State of California
The Resources Agency
Department of Water Resources

MATRIX OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES SP-F15 TASK 1 SP-F21 TASK 1

CHINOOK SALMON

Oroville Facilities Relicensing
FERC Project No. 2100

APRIL 2004

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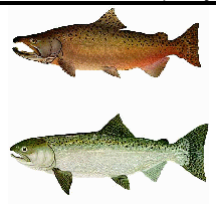
Element	Element Descriptor	General	Feather River Specific
General			
Common name (s)	English name (usually used by fishers and laypeople).	Chinook salmon, king salmon	
Scientific name (s)	Latin name (referenced in scientific publications).	The scientific name of Chinook salmon is *Oncorhynchus tshawytscha*	
Taxonomy (family)	Common name of the family to which they belong. Also indicate scientific family name.	Chinook salmon belong to the *Salmonidae* family, which includes salmon, trout, and char (Moyle 2002). Chinook salmon are most closely related to coho salmon. Within the Chinook salmon species, there are many distinct populations, usually recognized as "runs" or "stocks" (Moyle 2002).	
Depiction	Illustration, drawing or photograph.	 	
Range	Broad geographic distribution, specifying California distribution, as available.	Chinook salmon are distributed from Alaska to California, with the southernmost spawning runs occurring in the Central Valley, specifically in the San Joaquin and King Rivers of Fresno County. Chinook salmon are widely distributed in the pelagic zone of the north Pacific Ocean. The extent of distribution reportedly depends on water temperature, with the greatest number of Chinook salmon found north of 40°N, except those occurring off the coast of California which is about 35°N (Moyle 2002). In the Central Valley, spawning reportedly occurs in all major streams in the Sierra Nevada drainage, although the distribution of spawning fish has been severely truncated by dams blocking access to upstream areas.	The historical upstream extent of Chinook salmon distribution in the Feather River drainage is reported as: 1) West Branch Feather River to the vicinity of Stirling City; 2) North Fork Feather River to approximately 6 miles above Lake Almanor, 3 miles up Hamilton Branch, and to Indian Falls on the East Branch of North Fork; 3) Middle Fork Feather River to Bald Rock Falls; and 4) South Fork Feather River to the upper limit of Lake Oroville (6 miles above the former mouth of South Fork) (Yoshiyama et al. 1998)

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		Along the Sacramento River, spawning reportedly occurs in numerous tributary creeks, streams and major rivers including the American River, Feather River, Yuba River, as well as the mainstem Sacramento River (Moyle 2002). Generally, ocean-type (fall-run) Chinook salmon are reportedly predominantly distributed south of 55°N, while stream-type (spring-run) Chinook salmon are reportedly predominantly distributed north of 55°N parallel (Myers et al. 1998). In the Sacramento-San Joaquin River drainages, 10% to 18% of Chinook salmon are reported to be stream type (spring-run and late-fall-run) and 82% to 90% of Chinook salmon are reported to be ocean type (fall-run) (USFWS 1995).	
Native or introduced	If introduced, indicate timing, location, and methods.	Chinook salmon are native to California. (Moyle 2002).	
ESA listing status	Following the categories according to California Code of Regulations and the Federal Register, indicate whether: SE = State-listed Endangered; ST =State-listed Threatened; FE = Federally listed Endangered; FT = Federally-listed Threatened; SCE = State Candidate (Endangered); SCT = State candidate (Threatened); FPE = Federally proposed (Endangered); FPT = Federally proposed (Threatened); FPD = Federally proposed (Delisting); the date of listing;	NOAA Fisheries identified five Evolutionary Significant Units (ESU) of Chinook salmon in California, based on genetic and life history similarities: 1) Southern Oregon and California ESU 2) Upper Klamath and Trinity Rivers ESU 3) Central Valley fall-run ESU 4) Central Valley spring-run ESU 5) Sacramento River winter-run ESU (Myers et al. 1998).	Two ESUs specific to the Feather River are the Central Valley spring-run ESU and the Central Valley fall-run ESU(Myers et al. 1998). The Central Valley spring-run Chinook salmon ESU includes spawning populations in the Sacramento River and its tributaries (including the Feather River). Spring-run chinook salmon were federally-listed as Threatened on September 16, 1999 (NOAA 1999). The Central Valley fall-run Chinook salmon ESU includes spawning populations in the Sacramento River and its tributaries (including the Feather River). Fall-run Chinook salmon were designated a candidate for listing on September 16, 1999 (NOAA 1999).

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	or N = not listed.		
Species status	If native, whether: Extinct/extirpated; Threatened or Endangered; Special concern; Watch list; Stable or increasing. If introduced, whether: Extirpated (failed introduction); highly localized; Localized; Widespread and stable; Widespread and expanding.	The Chinook salmon population has been reported as stable. Although Chinook salmon are reported to be in long-term decline in California, they are not, as a species, in immediate danger of extinction (Moyle 2002).	Central Valley fall-run Chinook salmon are on the watch list. Central Valley fall-run Chinook salmon are considered a candidate species for Threatened status by NOAA Fisheries (Moyle 2002). Central Valley spring-run Chinook salmon were federally listed as Threatened by NOAA Fisheries in 1999.
Economic or recreational value	Indicate whether target species sought for food or trophy. Whether desirable by recreational fishers, commercial fishers, or both.	The commercial Chinook salmon fishery in California reportedly started around 1850 in the San Francisco Bay and the Sacramento-San Joaquin Delta region, where it formed the nucleus of the first major fishery conducted by Euro-American immigrants (Yoshiyama et al. 1998).	In the Feather River, a significant recreational fishery persists (Yoshiyama et al. 1998).
Warmwater or coldwater	Warmwater if suitable temperature range is similar to basses; coldwater if suitable temperature range is similar to salmonids.	Chinook salmon are a coldwater species (Moyle 2002).	
Pelagic or littoral	Environment: Pelagic - living far from shore; Littoral - living near the shore.	Chinook salmon reportedly tend to stay along the California coast, with a general northward movement. High productivity off the coast of Washington is reportedly caused by upwelling generated by the phenomenon known as the California Current, a southward-moving current originating in the Gulf of Alaska (Moyle 2002; Allen and Hassler 1986).	
Bottom or water column distribution	Environment: bottom (benthic) or along water column.	The vertical distribution of Chinook salmon in the water column reportedly varies with season, ranging from 0 to 328 feet (0 to 100 meters). The vertical distribution of Chinook salmon is typically deeper than the distribution of other salmonids and typically ranges from 65.6 to 147.6 feet (20 to 45 meters) (Moyle 2002).	

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Lentic or lotic	Environment: Lentic - pertaining to stagnant water, or lake-like; Lotic - moving water, or river-like.	Chinook salmon reportedly have a freshwater, nearshore orientation and move into swifter, deeper water as larger juveniles (Moyle 2002).	
Adults			
Life span	Approximate maximum age obtained.	The maximum reported life span for Chinook salmon is 9 years (Froese and Pauly 2002).	
Adult length	Indicate: Length at which they first reproduce; average length and maximum length the fish can attain.	Chinook salmon are reportedly the largest (average size) of the five species of Pacific salmon (Raleigh et al. 1986). Spawning adults, typically range from 29.5 to 31.5 inches (75 to 80 cm) standard length (SL), with lengths in excess of 55.1 inches (140 cm) (Moyle 2002). Sacramento River fall-run Chinook salmon reportedly average 21.7 inches (55 cm) fork length at 2 years of age, 27.6 inches (70 cm) at 3 years of age, 35.4 inches (90 cm) at 4 years of age, and 39.4 inches (100 cm) at 5 years of age (Moyle 2002). Spring-run Chinook salmon reportedly reach 29.5 to 39.4 inches (75 to 100 cm) SL (Moyle 2002). Spring-run Chinook salmon reportedly mostly spawn at age 3. Fall-run Chinook salmon reportedly mostly spawn as 4- or 5-year-olds (Moyle 2002). The average age at maturity for all Chinook salmon runs in Sacramento-San Joaquin River drainages was reported as 3 years (Myers et al. 1998).	
Adult weight	Indicate: Weight at which they first reproduce; average weight and maximum weight the fish can attain.	The angling record for Chinook salmon reportedly is 135.4 pounds (61.4 kilograms) (Froese et al. 2002). The angling record for Chinook salmon is reported to be 59.1 inches (150 cm) total length (Froese et al. 2002).	

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		The largest Chinook salmon reported in California weighed 85.1 pounds (38.6 kilograms) (Moyle 2002). Spring-run Chinook salmon weigh reportedly 19.8 to 22 pounds (9 to 10 kilograms) or more (Moyle et al. 1995). Spawning adult Chinook salmon can weigh reportedly in excess of 99 pounds (45 kilograms) (Moyle 2002).	
Physical morphology	General shape of the fish: elongated, fusiform, laterally compressed, etc.	Chinook salmon have fusiform (streamlined) bodies (Moyle 2002).	
Coloration	Indicate color, and color changes, if any, during reproduction phase.	Spawning adult Chinook salmon are reportedly olive brown to dark maroon. Spawning males are reportedly darker than females (Moyle 2002). Chinook salmon reportedly can be distinguished from other spawning salmon by color pattern, particularly the spotting on the caudal fin and the black gums of the lower jaw (Moyle 2002).	
Other physical adult descriptors	Unique physical features for easy identification.	Spawning Chinook salmon males have hooked jaws and a slightly humped backed. Numerous small spots on the back, dorsal fin and both lobes of the tail exist in both sexes (Moyle 2002).	
Adult food base	Indicate primary diet components.	After juvenile Chinook salmon enter the ocean, they become voracious predators on small fish and crustaceans. Small Chinook salmon reportedly feed heavily on invertebrates such as crab larvae and amphipods. As Chinook salmon grow larger, fish increasingly dominate their diet (Moyle 2002).	
Adult feeding habits	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder.	Adult Chinook salmon typically feed on the most abundant pelagic planktivore, including herrings, anchovies, juvenile rockfish, and sardines off the California coast (Moyle 2002).	

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Adult in-ocean residence time	For anadromous species, age when they migrate to the ocean and duration spent in the ocean before returning to freshwater to spawn.	The ocean stage of the Chinook salmon life cycle lasts 1 to 5 years. Chinook salmon reportedly enter the ocean as juveniles (Moyle 2002). Chinook salmon in-ocean residence reportedly ranges from 1 to 6 years, and is more commonly 2 to 4 years, with the exception of a small proportion of yearling males which mature in freshwater or return after 2 or 3 months in saltwater (Myers et al. 1998).	
Adult habitat characteristics in-ocean	For anadromous species, description of the ocean habitat utilized: whether along major current systems, gyres, pelagic (beyond continental shelves) and neritic (above continental shelves) zones, etc.	When juvenile Chinook salmon first enter the ocean, they reportedly tend to stay along the California coast. Juvenile Chinook salmon reportedly may exhibit a general northward movement off Washington where there is high productivity caused by upwelling generated by the complex phenomenon known as the California Current, a southward-moving current originating in the Gulf of Alaska (Moyle 2002; Allen et al. 1986).	
Adult Upstream Migration (Immigration)			
Range of adult upstream migration timing	Time of year adults migrate upstream. If applicable, indicate for various runs.	Sacramento River basin spring-run Chinook salmon adults reportedly immigrate from March through September (Yoshiyama et al. 1998). Sacramento River spring-run Chinook salmon adults reportedly immigrate from mid-March through July (Myers et al. 1998). Spring-run Chinook salmon adults typically enter rivers as immature fish in spring and early summer and remain in freshwater until they spawn in the early fall (Moyle 2002). Sacramento River Basin fall-run Chinook salmon adults reportedly immigrate from June through December (Yoshiyama et al. 1998). Sacramento River fall-run Chinook salmon adults reportedly immigrate from mid-August through	Spring-run Chinook salmon reportedly enter the Feather River from March through June and spawn the following autumn (Sommer et al. 2001). Fall-run Chinook salmon reportedly return to the Feather River to spawn from September through December and spawn immediately (Sommer et al. 2001). Fall-run Chinook salmon reportedly enter the Feather River from October through early December, while spring-run Chinook salmon enter the Feather River from March through June (DWR 1982; NOAA 1999).

