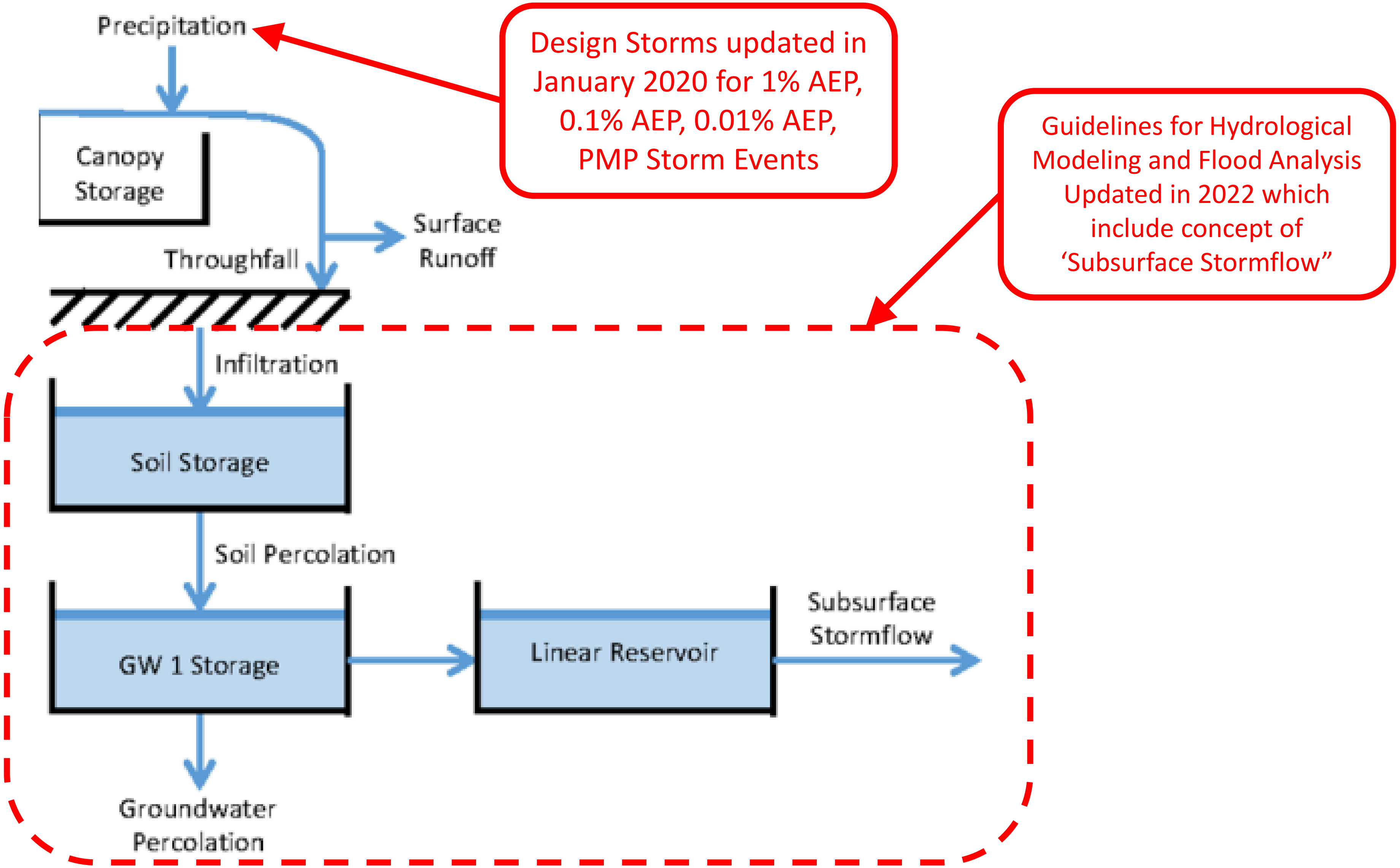
Lake Avery Preliminary Site Studies

Hydrology Study and Hydrologic Hazard Analysis

Hydrology Study – Overview of New Hydrology Guidelines



Hydrology Study – Overview of New Hydrology Guidelines

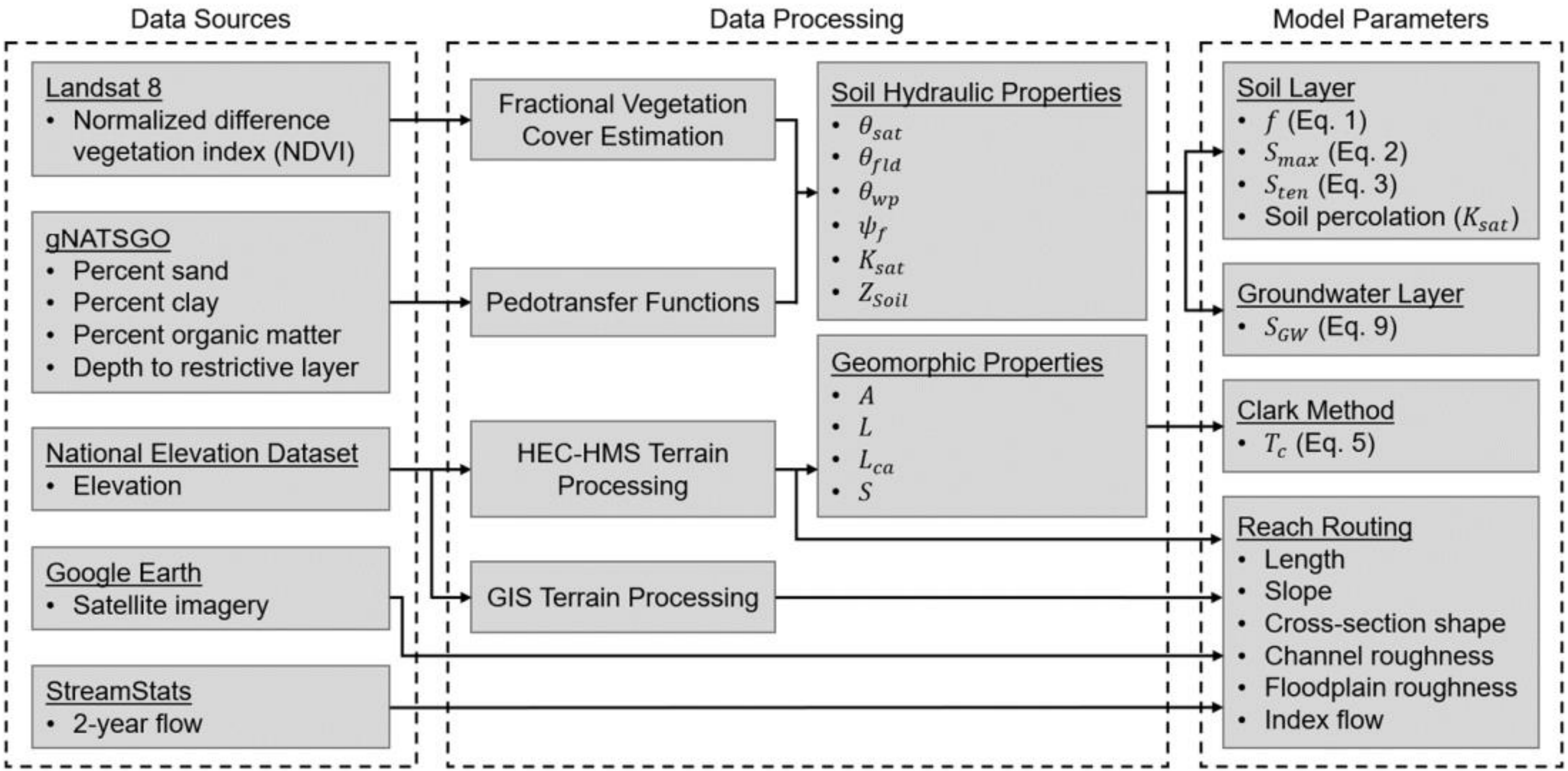


Figure 7: Overview of data sources, processing, and model parameters