RISK ANALYSIS

Risk and uncertainty are related in that flood damage reduction studies rely on an estimation of flood risk that is based on uncertain information. Uncertainty is an expression of doubt in the accuracy of knowledge or information. Flood damage reduction studies regularly use and estimate information, such as stream flow records or stage predicted by hydraulic models, with varying degrees of accuracy and reliability. Uncertainty is also associated with environmental conditions and assumptions that could affect the success of restoration efforts.

The Corps historical approach to flood damage reduction planning has accounted for uncertainty by using safety factors, freeboard, worst-case scenarios, and other procedures that acknowledge uncertainty, but do not explicitly quantify it. Today, advances in statistical hydrology and high-speed computerized analysis tools have made it possible to explicitly account for uncertainty. The Comprehensive Study has adopted a risk analysis approach that utilizes HEC's Flood Damage Assessment (HEC-FDA) computer model to analytically incorporate considerations of risk and uncertainty to express engineering and economic performance in terms of probability distributions.

Traditional Risk Analysis Approach

Traditional risk analyses rely on information in the form of discharge-frequency, stage-frequency, and stage-damage functions identified at index points. The index points represent the location where hydrology, hydraulics, geotechnical considerations, and types of damage are equated to flood damages or flood risk. The discharge-frequency, stage-frequency, and stage-damage functions describe the hydrologic, hydraulic, geotechnical, and economic conditions at each index point.

Uncertainty distribution is the dispersion or variation of errors about the median or best estimate of values along a function. It is defined by error limits or a distribution of error associated with the key variables used in an analysis. There are error limits around the discharge in the discharge-frequency relationship, around stage in the stage-discharge relationship, around stage in the stage–probability of failure relationship, and damage in the stage-damage relationship.

Monte Carlo simulation provides a way to estimate the statistical properties of outputs when the inputs are random variables. For flood damage reduction, Monte Carlo sampling of the stage-discharge, discharge-frequency, stage-probability of failure, and stage-damage relationships is repeated an indefinite number of times until the outputs, such as expected annual damages (EAD) and annual exceedance probability (AEP), are statistically accurate.

Figure 10 illustrates the conceptual risk analysis approach for Corps' flood damage analyses. To find the damage for any given flood frequency, the discharge for that frequency is first located in the discharge-frequency panel (hydrology), then the river channel stage associated with that discharge value is determined in the stage-discharge panel (hydraulics). Most of the rivers being studied have levees that typically fail before the water reaches the top (geotechnical reliability). Once levees have failed and water enters the floodplain, then stages (water depths) in the floodplain cause damage to structures and crops (economics). This process is repeated thousands of times using Monte Carlo analysis and the results are plotted to form the damage-frequency curve (shown in **Figure 10** as the box at lower right).