Element	Element Descriptor	General	Feather River Specific
		September (Myers et al. 1998). Fall-run Chinook salmon adults reportedly enter rivers in summer or fall as adults and spawn soon afterwards (Moyle 2002).	
Peak adult upstream migration timing	Time of year most adults migrate upstream. If applicable, indicate for various runs.	Fall-run Chinook salmon migration reportedly peaked in early October in the Samish River, Washington (Ellis 1957) Reportedly, Chinook salmon increased to peak densities within Hawks Creek, British Columbia in late August (Scrivener et al. 1994). In August, densities of Chinook salmon were reportedly higher in pools than in riffles in the Upper South Umpqua River basin, Oregon (Scarnecchia and Roper 2000).	Fall-run Chinook salmon immigration reportedly peaks from mid-October through early December (Sommer et al. 2001).
Adult upstream migration water temperature tolerance	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Adult spring-run Chinook salmon reportedly tolerate water temperatures ranging from 38°F to 56°F (3.3°C to 13.3°C) (Bell 1991). Adult fall-run Chinook salmon reportedly tolerate water temperatures ranging from 51°F to 67°F (10.6°C to 19.4°C) (Bell 1991). In the San Joaquin River, adult Chinook salmon reportedly initiated immigration as water temperatures fell from 72°F to 66°F (22°C to 18.9°C) (USFWS 1995). Water temperatures ranging from 70°F to 72°F (21.1°C to 22.2°C) were reported as incipient lethal water temperatures for adult summer-run Chinook salmon and early fall-run Chinook salmon in the Columbia River (Becker 1973). The upstream migration of adult Chinook salmon from the Delta to the San Joaquin River is reported to have been prevented by water temperatures above 70°F	

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		(21.1°C). The upstream migration of adult Chinook salmon was reported to resume when temperatures cooled to 65°F (18.3°C) (Boles et al. 1988). In the Columbia River, adult Chinook salmon reportedly tend to cease upstream migration if water temperatures are greater than 70°F (21.1°C) (Becker 1973). Adult Chinook salmon immigrants in the Sacramento River reportedly exhibited poor survival and produced eggs that were less viable at water temperatures > 60°F (15.6°C) (Boles et al. 1988). The upper incipient lethal water temperature limit for pre-spawning adult Chinook salmon on the American River reportedly probably falls within the range of 62.6°F to 68°F (17°C to 20°C) (Marine 1992).	
Adult Holding (Freshwater Residence)			
Adult upstream migration water temperature preference	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	Water temperature preferences for adult fall-run Chinook salmon immigration have been reported as ranging from 45ºF to 60ºF (7.2°C to 15.6°C) in the Columbia River (Becker 1973); (Burrows 1963). A water temperature range of 42.8°F to 57.2°F (6°C to 14°C) was reportedly determined to be optimal for adult Chinook salmon migration and pre-spawning broodstock survival in the American River (Marine 1992). The “acceptable” water temperature range for Sacramento River winter-run Chinook salmon migration is reported as 57°F to 67°F (13.9°C to 19.4°C) (NOAA 1997).	
Water temperature tolerance for holding adults	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Records reportedly indicate that spring-run Chinook salmon in the Sacramento-San Joaquin River system spend the summer holding in large pools where summer water temperatures are usually below 69.8°F	

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		to 77°F (21°C to 25°C) (Moyle et al. 1995). Sustained water temperatures above 80.6°F (27°C) are reportedly lethal to adult spring-run Chinook salmon (Moyle et al. 1995). In the Sacramento River, adult immigrants held at hatcheries at water temperatures greater than 60°F (15.6°C) and less than 38°F (3.3°C) reportedly exhibited poor survival (Boles et al. 1988). The water temperature range for post-spawning Chinook salmon adults is reported as 37°F to 60°F (2.8°C to 15.6°C) (Boles et al. 1988). Pools in holding areas reportedly need to be sufficiently deep, cool, and oxygenated to allow over-summer survival of spring-run Chinook salmon (DWR and USBR 2000). Adult Sacramento River winter-run Chinook salmon holding at water temperature ranges of 55.0°F to 56.0°F (12.8°C to 13.3°C) reportedly have substantially better egg viability than those held at other water temperatures (NOAA 1997). The maximum water temperature tolerance for adult winter-run Chinook salmon holding in the Sacramento River reportedly ranged from 59°F to 60°F (15°C to 15.6°C) (NOAA 1997).	
Water temperature preference for holding adults	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	Mean water temperatures in pools where adult spring-run Chinook salmon reportedly held during the summer of 1986 in Deer and Mill creeks were 60.8°F (16°C) (range 53.1°F to 64.4°F [11.7°C to 18°C]) and 68°F (20°C) respectively (range 64.9°F to 70°F [18.3°C–21.1°C]) (Moyle et al. 1995).	

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Water depth range for holding adults	Reported range of observed (minimum and maximum) water depth utilization.	Spring-run Chinook salmon reportedly hold in pools that are at least 3.3 to 9.8 feet (1 to 3 meters) deep (Moyle et al. 1995). Pools in holding areas reportedly need to be sufficiently deep, cool, and oxygenated to allow over-summer survival of Chinook salmon (DWR et al. 2000).	
Water depth preference for holding adults	Reported range of most frequently observed water depth utilization.	Spring-run Chinook salmon reportedly select large deep pools, usually >6.6 feet (>2 meters) deep (Moyle 2002).	
Substrate preference for holding adults	If bottom dwellers, indicate substrate: mud, sand, gravel, boulders, aquatic plant beds, etc. If gravel, indicate range or average size of gravel.	Spring-run Chinook salmon reportedly select pools with bedrock bottoms (Moyle 2002).	
Water velocity range for holding adults	Reported range of observed (minimum and maximum) water velocity utilization.	Spring-run Chinook salmon adults reportedly prefer mean water column velocities of 0.49 to 2.6 ft/sec (0.15 to 0.8 m/sec) (Moyle 2002). Holding pools for adult spring-run Chinook salmon have reportedly been characterized as having moderate water velocities ranging from 0.5 to 1.3 ft/sec (0.2 to 12.1 m/sec) (DWR et al. 2000).	
Water velocity preference for holding adults	Reported range of most frequently observed water velocity utilization.	In Deer Creek, adult spring-run Chinook salmon reportedly preferred mean water velocities ranging from 2.0 to 2.6 ft/sec (0.6 to 0.8 m/sec) during a 1988 survey (Moyle et al. 1995).	
Other habitat characteristics for holding adults	General description of habitat (e.g. turbid or clear waters, lentic or lotic, presence of aquatic plant beds, debris, cover, etc.).	Holding pools reportedly usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day. Adult spring-run Chinook salmon also reportedly seek cover in smaller “pocket” water behind large rocks in fast water (Moyle et al. 1995). Holding pools for adult Spring-run Chinook salmon have reportedly been characterized as having cover such as bubble curtains (DWR et al. 2000).	

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Timing range for adult holding	Time of year (earliest-latest) and duration of stay from upstream migration to spawning.	Adult spring-run Chinook salmon reportedly may hold in their natal tributaries for up to several months before spawning (DWR et al. 2000). Adult Chinook salmon were reportedly seen residing in Jackson Creek, Oregon in the fall of 1992 (Roper and Scarnecchia 1999). Marked juvenile Chinook salmon released in 1953, reportedly returned to the Samish River, Washington as 3- and 4-year old spawners in the falls of 1955 and 1956 (Ellis 1957).	Adult spring-run Chinook salmon holding in the Feather River reportedly occurs for a longer duration than that of adult fall-run Chinook salmon, with the holding period ranging from the arrival in freshwater until the following autumn (Sommer et al. 2001). Adult fall-run Chinook salmon holding in the Feather River reportedly occurs for a relatively short time period, ranging from a few days to a few months (Sommer et al. 2001).
Timing peak for adult holding	Time of year when maximum number of adults are present before spawning.	Returns of adult fall-run Chinook salmon to the Samish River Washington were reportedly greatest during October (Ellis 1957). Adult spring-run Chinook salmon reportedly hold throughout the summer until approximately late-September or mid-October when they spawn (NOAA 1999).	
Adult Immigration and Holding (combined life stage water temperature index values)			
Immigration and holding timing	Time of year adults migrate upstream and hold in rivers. If applicable, indicate for various runs.	In the Central Valley, the upstream migration of adult Chinook salmon reportedly occurs from October to April for the late fall-run, from December to July for the winter-run, from March to September for the spring-run, and from June to December for the fall-run (Fisher 1994).	On the Feather River, the entire adult immigration and holding period lasts from March through October for spring-run Chinook salmon and from mid-July through December for fall-run Chinook salmon (DWR 1982; DWR 2003; Moyle 2002; NOAA 1999; Sommer et al. 2001).
Water temperature index values for adult immigration and holding life stage.	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate stressful or lethal levels.	**Index Value**	**Supporting Literature**

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		60°F	The maximum water temperature for adults holding, while eggs are maturing, is about 59-60 ^{o}F (NOAA 1997); The acceptable water temperature range for adults migrating upstream is 57^{o} to 67 ^{o}F (NOAA 1997); The upper limit of the optimal water temperature range for adults holding while eggs are maturing is 59°F to 60°F (NOAA 2000a); Many of the diseases that commonly affect Chinook become highly infectious and virulent above 60 ^{o}F (ODEQ 1995).
		64°F	The acceptable water temperature range for adults migrating upstream is 57^{o} to 67 ^{o}F (NOAA 1997); Disease risk becomes high at water temperatures above 64.4°F (EPA 2003b); Latent embryonic mortalities and abnormalities associated with water temperature exposure to pre-spawning adults occurs at 63.5°-66.2°F (Berman 1990).
		68°F	The acceptable water temperature range for adults migrating upstream range from 57^{o} to 67 ^{o}F (NOAA 1997); For chronic exposures, an incipient upper lethal water temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68.0°F (Marine 1992); Spring-run chinook salmon embryos from adults held at 63.5-66.2°F had greater numbers of pre-hatch mortalities and developmental abnormalities than embryos from adults held at 57.2°-59.9°F (Berman 1990); Water temperatures of 68°F resulted in nearly 100% mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963).

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Spawning			
Fecundity	Average or range in the number of eggs females lay in a spawning season.	Generally, fecundity of Chinook salmon reportedly ranges from 2,000 to 17,000 eggs per female. The number of eggs increases with body size and may vary among populations and runs (Moyle 2002). A regression model developed by DFG that predicted fecundity of spring-run Chinook salmon females based on form length estimated that Central Valley spring-run Chinook salmon fecundity ranged from 1,350 to 7,193 eggs per female, with a weighted average of 4,161 eggs per female. Estimates of fecundity made in the latter 19th century at Baird Hatchery using the number of females spawned and total egg take reportedly estimated that the fecundity of spring-run Chinook salmon ranged from 3,278 to 4,896 eggs per female, and averaged 4,159 eggs per female between 1877 and 1901 (DWR et al. 2000). Sacramento River fall-run Chinook salmon reportedly have exceptionally high fecundity for a given size. Spring-run Chinook salmon and fall-run Chinook salmon reportedly have fecundity estimates averaging 4,900 eggs per female and 5,500 eggs per female, respectively (Moyle 2002).	Average fecundity of Feather River Chinook salmon females is reported to be 5,522 eggs per female (DWR 2002).
Nest construction	Location and general description of nest -- substrates, aquatic plants, excavations, crevices, habitat types, etc.	Chinook salmon nests are reportedly predominantly constructed in loose gravels or small cobbles. Redd sites are chosen in part by the presence of subsurface flow, and thus redds from previous spawners are desirable places for later fish to spawn causing a phenomenon known as redd superimposition (Moyle 2002). Various studies reportedly have demonstrated the importance of subgravel flow during Chinook salmon redd site selection. During redd site selection, tailspill gravel mounds are reportedly created to stimulate subgravel flow. Redds are generally located at the head of a riffle. Adult Chinook salmon also reportedly	

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		may spawn in sites upstream of large gravel dunes to take advantage of the subgravel flow stimulated by the dunes (Healey 1991).	
Nest size	Size and average dimensions of the nest.	Chinook salmon redds reportedly average approximately 64.6 ft^2 (6 m^2) in size and are generally found in areas relatively free of silt (Raleigh et al. 1986). In the Sacramento-San Joaquin drainages, Chinook salmon redd size reportedly ranges from 22 ft^2 to 486 ft^2 (2.01 m^2 to 45.2 m^2) (USFWS 1995). In a review of several studies, Chinook salmon redd area was reported to range from 26 ft^2 to 43 ft^2 (2.4 m^2 to 4.0 m^2), 42 ft^2 to 70 ft^2 (3.9 m^2 to 6.5 m^2), 43 ft^2 to 161 ft^2 (4.0 m^2 to 15.0 m^2), 5.4 ft^2 to 296 ft^2 (0.5 m^2 to 27.5 m^2), and from 23 ft^2 to 482 ft^2 (2.1 m^2 to 44.8 m^2). Mean redd area was reported in one reviewed study as 102 ft^2 (9.5 m^2) and in another reviewed study as 183 ft^2 (17.0 m^2) (Healey 1991).	
Spawning process	Indicate whether nest builder, broadcast spawner, or other.	The female Chinook salmon reportedly digs a shallow depression in the gravel of the stream bottom in an area of relatively swift water by performing vigorous caudal flexions. The female reportedly deposits a pocket of eggs and covers it with gravel. Over the course of one to several days, the female deposits 4 or 5 pockets of eggs in a line running upstream (USFWS 1995). Female adult Chinook salmon reportedly dig a redd and deposit eggs within the stream sediment where egg incubation, hatching, and subsequent emergence take place following fertilization (DWR et al. 2000).	
Spawning substrate size/characteristics	Range of substrates used during spawning (e.g. mud, sand, gravel, boulders, beds of aquatic plants). Indicate presence of plant/wood debris,	Chinook salmon spawning substrate typically includes a mixture of gravel and small cobbles (Moyle 2002). Chinook salmon spawning substrate size reportedly ranges from 0.11 to 5.9 inches (0.3 to 15.0 cm) gravel	Chinook salmon redds in the Feather River were reportedly constructed in the substrate containing less than 60% fines between 0.2 inches and 1 inch (0.5 to 2.54 cm) (Sommer et al. 2001).

