SUMMARY OF CALFED BAY-DELTA PROGRAM ANALYSIS STRATEGY FOR CHINOOK SALMON ASSESSMENT VARIABLES

Chinook salmon in the Central Valley include five primary races: Sacramento fall-run chinook salmon, Sacramento winter-run chinook salmon, Sacramento spring-run chinook salmon, Sacramento late-fall run chinook salmon, and San Joaquin fall-run chinook salmon. For each race, five assessment variables have been identified for analysis of benefits to and impacts on chinook salmon from CALFED Bay Delta Program (CALFED) action components and programmatic alternatives: adult migration success, spawning success, early rearing success in rivers and tributaries, downstream transport and rearing success, and ocean survival.

The CALFED alternatives may include habitat, operational, and structural actions that cause direct or indirect beneficial and detrimental effects on the various runs of salmon. CALFED alternative components may directly affect a number of supporting variables (e.g., habitat, river flow, exports from the south Delta, and Delta outflow) that will lead to changes in the assessment variables (e.g., spawning success) through chains of relationships. Effects may be observable at various stages of the salmon's life cycle and may or may not be predictable in the adult population or escapement estimates; therefore, assessment variables include indices of effects on specific stages of the life cycle (e.g., downstream transport and rearing).

Chinook salmon populations in the Central Valley will be responsive to many of the proposed action components and structural and operational changes in the water management system that differ among alternatives. The ultimate tool to measure the effects of possible CALFED actions would be a population model that simulates responses in terms of changes in population abundance. However, such a tool is not available for reliable estimates of population changes. Intermediate variables that are directly affected by flow and habitat conditions may more useful as assessment variables to indicate potential population changes.

Seven basic categories of actions may affect salmon:

1. **Habitat Restoration**. Spawning, rearing, and migrating habitat would be increased directly or indirectly by a number of actions in the Bay-Delta and in the rivers and tributaries upstream of the Delta.

2. **Water Transport**. Constructing new water conveyance facilities in the Central Valley could reduce the number of salmon lost at existing diversion/export facilities.

3. **Water Storage**. Constructing new water storage facilities upstream of the Delta, within the Delta, or south of the Delta may indirectly reduce salmon losses and improve salmon survival by shifting the timing of diversions.

4. **Fish Protection and Transport**. Eliminating, reducing, or screening diversions may improve survival of juvenile salmon. Placing barriers, such as at the head of Old River, may keep juvenile salmon away from major diversions; indirectly improving survival. Improving floodway drainage may reduce the loss of juvenile salmon and improve upstream adult passage in bypasses. Improving fish protection and salvage facilities at Central Valley Project/State Water Project (CVP/SWP) pumping plants may reduce losses of salmon.

5. **Water Diversion Management**. Shifts in the timing of river and Delta flows and exports could reduce losses and improve survival of salmon. Real-time monitoring may reduce losses of salmon related to project operations. Predator-control measures could improve salmon survival.

6. **Fisheries Management**. Changing hatchery programs and fishery harvest practices may improve survival and population levels of salmon. Marking hatchery salmon may help reduce losses of wild salmon in fisheries.

7. **Water Quality Management and Protection**. Improvements in water quality could improve salmon survival.

Examples of relationships that could be used to assess the effects of these action components on salmon are discussed in the following section by life-history stage. Several of these relationships are shown in attachments.

- **Population Trends and Spawner-Recruitment Relationships**. A simple spawner-recruitment relationship can be used to assess effects of many of the action components. Spawning-escapement plots for each of the runs over the past 30 years are the most simple forms of spawner-recruit relationships. Long-term trends in spawning escapement patterns are essential tools in the management of most of the salmon runs in the Central Valley. Such a model, as developed by Reisenbechler (1986) for Sacramento fall-run chinook salmon, may indicate whether there has been any major shift in the spawner-recruitment relationship over the past several decades. Changes could be attributed to a shift in the productive capacity of the system over time and/or simply a gradual or drastic reduction in the number of spawners that holds the population down on the extreme left of the spawner-recruit relationship. Sudden shifts in the relationship between periods may be attributable to specific factors. With a spawner-recruitment relationship, future changes in population abundance relative to targets (e.g., doubling goals) could be simulated from arrays of actions if it is known how the actions translate into population losses or survival. Enhancements to the basic model may include adding independent factors, such as flow, harvest, and habitat conditions, that may affect recruitment independent of stock size. A basic spawner-recruitment model with independent factors, such as the CPOP model (BioSystems Analysis Inc. 1989) or EACH model (EA Engineering, Science, and Technology 1991), could be modified and used for CALFED purposes.