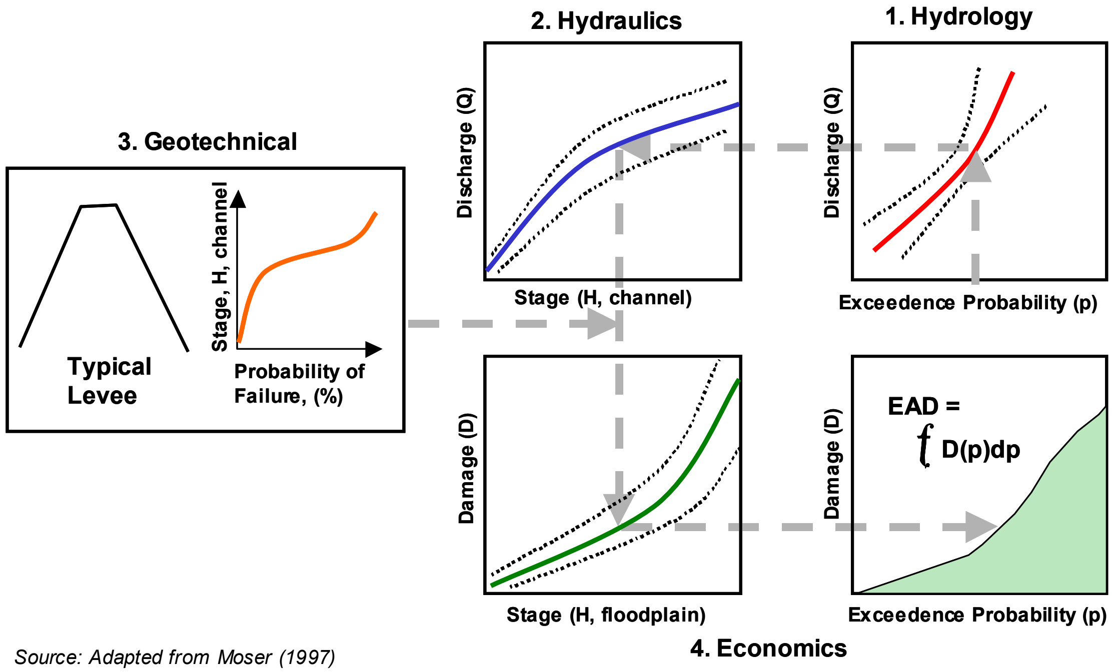

FIGURE 10 –THE CONCEPTUAL RISK AND UNCERTAINTY MODEL

Comprehensive Study Risk Analysis

The risk analysis methodology used during the Comprehensive Study deviates slightly from traditional methodology. The Monte Carlo simulation starts with a random number sampling of the stage-frequency, stage-probability of failure, and stage-damage relationships. However, there are no discharge-frequency relationships in the Monte Carlo simulations. The hydraulic model directly creates the stage-frequency relationships and uncertainty distributions at index points in the channel from five flood-event hydrographs (10%, 2%, 1%, 0.5%, and 0.2% chance of occurrence in any year) input into the hydraulic model. The risk analysis methodology can be applied to existing, baseline, and with-project conditions.

There are numerous uncertainties associated with flood damage reduction studies related to both natural systems (variations in climate, stream flow, river stage, etc) and engineered systems (reliability of levees, flood gates, etc). These uncertainties are shown in **Figure 10** as dashed "error bands" located above and below the hydrologic, hydraulic and economics curves. Some of the important uncertainties specific to the Comprehensive Study include:

Hydrologic **-** Uncertainty factors include hydrologic data record lengths (period of record) that may be shorter than desired or are not available on un-gaged tributaries; precipitation-runoff computational methods or statistics; and methods or models used to simulate reservoir operations that may deviate somewhat from actual operations. For the Comprehensive Study, the hydrologic periods of record were identified for each impact area.

Hydraulic **-** Uncertainty arising from the use of simplified models to describe complex hydraulic phenomena, including the availability of detailed geometric data, potential misalignments or misrepresentations of hydraulic structures, channel bed material variability, debris loading on structures (such as bridge piers) and errors in estimating slope and roughness factors.

Geotechnical **-** Uncertainty in the geotechnical performance of flood control structures during loading from random events, such as flood flows and earthquakes, affect levee performance. Other uncertainties may include geotechnical parameters such as soil and permeability values estimated in the analysis, mathematical simplifications in the analysis models, frequency and magnitude of physical changes or failure events, and unseen features such as rodent burrows, cracks within a levee, or other localized defects.

Economic **-** Uncertainty concerning land uses, depth/damage relationships, structure/content values, structure locations, first floor elevations, floodwater velocity, the amount of debris and mud, flood duration, warning time, and response of floodplain inhabitants.

Index Points and Impact Areas

Because the Comprehensive Study floodplains cover over 2.2 million acres (about 3,400 square miles), the floodplains were divided into smaller impact areas to facilitate the analysis. These were delineated based primarily upon flooding characteristics (sources and flow patterns) and land uses within the 2% floodplain. Within the Sacramento River basin, 62 impact areas were initially identified covering about 1.5 million acres. An additional six impact areas were delineated along the upper Sacramento River. In the smaller San Joaquin basin, 42 impact areas were identified covering about 654,000 acres. The impact areas are shown in **Figures 11** and **12.** The impact areas generally cover the 0.2% floodplains of the Sacramento and San Joaquin river mainstems and their major tributaries. The impact areas were not delineated to include the floodplains of smaller streams and waterways outside the focus of the Comprehensive Study.

One index point was assigned to represent each impact area. Each index point is located along the river or waterway that has the greatest influence on flooding in a particular impact area. The index points are the location where data from the hydraulic models is passed to the risk analysis in order to calculate project performance and economic damages within each impact area.

