Environmental Benefits Assessment of Fish Passage Restoration on the Truckee River, Nevada

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Ecosystem Management and Restoration Research Program

Environmental Benefits Assessment

Overview

- Activities
  - Reconnaissance / site screening
  - Developing passage alternatives
  - Metric selection, dependency, uncertainties
  - Model development, expert elicitation
  - Plan Comparison: CE/ICA, Uncertainty Analysis
  - Monitoring and adaptive management plans for fish passage and ecosystem restoration

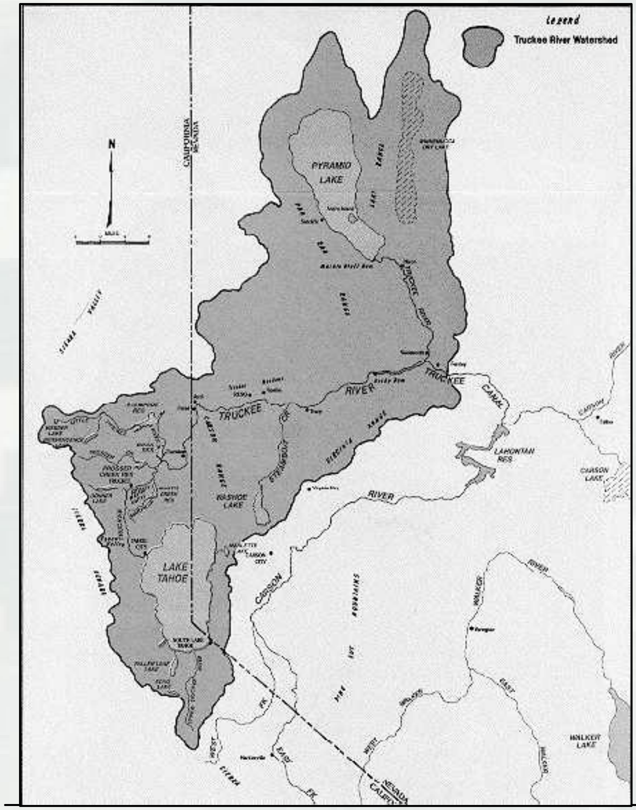
- Key Points
  - Communications with counterparts
  - Assessment of dependent benefits
  - Acknowledgement of uncertainties

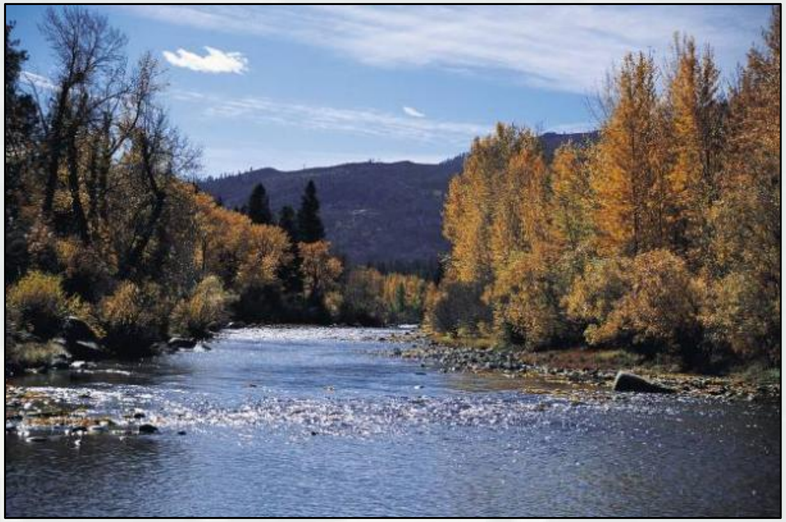
DISCLAIMER

- Sacramento District has completed the Truckee Meadows Flood Control Project's Independent Technical Review but is still preparing material for the Alternative Formulation Briefing. The methods outlined in this presentation have not been subjected to the full review process.
- ERDC-EL is preparing documentation for submittal of the fish passage environmental benefits assessment for model certification.
- This presentation discusses a problem-solving process, not an available product.

Project Background

- Truckee River Flood Project
  - Flood risk management
  - Ecosystem Restoration
  - Fish passage





Project Objectives—The "Living River Plan"

- Flood Damage Reduction
  - Reduce flood damages in the Reno-Sparks Metropolitan area from overbank flows to the fullest extent consistent with Federal participation and community financial capabilities.
  - Reduce potential loss of life from flooding.
  - Remove Reno-Sparks Metropolitan area from National Flood Insurance Program base floodplain by reducing flood risk to no greater than 1 in 100 chance of flooding in any given year.
- Ecosystem Restoration on the Truckee River from Reno to Pyramid Lake
  - Increase riparian habitat.
  - Restore hydrogeomorphic structure and function.
  - Increase wetland habitat within the historical floodplain.
  - Reduce nonnative invasive plant species.
  - Restore in-stream aquatic habitat.
- Recreation
  - Increase recreational opportunities by providing a multi-use recreational corridor along the Truckee River from Reno to Vista.

Current Impacts: Fragmentation and Abstraction

Challenges

- Eight coolwater and warmwater species impacted by fragmentation; many data gaps on swimming physiology, life history, home ranges, behavioral aspects of passage
- Diverse and conflicting counterpart group
- Potentially enormous permutation set of alternatives and alternative arrays
- Dependent benefits
- Significant potential uncertainty in estimates
- Extreme basin development pressures and water demands
- Time constraints

Fish Passage Alternative Formulation

Objectives

Target Species

Passage Alternatives

Passage Measures

Site Conditions

Fish Passage Objectives

- Increase the population and distribution of the endangered cui-ui and threatened Lahontan cutthroat trout (LCT) and other impacted species by reducing both upstream and downstream fish passage problems past barriers and diversion mouths on the Truckee River.
- To the extent possible, establish fish passage improvements that approach ideal passage, which are those that pass all aquatic and terrestrial species that require channel, boundary, or riparian zones to move, for all impacted species, for all movement windows.
- To the extent possible, restore riparian and upland habitat in the vicinity of any project modification work accomplished.

Fish Passage Data Needs and Issues

- Taxa-Specific
  - Physiological Capabilities & Tolerances
  - Behavioral & Life History Needs
- Site Specific
  - Hydrology and Hydraulics
  - Geology
  - Operations
- Upstream and downstream passage are important! Equally?
- Knowledge Gaps:
  - Historical focus on large hydropower barriers
  - Coolwater and warmwater species not well-studied
  - Historic or optimal migration ranges in an unfragmented system never documented; what is spatial scale of potential benefit?