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- **Preemergence survival.** Survival of egg embryos and preemergent newly hatched fry in spawning beds is primarily a function of water temperature. This control factor is very important to winter-run salmon, whose eggs oversummer in the gravel of the upper Sacramento River. Available relationships between temperature and riverflow allow prediction of potential survival of embryos in the gravel at different riverflows along the axis of the upper river spawning area.

- **Juvenile survival in Sacramento River.** Very little is known about factors affecting survival of juveniles during rearing in the rivers and tributaries. One known factor is survival in the Glenn-Colusa Irrigation District (GCID) bypass as a function of diversion rate. Another is the relationship of survival and growth to water temperature.

- **Spawning and rearing habitat.** Changes in the amount of optimal spawning and rearing habitat from flow changes or channel manipulation could be assessed using data from Instream Flow Incremental Methodology (IFIM) studies of the rivers and tributaries. Although translation of changes in habitat amount into population abundance may not be possible, predictions of areas of optimal habitat conditions among alternatives or for habitat restoration components could be valuable decision-making tools. The U.S. Fish and Wildlife Service (USFWS) SALMOD Model could be modified and used for CALFED purposes.

- **Fry movement to the Delta.** Movement of fry and fingerlings to the Delta in late fall and winter may improve survival of smolt, recruitment of smolts to the ocean, and early ocean survival. Higher Sacramento River flows appear to increase the proportion of fry and fingerlings that move to the Bay and Delta, where rearing habitat is possibly better than riverine rearing habitat.

- **Salvage of juvenile salmon at export facilities.** Over the past 25 years there has been an increase in the loss of salmon at the SWP and CVP export facilities. Changes in losses at these facilities could be simulated from salvage/loss relationships developed from the salvage data. The losses could be included in the spawner-recruitment or other population relationships to show the potential benefits of reducing losses at the export facilities.

- **Smolt survival through the Delta.** For those juveniles that remain in the rivers until smolting (including Coleman hatchery smolts), coded wire tag experiments have yielded data on survival through the Delta as a function of export rate, opening of the Delta Cross Channel (DCC), and water temperature. Regression models of survival as a function of these factors are available to predict smolt survival for changes in DCC operation, exports, and water temperature for both Sacramento and San Joaquin smolts.

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II. Biological Environment

J. Fish Populations

Assessment Variable	Supporting Variable				CALFED Action Component*
1-5. Chinook salmon abundance (winter-run, spring-run, late fall-run, Sacramento fall-run, San Joaquin fall-run)	Adult migration survival	Delta conditions	Channel flows		
		River flows			
		Barriers	Red Bluff Diversion Dam, Montezuma Slough Salinity Control Gate, Delta Cross Channel, weirs		Passage improvements
		Recreational harvest			Hatchery marking/wild fish release
	Spawning success	Area of quality habitat	River flows		
			Substrate	Gravel supply	Spawning habitat enhancements
				Sedimentation	Watershed and riparian management
			Water temperature	River flows	
				Water source	Shasta Reservoir operation
	Rearing survival	Area of quality habitat	Depth	River and Delta flows	
			Velocity	River and Delta flows	
			Substrate		Gravel
			Riparian habitat		Riparian habitat restoration, meander belts
			Food web production		
			Water quality	Toxicity	Iron Mt. Mine cleanup
			Water temperature	River flows	
			Wetland habitat		Protect, enhace, restore
		Diversion loss	Diversion rate	River flows	
			Screening		Screening, relocating diversions

Assessment Variable	Supporting Variable				CALFED Action Component*
1-5. Chinook salmon abundance (continued)		Stranding loss	River flows		
		Predation	Barriers		Predator removal
		Competition			
	Outmigration survival	River and Delta flows			
		Riparian habitat			Riparian habitat restoration, levee maintenance
		Foodweb production			
		Water quality	Toxicity		Iron Mt. Mine cleanup
		Water temperature	River flows		
		Wetland habitat			Protect, enhance, restore
		Diversion loss	Diversion rate	River flows	
			Screening		Screening, relocating diversions, flow management
		Stranding loss	River flows		
		Predation	Barriers		Predator removal
		Competition			
	Ocean survival	Ocean conditions	El Niño		
		Commercial harvest			Hatchery marking, monitoring
		Recreational harvest			Hatchery marking, monitoring

* FIXED = relationship is assumed to not change.
INPUT = monthly hydrologic or meteorologic conditions.
FEEDBACK = relationship is addressed elsewhere in table.
FLOWS = water management control.
IFIM = Instream Flow Incremental Methodology
BMP = Best Management Practices