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	crevices at spawning sites. If gravel, indicate range of average size.	(Raleigh et al. 1986).	
Preferred spawning substrate	Indicate preferred spawning substrate (e.g. mud, sand, gravel, boulders, plant bed, etc).	Chinook salmon reportedly spawned in gravel with an average size of 1.7 inches (4.2 cm) in California (Raleigh et al. 1986). The preferred Chinook salmon spawning substrate size reportedly ranged from 0.8 inch to 4.2 inch (2.0 to 10.6 centimeter) gravel (Raleigh et al. 1986). The preferred Chinook salmon spawning substrate size reportedly ranged from 1 inch to 6 inches (2.54 to 15.2 cm) in diameter. The reported optimal Chinook salmon spawning gravel size ranges from 0.5 inches to 4.02 inches (1.3 to 10.2 cm) in diameter; with 80% of the spawning gravel ranging from 0.5 inches to 2.01 inches (1.3 to 5.1 cm) and 20% of the spawning gravel larger than 2.01 inches (5.1 cm) in diameter (Allen et al. 1986). Suitable substrate for Chinook salmon embryos reportedly is a gravel/cobble mixture with a mean diameter of 1 to 4 inches (2.5 to 10.2 cm) and a composition including less than 5% fines (i.e., particles less that 0.3 inches [0.8 cm] in diameter) (DWR et al. 2000).	

Element	Element Descriptor	General	Feather River Specific
Water temperature preference for spawning	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Within the Columbia River, recommended water temperatures for Chinook salmon reportedly range from 45°F to 55°F (7.2°C to 12.8°C) for spawning (Becker 1973). Based on all literature reviewed by the EPA recommended water temperatures reportedly ranged from 42°F to 55°F (5.6°C to 12.8°C) for Chinook salmon spawning (EPA 2001). The reported upper limit of suitable water temperatures for Central Valley spring-run Chinook salmon spawning in the Sacramento River is < 56°F (13.3°C) (NOAA 2002b). The optimal water temperature range for pre-spawning brood stock survival, maturation, and spawning of Chinook salmon in the American River is reported to range from 42.8°F to 57.2°F (6°C to 14°C) (Marine 1992). Data from nine years of surveys support the conclusion that the onset of spawning of Chinook salmon in the lower American River is strongly influenced by a decline in water temperature below 60°F (15.6°C) (SWRI 2001).	
Water velocity range for spawning	Minimum and maximum speed of water current the spawning fish can tolerate.	Chinook salmon reportedly spawn in water velocities ranging from a few cm per second to several meters per second (0.49 to 6.2 ft/sec [0.15 to 1.9 m/sec]) (Moyle 2002). Water velocity ranges from 1.5 ft/sec to 2.5 ft/sec (0.46 to 0.76 m/sec) have been reported for spring-run Chinook salmon spawning and from 1.15 ft/sec to 3.8 ft/sec (0.35 to 1.15 m/sec) for fall-run Chinook salmon spawning (Raleigh et al. 1986). Chinook salmon spawning reportedly occurs in water velocities ranging from 1.2 ft/sec to 3.5 ft/sec (0.4 to	Water velocities measured during Chinook salmon spawning in the Feather River reportedly ranged from 0.04 ft/sec to 4.8 ft/sec (0.01 to 1.5 m/sec) (Sommer et al. 2001).

Element	Element Descriptor	General	Feather River Specific
		1.2 m/sec) (DWR et al. 2000).	
Water velocity preference for spawning	Preferred water current (flow velocity) during spawning.	Water velocity preferences for Chinook salmon spawning reportedly range from 0.98 ft/sec to 2.6 ft/sec (0.3 to 0.8 m/sec) (Moyle 2002). Water velocity preferences for Chinook salmon spawning reportedly range from 1.5 ft/sec to 2.5 ft/sec (0.5 to 0.8 m/sec) (Vogel and Marine 1991). The reported optimal range of water velocities for Chinook salmon spawning occurs from 0.98 ft/sec to 3.0 ft/sec (0.3 to 0.91 m/sec) (Allen et al. 1986).	The central 50% of water velocities measured during observations of spawning Chinook salmon in the Feather River reportedly occurred at water velocities ranging from 1.5 to 2.7 ft/sec (0.5 to 0.8 m/sec) (Sommer et al. 2001).
Water depth range for spawning	Reported range of observed (minimum and maximum) water depth utilization.	Chinook salmon reportedly spawn in water depths ranging from a few cm to several meters (Moyle 2002). Chinook salmon reportedly spawn in water depths greater than 0.8 feet (0.24 meters) (Allen et al. 1986).	Chinook salmon spawners observed in the Feather River reportedly utilized water depths ranging from 0.4 feet to 4 feet (0.1 to 1.2 meters) (Sommer et al. 2001).
Water depth preference for spawning	Reported range of most frequently observed water depth utilization.	Chinook salmon reportedly prefer spawning at water depths of 0.8 to 3.3 feet (0.2 to 1 meters) (Moyle 2002). Chinook salmon reportedly prefer to spawn in water depths exceeding 0.5 feet (0.2 meters) (USFWS 1995).	The central 50% of water depths measured during observations of spawning Chinook salmon in the Feather River ranged from 1.6 feet to 2.6 feet (0.5 to 0.8 meters) (Sommer et al. 2001).
Range for spawning timing	Earliest and latest time of season or year in which spawning occurs.	In the Sacramento River basin, spring-run Chinook salmon spawning reportedly occurs from late August through October, while fall-run Chinook salmon spawning occurs from late September through December (Yoshiyama et al. 1998). In the Sacramento River, spring-run Chinook salmon spawning reportedly occurs from August through October, while fall-run Chinook salmon spawning occurs from October through December (Myers et al. 1998).	Fall-run Chinook salmon reportedly return to the Feather River to spawn from September through December and spawn immediately (Sommer et al. 2001). Spring-run Chinook salmon reportedly spawn in the autumn following their upstream migration (Sommer et al. 2001).
Peak spawning timing	Time of year most fish start to spawn.	In the Sacramento River basin, peak spawning of spring-run Chinook salmon reportedly occurs in mid-September, while peak spawning of fall-run Chinook	Fall-run Chinook salmon spawning in the Feather River reportedly peaks in mid- to late- November (Myers et al. 1998).

Element	Element Descriptor	General	Feather River Specific
		salmon reportedly occurs from October through November (Yoshiyama et al. 1998). In the Sacramento River, peak spawning of spring-run Chinook salmon reportedly occurs from late August through mid-September, while peak spawning of fall-run Chinook salmon reportedly occurs in November (Myers et al. 1998).	
Spawning frequency (iteroparous/ semelparous)	Semelparous - producing all offspring at one time, such as in most salmon. Usually these fish die after reproduction. Iteroparous - producing offspring in successive, e.g., annual or seasonal batches, as is the case in most fishes.	Chinook salmon are semelparous spawners (Moyle 2002).	
Incubation/Early Development			
Egg characteristics	Shape, size, color, in clusters or individuals, stickiness, and other physical attributes.	Chinook salmon egg size and weight in the Pacific Southwest reportedly ranges from 0.2 inches to 0.3 inches (0.5 to 0.8 cm) in diameter and 0.012 ounces to 0.014 ounces (0.35 to 0.40 grams) in weight (Allen et al. 1986).	
Water temperature tolerance for incubation	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	High survival rates of Chinook salmon eggs and fry were reportedly observed at constant water temperatures of 50°F (10.0°C), 45°F (7.2°C), and 40.1°F (4.5°C). Very low survival was reportedly observed at water temperatures greater than 60.8°F (16°C) and at water temperatures less than 33.8°F (1°C) (Raleigh et al. 1986). Water temperatures greater than 59°F (15°C) were reportedly lethal to Chinook salmon embryos and fry (Raleigh et al. 1986). Chinook salmon egg survival rate reportedly decreases at water temperatures above 56°F (13.3°C), and at water temperatures above 62°F (16.7°C) no survival of eggs was observed (USFWS	

Element	Element Descriptor	General	Feather River Specific
		1995). Chinook salmon eggs reportedly have been successfully incubated and hatched at water temperatures ranging from 39.2°F to 60.8°F (4°C to 16°C). However, lower water temperatures reportedly can be tolerated in the later stages of embryonic development. Water temperature tolerance reportedly ranges from 42.4°F to 57.6°F (5.8°C to 14.2°C) in the later stages of embryonic development (Allen et al. 1986). Controlled laboratory experiments on the effects of water temperature to the early development of British Columbia Chinook salmon were conducted at 35.6°F, 39.2°F, 46.4°F, 53.6°F, and 59°F (2°C, 4°C, 8°C, 12°C, and 15°C). The survival rate from fertilization to hatching reportedly was zero at 35.6°F (2°C). Average survival rates were 0.88 at 39.2°F (4°C), 0.994 at 46.4°F (8°C); 0.988 at 53.6°F (12°C); and 0.933 at 59°F (15°C) (Beacham and Murray 1989). In the Sacramento River, at water temperatures ranging from 55°F to 57.5°F (12.8°C to 14.1°C), Chinook salmon egg mortality was reportedly low, but produced fry mortality in excess of 50%. Fry mortality was reportedly reduced to lower levels when eggs were incubated at constant water temperatures ranging from 50°F to 55°F (10°C to 12.8°C), or when water temperatures declined during incubation when initial incubation water temperatures ranged up to 60°F (15.5°C) (Boles et al. 1988). In the American River, Chinook salmon egg survival reportedly was highest when water temperatures ranged from 53°F to 54°F (11.7°C to 12.2°C) (DWR et al. 2000). Water temperatures for maximum survival of Central	

Element	Element Descriptor	General	Feather River Specific
		Valley Chinook salmon eggs and alevins reportedly ranged from 39.2°F to 53.6°F (4°C to 12°C) (Myrick and Cech Jr. 2001). The upper threshold water temperature limit for Sacramento River winter-run Chinook salmon egg incubation reportedly falls between 42°F and 56°F (5.6°C and 13.3°C) (NOAA 1997). Incubation of Sacramento River fall and winter-run Chinook salmon eggs above 56°F (13.3°C) reportedly results in significantly higher alevin mortality (USFWS 1995). Reportedly there is reduced Sacramento River winter-run egg viability and significant egg mortality at water temperatures in excess of 57.5°F (14.2°C) (NOAA 1997). An October 1 through October 31 water temperature criteria of less than or equal to 60°F (15.6°C) in the Sacramento River from Keswick Dam to Bend Bridge has been prescribed for protection of winter-run Chinook salmon late incubating larvae and newly emerged fry (NOAA 1993). A 100% mortality of Chinook salmon reportedly occurs during the yolk-sac stage in groups reared at 60°F (15.6°C) and 62.5°F (16.9°C) (Seymour 1956). Chinook salmon eggs incubated in the Sacramento River at water temperatures greater than 60°F (15.6°C) or less than 38°F (3.3°C) have reportedly suffered high mortalities (Boles et al. 1988). Reportedly there was a 100% mortality of fertilized Chinook salmon eggs incubated at 62°F (16.7°C) after 12 days (USBR 2003b).	

Element	Element Descriptor	General	Feather River Specific
		Water temperatures between 62°F and 64°F (16.7°C and 17.8°C) reportedly appear to be physiologically limiting for Sacramento River fall- and winter-run Chinook salmon embryo development, resulting in 80% to 100% mortality prior to emergence (USFWS 1999). Reportedly there was 100% mortality of Chinook salmon eggs incubated at 64°F (17.8°C) after 7 days and 100% mortality to alevins incubated at 64°F (17.8°C) after 10 days (USBR 2003b). Reportedly there was a 100% mortality of Chinook salmon eggs from Sacramento River stocks when incubated at a constant water temperature of 65°F (18.3°C) or higher (Boles et al. 1988).	
Water temperature preference for incubation	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Maximum Chinook salmon embryo survival reportedly occurs at water temperatures ranging from 41°F to 55.4°F (5°C to 13°C) (Moyle 2002). Water temperatures ranging from 35°F to 58°F (1.7°C to 14.4°C) are recommended for successful Chinook salmon egg incubation (Yoshiyama et al. 1998). Maximum survival of incubating Chinook salmon eggs and yolk-sac larvae reportedly occurs at water temperatures between 41°F and 56°F (5°C and 13.3°C) (USFWS 1995). Controlled laboratory experiments on the effects of water temperature to the early development of British Columbia Chinook salmon were conducted at 35.6°F, 39.2°F, 46.4°F, 53.6°F, and 59°F (2°C, 4°C, 8°C, 12°C, and 15°C). The highest average survival rate (0.994) from fertilization to hatching reportedly occurs at 46.4°F (8°C). Incubation time at this water temperature averaged 70 days (Beacham et al. 1989). The range of suitable water temperatures for Central	

