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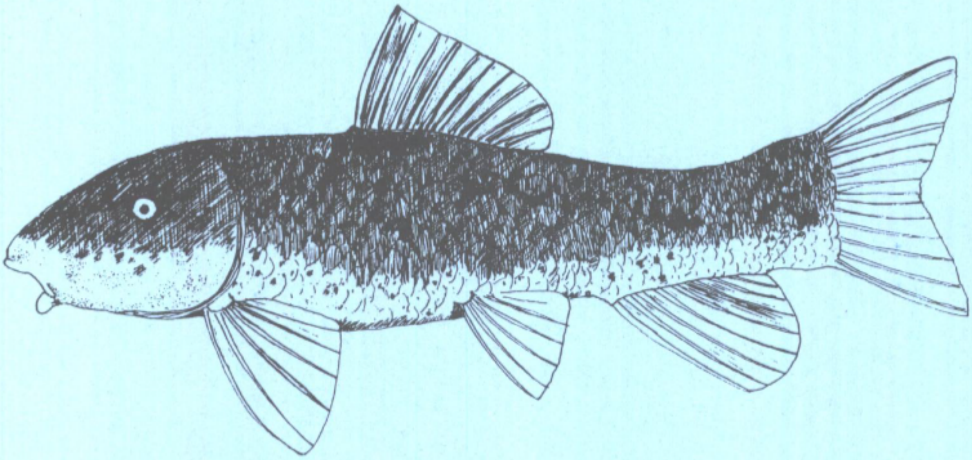
CUI-UI
(Chasmistes cujus)

Second Revision

RECOVERY PLAN



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C U I - U I
(<u>Chasmistes</u> <u>cujus</u>)

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RECOVERY PLAN

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Prepared by
The Cui-ui Recovery Team

for
Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved Marvin L Plenert
Regional Director, U.S. Fish and Wildlife Service

Date: May 15, 1992

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Chester Buchanan, U.S. Fish and Wildlife Service - Reno, Nevada,

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EXECUTIVE SUMMARY OF THE RECOVERY PLAN FOR CUI-UI

Current Status: This species is listed as endangered. The only population exists in Pyramid Lake, western Nevada. Cui-ui was extirpated from adjacent Lake Winnemucca which dried up in the 1930s.

Habitat Requirements and Limiting Factors: Cui-ui inhabits Pyramid Lake. Adults enter the lower river to spawn in Spring. Access to spawning habitat is restricted by attraction flows, a delta at the river mouth, and Marble Bluff Dam. Spawning and development of eggs and larvae are affected by water depth, velocity, temperature and quality, and availability and constancy of substrates. Spawning and rearing factors are functions of lower Truckee River runoff which is controlled by upstream storage, diversion and consumption, and by point and non-point source discharges. Stampede Reservoir is the only facility in the basin currently dedicated to store water for cui-ui.

Recovery Objective: Delisting

Recovery Criteria: Cui-ui will be considered for delisting when it is demonstrated that:

1. The species has a probability of at least 0.95 of persisting for 200 years;
2. Additional annual Truckee River inflow to Pyramid Lake of 65,000 acre-feet or the equivalent benefit beyond the amount required for reclassification (equivalent to 110,000 acre-feet) has been secured at a minimum rate of 5,000 acre-feet/year;
3. Estimated numbers of adult cui-ui and year classes of juveniles and adults have been stable or increasing during the previous 15 years;
4. Lake and river water quality standards have been achieved during the previous 15 years (see Appendix Table A-1);
5. The lower Truckee River floodplain has been rehabilitated;
6. Marble Bluff Fish Facility and Numana Dam Fish Ladder have been modified to pass upstream at least 300,000 adult cui-ui during a spawning run;
7. Maintenance and operation of various water storage and fish passage facilities for cui-ui have been secured; and
8. A hatchery refuge for brood stock has been established to protect against catastrophic events.

Cui-ui will be considered for reclassification from endangered to threatened when it is demonstrated that:

1. The species has a probability of at least 0.85 of persisting for 200 years;
2. Additional annual Truckee River inflow to Pyramid Lake of 45,000 acre-feet or the equivalent benefit have been secured at a minimum rate of 5,000 acre-feet/year; and
3. Estimated numbers of adult cui-ui and year classes of juveniles and adults has been stable or increasing during the previous 15 years.

Actions Needed:

1. Secure cui-ui spawning and rearing habitat by increasing inflow to Pyramid Lake, rehabilitating floodplain, achieving water quality standards, and improving fish passage.
2. Conduct research to collect new information to refine cui-ui model.
3. Use cui-ui model to evaluate benefits of conservation measures.
4. Manage cui-ui spawning runs.
5. Protect cui-ui population from extinction.

Costs: (in $1,000s, exclusive of tasks authorized by P.L. 101-618 for which appropriations have not been secured)

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Total
1992	165	160	64	293	0	682
1993	185	160	64	289	200	898
1994	280	230	64	289	110	973
1995	170	230	64	289	10	763
1996	150	220	64	399	10	843
1997	150	220	204	289	10	873
1998	100	70	64	289	50	573
1999	0	70	64	289	10	433
2000	0	70	64	289	10	433
2001	0	70	64	399	10	543
2002	0	70	64	289	10	633
2003	0	70	64	289	50	473
2004	0	70	64	289	10	433
2005	0	70	64	289	10	433
2006	0	70	64	399	10	543
2007	0	70	64	289	10	433
2008	0	70	64	289	50	473
2009	0	70	64	289	10	433
2010	0	70	64	289	10	433
2011	0	70	64	399	10	543
2012	0	70	64	289	10	433
2013	0	70	64	289	50	473
2014	0	70	64	289	10	433
2015	0	70	64	289	10	433
2016	0	70	64	399	10	543
Recovery Cost	1,200	2,550	1,740	7,779	690	13,959

Date of Recovery: Delisting could be initiated in 2016 if recovery criteria have been met.

PREFACE

The Regional Director, Region 1, U.S. Fish and Wildlife Service, Portland, Oregon re-established the Cui-ui Recovery Team in March 1989. Its mission was to update or revise the Cui-ui Recovery Plan. The Team decided that the plan needed extensive revision after reviewing recently collected biological, chemical and hydrological data, and the requirements of the Endangered Species Act as amended in 1988. The Team's revision (second) offers a quantifiable recovery objective (based upon probabilistic analysis of simulated cui-ui response to various hydrologic conditions) with site-specific tasks which, if implemented, are expected to achieve recovery (i.e., eventual delisting) of cui-ui.

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RECOVERY PLAN
FOR THE ENDANGERED CUI-UI (Chasmistes cujus) OF PYRAMID LAKE, NEVADA

I. INTRODUCTION

Cui-ui (Chasmistes cujus) is a lakesucker found only in Pyramid Lake, Nevada. It was federally listed as endangered on March 11, 1967 (32 FR 4001).

A. Description

Lakesuckers (genus Chasmistes) are differentiated from other members of the family Catostomidae by thin lips, the lobes of which are separated and may lack papillae, and by a large terminal, oblique mouth. The four recognized species are residents of three distinct drainage basins: cui-ui (C. cujus) in the Truckee River basin of western Nevada (Pyramid Lake); shortnose sucker (C. brevirostris) in the Klamath River basin of Oregon and California; June sucker (C. liorus) in Utah Lake; and the recently extinct Snake River sucker (C. muriei) of the upper Snake River in Wyoming (Miller and Smith 1981).

Cui-ui (Figure 1) was first described by Cope in 1883. Because of the species' restricted distribution and distinctive appearance, its taxonomic status has not changed.

Cui-ui is a large, robust sucker with a long, broad, and deep head. The dorsal side of its coarsely-scaled body is blackish-brown with a bluish-gray cast which fades to a creamy-white belly. Breeding males develop tubercles on the anal and caudal fins (LaRivers 1962; Miller and Smith 1981). Larvae were described by Snyder (1983). Cui-ui is probably the largest of the living species of Chasmistes, weighing up to 3.5 kg (7.72 lb) (Snyder 1917; Miller and Smith 1981). Female cui-ui have been documented exceeding a length of 700 mm (27.6 in) (Buettner, personal communication 1991) with males attaining 662 mm (26.1 in) (Rissler, personal communication 1991).

B. Distribution

1. Historical

The genus Chasmistes appears in the fossil record in the Miocene (about 20 million years ago), and numerous fossil sites from Wyoming to Oregon and south to southern California (Miller and Smith 1981) attest to its formerly widespread distribution west of the Continental Divide. Cui-ui fossils are known only from the Lahontan Basin, and all are Pleistocene in age.

Figure 1: Cui-ui (*Chasmistes cujus*)

Cui-ui occupied ancient Lake Lahontan, which covered much of northwest and west-central Nevada during the Pleistocene and more recently until 5-10,000 years ago. Lake level declined as the climate changed until only fragmented, remnant waters - Pyramid, Winnemucca, Walker, and Honey lakes - remained. As the deepest of these, Pyramid apparently remained permanent and thus continued to support cui-ui. The absence of cui-ui from Walker Lake supports the suggestion of Benson (1978) that Walker Lake has dried completely in the past. Fossil and archaeological cui-ui remains have been reported from the basins of Pyramid and Winnemucca lakes. Other archaeological remains from Churchill and Pershing counties, Nevada have been attributed to transport from Pyramid Lake by native Americans (Miller and Smith 1981).

2. Recent

At the beginning of the 20th century, cui-ui inhabited Pyramid Lake and Winnemucca lakes (Figure 2). Obligate stream spawners, cui-ui congregated near the mouth of the Truckee River in spring and migrated as far as 40 km (25 miles) upstream (to the vicinity of Wadsworth, Nevada) to spawn (Snyder 1917). The species was eliminated from Winnemucca Lake when it dried in the 1930s following unrestricted diversion of water from the Truckee River and a severe drought.

3. Current

Cui-ui is now restricted to Pyramid Lake and the lower Truckee River (downstream from Derby Dam). Pyramid Lake elevation is nearly 24 meters (80 feet) lower than at the turn of the century, and there are now structural impediments (e.g., Marble Bluff and Numana dams) to fish passage. Adult and juvenile cui-ui inhabit Pyramid Lake year-round. Adults utilize the lower 19 km (12 miles) of the Truckee River only during the spawning season (ranging from as early as April to as late as June) and only in years in which there is sufficient attraction flow and passage above or around the delta (Scoppettone et al. 1986). Most spawners utilize the 16-km (10-mile) reach between Marble Bluff and Numana dams; the fish ladder at Numana Dam is not conducive to passage of cui-ui.

C. Life History and Habitat

Cui-ui is a large, long-lived and omnivorous sucker. Pyramid Lake provides rearing habitat for larvae, juveniles, and adults. The lower Truckee River provides primary spawning habitat. Adults, eggs, and larvae may be present in the river for a maximum of several weeks. Spawning has been observed at freshwater interfaces and springs within Pyramid Lake (Koch 1973).

1. Lake Habitat

Pyramid Lake is the terminus of the Truckee River. It is saline (>4.1 ppt), alkaline (pH = 9.1-9.3) and categorized as oligotrophic to mesotrophic. From 1981 to 1990 maximum depth has ranged from 111 to 119 km (365-390 feet). Average annual evaporative loss is approximately 440,000 acre-feet, which creates a vertical drop of 1.2 m (4 feet). Pyramid is a

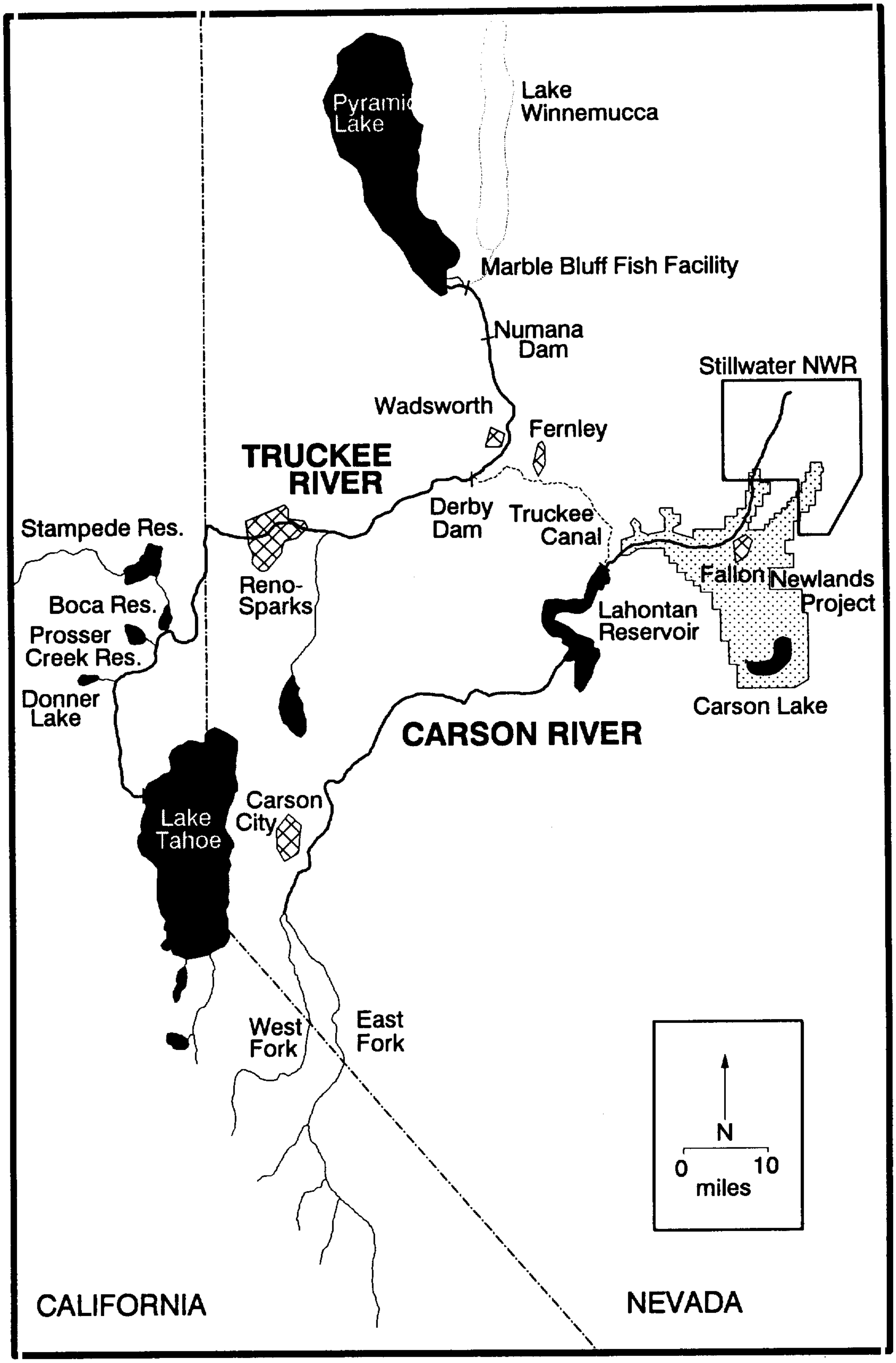

Figure 2. Major features of the Truckee/Carson River basin.

monomictic lake and may stratify as early as May; it usually remains stratified until December. Depth of the thermocline varies from 11 to 23 meters (35-85 feet) (Galat et al. 1981). As of November 1991, lake elevation was 1158.3 meters (3800.3 feet m.s.l.).

For much of the year adult and juvenile cui-ui inhabit the littoral zone at depths of 18 to 31 meters (60-100 feet). Juveniles appear to concentrate at the north and south ends of the lake. They are most active during summer and fall; however, a seasonal migration pattern has not been demonstrated (Scoppettone, personal communication 1991).

2. River Habitat

The lower Truckee River is a low- to moderate-gradient stream descending at a rate of approximately 1.5 m/km (7.9 feet/mile). The banks are composed of unstable sedimentary material which is vulnerable to severe erosion. The stream channel has changed significantly during this century. Lowering of Pyramid Lake and artificial straightening of the river for flood-control purposes (Gregory 1982) have created a shallow, braided, and unconfined channel network, and formed a broad delta at the mouth (Born 1970; Glancy et al. 1972). Marble Bluff Dam functions as a hydraulic control to reduce upstream erosion, and has also created several miles of habitat suitable for cui-ui spawning immediately upstream.

Discharge in the lower Truckee River is highly variable between seasons and years, depending, in part, on upstream storage and diversions at Derby Dam. Average annual inflow to Pyramid Lake for the period 1918-1970 was approximately 250,000 acre-feet with a low of 13,000 acre-feet in 1931 and a high of 1,450,000 acre-feet in 1907 (Matthai 1974). Runoff, a function of snowmelt, generally peaks in late spring (average of 56,000 acre-feet in May) and is lowest in late summer (average of less than 1,000 acre-feet in August).

Ambient water quality depends upon upstream conditions and discharge volume. Ranges (and means) for key water quality parameters measured at Nixon are: temperature - 0.5-29.6° C (mean = 13.2); dissolved oxygen - 6.0-15.5 mg/l (11.0); conductivity - 87-1050 micromhos (432); nitrate-N - 0.003-1.0 mg/l (0.31); unionized ammonia - 0.00-.50 mg/l (.002); and total dissolved phosphate - 0.002-0.45 mg/l (0.13). The period of record extends from 1968 to 1989 (Nevada DEP 1990).

Pollutants from point and non-point sources enter from municipal, agricultural, and industrial sources along the entire river. This results in high levels of nutrient loading to the Truckee River and Pyramid Lake (Appendix A). A variety of factors have degraded water quantity and quality which periodically have adversely affected cui-ui spawning and nursery areas. Increased temperatures and sediment loading, decreased dissolved oxygen and wetted perimeter, and other parameters have all reduced habitat quality for cui-ui.

When hydrologic conditions are suitable, cui-ui can access spawning habitat in the lower Truckee River either across the Truckee River delta or through the Pyramid Lake Fishway. Resource managers prefer that cui-ui pass over the delta rather than through the fishway for several reasons. Spawning runs that transit the delta are potentially earlier and larger; they may contain more year classes; and fish may experience less stress. Passage is determined by the elevation of Pyramid Lake. Passage via the fishway is possible when lake elevation is greater than 1,153 meters (3,784 feet) and via the delta when the elevation is generally greater than 1,161 meters (3,812 feet) (Buchanan 1987).

Inflow to Pyramid Lake is often insufficient to attract spawners or to stimulate fish movement into the river or Pyramid Lake Fishway. Sediment loads in the river, in conjunction with declining lake elevation, have created an extensive delta across the mouth that is frequently a barrier to upstream passage of cui-ui spawners.

3. Essential Habitat

Essential habitat identifies that portion of the Truckee River basin which provides spawning and rearing habitat for cui-ui and which has the greatest impact on physical, chemical and biological components of cui-ui spawning and rearing habitat. Essential habitat for cui-ui is determined to be the Truckee River from Hunter Creek (western Reno) to and including Pyramid Lake and its tributaries. This designation is substantiated by the following:

- the majority of point and non-point sources for pollutants in the Truckee River occurs from Reno downstream;
- the greatest volume of water is diverted from the river (numerous sources) from Reno downstream;
- the majority of habitat alteration in the river has occurred from Reno downstream; and
- there are reports (unconfirmed) of cui-ui spawning in the river as far upstream as Lockwood (east of Reno).

Critical habitat is defined by the Endangered Species Act as "...specific areas...essential to the conservation of the species and which may require special management considerations or protection..." but "...shall not include the entire geographical area which can be occupied by the threatened or endangered species." Critical habitat has not been designated for cui-ui.

4. Spawning

Adult cui-ui congregate in March and April near the mouth of the river prior to migration. Spawning runs begin in April or May, depending upon timing of runoff, river access, and water temperature. There is evidence that a high-volume spring runoff attracts more spawners and promotes egg ripening (Sonnevil 1981; Buchanan and Strekal 1988). Spawning occurs during April-May. Most spawners migrate less than 9.7 km (6 miles) upstream, but some may travel up to 19.3 km (12 miles). While most spawners spend only a few days in the river, some may remain up to 16 days. Spawning runs may continue for 4 to 8 weeks, but most fish migrate during a 1- to 2-week period (Coleman 1986).

Cui-ui spawn in groups of one to several individuals of each sex. Females broadcast eggs over an average of 50 m^2 (538 ft^2) of predominantly gravel substrate in water depths of .24 to 1.22 meters (0.8-4.0 feet) with velocities of 0.31 to 0.61 m/sec (1-2 ft/second). Individuals complete spawning over a 3- to 7-day period (Scoppettone et al. 1983). The area of spawning habitat between Marble Bluff and Numana dams is estimated to be 10,100 square meters (109,000 square feet) at 70.75 cms (2,500 cfs, the maximum managed spawning flow) and 18,800 square meters (202,000 square feet) at 28.3 cms (1,000 cfs, the minimum managed spawning flow - see Buchanan and Strekal 1988).

Upon return to the lake, spawners do not enter the river again that year (Scoppettone et al. 1986). Adult cui-ui seem to have the potential to spawn every year but most only spawn several times a decade because of passage barriers (Coleman et al. 1987; Buchanan and Burge 1988).

Fertilized eggs hatch in 1 to 2 weeks, depending upon water temperature; optimum range is 14.4 to 17.2° C. Survival of newly-fertilized eggs decreases markedly in water above 17.2° C. Embryos and larvae exhibit a greater tolerance than eggs to elevated temperature. After eggs hatch, yolk-sac larvae remain in the gravel 5 to 10 days prior to emergence (Scoppettone et al. 1983).

Upon emergence, most larvae are swept immediately downriver to the lake. Some may enter river backwaters and remain there for several weeks. Upon reaching the lake, larvae occupy the shallow littoral zone. They disperse into deeper lake waters in late summer, but seem to remain segregated from adults (Scoppettone et al. 1983; Rissler, personal communication 1991).

5. Fecundity

Females produce large numbers of small (2-3 mm) yellowish-white eggs. Fecundity ranges from 25,000 to 186,000 eggs for 430-mm to 657-mm (16.9-28.9 inch) females, respectively (Scoppettone et al. 1986). While females of 40+ years may still produce viable eggs and occasional males of 40+ years have been found with viable sperm, egg viability appears to decrease dramatically after females reach 30 years of age and few males or females in their mid-30's produce viable gametes (Scoppettone, personal communication 1991).

6. Growth, Survival and Longevity

The sexes grow at a similar rate and reach maturity in 6 to 12 years. While both sexes have been documented to live 40+ years, female cui-ui generally live longer and grow faster than males (Scoppettone et al. 1986).

Chatto (1979) demonstrated that cui-ui eggs cannot survive in the highly saline water of Pyramid Lake. The survival rate for eggs in the river has been estimated to range from 7.6-14.0% in water temperatures ranging from 20.6-14.4° C (the relation is inverse). Although there are no empirical data on larvae or juvenile survival, survivorship of cui-ui larvae is presumed to be extremely low (~0.2%) and the average annual survival rate for juveniles is presumed to be 75%. Results from tag release and recapture studies and comparisons of data on other long-lived fish suggest that adults may have an annual survival rate of 85% (Buchanan and Strekal 1988).

All life stages are subjected to predation. Eggs and emergent larvae in the river are eaten by Lahontan redside shiner (Richardsonius egregius) (Scoppettone et al. 1983). Young cui-ui are prey for tui chub (Gila bicolor) and Lahontan cutthroat trout (Onchorhyncus clarki henshawi). Lake-dwelling adults apparently have no predators, but adults are vulnerable to American white pelican (Pelecanus erythrorhynchos) and double-crested cormorant (Phalacrocorax auritus) attacks while in the river (Scoppettone et al. 1986).

7. Population Size

Tagging studies of adult cui-ui from 1982 to 1986 suggest that prespawning aggregations contained from 90,000 to 200,000 adults (Scoppettone et al. 1986; Coleman et al. 1987). Preliminary results of recent tag release and recapture studies indicate that approximately 300,000 adults (age 9+ years) and one to several million juveniles comprise the current cui-ui population (Scoppettone, personal communication 1991).

8. Food

Scoppettone et al. (1986) found that cui-ui larvae feed primarily on zooplankton and chironomid larvae, while adults consume mostly zooplankton (cladocerans and copepods). Recent studies indicate that juvenile cui-ui feed on zooplankton (cladocerans, copepods and ostracods), chironomid larvae, and algae; it is suspected that adults also feed on chironomid larvae and ostracods (Scoppettone, personal communication 1991).

9. Genetics

In 1988, sub-adult cui-ui with unusual head and lip morphology were captured. This aroused suspicion that hybridization had occurred with Tahoe suckers (Catostomus tahoensis), and that a substantial number of hybrids were entering the breeding population. An allozyme study was subsequently performed, but 18 putative hybrids were genetically identical to known cui-ui of older year classes. The apparent differences in morphology may reflect genetic plasticity in the species or may be a developmental response to environmental factors. Individual cui-ui exhibited low levels of allozyme variability which may be attributed to genetic bottlenecks or reductions in effective size of the spawning population (Brussard et al. 1990).

D. Reasons for Listing

Upstream storage and diversions of water in the Truckee River reduced inflow to Pyramid Lake and endangered the cui-ui. Timber harvesting and irrigated agriculture in the basin in the 19th century altered the quantity and quality of Truckee River runoff. Derby Dam (completed in 1905 as a key feature of the Newlands Project) became the largest single diversion of Truckee River water. Increasing agricultural, municipal, and industrial water demands altered the volume and timing of river flows which disrupted cui-ui reproduction. Also, channelization, grazing, and timber harvesting in and along the Truckee River reduced riparian canopy and increased bank erosion. These detrimental conditions have intensified with further urban and agricultural development.

Extirpation of Lahontan cutthroat trout from Pyramid Lake in the 1940s was viewed as a harbinger for cui-ui endangerment because both species are obligate river spawners. Catch in the cui-ui fishery dropped dramatically from 1956 to 1968, which suggested a decline of the cui-ui population; the predominance of females signified an aging population. Thus, cui-ui was listed as federally endangered in 1967.

Recent studies have substantiated the validity of this status. Restriction of river access and elimination of spawning habitat caused a steady decrease in the size and frequency of cui-ui spawning runs (U.S. Fish and Wildlife Service 1977). Only three year classes (1942, 1946 and 1950) existed in 1966; in 1983 an additional year class (1969) comprised 97% of the spawning run (Scoppettone et al. 1986).

E. Recent Conservation Measures

1. Recovery Plans and Recovery Teams

The first cui-ui recovery plan was written in 1978 by a recovery team composed of representatives from the U.S. Fish and Wildlife Service (Service), Nevada Department of Wildlife, and Pyramid Lake Paiute Indian Tribe (Tribe). The plan was updated in 1980 and revised in 1983 with the team's concurrence. The team agreed to disband in 1984. That plan has guided recovery actions to date.

The primary objective of the first recovery plan was to "restore the species to a non-endangered status and reclassify from endangered to threatened" (U.S. Fish and Wildlife Service 1978). Because little was known of cui-ui life history and habitat, requirements for reclassification were not quantified. Recovery strategy was divided into three elements: 1) protection of the existing population; 2) population augmentation with hatchery-reared fish; and 3) restoration of essential habitat. Because restoration was hampered by lack of knowledge, the highest priority was to conduct research on cui-ui life history and habitat requirements. Hatchery operations were recommended as a means of augmenting the population until natural reproduction was re-established and to provide some protection from catastrophic events.

The 1980 version of the plan retained its original objective (U.S. Fish and Wildlife Service 1980). Although the general strategy did not change, the updated plan contained new information. The updated version emphasized: 1) continuation of experimental hatchery operations for rearing both larval and juvenile stages; and 2) establishment of successful spawning runs in the Truckee River. It recommended continuation of the life history and habitat studies, and continued operation and improvement of Marble Bluff Fish Facility and Pyramid Lake Fishway.

