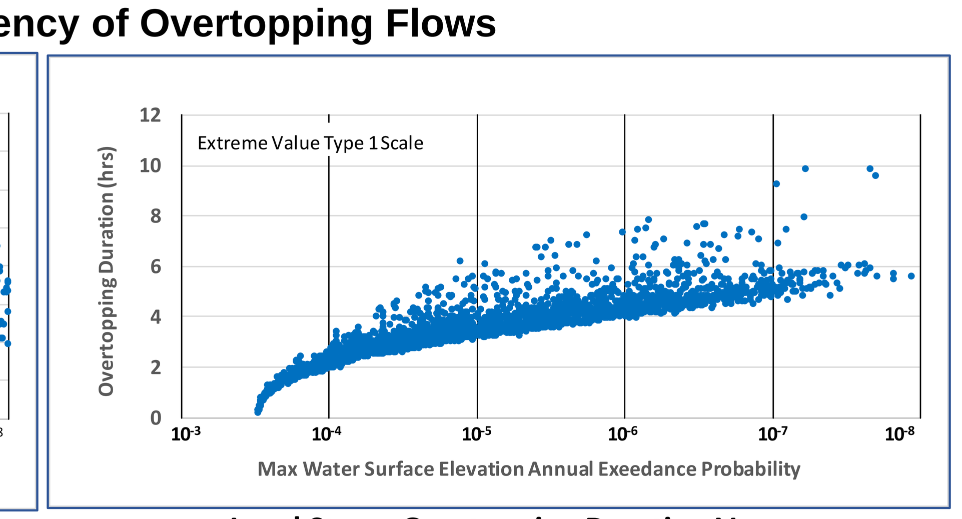


Local Storm Elevation Magnitude-Frequency

Depth-Duration-Frequency of Overtopping Flows



General Storm Overtopping Duration Vs. Overtopping Exceedance Probability



Local Storm Overtopping Duration Vs. Overtopping Exceedance Probability

5. Discussion

The Hydrologic Hazard Curve for maximum reservoir level (reservoir elevation-frequency) is being using in a Risk Informed Decision Making (RIDM) analysis for the dam, which will lead to improvements to meet FERC risk guidelines. The population at risk are located at campgrounds and a ranger station downstream of the project, which are occupied during the summer and fall. Floods from both storm types (general and local) can lead to dam overtopping and potential erosive failure while these downstream areas are occupied. The annual overtopping probability for each storm type is nearly the same; 1:3,700 for the general storm and 1:3,800 for the local storm.

The duration of overtopping differs dramatically between the two storm types. For example, at 10^{-4} annual exceedance probability, the mean overtopping duration is 18 hours for the general storm and 2.2 hours for the local thunderstorm. This information will be used by geotechnical and structural engineers to estimate the amount of embankment erosion and assess the likelihood of an overtopping induced dam failure. The resulting probability of failure for each storm type will be combined and used in the calculation of flood risk. Life Safety Risk in this context is defined as the product of the annual probability of dam failure and the estimated life-loss.