Element	Element Descriptor	General	Feather River Specific
		Valley spring-run Chinook salmon egg incubation and fry emergence is reported to be 48°F to 52°F (8.9°C to 11.1°C) (NOAA 2002b). Optimum water temperatures for winter-run Chinook salmon egg development reportedly ranges from 43°F to 56°F (6.1°C to 13.3°C) (NOAA 1993). The highest survival of Chinook salmon eggs in the Sacramento River reportedly occurred when eggs were incubated at water temperatures of 53°F to 57.5°F (11.7°C to 14.2°C) (Boles et al. 1988). The preferred water temperatures for Central Valley spring-run Chinook salmon eggs and fry reportedly ranged from 53°F to 58°F (11.7°C to 14.4°C) (NOAA 2002b). The "natural rate" of mortality for Chinook salmon alevins reportedly occurs at water temperatures of 58°F (14.4°C) or less (USBR 2003b). There reportedly was a substantial reduction in the survival of incubating Chinook salmon eggs and pre-emergent fry at water temperatures of 60°F (15.6°C) (Placer County Water Agency 2002).	
Time required for incubation	Time duration from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent.	The time required for Chinook salmon egg incubation reportedly ranges from 40 to 60 days in water temperatures ranging from 41°F to 55.4°F (5°C to 13°C) and in saturated oxygen conditions (Moyle 2002). 900 to 1,000 thermal units (TU), are reportedly required for incubation of Chinook salmon eggs (1 T.U. = 1°C above freezing x 24 hours) (Raleigh et al. 1986). In the Sacramento-San Joaquin River drainages, approximately 6 to 9 weeks is required for Chinook	

Element	Element Descriptor	General	Feather River Specific
		salmon egg incubation (USFWS 1995). Controlled laboratory experiments with British Columbia Chinook salmon stocks on the effects of water temperature on early development phase incubation and survival were conducted at 35.6°F, 39.2°F, 46.4°F, 53.6°F, and 59°F (2°C, 4°C, 8°C, 12°C, and 15°C). Egg incubation reportedly averaged 129 days at a water temperature of 39.2°F (4°C). Egg incubation reportedly averages 70 days at 46.4°F (8°C). Egg incubation reportedly averaged 44 days at 53.6°F (12°C), and at 59°F (15°C) egg incubation reportedly averaged 35 days. The survival rates are reportedly highest at 46.4°F (8°C) (Beacham et al. 1989).	
Size of newly hatched larvae	Average size of newly hatched larvae.	In controlled laboratory experiments with British Columbia Chinook salmon stocks, the average size of alevins incubated at water temperatures ranging from 39.2°F to 59°F (4°C to 15°C) reportedly averaged 0.83 inch (2.1 cm) in size (Beacham et al. 1989).	
Time newly hatched larvae remain in gravel	Time of year of hatching, and duration between hatching and emergence from gravel.	After hatching, larvae reportedly remain in the gravel for approximately 4 to 6 weeks until the yolk sac is absorbed (Moyle 2002). The number of days between Chinook salmon hatching and emergence depends on the water temperature. Controlled laboratory experiments with British Columbia Chinook salmon stocks suggest that, depending upon the acclimation temperature, the average number of days to emergence ranges from 62 to 214 days, as illustrated below (Beacham et al. 1989). Acclimation Water Temperature °F (°C) — Average Time to Emergence (days) 39.2°F (4°C) — 214 46.4°F (8°C) — 119 53.6°F (12°C) — 77 59.0°F (15°C) — 62	

Element	Element Descriptor	General	Feather River Specific
Other characteristics of larvae	Alevin -- early life history phase just after hatching (larva) when yolk-sac still present.	Chinook salmon fry reportedly remain in the gravel for two to four weeks until the yolk is absorbed (USFWS 1995). After hatching, Chinook salmon alevins reportedly remain in the gravel interstices for a month or longer. Chinook salmon alevins are negatively phototactic and positively geotactic (movement as reaction to gravity) and thigmotactic (reaction to solid object or touch). These characteristics reportedly serve to prevent premature emergence. Alevins reportedly remain inactive unless forced to disperse in response to excessive levels of carbon dioxide or metabolic waste, or in order to avoid desiccation during low flow (Allen et al. 1986).	In the upper Sacramento River, Chinook salmon fry growth reportedly ranged from 0.009 inch/day to 0.015 inch/day (0.24–0.40 mm/ day), with mean growth of 0.012 inch/day (0.33 mm/day). During the same period, growth of Chinook salmon fry in the San Francisco Bay estuary ranged from 0.02 inch/day to 0.03 inch/day (0.4 to 0.69 mm/day), with mean growth of 0.02 inch/day (0.53 mm/day) (Allen et al. 1986).
Timing range for emergence	Time of year (earliest-latest) hatchlings (larvae and alevins) leave or emerge from the nesting/hatching (gravel) sites.	Chinook salmon juvenile emergence in the Sacramento River Basin reportedly occurs approximately 4 to 6 weeks after hatching and generally occurs from November through March for spring-run Chinook salmon and from December through March for fall-run Chinook salmon (Yoshiyama et al. 1998). Fry emergence of fall-run Chinook salmon in the Snake River, Washington reportedly occurred in late spring and early summer (Connor et al. 2002).	
Timing peak for emergence	Time of year most hatchlings emerge.	Fall-run Chinook salmon in the Snake River, Washington reportedly typically started emigrating in April (Connor et al. 2002).	Spring-run Chinook salmon and fall-run Chinook salmon fry reportedly emerge from spawning gravel as early as November and remain in the stream for at least several weeks (Sommer et al. 2001).
Size at emergence from gravel	Average size of hatchlings at time of emergence.	Fall-run Chinook salmon fry in the Sacramento-San Joaquin River drainages are reportedly typically less than 2 inches (5.1 cm) in length (USFWS 1995). Newly emerged Chinook salmon fry reportedly are approximately 1.4 inches to 1.7 inches (3.6 to 4.3 cm)	

Element	Element Descriptor	General	Feather River Specific
		long and weigh as much as 0.018 ounce (0.5 gram) (Allen et al. 1986). In controlled laboratory experiments with British Columbia Chinook salmon stocks incubated and reared at water temperatures ranging from 39.2°F to 59°F (4°C to 15°C), average size of fry was reported to be approximately 1.4 inches (3.6 cm) (Beacham et al. 1989).	
Spawning and Embryo Incubation (combined life stage water temperature index values)			
Timing Range for spawning and embryo incubation.	Earliest and latest time of season or year in which spawning occurs and the time from fertilization to hatching. Timing for spawning and embryo incubation life stage includes redd site selection by spawning adults, spawning, and embryo incubation.	In the Sacramento River basin, Chinook salmon spawning reportedly occurs from early January to April for the late-fall-run, from late April to early August for the winter-run, from late August to October for the spring-run, and from late September to December for the fall-run (Fisher 1994). The duration of embryo incubation is dependent on water temperature and can be variable (NOAA 2002b). In Butte and Big Chico creeks, emergence of spring-run Chinook salmon reportedly occurs from November through January (NOAA 2002b). In Mill and Deer creeks, colder water temperatures reportedly delay emergence to January through March (DFG 1998). In the lower American River, fall-run Chinook salmon emergence generally begins in March (SWRI 2004).	In the Feather River, adult spawning and embryo incubation reportedly occurs from September through mid-February (DWR 2004).
Water temperature tolerance for spawning and embryo incubation	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate stressful or lethal levels.	**Index Value**	**Supporting Literature**
		56°F	Less than 56°F reportedly results in a

Element	Element Descriptor	General	Feather River Specific
			natural rate of mortality for fertilized Chinook salmon eggs (USBR 2003a); Optimum water temperatures for egg development reportedly are between 43°F and 56°F (NOAA 1993); The upper value of the range provided for maximum survival of eggs and yolk-sac larvae in the Central Valley of California was 56°F (USFWS 1995); The upper value of the range provided for the preferred water temperature for Chinook salmon egg incubation in the Sacramento River was 56°F (NOAA 1997); Incubation water temperatures above 56°F reportedly result in significantly higher alevin mortality (USFWS 1999); The upper limit of suitable water temperatures for spawning spring-run Chinook salmon in the Sacramento River reportedly was 56°F (NOAA 2002b); Water temperatures averaged 56.5°F during the week of fall-run Chinook salmon spawning initiation on the Snake River (Groves and Chandler 1999).
		58°F	The upper limit of the range provided for preferred water temperatures for eggs and fry was 58°F (NOAA 2002b); Constant egg incubation water temperatures between 42.5°F and 57.5°F reportedly resulted in normal development (Combs et al. 1957); The natural rate of mortality for alevins reportedly occurs at 58°F or less (USBR 2003a).
		60°F	100% mortality reportedly occurs during the yolk-sac stage when embryos are incubated at 60°F (Seymour 1956); An October 1- October 31 water

Element	Element Descriptor	General	Feather River Specific
			temperature criteria of less than or equal to 60°F in the Sacramento River from Keswick Dam to Bend Bridge has been required for the protection of late incubating larvae and newly emerged fry (NOAA 1993); Mature females subjected to prolonged exposure to water temperatures above 60°F reportedly have poor survival rates and produce less viable eggs than females exposed to lower water temperatures (USFWS 1995); The mean weekly water temperature at the first observed Chinook salmon spawning in the Columbia River reportedly was 59.5°F (Dauble and Watson 1997); Consistently higher egg losses reportedly resulted at water temperatures above 60.0°F than at higher temperatures (Johnson and Brice 1953).
		62°F	100% mortality of fertilized Chinook salmon eggs was reported after 12 days at 62°F (USBR 2003a); Incubation water temperatures of 62°F to 64°F reportedly appear to be the physiological limit for embryo development resulting in 80% to 100% mortality prior to emergence (USFWS 1999); 100% loss of eggs reportedly occurred when incubated at water temperatures above 62°F (Hinze 1959).
		64°F	100% mortality of fertilized Chinook salmon eggs reportedly occurred after being incubated for 7 days at 64°F, and 100% mortality of alevins reportedly occurred after being incubated at 10 days at 64°F (USBR 2003a); Incubation at 64°F reportedly resulted in 100% mortality of winter-run Chinook salmon

Element	Element Descriptor	General	Feather River Specific
			(USFWS 1999).
Juvenile Rearing			
General rearing habitat and strategies	General description of freshwater environment and rearing behavior.	Fall-run Chinook salmon juveniles reportedly emerge from the gravel and move downstream within a few months to rear in mainstem rivers before emigrating to the ocean (Moyle 2002). Spring-run Chinook salmon reportedly may rear in streams for 3-15 months, depending on flow conditions (Moyle 2002). Movement of Chinook salmon fry reportedly occurs mostly at night and tends to cease after a few weeks, when fry settle into rearing habitat. Reportedly, there is a shift in microhabitat utilization by juvenile Chinook salmon to deeper and faster water as they grown larger. Microhabitat use and foraging behavior reportedly can be influenced by the presence of predators, which may result in selection of habitat with heavy cover. Additionally, during the night, juvenile Chinook salmon may abandon foraging areas in swift-moving water in favor of quiet edgewaters or pools (Moyle 2002).	
Water temperature tolerance for juvenile rearing	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Rearing juvenile Chinook salmon reportedly can tolerate water temperatures ranging from 32°F to 75.2°F (0°C to 24°C) (Raleigh et al. 1986). The lethal water temperature limits of young Chinook salmon, based on laboratory experiments as reported by (Brett 1952) are presented below Acclimation Water Temperature / Lower lethal limit / Upper lethal limit 75.2°F (24°C) / 45.3°F (7.4°C) / 77.2°F (25.1°C) 68°F (20°C) / 40.1°F (4.5°C) / 77.2°F (25.1°C) 59°F (15°C) / 36.5°F (2.5°C) / 77°F (25.0°C) 50°F (10°C) / 33.4°F (0.8°C) / 75.7°F (24.3°C)	The upper lethal water temperature limit for juvenile Chinook salmon in a laboratory study conducted at the Nimbus and Feather River hatcheries and at the Tracy pumping station reportedly was 78.5°F (25.8°C) for juveniles acclimated between 55ºF and 73°F (12.8°C and 22.8°C) (Orsi 1971).

Element	Element Descriptor	General	Feather River Specific
		41°F (5°C) —— 70.7°F (21.5°C) For Chinook salmon fry from a Washington River, the most rapid growth at a constant water temperature reportedly occurred at 55°F (12.8°C). At variable water temperatures, the maximum growth rate reportedly occurred at water temperatures near 60°F (15.6°C) (Seymour 1956). At the Nimbus Hatchery, juvenile Chinook salmon reportedly achieve optimum growth under laboratory conditions at water temperatures ranging from 54°F to 60°F (12.2°C to 15.6°C) (Rich 1987). Juvenile fall-run Chinook salmon in a Washington laboratory study reportedly had optimum propagation at a water temperature of 60°F (15.6°C) (Banks et al. 1971). Juvenile Chinook salmon in British Columbia reportedly achieved optimum growth under laboratory conditions when fed maximum ration and water temperatures averaged 66°F (18.9°C). Optimum food conversion efficiency during the study reportedly occurred at water temperatures ranging from 67°F to 68°F (19.4°C to 20°C) (Brett et al. 1982). In the Sacramento River, the upper lethal water temperature limit for chronically exposed Chinook salmon is reported to be 78.5°F (25.8°C), although higher water temperatures can be tolerated for brief periods of time (Boles et al. 1988). In the Sacramento River from Keswick Dam to Bend Bridge a water temperatures less than or equal to 60°F (15.6°C) has been prescribed from October 1 through October 31 for the protection of winter-run Chinook salmon late incubating larvae and newly emerged fry (NOAA 1993).	