The 1983 revision changed both the recovery goal and strategy (U.S. Fish and Wildlife Service 1983). The goal became delisting of cui-ui to non-endangered status by restoring and maintaining an optimum, self-sustaining population in the Truckee River - Pyramid Lake system. As with the original plan, the goal was not quantified. Though the recovery strategy was changed considerably, the change was more of format than substance. The three main thrusts were: 1) identification, rehabilitation, and maintenance of sufficient habitat for cui-ui in the Truckee River and Pyramid Lake to maintain the optimum population through natural reproduction; 2) protection and management of the optimum self-sustaining cui-ui population; and 3) education of the public about the recovery effort. Emphasis continued to be placed on identification and rehabilitation of habitat and proper management of the population.

2. Tribal Fishery

Historically, the Pyramid Lake band of Northern Paiute Indians relied heavily upon annual spawning runs of cui-ui for food. To aid protection and restoration of cui-ui, the Tribal Council passed resolutions in 1969 and 1979 ceasing harvest of cui-ui by non-Indians and tribal members, respectively. These resolutions were reemphasized in 1984 when the Council passed a motion reiterating the moratorium on a cui-ui fishery.

3. Hatchery Operations

In 1971, the Service urged that immediate action be taken to preserve the cui-ui population in Pyramid Lake. Without such protection it was feared that the species might become extinct within 10 years (U.S. Fish and Wildlife Service 1971). A remedial action was the development of cui-ui propagation techniques to supplement the population until it became self-sustaining and to provide a contingency stock in case of catastrophic spawning failure or population loss (U.S. Fish and Wildlife Service 1976, 1978, 1983).

In 1972, David Koch and the Service developed cui-ui propagation techniques and established the first cui-ui culture facility at Hardscrabble Creek near Sutcliffe, Nevada (Koch 1972; U.S. Fish and Wildlife Service 1972; Koch and Contreras 1973). A rudimentary hatchery operation began in 1973 after the Service improved the facilities and production techniques (U.S. Fish and Wildlife Service 1976). With completion of the David Koch Cui-ui Hatchery by the Tribe and training of Tribal personnel in cui-ui culture techniques, the Service transferred operation and control of the program to the Tribe in 1977 (Sonnevil 1978), which continues to the present.

From 1972 through 1990, millions of hatchery-reared cui-ui larvae and several thousand juveniles were stocked in Pyramid Lake (Coleman et al. 1987; Buchanan and Strekal 1988). Though no direct evidence exists as to their contribution to the adult population, information derived from larvae of other long-lived fishes suggests that few larvae would be recruited to the adult population. Because of these concerns, the Tribe, in consultation with the Service (mid-1980s), redirected the hatchery program from larvae production to extended rearing to increase recruitment to the adult population. This will require subjecting fewer adult fish to the rigors of artificial spawning. On the negative side, however, use of fewer adults decreases the probability of maintaining genetic variability. This program must, therefore, be accompanied by genetic analyses (see below) and maintenance of pedigrees in the broodfish to avoid inbreeding and inadvertent production of genetic bottlenecks.

4. Marble Bluff Dam, Marble Bluff Fish Facility, and Pyramid Lake Fishway

In 1976 under authority of the Washoe Project Act (70 Stat. 775 dated August 1, 1956), the Service assisted in the design and the U.S. Bureau of Reclamation (Reclamation) built Marble Bluff Dam and Marble Bluff Fish Facility (which includes Pyramid Lake Fishway). The dam and fish facility are located on the Truckee River about 4.8 km (3 miles) upstream of Pyramid Lake. The fishway - a clay-lined canal with a terminal structure in Pyramid Lake and 5 fish ladders (including the facility by-pass ladder) - provides an alternate access route to upstream spawning areas in the Truckee River. The fishway terminates at the fish facility which contains equipment for holding, counting, and handling fish for release upstream. A trap at the base of the dam provides a means of capture and upstream passage over the dam for fish which migrate via the delta.

These structures were intended to enhance conservation of cui-ui by providing passage around the river delta and by helping to control erosion in spawning habitat upstream of the dam. The Service initiated operation and maintenance of the fishway in 1977 (Ringo and Sonnevil 1977).

The fishway and fish facility are less effective in attracting and passing cui-ui spawning runs than anticipated (Sonnevil 1978, 1981; Coleman 1986; Scoppettone et al. 1986). The 35-50 cfs discharge at the terminus of the fishway is small in relation to flow over the delta and inadequate to attract large numbers of cui-ui. Ladders in the fishway were patterned after those used at Ice Harbor Dam on the Snake River for passage of migrating salmon and anadromous trout. They create velocities and turbulence that impede passage of cui-ui.

Once fish enter the fish-handling facility, they are concentrated and mechanically raised for release upstream of the dam. In years when fish passage is available across the delta, cui-ui are captured at the base of the dam in an underwater trap/elevator combination that raises them to the elevation of the impoundment. Many cui-ui have died in the fish facility from stress and physical harm (Buchanan 1986). Although many corrections have been made in recent years, numerous problems still exist and fish continue to be lost (U.S. Fish and Wildlife Service 1987; Buchanan and Burge 1988).

5. Stampede Reservoir

The completion of Stampede Dam and Reservoir on the Little Truckee River, nearly 90 miles upstream of Pyramid Lake, was a significant contribution to reestablishing river flows suitable for cui-ui. Built under the authority of the Washoe Project Act, the dam became operational in 1970. The maximum storage capacity of the reservoir is 226,000 acre-feet, with an average annual yield for cui-ui use of roughly 37,000 acre-feet. In the early 1970s, the Secretary of the Interior (Secretary) ordered that the reservoir be operated principally for the benefit of threatened and endangered fishes of Pyramid Lake and for limited flood control. This order was based on the Endangered Species Act and trust responsibility to the Tribe.

Since 1976, the Service has used water from Stampede Reservoir to adjust volume and timing of river flow to enhance cui-ui and Lahontan cutthroat trout spawning runs and to maintain water temperatures suitable for egg incubation. The Service produced Stampede storage management plans from 1982 through 1987, the last year water was released for spawning (U.S. Fish and Wildlife Service 1982b, 1983b, 1985, 1986, 1987b). In 1982 the U.S. District Court for the District of Nevada affirmed the Secretary's authority by ruling that the Secretary was to use "...the waters stored in Stampede Reservoir for the benefit of the Pyramid Lake fishery until such time as the cui-ui and Lahontan cutthroat trout are no longer classified as threatened or endangered, or until sufficient water becomes available from other sources to conserve the cui-ui and Lahontan cutthroat trout." The U.S. Ninth Circuit Court of Appeals affirmed this decision, and the U.S. Supreme Court declined to review the case. This gave cui-ui its only assured water supply.

6. Spawning Run Management

The management objective of the Service, which has the lead responsibility for research and management, is to enhance prospects for cui-ui survival by producing as many year classes as possible. This is done by managing Stampede Reservoir releases to maximize occurrence of suitable river stages and lake conditions during spawning runs, and by operating Marble Bluff Fish Facilities to provide passage around the delta. Managed flows also enable collection of cui-ui eggs for hatchery incubation. Water in storage is to be used to supplement background flows and to maintain spawning habitat. Only excess storage in Stampede is used for Lahontan cutthroat trout spawning in the river (Buchanan 1987; Buchanan and Coleman 1987).

For cui-ui to reproduce successfully, Truckee River discharge into Pyramid Lake must satisfy several criteria. The volume must be sufficient to attract potential spawners to the delta and to provide a stimulus to initiate the spawning run. Flows must also be adequate for maintenance of spawning, incubation, and rearing habitat in the river, and to provide for outmigration of adults and larvae (Buchanan 1987). It is estimated that a minimum attraction volume of 60,000 acre-feet is required from January through April when delta passage is available, and 176,000 acre-feet with fishway access alone (Buchanan and Burge 1988). The number of fish in the spawning run generally increases with water flows above the minimum attraction volume. The minimum managed spawning flow during May and June is set at 1,000 cfs (approximately 60,000 acre-feet/month) to achieve (with normal air temperature) an average daily maximum water temperature of 17.2° C at Nixon, Nevada. Flows greater than 1,000 cfs will improve egg survival by maintaining lower water temperatures. June flows are managed to equal May flows (but not to exceed 2,500 cfs) to reduce the potential for killing eggs and yolk-sac larvae by scouring and to enable adult movement (Buchanan 1987; Buchanan and Burge 1988; Buchanan and Strekal 1988).

If the spawning migration peaks in late April, then June flows would provide for the completion of incubation and for outmigration. If the spawning migration peaks in May, then June flows would provide for incubation and the beginning of outmigration and July flows (an average of 520 cfs for the month) would be required for completion of outmigration (Buchanan 1987; Buchanan and Strekal 1988).

The preceding flow regimes are used as a guide for controlling flows in the lower river. Each year, beginning in January, the Service, in cooperation with Reclamation and the Tribe, develops a water release program for Stampede Reservoir to promote cui-ui spawning. The program is based on information regarding Stampede storage and forecasts of Truckee River runoff, and is updated frequently as new information about the cui-ui prespawning aggregation and spawning run, larvae outmigration, and lower Truckee River water temperatures and forecasts are obtained.

7. Research: life history, population dynamics, genetics, and habitat

After Cope's (1883) taxonomic description of cui-ui, Snyder (1917) was the first to describe various aspects of cui-ui life history from observations of the 1913 spawning migration. Little more was written about cui-ui until the mid-1950s when the Nevada Fish and Game Commission began life history investigations of spawning migrations, lake distribution, and food habits (Jonez 1955, Johnson 1958, La Rivers 1962). At that time, the population appeared large, but major declines in catch during the 1960s renewed concern for the species. Gill net surveys in 1971 and 1972 by Koch (1972) yielded additional evidence that the population was greatly reduced. He also provided information on lake spawning (Koch 1973), hatching techniques (Koch and Contreras 1973) and early life history (Koch 1976). From 1972 through 1982, the Service conducted a cui-ui spawning run monitoring program. Initially this program was intended to monitor population status and collect fish for hatchery propagation. It was expanded later to include an evaluation of the relation between prespawning aggregation and Truckee River flow (Sonnevil 1977, 1978, 1981).

Research in the early 1980s focused on riverine life history requirements, larvae emigration, population estimation, age, and growth (Scoppettone et al. 1986, Coleman et al. 1987, Buchanan and Burge 1988). In 1988 the Service (Seattle National Fishery Research Center) began an extensive study of cui-ui population dynamics and life history. Objectives were to estimate cui-ui population size, annual survivorship of each life stage, and to determine the species' lake habitat requirements. This information is essential for refining the cui-ui model (Buchanan and Strekal 1988) developed to simulate impacts of different Truckee River water management plans on population dynamics, and to optimize releases from Stampede Reservoir for cui-ui spawning (Appendix B).

Studies have also been conducted on cui-ui embryology (Bres 1978), growth and longevity (Scoppettone 1988), taxonomy of early life stages (Snyder

1983), spawning behavior (Scoppettone et al. 1983), adult swimming ability (Koch 1972), and effects of salinity, nitrogen products, and water temperature on hatching success (Chatto 1979; Koch et al. 1979; Koch 1981; Coleman et al. 1987; Buettner et al. in press). Other investigations have included evaluations of temperature tolerance in juvenile and adult cui-ui (Koch 1982) and salinity bioassay on eggs, larvae, and juveniles (Lockheed 1982). Because of concerns that mass hybridizations may have occurred, Brussard et al. (1990), using starch-gel electrophoresis of proteins, determined that cui-ui have not hybridized with Tahoe suckers and that they have an extremely low level of heterozygosity.

8. Regulation of Newlands Project Water Diversions

The Newlands Project (Project) provides water for irrigation and other purposes to a defined service area in western Nevada along the Truckee Canal near Fernley and in the lower Carson River basin near Fallon. The Project service area consists of approximately 73,800 acres of land that are entitled to receive irrigation water. Water for these lands is supplied from the Truckee and Carson rivers. Water from the Truckee River is diverted at Derby Dam via the Truckee Canal for direct delivery to irrigators in the Truckee Division of the Project and to supplement Carson River flows stored in Lahontan Reservoir for later distribution to the Carson Division.

Major features of the Project were completed by Reclamation in 1915. Since that time, the Project has been involved in controversy resulting from intense competition for the limited water and adverse impacts of diversions on fish and wildlife resources of Pyramid Lake and wetlands in both the Truckee and Carson basins. This competition resulted in considerable litigation to settle water disputes.

In 1964, the Secretary formed a task force to study and report on methods to resolve these controversies. The task force made numerous recommendations for diverting and managing Project water. One recommendation was the formulation of Operating Criteria and Procedures (OCAP) for the Project that would maximize use of Carson River flows to satisfy project requirements and minimize diversions from the Truckee River for the benefit of Pyramid Lake fish resources. After numerous court challenges over technical and legal issues and several attempts to develop OCAP, the Secretary of the Interior adopted OCAP in 1988 (U.S. Department of the Interior 1988).

From 1918 through 1970, the average net diversion from the Truckee River to the Newlands Project was approximately 250,000 acre-feet/year, nearly 50% of average annual flow (Matthai 1974). After OCAP are fully implemented in 1992, average annual diversions from the Truckee River to the project are expected to be reduced by over 50% (U.S. Department of the Interior 1988).

9. Benefits of Conservation Measures

Cui-ui have benefitted in recent years from several actions and events. These have included:

1) The Secretary's implementation of recommendations by Interior's 1964 Task Force on the Newlands Project, and adoption of OCAP and other management measures for the Truckee and Carson rivers;

2) construction and operation of Marble Bluff Fish Facility and Pyramid Lake Fishway;

3) storage releases from Stampede Reservoir; and

4) three abnormally wet years in the 1980s that raised the elevation of Pyramid Lake more than 9 meters (30 feet).

From 1980 through 1987, cui-ui reproduced successfully in 7 years. This is a substantial improvement compared to production of only two major year classes from 1950 through 1979. Spawning runs in the 1980s averaged 12,470 fish annually and ranged from 5,000 to 36,300 fish. In spite of this apparent improvement, these are small numbers of fish in comparison to historic runs (Buchanan and Burge 1987). Although hundreds of millions of larvae were produced, the information is not available to assess their survival or potential for recruitment to the adult population (Scoppettone, personal communication 1991). Insufficient water from 1988 through 1991 precluded spawning runs.

F. Future Conservation Measures

Four conservation measures are ongoing:

1. Truckee-Carson-Pyramid Lake Settlement Act

The Truckee-Carson-Pyramid Lake Water Rights Settlement Act of 1990 (P.L. 101-618) has tremendous potential for conserving cui-ui. It provides avenues for settling many long-standing disputes over apportionment of water from the Truckee and Carson rivers and for promoting efficient use of these waters. This Act also authorizes the acquisition of sufficient water rights to promote recovery of cui-ui. It emphasizes the rehabilitation of the lower Truckee River and allocates previously uncommitted water in Prosser Creek Reservoir and water conserved from the Fallon Naval Air Station for listed fishes of Pyramid Lake. Provisions governing OCAP for the Newlands Project and management of Truckee River reservoirs may also benefit cui-ui by making more water available in the lower river, particularly during the spawning season. These benefits may not be realized for many years and may be offset somewhat by increased consumptive use of water upstream which is also allowed by the Act.

2. Cui-ui Research

The Service is conducting an 8-year population dynamics study (to be completed in late 1996) to improve accuracy of cui-ui population estimates and assess annual survivorship of each life stage. This information is essential for refining the cui-ui model when used with the stochastic hydrologic data base to define recovery (Appendix C). Funding for this study is not assured, however, beyond FY 1992.

3. Pyramid Lake Nutrient Loading Study

The Tribe has contracted with the Limnological Research Group at the University of California, Davis for a multi-year study of potential effects of nutrient loading on Pyramid Lake. This project (1993 completion date) should provide management agencies with an empirical and mechanistic model to predict hypolimnetic dissolved oxygen from internal and external nutrient loading. Such information is essential to establishing water quality standards for protecting cui-ui lake habitat.

4. Management Actions

The Service will continue to operate the Marble Bluff Fish Facility and to develop annual plans for the effective use of Stampede storage for cui-ui and Lahontan cutthroat trout. The Tribe will continue to operate and maintain the David Koch Cui-ui Hatchery.

G. Recovery Strategy

Recovery is predicated on conserving the cui-ui ecosystem, while recognizing that Truckee River flows will continue to be managed to satisfy many beneficial uses. The following measures are required to recover cui-ui.

1. Secure Habitat

Recovery will require opportunities for cui-ui reproduction and recruitment to the adult population beyond the current level. This necessitates securing spawning habitat in the lower Truckee River and rearing habitat in Pyramid Lake.

Additional water must be secured for the lower Truckee River during the cui-ui spawning season to expand spawning habitat and maintain suitable water quality for egg development. This might be accomplished by developing and implementing an operating agreement for upper Truckee River reservoirs, purchasing Truckee River water rights for delivery to the lower river and Pyramid Lake during the spawning season, and/or reducing diversions from the Truckee River. The initial measure only changes the timing of available water to provide more during spawning season; the latter two measures increase available supply to Pyramid Lake to expand spawning habitat and improve river access during the spawning season, and maintain rearing habitat year-round .

Rehabilitation of the lower Truckee River channel would return the existing straight, wide, shallow, braided and sparsely vegetated lower river to its historic meandering, narrow, deep, shaded and stable character. Rehabilitation could be accomplished by reestablishing a native tree canopy within the floodplain, controlling grazing, and stabilizing the river channel. This would likely increase the amount and stability of cui-ui spawning habitat, and would reduce ambient river temperature to increase egg survival and recruitment of larvae.

Reduction in nutrient loading and total dissolved solids (TDS) from point and non-point sources to the Truckee River would improve water quality in the lake and the river. Improvement of river water quality would reduce algal growth and microbial activity on and within spawning gravels, thereby increasing egg survival. Reduction of TDS to the lake may limit adverse effects on cui-ui and its planktonic food sources. It could also decrease the frequency or intensity of blue-green algae blooms and reduce hypolimnetic oxygen demand.

Existing fishway and river trap facilities must be operated, maintained, and improved to ensure upstream passage of cui-ui each year when sufficient water is available to promote spawning. Because river passage is less restrictive than the fishway, greater emphasis should be placed upon increasing the efficiency and capacity of the Marble Bluff river trap and on providing access over the Truckee River delta. Hydraulic improvements within the delta, if feasible, may permit passage of spawners over an increased range of Pyramid Lake elevations. Increases in Pyramid Lake elevation resulting from increased Truckee River inflow may, however, obviate such measures.

Upstream migration is restricted at Numana Dam. If spawning habitat becomes limiting in the lower river, the existing Numana fish ladder must be modified or replaced.

2. Research

Continued research on cui-ui population dynamics, life history, and habitat is necessary to further characterize life stage requirements and identify water quality limitations. Research will provide additional information to improve water and facilities management, and to formulate measures to enhance habitat quality. Research must include monitoring of cui-ui population size and condition to enable resource managers to evaluate effectiveness of conservation measures. Additional research on the genetic composition of the cui-ui population should be conducted to ensure that water and facilities management have not created and do not create bottlenecks in gene flow and thereby restrict genetic variability.

3. Operate Cui-ui Hatchery

Information about the genetic integrity of the cui-ui population will have direct application to operation of the David Koch Cui-ui Hatchery. That facility should continue to be operated to maintain the species in the event of catastrophic events in the wild, and is not intended to be a surrogate for the ecosystem. A hatchery operation should produce genetically diverse fish for release after substantial growth so that individuals are sufficiently large to avoid predation upon release to Pyramid Lake. Rearing of a second captive stock at another location should be considered as a back-up.

4. No Translocation

Service policy states that "relocation or transplantation of native endangered or threatened species or subspecies outside their historic range is contrary to the purpose of the Endangered Species Act and will not be authorized as a means of alleviating ...conflicts" (U.S. Fish and Wildlife Service 1982). This policy is rooted in the stated purpose of the Endangered Species Act to conserve the ecosystems upon which endangered and threatened species depend. From a management standpoint, it is more practical and appropriate to support the preservation and restoration of existing natural ecosystems than to attempt to re-create and maintain them artificially because of all their subtle and complex interactions.

Recovery cannot be achieved by introducing cui-ui into another river-lake system. There is no system within the species' historical range that provides spawning and rearing habitat similar to that of Truckee River-Pyramid Lake and certainly none that enjoys a similar measure of regulatory protection: Winnemucca Lake is dry; Honey Lake is ephemeral; and Walker Lake is highly saline, with variable and limited Walker River inflow. Recovery can only be achieved within the Truckee River-Pyramid Lake system.

5. Use Computer Models

The Dynamic Stream Simulation and Assessment Model (DSSAM) is a tool being developed by the U.S. Environmental Protection Agency and Nevada Division of Environmental Protection to determine the efficacy of various water quality management scenarios to meet water quality standards in the Truckee River. The model should be used to develop the most effective strategies to achieve water quality management objectives (see Appendix A).

Water operations (Truckee-Carson basin) and biological (cui-ui) computer models have been used with a historic monthly hydrologic data base to compare the relative impacts of water management plans on lower Truckee River flow and, indirectly, cui-ui reproduction (see Appendix B). Because a comparative approach alone cannot determine which water management plan(s) may lead to recovery of the species, this Recovery Plan uses a probabilistic predictive approach with available computer models to identify a set of conditions which, if implemented, could help to achieve delisting of cui-ui with a high degree of certainty. The probabilistic technique used to define reclassification/delisting is described in Appendix C; an evaluation of measures to achieve the recommended results from that technique is presented in Appendix D. Computer-aided techniques will continue to be used to develop and evaluate water and habitat management plans for the eventual recovery of the species.

6. Update and Revise Recovery Plan and Objective

The recovery plan should be updated as tasks are completed, or revised as conditions in the basin change and as additional information becomes available. The recovery objective may change as the effectiveness of implemented conservation measures are evaluated, water supply and management in the Truckee River basin are altered, the cui-ui information base is improved, and the Truckee-Carson Hydrologic and cui-ui models are refined.

II. RECOVERY

A. Objective

Cui-ui will be considered for reclassification from endangered to threatened when it is demonstrated that:

1. The species has a probability of at least 0.85 of persisting for 200 years;
2. Additional annual Truckee River inflow to Pyramid Lake of 45,000 acre-feet or the equivalent benefit have been secured at a minimum rate of 5,000 acre-feet/year; and
3. Estimated numbers of adult cui-ui and year classes of juveniles and adults has been stable or increasing during the previous 15 years.

Reclassification could be accomplished within 11 years if efforts are begun no later than 1994.

Cui-ui will be considered for delisting when it is demonstrated that:

1. The species has a probability of at least 0.95 of persisting for 200 years;
2. Additional annual Truckee River inflow to Pyramid Lake of 65,000 acre-feet or the equivalent benefit beyond the amount required for reclassification (equivalent to 110,000 acre-feet) has been secured at a minimum rate of 5,000 acre-feet/year;
3. Estimated numbers of adult cui-ui and year classes of juveniles and adults have been stable or increasing during the previous 15 years;
4. Lake and river water quality standards have been achieved during the previous 15 years (see Appendix Table A-1);
5. The lower Truckee River floodplain has been rehabilitated;
6. Marble Bluff Fish Facility and Numana Dam Fish Ladder have been modified to pass upstream at least 300,000 adult cui-ui during a spawning run;
7. Maintenance and operation of various water storage and fish passage facilities for cui-ui have been secured; and
8. A hatchery refuge for brood stock has been established to protect against catastrophic events.

Delisting could be accomplished within 24 years if efforts are begun no later than 1994.

These objectives were based, in part, on probabilistic projections of future hydrologic conditions in the Truckee River Basin and the simulated response of cui-ui. Rationale for this objective and schedule is presented in Appendix A and C. A discussion of the methods to acquire equivalent benefits for cui-ui is presented in Appendix D. A simplified diagram of the strategy for recovery of cui-ui is presented in Figure 3.

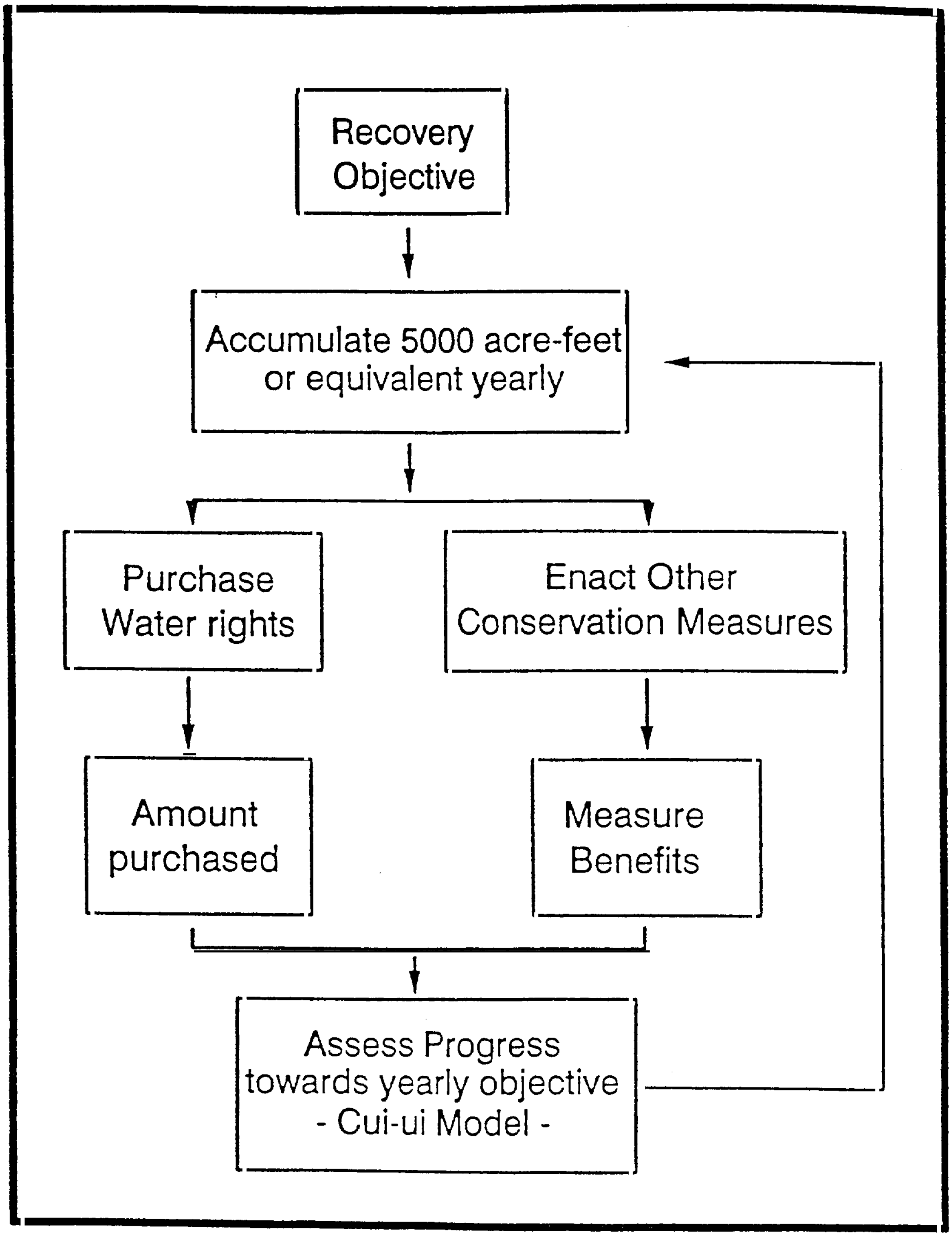

Figure 3. Strategic Plan for Obtaining Recovery.

B. Narrative Outline Plan for Recovery Actions Addressing Threats

Cui-ui was listed as endangered because human activities upset the natural hydrologic dynamics of the Truckee River/Pyramid Lake system by extensive storage, diversion and use of river water. Cui-ui may be reclassified or recovered by implementing a variety of conservation measures; the potential depends upon the level to which the river/lake system can be restored. These measures include: Securing and maintaining cui-ui habitat in the lower Truckee River and Pyramid Lake; operating water storage and fish passage facilities to promote spawning; and protecting the population from catastrophic events. Each lead Federal agency identified in the Implementation Schedule will be responsible for implementing appropriate measures from the following list.