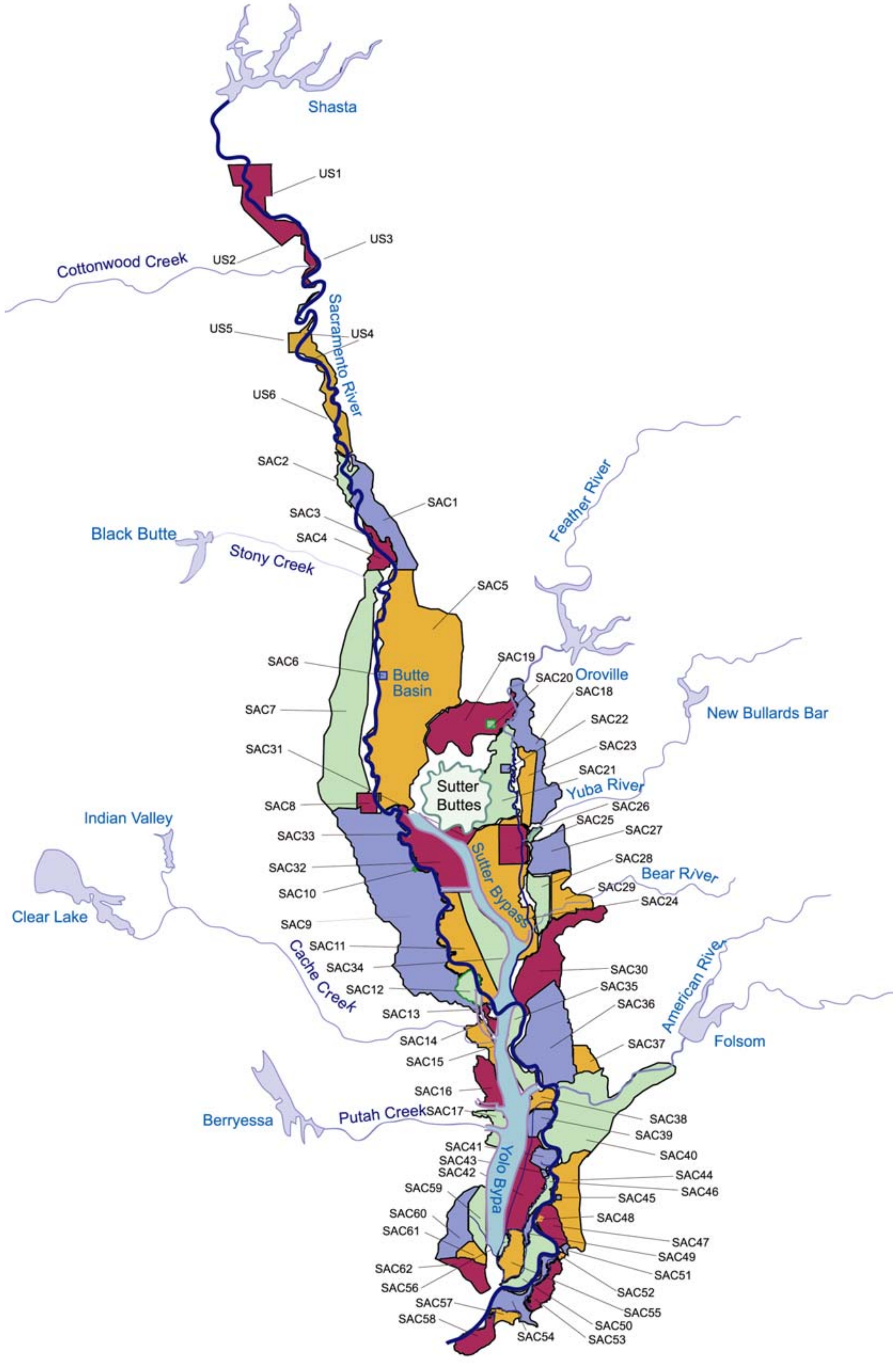

FIGURE 11 – SACRAMENTO RIVER BASIN ECONOMIC IMPACT AREAS

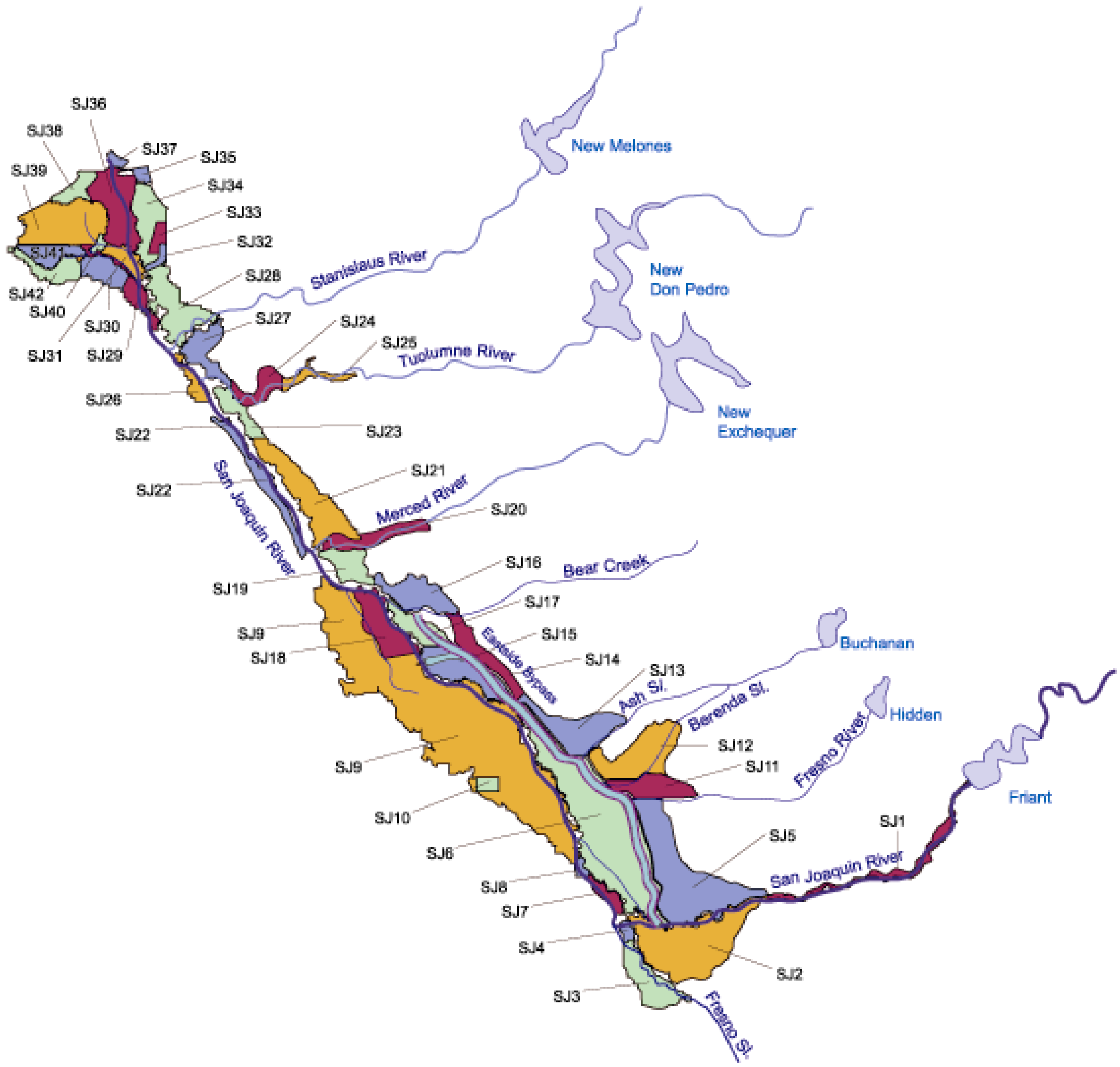

FIGURE 12 – SAN JOAQUIN RIVER BASIN ECONOMIC IMPACT AREAS

Technical Tools

While no model is a perfect representation of actual conditions, the models developed for the Comprehensive Study are of sufficient detail to provide appropriate results for a systematic flood damage analysis of the two basins. The models and tools that are directly related to risk analysis are described briefly below.

HEC-FDA

HEC-FDA is the principal tool used by the Corps to calculate flood damage risks. The HEC-FDA model performs the Monte Carlo random sampling of the discharge-frequency, stage-discharge, stage-probability of failure, and damage-stage relationships, and their respective uncertainty distributions. The primary outputs of HEC-FDA are expected annual damage (EAD) and project performance statistics. Project performance statistics include the annual exceedance probability (AEP), or the expected annual probability of flooding in any given year, the long-term risk of flooding over a 10-, 25-, or 50-year period, and the conditional non-exceedance (CNE) probability for specific events (the probability of passing specific flood events).

@RISK

Stage-damage curves were generated outside the HEC-FDA program using @RISK. Because flood flows can originate from outside an impact area (overland flow from an upstream levee break, for example), it was desirable to link flood damage to flood depths at parcels regardless of the source of flooding. @RISK was used to develop the stage-damage curves using parcel and depth information developed in a geographic information system (GIS), and the completed curves were input into HEC-FDA. The @RISK model incorporated key economic uncertainty factors, including structural value, content value, foundation height number of stories, and depth-damage relationships that are described in more detail in *Appendix F – Economics Technical Documentation*.

Considerations and Assumptions

The results of the Risk Analysis are affected by technical considerations and assumptions regarding the input to HEC-FDA. For example, the geotechnical studies developed relationships that characterized the reliability of the levees, which were utilized to trigger levee failures in the hydraulic models, which ultimately affected the stage-frequency curves used in the risk analysis.

Perhaps the most significant assumption is the failure methodology, which can significantly influence simulated flood flows. The methodology was chosen to provide a conservative and consistent simulation of potential flooding extent for system-wide hydraulic and economic evaluations. It does not represent conditions that would occur during an actual flood event, when flood fighting and other emergency actions are likely to take place, and fewer failures are likely to occur. In some cases, the cumulative affect of multiple upstream failures can reduce the volume of flow in downstream reaches, or large breaches can produce pronounced reductions in stage. These effects are less pronounced in the San Joaquin River basin where flood volumes are relatively smaller, levees tend to be shorter, and overbank flooding occurs more frequently than in the Sacramento River basin. While this levee failure methodology is sufficient for the basin-wide risk analyses, it should be considered when interpreting model results.

Project Performance

The three primary project performance or flood risk results reported by HEC-FDA are annual exceedance probability, long-term risk, and conditional non-exceedance probability.