Element	Element Descriptor	General	Feather River Specific
		Sacramento River Chinook salmon fry reportedly cannot tolerate water temperatures above 60°F to 61°F (15.6°C to 16.1°C) (Healey 1977). The preferred water temperature for Central Valley spring-run Chinook salmon in the Sacramento River is reported by (NOAA 2002b) to be 60°F (15.6°C). Brett et al. (1952) *in* Raleigh et al. (1986) reported that excellent growth of juvenile Chinook salmon occurred at test water temperatures ranging from 59°F to 66.2°F (15°C to 19°C). Growth reportedly slowed significantly at water temperatures $\geq$ 66.2°F (19°C) and mortality was "excessive" at 76.6°F (24.8°C). Survival of Central Valley Chinook salmon juveniles reportedly declines as water temperatures increase above 64.4°F to 75.2°F (18°C to 24°C) (Myrick et al. 2001). The upper lethal water temperature limit for juvenile Chinook salmon is reported to be 67.6°F (19.8°C) (Bell 1991; Chambers 1956; Leidy and Leidy 1984; McEwan and Nelson 1991; Raleigh et al. 1986; Reiser and Bjornn 1979; Rich 1987; Oregon Department of Fish and Wildlife and Oregon Department of Forestry 1995). Coutant (1972) *in* McCullough (1999) reported that the upper lethal water temperature for juvenile Chinook salmon measuring 39 mm to 124 mm in the Columbia River is 74.3°F (23.5°C) when acclimated at a water temperature of 64.4°F (18°C). Coutant (1972) and Armour (1991) *in* McCullough (1999) reported that the upper lethal water temperature for hatchery reared juvenile Chinook	

Element	Element Descriptor	General	Feather River Specific
		salmon 3.6 months old is 77.2°F (25.1°C) when the acclimation water temperature ranged from 59°F to 75.2°F (15°C to 24°C). Coutant (1972), and Blahm and McConnell (1970) *in* McCullough (1999) reported that the upper lethal water temperature limit for hatchery raised juvenile Chinook salmon 90.6 mm in length ranged from 75.6°F to 76.1°F (24.2°C to 24.5°C) when the acclimation water temperature ranged from 51.8°F to 68°F (11°C to 20°C). The upper lethal water temperature for juvenile Chinook salmon reportedly is 77.2°F (25.1°C), when acclimation water temperatures range from 68°F to 75.2°F (20°C to 24°C) (EPA 2001). The upper lethal water temperature for juvenile Chinook salmon reportedly ranges from 73.4°F to 78.8°F (23°C to 26°C) (EPA 2001). The upper lethal water temperature for juvenile Chinook salmon on the Columbia River reportedly ranges from 74.8°F to 77.2°F (23.8°C to 25.1°C)(Becker 1973); (Brett 1952); (Orsi 1971). The water temperature reported as lethal to juvenile Chinook salmon after a one-week exposure reportedly ranges from 73.4°F to 78.8°F (23°C to 26°C) (Palmer 2003). Burck et al. (1980) *in* McCullough (1999) reported that Chinook salmon juveniles were not found in areas of the North Fork and Middle Fork John Day River, Oregon having mean weekly water temperatures of 69.8°F to 71.6°F (21°C to 22°C). Lindsay et. al. (1986) *in* McCullough (1999) reported that no juvenile Chinook salmon were found in	

Element	Element Descriptor	General	Feather River Specific
		reaches of the North Fork John Day River, Oregon where water temperatures exceeded 73°F (22.8°C). During rising water temperature conditions, the water temperature reported as lethal to juvenile Chinook was 77°F (25°C) (Cherry et al. 1977). Growth of juvenile Chinook salmon reportedly increased when water temperatures ranged from 44.6°F to 62.6°F (7°C to 17°C) (Clarke and Shelbourn 1985). The EPA et al. (2001) reported water temperatures for optimal growth of juvenile Chinook salmon range from 59°F to 68°F (15°C to 20°C). When feeding in water temperatures between 50°F to 60°F (10°C to 15.6°C) the growth rates of juvenile Chinook salmon were reported to be >80% of the maximum level observed (Brett et al. 1982). Burrows (1963) *in* Becker (1973) reported that, in the Columbia River, maximum production of fingerling Chinook salmon occurred at water temperatures between 50°F and 59°F (10°C to 15°C). The water temperature range recommended by EPA (1971) for Chinook salmon production in the Columbia River is 50°F to 60°F (10°C to 15.6°C) The water temperature range reported for optimum growth of juvenile Chinook salmon is 50°F to 60°F (10°C to 15.6°C) (Burrows 1963). Fingerling Chinook salmon reared in water temperatures >65°F (18.3°C) reportedly contracted columnaris and experienced high mortality rates (Johnson et al. 1953); (Bisson and Davis 1976; Marine 1997).	

Element	Element Descriptor	General	Feather River Specific
		The water temperature range reported for positive growth of juvenile Chinook salmon is 40.1°F to 66.4°F (4.5°C to 19.1°C) (Armour 1991). The water temperature range reported for maximum productivity of fingerling Chinook salmon is 50°F to 60°F (10°C to 15.6°C) (Burrows 1963). First feeding Chinook salmon fingerlings reportedly did not rear normally above water temperatures of 55.5°F (13.1°C) (Burrows 1963). McCullough (1999) reported that, at a water temperature of 66.4°F (19.1°C), the mortality rate in juvenile Chinook salmon populations is equal to the growth rate. Juvenile Chinook salmon reportedly avoided water temperatures below 59°F and above 78.8°F (15°C and 26°C) (Cherry et al. 1977). Juvenile Chinook salmon mortality rates due to columnaris disease reportedly were negligible at water temperatures ≤55°F (12.8°C), but significant increases in mortality reportedly occurred at water temperatures above 59°F (15°C)(EPA 2001; Fish and Rucker 1943). The water temperature threshold at which disease infection rates in juvenile Chinook salmon reportedly increase is 60°F (15.6°C) (Burrows 1963). Columnaris infection rates and associated mortality rates reportedly were high in fingerling Chinook salmon reared in water temperatures above 65°F (18.3°C) (Johnson et al. 1953). Rearing and emigrating Central Valley juvenile spring-	

Element	Element Descriptor	General	Feather River Specific
		run Chinook salmon in Clear Creek reportedly preferred water temperatures between 50°F and 60°F (10°C to 15.6°C) (NOAA 2002b). Water temperatures above 62.6°F (17°C) reportedly resulted in a deterioration of successful Chinook salmon smolt transformation in the Central Valley (Myrick et al. 2001). Reportedly, osmoregulatory pre-adaptation to seawater was highest when juvenile Chinook salmon reared in water temperatures ranging from 50°F to 63.5°F (10°C to 17.5°C) (Clarke et al. 1985). Marine (1997) reported that data indicate that both acceleration and inhibition of Sacramento River Chinook salmon smoltification may occur at water temperatures above 62.6°F (17°C). Significant inhibition of gill sodium ATP-ase activity and associated reductions of hypoosmoregulatory capacity also may occur when chronic elevated water temperatures exceed 68°F (20°C).	
Water temperature preference for juvenile rearing	Range of suitable, preferred, or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Chinook salmon fingerlings rearing in a hatchery environment reportedly preferred water temperatures ranging from 53.6°F to 57.2°F (12°C to 14°C)(Brett 1952; Banks et al. 1971). A water temperature of 60°F (15.6°C) was reported as optimal for growth of fingerling Chinook salmon based on laboratory experiments comparing growth at 50°F (10°C), 55°F (12.8°C), 60°F (15.6°C), and 65°F (18.3°C) (Banks et al. 1971). Reported optimal water temperatures for Chinook salmon fry rearing range from 50°F to 54°F (10°C to 12.2°C) (Rich 1997). In the Sacramento River, preferred water temperatures for rearing Chinook salmon fry	

Element	Element Descriptor	General	Feather River Specific
		reportedly range from 53°F to 57.5°F (11.7°C to 14.2°C) (Boles et al. 1988). In the Sacramento River rearing fingerling Chinook salmon reportedly preferred water temperatures ranging from 53.6°F to 57.2°F (12°C to 14°C). Maximum growth reportedly occurs in rearing fingerling Chinook salmon in the Sacramento River reportedly at 55°F (12.8°C) (Boles et al. 1988). Spring-run Chinook salmon fry in Washington reportedly preferred a constant water temperature of 54°F to 55°F (12.2°C to 12.8°C) (Brett 1952). In the Columbia River, rearing Chinook salmon reportedly preferred water temperatures ranging from 50°F to 60°F (10°C to 15.6°C) (Becker 1973). In a laboratory study, juvenile American River fall-run Chinook salmon reportedly achieved maximum growth in water temperatures ranging from 55°F to 60°F (12.8°C to 15.6°C) (Rich 1987). In a laboratory study, juvenile American River fall-run Chinook salmon reportedly achieved maximum growth and food conversion efficiency at a water temperature of 66°F (19°C). The experiments were conducted at oxygen levels greater than 90% of saturation levels and in pathogen free water (Cech Jr. and Myrick 1999). Water temperatures reported as optimal for Sacramento River winter-run Chinook salmon fry are within the range of 53.6°F to 57.2°F (12°C to 14°C), with maximum growth reportedly occurring at 55°F (12.8°C) (NOAA 1997). Water temperatures between 53°F and 58°F (11.7°C to 14.4°C) reportedly are preferred for spring-run	

Element	Element Descriptor	General	Feather River Specific
		Chinook salmon eggs and fry (NOAA 2002b). Rearing spring-run juvenile Chinook salmon with mean fork lengths of 1.7 inches (3.6 months old) reportedly preferred a water temperature range of 53.6°F to 57.3°F (12°C to14.1°C) (Brett 1952; Boles et al. 1988; NOAA 1993). The optimal water temperature range for growth of winter-run Chinook salmon in estuaries reportedly is 54°F to 57°F (12.2°C to 13.9°C) (Brett 1952 *in* NOAA 1997). The optimal water temperature range for Central Valley Chinook salmon survival and growth reportedly is 53°F to 64°F (11.7°C to 17.8°C) (Raleigh 1986 *in* USFWS 1995). The optimum water temperature range for rearing Chinook salmon juveniles reportedly is 53°F to 56.1°F (11.7°C to 13.4°C) (Bell 1991;Chambers 1956; Leidy et al. 1984; McEwan et al. 1991; Raleigh et al. 1986; Reiser et al. 1979; Rich 1987; Oregon Department of Fish and Wildlife et al. 1995). The optimum water temperature recommended for juvenile Chinook salmon growth reportedly is 59°F (15°C) (Banks et al. 1971). The water temperature reported for optimum growth of juvenile Chinook salmon fed on 60% of maximum ration is 58.6°F (14.8°C) (Brett et al. 1982). The water temperature reported for optimum growth of juvenile Chinook salmon fed on unlimited rations is 66.2°F (19°C) (Brett et al. 1982). The preferred water temperature reported for rearing juvenile Chinook salmon is 58.3°F (14.6°C)(Reiser et	

Element	Element Descriptor	General	Feather River Specific
		al. 1979). The preferred water temperature range reported for Sacramento River Chinook salmon fingerlings is 53.6°F to 57°F (12°C to 13.9°C) (Brett 1952; Boles et al. 1988). The preferred water temperature range reported for rearing juvenile Chinook salmon is 53.6°F to 58.5°F (12°C to 14.7°C) (McCullough 1999). The preferred water temperature reported for rearing juvenile Chinook salmon is less than 66.2°F (19°C) (Cherry et al. 1977) Juvenile Chinook salmon reportedly prefer water temperatures less than 71.6°F (22°C) (Myers et al. 1998).	
Water velocity ranges for rearing juveniles	Reported range of observed (minimum and maximum) water velocity utilization.	Water velocities selected by Young-of-Year Chinook salmon reportedly ranged from 0 to 2.0 ft/sec (0 to 0.6 m/sec) (Raleigh et al. 1986).	
Water velocities preferred by rearing juveniles	Reported range of most frequently observed water velocity utilization.	Water velocities preferred by Young-of-Year Chinook salmon reportedly ranged from 0 to <1.3 ft/sec (0 to <0.4 m/sec) (Raleigh et al. 1986). Chinook salmon juveniles reportedly prefer water velocities ranging from 0.20 to 0.79 ft/sec (0.06 to 0.24 m/sec) (Allen et al. 1986).	
Water depth range for juvenile rearing	Reported range of observed (minimum and maximum) water depth utilization.	Chinook salmon fry and juveniles reportedly have been observed in pools at depths greater than 0.5 feet (0.2 meters) (Raleigh et al. 1986). Based on habitat suitability curves, Chinook salmon fry reportedly utilize depths ranging from 0.1 feet (0.3 meters) to approximately 4.9 feet (1.5 meters) (Raleigh et al. 1986).	
Water depth preference for	Reported range of most frequently observed water depth	Based on habitat suitability curves, Raleigh et al. (1986) reported that Chinook salmon fry prefer depths	