As conservation measures are accomplished and/or new information is gained about cui-ui life history and habitat needs, progress toward recovery should be evaluated through the cui-ui model (Appendix B). Results of these analyses will guide design and implementation of future conservation measures. In this way, contemplated or ongoing conservation measures may be adjusted to enhance benefits of other measures.

1 Secure adequate habitat to meet recovery objective

The equivalent and cumulative benefit of 5,000 acre-feet/year must be secured, beginning no later than 1994, to promote recovery of the species (Appendix C). To "secure" is to ensure the benefit of a conservation measure for 200 years.

There are many conservation measures that could help secure adequate habitat for cui-ui recovery (Appendix D). For example, improvements in watershed management, including timing of storage releases and efficient water use, could promote recovery.

Four broad categories of conservation measures must be implemented to improve and protect cui-ui spawning and rearing habitat: Increase volume and improve timing of inflow; rehabilitate the lower river; achieve water quality standards; and improve fish passage in the lower Truckee River. Certain specific measures within these broad categories will provide short-term benefits, while other measures will provide long-term benefits. Some measures can be accomplished immediately and yield immediate benefits, and others will require a number of years for implementation and securance of habitat. Immediate measures include purchase of Truckee River water rights (which are limited but which will secure habitat) and reduction of diversions from the Truckee River (also limited, but may not secure habitat). Long-term measures include rehabilitation of the lower Truckee River floodplain and achievement of water quality standards in the lower Truckee River.

1.1 Increase volume and improve timing of lower Truckee River flows

Increasing annual and spawning flows in the lower Truckee River will increase the likelihood of recruitment to the cui-ui population and complement other conservation measures. These conditions could be achieved by implementing the Truckee River Operating Agreement (TROA), reducing diversions from the Truckee and Carson rivers, recoupment of water from the Newlands Project, and purchase of Truckee River water rights.

The Secretary, in cooperation with the states of Nevada and California and other interested parties, is developing a plan (TROA) for improving the management of Truckee River flows. The primary component of TROA will be the integrated management of all Federal and private reservoirs on the Truckee River, including Stampede Reservoir which is presently dedicated solely for the benefit of listed fishes of Pyramid Lake. It is intended that this plan will increase benefits to cui-ui, beyond those provided by Stampede, by increasing water availability through fishery credit storage procedures and release during the spawning period.

Reducing diversion of Truckee River water will increase availability of water in the lower Truckee River seasonally as well as annually (Appendix D). This could be accomplished in the Newlands Project, in part, by improving water distribution system efficiency, reducing storage targets for Lahontan Reservoir (as specified in Operating Criteria and Procedures) as Project water demand decreases, and by reducing water demand on Fallon Naval Air Station through a modified dust, fire, and foreign object management plan. Implementation of water conservation measures in the Reno/Sparks area could also decrease diversion from the Truckee River. Recoupment of approximately 1,000,000 acre-feet diverted from the Truckee River to the Newlands Project from 1973 through 1985, purportedly in violation of orders from the Secretary and the U.S. District Court for the District of Columbia, could provide a short-term supply to help maintain Pyramid Lake elevation, improve river access for spawning, and improve spawning habitat. Increasing irrigation water distribution system efficiency in the upper Carson basin (in compliance with the Alpine decree) could decrease diversion from the Truckee River by increasing Carson River inflow to Lahontan Reservoir.

Acquisition of water rights would increase inflow to Pyramid Lake and secure spawning and rearing habitat. Only active water rights from the Truckee River should be acquired. Place-of-use should be transferred to Pyramid Lake and beneficial use changed through the Nevada State Water Engineer for the benefit of cui-ui. Securing certain of those rights, especially those with the potential for upstream storage, should be given special consideration.

P.L. 101-618 authorizes all of the preceding conservation measures, except upper Carson basin efficiency measures, to benefit cui-ui.

1.1.1 Develop Action Plan to increase volume and improve timing of lower Truckee River flows

An action plan should be developed immediately to identify which of the above-cited actions must be implemented to achieve the benefits of the conservation measures. Selection of those measures should be based on quantification of benefits and likelihood of implementation. Action agencies should be identified.

1.1.2 Implement Action Plan to increase volume and improve timing of lower Truckee River flows

The action plan to increase volume and improve timing of lower Truckee River flows must be implemented by 1994 to promote recovery. Implementation should conform with conservation measures and be based upon best available information.

1.2 Rehabilitate lower Truckee River floodplain

P.L.101-618 directs the Secretary of the Army (Corps of Engineers) to study the rehabilitation of the lower Truckee River for the benefit of listed fishes of Pyramid Lake. A final reconnaissance report to be completed by June 1992 should include recommendations for improving spawning substrate, river canopy, and delta passage. The planning process should continue to the feasibility phase. An implementation plan should be developed and funding should be sought.

1.2.1 Improve intergravel environment

Survival of cui-ui embryos in the intergravel environment depends upon the free flow of well-oxygenated water. Factors restricting this flow and controlling oxygen consumption, such as periphyton growth and siltation, should be investigated.

1.2.1.1 Develop plan to improve intergravel environment

A plan to improve the intergravel environment in the lower Truckee River and promote cui-ui embryo survival should be developed.

1.2.1.2 Implement plan to improve intergravel environment

The plan to improve the intergravel environment in the lower Truckee River and promote cui-ui embryo survival should be implemented.

1.2.2 Re-establish riparian vegetation along the lower Truckee River

The riparian vegetation of the lower river, which is important to stabilizing the river channel and maintaining lower water temperatures, has been greatly degraded over the last few decades. Rehabilitation of the lower river will require a comprehensive understanding of the river's dynamics. Under the direction of P.L.101-618, the Corps of Engineers should seek funding and conduct an investigation to determine the hydraulics of the lower river and methods to re-establish the lower river canopy.

1.2.2.1 Develop plan to re-establish riparian vegetation along the lower Truckee River

A plan to re-establish riparian vegetation along the lower Truckee River should be developed.

1.2.2.2 Implement plan to re-establish the riparian canopy

The plan to re-establish riparian vegetation along the lower Truckee River should be implemented.

1.2.3 Improve cui-ui passage over the delta at the mouth of the Truckee River

P.L.101-618 directs the Secretary of the Army to determine the feasibility of controlling delta growth and improving cui-ui access to the Truckee River. If these goals are feasible, a remedial plan should be developed and implemented.

1.2.3.1 Develop plan to improve cui-ui passage over the Truckee River delta

A plan to improve cui-ui passage over the Truckee River delta should be developed.

1.2.3.2 Implement plan to improve cui-ui passage over the Truckee River delta

The plan to improve cui-ui passage over the Truckee River delta should be implemented.

1.3 Achieve water quality standards in the lower Truckee River

Water quality of the lower Truckee River must be improved. Water quality problems are due to point and non-point sources from Lake Tahoe to Marble Bluff Dam. These sources must be reduced to achieve water quality standards as soon as possible. Many water pollution abatement techniques and procedures have been identified, but only a few have been fully implemented. Corrective actions should focus on reducing inputs from those sources that are the most important in affecting the lower river and Pyramid Lake. Water quality parameters which could potentially adversely impact cui-ui survival and recovery include nutrient loading, total dissolved solids (TDS), and suspended solids.

1.3.1 Continue nutrient study of Pyramid Lake

Water quality standards for nutrients are frequently exceeded in the Truckee River; this condition increases nutrient loading to Pyramid Lake. Knowledge of impacts of nutrients on cui-ui rearing habitat is essential to designing conservation measures. The ongoing nutrient loading study of Pyramid Lake by the University of California - Davis should continue.

1.3.2 Determine impact of river TDS and suspended solids on Pyramid Lake

A study should be conducted to determine the long-term effect of TDS and suspended solids in the Truckee River on water quality and biological diversity in Pyramid Lake.

1.3.3 Develop Truckee River water quality model

Efforts to develop and verify the Truckee River water quality model (Dynamic Stream Simulation and Assessment Model, or DSSAM) as part of the Truckee River Strategy should continue.

1.3.4 Achieve point and non-point source discharge compliance with water quality standards

Point and non-point sources contribute to degraded water quality in the Truckee River. Most of the point sources are located in the Truckee Meadows area. Non-point sources are generally associated with agricultural activities in the Truckee basin.

1.3.4.1 Ensure compliance with wastewater permit conditions

Coordination among the cities of Reno and Sparks, Washoe County, and the State of Nevada is required to meet permit conditions for discharges from wastewater treatment facilities.

1.3.4.2 Eliminate non-point sources detrimental to Truckee River water quality

Agricultural and domestic activities along the Truckee River contribute to non-point source water quality problems. Lands contributing significant loads of pollutants should be identified. A plan to eliminate those sources should be developed and implemented.

1.3.4.2.1 Identify detrimental non-point sources along the Truckee River

Non-point sources detrimental to Truckee River quality should be identified.

1.3.4.2.2 Develop plan to eliminate detrimental non-point sources

A plan to eliminate non-point sources detrimental to Truckee River quality should be developed.

1.3.4.2.3 Implement plan to eliminate detrimental non-point sources

The plan to eliminate non-point sources detrimental to Truckee River quality should be implemented.

1.4 Improve fish passage through lower Truckee River fish facilities

Because existing fish passage facilities are only marginally effective in attracting and passing cui-ui upstream, studies should be conducted to determine how to improve them. The facilities should also be modified to reduce the stress to and accidental death of cui-ui while traversing the system. The Service must evaluate the impact of allowable mortality. As studies are completed and recommendations made, funds should be sought to implement the recommendations. Potential benefits of different modification designs can be evaluated through the cui-ui model.

1.4.1 Improve fish passage through Marble Bluff Fish Facility

Marble Bluff Fish Facility provides passage over Marble Bluff Dam for all cui-ui spawning runs. Fish ascending the river are captured in the river trap and raised to the level of the upstream impoundment. Those ascending the Pyramid Lake Fishway are captured and passed upstream through an elevator and chute system. Both of these passage avenues interfere with the timing and number of cui-ui reaching spawning habitat; they have insufficient capacity for attraction flows and the fishway ladders restrict passage.

1.4.1.1 Develop plan to improve Marble Bluff Fish Facility

A plan to improve the timing and increase the number of cui-ui passing through the river trap and fishway should be developed.

1.4.1.2 Implement plan to improve Marble Bluff Fish Facility

The plan to improve the timing and increase the number of cui-ui passing through the river trap and fishway should be implemented.

1.4.2 Improve cui-ui passage through Numana Dam Fish Ladder

This ladder can provide passage to spawning habitat upstream of Dead Ox Canyon. The current design impairs fish passage. Though this ladder is not used at present, upstream spawning may be required to achieve the recovery objective.

1.4.2.1 Develop plan to improve Numana Dam Fish Ladder

A plan to improve cui-ui passage through Numana Dam Fish Ladder should be developed.

1.4.2.2 Implement plan to improve Numana Dam Fish Ladder

The plan to improve cui-ui passage through Numana Dam Fish Ladder should be implemented.

2 Refine cui-ui model with new information

Refining the cui-ui model should be a continuous function in the cui-ui recovery program. The model should be updated as new information about conservation measures, life history, hydrology, geomorphology, and other aspects important to cui-ui recovery becomes available.

2.1 Collect data on impacts of conservation measures

Conduct studies necessary to quantify the benefits of completed conservation measures.

2.2 Collect data for refining the cui-ui model and hydrologic data base

The predictive capacity of the cui-ui model can be enhanced by increasing knowledge of cui-ui and its habitat requirements, and by increasing knowledge of Truckee River geomorphology and hydrology.

2.2.1 Update hydrologic data base

Stochastically created water year scenarios used in the cui-ui model were based on data derived from 89 years of monitoring the Truckee River. The reliability of these scenarios is a function of the length and accuracy of the hydrologic record. As the hydrologic data base expands, our ability to forecast future water events should improve. It is also essential that projection of future demands on the water resources of the Truckee River be updated continually. Improved hydrologic projections will be used with the cui-ui model to improve reliability of cui-ui population projections.

2.2.2 Increase knowledge of existing river conditions

Investigations of geomorphological and hydraulic characteristics of the lower Truckee River and the Truckee River delta should be conducted to increase knowledge necessary to improve access to spawning habitat; knowledge of substrate conditions will be used to improve and maintain spawning habitat. Information on the condition of and controlling factors associated with floodplain vegetation in conjunction with water quality is also needed to improve and maintain spawning habitat. A portion of this work may be accomplished through task 1221.

2.2.3 Increase knowledge of fish spawning requirements

Though much information about cui-ui spawning requirements has been gained over the last decade, additional information is needed to develop and modify conservation measures and to refine the predictive capacity of the cui-ui model.

2.2.3.1 Gather additional data on the relation between river discharge and cui-ui attraction

The relation between attraction flow and the timing and size of cui-ui spawning runs must be improved. This information is essential to the effective use of upstream storage for cui-ui.

2.2.3.2 Gather additional data on the relation of river flow and water temperature

River temperature is critical to cui-ui egg development and reproductive success. The relation of flow in the lower Truckee River to water temperature is currently based on median monthly water and air temperatures. To ensure that releases from dedicated water storage promotes cui-ui reproduction, this relation must be based on hourly data. A model should be developed to predict water temperatures along the entire river; it should incorporate the effects of evaporation, solar radiation, shading, wind, and air temperature.

2.2.3.3 Refine knowledge of cui-ui spawning habitat

Little is known of the water quality requirements and tolerances of cui-ui while in the river. Ongoing research will help to elucidate which of these factors may be limiting the potential for recovery.

2.2.4 Refine estimates of cui-ui survival

Determination of annual survival rates for all life stages and of factors that influence these rates is essential to the restoration of the species. At present, survival rate estimates for adults are not precise and only surmised for the other stages. Little is known of factors (density dependent and independent, intraspecific and interspecific competition, predation, and water quality) that influence these survival rates. Research should be conducted to acquire information to determine these rates.

2.2.5 Describe cui-ui genome

Recent electrophoretic analysis indicates that individual cui-ui may have little genetic variability. A study to determine if a genetic bottleneck has occurred should be conducted as soon as possible. Results of this study will be used in performing tasks 226, 4221, and 511.

2.2.6 Determine impact of spawning frequency on cui-ui genome

Because of restricted access to river spawning habitat, current cui-ui spawning run size and frequency are probably much smaller than historic levels. A study should be conducted to determine if response to current spawning conditions has changed or is likely to change the species genome.

2.2.7 Refine knowledge of cui-ui rearing habitat

Little is known of the lake habitat requirements and tolerances of cui-ui, quality of existing lake habitat, food preferences and availability, spatial and temporal distribution, and carrying capacity of the lake for each life stage. Ongoing research will help to elucidate which of these factors may be limiting the potential for recovery.

3 Use cui-ui model to predict benefits of conservation measures

As new information about conservation measures, life history and hydrology is obtained to refine the cui-ui model (task 2), the cui-ui model should be used with the stochastic hydrology data base and the hydrologic model to predict the benefits attributed to implemented and proposed conservation measures.

3.1 Predict benefits of implemented conservation measures

The cui-ui model should be used to predict the benefits of implemented conservation measures relative to the recovery objective.

3.2 Establish priorities for proposed conservation measures

The cui-ui model should be used to update and revise the plan objective and tasks based upon changing conditions in the basin.

4 Manage cui-ui spawning runs

Because humans will always be needed to control various aspects of the cui-ui ecosystem, funds must be provided for maintaining and operating various water storage and fish passage facilities and for monitoring the size of the cui-ui population and spawning runs.

4.1 Operate and maintain dedicated storage reservoirs

Storage facilities must be maintained to provide intended benefits when scheduled. Plans for releasing water from upstream storage to supplement lower Truckee River flows for cui-ui spawning runs must be developed each year. These plans must be consistent with all relevant river and reservoir operating agreements, flood control criteria, safety standards, and court decrees.

4.1.1 Maintain dedicated storage reservoirs

Stampede Reservoir is the only facility currently dedicated to store water for the benefit of cui-ui spawning. Other storage facilities may become available through implementation of TROA. Stampede and other Federal storage facilities will continue to be maintained by Reclamation.

4.1.2 Operate dedicated storage reservoirs to promote cui-ui spawning

Storage reservoirs dedicated for cui-ui are currently operated by the Federal Water Master in consultation with the Service. Future scheduling and operation activities for reservoirs storing water dedicated for cui-ui spawning will be identified in TROA.

4.1.2.1 Develop annual plan for release of water for spawning run

An annual operating plan for the release of Stampede and other dedicated storage water to promote cui-ui spawning should be developed by the Service in consultation with Reclamation, the Tribe and Federal Water Master (or TROA watermaster).

4.1.2.2 Implement annual plan for release of water for spawning run

The plan will be implemented by the Federal Water Master (or TROA watermaster).

4.2 Operate and maintain lower Truckee River fish passage facilities

Marble Bluff Fish Facility (river trap and fishway) and Numana Dam Fish Ladder will continue to be required for upstream passage of cui-ui spawners. These facilities must continue to be maintained with operation coordinated to promote passage of cui-ui spawners.

4.2.1 Maintain lower Truckee River fish passage facilities

Marble Bluff Fish Facility and Numana Dam Fish Ladder must be maintained to provide fish passage when required.

4.2.2 Operate lower Truckee River fish passage facilities

An annual operating plan will insure that operations of Marble Bluff Fish Facility and Numana Dam Fish Ladder are coordinated and passage of cui-ui spawners is promoted.

4.2.2.1 Develop annual operating plan for spawning run

An annual operating plan should be developed by the Service to coordinate operations of Marble Bluff Fish Facility and Numana Dam Fish Ladder for passage of cui-ui spawners.

4.2.2.2 Implement annual operating plan for spawning run

An annual operating plan should be implemented by the Service to coordinate operations of Marble Bluff Fish Facility and Numana Dam Fish Ladder for passage of cui-ui spawners.

4.3 Monitor cui-ui population

A monitoring program will provide essential information for evaluating conservation measures, management actions, and status of the species.

4.3.1 Conduct annual monitoring program

An annual monitoring program should be established to estimate size of the prespawning aggregate, number of spawners which migrate up- and downriver, and recruitment to the population.

4.3.2 Conduct monitoring program every five years

A detailed study should be conducted every five years to estimate size of the cui-ui population in the lake.

5 Protect cui-ui population

The effectiveness of conservation measures and management activities will diminish if the population and its environment is not protected. Various protective measures must be implemented.

5.1 Operate cui-ui hatchery

The David Koch Cui-ui Hatchery should be operated and maintained as a refuge for the species. Extended rearing should be instituted to ensure survival of hatchery-reared cui-ui released to the lake.

5.1.1 Maintain rotating brood stock

The hatchery should maintain a rotating brood stock that reflects the genetic characteristics of the wild population. This brood stock will provide a back-up population in case a catastrophic event were to decimate the wild population. Research (identified in task 225) is required to determine how to select these individuals and how many individuals should be spawned. Holding capacity within the hatchery may need to be expanded to maintain these individuals.

5.1.2 Evaluate effectiveness of hatchery operation

The survival of cui-ui reared in the hatchery for extended periods and released to Pyramid Lake should be determined. A procedure to mark/tag hatchery-reared cui-ui should be implemented. Information on the effectiveness of the hatchery operation to produce viable and genetically diverse cui-ui will be gathered and analyzed in conjunction with task 4.3.

5.2 Conduct toxic spill risk assessment for the Truckee River

Pyramid Lake is highly susceptible to toxic substances carried by the Truckee River. Potential toxicant sources or catastrophic events should be identified and a spill prevention and remediation plan should be developed and implemented.

5.2.1 Identify potential sources of toxic spill

Potential sources of toxic spill to the Truckee River should be identified.

5.2.2 Develop a spill prevention and remediation plan for the Truckee River

A spill prevention and remediation plan should be developed for the Truckee River

5.2.3 Implement the spill prevention and remediation plan for the Truckee River

The spill prevention and remediation plan for the Truckee River should be implemented.

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III. IMPLEMENTATION SCHEDULE

The table that follows is a summary of scheduled actions and costs for this recovery program. It is a guide to meet the objectives of the Cui-ui Recovery Plan. This table indicates the priority in scheduling tasks to meet the objectives, which agencies are responsible to perform these tasks, a timetable for accomplishing these tasks, and the estimated costs to perform them. Implementing Part III is the action of this plan, that when accomplished, will satisfy the recovery objective. Initiation of these actions is subject to the availability of funds.

Priorities in Column 1 of the following implementation schedule are assigned as follows:

> Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
>
> Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.
>
> Priority 3 - All other actions necessary to provide for full recovery of the species.

Recovery Plan Implementation Schedule for Cui-ui

Priority #	Task #	Task Description	Task Duration (YRS)	Responsible Party	Total Cost	Cost Estimates ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
1	111	Develop Action Plan for lower Truckee River flows	2	DOI* NV CA PLT	50	15	35	**	**	**	
1	112	Implement Action Plan for lower Truckee River flows	cont.	DOI* NV CA PLT	**		**	**	**	**	
1	1221	Develop plan to re-establish riparian vegetation	2	COE	**	**	**				
1	1222	Implement plan to re-establish riparian vegetation	8	COE	**			**	**	**	
1	1231	Develop plan to improve fish passage over the delta	2	COE	**	**	**				
1	1232	Implement plan to improve fish passage over the delta	8	COE	**			**	**	**	
1	21	Collect data on impacts of conservation measures	cont.	FWS-FWE	1,610	0	0	70	70	70	
1	225	Describe genome	1	FWS-FR	10	10	0	0	0	0	
1	226	Determine impact of spawning frequency on genome	3	FWS-FR	30	0	10	10	10	0	
1	411	Maintain dedicated storage reservoirs	ongoing	BR	3,000	120	120	120	120	120	

Recovery Plan Implementation Schedule for Cui-ui

Priority #	Task #	Task Description	Task Duration (YRS)	Responsible Party	Total Cost	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
3	522	Develop spill prevention and remediation plan	1	NDEP*	30	0	30	0	0	0	
				FWS-FWE	30	0	30	0	0	0	
3	523	Implement spill prevention and remediation plan	1	NDEP*	50	0	0	50	0	0	
				FWS-FWE	50	0	0	50	0	0	
		NEED 5			690	0	200	110	10	10	
				Totals	13,959	682	898	973	763	843	

Continual = Task will be implemented on an annual basis once it is begun.
Ongoing = Task is currently being implemented and will continue until action is no longer necessary for recovery.
Unknown = Implementation of task and associated cost cannot be determined with certainty.
* = Lead Agency
** = Actions authorized by P.L.101-618, but funding for task development and implementation unknown at this time
*** = Tasks 224 and 227 are incorporated with Task 2231
**** = Task 512 is incorporated with Tasks 431 and 432

Total Cost = Projected cost of task from start to task completion.
N.B.: Totals do not reflect costs associated with P.L.101-618.

Responsible Parties:

- DOI = Department of the Interior, primarily FWS, BR, and GS
- BR = Bureau of Reclamation
- GS = Geological Survey
- COE = Army Corps of Engineers
- NV = State of Nevada
  - NDEP = Division of Environmental Protection
- CA = State of California
- PLT = Pyramid Lake Paiute Indian Tribe
- FWM = Federal Water Master
- WC = Responsible water resource agency in Washoe County
- FWS = Fish and Wildlife Service
  - FWE = Division of Fish and Wildlife Enhancement, Region 1
  - FR = Division of Fishery Resources, Region 1
  - NFRS = National Fishery Research, Seattle, Region 8

Recovery Plan Implementation Schedule for Cui-ui

Priority #	Task #	Task Description	Task Duration (YRS)	Responsible Party	Total Cost	Cost Estimates ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
1	4121	Develop annual plan for release of water for spawning run	ongoing	FWS-FWE* BR PLT FWM	75	3	3	3	3	3	
1	4122	Implement annual plan for release of water for spawning run	ongoing	FWM	125	5	5	5	5	5	
1	421	Maintain lower Truckee River fish passage facilities	ongoing	FWS-FR	2,000	80	80	80	80	80	
1	4221	Develop annual operating plan for spawning run	ongoing	FWS-FR	29	5	1	1	1	1	
1	4222	Implement annual operating plan for spawning run	ongoing	FWS-FR	1,000	40	40	40	40	40	
2	1211	Develop plan to improve intergravel environment	1	COE	30	0	0	30	0	0	
2	1212	Implement plan to improve intergravel environment	3	COE	170	0	0	0	70	50	
2	131	Continue nutrient study of Pyramid Lake	3	PLT* EPA	450	150	150	150	0	0	
2	132	Determine impact of river TDS	5	GS* FWS-NFRS	500	0	0	100	100	100	
2	133	Develop Truckee River water quality model	ongoing	NDEP* EPA	unk.						
2	1341	Ensure compliance with wastewater permit conditions	ongoing	NDEP	unk.						
2	13421	Identify detrimental non-point sources	unk.	WC	unk.						

Recovery Plan Implementation Schedule for Cui-ui

Priority #	Task #	Task Description	Task Duration (YRS)	Responsible Party	Total Cost	Cost Estimates ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	13422	Develop plan to eliminate detrimental non-point sources	unk.	WC	unk.						
2	13423	Implement plan to eliminate detrimental non-point sources	unk.	WC	unk.						
2	1411	Develop plan to improve Marble Bluff Fish Facility	unk.	FWS-FR* COE	unk.						
2	1412	Implement plan to improve Marble Bluff Fish Facility	unk.	FWS-FR* COE	unk.						
2	1421	Design plan to improve Numana Dam Fish Ladder	unk.	FWS-FR* COE	unk.						
2	1422	Implement plan to improve Numana Dam Fish Ladder	unk.	FWS-FR* COE	unk.						
		NEED 1			1,200	165	185	280	170	150	
2	221	Update hydrologic data base	ongoing	GS	**	**	**	**	**	**	
2	222	Increase knowledge of existing river conditions	unk.	COE* FWS-FWE	unk.						
2	2231	Study relation between river discharge and cui-ui attraction	6	FWS-NFRS	900	150	150	150	150	150	
2	2232	Study relation of river flow and water temperature	6	GS	**		**	**	**	**	
2	2233	Refine knowledge of cui-ui spawning habitat	6	FWS-NFRS	***	***	***	***	***	***	

Recovery Plan Implementation Schedule for Cui-ui

Priority #	Task #	Task Description	Task Duration (YRS)	Responsible Party	Total Cost	Cost Estimates ($1,000)					Comments
						FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	
2	224	Refine estimates of cui-ui survival	6	FWS-NFRS	***	***	***	***	***	***	
2	227	Refine knowledge of cui-ui rearing habitat	6	FWS-NFRS	***	***	***	***	***	***	
		NEED 2			2,550	160	160	230	230	220	
2	31	Evaluate benefits of implemented conservation measures	ongoing	BR* FWS-FWE	1,060 580	40 20	40 20	40 20	40 20	40 20	
2	32	Establish priorities for proposed conservation measures	ongoing	BR* FWS-FWE	75 25	3 1	3 1	3 1	3 1	3 1	
		NEED 3			1,740	64	64	64	64	64	
2	431	Conduct annual monitoring program	ongoing	FWS-FH	800	40	40	40	40	0	
2	432	Conduct five-year monitoring program	cont.	FWS-FH	750	0	0	0	0	150	
		NEED 4			7,779	293	289	289	289	399	
2	511	Maintain rotating brood stock	ongoing	PLT	490	0	100	10	10	10	
2	512	Evaluate effectiveness of hatchery operation	cont.	FWS-FH	****	****	****	****	****	****	
3	521	Identify potential sources of toxic spill	1	NDEP* FWS-FWE	20 20	0 0	20 20	0 0	0 0	0 0	

IV. APPENDICES

A. Truckee River and Pyramid Lake Water Quality

B. Cui-ui Model

C. Probabilistic Cui-ui Response

D. Evaluation of Measures to Secure Water for Cui-ui

E. Individuals Contacted During Technical/Agency Review

APPENDIX A:

LOWER TRUCKEE RIVER BASIN WATER QUALITY

INTRODUCTION

Reduction of lower Truckee River flows resulting primarily from diversions of river water to agricultural interests was the major cause of the decline of the cui-ui population and eventual listing of the species as federally endangered. Such reductions historically were of such magnitude to preclude consideration of other causal factors in the species decline. Recent emphasis on recovery of the species has led to allocation of Stampede Reservoir storage to promote and enhance cui-ui (primarily) spawning and recruitment. Such benefits are offset, however, by urbanization in the basin (particularly Truckee Meadows, the Reno-Sparks area) which has drawn increasing attention to water quality conditions in the river downstream from point-source discharges and to previously unregulated nonpoint-source discharges. The following presentation summarizes current data for pertinent water quality parameters and data collection programs for the lower Truckee River and Pyramid Lake which may impact cui-ui, with specific implications for the species' eventual recovery.