for the CSU-SMA modeling method (from Irvin et al, 2021, with permission).

Hydrology Study – Overview of New Hydrology Guidelines

New guidelines incorporate "Reasonableness Checks" and extensive model calibration into the Hydrologic Flood Modeling process.

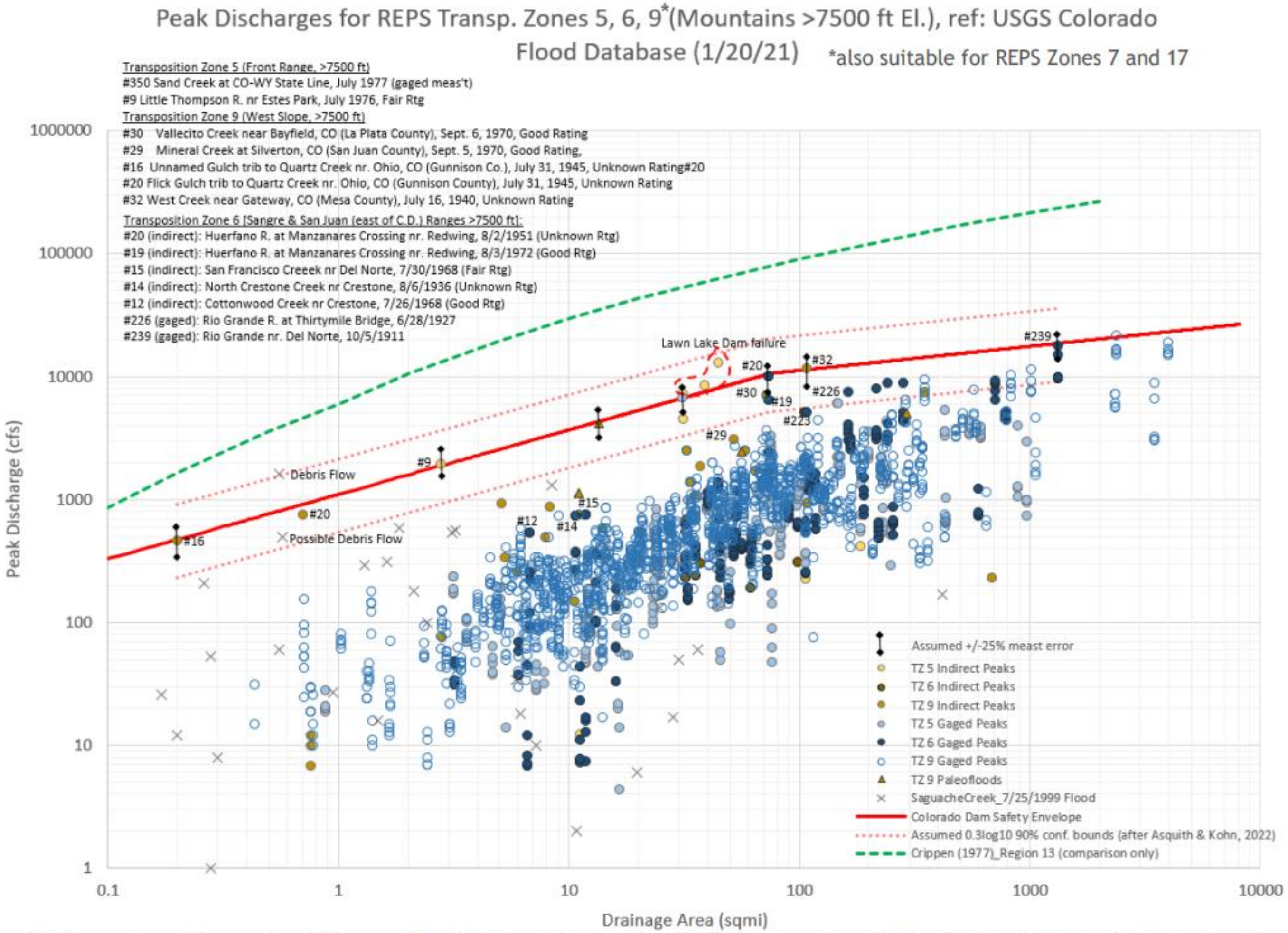
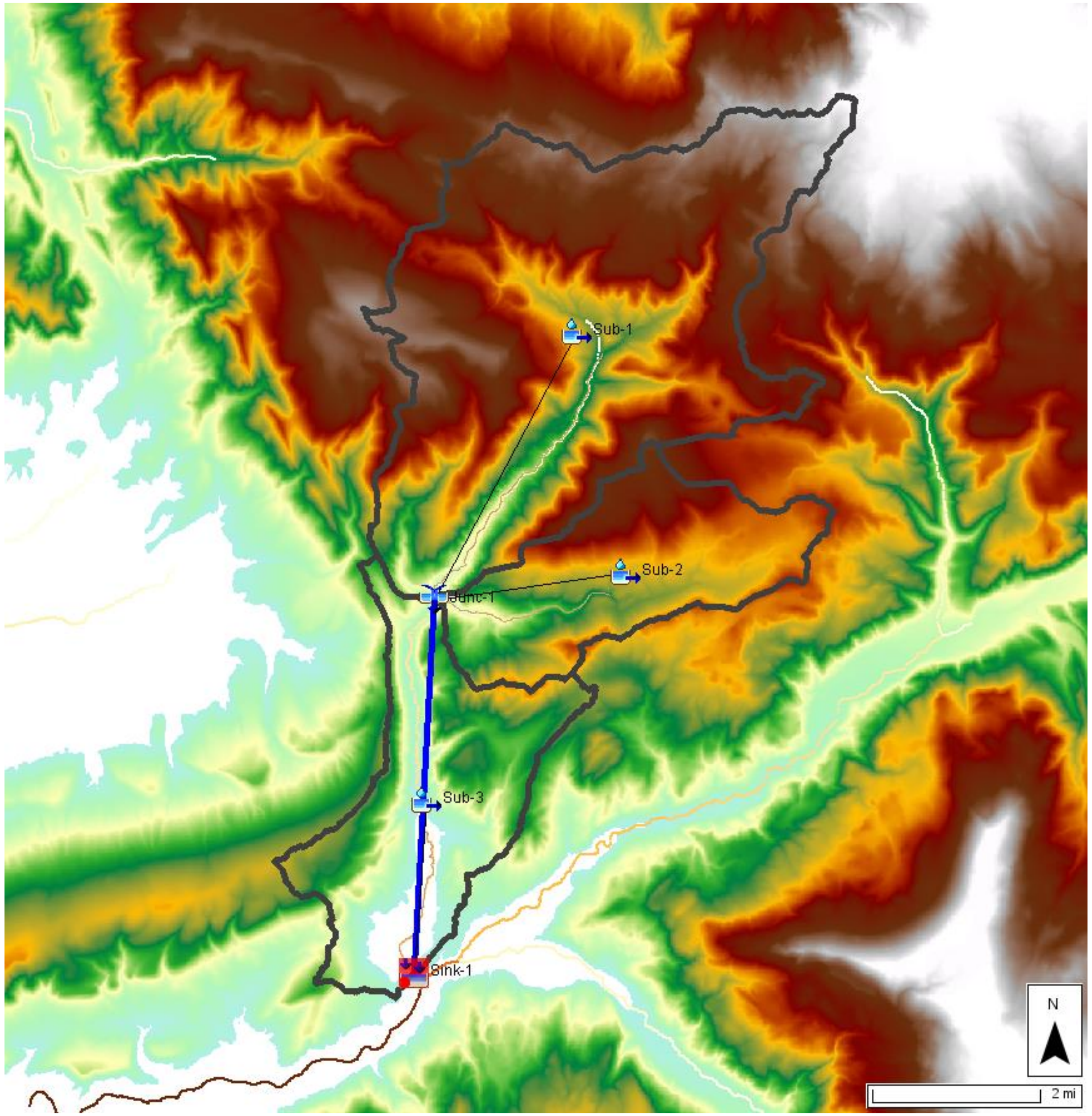