Common upstream passage techniques comparison

Category	US passage of target spp., age classes	US passage of full aquatic and riparian community	Risk of DS injury and effects on predation vulnerability	DS passage of sediment and debris	O&M costs	Capital costs	Secondary risks (liability, operator error, structural failure)
Fish ladder (all types)	Fair (w/high standard deviation)	Poor	Poor	Poor	$$$	$$$$	Moderate to high
Pumps, lifts, locks	Good	Poor	Fair	Poor	$$$$	$$$$	Moderate to high
Trap-and-truck	Good	Poor	Poor to fair	Poor	$$$$	$$$	Moderate to high
Bypass channel	Fair to very good	Fair to very good	Fair to good	NA	$$	$$	Low to moderate
Partial structure removal with secondary grade structures	Excellent	Good to very good	Very good	Excellent	$$	$$	Low to moderate
Full structure removal	Excellent	Excellent	Excellent	Excellent	$	$$$	Low

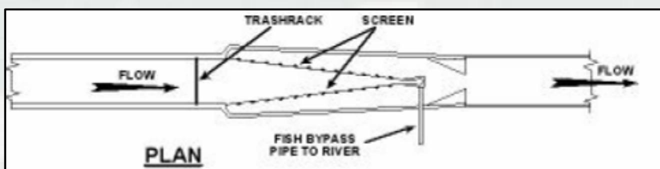
Common downstream passage techniques comparison

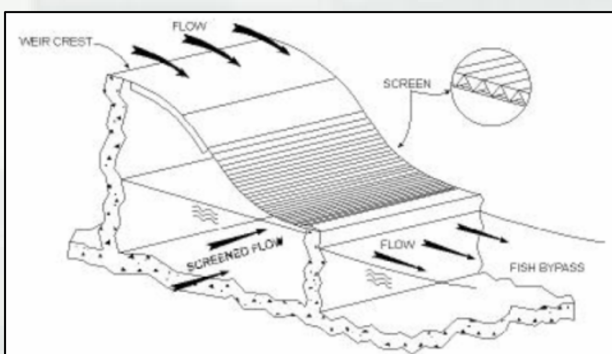
DOWNSTREAM PASSAGE TECHNOLOGY	FISH EXCLUSION OR PASSAGE EFFECTIVENESS	MAINTENANCE REQUIREMENTS	PROVEN TECHNO-LOGY	CAPITAL COSTS
Physical Barrier Devices				
Flat plate screens	Good	Fair	Good	$$$
Turbine intake screen	Fair	Fair	Good	$$
Drum screen	Good	Fair	Good	$$$
Inclined screen	Good	Fair	Good	$$$
Coanda screen	Good	Good	Fair	$$
Cylindrical screen	Good	Fair	Good	$$$
Traveling screen	Good	Poor	Good	$$$$
Structural Guidance Devices				
Angled bar/trash rack	Fair	Fair	Poor	$$
Louver array	Fair	Fair	Fair	$$
Surface collector	Fair	Fair	Fair	$$$$
Complements to Technology				
Bypass chute	Fair	Good	Fair	$$$
Sluiceway/spillway	Fair	Good	Fair	$$$$

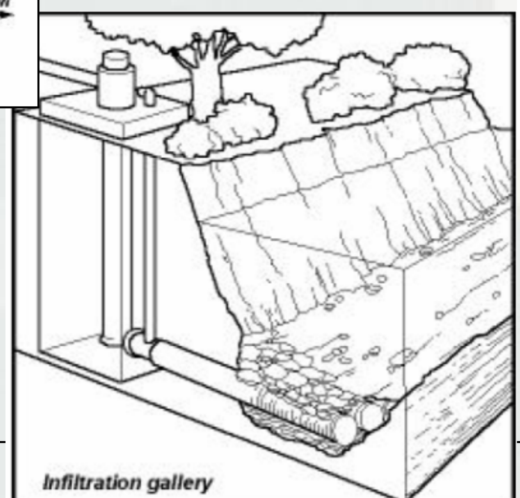
Downstream Passage Measures

- Physical barriers
- Diversion or structural guidance systems
- Behavioral guidance devices
- Collection systems

Downstream Passage Technology	In Use	Considered Experimental
Physical Barrier Devices		
Drum screen	X	
Traveling screen (submersible; vertical)	X	
Fixed screen (simple; inclined)	X	
Turbine intake (gate well) screen	X	
Eicher screen		X
Modular inclined screen	X	X
Barrier net	X	X
Coanda screen	X	X
Structural Guidance Devices		
Angled bar/trash rack	X	
Louver array	X	
Surface collector	X	X
Alternative Behavioral Guidance Devices		
Acoustic array	X	X
Strobe and mercury lights	X	X
Electric field	X	X
Bubble screens, chains, jets	X	X
Other Methods		
Trapping and trucking	X	X
Pumping	X	X
Spilling	X	X
Barging	X	X
Turbine passage	X	







- Passage Efficacy
- O&M
- Capital Cost
- Proven technology

Site Inventory

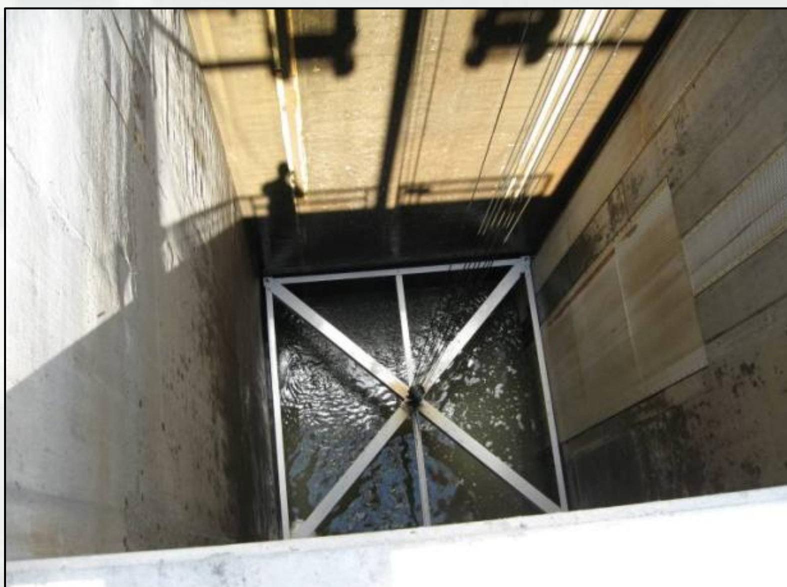
- Over 30 structures
  - Purpose: irrigation, grade control, power plant, recreational, municipal
  - Head loss = 0 to 35 ft
  - Discharge Impact = 0 to 44%
- Narrowed set for USACE to consider
  - Existing passage
  - Planned actions by others
  - 18 structures assessed