Element	Element Descriptor	General	Feather River Specific
juvenile rearing	utilization.	ranging from approximately 0.9 feet (0.3 meters) to approximately 2.0 feet (0.6 meters).	
Cover preferences for rearing juveniles	Type of cover for protection from predators used by rearing juveniles (e.g. crevices, submerged aquatic vegetation, overhanging vegetation, substrate cover, undercover bank, small woody debris, large woody debris).	According to Moyle (2002), after emerging from the gravel, Chinook salmon fry are generally washed downstream into back- or edge-water areas, where velocities are low, cover is dense, and small food items are abundant. Juvenile Chinook salmon preferred habitat reportedly includes abundant instream and overhead cover (e.g., undercut banks, submerged and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrate and larval fish prey. Additionally, rearing fry reportedly use low velocity areas where substrate irregularities and other habitat features create velocity refuges and they may increasingly rely on turbidity as cover (DWR et al. 2000).	
Food base of juveniles	Indicate primary diet components. Also indicate the diet changes, if any, as growth occurs.	In streams, Chinook salmon fry are reported to feed mainly on drifting terrestrial and aquatic insects, but zooplankton become more important in lower river reaches and estuaries (USFWS 1995). According to DWR and USBR (2000), chironomids (midges) are typically cited as an important prey source for juvenile Chinook salmon upstream of the Delta, whereas crustaceans may be more important in the western Delta. In the Sacramento and American rivers, small Chinook salmon (1.6 to 3.1 inches [4.1 to 7.9 cm] FL) reportedly feed mainly on larvae and pupae of chironomid midges, baetid mayfly larvae and adults, and hydropsychid caddisfly larvae and adults (Moyle 2002). In the Sacramento-San Joaquin Delta, terrestrial insects reportedly are the most important food item	

Element	Element Descriptor	General	Feather River Specific
		for rearing juvenile Chinook salmon, but crustaceans are also eaten (Moyle 2002).	
Feeding habits of rearing juveniles	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder. Also indicate change of feeding habits growth occurs.	Reportedly, juvenile Chinook salmon are opportunistic drift feeders that eat a wide variety of terrestrial and aquatic insects. They feed mostly during the day, with peak feeding activity occurring at dawn and during the afternoon (Moyle 2002).	
Predation of juveniles	Indicate which species prey on juveniles.	According to NOAA (1988), Sacramento pikeminnow constitute a serious problem for native salmonid populations. Because rearing conditions in the Sacramento River include warm water, low and irregular flow, standing water, and water diversions, they are more conducive to warmwater species such as Sacramento pikeminnow and striped bass than to native salmonids (NOAA 1998).	
Timing range for juvenile rearing	Range of time of year (months) during which rearing occurs.	Juvenile Chinook salmon reportedly were collected from May to June in seven nonnatal tributaries of the lower Fraser River in British Columbia (Murray and Rosenau 1989).	Juvenile Chinook salmon rearing in the Feather River reportedly occurs for several weeks after emergence (Sommer et al. 2001). Rearing locations for Feather River juvenile Chinook salmon are reportedly largely unknown, but in wetter years juveniles rear for weeks to months in Yolo bypass floodplain immediately downstream of the Feather River before migrating to the estuary (Sommer et al. 2001).
Timing peak for juvenile rearing	Time of year (months) during which most rearing occurs.		
Juvenile Emigration			
Time spent in fresh water prior to emigrating	Duration (in years and/or months) from emergence to emigration to the ocean.	In the Sacramento River Basin, juvenile Chinook salmon stream residency, from emergence to emigration, reportedly ranges from three to 15 months for spring-run Chinook salmon, and one to seven months for fall-run Chinook salmon (Yoshiyama et al.	

Element	Element Descriptor	General	Feather River Specific
		1998). For Chinook salmon runs in the Sacramento-San Joaquin River drainages, juveniles reportedly spend less than 1 year in fresh water prior to emigration to the ocean (Myers et al. 1998).	
Water temperature tolerances during emigration	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Based on studies of steelhead and coho salmon, water temperatures ranging from 50°F to 55°F (10°C to 12.8°C) have been recommended by DWR and USBR (2000) as the optimal thermal range for smoltification and emigration of juvenile Chinook salmon.	
Water temperature preferences during emigration	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Water temperatures ranging 50°F to 55°F (10°C to 12.8°C) are reported to be optimal for Chinook salmon smoltification (Rich 1987). In a British Columbia laboratory study, fall-run Chinook salmon reportedly had the highest osmoregulatory preadaptation at water temperatures ranging from 50°F to 63.5°F (10°C to 17.5°C) (Clarke et al. 1985). Central Valley spring-run Chinook salmon in Clear Creek preferred a water temperature range of 50°F to 60°F (10°C to 15.6°C) for rearing and emigration (NOAA 2002b).	
Emigration timing range	Time of year juveniles commence emigration and duration of emigration	In the Sacramento River Basin, spring-run Chinook salmon reportedly emigrate from March through June and from November through March, while fall-run Chinook salmon emigration occurs from March through July (Yoshiyama et al. 1998). Many subyearling fall-run Chinook salmon in the Snake River reportedly began seaward movement in the summer and fall, overwintered in reservoirs, and then resumed emigration in the spring (Connor et al. 2002).	Emigration of juvenile Chinook salmon in the Feather River reportedly occurs from December through June (Sommer et al. 2001). Emigration of juvenile Chinook salmon in the Feather River reportedly occurs from November through June (DWR 2002).

Element	Element Descriptor	General	Feather River Specific
		In the Rogue River, Oregon juvenile spring-run Chinook salmon reportedly reside in the upper portion of the river and begin seaward migration in June. By September, they have reportedly left the upper portions of the river (Buckman and Ewing 1982). Chinook salmon reportedly started emigrating form their upstream natal tributaries of Hawks Creek, British Columbia in mid-April and emigration ended by late June (Scrivener et al. 1994).	
Emigration timing peak	Time of year most juveniles are emigrating.	Approximately 98% of juvenile fall-run Chinook salmon in the Snake River reportedly reached parr size and started emigrating by the end of May (Connor et al. 2002). Reportedly, Chinook salmon reared at Cole Rivers Hatchery, Oregon have shown peaks of activity in September and November whereas fish reared at the Corvallis Fish Research Laboratory consistently have shown a single peak activity in October (Buckman et al. 1982) Within Hawks Creek, British Columbia peak emigration for Chinook salmon reportedly occurred during mid-May (Scrivener et al. 1994).	Most juvenile Chinook salmon in the Feather River reportedly emigrate as fry from February through April (Sommer et al. 2001). Emigration of fall-run Chinook salmon in the Feather River reportedly peaks in February. Rotary screw trap data from 1998-2000 indicates that 96% of juvenile Chinook salmon caught were caught in January through March. Nearly all fall-run size juvenile Chinook salmon (>95%) emigrate from the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet within a few weeks after emergence (DWR 2002). Based on 1998-2000 rotary screw trap data, emigration of spring-run juvenile Chinook salmon in the Feather River reportedly peaks in December. Additionally, another pulse of juvenile emigrants reportedly appears at Live Oak in April and May (DWR 2002).
Size range of juveniles during emigration	Minimum and maximum sizes (inches or mm) of emigrating juveniles. Indicate average size.	Reportedly, the average size of subyearling fall-run Chinook salmon smolts sampled at the ocean entrance was 3.5 inches (88 mm), while the average size for subyearling spring-run Chinook salmon	Of the fall-run Chinook salmon caught at the Thermalito Afterbay Outlet rotary screw trap between 1998 and 2000, reportedly 96.6% were less than 2

Element	Element Descriptor	General	Feather River Specific
		smolts reportedly was 3.3 inches (83 mm) (Myers et al. 1998). Emigrating juveniles in the upper Sacramento River reportedly are greater than 2.8 inches (70 mm) in size. Fry greater than 2.8 inches (70 mm) reportedly have been observed rearing in the Sacramento-San Joaquin estuary for 2 months before entering ocean (Myers et al. 1998). Chinook salmon fry emigrants reportedly range from 1.2 to 1.8 inches (30 to 45 mm) in fork length and fingerling emigrants range from 2 to 4.7 inches (50 to 120 mm) in fork length (Healey 1991). Fall-run Chinook salmon smolts reportedly average 3.15 inches (80 mm) total length when they leave the Sacramento-San Joaquin Estuary (Allen et al. 1986).	inches (50 mm) long, and 81.4 % of the fall-run Chinook salmon caught at the Live Oak rotary screw trap were less than 2 inches (50 mm). Emigrating salmon reportedly ranged from 0.9 to 8.3 inches (24 to 210 mm) fork length (DWR 2002). Reportedly, in the Feather River, the majority of Chinook salmon emigrants are “pre-smolt” (i.e., are less than 2 inches (<50 mm) (DWR 2002).
Factors associated with emigration	Pulse flows, water temperature changes, turbidity levels, photoperiod, etc.	Curet (1994) reported that juvenile fall-run Chinook salmon remained along the shoreline of Lower Granite Reservoir, Washington later into the year when the water was cool and dispersal from the shoreline occurred when water temperatures exceeded 64.4°F (18°C) (Connor et al. 2002). The physiological changes that prepare Chinook salmon for seaward migration reportedly include increases in osmoregulatory capacity and increases in gill sodium–potassium ATPase (adenosine triphosphatase) (Buckman et al. 1982). Hatchery subyearling fall-run Chinook salmon reportedly migrated during high flows in the Snake River (Tiffan et al. 2000). It has been reported that, on average, two thirds of yearly Chinook salmon smolt runs in the upper South Umpqua River basin, Oregon occurred when the moon was either waning or new (Roper et al. 1999).	

Element	Element Descriptor	General	Feather River Specific
Juvenile Rearing and Downstream Movement (combined life stage water temperature index values)			
Juvenile rearing and emigration timing range	Range of time of year (months) during which rearing occurs and time and duration of juvenile emigration. The juvenile life stage is comprised of fry, fingerlings, and smolts	In the Sacramento River basin, the duration that juvenile Chinook salmon rear in natal streams varies according to run-type. Late-fall-run juvenile Chinook salmon reportedly emerge from the spawning substrate as fry from April-June and rear in their natal stream for 7-13 months (Fisher 1994). Winter-run juvenile Chinook salmon reportedly emerge from the spawning substrate from July-October and rear for 5-10 months (Fisher 1994). Spring-run juvenile Chinook salmon reportedly emerge from the spawning substrate from November-March and rear for 3-15 months (Fisher 1994). Fall-run juvenile Chinook salmon reportedly emerge from the spawning substrate from December-March and rear for 1-7 months (Fisher 1994). Recent studies from the American and Feather Rivers indicate that most juvenile Chinook salmon emigrate as fry shortly after they emerge from the spawning gravel (DWR 2002; Snider and Titus 2000). In the Sacramento River, juvenile Chinook salmon reportedly move downstream during all months, as both fry and smolts (Moyle 2002).	
Water temperature tolerances during juvenile rearing and emigration	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate stressful or lethal levels.	**Index Values**	**Supporting Literature**
		60°F	The optimum water temperature for Chinook salmon fry growth reportedly is between 55.0°F and 60°F (Seymour 1956); The water temperature range that reportedly produced optimum growth in juvenile Chinook salmon was between 54.0°F and 60.0°F (Rich 1987); A water

Element	Element Descriptor	General	Feather River Specific
			temperature of ≤60.0°F for the protection of Sacramento River winter-run Chinook salmon from Keswick Dam to Bend Bridge was recommended (NOAA 1993); The upper limit of the optimal water temperature range for Sacramento River fall-run Chinook salmon fry and fingerlings was reported as 60.8°F (Marine 1997); The upper water temperature reportedly preferred by spring-run Chinook salmon fry and fingerlings during growth and development was 60.0°F (NOAA 2000a; NOAA 2002b); To protect fry and juvenile Chinook salmon in the upper Sacramento River, daily average water temperatures should not exceed 60°F after September 30 according to NOAA Fisheries (NOAA 1997); A water temperature of 60°F reportedly appeared closest to the optimum for growth of fingerlings (Banks et al. 1971); Optimum growth of Nechako River Chinook salmon juveniles reportedly would occur at 59°F at a feeding level that is 60% of that required to satiate them (Brett et al. 1982).
		63°F	Acceleration and inhibition of Sacramento River Chinook salmon smolt development reportedly may occur at water temperatures above 62.6°F (Marine 1997); Laboratory evidence suggests that survival and smoltification become compromised at water temperatures above 62.6°F (Zedonis and Newcomb 1997); Juvenile Chinook salmon growth reportedly was highest at 62.6°F (Clarke et al. 1985).
		65°F	Water temperatures between 45-65^{o} F

Element	Element Descriptor	General	Feather River Specific
			reportedly are preferred for growth and development of fry and juvenile spring-run Chinook salmon in the Feather River (NOAA 2002a); A summer maximum water temperature of 64.4°F was recommended for migration and non-core rearing (EPA 2003a); Water temperatures >64.0ºF were considered "not properly functioning" by NOAA Fisheries in Amendment 14 to the Pacific Coast Salmon Plan (NOAA 1995); Fatal infection rates caused by *C. columnaris* reportedly were high at water temperatures ≥64.0ºF (Fryer and Pilcher 1974 *in* McCullough 1999). Disease mortalities reportedly diminish at temperatures below 65.0ºF (Ordal et al. 1963); Fingerling Chinook salmon reared in water >65.0ºF reportedly contracted *C. columnaris* and exhibited high mortality rates (Johnson et al. 1953); Water temperatures >64.9ºF were identified as being stressful in the Columbia River Ecosystem (Independent Scientific Group 1996 *in* EPA 2003a); Juvenile Chinook salmon reportedly have an optimum water temperature for growth that appears to occur at about 66.2°F (Brett et al. 1982); Juvenile Chinook salmon reportedly obtained maximum growth rates at 66.2°F (Cech Jr. et al. 1999); The optimal range for Chinook salmon survival and growth was reported to be between 53.0°F and 64.0°F (USFWS 1995); The survival of Central Valley juvenile Chinook salmon reportedly declines at water temperatures greater than 64.4°F (Myrick et al. 2001);