Figure 30: Observed peak flows and peak flow envelope for Colorado's Mountains >7,500 feet elevation. Red line is Colorado Dam Safety's visually estimated envelope; red dotted lines are conceptual 90% confidence bounds (±0.3log10 cycle).

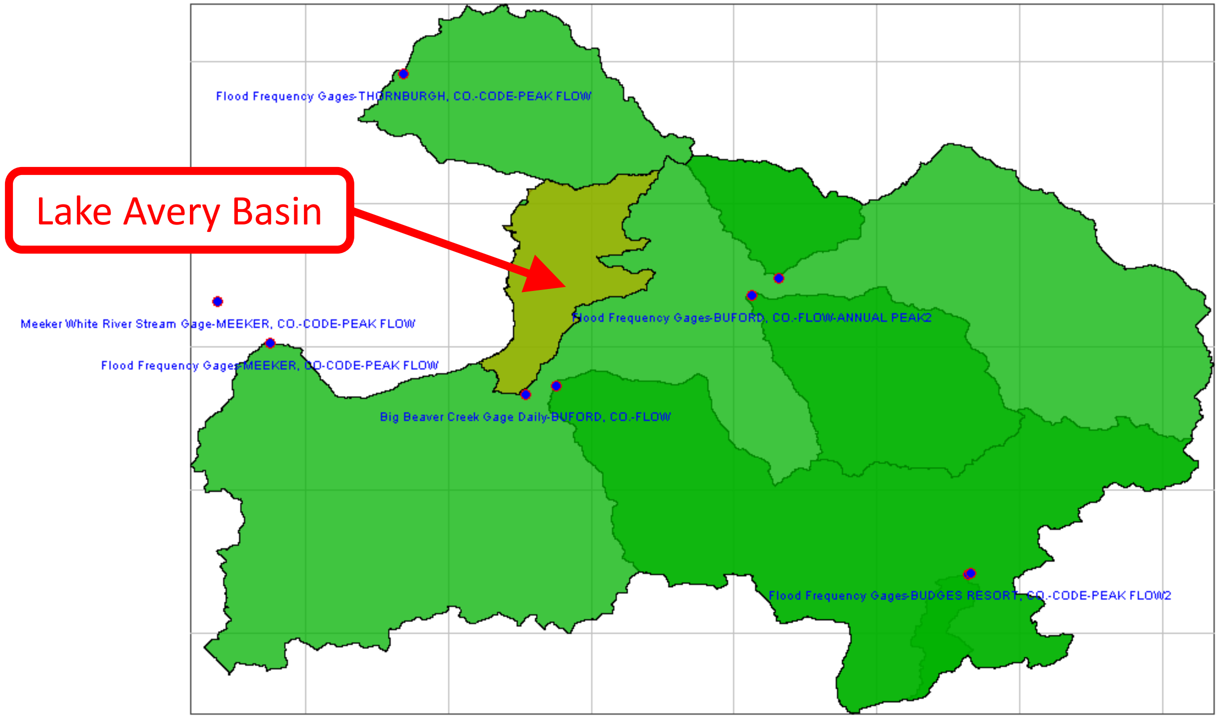
Hydrology Study – Lake Avery Drainage Basin Model



Method	Parameter (units)	Parameter estimation method	Parameter value by Sub-basin		
			sub-1	sub-2	sub-3
Meteorological Model					
Precipitation Specified Hyetograph	Specified Hyetograph	See REPS Guidance document for creating REPS design storms and entering as HEC-HMS Time Series -> Precipitation gages	**see hyetograph Figures X - Y**		
Annual Evapotranspiration	Rate (in/day) (NOTE: include subbasins=yes)	Use uniform 2-2.5 mm/day (0.079 - 0.098 in/day), per CSU research (ref: Sujana Timilsina)	0.098	0.098	0.098
Basin Model					
Simple Canopy	Initial Storage (%)	parsimony	0	0	0
	Max Storage (in)	Use uniform 4.3 mm (0.169 inch), avg of NFS & SFS from Cache La Poudre site	0.169	0.169	0.169
SMA Loss	Soil (%)	For design storms, base AMC on seasonality	50.31	50.33	50.04
	GW1 (%)	Parsimony	0	0	0
	GW2 (%)	Parsimony	0	0	0
	Max Infiltration (in/hr)	Green & Ampt infiltration rate using ½ Ksat and delta = 75mm (~3 in)	1.68	1.64	1.34
	Impervious (%)	Uniform, based on CSU calibrations/verifications	5	5	5
	Soil Storage (in)	Allocate 85-95% of total soil water storage to soil storage, per CSU recommendation	18.09	18.32	17.86
	Tension Storage(in)	Soil water storage between field capacity and wilting point	10.11	10.24	9.94
	Soil Percolation (in/hr)	Use 1/4* Ksat, calculated by Saxton & Rawls pedotransfer functions	0.097	0.095	0.079
	GW 1 Storage (in)	Allocate 5-15% of total soil storage to GW1 layer, per CSU recommendation	2.01	2.04	1.98
	GW1 Percolation (in/hr)	Uniform try 2.5mm/hr (0.1 in/hr), based on CSU calibrations/verifications	0.02	0.02	0.02
	GW1 Coefficient (hr)	Use 3 x Clark UH storage coefficient (i.e.,	21.00	18.00	20.10
	GW2 Storage (in)	Parsimony	0	0	0
	GW2 Percolation (in/hr)	Parsimony	0	0	0
	GW2 Coefficent (hr)	parsimony	0	0	0
Clark Unit Hydrograph Transform	Method	See Guidelines Section 5.6 or Section 9	Standard	Standard	Standard
	Time of Concentration, Tc (hr)	Use Tc from Sabol (2008) HBRPEG (pg. 7) for	2.60	1.99	2.23
	Storage Coefficient, R (hr)	Calculate R using R/(Tc+R)=0.6 to 0.8 for	7.00	6.00	6.70
	Time-area Method	Use default	Default	Default	Default
Linear Reservoir Baseflow	Reservoirs (#)		1	1	1
	Initial Type		Discharge	Discharge	Discharge
	GW1 Initial (cfs)		0	0	0
	GW1 Fraction				
	GW Coefficient	Use 3 x Clark UH storage coefficient (i.e.,	21.00	18.00	20.10
	GW1 Steps		1	1	1
			Reach-1		
Muskingum-Cunge Reach Routing	Length (ft)		22,820		
	Slope (ft/ft)		0.013		
	Initial Type		inflow		
	Mannings n	Use acceptable reference	0.03		
	Index Method		Flow		
	Index Flow (cfs)	Use Q-2yr (50% AEP) estimate from	213.00		
	Shape	Trapazoid or 8-point, etc., depending on	8-point		