Selection Criteria (Detailed)

- Inherent characteristics of relevant alternatives for efficiency and related factors: In systems with multiple structures, optimal passage efficiency is critical if cumulative effects are to be avoided.
- Efficiency at present (a function of target species)
  - Percent passing
  - Temporal efficiency (incl. timing, delays, etc.)
  - Related predation, stress, or morbidity/mortality from other factors
  - Vulnerability to restricted or interrupted efficacy due to operator limitations, maintenance needs, etc.
- Position in channel network
- Corollary ecosystem benefits: e.g., floodplain connectivity, bedload transport, and woody debris passage
- Site constraints and opportunities
- Cost (N.B. Not an element in environmental benefits analysis, but noted)
  - Capital construction cost, including ROW, water rights, etc.
  - O&M costs
- Constructability
  - Access
  - Available ROW and adjacent infrastructure constraints
  - Equipment and material handling requirements
- Acceptability
  - Relative impacts to other users
  - Owner perspective/need
- Environmental Impacts
  - Construction impacts to high-value habitats (e.g. wetlands)
  - Influence on exotic distributions
  - Contaminant dispersal

Marble Bluff

- Grade Control Structure (no diversion)
- 35ft head loss
- Existing Passage



	Measures Considered							
	Bypass Channel	Fish Ladder	Mods to Fish Ladder	Dam Removal	Pump Diversion	Secondary Structure	Screens	Mods to existing structure
Measures Selected[1]	X		X				2	
Justification	Works with existing fluvial system's attraction flows and avoids chronic littoral deposition at lake terminus; can be sized for perennial flows.	Existing lock/lift and fishway main-tained as comple mentary backups	Further modifica tion of fishway ladders to lessen slopes relieves known bottle-neck	Dam provides grade control	Not applicable	High hydraulic head and wide valley widths below the structure make this cost-prohibitive		High hydraulic head and wide valley widths below the structure make this cost-prohib-itive

[1] Key: X preferred alternative, x potential alternative, (x) alternative under some scenarios
[2] A guidance system into the bypass channel, if the design's effectiveness were verified, could significantly reduce fish injury and mortality experienced by fish washing over the dam and its dissipaters.

S-S Diversion

- UNR Ag irrigation
- Washed out 2005
- Planned repair
- Dynamic reach
- Pump recommended

	Measures Considered							
	Bypass Channel	**Fish Ladder**	**Mods to Fish Ladder**	**Dam Removal**	**Pump Diversion**	**Secondary Structure**	**Screens**	**Mods to existing structure**
Measures Selected[1]				x	X		X	X
Justification	Not required for this low head, small diver-sion	Not required for this low head, small diver-sion	Not applica-ble	Current structure is largely gone; concrete and rebar debris remain	Small diversion rate and proximity to existing infrastruct ure make this viable.	Not needed.	Easily implem ented.	Debris removal for aesthetic and liability reasons.

[1] (Key: X preferred alternative, x potential alternative, (x) alternative under some scenarios)