<u>Annual Exceedance Probability (AEP)</u> **-** AEP is a measure of the likelihood that an area will be flooded in any given year, considering the full range of floods that can occur and all sources of uncertainty. AEP is typically expressed as a fractional or percentage probability. For example, the 1% probability flood event has one chance in a hundred of occurring in any

given year. The 1% exceedance flood event is often termed the 100-year event, but it does not represent an event that will only occur once during a century. Over a very long period of time (many thousands of years) the 1% exceedance event would occur, on average, about once every 100 years; however, over that extended period it could occur several times during a given century, or not at all.

Long Term Risk (LTR) **-** Long-term risk is the probability of damages occurring during a specified period of time. LTR is reported for 10-year, 25-year, and 50-year time periods. For example, a value of 0.850 for the 25-year reporting period reflects an 85% chance of flooding during a 25-year period.

Conditional Non-Exceedance Probability by Events (CNE) - Conditional non-exceedance is the probability of safely containing an event with a known frequency, should that event occur. CNE is reported by HEC-FDA for the 10%, 4%, 2%, 1%, 0.5%, and 0.2% exceedence events. For example, a value of 0.04 for the 2% exceedence event corresponds to a four percent chance that the river system will contain a flood with a 2% chance of occurring in any year.

Although these measures of performance and risk seem similar, there are distinct differences between them. AEP accumulates all the uncertainties into a single probability, whereas CNE is conditional on the severity of the flood event. Further, while AEP describes the likelihood that flooding *will occur*, CNE describes the likelihood that flooding *will not occur* during a given year (NRC 2000). Other agencies also use these measures of risk and uncertainty in flood management. For example, FEMA uses conditional non-exceedance in its certification criteria for levees, requiring a 90% or higher probability of containing the 1% flood event.

Existing Condition

Project performance statistics have been developed in the Sacramento and San Joaquin River basins for the existing condition. The results are summarized by impact area in **Tables 7 and 8**. The annual exceedance probability was generally lower (indicating a lower risk of flooding) in the Sacramento River basin than in the San Joaquin River basin. This can be attributed primarily to the higher level of flood protection provided by the Sacramento River Flood Control Project. The San Joaquin River Flood Control Project was generally designed to convey smaller and late-season snowmelt floods. These differences are largely due to the level of urban and agricultural development that was present at the time the systems were designed.