Hydrology Study – Lake Avery Reasonableness Checks

Map of USGS Stream Gages Considered in Analysis



Drainage Basin Comparison for Reasonableness Check

			HEC-HMS Model Results		Milk Creek near	South Fork White	Lost Creek
			Base Model	*Calibrated Model*	Thornburgh	River at Budges Resort	near Buford
HEC-HMS CSU-SMA Output							
	1% AEP LS 2-hr	cfs	1,388	1,031	N/A	N/A	N/A
	0.1% AEP LS 2-hr	cfs	2,762	2,129	N/A	N/A	N/A
	0.01% AEP LS 2-hr	cfs	4,521	3,591	N/A	N/A	N/A
	PMP LS 2-hr Stacked	cfs	14,150	11,730	N/A	N/A	N/A

StreamStats Peak-Flow Statistics

Peak Flow Statistics	1% AEP	cfs	**621**	**1010**	**1610**	**532**
	1% AEP 5% Confidence Limit	cfs	*940*			
	1% AEP 95% Confidence Limit	cfs	*410*			
	0.5% AEP	cfs	683	1140	1690	575
	0.2% AEP	cfs	798	1350	1830	653
Extrapolated Values	0.1% AEP	cfs	**900**	**1500**	**1950**	**700**
	0.1% AEP 5% Confidence Limit	cfs	*1331*			
	0.1% AEP 95% Confidence Limit	cfs	*608*			

Bulletin 17C Flood Frequency Analysis

	USGS Streamgage		9304100	09250000	0903300	09302450
	Period of Record	yr	1956-1964	1953-1986	1976-1995	1965-1989
	Typical Month of Peak Events	month	May-June	May	May - June	April-May
1% AEP	Computed Curve Flow	cfs	N/A	**1770.4**	**2783.7**	**1093**
	5% Confidence Limit Flow	cfs	*N/A*	*4334.5*	*6012*	*1743.4*
	95% Confident Limit Flow	cfs	*N/A*	*1231.2*	*2076.4*	*927*
0.1% AEP	Computed Curve Flow	cfs	N/A	**3050.1**	**3865**	**1315.1**
	5% Confidence Limit Flow	cfs	*N/A*	*15378.8*	*14024.8*	*2642.6*
	95% Confident Limit Flow	cfs	*N/A*	*1769.5*	*2532.5*	*1053.1*
0.01% AEP	Computed Curve Flow	cfs	N/A	**4796.3**	**4999.4**	**1514.1**
	5% Confidence Limit Flow	cfs	*N/A*	*47085.4*	*29192.4*	*3718.1*
	95% Confident Limit Flow	cfs	*N/A*	*2282.5*	*2855.6*	*1143.7*