TRUCKEE RIVER WATER QUALITY

Water quality parameters potentially influencing cui-ui success and larvae survival include, but may not be limited to, temperature, nutrients (nitrogen and phosphorus), total suspended solids (siltation) and intergravel dissolved oxygen (DO). Possibly the most important factor controlling water quality in the lower Truckee River during the cui-ui spawning run, April through June, is the large volume of water ($\geq$1000 cfs) necessary to maintain acceptable water temperature. Such flows, under average air temperature, would produce an average daily maximum water temperature of 17° C at Nixon, provide sufficient spawning area, and allow for adult and larvae outmigration (Buchanan 1987). Due to the high dilution factor, point source, as well as non-point source, pollutants generally remain at acceptably low concentrations and water quality standards are achieved. In addition, factors that control biostimulation such as light, temperature and scouring are sub-optimal for periphyton production and thus their effects on DO and pH are minimal. Water quality standards for the lower Truckee River (1991) are presented in Table A-1.

Intergravel Dissolved Oxygen - Scoppettone et al. (1983) showed that adult cui-ui spawn over predominantly gravel substrate and bury their eggs as deep

TABLE A-1: Current water quality standards for lower Truckee River and Pyramid Lake as set by Environmental Protection Agency.

445.1302 "SAR" defined. "SAR" means sodium adsorption ratio.
(Added to NAC by Environmental Comm'n, eff. 6-29-84)

445.1304 "S.V." defined. "S.V." means single value.
(Added to NAC by Environmental Comm'n, eff. 6-29-84)

445.1306 "≥" defined. "≥" means greater than or equal to.
(Added to NAC by Environmental Comm'n, eff. 6-29-84)

445.1308 "≤" defined. "≤" means less than or equal to.
(Added to NAC by Environmental Comm'n, eff. 6-29-84)

445.1337 Cooperation regarding Colorado River; salinity standards.

1. The State of Nevada will cooperate with the other Colorado River Basin states and the Federal Government to support and carry out the conclusions and recommendations adopted April 27, 1972, by the reconvened 7th session of the conference in the matter of pollution of interstate waters of the Colorado River and its tributaries.
2. Pursuant to subsection 1, the values for total dissolved solids in mg/l at the three lower main stem stations of the Colorado River are as follows:

Below Hoover Dam	723
Below Parker Dam	747
Imperial Dam	879

[Environmental Comm'n, Water Pollution Control Reg. Appendix B, eff. 5-2-78]--(NAC A 12-3-84)

Table A-1(Cont.)

c. Based on the minimum of not less than 5 samples taken over a 30-day period, the fecal coliform bacterial level may not exceed a geometric mean of 200 per 100 ml nor may more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.
d. Increase in color must not be more than 10 PCU above natural conditions.

[Environmental Comm'n, Water Pollution Control Reg. part § 4.2.5, Table 42.1, eff. 5-2-78; A 1-25-79; 8-28-79; 1-25-80; 12-3-80]--(NAC A 10-25-84)

Table A-1(Cont.)

445.1339 Standards for toxic materials applicable to designated waters. Except as otherwise provided in this section, the following standards for toxic materials are applicable to the waters specified in NAC 445.121 to 445.125, inclusive, and NAC 445.134 to 445.1385, inclusive. If the standards are exceeded at a site and are not economically controllable, the commission will review and adjust the standards for the site.

Chemical	**Municipal or Domestic Supply** ($\mu g/l$)	**Aquatic Life** ($\mu g/l$)	**Irrigation** ($\mu g/l$)	**Watering of Livestock** ($\mu g/l$)
Antimony	146[a]	-	-	-
Arsenic	50[b]	-	100[c]	200[d]
Arsenic (III)	-	-	-	-
1-hour average	-	360[a]	-	-
96-hour average	-	190[a]	-	-
Barium	1,000[a,b]	-	-	-
Beryllium	0[a]	-	100[c]	-
hardness <75 mg/l	-	-	-	-
hardness > = 75mg/l	-	-	-	
Boron	-	550[e]	750[a]	5,000[d]
Cadmium	10[a,b]	-	10[d]	50[d]
1-hour average	-	$\exp\{1.128 \ln(H)-3.828\}$[a]	-	-
96-hour average	-	$\exp\{0.7852 \ln(H)-3.490\}$[a]	-	-
Chromium (total)	50[b]	-	100[d]	1,000[d]
Chromium (VI)	-	-	-	-
1-hour average	-	16[a]	-	-
96-hour average	-	11[a]	-	-

Table A-1 (Cont.)

Chemical	Municipal or Domestic Supply (μg/l)	Aquatic Life (μg/l)	Irrigation (μg/l)	Watering of Livestock (μg/l)
Chromium (III)	-	-	-	-
1-hour average	-	$\exp\{0.8190\ \ln(H)+3.688\}$[a]	-	-
96-hour average	-	$\exp\{0.8190\ \ln(H)+1.561\}$[a]	-	-
Copper	-	-	200[d]	500[d]
1-hour average	-	$\exp\{0.9422\ \ln(H)-1.464\}$[a]	-	-
96-hour average	-	$\exp\{0.8545\ \ln(H)-1.465\}$[a]	-	-
Cyanide	200[a]	-	-	-
1-hour average	-	22[a]	-	-
96-hour average	-	5.2[a]	-	-
Fluoride	-	-	1,000[d]	2,000[d]
Iron	-	1,000[a]	5,000[d]	-
Lead	50[a,b]	-	5,000[d]	100[d]
1-hour average	-	$\exp\{1.273\ \ln(H)-1.460\}$[a]	-	-
96-hour average	-	$\exp\{1.273\ \ln(H)-4.705\}$[a]	-	-
Manganese	-	-	200[d]	-
Mercury	2[b]	-	-	10[d]
1-hour average	-	2.4[a]	-	-
96-hour average	-	0.012[a]	-	-
Molybdenum	-	19[e]	-	-
Nickel	13.4[a]	-	200[d]	-
1-hour average	-	$\exp\{0.8460\ \ln(H)+3.3612\}$[a]	-	-
96-hour average	-	$\exp\{0.8460\ \ln(H)+1.1645\}$[a]	-	-
Selenium	10[a,b]	-	20[d]	50[d]
1-hour average	-	20[a]	-	-
96-hour average	-	5.0[a]	-	-

Table A-1 (Cont.)

Chemical	**Municipal or Domestic Supply** (μg/1)	**Aquatic Life** (μg/1)	**Irrigation** (μg/1)	**Watering of Livestock** (μg/1)
Silver	50[a,b]	exp{1.72 ln(H)-6.52}[a]	-	-
Sulfide				
undissociated hydrogen sulfide	-	2[a]	-	-
Thallium	13[a]	-	-	-
Zinc	-	-	2,000[d]	25,000[d]
1-hour average	-	exp{0.8473 ln(H)+0.8604}[a]	-	-
96-hour average	-	exp{0.8473 ln(H)+0.7614}[a]	-	-
Acrolein	320[a]	-	-	-
Aldrin	0[a]	3[a]	-	-
Chlordane	0[a]	2.4[a]	-	-
24-hour average	-	0.0043[a]	-	-
2,4-D	100[a,b]	-	-	-
DDT & metabolites	0[a]	1.1[a]	-	-
24-hour average	-	0.0010[a]	-	-
Demeton	-	0.1[a]	-	-
Dieldrin	0[a]	2.5[a]	-	-
24-hour average	-	0.0019[a]	-	-
Endosulfan	75[a]	0.22[a]	-	-
24-hour average	-	0.056[a]	-	-
Endrin	0.2[b]	0.18[a]	-	-
24-hour average	-	0.0023[a]	-	-
Guthion	-	0.01[a]	-	-
Heptachlor	-	0.52[a]	-	-
24-hour average	-	0.0038[a]	-	-

Table A-1 (Cont.)

Chemical	**Municipal or Domestic Supply (μg/l)**	**Aquatic Life (μg/l)**	**Irrigation (μg/l)**	**Watering of Livestock (μg/l)**
Lindane	4[b]	2.0[a]	-	-
24-hour average	-	0.080[a]	-	-
Malathion	-	0.1[a]	-	-
Methoxychlor	100[a,b]	0.03[a]	-	-
Mirex	0[a]	0.001[a]	-	-
Parathion	-	-	-	-
1-hour average	-	0.065[a]	-	-
96-hour average	-	0.013[a]	-	-
Silvex (2,4,5-TP)	10[a,b]	-	-	-
Toxaphene	5[b]	-	-	-
1-hour average	-	0.73[a]	-	-
96-hour average	-	0.0002[a]	-	-
Benzene	5[b]	-	-	-
Monochlorobenzene	488[a]	-	-	-
m-dichlorobenzene	400[a]	-	-	-
0-dichlorobenzene	400[a]	-	-	-
p-dichlorobenzene	75[b]	-	-	-
Ethyibenzene	1,400[a]	-	-	-
Nitrobenzene	19,800[a]	-	-	-
1,2-dichloroethane	5[b]	-	-	-
1,1,1-trichloroethane (TCA)	200[b]	-	-	-
Bis (2-chloroisopropyi) ether	34.7[a]	-	-	-
Chloroethylene (vinyl chloride)	2[b]	-	-	-

Table A-1 (Cont.)

Chemical	**Municipal or Domestic Supply** (μg/l)	**Aquatic Life** (μg/l)	**Irrigation** (μg/l)	**Watering of Livestock** (μg/l)
1,1-dichloroethylene	7[b]	-	-	-
Trichloroethylene (TCE)	5[b]	-	-	-
Hexachlorocyclopentadiene	206[a]	-	-	-
Isophorone	5,200[a]	-	-	-
Trihalomethanes (total)[f]	100[c]	-	-	-
Tetrachloromethane (carbon tetrachloride)	5[b]	-	-	-
Phenol	3,500[a]	-	-	-
2,4-dichlorophenol	3,090[a]	-	-	-
Pentachlorophenol	1,010[a]	-	-	-
1-hour average	-	$\exp(1.005\ (\mathrm{pH})-4.830)$[a]	-	-
96-hour average	-	$\exp(1.005\ (\mathrm{pH})-5.290)$[a]	-	-
Dinitrophenols	70[a]	-	-	-
4,6-dinitro-2-methylphenol	13.4[a]	-	-	-
Dibutyl phthalate	34,000[a]	-	-	-
Diethyl phthalate	350,000[a]	-	-	-
Dimethyl phthalate	313,000[a]	-	-	-
Di-2-ethylhexyl phthalate	15,000[a]	-	-	-
Polychlorinated biphenyls (PCBs)	0[a]	-	-	-
24-hour average	-	0.014[a]	-	-
Fluoranthene (polynuclear aromatic hydrocarbon)	42[a]	-	-	-
Dichloropropenes	87[a]	-	-	-
Toluene	14,300[a]	-	-	-

Table A-1 (Cont.)

Footnotes and References

(1) Single concentration limits and 24-hour average concentration limits must not be exceeded. One-hour average and 96-hour average concentration limits may be exceeded only once every 3 years. See reference a.

(2) Hardness (H) is expressed as mg/l $CaCO_3$.

(3) If a criteria is less than the detection limit of a method that is acceptable to the division, laboratory results which show that the substance was not detected will be deemed to show compliance with the standard unless other information indicates that the substance may be present.

(4) If a standard does not exist for each designated beneficial use, a person who plans to discharge waste must demonstsrate that no adverse effect will occur to a designated beneficial use. If the discharge of a substance will lower the quality of the water, a person who plans to discharge waste must meet the requirements of NRS 445.253.

a. U.S. Environmental Protection Agency, Pub. No. EPA 440/5-86-001, Quality Criteria for Water (Gold Book)(1986).

b. Federal Maximum Contaminant Level (MCL), 40 C.F.R. §§ 141.11, 141.12, 141.61 and 141.62 (1988).

c. U.S. Environmental Protection Agency, Pub. No. EPA 440/9-76-023, Quality Criteria for Water (Red Book)(1976).

d. National Academy of Sciences, Water Quality Criteria (Blue Book)(1972).

e. California State Water Resources Control Board, Regulation of Agricultural Drainage to the San Joaquin River: Appendix D, Water QualityCriteria (March 1988 revision).

f. The criteria for trihalomethanes (total) is the sum of the concentrations of bromodichloromethane, dibromochloromethane, tribromomethane (bromoform) and trichloromethane (chloroform). See reference b.

(Added to NAC by Environmental Comm'n, eff. 9-13-85; A 9-25-90)

Table A-1 (Cont.)

445.134 **Control points: Prescription and applicability of numerical standards for water quality; designation of beneficial uses.**

1. Control points are locations where water quality criteria are specified. Criteria so specified apply to all surface waters of Nevada in the watershed upstream from the control point or to the next upstream control point or to the next water named in NAC 445.121.
2. If there are no control points downstream from a particular control point, the criteria for that control point also apply to all surface waters of Nevada in the watershed downstream of the control point or to the next water named in NAC 445.121.
3. Each standard is set to protect the beneficial use which is most sensitive with respect to that particular standard.
4. NAC 445.1341 to 445.1385, inclusive, prescribe numerical standards for water quality and designate beneficial uses at particular control points.

[Environmental Comm'n, Water Pollution Control Reg. § 4.2.5, eff. 5-2-78; A 1-25-79; 8-28-79; 1-25-80; 12-3-80]--(NAC A 11-22-82; 9-25-90)

445.13405 **Beneficial uses for Carson River.** The standards for water quality for the Carson River from Lahontan Dam to the state line are prescribed in NAC 445.1341 to 445.13422, inclusive. The beneficial uses for this area are:

1. Irrigation;
2. Watering of livestock;
3. Recreation involving contact with the water;
4. Recreation not involving contact with water;
5. Industrial supply;
6. Municipal or domestic supply, or both;
7. Propagation of wildlife; and
8. Propagation of aquatic life, more specifically, the species of major concern are:

Table A-1(Cont.)

(a) West Fork at the state line, rainbow trout and brown trout.
(b) Bryant Creek, rainbow trout and brown trout.
(c) East Fork Carson at the state line, rainbow trout and brown trout.
(d) From the East Fork Carson at the state line to near Highway 395 south of Gardnerville, rainbow trout and brown trout.
(e) From the East Fork Carson near Highway 395 south of Gardnerville to Muller Lane, rainbow trout and brown trout.
(f) From the Carson River at Genoa Lane to the East Fork Carson at Muller Lane and to the West Fork Carson at the state line, catfish, rainbow trout and brown trout.

Total Dissolved Solids - mg/l

Annual Average........................	not more than	125.0
Single Value...........................	not more than	165.0

Color - Color must not exceed that characteristic of natural conditions by more than 10 units on the Platinum-Cobalt Scale.

Turbidity - Turbidity must not exceed that characteristic of natural conditions by more than 10 Jackson Units.

Fecal Coliform - The more stringent of the following apply:

The fecal coliform concentration must not exceed a geometric mean of 1000 per 100 milliliters nor may more than 20 percent of total samples exceed 2400 per 100 milliliters.

Table A-1(Cont.)

The annual geometric mean of fecal coliform concentration must not exceed that characteristic of natural conditions by more than 200 per 100 milliliters nor may the number of fecal coliform in a single sample exceed that characteristic of natural conditions by more than 400 per 100 milliliters.

[Environmental Comm'n, Water Pollution Control Reg. part § 4.2.5, Table 38, eff. 5-2-78; A 1-25-79; 8-28-79; 1-25-80; 12-3-80]

445.134625 Beneficial uses for Truckee River from Pyramid Lake to the state line. The water quality standards for the Truckee River from Pyramid Lake to the state line are prescribed in NAC 445.13463 to 445.13471, inclusive.
The beneficial uses for this area are:
1. Irrigation;
2. Watering of livestock;
3. Recreation involving contact with the water;
4. Recreation not involving contact with water;
5. Industrial supply;
6. Municipal or domestic supply, or both;
7. Propagation of wildlife; and
8. Propagation of aquatic life. The species of major concern are:

(a) At the state line, mountain whitefish, rainbow trout and brown trout.
(b) From the state line to Idlewild, mountain whitefish, rainbow trout and brown trout.
(c) From Idlewild to East McCarran, rainbow trout and brown trout.
(d) From East McCarran to Lockwood, brown trout.

Table A-1(Cont.)

(e) From Lockwood to Derby, brown trout. However, the species which are sensitive to temperature are expected to seek a cooler habitat during July and August and may migrate out of the reach.

(f) From Derby to Wadsworth, early spawning Lahontan cutthroat trout and their migration during the late spring or early summer depending on hydrological conditions.

(g) From Wadsworth to Pyramid Lake, early spawning Lahontan cutthroat trout and their migration during the late spring or early summer depending on hydrological conditions, and cui-ui and their spawning and incubation from May through June 15, and their migration through July.

(Added to NAC by Environmental Comm'n, eff. 10-25-84; A 9-25-90)

Table A-1(Cont.)

445.13468 Truckee River at Derby Dam.

STANDARDS OF WATER QUALITY
Truckee River

Control Point at Derby Dam. The limits in this table apply from Derby Dam to the Lockwood Bridge control point.

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Temperature °C - Maximum		Nov.-Mar.: ≤13°C Apr.: ≤21°C May: ≤22°C	Aquatic life[b] and water contact recreation.
▲T[a]	▲T = 0°C	▲T ≤2°C	
pH Units	-	S.V.: 7.0 - 8.3 ▲pH: ±0.5 Max	Water contact recreation[b], wildlife propagation[b], aquatic life, irrigation, stock watering, municipal or domestic supply and industrial supply.
Dissolved Oxygen - mg/l	-	S.V.: Nov.-Mar.: ≥6.0 Apr.-Oct.: ≥5.0	Aquatic life[b], water contact recreation, wildlife propagation, stock watering, municipal or domestic supply and noncontact recreation.

Table A-1(Cont.)

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Chlorides - mg/l	A-Avg.: ≤21.0 S.V.: ≤30.0	S.V.: ≤250	Municipal or domestic supply[b], wildlife propagation, irrigation and stock watering.
Total Phosphates (as P) - mg/l	-	A-Avg.: ≤0.05	Aquatic life[b], water contact recreation[b], municipal or domestic supply and noncontact recreation.
Nitrogen Species (N) - mg/l	-	TN A-Avg.: ≤0.75 TN S.V.: ≤1.2 Nitrate S.V.:≤2.0 Nitrite S.V.:≤.04 Amonia S.V.: ≤.02 (un-ionized)	Aquatic life[b], water contact recreation[b], municipal or domestic supply and noncontact recreation.
Total Dissolved Solids - mg/l	A-Avg.: ≤215.0 S.V.: ≤265.0	A-Avg.: ≤500	Municipal or domestic supply[b], irrigation and stock watering.
Turbidity - NTU	A-Avg.: ≤8.0	S.V.: ≤10	Aquatic life[b] and municipal or domestic supply.
Color - PCU	d	S.V.: ≤75	Municipal or domestic supply.

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Alkalinity (as $CaCO_3$) - mg/l	-	less than 25% change from narural conditions	Aquatic life[b] and wildlife propagation.
Fecal Coliform - No./100 ml	A.G.M.: ≤80.0	≤200/400[c]	Water contact recreation[b], noncontact recreation, municipal or domesticsupply,irrigation, wildlife propagation and stock watering.
Suspended Solids - mg/l	A-Avg.: ≤24.0 S.V.: ≤40.0	S.V.: ≤50	Aquatic life[b].
Sulfate - mg/l	A-Avg.: ≤39.0 S.V.: ≤46.0	S.V.: ≤250	Municipal or domestic supply[b].
Sodium - SAR	A-Avg.: ≤1.5 S.V.: ≤2.0	A-Avg.: ≤8	Irrigation[b] and municipal or domestic supply.

a. Maximum allowable increase in temperature above water temperature at the boundary of an approved mixing zone, but the increase must not cause a violation of the single value standard.

b. The mosts restrictive beneficial use.

Table A-1(Cont.)

445.13467 Truckee River at Wadsworth Gage.

STANDARDS OF WATER QUALITY
Truckee River

Control Point at Wadsworth Gage. The limits in this table apply from the Wadsworth Gage control point to Derby Dam.

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Temperature °C. Maximum		Nov.-Mar.: ≤13°C° Apr.-June: ≤14°C July: ≤26°C	Aquatic life[b] and water contact recreation.
▲T[a]	▲T = 0°C	▲T ≤2°C	
pH Units	-	S.V.: 7.0 - 8.3 ▲pH: ±0.5 Max	Water contact recreation[b], wildlife propagation[b], aquatic life, irrigation, stock watering, municipal or domestic supply and industrial supply.
Dissolved Oxygen - mg/l	-	S.V.: Nov.-June: ≥6.0 July-Oct.: ≥5.0	Aquatic life[b], water contact recreation wildlife propagation, stock watering, municipal or domestic supply and noncontact recreation.

Table A-1(Cont.)

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Chlorides - mg/l	A-Avg.: ≤20.0 S.V.: ≤28.0	S.V.: ≤250	Municipal or domestic supply[b], wildlife propagation, irrigation and stock watering.
Total Phosphates (as P) - mg/l	-	A-Avg.: ≤0.05	Aquatic life[b], water contact recreation[b], municipal or domestic supply and noncontact recreation.
Nitrogen Species (N) - mg/l	-	TN A-Avg.: ≤0.75 TN S.V.: ≤1.2 Nitrate S.V.:≤2.0 Nitrite S.V.:≤.04 Amonia S.V.: ≤.02 (un-ionized)	Aquatic life[b], water contact recreation[b], municipal or domestic supply and noncontact recreation.
Total Dissolved Solids - mg/l	A-Avg.: ≤245.0 S.V.: ≤310.0	A-Avg.: ≤500	Municipal or domestic supply[b], irrigation and stock watering.
Turbidity - NTU	-	S.V.: ≤10	Aquatic life[b] and municipal or domestic supply.
Color - PCU	d	S.V.: ≤75	Municipal or domestic supply.

Table A-1(Cont.)

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Alkalinity (as $CaCO_3$) - mg/l	-	less than 25% change from natural conditions	Aquatic life[b] and wildlife propagation.
Fecal Coliform - No./100 ml	A.G.M.: ≤50 S.V.: ≤250	≤200/400[c]	Water contact recreation[b], noncontact recreation, municipal or domestic supply, irrigation, wildlife propagation and stock watering.
Suspended Solids - mg/l	A-Avg.: ≤25.0	S.V.: ≤50	Aquatic life[b].
Sulfate - mg/l	A-Avg.: ≤39.0 S.V.: ≤46.0	S.V.: ≤250	Municipal or domestic supply[b].
Sodium - SAR	A-Avg.: ≤1.5 S.V.: ≤2.0	A-Avg.: ≤8	Irrigation[b] and municipal or domestic supply.

Table A-1(Cont.)

a. Maximum allowable increase in temperature above water temperature at the boundary of an approved mixing zone, but the increase must not cause a violation of the single value standard.
b. The most restrictive beneficial use.
c. Based on the minimum of not less than 5 samples taken over a 30-day period, the fecal coliform bacterial level may not exceed a geometric mean of 200 per 100 ml nor may more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.
d. Increase in color must not be more than 10 PCU above natural conditions.
e. This is to provide for propagation of cui-ui and early spawning (Nov.-Mar.) Lahontan cutthroat trout and Spring passage of Lahontan cutthroat trout when flows are adequate to induce spawning runs.

[Environmental Comm'n, Water Pollution Control Reg. part § 4.2.5, Table 43, eff. 5-2-78; A 1-25-79; 8-28-79; 1-25-80; 12-3-80]--(NAC A 10-25-84)

Table A-1(Cont.)

445.13471 Truckee River at Pyramid Lake.

STANDARDS OF WATER QUALITY
Truckee River

Control Point at Pyramid Lake. The limits in this table apply from the mouth of the Truckee River at Pyramid Lake to the Wadsworth Gage control point.

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Temperature °C. Maximum		Nov.-Mar.: ≤13°C° Apr.-June: ≤14C July: ≤26°	Aquatic life[b] and water contact recreation.
▲T[a]	▲T = 0°C	▲T ≤2°C	
pH Units	-	S.V.: 7.0 - 8.3 ▲pH: ±0.5 Max	Water contact recreation[b], wildlife propagation[b], aquatic life, irrigation, stock watering, municipal or domestic supply and industrial supply.
Dissolved Oxygen - mg/l	-	S.V.: Nov.-June: ≥6.0 July-Oct.: ≥5.0	Aquatic life[b], water contact recreation, wildlife propagation, stock watering, municipal or domesticsupply and noncontact recreation.

Table A-1(Cont.)

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Chlorides - mg/l	A-Avg.: ≤105.0 S.V.: ≤130.0	S.V.: ≤250	Municipal or domestic supply[b], wildlife propagation, irrigation and stock watering.
Total Phosphates (as P) - mg/l	-	A-Avg.: ≤0.05	Aquatic life[b], water contact recreation[b], municipal or domestic supply and noncontact recreation.
Nitrogen Species (N) - mg/l	-	TN A-Avg.: ≤0.75 TN S.V.: ≤1.2 Nitrate S.V.:≤2.0 Nitrite S.V.:≤.04 Amonia S.V.: ≤.02 (un-ionized)	Aquatic life[b], water contact recreation[b], municipal or domestic supply and noncontact recreation.
Total Dissolved Solids - mg/l	A-Avg.: ≤415.0	A-Avg.: ≤500	Municipal or domestic supply[b], irrigation and stock watering.
Turbidity -NTU	-	S.V.: ≤10	Aquatic life[b] and municipal or domestic supply.
Color - PCU	d	S.V.: ≤75	Municipal or domestic supply.

PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARDS FOR BENEFICIAL USES	BENEFICIAL USES
Alkalinity (as $CaCO_3$) - mg/l	-	less than 25% change from natural conditions	Aquatic life[b] and wildlife propagation.
Fecal Coliform - No./100 ml	A.G.M.: ≤40 S.V.: ≤250	≤200/400[c]	Water contact recreation[b], noncontact recreation, municipal or domestic supply, irrigation, wildlife propagation and stock watering.
Suspended Solids - mg/l	A-Avg.: ≤25.0	S.V.: ≤50	Aquatic life[b].
Sulfate - mg/l	A-Avg.: ≤85.0 S.V.: ≤106.0	S.V.: ≤250	Municipal or domestic supply[b].
Sodium - SAR	A-Avg.: ≤2.4 S.V.: ≤2.9	A-Avg.: ≤8	Irrigation[b] and municipal or domestic supply.

a. Maximum allowable increase in temperature above water temperature at the boundary of an approved mixing zone, but the increase must not cause a violation of the single value standard.

b. The most restrictive beneficial use.

Table A-1(Cont.)

c. Based on the minimum of not less than 5 samples taken over a 30-day period, the fecal coliform bacterial level may not exceed a geometric mean of 200 per 100 ml nor may more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.

d. Increase in color must not be more than 10 PCU above natural conditions.

e. This is to provide for propagation of cui-ui and early spawning (Nov.-Mar.) Lahontan cutthroat trout and Spring passage of Lahontan cutthroat trout when flows are adequate to induce spawning runs.