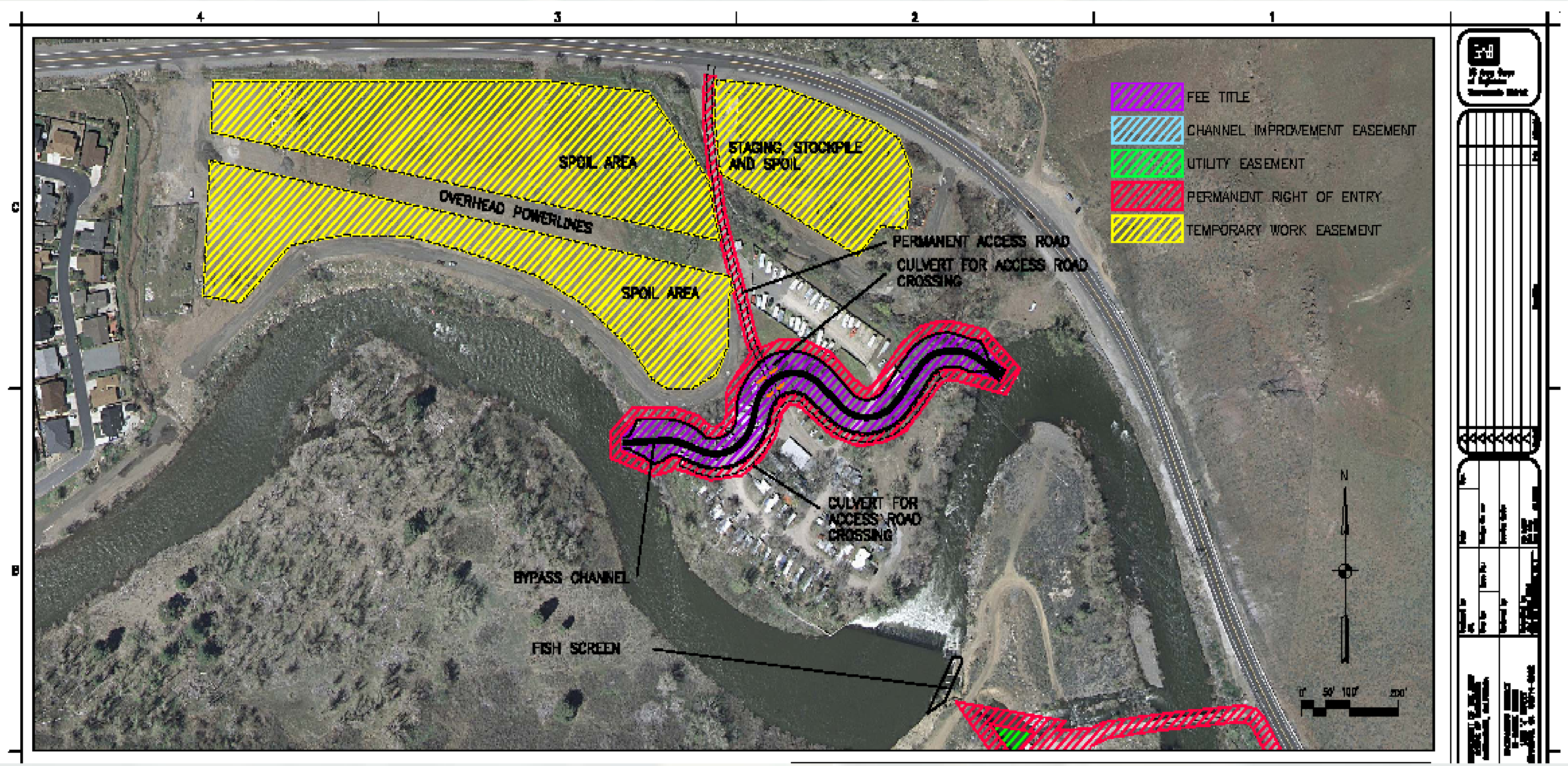
Fleisch Dam

- Hydropower dam
- High diversion rate (40%)
- 14 ft head loss
- Flood Avulsion

	Measures Considered							
	Bypass Channel	Fish Ladder	Mods to Fish Ladder	Dam Removal	Pump Diversion	Secondary Structure	Screens	Mods to existing structure
Measures Selected[1]	X						X	
Justification	Option with highest efficiency and lowest O&M costs. Can be sited in extant avulsion channel.	High capital and maintenance costs for low efficiency	Not viable.	Dam needed for high head, high rate diver-sion.	Too costly at this diver-sion rate.	Extreme cost at this valley width, may threaten diversion channel at peak flows.	Needed at this high rate.	Not viable.

[1] (Key: X preferred alternative, x potential alternative, (x) alternative under some scenarios)

Washoe Highland Dam

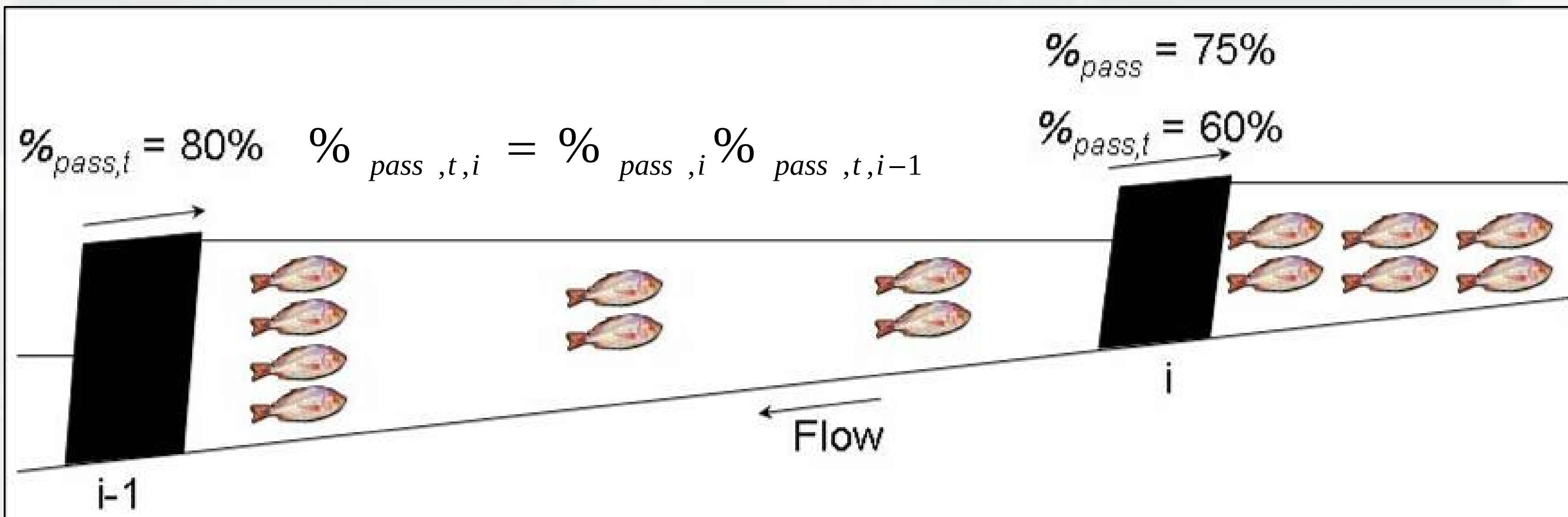


- Upstream: Bypass channel
- Downstream: screen canal

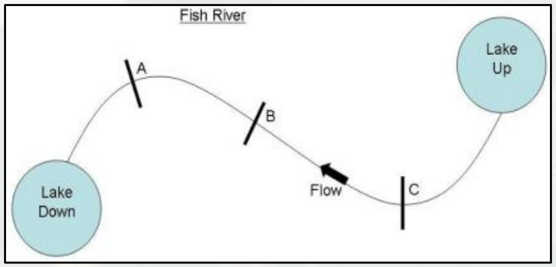
Metric Selection

- Objective: Implementation of the most effective measures for fish passage improvement on the Truckee River
- Modification of existing technique for upstream passage benefits for salmonids (WDFW 2000)

- Any metric set should minimally address:
  - Bidirectional passage efficiency
  - Cumulative effects and dependency in actions
  - Habitat accessed (quantity and quality)
  - Species-specific issues