Transposition Analysis

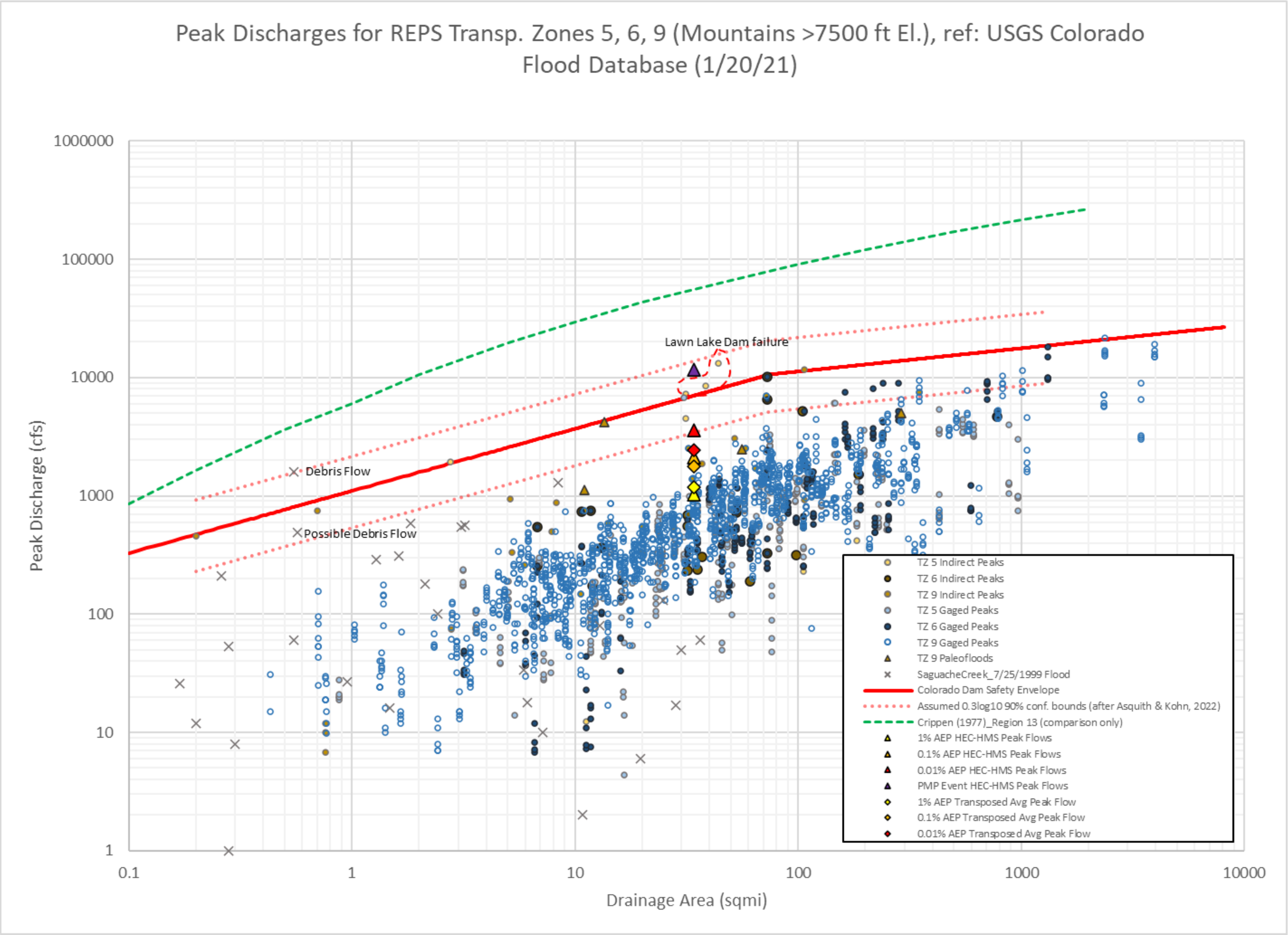
Area Ratio	1	0.54	0.66	1.58

Transpoisition of Bulletin 17C flows based on StreamStats parameters for various AEP per the following equation…

$$Q_{T(u)} = Q_{T(g)}\ (A_u / A_g)^x (P_u / P_d)^y (S_u / S_d)^z$$

			Base Model	**Calibrated Model**			
1% AEP	1% AEP Peak Flow	cfs	**1,388**	**1,031**	**1,237**	**1,066**	**1,265**
	5% Confidence Limit Flow	cfs			*3,029*	*2,301*	*2,017*
	95% Confident Limit Flow	cfs			*860*	*795*	*1,073*
0.1% AEI	0.1% AEP Peak Flow	cfs	**2,762**	**2,129**	**2,122**	**1,651**	**1,571**
	5% Confidence Limit Flow	cfs			*10,698*	*5,992*	*3,156*
	95% Confident Limit Flow	cfs			*1,231*	*1,082*	*1,258*
0.01% AE	0.01% AEP Peak Flow	cfs	**4,521**	**3,591**	**3,336**	**2,136**	**1,809**
	5% Confidence Limit Flow	cfs			*32,753*	*12,472*	*4,441*
	95% Confident Limit Flow	cfs			*1,588*	*1,220*	*1,366*

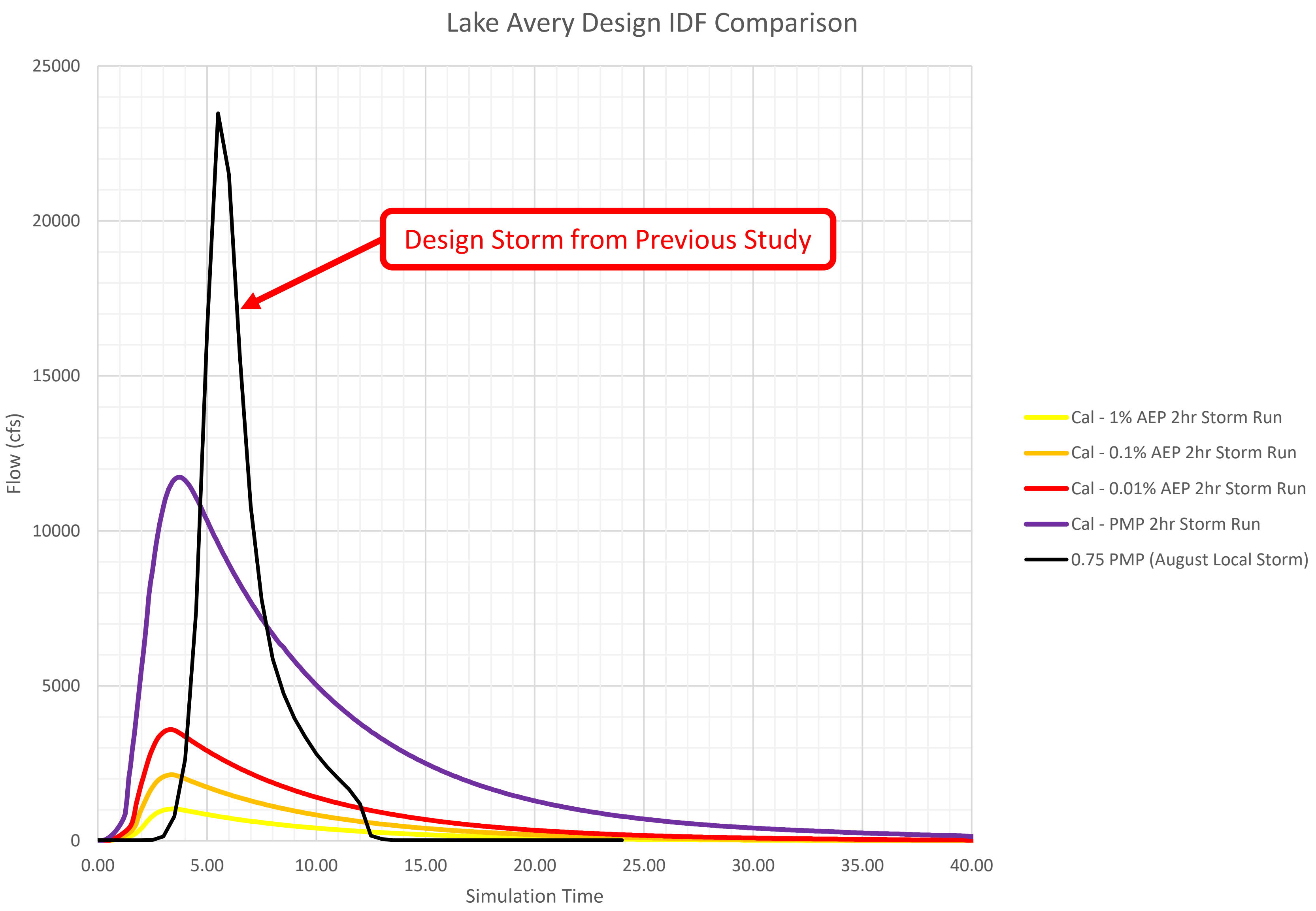
Hydrology Study – Lake Avery Reasonableness Checks