[Environmental Comm'n, Water Pollution Control Reg. part § 4.2.5, Table 43.1, eff. 5-2-78; A 1-25-79; 8-28-79; 1-25-80; 12-3-80]--(NAC A 10-25-84)

as 10 cm. Many eggs that are not buried are eaten by Lahontan redside shiners (Richardsonius egregius).

Hoffman and Scoppettone (1988) discovered that artificially planted Lahontan cutthroat trout eggs experience high mortality due to low concentrations (<5 mg/l) of intergravel DO at depths of 15 to 20 cm. They postulated that decomposing organic matter, intergravel biochemical oxygen demand, or uptake of oxygen by trout eggs are factors which may, singularly or in combination, be responsible for the low DO levels observed. Studies have not been conducted to determine if DO levels are also too low for cui-ui eggs.

Periphyton accumulation in the lower Truckee River is significant during the growing season when flow is low (Cooper et al. 1984; Nowlin 1987; Brock et al. 1989). Evidence of biostimulation include high periphyton standing crop and large diel variations in DO and pH (Reno-Sparks Wastewater Treatment Plant monitoring data). Dissolved oxygen in the surface water may range from 3 to 4 mg/l at sunrise to 12 to 15 mg/l in mid-afternoon. Organic matter accumulation from excessive summer-time periphyton growth at the water-streambed interface may be at least partially responsible for low intergravel DO levels observed throughout the year.

Studies on nutrient loading to the Truckee River are currently being conducted. Estimated total phosphorus and total nitrogen loading to the lower Truckee River (McCarran Blvd. in Reno to Derby Dam) during a September 1989 "snapshot" is estimated in Figures A-1 and A-2. Preliminary information suggests that a nutrient strategy between McCarran to Derby Dam may be entirely different than one from Derby Dam to Marble Bluff Dam. Point and non-point sources dominate river loading between McCarran and Derby Dam, while non-point sources dominate the loading downstream from Derby Dam.

Current research being funded by the U.S. Environmental Protection Agency, Nevada Division of Environmental Protection and others has focused on nutrient-algae response relationships in the Truckee River system. The development of the Dynamic Stream Simulation and Assessment Model (DSSAM) should improve the understanding of nutrient dynamics and provide a more sophisticated tool for development of a sound nutrient strategy for the watershed.

Siltation by suspended solids may also be a factor in compacting cui-ui spawning gravels by impeding subsurface flow of water. The lower river has a scoured, braided, and exposed channel that makes it highly susceptible to erosion. Non-point sources, such as agricultural returns and stormwater runoff, also contribute to this problem. The goal should be a meandering channel enhanced and stabilized by a well-managed riparian habitat. Physical erosion control structures may have to be considered in extremely eroded areas. Other sources of suspended solids should be managed by encouraging Best Management Practices. A future flow prescription may include an annual "flushing flow" that would precede the spawning run for the effect of removing fine sediments and accumulated organic matter from the substrate. These "flushing flows" are often overlooked during instream flow studies on regulated river systems (Gore and Petts 1989).

Total Dissolved Solids (TDS) - Bioassay studies conducted by Lockheed Ocean Science Laboratories (LOSL, 1982) is the only definitive work available on the effect of TDS on cui-ui development and larvae survival. Their study was designed to determine the effects of increasing Pyramid Lake TDS (>5800 mg/l) rather than on increasing Truckee River TDS (<500 mg/l); however some information could be obtained. Eggs hatched in control water (525 mg/l TDS) showed typical embryonic development with a 75 percent hatch rate, with no abnormalities thereafter. During the April through June cui-ui spawning period, TDS is typically less than 200 mg/l when suitable attraction flows are achieved. This information suggests that existing TDS concentrations in the river (≤200 mg/l) during the spawning run are not detrimental to early cui-ui life stages.

Temperature - Cui-ui eggs are extremely sensitive to changes in water temperature during incubation; after hatching sensitivity decreases. Recent studies conducted by the U.S. Fish & Wildlife Service concluded that acceptable survival of eggs could be achieved at or below a daily maximum temperature of 17° C (Coleman et al. 1987).

Using the Bureau of Reclamation's Truckee River Prediction Model (Rowell 1975), estimates were made of flow needs to maintain water temperatures at or below 17° C. With average air temperature, minimum flow requirement for May was predicted to be 1000 cfs to maintain minimum acceptable temperatures. An instream study between Numana and Marble Bluff Dams found that maximum spawning area occurs at 750 cfs (8,274 ft^2 /1000 linear feet); this area decreases by about 600 ft^2 per 1000 linear feet at the 1000 cfs minimum flow requirement. The spawning area created at 1000 cfs is adequate for current spawning runs (Buchanan and Strekal 1988). The relatively high incubation flows also provide a higher rate of surface to intergravel water exchange, increasing intergravel DO and flushing of metabolic wastes.

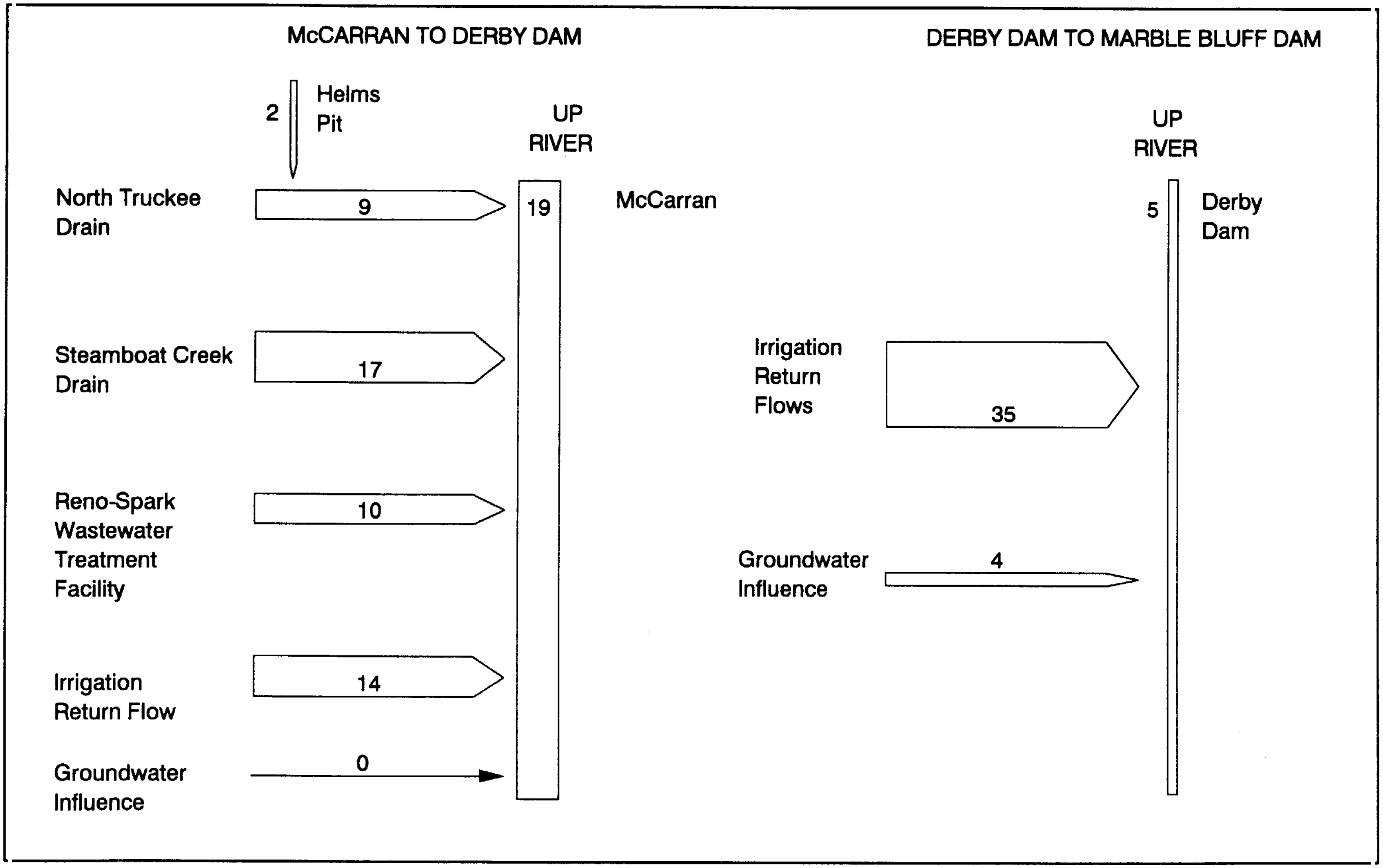

Figure A-1. Estimated total phosphorus loading (kg/day) to the Truckee River during September 1989 (Brock 1991)

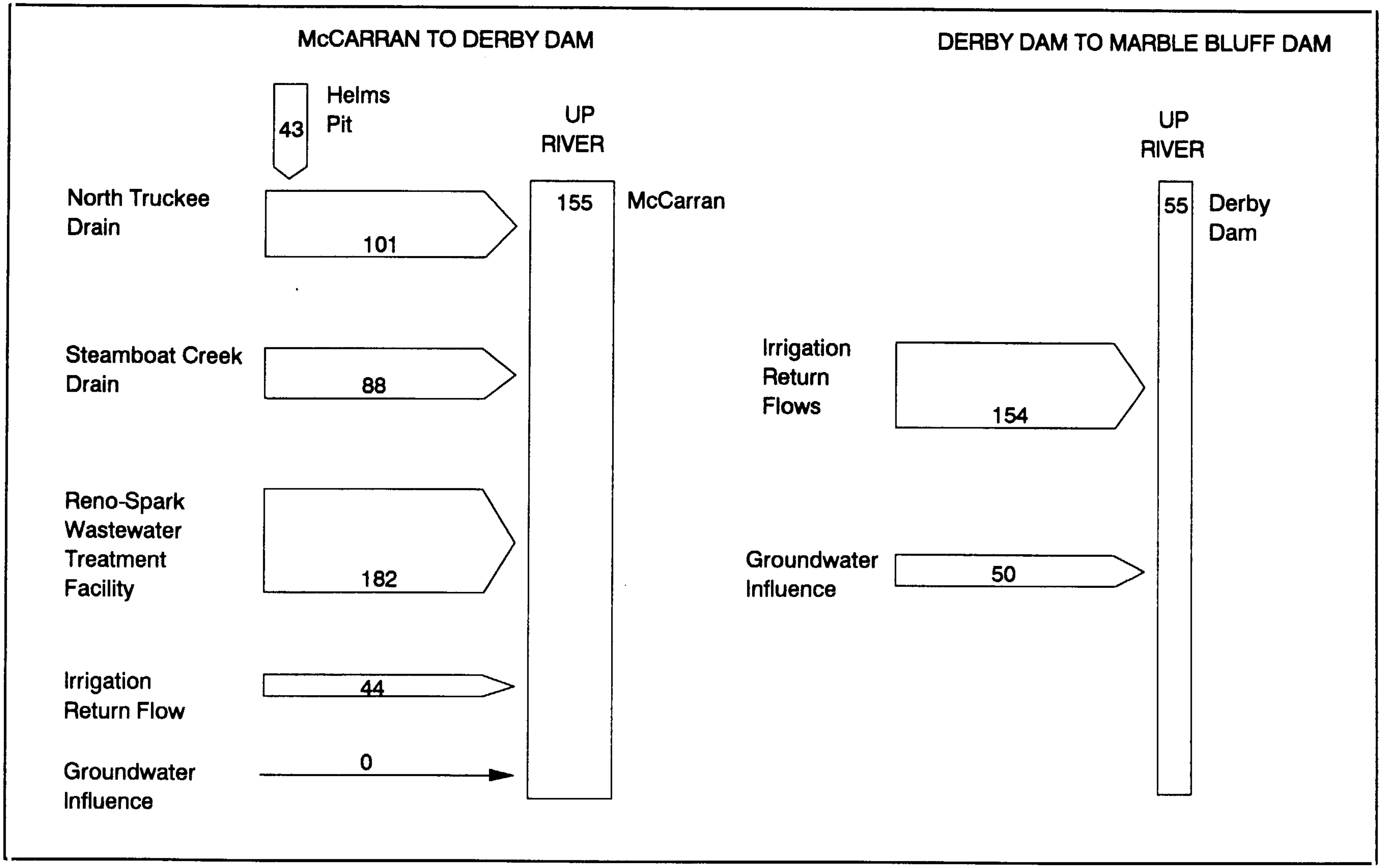

Figure A-2. Estimated total nitrogen loading (kg/day) to the Truckee River during September 1989 (Brock 1991)

In summary, temperature is the most critical of the habitat requirements of cui-ui. Though a monthly mean temperature predictive model exists for the Truckee River, a daily model is required to properly manage available storage and spawning flows. The model should incorporate all factors known to influence water temperature such as flow, wind, shading, evaporation, solar radiation, air temperature, etc. Such a model could be used by resource management agencies in understanding which environmental variables are the most important and which alternatives are the most cost-effective in maintenance of low water temperature and thus the flow regulatory scheme necessary to maintain optimum habitat.

PYRAMID LAKE WATER QUALITY

Water quality variables which could potentially impact cui-ui survival in Pyramid Lake include TDS and DO. Because Pyramid Lake is terminal, inflowing salts accumulate in the lake, causing it to become moderately saline. The TDS concentration in Pyramid Lake is inversely related to volume. Therefore, the primary factor responsible for recent increases in lake TDS has been upstream Truckee River diversions causing the Lake to recede in volume. Since upstream diversions began in 1905, Pyramid Lake has lost 30 percent of its volume and salinity has increased from about 3,500 mg/l to in excess of 5,000 mg/l (Benson 1978, Galat 1981). In 1991 TDS was approximately 5,400 mg/l. Concern over increasing TDS and declining fisheries resulted in studies to determine effects on the food chain (LOSL 1982). Water quality standards for the lower Truckee River at Pyramid Lake (1991) are presented in Table A-1.

Only 8 percent of cui-ui eggs hatched in Pyramid Lake water with a TDS of about 5,900 mg/l (LOSL 1982). Chatto (1979) found that some cui-ui eggs could hatch in Pyramid Lake where salinity approximated 1,800 mg/l, but success would decline when salinity approached 3,800 mg/l.

Eggs that were allowed to develop in 525 mg/l for 24-96 hours prior to being placed in 5,900 mg/l developed as well as those in control water, although some abnormalities were found (LOSL 1982). Three-day-old cui-ui larvae subjected to test concentrations of 350 and 5,800 mg/l all survived the first 96 hours; however, after 192 hours the 5,800 mg/l test exhibited increased mortality and abnormalities. Chronic 180-day tests on juvenile cui-ui suggest an increased tolerance to higher TDS levels, although reduced survival occurred at levels ranging from 3,600 to 5,200 mg/l.

Results of these bioassays suggest that current TDS levels in Pyramid Lake are at or above optimum for cui-ui survival. Data also show that substantial increases in TDS above ≈5,900 mg/l may cause significant degradation of Pyramid Lake's entire food chain, including biomass, species composition, and diversity. Based on these findings, Pyramid Lake TDS should not be allowed to increase appreciably.

Excessive nutrient loading to lakes generally leads to increases in primary production and the potential for hypolimnetic DO depletions. Maintaining adequate DO concentrations in Pyramid Lake is critical for cui-ui habitat. Seasonal warming of surface water isolates deeper water from atmospheric and internally-generated sources of DO. The hypolimnion becomes progressively depleted of oxygen through the period of stratification due to the decomposition of organic matter.

Galat et al. (1981) reported that deep water (75-95m) oxygen concentration minima were less than 2 mg/l, but DO deficits were apparent in both the metalimnion and hypolimnion beginning in July. They concluded that the lake's trout population may be excluded from only the deepest waters. Lebo et al.(1990) reported that bottom water DO depletions occur throughout Pyramid Lake. They found a progressive depletion of oxygen throughout the summer months, and that bottom waters (≥100 m) of the deep basin may go anoxic if the lake does not overturn each year. Recent studies conducted by the U.S. Fish and Wildlife Service found cui-ui utilizing deep water habitat (Scoppettone, personal communication 1991).

While the impact of nutrient concentrations on the lower Truckee River is relatively well understood, little is known about the effects of nutrient loading on Pyramid Lake. In September 1989, the Pyramid Lake Tribe (through Pyramid Lake Fisheries) contracted with the Limnological Research Group at the University of California, Davis to begin a multi-year study to determine the potential effects of nutrient loading on Pyramid Lake. The goals for the current four-year study are (from U.C. Davis research proposal submitted to Pyramid Lake Tribe):

1. Expand and formalize the routine water quality monitoring program for Pyramid Lake.
2. Quantitative determination of a nutrient budget for the Lake.
3. Determine the effects that nutrient loading is currently having on Pyramid Lake, and what effect additional loads will have on the future of water quality.

4. Determine appropriate and realistic water quality standards for Pyramid Lake and the lower Truckee River to protect beneficial uses.

5. Design and implementation of an effective water quality, lake enhancement and watershed management program.

The U.C. Davis research project (1993 completion date) should provide management agencies with an empirical and mechanistic model to predict hypolimnetic DO from internal and external nutrient loading. The Nevada Division of Environmental Protection is currently reviewing Truckee River water quality standards and waste load allocations and revisions are expected. Revisions to the water quality standards that would cause an increase in the existing permitted nutrient load to Pyramid Lake would be unacceptable until the on-going studies are completed. When the Lake model becomes available, water quality standards for the Truckee River should incorporate criteria for maximum permissible loadings to Pyramid Lake.

CONCLUSIONS AND RECOMMENDATIONS

- Studies should be conducted to determine if intergravel habitat is suitable for cui-ui egg incubation and development.
- A watershed nutrient strategy should be developed for the Truckee River to minimize detrimental effects on lower Truckee River cui-ui habitat. This strategy would focus on both point and non-point sources of nutrient loading and identify those sources that would produce greatest lower river benefits.
- A daily predictive water temperature model should be developed for the Truckee River system.
- Truckee River TDS levels do not appear to detrimentally impact cui-ui early life stages.
- Pyramid Lake TDS should not be allowed to increase above 5,900 mg/l. Studies should be conducted to determine the effects of TDS loading from the Truckee River on Pyramid Lake.
- Until ongoing nutrient studies at Pyramid Lake are complete, permitted nutrient waste loads to the Truckee River should not be increased.

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APPENDIX B:

CUI-UI MODEL

[The following information was excerpted from Simulated Water Management and Evaluation Procedures for Cui-ui (Chasmistes cujus) by C.C. Buchanan (U.S. Fish and Wildlife Service, Reno NV) and T.A. Strekal (U.S. Bureau of Reclamation, Carson City NV), 1988.]

The Cui-ui Population Index Subroutine (cui-ui model, or model) developed by Buchanan and Strekal (1988) compares the possible effects of various water management plans on cui-ui population dynamics. The model synthesizes hydrologic data (generated by a water-management model as described by Cobb et al 1990), known and attributed biological characteristics and population dynamics of cui-ui to simulate the reproductive response of the cui-ui population to varying instream flow and Pyramid Lake elevation over time. It is a single-species time-series model that combines the basic elements of the Leslie matrix model, a discrete time-age structure model, with those of the Effective Habitat Time Series Analysis, a model of fluctuating river habitat availability and fish requirements (Bovee 1982; Begon and Mortimer 1986). These elements are combined further with environmental characteristics unique to the Truckee River/Pyramid Lake system and behavioral characteristics of cui-ui. Matrix algebra has been replaced by computer logic.

The model evolved from the Habitat Evaluation Subroutine included in the Draft EIS for Newlands Project Operating Criteria and Procedures (U.S. Bureau of Reclamation 1986). The earlier version used prescribed lower Truckee River inflow to Pyramid Lake as the sole parameter affecting cui-ui reproduction; the present version is more sensitive to hydrologic variability and incorporates a greater array of biological and physical information. It simulates the number of yolk-sac larvae recruited to the population each year (i.e., new year class) and the number of individuals remaining in each year class by incorporating the following parameters: river access; attraction flows; instream flow/temperature relation; fecundity rates; egg viability; temperature tolerance of eggs; annual mortality rates; and population size. A description of empirical data and assumptions used in the model is presented in Buchanan and Strekal (1988).

Female numbers are the limiting factor in the cui-ui population because of egg viability and production. Males are not limiting because they enter spawning runs more frequently than females, and may spawn with numerous females. Therefore, the model tracks only female cui-ui.

The model is initiated with a known number of female cui-ui in each year class. In the 1988 report, it is begun with the number of cui-ui per year class calculated to exist in the summer of 1987, so that the simulated impacts on the population would reflect then-current conditions. The number of hatchery produced cui-ui planted in Pyramid Lake is included in the model to develop the population estimate. The initial elevation of Pyramid Lake is established at the April 1988 level of 3812.4 feet m.s.l. and Stampede Reservoir storage at 90,000 acre-feet.

The occurrence and size of a spawning run depend upon the total inflow to Pyramid Lake from January through April (attraction flow), the number of adult females in the population, and lake elevation at the beginning of May. There is no minimum number of adults required to initiate the run, but the minimum lake elevation for river access is 3784.0 feet and the minimum attraction volume is 60,000 acre-feet. The relation of these variables to one another is based on observations at Marble Bluff Fish Facility from 1980 through 1987. Run size and timing also depend upon the passage avenue. For example, if Pyramid Lake elevation is at or below 3812.0 feet, but above 3784.0 feet passage is only available through the Pyramid Lake Fishway. At these elevations, less than 0.1 percent of the population would enter the fishway with an attraction flow of 51,000 acre-feet, 1.5 percent with 176,000 acre-feet, and 5.0 percent for flows greater than 349,000 acre-feet. When lake elevation exceeds 3812.0 feet passage is assumed to be available over the delta and the spawning run percentages increase. With an attraction flow of 60,000 acre-feet, 4.8 percent of the adult female population enters the spawning run, 6.3 percent enter at 87,000 acre-feet, 12.4 percent at 491,000 acre-feet, and 23.5 percent at and above 715,000 acre-feet. No spawning runs occur below the lowest elevation and inflow.

Fish of prime reproductive age are represented proportionately in the spawning run. For example, if attraction volume and lake elevation indicate that 6.0 percent of the population would enter the run, then 6.0 percent of the females in each prime reproductive year class is assumed to enter the run. Percentages are reduced for fish older than prime reproductive age. Because Pyramid Lake Fishway and the river trap (required when cui-ui use the delta) at Marble Bluff Fish Facility has restricted passage capacities, the maximum run size is limited to 20,000 females through the fishway and 100,000 females through the river trap. Run size is then reduced by 12.5 percent, under the assumption that some fish are swept over the Marble Bluff Dam spillway before they are able to spawn.

The total number of eggs deposited is estimated by multiplying the number of female spawners by the average fecundity rate for their respective ages, then reducing the total by 10 percent for egg retention. The number of yolk-sac larvae produced by these eggs depends upon the age of the female producer (i.e., egg viability), water temperature during incubation, and variability of instream flow.

The number of females in each year class, including the new year class, is then reduced by natural mortality each year. At this point, the model repeats for the next hydrologic year.

The model output can be interpreted as: 1) an index of the relative abundance of adult females; or 2) the number of adult females. A comparison of relative differences among indices is limited to determining which of two or more water management plans is best for cui-ui, while the female number is necessary to determine the adequacy of a water management plan to maintain the population above a certain level.

Model output varies directly with the amount of water associated with a particular hydrologic series. If output is to be used only for relative comparisons, then the selection of a hydrologic series is not necessarily limiting. A hydrologic series with a low probability of occurrence (extremely wet or extremely dry), however, would cause difficulties in ascertaining the relative differences among plans. Only series with moderate to high probabilities of occurrence should be used when determining which plan among many would likely be most beneficial for the species.

If the end product is to be viewed as the potential number of adult females associated with a particular water management plan, then a stochastic hydrologic series - based on the probability of a given hydrologic condition occurring during any year in the future - should be used. By using a series of stochastic replicates (probability-conditioned hydrologic series) the adequacy of alternate plans can be based on probability and risk.

For the stochastic analysis presented in Appendix C, the hydrologic period of record was expanded to 1989 (i.e., 89 years) and the period of analysis was 200 years. Reservoirs and lakes were initialized at April 1990 levels. Inflow to Pyramid Lake was supplemented independent of existing operating constraints.

Changes were also made to the cui-ui model (identified in the Truckee-Carson Hydrologic Model as "HAB13"):

> o three additional years, 1987 through 1989, were added to the spawning record (all zeroes) so all previous year classes became three years older;

o cui-ui larvae survival rates of 0.002 and 0.003 (in addition to 0.001) were included in the analysis;

o cui-ui larvae numbers were adjusted for each respective survival rate so that number of adults for each documented year class at initiation of each model run would be identical;

o cui-ui juvenile survival rate was revised to 0.444 (from ~0.777); and

o number of spawners was allowed to double when Pyramid Lake elevation was greater than 3,848.0 feet (height of Marble Bluff Dam spillway) to reflect possible benefits from supplemental water - rising lake level would inundate the delta to enhance fish passage to the dam and, once the spillway is topped, obviate mechanical transport upstream of the dam - and to permit utilization of all currently-identified spawning habitat by a maximum of 200,000 female cui-ui.