Element	Element Descriptor	General	Feather River Specific
			Increased incidence of disease, reduced appetite, and reduced growth rates reportedly occur at 66.2°F ± 1.4°F (Rich 1987).
		68°F	Sacramento River juvenile Chinook salmon reared at water temperatures ≥ 68.0°F reportedly suffer reductions in appetite and growth (Marine 1997); Significant inhibition of gill sodium ATPase activity and associated reductions of hypoosmoregulatory capacity, and significant reductions in growth rates, reportedly may occur when chronic elevated temperatures exceed 68°F (Marine 1997); Water temperatures supporting smoltification of fall-run Chinook reportedly range between 50°F and 68°F. Water temperatures between 50°F and 62.6°Freportedly represent more optimal conditions while water temperatures between 626 °F and 68°F reportedly represent marginal conditions (Zedonis et al. 1997); Juvenile spring-run Chinook salmon reportedly were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck et al. 1980 *in* McCullough 1999); Results from a study on wild spring-run Chinook salmon in the John Day River system, Oregon, indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (Lindsay et al. 1986 *in* McCullough 1999).
		70°F	Reportedly, no growth occurred in Nechako River juvenile Chinook salmon at 70.5°F (Brett et al. 1982); Juvenile spring-run Chinook salmon reportedly

Element	Element Descriptor	General	Feather River Specific
			were not found in areas having mean weekly water temperatures between 67.1°F and 71.6°F (Burck et al. 1980 *in* McCullough 1999); Results from a study on wild spring-run Chinook salmon in the John Day River system indicate that juvenile fish were not found in areas having mean weekly water temperatures between 67.1°F and 72.9°F (Lindsay et al. 1986 *in* McCullough 1999); Increased incidence of disease, hyperactivity, reduced appetite, and reduced growth rates reportedly occur at 69.8 ± 1.8 (Rich 1987)
		75°F	For juvenile Chinook salmon in the lower American River fed maximum rations under laboratory conditions, 75.2ºF reportedly was determined to be 100 percent lethal due to hyperactivity and disease (Rich 1987); The lethal water temperature threshold for fall-run juvenile Chinook salmon reportedly was between 74.3°F and 76.1°F (National Academy of Sciences 1972 *in* McCullough 1999).
Other Potential Factors			
Dissolved oxygen	Levels of dissolved oxygen in water expressed in mg/l tolerated by fish.	Based on laboratory studies, survival from embryo to fry reportedly is highest at dissolved oxygen (DO) concentrations of 10.5 mg/l and lowest at 3.5 mg/l for all water temperatures tested including 50.9°F, 53.6°F, 56.3°F, and 59°F (10.5°C, 12.0°C, 13.5°C and 15.0°C) (Raleigh et al. 1986). The minimum dissolved oxygen concentration required for Chinook salmon is reported to be 8 mg/l. Chinook salmon juveniles reportedly can survive short-term exposure to DO concentrations of 3 mg/l at a water temperature of 41°F (≤5°C). Optimal levels of dissolved oxygen are reportedly greater than 9 mg/l at	

Element	Element Descriptor	General	Feather River Specific
		water temperatures less than 50°F (10°C) and 13 mg/l at water temperatures greater than 50°F (10°C) (Raleigh et al. 1986). Chinook salmon egg incubation is reported as optimal when water is saturated with dissolved oxygen. Dissolved oxygen concentrations of less than 1.6 mg/l reportedly are lethal (Allen et al. 1986).	
pH	Alkalinity/acidity of water (expressed in pH) that fish can tolerate.	Chinook salmon reportedly tolerate a pH range of 5.5 to 9.0, with the optimal range reported as 6.8 to 8.0 (Raleigh et al. 1986).	
Turbidity	Indicate turbidity or state of water (e.g., clear water or presence of siltation or organic/inorganic matter in water) that fish can tolerate.	Juvenile Chinook salmon reportedly are capable of tolerating turbidity as high as 1,000 parts per million (ppm). The migration of adult salmon reportedly may be inhibited at turbidities greater than 4,000 ppm. Given a choice, Chinook salmon will avoid turbid waters (Allen et al. 1986).	
Factors contributing to mortality	Indicate causes of mortality (e.g. fishing/angling mortality, drastic habitat alterations, unfavorable climatic changes, etc).	The decline of the Central Valley Chinook salmon reportedly was caused by several factors including overfishing, blockage and degradation of streams by mining activities, and reduction of salmon habitat and river flow by dams and water diversions (Yoshiyama et al. 1998). Overharvesting in the Central Valley reportedly is a contributing factor to the decline of Chinook salmon populations. Overall ocean harvest rate indices for 1990 through 1994 reportedly range from 71 to 79 and freshwater recreational harvest is increasing and approaching 25 (Index = catch / [catch + escapement]) (NOAA 1998).	
General passage considerations (upstream and downstream)	Indicate passage effects to fish (e.g. burst speed, max speed, handling stress, survival rates, stressors, body type, etc).	Handling stress reportedly occurred in fall-run Chinook salmon during laboratory studies. For example,: • Twenty minutes after capture fall-run Chinook salmon had high plasma catecholemine concentrations • After 1 hr in a net, adrenaline levels were higher	

Element	Element Descriptor	General	Feather River Specific
		than normal levels • After 3 days of recovery, plasma levels of stress indicators were similar to spring-run Chinook salmon that had been in ponds for 6 months • Females appeared to be more sensitive to stress than males (Mazeaud et al. 1977). Stress in Chinook salmon reportedly induces changes in blood cell count. Additionally, hematocrit has been reported to respond in different ways to stress (Kirk 1974 *in* Mazeaud et al. 1977). The impact on Chinook salmon white blood cells from stress reportedly includes lymphopenia, a condition in which there exists an abnormally low number of white blood cells (Weinreb 1958; Ball and Slicher 1962; Pickford et al. 1971; Mcleay 1973, 1975; Bennett and Gaudio Neville 1975 *in* Mazeaud et al. 1977). Reportedly Archimedes lifts have low mortality and injury rates during transfer of juvenile Chinook salmon (McNabb et al. 2000 *in* Weber et al. 2002). Mean cortisol concentrations reportedly did not differ significantly between treatment and control groups in 1998 laboratory study indicating that passage through Archimedes lifts did not appreciably stress Chinook salmon ($F = 0.01$, $P = 0.9351$, $df = 1$, $N = 706$) (Weber et al. 2002). Stress reportedly may result in direct mortality of Chinook salmon when physiological tolerance limits are exceeded (Maule et al. 1988; Olla et al. 1995 *in* Weber et al. 2002)) or indirect mortality as fish become more vulnerable to disease (Wedemeyer et al. 1976;Maule et al. 1997; Barton and Iwama 1991 *in* Weber et al. 2002) and predation (Olla et al. 1992, 1995; Mesa 1994 *in* Weber et al. 2002).	

Element	Element Descriptor	General	Feather River Specific
		Long-term stress in Chinook salmon reportedly could also reduce growth rates and increases reproductive stresses (Adams et al. 1985 *in* Weber et al. 2002). Cortisol levels in juvenile Chinook salmon stressed to death were reported to be between 400 and 500 ng/mL (Strange et al. 1978;Barton et al. 1986; Maule et al. 1988 *in* Weber et al. 2002). Repeated stress in Chinook salmon reportedly can result in the loss of homeostasis (Barton et al. 1986; Maule et al. 1988; Olla et al. 1995 *in* Weber et al. 2002). A study conducted on the Columbia-Snake River system reported that behavioral changes associated with parr-smolt transformation may affect fingerling Chinook salmon susceptibility to guidance by a submersible traveling screen (Giorgi et al. 1988). Reportedly, Chinook salmon are stressed by crowding, handling, grading, transporting, and routine measurement/marking procedures (Mesa 1994). Reportedly fish stressed by agitation in laboratory studies were significantly more likely to be preyed upon (Mesa 1994). Reportedly, with successive handlings in laboratory studies, plasma cortisol and glucose levels in juvenile Chinook salmon increased but plasma lactate did not (Mesa 1994). Mesa (1994) suggested that reducing stress or protecting fish as they migrate through dam tailraces may help decrease predation. Schooling reportedly allows juvenile salmonids to increase predator avoidance shortly after exposure to a stressor (Pitcher 1986; Magurran 1990 *in Mesa*	

Element	Element Descriptor	General	Feather River Specific
		1994). According to Mesa (1994), two groups of fish exposed to predation probably had distinct physiology profiles but little correlation existed between predator avoidance ability and clinical indications of stress. In a laboratory study, hepatic glycogen concentrations reportedly decreased significantly, which led to increased plasma glucose levels and increased energy demands in stressed juvenile Chinook salmon (Barton et al. 1986). In a laboratory study conducted by Barton et al. (1986) compounded responses of plasma lactate, sodium, and potassium to repeated handling reportedly were greater than those following a single disturbance (Barton et al. 1986). The eight dams of the Columbia-Snake River system were reported to cause a 32-day delay in juvenile Chinook salmon emigration. Possible effects of delayed migration include: • Increased fingerling predation risk • Prolonged exposure to increased water temperatures increasing the risk of contracting disease • Cessation of emigration due to holding over in reservoirs (Bentley and Raymond 1976). It has been reported that juvenile Chinook salmon mortality in the Columbia River Estuary may have been a result of cumulative stresses during in-river emigration (Budy et al. 2002). Fish going through the bypasses of dams on the Snake River reportedly experienced increased in turbulence and rapid deceleration (Budy et al. 2002).	

Element	Element Descriptor	General	Feather River Specific
		Several negative effects to juvenile Chinook salmon associated with passage through dams by way of collection, bypass, and direct passage through turbines on the Snake River have been reported including: • Delay of smolts in the forebay of each dam • Concentration of smolts in forebay and tailrace at bypass outflow of each dam • Increased predation rates where smolts congregate • Exposure to pressure changes • Mechanical injuries (Budy et al. 2002). The use of spillways to pass juvenile Chinook salmon fish through dams reportedly results in: • Less delay in emigration than other methods • Avoidance of mechanical injury • Lower predation rates because predators are more dispersed in the tail water of spillways (Budy et al. 2002). Stressed Chinook salmon smolts reportedly avoid saltwater entry (Budy et al. 2002). Stressed juvenile Chinook salmon reportedly exhibit lowered resistance to disease (Budy et al. 2002). Transport of juvenile Chinook salmon by truck or barge reportedly shortens in-river travel time and may result in premature saltwater entry prior to the fish being physiologically ready for exposure to saltwater (Budy et al. 2002). Low-flow conditions on the Snake River reportedly increased hydrosystem related stress (i.e. increased travel time) during juvenile emigration (Budy et al. 2002).	

Element	Element Descriptor	General	Feather River Specific
		In the Snake River, direct mortality associated with passage through turbines or spillways reportedly may be lowered by bypassing emigrating juveniles around dams (Budy et al. 2002). Passage through the collection system at McNary Dam on the Columbia River reportedly caused increased levels of plasma cortisol, decreased numbers of white blood cells, and decreased swimming ability in juvenile fall- and spring-run Chinook salmon indicating increased levels of stress (Maule et al. 1988). Stress responses in juvenile Chinook salmon associated with exposure to collection facilities reportedly were acute and cumulative for each element of the collection system (Maule et al. 1988). Chinook salmon allowed to recover from collection facility induced stress reportedly had lower potential for osmoregulatory difficulty than fish not allowed to recover from stress (Maule et al. 1988). According to Maule et al. (1988), during studies conducted at the McNary Dam on the Columbia River spring-run Chinook salmon reportedly appeared to be more susceptible stress associated with collection and transport than were fall-run Chinook salmon. Reportedly, the most stressful event in transportation of juvenile Chinook salmon during studies conducted at the McNary Dam on the Columbia River appeared to be the loading of fish into a tank truck or barge(Maule et al. 1988). Stress levels of fish removed from barges reportedly were similar to fish removed from trucks during transport on the Columbia River system (Maule et al. 1988).	

Element	Element Descriptor	General	Feather River Specific
		During studies conducted on the Columbia River, fall-run Chinook salmon reportedly recovered from stress associated with transportation within 24 hours (Maule et al. 1988). According to Maule et al. (1988), the primary advantage of barge use compared to truck use for juvenile Chinook salmon transport is that fish are allowed greater time for recovery from stress associated with loading. During the years 1969 to 1984, there reportedly were major increases in Chinook salmon smolt mortalities along the Snake River and mid-Columbia River system due to gas bubble disease associated with supersaturated atmospheric gases, increased predation due to increased emigration times, and direct mortality associated with passage through turbines (Raymond 1988). Hatchery produced spring-run Chinook salmon reportedly did not respond as well as wild stocks to enhancement measures designed to improve downstream survival (Raymond 1988). Survival of juvenile Chinook salmon reportedly was decreased due to stress associated with passage through a collector system and subsequent transport below Lower Granite Dam, Washington (Raymond 1988). Disease and stress reportedly were identified as factors influencing Chinook salmon mortality within the Columbia-Snake River system (Monk et al. 1989). In 1971 through 1975, mortality studies reported that 15-20% of Chinook salmon died within 48 hours after release from transport trucks (Monk et al. 1989).	