TABLE 7
EXISTING CONDITION PROJECT PERFORMANCE STATISTICS FOR THE SACRAMENTO RIVER BASIN

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10% (1 in 10)	4% (1 in 25)	2% (1 in 50)	1% (1 in 100)	0.5% (1 in 200)	0.2% (1 in 500)
SAC01	Woodson Br East	0.1400	0.7778	0.9767	0.9995	0.2356	0.0075	0.0000	0.0000	0.0000	0.0000
SAC02	Woodson Br West	0.1870	0.8734	0.9943	1.0000	0.0659	0.0010	0.0000	0.0000	0.0000	0.0000
SAC03	Hamilton City	0.4860	0.9987	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC04	Capay	0.4860	0.9987	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC05	Butte Basin	0.1550	0.8141	0.9851	0.9998	0.0403	0.0018	0.0000	0.0000	0.0000	0.0000
SAC06	Butte City	0.1540	0.8129	0.9849	0.9998	0.0406	0.0014	0.0000	0.0000	0.0000	0.0000
SAC07	Colusa Basin North	0.4380	0.9969	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC08	Colusa	0.3690	0.9901	1.0000	1.0000	0.4862	0.4038	0.3225	0.2288	0.0031	0.0000
SAC09	Colusa Basin South	0.5190	0.9993	1.0000	1.0000	0.3382	0.1163	0.0027	0.0000	0.0000	0.0000
SAC10	Grimes	0.5180	0.9993	1.0000	1.0000	0.3390	0.1176	0.0029	0.0000	0.0000	0.0000
SAC11	Rec Dist 1500 West	0.2540	0.9467	0.9993	1.0000	0.5042	0.0648	0.0100	0.0000	0.0000	0.0000
SAC12	Sycamore Slough	0.1140	0.7002	0.9508	0.9976	0.7133	0.3165	0.1750	0.0267	0.0000	0.0000
SAC13	Knight's Landing	0.0700	0.5155	0.8366	0.9733	0.8227	0.3948	0.2753	0.0871	0.0000	0.0000
SAC14	Ridge Cut North	0.1250	0.7368	0.9645	0.9987	0.6217	0.5669	0.5167	0.3437	0.0012	0.0000
SAC15	Ridge Cut South	0.0740	0.5368	0.8540	0.9787	0.6901	0.3614	0.2567	0.1196	0.0000	0.0000
SAC16	RD2035	0.0790	0.5631	0.8738	0.9841	0.6859	0.5905	0.5481	0.5300	0.0620	0.0000
SAC 17	East of Davis	0.0400	0.3380	0.6435	0.8729	1.0000	0.5463	0.0021	0.0000	0.0000	0.0000
SAC18	Honcut	0.0260	0.2346	0.4874	0.7372	1.0000	0.7576	0.4562	0.1972	0.0707	0.0210
SAC19	Sutter Buttes North	0.0010	0.0135	0.0330	0.0656	1.0000	0.9951	0.9950	0.9949	0.9159	0.3912
SAC20	Gridley	0.0010	0.0116	0.0288	0.0568	1.0000	0.9950	0.9949	0.9948	0.9152	0.3920
SAC21	Sutter Buttes East	0.0030	0.0280	0.0685	0.1323	1.0000	1.0000	1.0000	1.0000	0.9188	0.0991
SAC22	Live Oak	0.0030	0.0301	0.0736	0.1418	1.0000	1.0000	1.0000	1.0000	0.8653	0.0973
SAC23	District 10	0.0030	0.0298	0.0729	0.1405	1.0000	1.0000	1.0000	0.9969	0.8612	0.0638
SAC24	Levee District 1	0.0760	0.5476	0.8623	0.9810	0.6772	0.3377	0.2594	0.0863	0.0000	0.0000
SAC25	Yuba City	0.0100	0.0979	0.2271	0.4027	1.0000	0.9119	0.8764	0.8074	0.2296	0.0019
SAC26	Marysville	0.0050	0.0486	0.1172	0.2207	1.0000	0.9897	0.9813	0.9552	0.6036	0.0064
SAC27	Linda-Olivehurst	0.0360	0.3100	0.6045	0.8436	0.9880	0.5989	0.3015	0.0983	0.0345	0.0131
SAC28	RD784	0.0100	0.0992	0.2299	0.4070	1.0000	0.9287	0.8673	0.7864	0.2069	0.0000
SAC29	Best Slough	0.0650	0.4889	0.8132	0.9651	0.7299	0.4256	0.2106	0.0734	0.0721	0.0713
SAC30	RD1001	0.0790	0.5594	0.8711	0.9834	0.6472	0.4960	0.4421	0.3209	0.0035	0.0000
SAC31	Sutter Buttes South	0.0380	0.3204	0.6193	0.8550	0.8694	0.7214	0.5960	0.4835	0.0351	0.0000
SAC32	RD70/1660	0.0400	0.3353	0.6398	0.8702	0.8524	0.7122	0.5850	0.4680	0.3564	0.0981
SAC33	Meridian	0.0420	0.3478	0.6564	0.8820	0.8525	0.7123	0.5849	0.4406	0.0237	0.0000
SAC34	RD1500 East	0.2550	0.9472	0.9994	1.0000	0.5031	0.0644	0.0102	0.0000	0.0000	0.0000
SAC35	Elkhorn	0.4990	0.9990	1.0000	1.0000	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000
SAC36	Natomas	0.0200	0.1869	0.4039	0.6447	0.9924	0.8062	0.6539	0.6029	0.0126	0.0000
SAC37	Rio Linda	0.0060	0.0608	0.1452	0.2693	1.0000	1.0000	1.0000	1.0000	0.0190	0.0000
SAC38	West Sacramento	0.0070	0.0691	0.1639	0.3009	1.0000	1.0000	0.9967	0.9808	0.0208	0.0000
SAC39	RD900	0.0050	0.0493	0.1186	0.2232	1.0000	1.0000	1.0000	1.0000	0.2393	0.0089
SAC40	Sacramento	0.0100	0.0918	0.2140	0.3823	0.9837	0.9826	0.9819	0.9517	0.0000	0.0000
SAC41	RD302	0.0060	0.0606	0.1446	0.2684	1.0000	1.0000	1.0000	0.9971	0.0684	0.0021
SAC42	RD999	0.1220	0.7276	0.9613	0.9985	0.6032	0.5683	0.5521	0.4847	0.0216	0.0000
SAC43	Clarksburg	0.1220	0.7276	0.9613	0.9985	0.6032	0.5683	0.5521	0.4847	0.0216	0.0000
SAC44	Stone Lake	0.1000	0.6508	0.9280	0.9948	0.5882	0.5004	0.4865	0.3488	0.0000	0.0000
SAC45	Hood	0.1000	0.6509	0.9280	0.9948	0.5894	0.4877	0.4752	0.3502	0.0000	0.0000
SAC46	Merritt Island	0.1510	0.8054	0.9833	0.9997	0.4893	0.0727	0.0212	0.0045	0.0000	0.0000
SAC47	RD551	0.0370	0.3172	0.6148	0.8516	0.8188	0.7555	0.6821	0.5548	0.0069	0.0000
SAC48	Courtland	0.0370	0.3176	0.6153	0.8520	0.8179	0.7549	0.6815	0.5543	0.0063	0.0000

TABLE 7 (CONT.)