A copy of the cui-ui model follows.

```
      PROGRAM HAB13
C
C                This program performs the "HAB13" functions as defined in the
C                USBR subroutine of May 25, 1988....This is version "1.1"...
C
C             July 1988  HAB13.ORG        (4-22-89) AND CHANGED(6-27-90)
C       DIMENSION FPOPO(38),YOYT(100),FYOY(100),XREGM(100),AVG(13),
     1 AVG2(13),AFPOP(100),TTSTBL(2,100),FLOW(100),STG(100),
     2 DX(12),FPOP(38),TFORC(100)

       COMMON /BLOCKA/PCOGF(100),FSPWT(100),CFS(2),COGF,STG4,IAGE,KDBG
C
       CHARACTER*10 TITL(8)
C
       OPEN(UNIT=10,FILE='HAB13.CON')
       OPEN(UNIT=11,FILE='CUIUI.DAT')
       OPEN(UNIT=20,FILE='HB13RSLT')
       REWIND 10
       REWIND 11
       REWIND 20
C
   10  FORMAT(2X,10F7.0)
   11  FORMAT(3X,I2,3X,I2)
   12  FORMAT(5X,F3.0,6F8.2,2F9.2/2X,F9.2)
   13  FORMAT(8A10)
C
   20  FORMAT(3I4,F4.0,3F12.1,F7.3,F12.1,F8.5,F12.3,F8.0,F8.1/
     1 2X,F6.3,2F12.1)
   21  FORMAT(2I5,F15.5,4F15.3,F12.1)
C
  495  FORMAT('')
  496  FORMAT(/15X,'CUI-UI POPULATION INDEX SUBROUTINE OF MAY 1988',10X,
     1 'PAGE NO.',I2)
  497  FORMAT(1X,5HSTUDY,12X,9HN0. ADULT,12X,11HNO. FEMALES,7X,13HYOUNG-O
     1 F-YEAR)
  498  FORMAT(2X,2HYR,15X,7HFEMALES,15X,8HSPAWNERS,11X,8HPRODUCED,10X,
     1 14H% EGG SURVIVAL )
  499  FORMAT(18X,11H AGES(7-37),10X,11H AGES(7-37),10X,6H AGE 0,11X,
     1 12H  AGE(7-30) /)
  500  FORMAT(2X,I2,2F22.0,F20.0,F19.2)
  501  FORMAT(/41X,22HHEM II HYDROLOGIC DATA ,25X,'PAGE NO.',I2)
  502  FORMAT(//)
C      SWITH COMMENTS ON '503' TO WRITE FORCAST NUMANA RATHER
C      THAN AVAILABLE NUMANA.
C 503  FORMAT(1X,5HSTUDY,2X,16HAVAILABLE NUMANA,9X,4HFLOW,8X,
C    1 12HPYRAMID LAKE,14X,14HPYRAMID INFLOW,13X,14H% EGG SURVIVAL)
  503  FORMAT(1X,5HSTUDY,2X,15HFORECAST NUMANA,9X,4HFLOW,8X,
     1 12HPYRAMID LAKE,14X,14HPYRAMID INFLOW,13X,14H% EGG SURVIVAL)
  504  FORMAT(2X,2HYR,7X,10HMARCH-JUNE,11X,6HREGIME,5X,'ELEVATION (APRIL)
     1 '   , 6X,25HJA-APR      MAY      JUNE ,8X,12H  AGE(7-30) /)
  505  FORMAT(2X,I2,5X,F10.2,13X,F5.2,2X,F15.2,8X,3F10.2,8X,F9.2)
  506  FORMAT(10X)
  507  FORMAT(1X,'AVG',2F22.0,F20.0,F19.2)
  508  FORMAT(/1X,'1925-1967')
  509  FORMAT(7X,6A10,5X,2A10)
  510  FORMAT(15X,6A10,5X,2A10)
C      THOU = 1000.0
       TWNTHO = 20000.
       HUNTHO = 100000.
       ZERO = 0.0
C
       READ(10,11)KDBG
       READ(10,10)(FPOPO(I),I=1,38)
       READ(11,11)IPFYR,IPLYR
       READ(11,13)(TITL(I),I=1,8)
       READ(11,11)I
       DO 110 I=1,100
               FSPWT(I) = ZERO
```

```
                YOYT(I) = ZERO
                FYOY(I) = ZERO
                AFPOP(I) = ZERO
                PCOGF(I) = ZERO
C**      V 1.1
          IF(I .LE. 38 ) FPOP(I) = ZERO
C**
          IF(I.LE.38) FPOPO(I) = THOU*FPOPO(I)
          IF(I.LE.5) AVG(I) = ZERO
          IF(I.LE.5) AVG2(I) = ZERO
  110    CONTINUE
C
C        CALCULATE EACH YEARS FISH POPULATION, SPAWNING, ETC.
C
         J2 = 0
         DO 150 JYR = IPFYR,IPLYR
         J2 = J2 + 1
C
C        READ JANUARY TO JUNE FLOWS,  APRIL LAKE ELEVATION, AND MARCH-JUNE
C        NUMANA TOTAL FLOW. IN READ BELOW, REVERSE THE 'TFORC' AND
C        THE 'DOG' TO READ FORECAST NUMANA RATHER THAN THE OBSERVED NUMANA
         READ(11,12)XREGM(J2),(DX(I),I=4,7),TTSTBL(1,J2),TTSTBL(2,J2),
     1   STG4,DOG, TFORC(J2)
         CFS(1) = 16.263*TTSTBL(1,J2)
         CFS(2) = 16.806*TTSTBL(2,J2)
         FLOW(J2) = ZERO
         DO 120 I5=4,7
         FLOW(J2) = FLOW(J2) + DX(I5)/THOU
  120    CONTINUE
C
C        ANALYZE SPAWNING, MORTALITY, ETC. FOR EACH AGE CLASS
C
         DO 130 J=1,37
         IAGE = J
         L = J2
         AGE = FLOAT(IAGE)
C                MORTALITY FROM AGE ONE TO CURRENT AGE
                 IF(IAGE.GE.7)THEN
         F = 2.71828**(-.16*(AGE - 7.0))
         FPOP(IAGE) = 0.7778388*F*0.77880091*FPOPO(IAGE)/THOU
C
         AFPOP(L) = AFPOP(L) + FPOP(IAGE)
                 ENDIF
C        IF(FLOW(J2).GE.0.060.AND.IAGE.GE.7.AND.STG4.GT.3784.)THEN
C  ***   .060 CHANGE TO .051 BY TOM (6-27-90)******************
         IF(FLOW(J2).LT.0.051.OR.IAGE.LT.7.OR.STG4.LE.3784.)GO TO 130
C        IF(FSPWT(L).NE.HUNTHO.OR.STG4.LE.3812.00)THEN
         IF(FSPWT(L).GE.HUNTHO)GO TO 130
C        IF(FSPWT(L).NE.TWNTHO.OR.STG4.LE.3784.)THEN
         IF(FSPWT(L).GE.TWNTHO.AND.STG4.LE.3812.00)GO TO 130
C
C        CALCULATE NUMBER OF EGGS PER FEMALE
C
                 IF(IAGE.GT.33)THEN
         POL = 143.0*AGE + 100280.0
                 ELSE
         POL = -669923.3 + THOU*AGE*(251.0787 + AGE*(-37.4239 + AGE*(
     1   3.169079 + AGE*(-0.1599236 + AGE*(0.0047438 + AGE*(-0.00007620895
     2   + AGE*(0.0000005111523)))))))
                 ENDIF
         IF(IAGE.GE.8)GO TO 128
C
C        CALCULATE PERCENT OF FEMALES TRYING TO SPAWN, ONLY NEED TO DO
C        THIS ONCE IN THE AGE CLASS DO LOOP.
C
C        IF(STG4.LT.3812.00)THEN
         IF(STG4.GE.3812.00)GO TO 126
         PERC = 0.0001
C *****  .GE. CHANGE TO .GT. BY TOM (6-27-90)  ********
```

```
         IF(FLOW(J2).GT.0.051.AND.FLOW(J2).LE.0.176)PERC = 0.12*FLOW(J2)
       1 - 0.00612
         IF(FLOW(J2).GT.0.176)PERC = AMIN1(0.050,0.20231*FLOW(J2) -.02061)
         GO TO 128
C
C        IF(STG4.GE.3812.00)THEN
126      PERC = ZERO
         IF(FLOW(J2).GE.0.060.AND.FLOW(J2).LE.0.087)PERC = 0.01467 +
       1 0.55556*FLOW(J2)
         IF(FLOW(J2).GT.0.087.AND.FLOW(J2).LE.0.491)PERC = 0.04986 +
       1 0.15099*FLOW(J2)
         IF(FLOW(J2).GT.0.491)PERC = AMIN1(0.235,0.49554*FLOW(J2) -
       1 0.11931)
C
C        CALCULATE SUCCESSFUL SPAWNERS
C
128      FSPAWN = PERC*0.875*FPOP(IAGE)
         IF(IAGE.GT.30)FSPAWN = AMAX1(ZERO,0.125*(38.0 - AGE)*
       1 FSPAWN)
         IF(FSPAWN.LT.1.0)FSPAWN = ZERO
         XLIM = HUNTHO
         IF(STG4.LE.3812.00)XLIM = TWNTHO
         DOG = FSPWT(L) + FSPAWN
         IF(KDBG.GE.1)WRITE(20,20)JYR,J2,IAGE,AGE,FPOP(IAGE),AFPOP(L),
       1 FSPWT(L),FLOW(J2),POL,PERC,FSPAWN,XLIM,DOG,F,FPOPO(IAGE)
C        WRITE(20, 201)JYR, J2, IAGE, FPOP(IAGE), AFPOP(L),
C      1 FPOPO(IAGE), PERC, FSPWT(L), FSPAWN, XLIM, DOG, FLOW(J2)
C 201    FORMAT(  3I4, 3F15.1, F7.3  /  12X, 4F15.1, F5.3 )
C        IF(DOG.GT.XLIM)FSPAWN = XLIM - FSPWT(L)
         FSPWT(L) = AMIN1(DOG,XLIM)
         F1 = FSPAWN
C
C        CALCULATE NUMBER OF EGGS LAID BY THIS AGE FEMALE
C
         E1 = 0.9*F1*POL
C
C         CALL EGG SURVIVAL SUBROUTINE
C
         IF(IAGE.EQ.7.OR.IAGE.GE.31)CALL SURVSH(J2)
C
C        CALCULATE ONE-YEAR OLD FISH AND ONE-YEAR OLD FEMALES PRODUCED
C
         E2 = 0.01*COGF*E1
         FYOY(L) = 0.5*E2
         YOYT(L) = YOYT(L) + FYOY(L)
         IF(KDBG.GE.1)WRITE(20,21)JYR,L,F1,E1,E2,COGF,FYOY(L),YOYT(L)
130      CONTINUE
C
C        NOW SHIFT POPULATION ONE YEAR IN THE ARRAY
C
         DO 140 KK=1,37
         K = 38 - KK
         FPOPO(K+1) = FPOPO(K)
140      CONTINUE
         FPOPO(1) = YOYT(L)
         STG(J2) = STG4
150      CONTINUE
C
C        NOW WRITE THE RESULTS
C
         NN = 0
         I2 = IPFYR - 1
         FACTOR = FLOAT(IPLYR - I2)
         FACTR2 = FLOAT(MIN0(IPLYR,67) - MAX0(IPFYR,24))
         DO 155 IP=1,2
         I1 = I2 + 1
         I2 = MIN0(I2+45,IPLYR)
         WRITE(20,495)
         WRITE(20,496)IP
```

```
      WRITE(20,509)(TITL(I),I=1,8)
      WRITE(20,497)
      WRITE(20,498)
      WRITE(20,499)
C
      DO 155 NK=I1,I2
      NN = NN + 1
      WRITE(20,500)NK,AFPOP(NN),FSPWT(NN),YOYT(NN),PCOGF(NN)
      J = NK/5*5/NK
      IF(J.GE.1)WRITE(20,506)
C
      AVG(2) = AVG(2) + AFPOP(NN)/FACTOR
      AVG(3) = AVG(3) + FSPWT(NN)/FACTOR
      AVG(4) = AVG(4) + YOYT(NN)/FACTOR
      AVG(5) = AVG(5) + PCOGF(NN)/FACTOR
      IF(NK.LT.25.OR.NK.GT.67)GO TO 155
      AVG2(2) = AVG2(2) + AFPOP(NN)/FACTR2
      AVG2(3) = AVG2(3) + FSPWT(NN)/FACTR2
      AVG2(4) = AVG2(4) + YOYT(NN)/FACTR2
      AVG2(5) = AVG2(5) + PCOGF(NN)/FACTR2
C
155   CONTINUE
      WRITE(20,507)(AVG(I),I=2,5)
      WRITE(20,508)
      WRITE(20,507)(AVG2(I),I=2,5)
C
      NN = 0
      I2 = IPFYR - 1
      DO 160 IP=1,2
      I1 = I2 + 1
      I2 = MIN0(I2+45,IPLYR)
      WRITE(20,495)
      WRITE(20,501)IP
      WRITE(20,510)(TITL(I),I=1,8)
      WRITE(20,503)
      WRITE(20,504)
C
      DO 160 NK=I1,I2
      NN = NN + 1
      FLOW(NN) = THOU*FLOW(NN)
      WRITE(20,505)NK,TFORC(NN),XREGM(NN),STG(NN),FLOW(NN),TTSTBL(1,
     1 NN),TTSTBL(2,NN),PCOGF(NN)
      J = NK/5*5/NK
      IF(J.GE.1)WRITE(20,506)
160   CONTINUE
      END



      SUBROUTINE SURVSH(KYR)
C
C     THIS SUBROUTINE CALCULATES THE CUI-UI LARVAL SURVIVAL.
C
      COMMON /BLOCKA/PCOGF(100),FSPWT(100),CFS(2),COGF,STG4,IAGE,
     1 KDBG
      DIMENSION Q1(6),Q2(7),A1(6),A2(7),A3(7),B1(6),B2(7),B3(7)
C
      DATA Q1/999.9,1400.,1900.,3500.,5000.,6000./ ,A1/13.15,13.22
     1 , 13.34,27.62,47.29,0.01/ ,B1/.00025,.0002,.000133,-.003947,
     2 -.00788,0./,Q2/1300.,1700.,2200.,2800.,3500.,5000.,6000./, A2/
     3 4.25552,5.66767,6.09319,6.8333,8.7,24.403,41.77/, B2/.003344,
     4 .002256,.002,.001667,.001,-.003487,-.00696/, A3/.01845,-.00377
     5 ,.01508,.00533,.01131,.01729,.00755/, B3/.86409,.7326,.59666,
     6 .46371,.32926,.19482,.06187/
C
10    FORMAT(1X,'SURVSH',3I4,7F10.3)
C
      ZERO = 0.0
```

APPENDIX D:

EVALUATION OF MEASURES TO SECURE WATER FOR CUI-UI

INTRODUCTION

Negotiation of water conflicts has been aided by computer simulations of hydrologic events (Truckee-Carson Hydrologic Model) and cui-ui response (Cui-ui Model - see Appendix B) using a historic data base (Buchanan and Strekal 1988; Cobb et al 1990). Those tools are utilized here to design and evaluate a series of alternatives to increase inflow to Pyramid Lake and equivalent actions with the objective to recover cui-ui.

BACKGROUND

The Truckee River originates at Tahoe Dam (the outlet of Lake Tahoe) and terminates at Pyramid Lake. River flow is provided by releases from Lake Tahoe and other reservoirs in the upper Truckee River basin and by uncontrolled runoff from unimpounded subbasins. Reservoir releases are coordinated to the extent possible to conform to a variety of operating agreements, decrees, orders, criteria, and standards. California uses river water from the headwaters downstream to the State line at Farad. In Nevada the Truckee is the principal source of water for irrigation, municipal, industrial and domestic uses in Truckee Meadows (Reno-Sparks area). A major portion of Truckee flow is diverted at Derby Dam to provide irrigation water for the Newlands Project in the vicinity of Fernley and Fallon (Carson River drainage). Diversion to the Fallon area is a function of project demand which cannot be satisfied by the Carson River. Water not diverted for other irrigators downstream from Derby Dam flows to Pyramid Lake.

Diversion of Truckee River runoff has been a major cause of the decline of the cui-ui population. Since 1982 Stampede Reservoir (capacity = 226,000 acre-feet) has been the only dedicated facility in the Truckee basin for storing water and regulating flows for cui-ui spawning.

The status of cui-ui can be improved by increasing population size and year-class diversity. This can be achieved by increasing the frequency of spawning runs and the survival (and consequent recruitment) of young. Eventual reclassification and delisting of cui-ui can be accomplished most directly by increasing inflow to Pyramid Lake, particularly during the spawning season.

Probabilistic (i.e., stochastic) analysis of Truckee River hydrology and cui-ui population response has indicated that annual inflow to Pyramid Lake must increase to ensure recovery (Appendix C). Additional water could be secured directly by purchasing active Truckee River water rights. For this measure to be effective, though, demands by other water users in the basin must not increase. Conversely, inflow to Pyramid Lake could be increased by reducing diversions from the Truckee River, but receipt of such water could be sporadic and require supplementation from dedicated storage facilities upstream to promote spawning and limit mortality of eggs and larvae.

Recovery might also be achieved by increasing runoff in the Truckee River while maintaining current levels of demands; such an alternative would require extensive changes in land use practices and water management. The simplest way for runoff to increase, of course, would be from climate change which is beyond the scope of this analysis.

Several sources of water for Pyramid Lake have been identified. While it may be possible to import water of suitable quality from a neighboring basin, it would be cheaper to purchase water rights from the Truckee Basin and/or reduce diversions to the Newlands Project. Operational changes at upper Truckee River reservoirs could improve timing of releases to benefit cui-ui spawning, which would be equivalent to acquiring a certain amount of water. Structural changes in the lower river could supplement or complement flow augmentation and promote recovery of cui-ui.

All of the measures presented or evaluated in this analysis are at least generally identified in the Truckee-Carson-Pyramid Lake Water Settlement Act (P.L.101-618). Certain specific measures and recommendations were developed to encompass likely possibilities to promote recovery of the species.

METHODS AND ALTERNATIVES

The Truckee-Carson Hydrologic Model has been used regularly to evaluate and compare operating plans for the Truckee-Carson river system. There are two versions of the model currently in use, the "Negotiation" and "Reclamation" models; this analysis uses the Negotiation model because it can be run with or without provisions of the Preliminary Settlement Agreement (PSA) for management of upper basin reservoirs, as identified in P.L.101-618. (PSA provides, in part, for storage of privately-owned municipal water in Stampede Reservoir and other upper Truckee River reservoirs for drought supply; in exchange, court-decreed Truckee River flow rates are relaxed and differential water credited for later release to improve cui-ui spawning conditions.) It is a monthly mass-balance accounting type model that adds inputs, subtracts outputs, and adjusts reservoir storage based upon a complex set of legal constraints and operating criteria. The model computes monthly flow and storage volumes throughout the system, including Pyramid Lake inflow and elevation.

The data base in the model reflects 80 years (1901-1980) of monthly average flows at key locations in the system for simulation, except it uses estimates of future demand in the Truckee Meadows area based upon planned acquisition of water rights, conversion of water use from agriculture to municipal and industrial, and changes in runoff caused by urbanization. The data base is also adjusted to reflect estimated future depletions in the Lake Tahoe Basin (Westpac Utilities 1989; Cobb et al 1990). All other demands in the basin - including California depletions downstream from Lake Tahoe, Newlands Project, cui-ui spawning flows, and irrigation downstream from Derby Dam - can be held constant at current levels and all existing storage and diversion structures are assumed to be in place and operating for the 80-year period of record.

The Cui-ui Model simulates the reproductive response of the assumed cui-ui population to changes in environmental conditions (primarily lower Truckee River flow) over time. It incorporates a number of biological parameters - fecundity, egg viability, temperature tolerance, mortality rate, and population size - and physical parameters - lake elevation, river access, attraction flow, and flow/temperature relation - to calculate an annual population index. Only females are accounted for because they are the limiting factor in spawning. The index responds to fluctuations in monthly as well as annual hydrologic conditions; the indexes produced by various operating plans can be readily compared to evaluate relative impacts to cui-ui reproduction (Buchanan and Strekal 1988).

Unlike the probabilistic hydrologic (i.e., stochastic) data base, the 80-year hydrologic record only indicates the relation of proposed conservation measures to past conditions and so cannot be used to predict future conditions and impacts to cui-ui survival. Used in conjunction with the hydrologic model, the 80-year data base provides a rapid method for evaluating the relative benefits (i.e., increased inflow to Pyramid Lake) of conservation measures. Such a data base cannot, however, be used to determine the adequacy of a conservation measure; only a probabilistic data base can be used for such a purpose. A detailed discussion is provided on appendix pages B-3 and C-2.

A series of likely future water demand/management conditions and various water-saving and habitat rehabilitation measures were evaluated with the negotiation model. Four alternatives were developed which incorporated four scenarios and a series of options and suboptions. The model was run for the 80-year hydrologic record for three of the alternatives. Results for inflow to

Pyramid Lake (average annual value) and cui-ui index from those runs were then compared to those of the "Base Run" (i.e., with current water management procedures and current water demands for several parameters) to compare relative benefits (absolute benefits can only be quantified using a stochastic hydrologic data base). This modeling approach was used to identify the measure(s) which might achieve the annual supplemental water requirement for reclassification (40,000 acre-feet immediate, or 45,000 acre-feet secured at 5,000 acre-feet/ year) and delisting (70,000 or 110,000 acre-feet, respectively) (Appendix C). The stochastic data base was only used for the fourth alternative to determine likelihood of cui-ui persistence.

Alternatives - The four alternatives examine different management approaches for the lower Truckee River:

- Alternative 1 is predicated upon current modeled conditions including 1988 Operating Criteria and Procedures (OCAP) for the Newlands Project;
- Alternative 2 modifies diversion criteria for the Newlands Project by reducing Lahontan Reservoir target storage levels concurrent with reduced demand: January-June target levels were reduced to 185,000 acre-feet for Option 1 and in 5,000 acre-foot increments for consecutive options to 165,000 acre-feet for Option 5; December storage limits were similarly reduced (to 170,000 acre-feet for Option 1 and in 5,000 acre-foot increments for consecutive options to 150,000 acre-feet for Option 5);
- Alternative 3 assumes that rehabilitation of the lower Truckee River channel reduces the May/June minimum spawning flow requirement by 300 cfs (= 18,000 acre-feet/month), an equivalent river temperature reduction of 1°F;
- Alternative 4 assumes that structural improvements in the Truckee River delta gradually reduce elevation required for fish passage from 3,812 to 3,800 feet (m.s.l.).

Scenarios - Four scenarios present various water management approaches for the upper Truckee River:

- Scenario 1 (referred to as the "base" scenario) represents current upper basin reservoir management practices and current California demand for Truckee River water;

- Scenario 2 incorporates the PSA to operate upper Truckee basin reservoirs with current California demand;
- Scenario 3 increases California demand for Truckee River water by 8,000 acre-feet/year above the current level with PSA in effect.
- Scenario 4 increases California demand for Truckee River water by 12,000 acre-feet/year above the current level with PSA in effect.

Options - Eight options were identified to successively reduce Newlands Project irrigation water demand (Table D-1):

- Option 1 ("base" option) assumes that total irrigated water-righted acreage for the project is 64,000, as specified in 1988 Operating Criteria and Procedures for the Newlands Project (OCAP) - options 1 through 7 reduce Newlands Project relative to the base;
- Option 2 adjusts Newlands Project irrigated water-righted acreage to 59,000;
- Option 3 incorporates Option 2 and further reduces demand by adjusting bench and bottom land designations (which changes water duty) according to revised project maps;
- Option 4 incorporates Options 2-3 and further reduces demand in conformance with assumed changes in Fallon Naval Air Station irrigation practice;
- Option 5 incorporates Options 2-4 and further reduces diversion to the Newlands Project as a result of water right purchases for wetlands (the water duty is reduced when irrigation rights are transferred to wetlands);
- Option 6 incorporates Options 2-5 but with Truckee Division water rights purchased for Pyramid Lake;
- Option 7 allows Newlands Project delivery of Truckee River water only to the Truckee Division;
- Option 8 eliminates all diversions to the Newlands Project.

Suboptions - Suboptions apply an efficiency factor to Newlands Project water distribution to adjust project demand (Table D-1). Efficiency is the total water delivered to all farm head gates in the project divided by the total water released to the project, expressed as a percent - higher efficiency produces lower demand if all other factors remain constant:

- Suboption A efficiency is 68.4% as specified in 1988 OCAP to be achieved in 1992 and for future years;
- Suboption B efficiency is 75%, a condition which will be evaluated in a feasibility study required by P.L. 101-618.

"Base condition" provides a basis for comparing relative benefits for all conservation measures to current operations. It is the Base Option with Suboption A (annual Newlands demands of 320,000 acre-feet) under Scenario 1 (no PSA and current California water demand from the Truckee River) for Alternative 1 (Newlands diversions governed by 1988 OCAP, i.e. diversion criteria E10, and no structural changes in the lower Truckee River). It is readily identified in model results by a "0" relative change in flow or cui-ui index. It was also the base for model runs described in Appendix C. Input data for the Negotiation Model are presented in Table D-2.

RESULTS

Alternative 1 - Absent operational modifications or structural changes in the lower Truckee River, model results (Figure D-1) suggest that inflow to Pyramid Lake generally increases as demand for Truckee River water decreases. Implementation of PSA does not markedly affect annual average inflow compared to the base condition. Inflow to Pyramid Lake might be increased by implementing several of the Newlands Project options described above. Increasing project (or other) efficiency increases the likelihood that a target flow can be achieved, and increasing California (or other) demand from the Truckee River decreases it.

Figure D-2 illustrates that the cui-ui population index generally increases as Newlands demand decreases. While PSA does not increase lower river flow, it does produce a higher index than the base condition. Increases in upper basin demand initially produce a lower index than the base and consistently lower than the PSA-only option. The benefit of PSA is in improved timing of lower river flow, i.e., water stored in upper basin reservoirs (credit water) is released to augment and equalize cui-ui spawning flows to enhance egg development and recruitment of young; hence, the index (population) is greater.

Alternative 2 - Criteria for diversion of the Truckee River to the Newlands Project were modified to compensate for reduced demand. Increases in inflow are greater for each scenario and option for Alternative 2 compared to those for Alternative 1 as exemplified by the base scenario (Figure D-3). The cui-ui index is sensitive to changes in project diversions; index response is markedly greater for each scenario compared to Alternative 1 (Figure D-4). In addition to increasing annual inflow to Pyramid Lake, modified diversion criteria tailored to cui-ui reproductive requirements undoubtedly increase spawning flows.

Alternative 3 - Rehabilitation of the lower Truckee River could promote cui-ui spawning as a supplement or complement to increased flow. Reducing the May/June flow requirement had a minimal effect on lower river flows but did increase the index compared to the base condition condition (Figure D-5); relative benefits were similar in magnitude to those obtained in Alternative 2.

Alternative 4 - Lowering the elevation of the delta can improve passage for cui-ui spawners and, thus, reproductive success (Figure D-6). Results from the stochastic analysis (Appendix A) for delta passage threshold demonstrate that the volume of supplemental water for the lower Truckee to achieve equivalent levels of persistence varies directly with delta elevation. Simply stated, spawning success and recruitment increase as passage becomes less restrictive. Supplemental flows for reclassification and delisting could be reduced considerably if the delta were lowered by 4 (3,808) to 12 (3,800) feet.

DISCUSSION

Several opportunities exist to increase inflow to Pyramid Lake by the equivalent of 40,000-70,000 acre-feet/year (acquired immediately) to meet the recovery objective. The alternatives were based upon anticipated changes in water management and possible changes in Newlands Project operation. They were intended to identify relative magnitude of water-savings. Because such simulations are based upon an 80-year scenario that will not likely recur, differences among alternatives should not be considered as absolutes but as indicators of possible water-saving measures. Recommended measures will likely need to be modified (and perhaps new alternatives developed) as the hydrologic and biological records are expanded, models are improved, and the effectiveness of implemented measures is evaluated. Also, alternatives were developed irrespective of economic or political constraints; some may not be achievable.

Water-rights purchase was introduced as the most straightforward means of securing the water identified to achieve the recovery objective.[1] Purchase is dependent upon water availability and funding. In the upper Truckee basin,

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[1] This analysis is not intended to imply that any water rights have been solicited for purchase or that they have been offered for sale by any party.

the most readily identifiable water rights (surface water irrigation) for purchase are in the Truckee Meadows area and in the Truckee Division of the Newlands Project. Available irrigation water rights in Truckee Meadows could increase average lower Truckee River flow by approximately 50,000 acre-feet; assuming the equivalent of $3,500/acre-foot, purchase of these rights would cost approximately $175 million. Purchase of active water rights in the Truckee Division could increase average lower river flow by approximately 26,000 acre-feet; assuming the equivalent of $1,000/acre-foot, this alternative would cost approximately $26 million. The total cost to increase inflow to Pyramid Lake by 70,000 acre-feet strictly by purchase of water rights above Derby Dam would be $180-195 million; for 40,000 acre-feet, the cost would be $75-140 million.

There are also approximately 30,000 acre-feet of irrigation water rights along the lower Truckee River. Assuming $2,500/acre-foot, this alternative would cost $75 million.

There is also a water right for diversion of 60 cfs from the Little Truckee River to Sierra Valley, California during the irrigation season (March 15-September 30). Dependent upon runoff, delivery to that water right has ranged from 2,000 to 9,000 acre-feet/year; average delivery is approximately 6,000 acre-feet/year. At $2,500/acre-foot, acquisition of that water right would cost $15 million. This water could be readily stored in Stampede Reservoir and, thus, gives an additional benefit of controlled release.

Acquisition of a water right without a corresponding storage right diminishes the benefit of that water right because water can only be delivered when available (depending upon priority of that right and runoff) and there is no protection of supply in the event of a drought. Also, there is increasing competition in the basin for water rights for wetlands and municipal and industrial supply. Water rights may not be available when funding is provided for purchase or the cost of those rights may escalate. Thus, less water than anticipated might result from an identified source.

The Newlands Project is identified as a primary source of water for cui-ui recovery because it contains the largest block of water rights at the lowest cost that creates a demand for Truckee River water - directly, to the Truckee Division along the Truckee Canal, and indirectly, to Lahontan Reservoir to supplement Carson River runoff and as carryover storage. Development of criteria and procedures to establish an equitable distribution of water between Newlands and Pyramid Lake has been the subject of protracted litigation and, most recently, legislation (P.L. 101-618).