Element	Element Descriptor	General	Feather River Specific
		Juvenile Chinook salmon from the Columbia-Snake River system transported in 5 parts per thousand (ppt) salt water reportedly were free of saprolegnia (a fungus that infects weakened fish) whether held in salt or fresh water (Monk et al. 1989). Reported physiological effects of a single handling event indicating stress include: • Changes in plasma hormone levels • Elevations of plasma glucose and lactic acid • Changes in blood pH and electrolytes • Depletion of liver glycogen • Histological changes • Suppression of the immune system (Pickering 1981 *in* Sigismondi and Weber 1988). Laboratory results reportedly indicate that acute handling stress increased the time it took for juvenile Chinook salmon to respond to a stimulus. Additionally, stressed fish exhibited generally lethargic behavior (Sigismondi et al. 1988). Laboratory tests reportedly demonstrated that fish subjected to 2 or more stresses had less tendency to respond to a stimulus and required longer recovery times than fish stressed only once (Sigismondi et al. 1988). It has been observed under laboratory conditions that unstressed fish tested individually reportedly had longer median response times than did fish tested in groups (Sigismondi et al. 1988). Acute handling stresses reportedly increased the response time of juvenile Chinook salmon to light (Sigismondi et al. 1988).	

Element	Element Descriptor	General	Feather River Specific
		Laboratory studies reportedly concluded that yearling and sub-yearling juvenile Chinook salmon exhibited avoidance responses when exposed to near field of high particle acceleration infrasound (Mueller et al. 1998 *in* Mueller et al. 2001). Juvenile Chinook salmon responses to infrasound reportedly include, startle behavior, movement patterns generally down and away from the origin of the sound (VDS), and a rapid decrease in avoidance responses to repeated exposures during short term testing (Mueller et al. 2001). According to Anderson et al. (1988) *in* Mueller et al. (2001), in clear water under low ambient light conditions strobe lights reportedly were found to be more effective at eliciting a more consistent avoidance responses than infrasound. Results from tests at Roza Diversion Dam on the Yakima River, Washington suggested that drop light and strobe light stimuli did not affecting Chinook salmon behavior under some conditions (Amaral et al. 2001). Reportedly, 2-minute drop light exposures had little effect on Chinook salmon displacement (Amaral et al. 2001). Chinook salmon reportedly demonstrated a strong pattern of avoidance to both strobe light flash rates during night 60-minute exposure tests (Amaral et al. 2001). Chinook salmon avoidance responses to strobe light exposure reportedly decreased with each successive 10 minute interval at Roza Diversion Dam on the Yakima River, Washington (Amaral et al. 2001).	

Element	Element Descriptor	General	Feather River Specific
		Chinook salmon reportedly did not exhibit avoidance or startle reactions when exposed to 5 infrasound frequencies at Roza Diversion Dam on the Yakima River (Amaral et al. 2001). Drop lights reportedly were ineffective at producing avoidance responses in Chinook salmon under all background conditions tested at Roza Diversion Dam on the Yakima River, Washington (Amaral et al. 2001). Results from studies conducted at the Lower Granite Dam on the Snake River reportedly suggest that Chinook salmon display flight and avoidance responses to intense infrasound (10 Hertz) (American Fisheries Society 2001). Surface bypasses reportedly are thought to be less stressful to smolts than are powerhouse bypass systems that use intake screens (Johnson et al. 2000). Fish distribution patterns reportedly were greatly altered by strobe light use during daytime fill events at dams on the Snake River (Johnson et al. 2001). On the Snake River, strobe lights reportedly were shown to effectively clear the immediate area in front of a culvert entrance of juvenile Chinook salmon (Johnson et al. 2001). In laboratory studies, Chinook salmon reportedly demonstrated avoidance responses to strobe light illumination during all tests conducted. However, stronger avoidance responses were exhibited during daytime tests compared to tests conducted at night (Popper and Carlson 1998). Passage efficiency for adult Chinook salmon at the	

Element	Element Descriptor	General	Feather River Specific
		Lower Granite Dam on the Snake River was reportedly slightly higher with a behavioral guidance structure at the Lower Granite Dam on the Snake River (American Fisheries Society 2001). The American Fisheries Society (2001) recommended a behavioral guidance system at the Lower Granite Dam on the Snake River for use as a long-term smolt protection measure. According to Ward et al. (1997), survival of transported juvenile Chinook salmon was greater than the survival of fish left to migrate downstream through the Snake River system. Studies reportedly found that Archimedes lifts and Hydrostat pumps at Red Bluff Diversion Dam, California have the potential to pass fish without inflicting biologically significant damage (McNabb et al. 2003). Archimedes lifts reportedly caused slightly less mortality than Hydrostat pumps at Red Bluff Diversion Dam (McNabb et al. 2003). Studies conducted for one week at the Bonneville Dam second powerhouse on the Columbia River reportedly indicated that bar screens were more efficient at guiding juvenile Chinook salmon than submersible traveling screens (Gessel et al. 1991). Behavioral changes associated with smoltification reportedly influenced fish guidance at the Bonneville Dam second powerhouse on the Columbia River (Gessel et al. 1991). Concentrations of cortisol in Chinook salmon smolts reportedly were not significantly increased by passage through flumes in the Columbia River	

Element	Element Descriptor	General	Feather River Specific
		system (Congleton et al. 1988). During studies conducted on the Columbia River, blood plasma cortisol concentrations in juvenile Chinook salmon were decreased one hour after passage through a flume (Congleton et al. 1988). During daytime tests on the Columbia River, plasma cortisol concentrations reportedly were lower in juvenile Chinook salmon passed through darkened corrugated metal flumes than fish passed through reflective corrugated metal flumes (Congleton et al. 1988). Within the Columbia River basin, damage from spillways reportedly occurs to gills, eyes, and internal organs when the impact velocity of fish on the water surface exceeds 16m/s (Bell & Delacy 1972 *in Larinier 2000).* Water column critical velocity for fish is reportedly reached after a drop of 13 m. In studies conducted in the Columbia River basin, fish experiencing drops greater than 13 m reportedly exhibited significant injury and mortality increases in proportion to the height of the drop (i.e., 100% mortality occurred at drops between 50 m to 60 m) (Larinier 2000). Survival rates of juvenile Chinook salmon reportedly more than doubled when transporting fish below Bonneville Dam on the Columbia River (Ebel 1970). A study conducted on the Snake River reported that cumulative stress to subyearling Chinook salmon could be reduced during transport by: • Allowing fish to acclimate to the transport barge for 20 hours after transfer into the barge • Holding different salmonid species separately (i.e. not holding juvenile steelhead with juvenile	

Element	Element Descriptor	General	Feather River Specific
		Chinook salmon) • Holding fish at low densities (Bugert and Mendel 1997). Handling and anesthesia reportedly may have negatively affected the survival of juvenile Chinook salmon migrants during a passage study in the Columbia and Snake rivers (i.e., handled and anesthetized fish may have been more vulnerable to predators) (Muir et al. 2001). In several studies reviewed by NOAA (2002), return rates from all recovery areas near the McNary Dam on the Columbia River reportedly were significantly higher for fish transported as juveniles than for in-river migrants (NOAA 2000b). Barged yearling hatchery Chinook salmon reportedly migrated slower than in–river migrating juvenile Chinook salmon (NOAA 2000b). Although no direct evidence is available, NOAA (2000b) reported rates of straying for Snake River Chinook salmon between 1 and 3%. In studies conducted between 1975 and 1980 using marked fish, 0.9% of Chinook salmon reportedly were identified as strays (NOAA 2000b) Based on several studies of Chinook salmon collection and transport, mortality rates reportedly are: • Between 0.1% and 8.9% at collection facilities depending on the facility, species, and life stage (Council on Environmental Quality 1997). • Less than 2% for collection and transportation (based on USACE estimates that average seasonal direct mortality) (Council on Environmental Quality 1997).	

Element	Element Descriptor	General	Feather River Specific
		Studies conducted from 1992 through 1996 reportedly showed no evidence of large-scale predation on smolts immediately following release from barges (NOAA 2000b). Elevated plasma cortisol levels associated with stress induced from handling and marking procedures was reported to decrease significantly after a 3-hour truck transportation (Matthews et al. 1977). A 1993 study reportedly showed that previously elevated stress indicators decreased during barge transport (Schreck et al. 1994). Studies reviewed and reported by NOAA (2000) indicated that elevated blood plasma cortisol levels in barged Chinook salmon largely returned to normal during the trip downriver except during peak migration when plasma cortisol levels remained elevated throughout the collection and transportation process (NOAA 2000b). According to Schreck et al. (1994) stress responses differed between hatchery and wild fish. Adult Chinook salmon homing in the Columbia and Snake rivers reportedly is not adversely affected by transport of juveniles downstream (Matthews 1992) Ingram & Korn (1968) *in* CH2M Hill (1980) reported that water temperature in the tailrace channel at Cougar Lake, Oregon was too cold for attracting upstream migrants and so adult Chinook salmon migrating upstream were attracted to the regulating outlet channel. Ruggles and Ryan (1964) *in* CH2M Hill (1980) found louvers to be successful in guiding juvenile Chinook salmon.	

Element	Element Descriptor	General	Feather River Specific
		The Brownlee Skimmer Net, located in Brownlee Reservoir on the Snake River, reportedly proved only partially successful because many fingerling Chinook salmon passed under or through the net and left the reservoir via turbine or spillway. Therefore, the net was removed in 1964 (Sims 1970 *in* CH2M Hill 1980). Sustained swimming speeds for Chinook salmon in the Columbia River are reported to be in the range of 0 to 3.4 ft/sec (DWR 2003). Chinook salmon prolonged swimming speeds in the Columbia River are reported to be in the range of 3.4 to 10.8 ft/sec. Burst swimming speeds for Chinook salmon in the Columbia River are reported to be between 10.8 and 22.4 ft/sec (Mills et al. 2003). Adult anadromous-sized Chinook salmon, with a burst swimming speed of 22.4ft/sec, have been reported to jump 7.8 feet [HL = (22.4 ft/sec(sin 90°))^2/2*32.2 ft/sec)] (Mills et al. 2003). The most conservative estimate of the height of Salmon Falls, Feather River is 15 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 feet. The available information suggests that Salmon Falls is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003 (Mills et al. 2003). The measured height of Miocene Dam, North Fork Feather River under low flow conditions was 10.1 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 feet. The available information suggests that Miocene Dam is an elevation barrier for anadromous-sized Chinook salmon under the low	

Element	Element Descriptor	General	Feather River Specific
		flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Miocene Dam, North Fork Feather River under high flow conditions was 7.9 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 feet. The available information suggests that Miocene Dam is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003 (Mills et al. 2003). The most conservative measured height of Big Bend Dam, North Fork Feather River under low flow conditions was 30 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 feet. The available information suggests that Big Bend Dam is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Curtain Falls, Middle Fork Feather River under low flow conditions was 25 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that Curtain Falls is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003). The most conservative estimated height of Ponderosa Dam, South Fork Feather River under low flow conditions was 35 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that Ponderosa Dam is an	

Element	Element Descriptor	General	Feather River Specific
		elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured heights of Middle Concow Creek Falls and Upper Concow Creek Falls, Concow Creek under low flow conditions were 8 feet and 13 feet, respectively. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that both Middle Concow Creek Falls and Upper Concow Creek Falls are elevation barriers for anadromous-sized Chinook salmon under the low flow conditions observed in July 2003 (Mills et al. 2003). The estimated height of each of the three potential barriers (Berry Creek Falls #1, Berry Creek Old Dam, and Berry Creek Falls #2) on Berry Creek, a tributary of the North Fork Feather River, was 27 feet, 5.8 feet, and 12 feet, respectively. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that each of the potential barriers is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of lower French Creek Falls, French Creek, which is a large tributary of the North Fork Feather River, under low flow conditions was 10 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that lower French Creek Falls is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003).	

Element	Element Descriptor	General	Feather River Specific
		The measured height of lower French Creek Falls French Creek, which is a large tributary of the North Fork Feather River, under high flow conditions was 7 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that lower French Creek Falls is an elevation barrier for anadromous-sized Chinook salmon under the high flow conditions observed in March 2003 (Mills et al. 2003). The measured height of Chino Creek Falls #1 and Chino Creek Falls #2, Chino Creek, which is a tributary of the North Fork Feather River, was 20 feet and 14.2 feet, respectively. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The analysis available information suggests that Chino Creek Falls #1 and Chino Creek Falls #2 are both elevation barriers for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Stony Creek Falls, Stony Creek, which is a tributary of the North Fork Feather River, was 20 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that Stony Creek Falls is an elevation barrier for anadromous-sized Chinook salmon under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Sucker Run Creek Boulder Falls, Sucker Run Creek, which is a tributary of the South Fork Feather River, was 4.1 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 feet (Mills et al. 2003).	

Element	Element Descriptor	General	Feather River Specific
		The estimated range of Sucker Run Creek Boulder Falls was 7.7 feet. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 3.9 feet (Mills et al. 2003). The measured heights of Fall River Falls and Feather Falls, Fall River, which is a tributary of the Middle Fork Feather River were 20 feet and 640 feet, respectively. The maximum height of the fish's leap for anadromous-sized Chinook salmon for this location was reported to be 4.4 ft. The available information suggests that Fall River Falls and Feather Falls are elevation barriers for anadromous-sized Chinook salmon under the low flow conditions observed in July 2002 (Mills et al. 2003).	

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