Hydrology Study – Lake Avery Hydrology Results

Storm	Return Interval	Precip Depth (in)	Base Model Results: Peak IDF Q (cfs)	Base Model Results: Runoff Volume (ac-ft)	Base Model Results: Peak Reservoir Stage (ft)	Calibrated Model Run: Peak IDF Q (cfs)	Calibrated Model Run: Runoff Volume (ac-ft)	Calibrated Model Run: Peak Reservoir Stage (ft) Existing Spillway	Calibrated Model Run: Peak Reservoir Stage (ft) Proposed Spillway	
LS 2-hr	1%	1.27	1388	830	6997.09	1031	717	6996.85	7000.52	<--- 1% AEP Design Storm
	0.1%	1.84	2762	1645	6998.15	2129	1473	6997.83	7000.86	<--- 0.1% AEP Design Storm
	0.01%	2.52	4521	2690	6999.22	3591	2511	6998.83	7001.25	<--- 0.01% AEP Design Storm
MEC 6-hr	1%	1.5	1194	734	6996.93					
	0.1%	2.11	2255	1638	6997.86					
	0.01%	2.83	3651	2755	6998.77					
MLC/TSR 48-hr	1%	3.76	661	4146	6997.66					
	0.1%	5.16	725	6231	6997.75					
	0.01%	6.72	837	8546	6997.82					
LS 2-hr Stacked	PMP	6.26	14150	9199	7004	11730	8862	7003.11	7003.34	<--- PMP Design Storm
LS 6-hr		6.31	11087	8190	7002.61					
GS 72-hr		13.5	7044	19854	7002.22					

Lake Avery Design Inflow Design Flood



Hydrologic Hazard Analysis – Overview of New Rules

The *Rules and Regulations for Dam Safety and Construction* were updated in 2020 to include the concept of Hydrologic Hazard which determines the spillway sizing criteria for dams and reservoir in Colorado. This concept classifies dams into either Low, Significant, High, or Extreme Hydrologic Hazard groups based on the expected loss of life and significant damage resulting from an overtopping dam failure initiated by a storm event. Please note that Hydrologic Hazard Analysis is an iterative process started by assuming a low Hydrologic Hazard designation and then repeating the analysis as necessary by increasing the Hydrologic Hazard rating assumption, and thus design Inflow Design Flood, until the consequences match the criteria for the initial Hydrologic Hazard rating assumption.

Hydrologic Hazard	Consequence Criteria	Critical Rainfall
Extreme	Life loss potential greater than 1	Probable Maximum Precipitation
High	Life loss potential less than 1	0.01% AEP Storm Event
Significant	No life loss potential but significant damage expected	0.1% AEP Storm Event
Low	No life loss potential or significant damage expected	1% AEP Storm Event

Hydrologic Hazard Analysis – Overview of Fatality Rate Curve

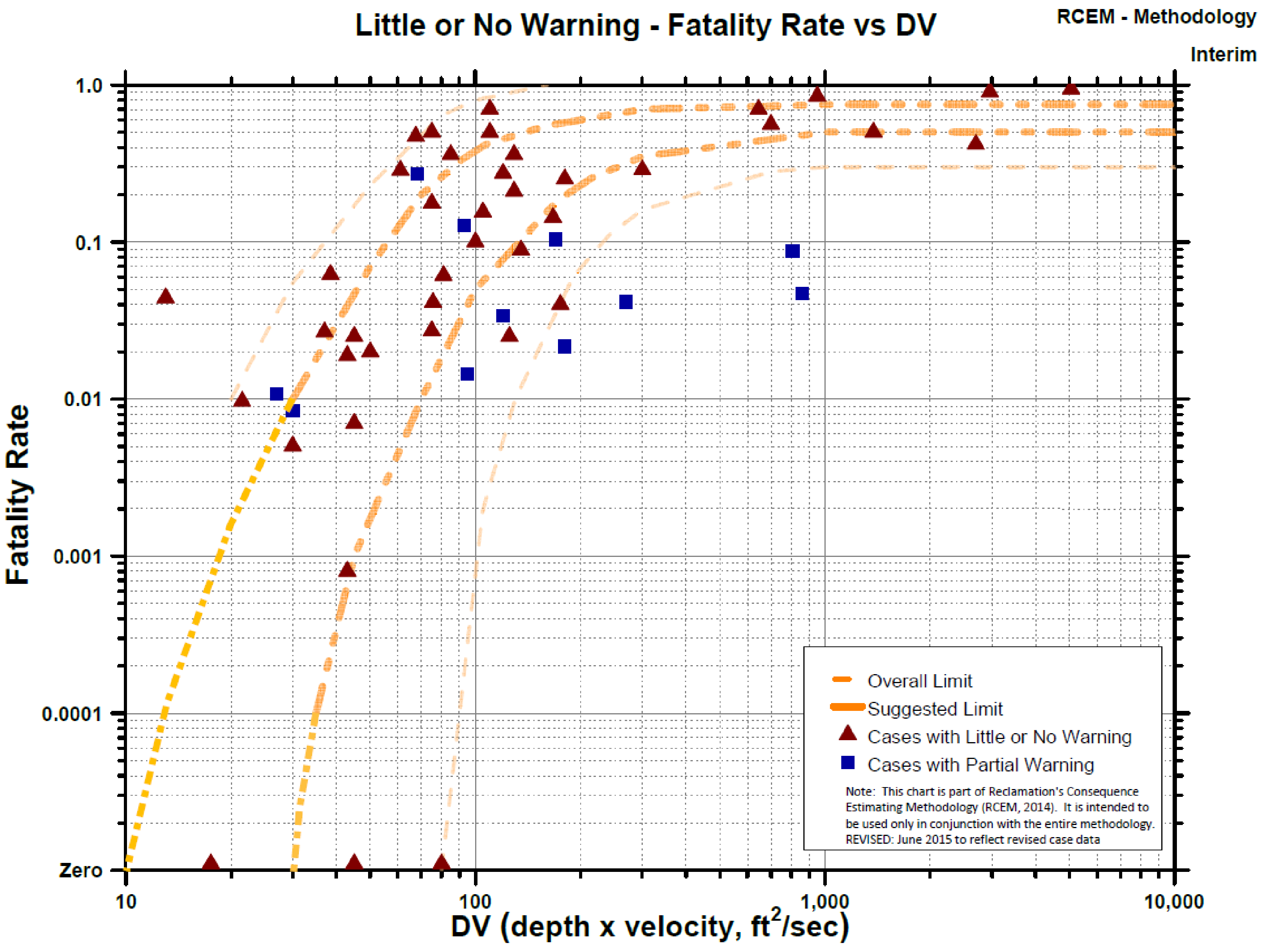
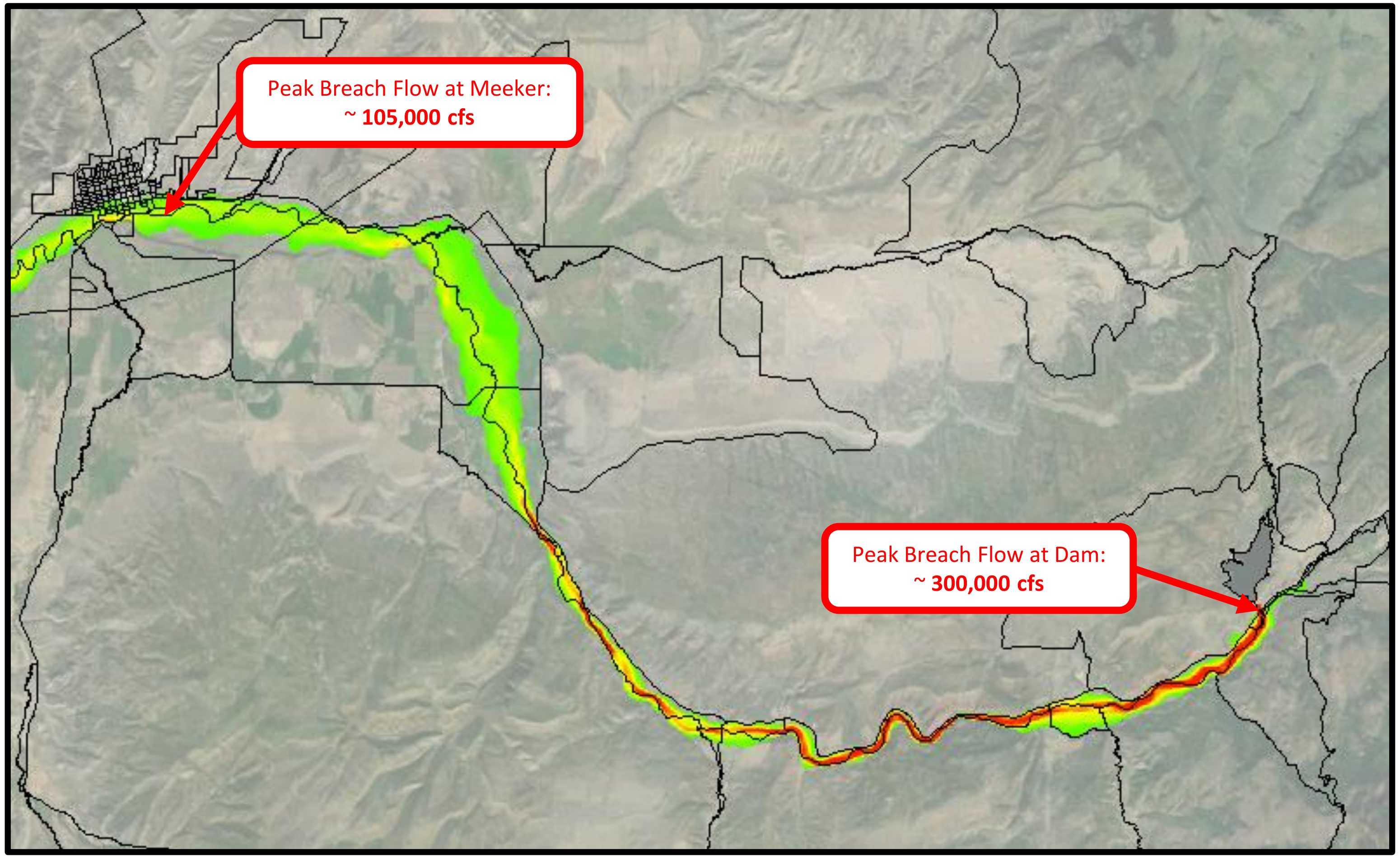