Improvement in water distribution system efficiency and a variety of land use and operational changes on the Newlands Project (as enumerated in Table D-1) could also increase inflow to Pyramid Lake. Within the context of the Negotiation model, reductions in project demand of 29,000, 49,000 and 73,000 acre-feet/year would increase Pyramid inflow by approximately 18,000, 29,000 and 41,000 acre-feet/year, respectively, assuming base conditions. Diversion of Truckee River water to the Truckee Division only (i.e., no diversion to Lahontan Reservoir) would increase lower river flows by approximately 84,000 acre-feet. Closure of the Truckee Canal would increase inflow by 115,000 acre-feet. Any of these relative benefits would be diminished by increases in other demands (e.g., California) in the basin.

As shown above, neither direct purchase of Truckee Meadows water rights nor reduction in diversion to the Newlands Project gives the equivalent benefit to Pyramid Lake. The delivery of water throughout the basin, as regulated by a panoply of orders, decrees, agreements and criteria, is dependent upon the hydrologic cycle. Diversion of water to upstream water right holders will be determined by the daily or (in terms of the negotiation model) monthly runoff as well as the annual amount - Pyramid Lake would likely receive less water during a drought. Shortfalls in storage as a result of drought would be replenished in a succeeding year which, even if slightly above normal, would limit lower Truckee River flow.

The importance of timing of lower river runoff to supplement spawning flows has been emphasized along with volume (Buchanan and Strekal 1988). Stampede Reservoir is the only storage facility currently serving that function, although P.L. 101-618 also designates Prosser Creek Reservoir (i.e., storage not needed for Tahoe-Prosser Creek exchange) to be used for Pyramid Lake fishes. Development of an Operating Agreement (Agreement) for upper Truckee basin reservoirs as prescribed in P.L. 101-618 will expand that supplementation function. The PSA option illustrated the importance of coordinating releases to enhance spawning (Figure D-2). Incorporation of that Agreement into river operations will complement water augmentation plans to achieve the recovery objective. The Agreement that is finally adopted may or may not be identical to the modeled PSA. It is assumed that the Agreement will integrate operation of Tahoe Dam with that of other basin reservoirs to provide storage and releases to meet basin water-right demands and criteria for cui-ui recovery. A monitoring program will be required to determine the effectiveness of the Agreement in meeting these objectives.

Diversion criteria presented in OCAP are predicated upon a project demand of 320,000 acre-feet. Target storage levels for January-June were reduced by an amount corresponding roughly to reductions in annual project demand. Changes in Newlands Project diversion criteria could increase inflow to

Pyramid Lake by a marginal amount. The real benefit of such changes, however, appears to be increase of spawning flows. Improved timing of supplementary water, as shown in Figure D-4, in conjunction with reduction of diversions is a reasonable approach to recovery.

An additional alternative to improve timing of spawning flows has developed from a need to reduce the impacts of sewage effluent from the Reno-Sparks area. Effluent (from 20 to 60 million gallons/day) would be piped to Dodge Flats (along the lower Truckee River partly within the Pyramid Lake Indian Reservation) for treatment by rapid infiltration to ground water. The potential groundwater reservoir of 150-170,000 acre-feet could be pumped as needed to promote cui-ui spawning. Computer simulations incorporating present Newlands Project demand and full California demand with PSA and the Dodge Flats alternative produce cui-ui indices as much as 67,000 greater than the base condition (Sierra Hydrotech 1990), similar to results obtained by reducing Newlands demand by approximately 90,000 acre-feet/year (and equivalent to increasing Pyramid Lake inflow by 65,000 acre-feet/year). This alternative adds no additional water to the lower river - the cui-ui index increases because the Dodge Flats groundwater reservoir is operated in a manner similar to Stampede Reservoir, i.e., to augment spawning flows. This alternative assumes that groundwater can be pumped to meet the instream cui-ui spawning requirement and that water quality (particularly total dissolved solids, nutrients and temperature) will not impact egg and larvae development in the river or biotic diversity in the lake. Program development for this alternative has been postponed pending completion of a coordinated regional water resources study.

Rehabilitation of the lower Truckee River channel and floodplain has many apparent benefits - stabilization of river banks, substrate and the delta, and energy dissipation - but the primary benefit modeled is temperature reduction. Reestablishment of a tree canopy and deep river channel would cool the water which would increase survival of eggs and larvae. Cooler water would reduce the instream flow requirement by an average of 300 cfs/month in the model for both May and June. This in turn would generally allow more fish water to remain in storage for release in a succeeding drier year in which normal lower river flow would be insufficient to promote cui-ui spawning and recruitment. Figure D-3 indicates that restoring the river channel is potentially equivalent to increasing lower river flow. Typical recommendations for rehabilitation have included channel regrading, dredging, riprap and gabion bank protection (Water Engineering and Technology 1983; U.S. Bureau of Reclamation 1982, 1983). A recent study of the river has concluded that the channel can be stabilized by reestablishing the riparian forest (Jones and Stokes 1990). Pursuant to P.L. 101-618 the U.S. Army Corps of Engineers (COE) has begun a reconnaissance study to assess how to achieve stability of the lower river. In the absence of an approved rehabilitation plan, it is difficult to determine the effectiveness, costs or a schedule for completion of such a project.

Efficacy of improving delta passage cannot be evaluated using the standard hydrology of the negotiation model - below a certain elevation threshold all results are identical; thus, the stochastic technique was utilized to introduce hydrologic variability. Results of stochastic analysis suggest that maintaining a lower threshold passage through the Truckee River delta could increase cui-ui reproductive success and reduce the incremental water requirement for recovery. Typical recommendations for lowering the delta have included a regular dredging program, riprap, and flow deflectors. As with lower river rehabilitation, there is currently no approved plan to correct the situation nor any cost or construction schedules, but COE has been directed to study the problem of delta passage. Again, the effectiveness of such a project cannot be anticipated; maintenance of structural units must be considered. Augmentation of lower river flows would achieve the same results as excavating the delta and would require no operation and maintenance budget.

Overdiversion of Truckee River water to the Newlands Project (relative to a court-decreed diversion allowance) from 1973 to at least 1985 may have exceeded 800,000 acre-feet. Recoupment of that water may be the most immediate method to initiate recovery activities. Distributed over a number of years, delivery of a portion of that water to Pyramid Lake each year would increase inflow and provide a short-term benefit while other alternatives are being developed and implemented for long-term benefit and eventual delisting.

The alternatives presented in this analysis have been developed irrespective of potential political and economic restrictions or conflicts and of environmental impacts other than inflow to Pyramid Lake and cui-ui spawning and recovery. Possible effects of reducing Newlands Project diversions and increasing efficiency include reduced agricultural production and depressed agricultural economy, loss of wetlands from reduced drainage of degraded quality, and loss of fish, wildlife, and recreational values at Lahontan Reservoir. Many of the items have been included in P.L. 101-618 and compliance with the National Environmental Policy Act, Endangered Species Act and various other laws, regulations and orders has already been identified.

Computer simulations of the alternatives indicate a number of promising measures which, individually or in combination, might result in recovery and eventual delisting. As measures are implemented and additional hydrologic and biological data are obtained, stochastic analysis will need to be performed to evaluate relative success in achieving the recovery objective. Reduction of diversions from the Truckee River in conjunction with a limit on future demands should prove beneficial to cui-ui. Reductions only provide benefits, however, relative to an ideal condition; magnitude of benefits depends ultimately upon runoff.

SUMMARY

Computer simulations indicate that the following measures, if implemented individually and immediately, might provide the annual equivalent of 70,000 acre-feet for delisting or 40,000 acre-feet for reclassification of cui-ui:

- purchase of water rights in Truckee Meadows, Sierra Valley, Truckee Division of the Newlands Project, and/or lower Truckee basin - estimated total cost $75-195 million;
- reduce Newlands Project demand by approximately 80,000-100,000 acre-feet - cost unknown;
- reduce Newlands Project demand by approximately 40-80,000 acre-feet in conjunction with modifying diversion criteria to compensate for reduced demand - cost unknown;
- reduce Newlands Project demand by approximately 40-80,000 acre-feet in conjunction with rehabilitation of the lower Truckee River to reduce average May/June temperatures - estimated cost unknown;
- lower passage threshold of cui-ui through the Truckee River delta by approximately 12 feet - estimated cost unknown.

These measures might also be implemented in various degrees and combinations to achieve the recovery objective. Additional measures would be required to achieve increases of 45,000 to 110,000 acre-feet in annual inflow for recovery if benefits are secured at a rate of 5,000 acre-feet/year.

Implementation of an annual recoupment plan for excess water diverted to the Newlands Project would provide a short-term benefit toward recovery. Development and administration costs for this measure are unknown.

RECOMMENDATIONS

All measures presented in this analysis should be investigated to determine which one or ones will produce the greatest benefits for cui-ui. Measures that cost least and those for which precedent and legislation have been established are most likely to be implemented and should be pursued. It should be assumed that measures addressed in this analysis cannot be implemented immediately and that recovery of cui-ui will require more than 40,000 and

70,000 acre-feet/year identified for immediate reclassification and delisting, respectively. It should be assumed that a total increase in annual Truckee River inflow to Pyramid Lake of 45,000 to 110,000 acre-feet will be required for recovery (secured at 5,000 acre-feet/year).

Recovery efforts should emphasize measures which will improve cui-ui habitat, increase recruitment to the population, and lead ultimately to delisting. A combination of nonstructural (water rights purchases for Pyramid Lake, upper Truckee River operating agreement, and decreasing diversions from the Truckee River) and structural improvements (lower river floodplain, delta and fish facility rehabilitation) is required. Implementation of a combination of measures will improve habitat over a wide range of hydrologic conditions.

All proposals to secure water and improve habitat for cui-ui should be evaluated using the stochastic technique. Monitoring of measures as they are implemented will reveal benefits achieved. Refinements of hydrologic models - daily/hourly flows, temperature prediction, and nutrient cycling - will enable more reliable predictions of water quantity/quality. Incorporation of additional biological data in the cui-ui population model will assist in determining when recovery has been achieved. The recovery plan must be modified or revised as conditions in the Truckee Basin change and as data on cui-ui are acquired.

Table D-1: Annual Newlands Project demand which may receive diversions from the Truckee River for various Options -changes in irrigated acreage/water duties - and Suboptions - changes in water distribution system efficiency[2]

Option	Suboption A (68.4%) Acre-feet (x1000)	Suboption B (75%) Acre-feet (x1000)
1 (BASE) -Irrigated water righted acreage = 64,000	320	293
2 - Irrigated water righted acreage = 59,000	291	265
3 - #2 + Revised Bench/Bottom land designations	282	257
4 - #3 + Modified irrigation on Fallon Naval Air Station	271	247
5 - #4 + Purchase of 16,600 acres for wetlands	258	235
6 - #5 + Purchase of Truckee Division water rights	230	208
7 - No Truckee Canal delivery to Lahontan Reservoir	28	27
8 - Truckee Canal closed	0	0

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[2] Options 1 (Base) through 6 represent total project demand (Carson and Truckee Divisions); option 7 allows diversion from the Truckee River to the Truckee Division, so only a portion of the project is represented; option 8 prohibits diversion from the Truckee River to the project.

Table D-2: Input data for the Truckee-Carson Negotiation Model "Base Condition"

```
-BASE RUN ALTERNATIVE 1  LID-320,OCAP-E10------31 MAY  1990
  INYR  MONE     LSYR      KWR     KDBG     KDON     KDBY     KDBM
  1901     1     1980        1        0        1        0        0
 40 VALUES OF "KALT" WITH 13 SPACING
     0     0        0        0        0        0        0        0        0        0        0        0        0        0
     0     0        0        0        0        0        0        0        0        1        0        2        1
     0     0        0        1        1        1        0        0        0        0        0        0        0
 TAHOE DONNER PROSSER   MARTIS  INDEPND  STAMPED     BOCA  LAHONTN      DOG  PYRAMID
548.00  5.00    10.00      0.1    15.40    90.00    15.00   174.00      0.0    23.13
 732.0   9.5     30.0      0.1     17.5    225.0     40.9    317.3     00.0    295.0
       INITIAL CUI-UI STORAGE
   .00     0     0.00        0        0     0.00      .00
       INITIAL M&I STORAGE
   .00     0      .00        0        0    00.00      .00
       TAHOE STORAGE LIMITS BY MONTH FOR ABOVE WHICH CREDIT CAN NOT BE STORED
  540.  500.     500.     500.     500.     520.     540.     610.     670.     700.     670.     600.
       MINIMUM DONNER MONTHLY STORAGE RELATIVE TO FISH RELEASES
   289   289      289      289      289      289      400      790      744      694      631      289
       MINIMUM RESERVOIR STORAGE
     0  2.89     1.20      0.1        0      5.0        0      2.0      0.0
       MAXIMUM NEVADA M&I CREDIT BY RESERVOIR                 SPOL2     WPCL     TCNL
 000.0     0     00.0        0        0     00.0     00.0     00.0      0.0     0.80
 SPOOL CDLHX    CDLAH    TAHS1    TAHS2    CRDT1    CRDT2    CRDT3    CRDT4    SP40R    CARDT     CGWP    THTRN
   5.0   0.0      0.0     700.     699.      0.0      0.0      0.0      0.0      .99    292.0     00.0        0
TAH WINTAH SU  PROSSR  MART-BO   STAMPE   INDEPN   DONNER      DOG  MIN RELEASES
    50    70        5        0       30        2        3    .0000
       NOV-DEC OCAP 3 PRECIP AND 3 STORAGE LIMITS BY MONTH
   4.5   9.0      99.     160.     160.     160.      6.0      9.0      99.     210.     210.     210.
   4.5   9.0      99.     160.     160.     160.      6.0      9.0      99.     210.     210.     210.
       NEXT FIVE LINES ARE STORAGE, LOSS, C1 AND C2 FOR JAN-JUNE OCAP CRITERIA
   80.     0        0     215.     215.     215.     215.     215.     215.     160.     140.     120.      TS1
    0.     0        0       0.       0.       0.       0.       0.       0.       0.       0.       0.      TS2
                          33.5     32.5     28.3     21.1     10.7     22.8     21.8     17.6     10.4       TL
                         1.166    1.046    0.915    0.723    0.330    0.836    0.716    0.584    0.392       C1
                          0.47     0.47     0.45     0.35     0.17     0.30     0.30     0.28     0.18       C2
       WESTPAC MONTHLY DEMAND (TOTAL)
   893   683      668      682      633      696      896     1198     1369     1526     1453     1203     SPPD
       WESTPAC IRRIGATION RIGHTS
   443   330      315      335      315      340      510      748     0957     1104     1015      796    SPIRT
       WESTPAC EXPORT
    11     7        7        7        7       11       13       20       22       25       22       16     STED
       NORMAL YEAR AND MAXIMUM GROUNDWATER PUMPING
   215   125      094      094      094      098      148      188      280      296      295      233   NY-GWP
   435   164      123      123      123      129      194      247      382      482      482      476   MX-GWP
       PERMISSIBLE WESTPAC SHORTAGE BY MONTH
    .1    .1       .0       .0       .0       .0       .0       .1       .1       .1       .1       .1    DEPAL
       TRUCKEE MEADOWS NON-WESTPAC IRRIGATION RIGHT DEMANDS
   327    40       40       40       40       40      445     1089     1090     1130     1146     0936     TMID
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      TCID TRUCKEE DIVISION DEMAND
 151    26      0       0       0      15     188     517     541     564     489     309    TRCD
      TCID CARSON DIVISION DEMAND
1729   470      0       0       0     456    2952    5198    5019    5244    4736    3396    CDDM
      LOWER TRUCKEE WATER RIGHT DEMAND
 130    30     50      50      40      50     150     320     300     290     260     240   ALTDM
      PERMISSIBLE REDUCTION IN LOWER TRUCKEE DEMANDS TO USE FOR CREDIT STORAGE
   0     0      0       0       0       0       0       0       0       0       0       0   RLTDM
      LOWER TRUCKEE BENCH WATER RIHTS DEMAND
 110    40      0       0       0      40     140     270     260     240     240     200   BENCH
      PERMISSIBLE REDUCTION IN TRUCKEE DIVISION DEMANDS TO USE FOR CREDIT STOR
   0     0      0       0       0       0       0       0       0       0       0       0   RTCKD
      SEWAGE PLANT DISCHARGE
 621   498    536     535     465     535     499     621     577     621     621     578     SEW
      LOWER DOG CREEK RIGHTS
.046  .030   .005       0       0       0    .193    .473    .211    .041    .029    .026    DGWR
      MINIMUM FARAD FLOW
 20.   11.    11.     11.     11.     11.     17.     28.     29.     30.     30.     26.   FRDMN
      TARGET CALIFORNIA TAHOE BASIN DEMAND
   0     0      0       0       0       0       0       0       0       0       0       0     TCD
      TARGET CALIFORNIA TAHOE BASIN RETURN FLOW FRACTION
 0.0     0      0       0       0       0     0.0    0.00    0.00    0.00    0.00    0.00     TCR
      TARGET NEVADA TAHOE BASIN DEMAND
 0.0     0      0       0       0       0     0.0     0.0     0.0     0.0     0.0     0.0     TND
      TARGET NEVADA TAHOE BASIN RETURN FLOW FRACTION
 0.0     0      0       0       0       0     0.0    0.00    0.00    0.00    0.00     0.0     TNR
      CALIFORNIA LITTLE TRUCKEE DEMAND
   0     0      0       0       0       0       0     0.0     0.0     0.0     0.0       0   CALIT
      CALIFORNIA TRUCKEE RIVER DEMAND
 .00   .00    .00     .00     .00     .00     .00    0.00    0.00    0.00    0.00    0.00   CALTR
      TARGET CALIFORNIA TRUCKEE RIVER RETURN FLOW FRACTION
.411  .577   .743    .720    .720    .670    .518    .364    .367    .437    .452    .429    TCRT
      CALIFORNIA STREAM FISH FLOW TARGETS
 0.0   0.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  CDFG 1
 0.0   0.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  CDFG 2
 0.0   0.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  CDFG 3
 0.0   0.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  CDFG 4
 0.0   0.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  CDFG 5
 0.0   0.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  CDFG 6
      GROUNDWATER DISCHARGE SCHEDULE (NATURAL CONDITIONS)
.055  .060   .067    .072    .072    .095    .111    .133    .124    .084    .069    .058    GWDS
      SCHEDULE OF RETURN FLOW FROM GROUNDWATER PUMPING
.0319 .0353  .0446   .0391   .0421   .0404   .0392   .0364   .0404   .0537   .0548   .0421   GWRFS
       1931 SPARKS PIT PUMPING
   0     0      0       0       0       0       0       0       0      .0      .0      .0
       1932 SPARKS PIT PUMPING
  .0     0      0       0       0       0       0       0       0       0       0       0
       1934 SPARKS PIT PUMPING
   0     0      0       0       0       0       0       0       0      .0      .0      .0
       1935 SPARKS PIT PUMPING
  .0     0      0       0       0       0       0       0       0       0       0       0
```

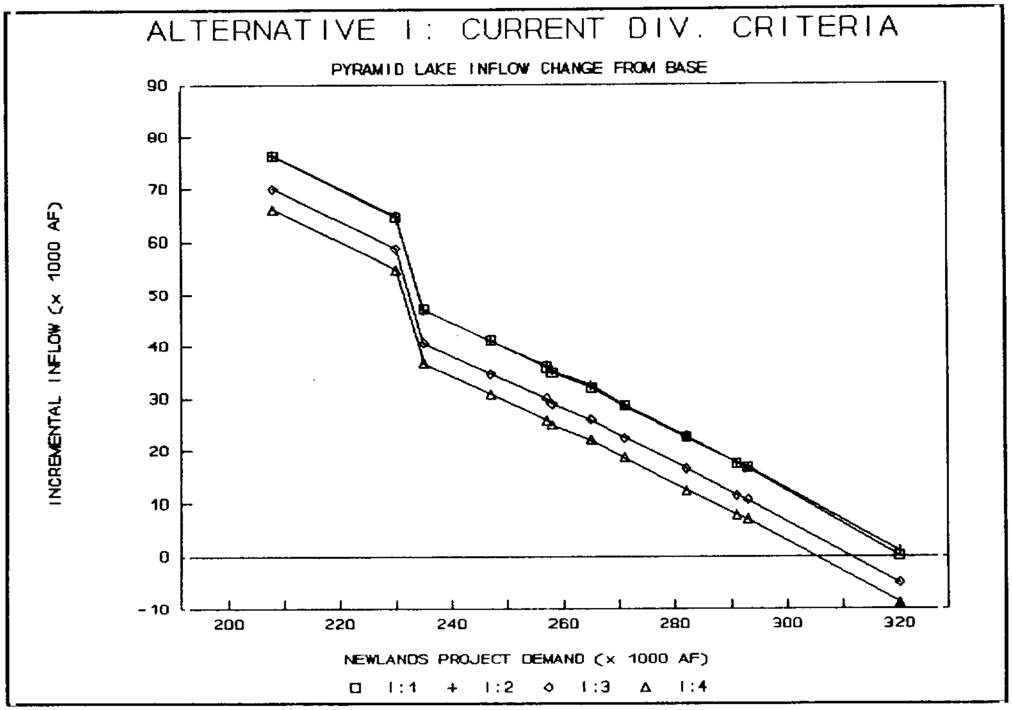

Figure D-1: I = Alternative; 1-4 = Scenarios (see text for explanation).

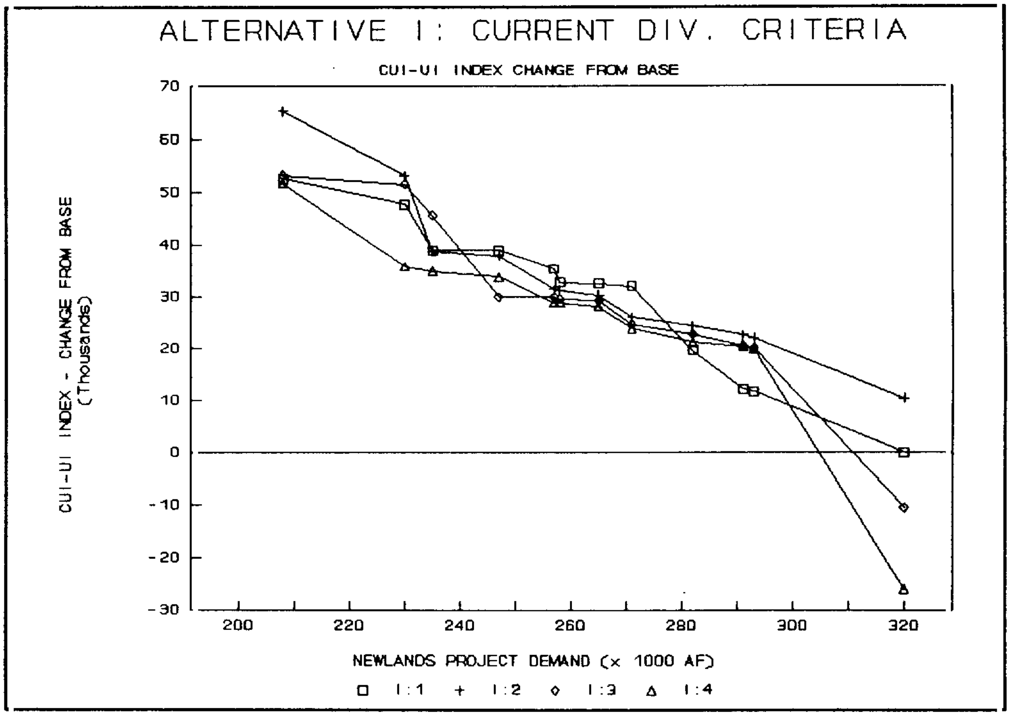

Figure D-2: I = Alternative; 1-4 = Scenarios (see text).

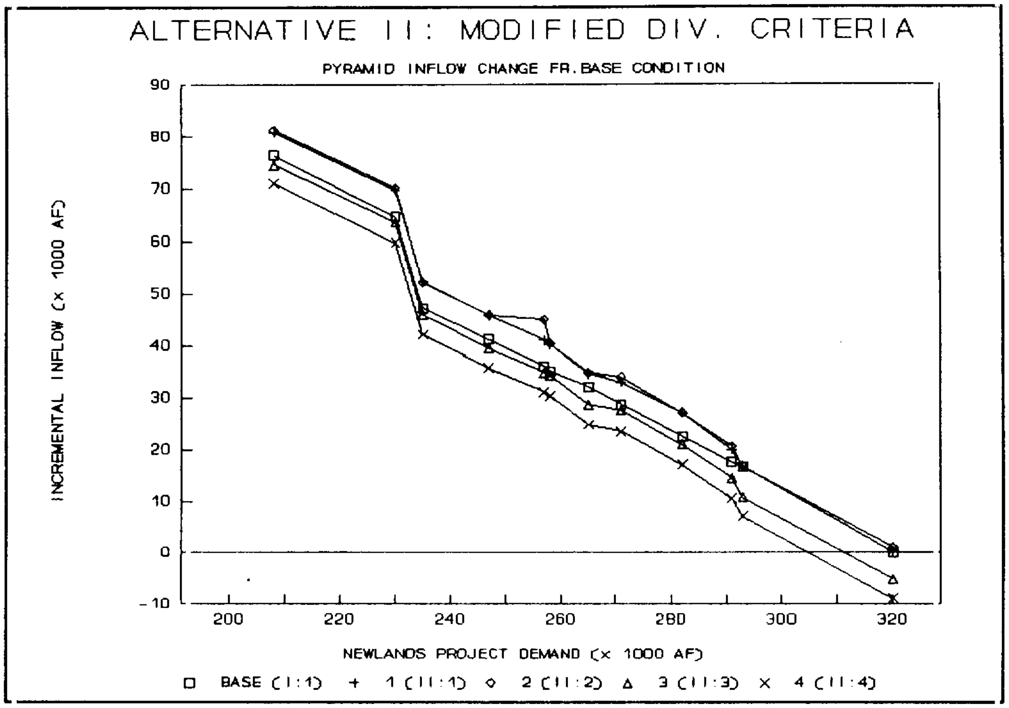

Figure D-3: I,II = Alternatives; 1-4 = Scenarios (see text for explanation).

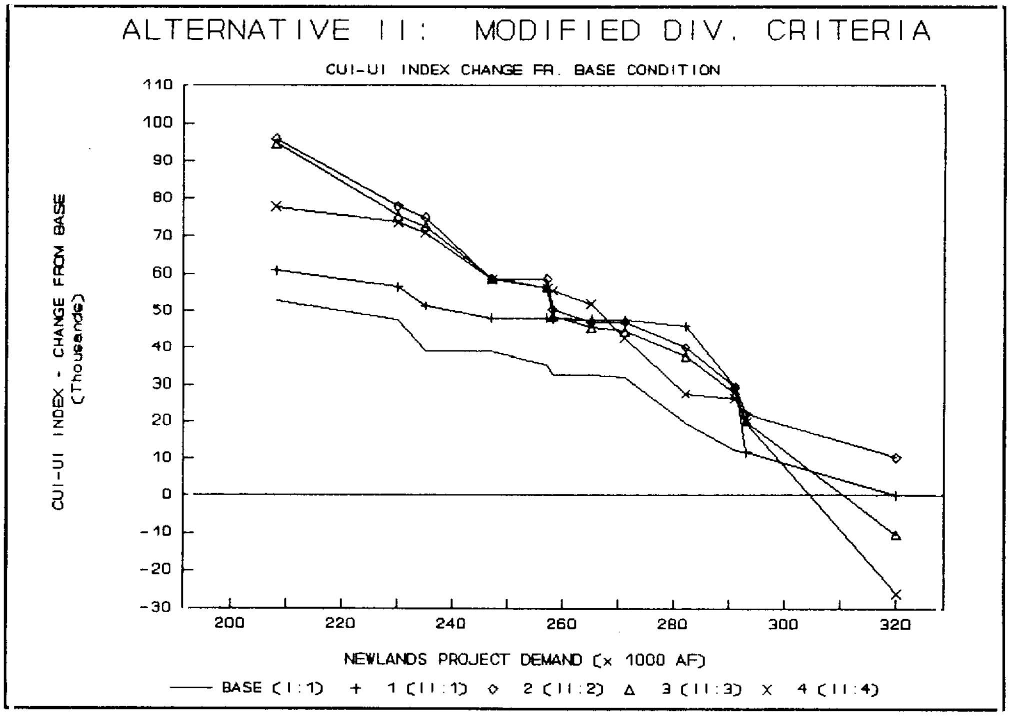

Figure D-4: I,II = Alternatives; 1-4 = Scenarios (see text).