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10% (1 in 10)	4% (1 in 25)	2% (1 in 50)	1% (1 in 100)	0.5% (1 in 200)	0.2% (1 in 500)
SAC49	Sutter Island	0.1050	0.6694	0.9372	0.9961	0.6025	0.0000	0.0000	0.0000	0.0000	0.0000
SAC50	Grand Island	0.1160	0.7075	0.9537	0.9979	0.6188	0.0000	0.0000	0.0000	0.0000	0.0000
SAC51	Locke	0.0260	0.2305	0.4807	0.7303	0.9744	0.7931	0.7163	0.1445	0.0000	0.0000
SAC52	Walnut Grove	0.0340	0.2951	0.5829	0.8260	0.9113	0.6957	0.5171	0.5104	0.0000	0.0000
SAC53	Tyler Island	0.8490	1.0000	1.0000	1.0000	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000
SAC54	Andrus Island	0.6710	1.0000	1.0000	1.0000	0.1599	0.1209	0.0605	0.0000	0.0000	0.0000
SAC55	Ryer Island	0.1310	0.7557	0.9705	0.9991	0.4556	0.0000	0.0000	0.0000	0.0000	0.0000
SAC56	Prospect Island	0.3130	0.9766	0.9999	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC57	Twitchell Island	0.3050	0.9736	0.9999	1.0000	0.6120	0.5493	0.4936	0.1944	0.0000	0.0013
SAC58	Sherman Island	0.5810	0.9998	1.0000	1.0000	0.2837	0.2558	0.2267	0.1897	0.0000	0.0000
SAC59	Moore	0.1260	0.7407	0.9658	0.9988	0.0225	0.0000	0.0000	0.0000	0.0000	0.0000
SAC60	Cache Slough	0.0660	0.4949	0.8187	0.9671	0.9600	0.0343	0.0044	0.0174	0.0000	0.0000
SAC61	Hastings	0.3370	0.9835	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC62	Lindsey Slough	0.0130	0.1215	0.2766	0.4767	1.0000	1.0000	0.7375	0.5036	0.0030	0.0000

TABLE 8
EXISTING CONDITION PROJECT PERFORMANCE STATISTICS FOR THE SAN JOAQUIN RIVER BASIN

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10% (1 in 10)	4% (1 in 25)	2% (1 in 50)	1% (1 in 100)	0.5% (1 in 200)	0.2% (1 in 500)
SJ 01	Fresno	0.0170	0.1548	0.3433	0.5688	0.9976	0.9976	0.9521	0.0003	0.0000	0.0000
SJ 02	Fresno Slough East	0.0280	0.2436	0.5023	0.7523	0.9942	0.9690	0.1795	0.0001	0.0000	0.0000
SJ 03	Fresno Sl West	0.4970	0.9990	1.0000	1.0000	0.4937	0.2502	0.2477	0.2452	0.0000	0.0000
SJ 04	Mendota	0.3280	0.9813	1.0000	1.0000	0.4531	0.2857	0.2834	0.2787	0.0000	0.0000
SJ 05	Chowchilla Bypass	0.0340	0.2940	0.5812	0.8246	0.9630	0.8810	0.0955	0.0001	0.0000	0.0000
SJ 06	Lone Willow Sl	0.1110	0.6912	0.9470	0.9972	0.7092	0.0001	0.0000	0.0000	0.0000	0.0000
SJ 07	Mendota North	0.0900	0.6112	0.9057	0.9911	0.5920	0.3008	0.2874	0.2780	0.0017	0.0000
SJ 08	Firebaugh	0.0700	0.5150	0.8362	0.9732	0.7395	0.5397	0.0034	0.0033	0.0000	0.0000
SJ 09	Salt Slough	0.1390	0.7750	0.9760	0.9994	0.4292	0.1704	0.1293	0.1243	0.0000	0.0000
SJ 10	Dos Palos	0.1380	0.7738	0.9757	0.9994	0.4323	0.1852	0.1084	0.1062	0.0000	0.0000
SJ 11	Fresno River	0.1320	0.7562	0.9707	0.9991	0.5144	0.1665	0.1154	0.1092	0.0000	0.0000
SJ 12	Berenda Slough	0.4500	0.9975	1.0000	1.0000	0.0015	0.0001	0.0001	0.0001	0.0000	0.0000
SJ 13	Ash Slough	0.3030	0.9731	0.9999	1.0000	0.1014	0.0001	0.0000	0.0000	0.0000	0.0000
SJ 14	Sandy Mush	0.0910	0.6158	0.9085	0.9916	0.5706	0.5680	0.4708	0.0000	0.0000	0.0000
SJ 15	Turner Island	0.1310	0.7535	0.9698	0.9991	0.5362	0.0028	0.0000	0.0000	0.0000	0.0000
SJ 16	Bear Creek	0.0550	0.4342	0.7592	0.9420	0.8674	0.5322	0.4780	0.1019	0.0000	0.0000
SJ 17	Deep Slough	0.0650	0.4900	0.8143	0.9655	0.7933	0.5318	0.3788	0.0000	0.0000	0.0000
SJ 18	West Bear Creek	0.1310	0.7535	0.9698	0.9991	0.4464	0.1465	0.0168	0.0000	0.0000	0.0000
SJ 19	Fremont Ford	0.2370	0.9330	0.9988	1.0000	0.2019	0.0000	0.0000	0.0000	0.0000	0.0000
SJ 20	Merced River	0.1680	0.8414	0.9900	0.9999	0.3111	0.3036	0.0000	0.0000	0.0000	0.0000
SJ 21	Merced R North	0.5460	0.9996	1.0000	1.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001
SJ 22	Orestimba	0.0090	0.0851	0.1994	0.3590	0.9972	0.9972	0.9811	0.7473	0.0000	0.0000
SJ 23	Tuolumne South	0.3070	0.9743	0.9999	1.0000	0.2981	0.0271	0.0000	0.0000	0.0004	0.0000
SJ 24	Tuolumne River	0.0060	0.0623	0.1486	0.2752	0.9974	0.9974	0.9974	0.9902	0.0559	0.0000
SJ 25	Modesto	0.0130	0.1225	0.2788	0.4799	0.9974	0.9974	0.9974	0.0393	0.0000	0.0000
SJ 26	3 Amigos	0.8540	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SJ 27	Stanislaus South	0.6260	0.9999	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SJ 28	Stanislaus North	0.3140	0.9770	0.9999	1.0000	0.0032	0.0000	0.0000	0.0000	0.0001	0.0000
SJ 29	Banta Carbona	0.2720	0.9580	0.9996	1.0000	0.2236	0.0174	0.0000	0.0000	0.0000	0.0000
SJ 30	Paradise Cut	0.3120	0.9764	0.9999	1.0000	0.3025	0.0037	0.0000	0.0000	0.0000	0.0000