Figure 3 - Fatality Rate vs. DV for Little or No Warning

Hydrologic Hazard Analysis – Lake Avery Results



Overview Map of Overtopping Breach Flood

Legend

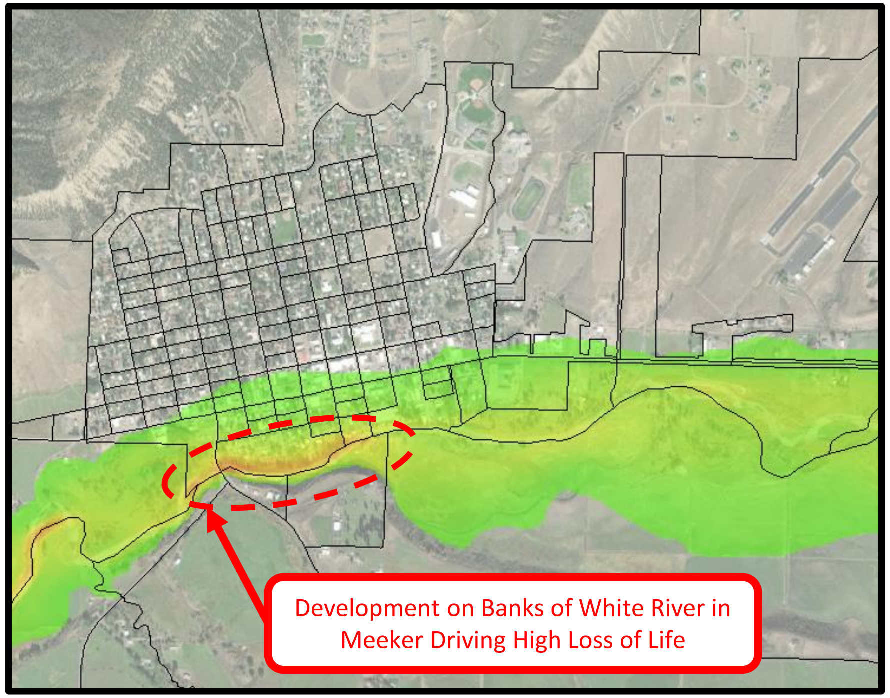
US Census Blocks

Breach Flood DxV Product

High : 1399.21

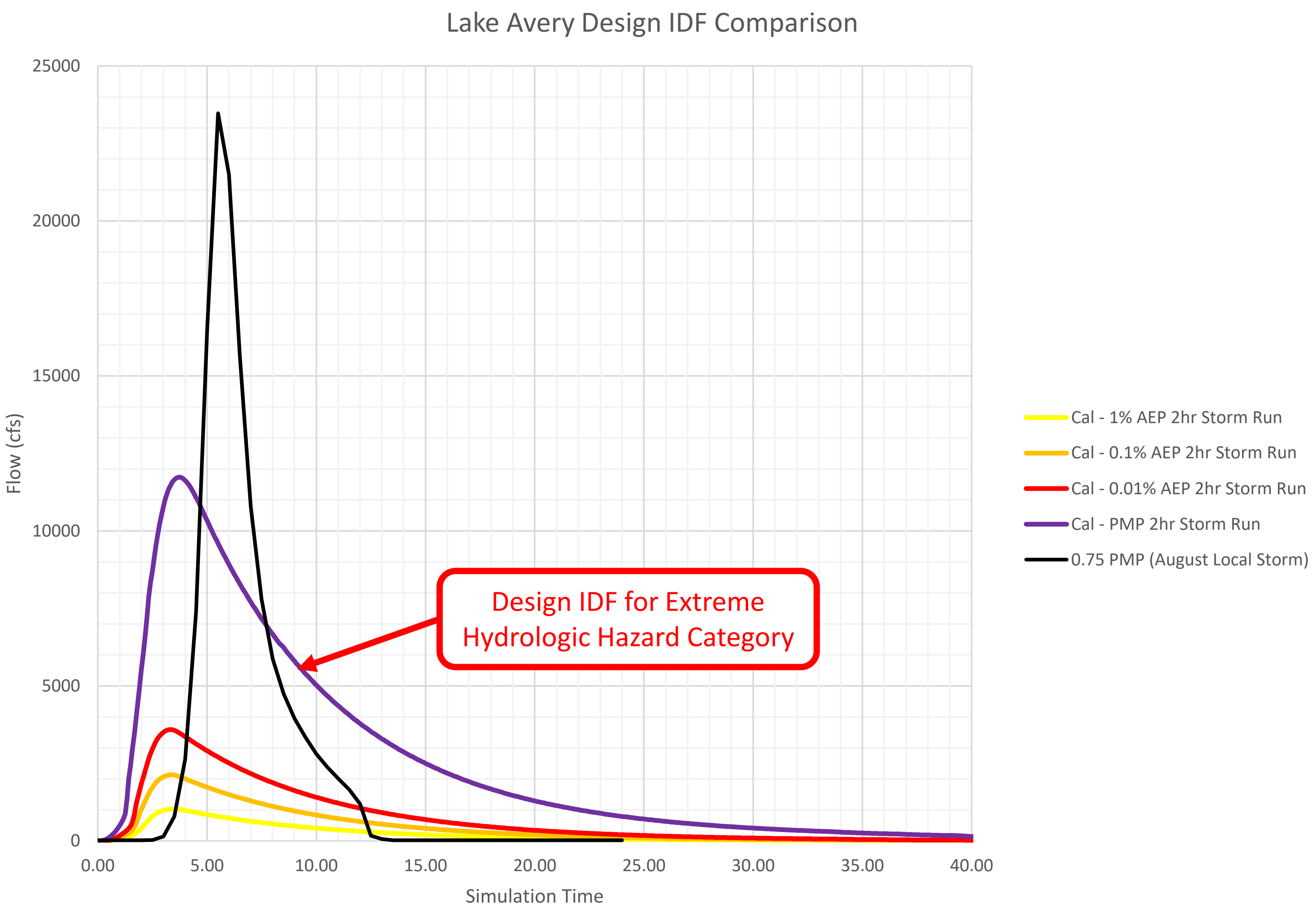
Low : 6.43479e-13

Expected Loss of Life:
~76.6 people
Extreme Hydrologic Hazard

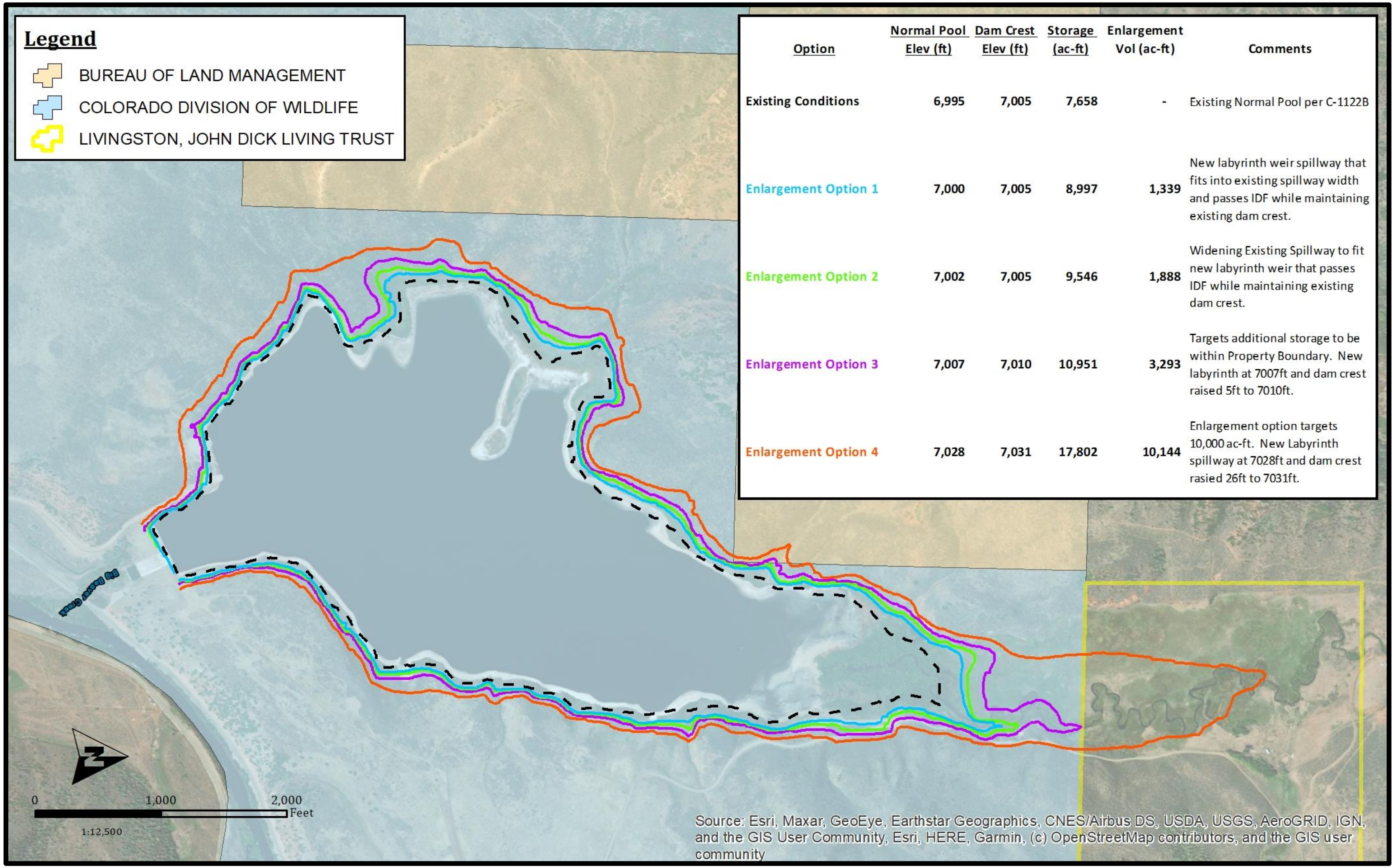


Blowup of Results at Meeker

Lake Avery Design Inflow Design Flood



Lake Avery Storage Options



Option	Normal Pool Elev (ft)	Dam Crest Elev (ft)	Storage (ac-ft)	Enlargement Vol (ac-ft)	Comments
Existing Conditions	6,995	7,005	7,658	-	Existing Normal Pool per C-1122B
Enlargement Option 1	7,000	7,005	8,997	1,339	New labyrinth weir spillway that fits into existing spillway width and passes IDF while maintaining existing dam crest.
Enlargement Option 2	7,002	7,005	9,546	1,888	Widening Existing Spillway to fit new labyrinth weir that passes IDF while maintaining existing dam crest.
Enlargement Option 3	7,007	7,010	10,951	3,293	Targets additional storage to be within Property Boundary. New labyrinth at 7007ft and dam crest raised 5ft to 7010ft.
Enlargement Option 4	7,028	7,031	17,802	10,144	Enlargement option targets 10,000 ac-ft. New Labyrinth spillway at 7028ft and dam crest rasied 26ft to 7031ft.