Passage Efficiency Scaling



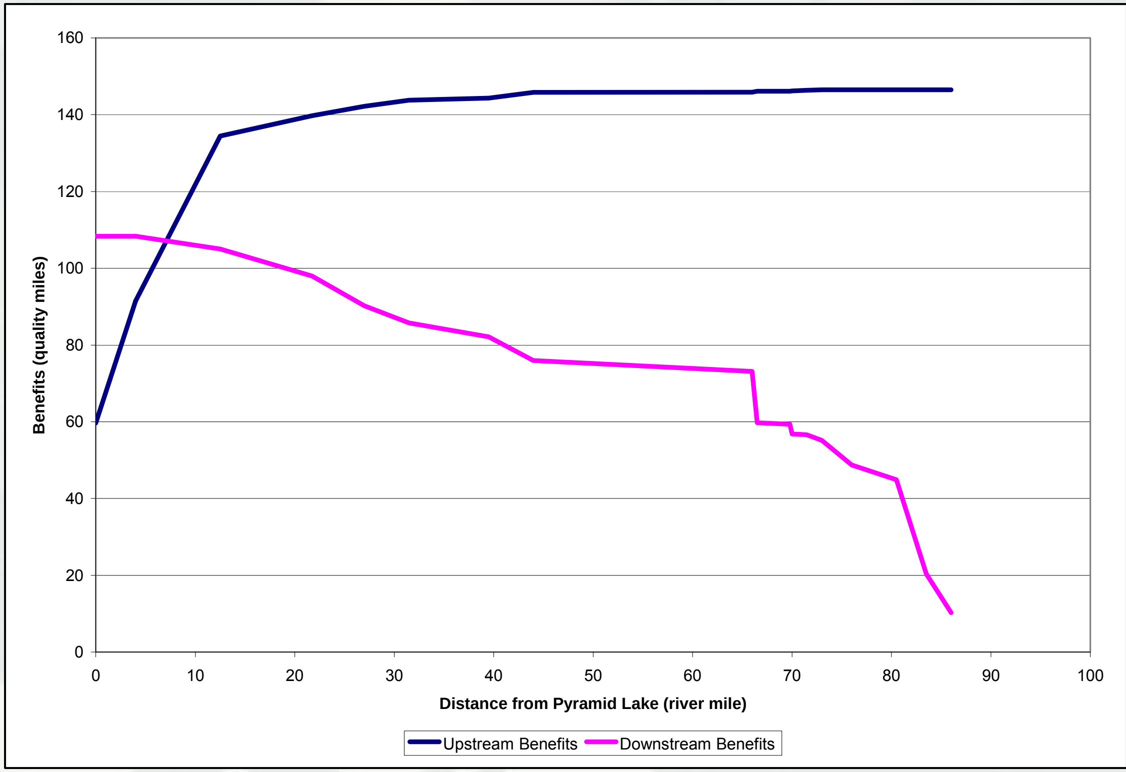
"Fish River" Scenarios

1. Baseline condition of upstream passage.
2. Restoration of passage efficiency at Structure B from 50% to 80%.
3. Restoration of passage efficiency at Structure C from 50% to 80%.

River Mile	Structure	Structure Passage Efficiency	Cumulative Efficiency	Upstream Habitat (mi)	"Benefit-miles"	Cumulative Benefit-miles
Scenario 1						
0	Lake Down	100	100	5	5	5
5	A	80	80	5	4	9
10	B	50	40	5	2	11
15	C	50	20	5	1	12
20	Lake Up		20	0	0	12
Scenario 2						
0	Lake Down	100	100	5	5	5
5	A	80	80	5	4	9
10	B	80	64	5	3.2	12.2
15	C	50	32	5	1.6	13.8
20	Lake Up		**32**	0	0	**13.8**
Scenario 3						
0	Lake Down	100	100	5	5	5
5	A	80	80	5	4	9
10	B	50	40	5	2	11
15	C	80	32	5	1.6	12.6
20	Lake Up		**32**	0	0	**12.6**

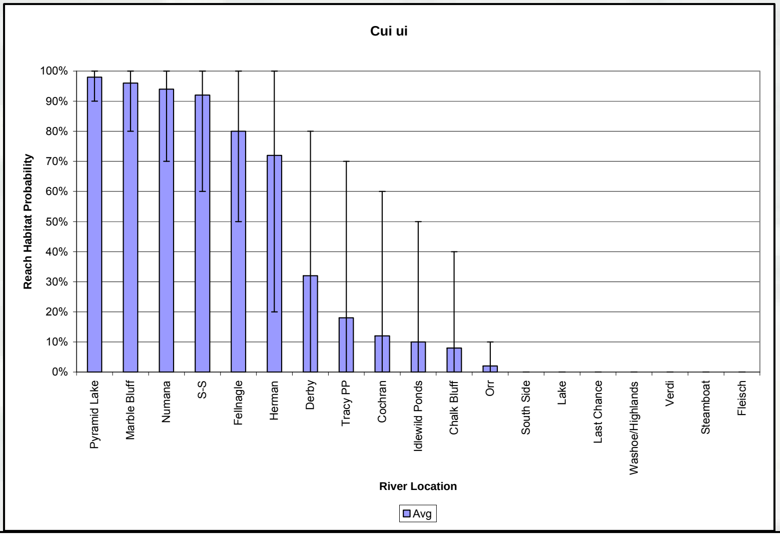
Fish Passage Metrics for Benefits Assessment

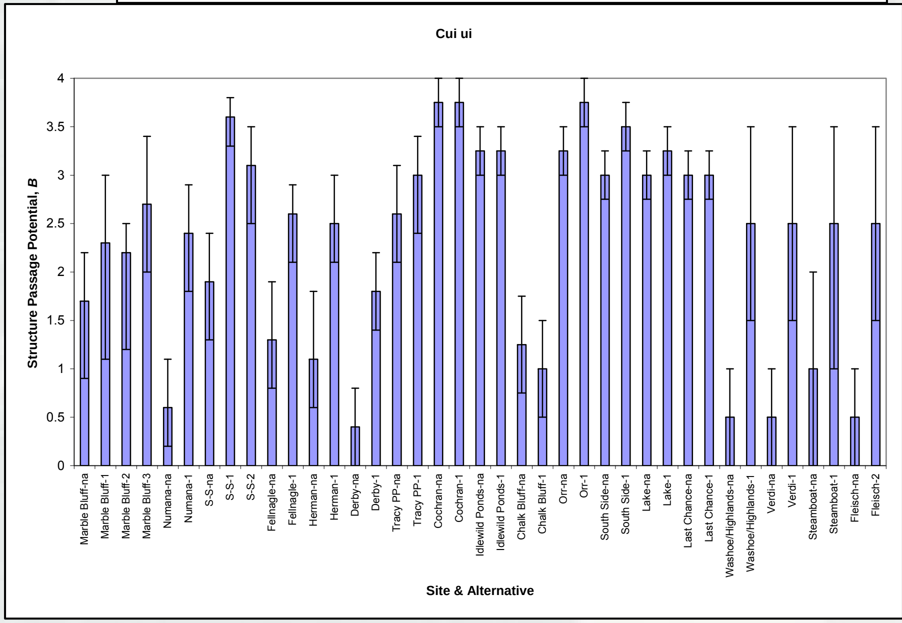
- Efficiency as core metric
  - Upstream passage efficiency
  - Downstream – diversion discharge impact & screening effectiveness
- Efficiency scaled by:
  - Habitat quantity and quality (utilization)
  - Population condition
  - Species mobility needs
  - Restoration impact
- Eight species