TABLE 8 (CONT.)

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10% (1 in 10)	4% (1 in 25)	2% (1 in 50)	1% (1 in 100)	0.5% (1 in 200)	0.2% (1 in 500)
SJ 31	Stewart Tract	0.3120	0.9762	0.9999	1.0000	0.2721	0.0146	0.0000	0.0000	0.0000	0.0000
SJ 32	East Lathrop	0.3080	0.9749	0.9999	1.0000	0.2397	0.0272	0.0096	0.0002	0.0000	0.0000
SJ 33	Lathrop/Sharpe	0.2220	0.9192	0.9981	1.0000	0.2542	0.0009	0.0005	0.0000	0.0000	0.0000
SJ 34	French Camp	0.2220	0.9191	0.9981	1.0000	0.2542	0.0009	0.0005	0.0000	0.0000	0.0000
SJ 35	Moss Tract	0.2230	0.9203	0.9982	1.0000	0.2435	0.0340	0.0006	0.0000	0.0000	0.0000
SJ 36	Roberts Island	0.3720	0.9905	1.0000	1.0000	0.2193	0.0050	0.0000	0.0000	0.0000	0.0000
SJ 37	Rough & Ready Is	0.2470	0.9417	0.9992	1.0000	0.1780	0.0721	0.0155	0.0000	0.0000	0.0000
SJ 38	Drexler Tract	0.3540	0.9874	1.0000	1.0000	0.2380	0.0290	0.0000	0.0000	0.0000	0.0000
SJ 39	Union Island	0.3210	0.9793	0.9999	1.0000	0.2405	0.0600	0.0003	0.0000	0.0000	0.0000
SJ 40	SE Union Island	0.2180	0.9147	0.9979	1.0000	0.2462	0.0297	0.0037	0.0000	0.0000	0.0000
SJ 41	Fabian Tract	0.2240	0.9205	0.9982	1.0000	0.2259	0.0119	0.0001	0.0000	0.0000	0.0000
SJ 42	RD 1007	0.2140	0.9097	0.9975	1.0000	0.2516	0.0181	0.0002	0.0000	0.0000	0.0000

Risk and Environmental Restoration

Uncertainty is also associated with the environmental restoration element of the Comprehensive Study. Like flood damage reduction studies, environmental restoration projects also rely on information and analytical methods associated with varying degrees of uncertainty and reliability. For example, the Ecosystem Function Model developed for the Comprehensive Study uses hydrologic data, topography, and simplified algorithms to estimate ecosystem health and predict the success of riparian habitat restoration. There is uncertainty in the hydrologic data, accuracy of mapping, and ability of the algorithms to address ecological complexity. The Comprehensive Study has advocated adaptive management as one method of addressing the uncertainties associated with the success of environmental restoration. It may also be possible to incorporate risk analysis in future versions of the Ecosystem Functions Model.

Summary & Conclusions

The risk analysis performed during the Comprehensive Study provides economic damages and project performance information suitable for basin-wide flood management and ecosystem restoration planning in the Sacramento and San Joaquin River basins. The models and other technical tools developed for the Comprehensive Study, including the HEC-FDA model, will continue to be updated and improved as projects are completed and implemented under the Comprehensive Plan.