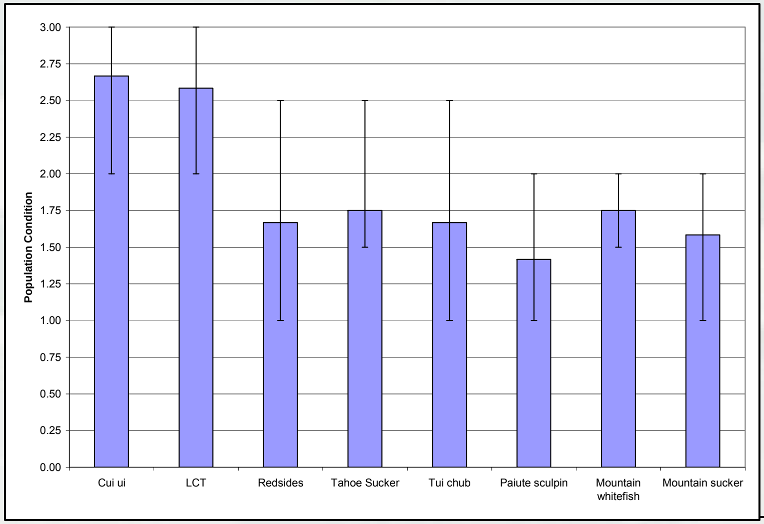


Expert Elicitation

- Criteria for expert selection
- How did they provide input?
  - Blank surveys and description of benefits methodology and alternatives
  - Uncertainty estimates – minimum, expected, and best case scenarios
- How were survey results used?
  - Examined for outliers
  - Average of each scenario







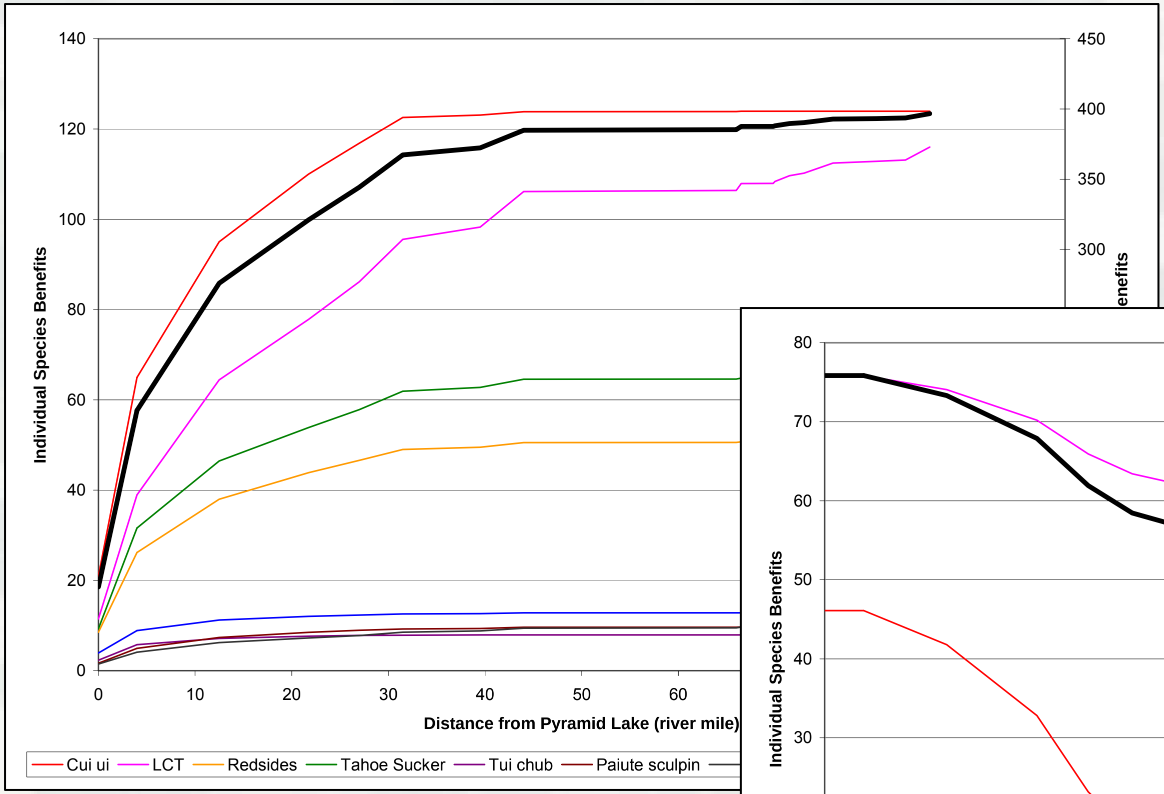
Plan Formulation

- Calculated benefits in Excel
- Developed "system-wide" fish passage improvement plans
- Logical sets were developed
- Upstream (6) and downstream (9) plans identified
- All combinations of up- and downstream plans were examined

	A	B	E	G	J	L	M	N	BU	FG	FJ	FM
1	Total Benefit	508.19	Average Annual Cost	1,832,706		River Mile	Trib Miles	Reach Habitat	Upstream Benef	Downstream Benefits	Average Annual Cost	Total First Cost
2	Upstream Benefit	326.38	Total First Cost	29,078,360	Min Average			H	X_u	Y_d	Total	Total
3	Downstream Benefit	181.81	Plan of Interest	30	Max			mi			$	$
4												
5	Location	Upstream Alternative:	Output Level:	Downstream Alternative	Output Level:				Total	Total		
6												
7	Pyramid Lake					0		4	59.6	181.8	0	0
8	Marble Bluff	Marble Bluff-1	Avg	Marble Bluff-na	Avg	4		8.5	156.4	181.8	371,287	6,126,700
9	Numana		Avg		Avg	12.5		9.25	230.8	175.9	0	0
10	S-S	S-S-1	Avg	S-S-na	Avg	21.8		5.25	267.9	163.3	14,129	259,560
11	Fellnagle	Fellnagle-1	Avg	Fellnagle-na	Avg	27		4.5	287.0	149.3	52,857	921,000
12	Herman	Herman-1	Avg	Herman-na	Avg	31.5		8	305.7	141.3	75,508	1,298,700
13	Derby		Avg		Avg	39.5		4.5	309.9	134.8	0	0
14	Tracy PP		Avg	Tracy PP-na	Avg	44		22	320.0	123.6	0	0
15	Cochran		Avg	Cochran-na	Avg	66		0.5	320.3	118.4	0	0
16	Idlewild Ponds		Avg	Idlewild Ponds-na	Avg	66.5		3.3	322.2	93.3	0	0
17	Chalk Bluff	Chalk Bluff-1	Avg	Chalk Bluff-na	Avg	69.8		0.2	322.2	92.6	8,058	150,000
18	Orr		Avg	Orr-na	Avg	70		1.5	322.6	87.7	0	0
19	Lake		Avg	Lake-na	Avg	71.5	4.5	6	323.8	87.4	0	0
20	Last Chance		Avg	Last Chance-na	Avg	73		3	324.3	84.6	0	0
21	Washoe/Highlands	Washoe/Highlands-1	Avg	Washoe/Highlands-1	Avg	76	8.2	12.7	326.4	72.4	545,763	8,648,100
22	Verdi	Verdi-na	Avg	Verdi-1	Avg	80.5		3	326.4	65.1	424,658	6,560,700

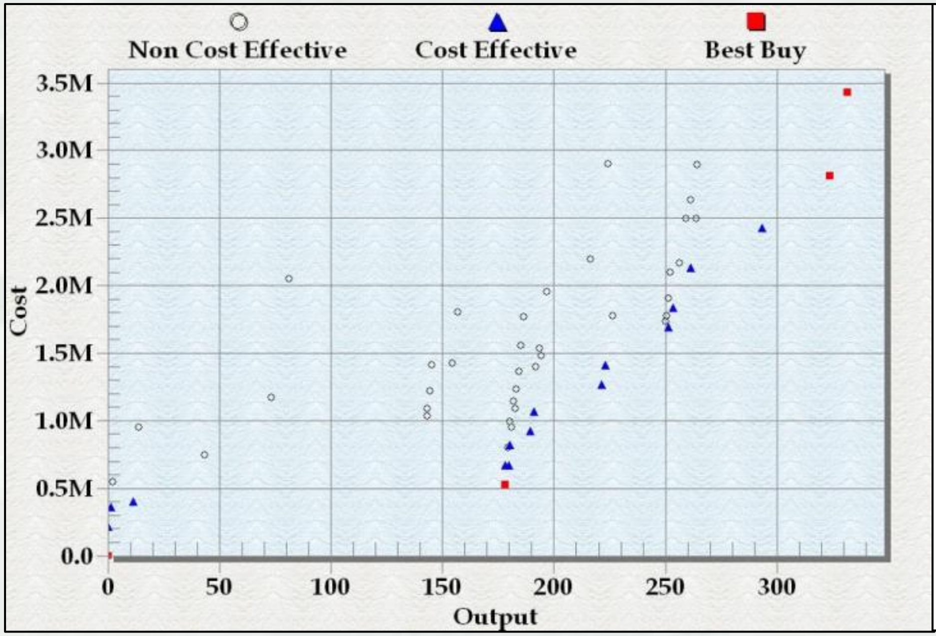
DownIn / CostIn / Calc / Plans / Results / UpBen / DownBen / Up-Down / MC_Calc / MC_Out / Probability

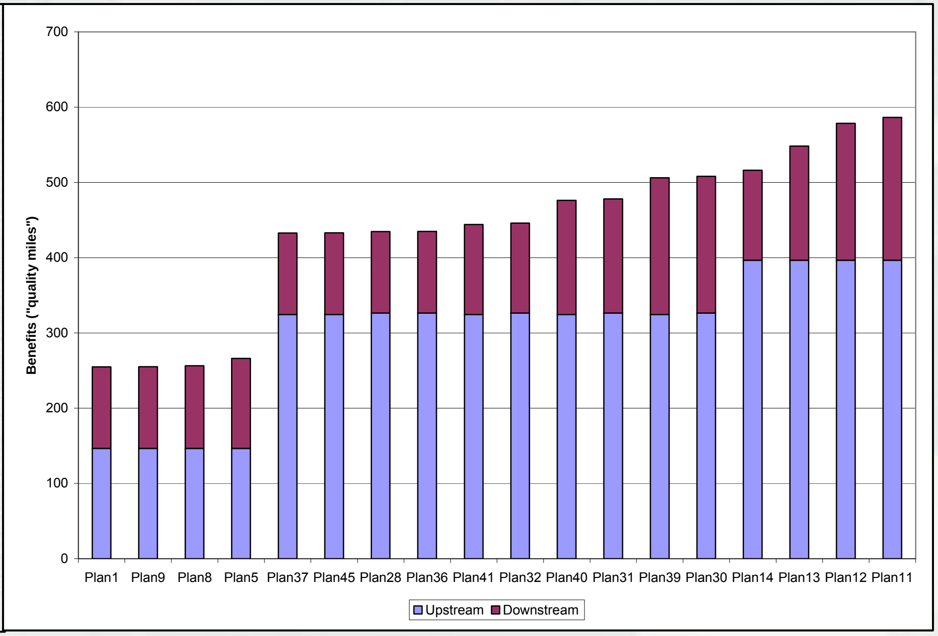
Maximum Benefit Plans: Sample Benefits Calculations



Plan Comparison

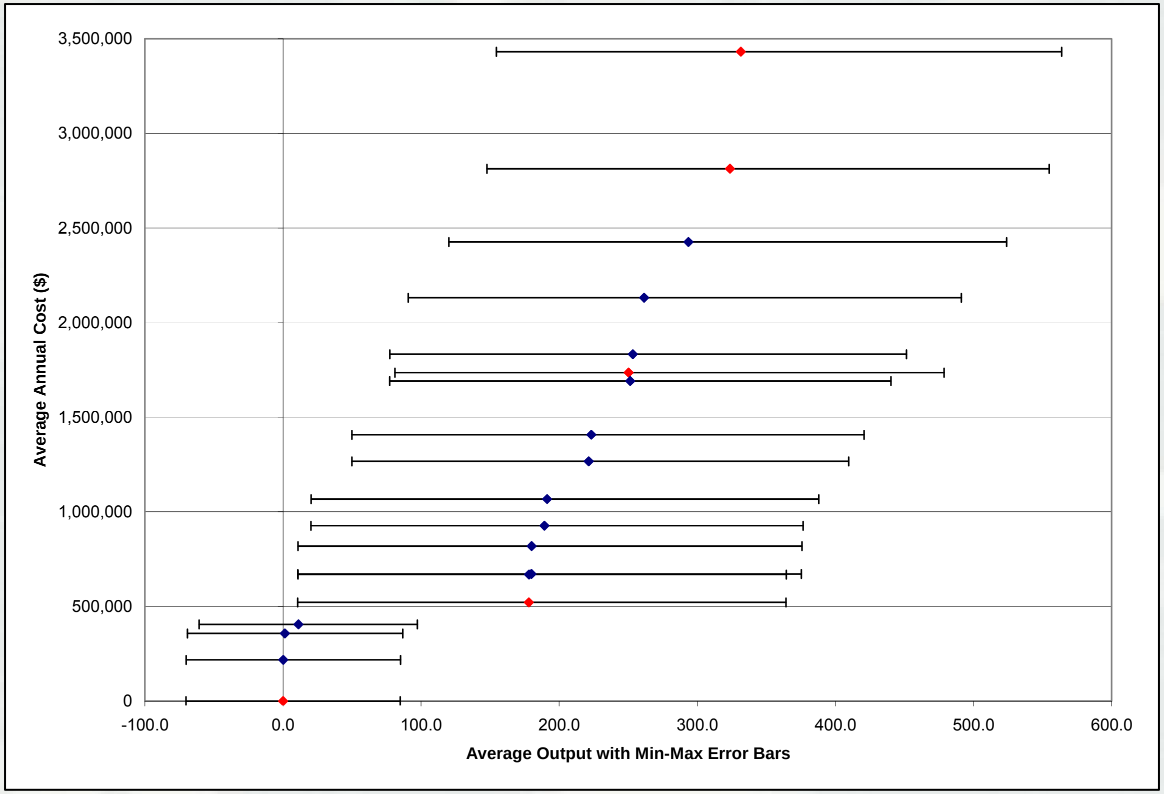
- All combinations of upstream (6) and downstream (9) plans were used in CE/ICA (54 plans total).
- Output = lift in “benefit-miles” over FWOP
- IWR Planning Suite





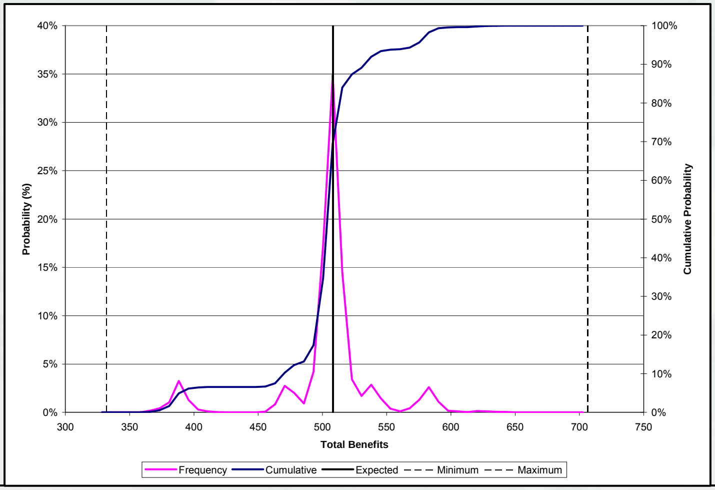
Uncertainty Analysis 1: Scenario

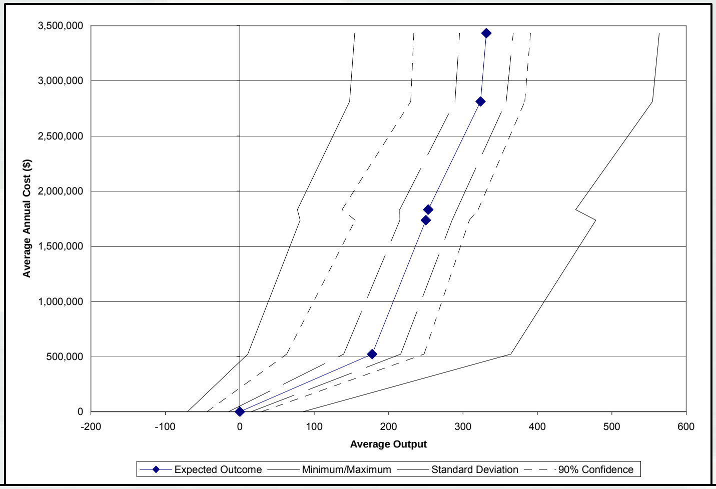
- Worst-Expected-Best
- Determination of consistently selected plans



Uncertainty Analysis 2: Parametric

- Monte Carlo simulation of efficiency
  - ▸ Mixes optimistic, expected, and pessimistic predictions
  - ▸ For a given plan over 9^{17} ($1.7*10^{16}$) iterations would have been required to examine all possible outcomes
  - ▸ Assumed normal distribution of scores
  - ▸ 5,000 random sets generated
- Only on plans “of interest” due to computational demands





Adaptive Management

- Indicated uncertainty underscores the need for adaptive management
- In the process of developing a programmatic (or system-wide) framework for monitoring and adaptive management
- Success depends on good data, efficient assessment, and effective decision-making and implementation processes

Final thoughts…

- System-wide fish passage restoration requires strategic and systematic planning
- New benefits algorithm prioritizes actions and accounts for cumulative benefits of multiple, interrelated actions
- Findings used in plan development and broad, recurring communication
- Plan selection informed by EBA, CE/ICA, & uncertainty assessment
- The process strongly underscores the value of data on habitat quality and life history, migration behavior, habitat utilization, swimming physiology, and population status for each relevant species. Rarely available, so assumptions and uncertainties need to be addressed.
- The process also clearly illustrates the need for an efficient, robust, and actionable monitoring and adaptive management program
- Designed for Truckee case, but easily adapted to other cases by altering algorithms

Central Partners

- SPK: Dan Artho, Jerry Fuentes, James Lee, Mario Parker
- IWR: Leigh Skaggs
- Expert Panel: Dan Fairbanks (PLPT), Lisa Heki (USFWS), Jay Kidder (NDOW), Matt Maples (NDOW), David Potter (USFWS), Gary Scoppettone (USGS), Kim Tisdale (NDOW), Craig Fischenich (ERDC-EL)

Questions & Feedback

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Truckee River Flood Project Website
http://www.truckeeflood.us/
Environmental Benefits Analysis Research Program Website
http://cw-environment.usace.army.mil/eba/

Current and Forthcoming Publications:

USACE SPK. 2010. Truckee River Fish Passage Improvement Study.

Conyngham, McKay, Fischenich, and Skaggs. 2009. Truckee River Fish Passage Restoration: Environmental Benefits, Cost Effectiveness, and Incremental Cost Analyses. Report to Sacramento District.

Conyngham, McKay, Fischenich, and Artho. 2010. Environmental Benefits Analysis of Fish Passage on the Truckee River, Nevada: A Case Study of Multi-action Dependent Benefits Quantification. ERDC TN-EMRRP-EBA-xx.