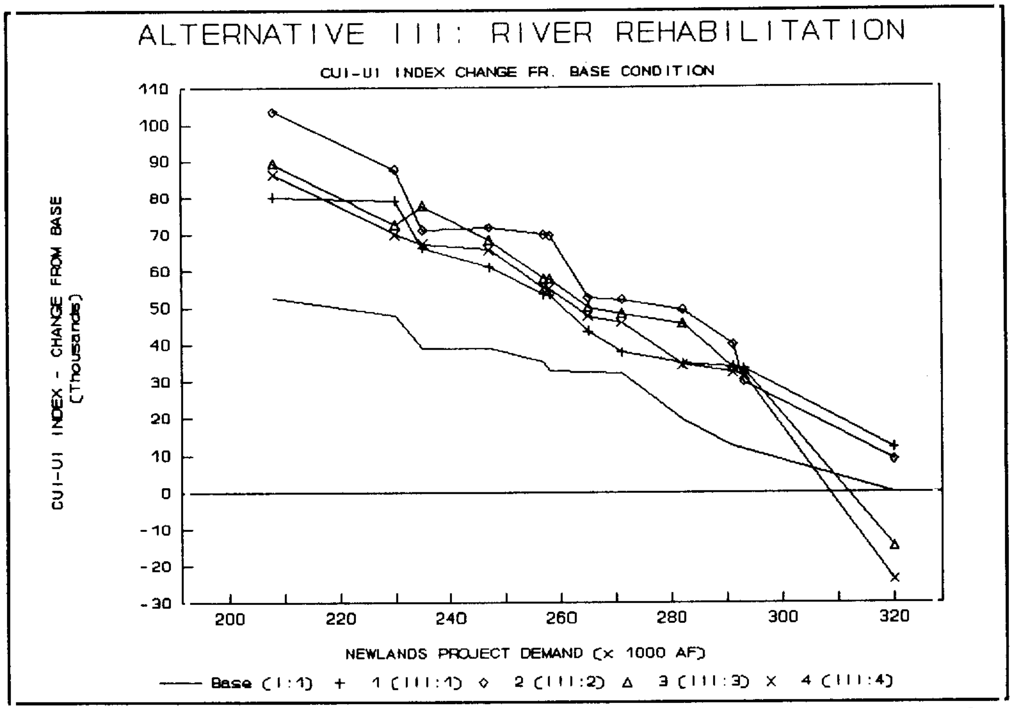

Figure D-5: I,III = Alternatives; 1-4 = Scenarios (see text for explanation).

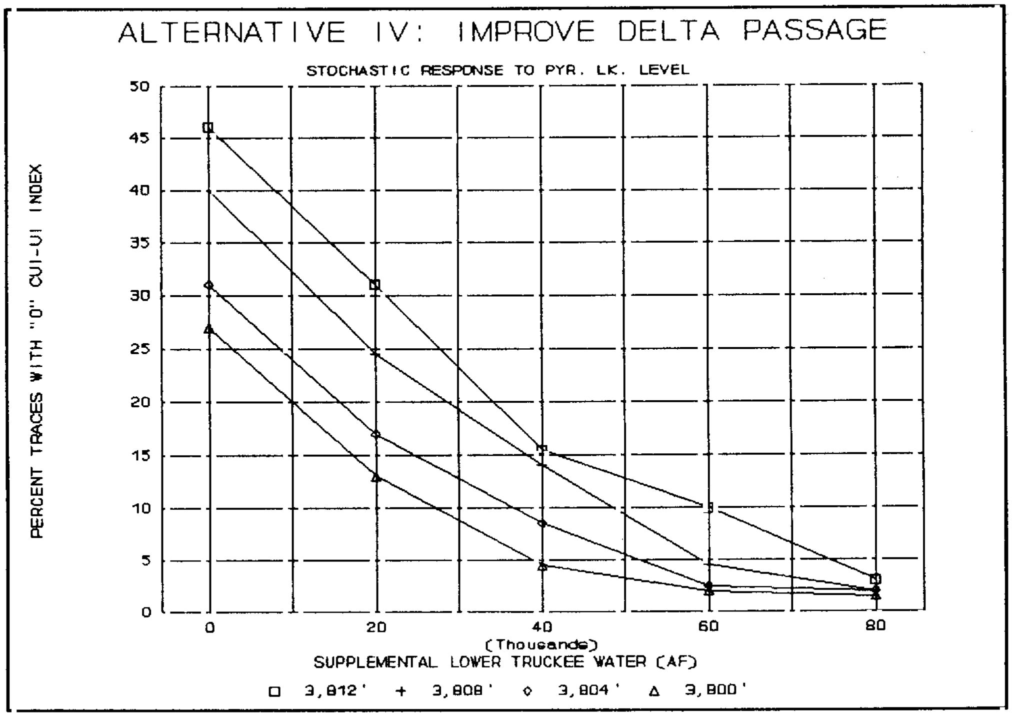

Figure D-6: Symbols indicate Pyramid Lake elevations for possible delta passage by cui-ui spawners.

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APPENDIX E

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```
      IF(CFS(1).GE.Q1(1).AND.CFS(2).GE.Q1(1))GO TO 110
      SURVIL = ZERO
      SURVAL = ZERO
      FSPWT(KYR) = ZERO
      GO TO 150
C
110   IF(STG4.LT.3812.00)GO TO 130
C
C     CALCULATE SURVIVAL WHEN LAKE LEVEL IS ABOVE 3812.
C
      K = 1
      DO 120 J=2,6
      IF(CFS(1).LT.Q1(J))GO TO 121
      K = K + 1
120   CONTINUE
121   SURVAL = A1(K) + B1(K)*CFS(1)
      GO TO 140
C
C     CALCULATE SUVIVAL WHEN LAKE LEVEL IS BELOW 3812.
C
130   DO 131 J=1,7
      K = J
      IF(CFS(2).LT.Q2(J))GO TO 132
      IF(J.GE.7)GO TO 121
131   CONTINUE
132   SURVAL = A2(K) + B2(K)*CFS(2)
140   C12 = AMIN1(CFS(1)/CFS(2),CFS(2)/CFS(1))
      IF(C12.GE.0.9851)C12 = 1.0
C
              IF(STG4.LT.3812.00)THEN
      SURVAL = C12*SURVAL
              ELSE
      SURVAL = SURVAL*(0.25 + 0.75*C12)
              ENDIF
C
      SURVIL = SURVAL
      IF(IAGE.GE.31)SURVIL = A3(IAGE-30) + B3(IAGE-30)*SURVAL
C
150   COGF = AINT(SURVIL*100.0 + .05)/100.
      IF(KDBG.GE.1)WRITE(20,10)K,IAGE,KYR,CFS(1),CFS(2),SURVAL,
     1 SURVIL,COGF,C12
      PCOGF(KYR) = SURVAL
      RETURN
      END
```

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APPENDIX C:

PROBABILISTIC CUI-UI RESPONSE

INTRODUCTION

A major factor which has contributed to the decline of the cui-ui (Chasmistes cujus) population and the species' eventual designation as endangered is diversion of water from the Truckee River. Supplementation of lower Truckee River flows, or its equivalent, is deemed the logical corrective action to promote expansion and eventual reclassification or delisting of the species. Standard computer-aided studies utilizing a historic monthly hydrologic data base and demographic data of the species have proved useful in comparing the relative value of water management plans to cui-ui. Such an approach, though, cannot be used to determine which plan or plans are likely to lead to recovery of the species. A probabilistic prediction of future hydrologic conditions is required. The following analysis integrates such a probabilistic hydrological data base with a biological computer model to quantify the water supplementation requirement and scheduling to achieve recovery.

Because cui-ui females are effectively reproductively impotent after age 38, a 38-year sequence of dry years or years in which human water use is such as to preclude spawning, could be expected to all but exterminate the population. There is no record of drought lasting this long and no reason to believe that anthropogenic effects will produce such a long run of poor years for the fish. On the other hand, a few females may continue to breed beyond age 38, while others may lose the ability at a younger age. Hence extinction must be dealt with in a probabilistic manner.

There is no assurance the population would disappear after 38, or even 45 sterile years and, similarly, no guarantee it would persist after ten. The biologist, or citizen worried about extinction, then, must be concerned with probabilities that sterile year sequences, of whatever duration, will do irreparable damage to the cui-ui. These probabilities are related to population size. The chance in any given year that at least one male and one female fish of reproductive age are present, and that at least one such female will spawn increases with the number of individuals in a population. Thus the likelihood of extinction rises markedly with decreasing population size. Finally, population size invariably drops in years without reproduction, and is likely to drop, even if reproduction occurs, if low water levels limit the number of spawners or survival of the eggs. It follows that even when poor conditions occur in sets of much less than 38 years, a disconnected but sufficiently proximate string of such short sequences easily could lead to the cui-ui's demise.

Human-assisted recovery of a species depends on managing the environment in such manner as to enhance reproduction and/or survival. The goal of this management must be to minimize the frequency of adverse years and the length of adverse year sequences, and to encourage maximum reproductive performance in years when spawning occurs. A number of measures, including the improvement of water quality, would be helpful to cui-ui. Because availability of water appears currently to be the critical limiting factor on reproduction and early survival, such management should concentrate first on providing for increased (restored) water flows during the critical periods in which attraction, passage, and early development take place. This, in turn, will require a decrease in the diversion of water from the Truckee River and/or improved water management.

Because of the economics and politics of water in this arid region, the diversion of any water from its present use must be carefully justified. Will supplementary water result in cui-ui recovery? To answer this question it is necessary to predict future cui-ui populations as a function of the amount of water restored to the lower Truckee River.

WHAT CONSTITUTES RECOVERY?

An endangered species can be said to have recovered when a management plan which assures indefinite persistence with some acceptable level of probability is implemented. Two terms require definition.

"Indefinite" persistence implies continued existence in perpetuity. In practice, this definition is not workable; even undisturbed by humans, populations eventually disappear. Natural alterations occur in the environment; social values and pressures change. A more workable approach is to consider "indefinite" as a time span reflecting diminishing interest in more and more distant future events by our present society. Conservation biologists are fond of thinking in terms of 1000 years. But when we stop to consider that 1000 years ago the Norman conquest was still three generations in the future, a millennium begins to seem like a very long time. A more reasonable and, in terms of a collective, societal attention span, realistic time frame is two centuries. Accordingly, the definition of "indefinite" is taken in this report to be 200 years. This value is similar to the 250 years considered in "A Conservation Strategy for the Northern Spotted Owl" (Thomas et al. 1990, Appendix M).

There is never certainty that a population will persist (for 200 years). At what level of "probability" are we to be satisfied that a species has recovered? There is little to guide us in an answer to this question; being satisfied is, after all, a matter of philosophy and values. In keeping with standard statistical procedure for distinguishing between a null hypothesis (extinction) and its alternative, we suggest 95 percent.

HYDROLOGIC DATA BASE AND MODEL

Because cui-ui population dynamics are strongly dependent on hydrology, and because acquired water would be only supplementary to the underlying natural hydrological events, predictions of future fish numbers must reflect future natural hydrologic scenarios. Unfortunately, these scenarios cannot be known with certainty. Thus it is necessary to rely on probabilistic projections. For such projections to be valid, the following criteria must be observed:

1. Hydrologic sequences, like those of other natural phenomena, are generally autocorrelated...that is, a wet year might more likely be followed by another wet year than a dry one (or vice versa). Of course the true pattern might be more complicated than this. For example, the correlation between adjacent years might be positive...wet years are likely followed by wet years, while the correlation between years t and t+2 might be negative. Any predicted future scenario must reflect such autocorrelations.

2. Hydrologic events at one point in a watershed are almost certainly related, and thus correlated with events at other points in the same watershed. Any predicted future scenario must also reflect these spatial relations.

The information inherent in the above two requirements can be captured by describing the probability that a certain hydrological condition will occur at some point, A, as a function of what is happening at points B, C, etc. and what has happened at point A in previous years. Such a description is known as a conditional probability density function. If we possessed such a density function and if, in addition, we knew point A's history and also the upcoming conditions at B, C, etc., we would be able to predict the probability of the upcoming condition at A. If we were to obtain an expression that gave this probability for all points A, B, etc., simultaneously (a multivariate conditional density function), we would be able to predict simultaneously the probability of any upcoming spatial configuration of conditions over the various points.

In fact, we could do better than this: we could produce hypothetical spatial configurations of conditions in proportion to their probabilities of occurrence and thus generate representative samplings of conditions that faithfully reproduce the relations in the observed (historical) hydrological data. By stringing a number of such outputs together, year-after-year, we could even produce representative sequences of conditions over as long a period as we wished. These sequences could then be used to predict hypothetical scenarios of cui-ui population dynamics, each scenario being an equally likely future. Then if for some regime of supplementary water, 20 (say) out of every 100 such simulations led to population die off, we could conclude that the chance of extinction under this particular regime was 20 percent.

Using a computer algorithm developed at the U.S. Bureau of Reclamation by W.L. Lane and D.K. Frevert (1989), we generated a multivariate conditional density function based on an 89-year (1901-1989) hydrology data set covering 15 locations in the Truckee-Carson watershed. The variance-covariance structure among locations was preserved as well as one- and two-year serial correlations. In the absence of reasons to believe otherwise, it was assumed that the temporal and spatial structure of the hydrology so described for the past 89 years would continue to characterize the Truckee-Carson system for the foreseeable future. Accordingly, a representative sampling of possible future scenarios was constructed by using this multivariate function to generate 200 "stochastic traces" (equally likely sequences) describing flow at several key locations These, in turn, were used as input to the Cui-ui Model (see below).

The Truckee-Carson hydrologic model uses hydrologic data from several key locations in the two river basins. Eleven parameters derived from these data are input to the model for every month of every year of record. Releases from Stampede Reservoir, reflecting Corps of Engineers flood control regulations and legal mandates for threatened and endangered fish species, are incorporated into this model, as are diversions for agriculture. Reservoir storage volumes are initiated at April 1990 levels, and seasonal distribution of irrigation demand and reservoir evaporation are assumed to be constant. Municipal and industrial demands are set at future (i.e., year 2015) levels; the Truckee River is assumed to be fully appropriated with all water rights activated so demand does not increase in the future. Eventually, lower Truckee River flow and Pyramid Lake level are computed (see Buchanan and Strekal, 1988).

CUI-UI MODEL

To project cui-ui numbers into the future we made use of a single-species, age-projection (Leslie) matrix with reproduction rates written as functions of hydrological input. Reproduction rates were characterized, on an age-specific basis, as the product of a female's likelihood of joining the pre-spawning aggregate (related to attraction flow from the Truckee River), likelihood of passage into the river (dependent on lake level), and survival of the eggs (a function of river flow). Specific relations are provided in Buchanan and Strekal (1988, Appendix C).

Density dependence acts, at least in part, via limits on the number of potentially spawning females that can migrate through the restricted passages leading upriver. Based on observations of migrating females and the nature of the Marble Bluff Fish Facility (fishway and river trap) through which the fish must pass, the maximum possible run was set at 100,000 females. Other density effects probably occur, but information is not available on their mode of action or their intensity. It was necessary, therefore, to ignore them in the model and to consider model output to err on the side of overestimation of female numbers. Several changes in the model and in demographic parameter estimates have been made since publication of the 1988 report cited above:

1. Based on discussions since 1988, cui-ui survival from age 2 to age 7 years was re-estimated to be 0.444 (i.e., 0.85/year), and yearly, after age 7, at 0.85. The age one to age two survival estimate remained unchanged at 0.75. Data are unavailable for survival from larval stage to age one year, but 0.001 is at the upper end of values characteristic of fish with broadcast larvae and fecundity on the order of that displayed by cui-ui (Dahlberg, 1979).

   The accuracy of this value for larvae survival can be crudely evaluated if we note that adults in 1990 (estimated at 300,000...Pers. Comm., G.G. Scoppettone, U.S. Fish and Wildlife Service Reno Field Station, Reno, Nevada) must have arisen either from larvae produced in 1981 or 1982 - virtually no 7-year olds are recruited into the (countable) adult population, and virtually all fish are mature by age 9 - or from adults present in 1989. Number of female larvae produced in 1981 and 1982, based on fecundity estimates and the size of the spawning run, were 14,000 and 12,550,500, respectively (for these and following larvae numbers, see Buchanan and Strekal, 1988, Table C-5). Hatchery input added 104,000 and 450,000 young. Because survival from age 1 to age 2 is approximately 0.75, that from age 2 to 7 years is about 0.444, and subsequent yearly survival is 0.85, the contribution of 1981 and 1982 larvae to the 1990 adult population should be approximately,

   $$(28{,}000 + 208{,}000)(.001)(.75)(.444)(.85)^2$$
   $$+(25{,}101{,}000 + 900{,}000)(.001)(.75)(.444)(.85)$$
   $$= 7{,}416.$$

   The contribution via existing adults can be calculated from the estimated (adjusted Peterson method) 1983 population of 146,000 and the contributions of larvae from year classes 1976-1980 (corresponding to adults entering the population between 1984 and 1988). Using larvae estimates provided in Buchanan and Strekal (1988), this becomes

$$\begin{aligned}
&(146{,}000)(.85)^7\\
&\quad + (33{,}000 + 747{,}000)(.001)(.75)(.444)(.85)^6\\
&\quad + (1{,}835{,}000)(.001)(.75)(.444)(.85)^5\\
&\quad + (57{,}000 + 5{,}663{,}000)(.001)(.75)(.444)(.85)^4\\
&\quad + (87{,}000 + 1{,}000)(.001)(.75)(.444)(.85)^3\\
&\quad + (1{,}507{,}000 + 317{,}000)(.001)(.75)(.444)(.85)^2\\
&\quad = 48{,}144.
\end{aligned}$$

Based on a larvae survival rate of .001, then, the projected 1990 adult population is 7,416 + 48,144 = 55,560. This is short of the estimated true value by a factor of 5.4 (= 300,000/55,560). Hence we must consider 0.001 to be a minimal estimate of larvae survival. Because 0.001 seemed already high based on general ecological considerations, a revised value five times that size seems inconceivable. In addition, it is entirely possible that either the 1983 or the 1990 population estimates could be in error. Accordingly, 0.003 was chosen as a compromise upper limit on estimated survival. On the presumption that the truth should lie somewhere between the minimal and maximal estimates, 0.002 was picked as the "best guess" value.

2. If the level of Pyramid Lake were to exceed 3,848 feet (mean sea level), the height of the Marble Bluff Dam spillway, water would inundate the delta, enhancing fish passage to the dam and, once the spillway was topped, hugely facilitate transport upstream of the dam. To reflect the corresponding benefits, number of spawners was permitted to double under this scenario. Doubling would effectively permit utilization of all currently identified spawning habitat by a maximum of 200,000 female spawners.

No information exists on year-to-year variability in demographic parameters. This being so, and inasmuch as existing variation is almost certainly not independent of hydrological events, it seemed foolhardy and almost certainly misleading to model birth and death as stochastic processes. Qualitatively, fecundity and probably also survival vary positively with water flow. Therefore, as the variance in these parameters increases, the severity of drought effects is magnified and population growth is curtailed. By utilizing fixed values, the model again errs (as with the treatment of density dependence) on the side of overestimating numbers.

A population of two individuals cannot reproduce, even under ideal conditions if both fish are of the same sex. Under such circumstances, and occasionally under even less stringent conditions, a real population would die out. The model, by ignoring this sort of statistical variation in fecundity, ignores also the corresponding possibility for extinction. In principle, this, yet again, means the model might err on the optimistic side. In fact, however, very few of the simulated populations, even under conditions of no supplementary water, ever fell below about 50 individuals without eventually going (and being recorded as) extinct.

To simulate the effects of supplementary water on future population dynamics, a total supplementary water budget was decided upon, and increments of water were added to the zero-supplement water levels, month by month, in amounts proportional to the historic mean monthly flows for January through June. The simulations were initialized to 1990 conditions using a population density structure based on estimated existing adult females and back-calculating larvae numbers from these estimates along with the presumed mortality rates.

RESULTS

To identify the amount of supplementary water needed for recovery, two sets of simulations were run. In the first, 200 stochastic traces were used to drive the cui-ui model utilizing the lower estimate (0.001) of early survival, the upper estimate (0.003) of early survival, and the intermediate "best" estimate (0.002). Supplementary water was added into the system beginning in the first year of simulation (1991).

The second set of simulations was designed to illustrate the consequences of procrastination in recovery efforts. These runs differed from those of the first set in that, in keeping with political and economic realities, supplementary water was not added until 1994, and then was allowed to increment, in equal steps, until the full yearly allotment was reached. Only the "best" estimate (0.002) of early survival was used in these simulations.

Results from the first set of runs are shown in Figure C-1. The uncertainty in the value of larvae survival, p_l, is reflected in the area between the upper ($p_l = 0.003$) and lower ($p_l = 0.001$) curves. Examining these curves and utilizing a decision maker's prerogative to set the satisfactory level of certainty on persistence at 95 percent, it can be seen that between 45,000 and 115,000 acre-feet of water will be required before the population can be said to be capable of recovery (95 percent of equally likely future scenarios lead to survival for cui-ui over 200 years or more). The gulf between these estimates of required water represents the extent of our uncertainty (vis a vis model predictions). This region is currently very wide, but it can be narrowed, thus resolving potential conflict between cui-ui advocates and opposing political and economic interests with improved data on demographic parameter values. Research continues, and as new, improved estimates become available, Figure C-1 will continue to be revised. For the moment, we concentrate on the intermediate "best" estimate results. The conclusion, in this case, is that cui-ui has only a 50-50 chance of survival if no supplementary water is available (baseline condition). Recovery requires that the annual inflow to Pyramid Lake be increased by about 70,000 acre-feet.

If this water were made available immediately, and if the model were known to be accurate, cui-ui could be considered recovered in 1991. Because the model and its input parameter (demographic) values cannot yet be considered exact, however, the term recovered, as used above, must be used tentatively. Assurance of recovery will require many years of monitoring and data refinement.

Lowering our sights somewhat and choosing an 85 percent certainty level of persistence, reclassification to threatened status would occur with the annual addition of between 15,000 and 100,000 acre-feet (corresponding to larvae survival = 0.003 and 0.001, respectively). The "best" estimate is about 40,000 acre-feet.

A cautionary note: recall, because the model minimizes density feedback and does not incorporate random, year-to-year fluctuations in mortality and fecundity, that predicted populations are overestimated. Thus the 40,000 and 70,000 acre-foot figures probably err on the low side. These levels were selected as the thresholds for reclassification and delisting, respectively.

The relations shown in Figure C-1 presume an immediate addition of the full yearly complement of supplementary water. It is unrealistic, though, to expect immediate acquisition. Accordingly, simulations were run for which supplementary water was first acquired in 1994, and then incrementally built up each year in amounts of either 3,000 or 10,000 acre-feet. Because each year of less than the estimated needed 70,000 acre-feet results, on average, in population decline, these more realistic schemes are likely to require higher, maximal supplementary water flows than those in which water becomes immediately available. Results of the runs (Figure C-2) show that when water is acquired in 10,000 acre-foot yearly increments, the eventual, sustained amount of supplementary water needed is 88,000 acre-feet; recovery will take 2+[88,000/10,000] = 11 years (by the year 2003). In the case of 3,000 acre-foot yearly increments, recovery will require well over a total of 120,000 acre-feet. Inasmuch as this amount of water is not realistically obtainable, recovery will not occur. In this scenario other conservation measures listed in the plan will become mandatory for recovery. Choosing 85 percent certainty, the 10,000 acre-foot yearly increment program leads to an eventual total of about 40,000 acre-feet (reachable by 1998), and the 3,000 acre-foot yearly increment program would achieve reclassification with a total of about 50,000 acre-feet (reachable by 2011).

Because of physical and economic limitations acquisition of 10,000 acre-feet/year was deemed unlikely, and 3,000 acre-feet/year will not achieve recovery. Therefore, a compromise acquisition rate of 5,000 acre-feet/year was selected for recovery activities, and probability values were interpolated from the 3,000- and 10,000-acre-foot data displayed in Figure C-2. At this rate, reclassification (85 percent certainty) would require 45,000 acre-feet (reachable in 11 years, by 2003) and recovery (95 percent certainty) would require approximately 110,000 acre-feet (reachable in 24 years, by 2016).

DISCUSSION AND CONCLUSION

The uncertainty in required supplementary water illustrated by the gap between the upper and lower curves in Figure C-1 demonstrates the critical need for better information on early survival in cui-ui. Model results will be updated and refined as better estimates of survival become available. For the moment, we must make do with the data we have. With this caveat, two conclusions can be made:

1. Immediate acquisition of supplementary water in the amount (best estimate) of 70,000 acre-feet/year (Figure C-1) would permit consideration of declassification of cui-ui now;

2. As the acquisition of supplementary water becomes increasingly protracted, larger acquisitions become necessary, delisting is progressively postponed, and the risk of coincidental extinction grows. At an acquisition rate of 5,000 acre-feet/year (Figure C-2), reclassification would require acquisition of a total of approximately 45,000 acre-feet and declassification would require a total of approximately 110,000 acre-feet.

3. At acquisition rates less than 5,000 acre-feet/year, the eventual yearly input of supplementary water would exceed realistic limits on availability, making recovery impossible without implementing some of the additional conservation measures discussed in the recovery plan.

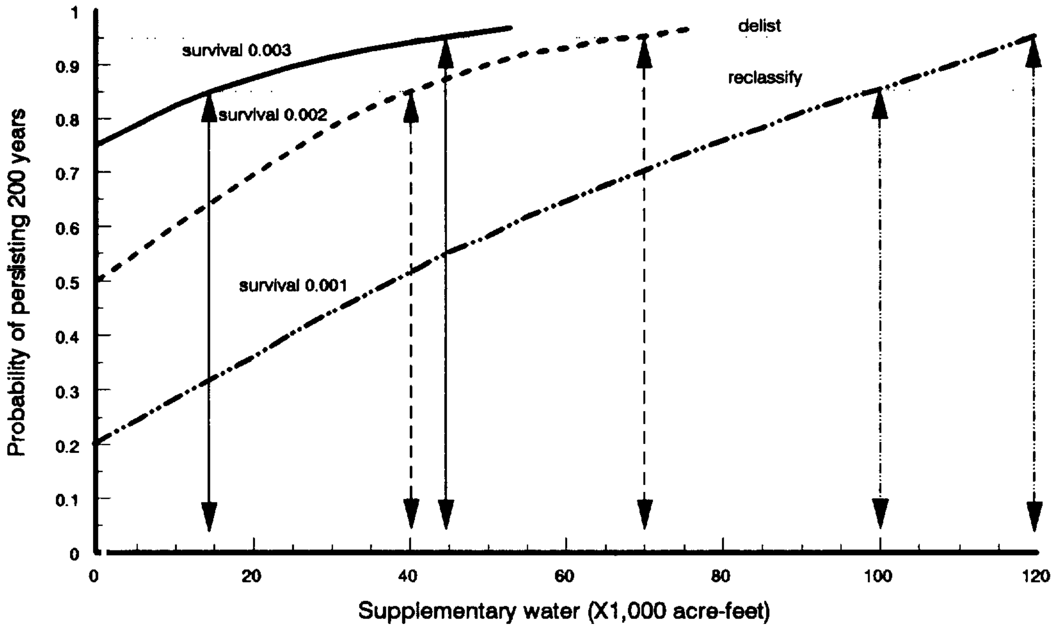

FIGURE C-1. Cui-ui persistence probability associated with different amounts of supplemental water in the lower Truckee River (acquired immediately) and larvae survival rates.

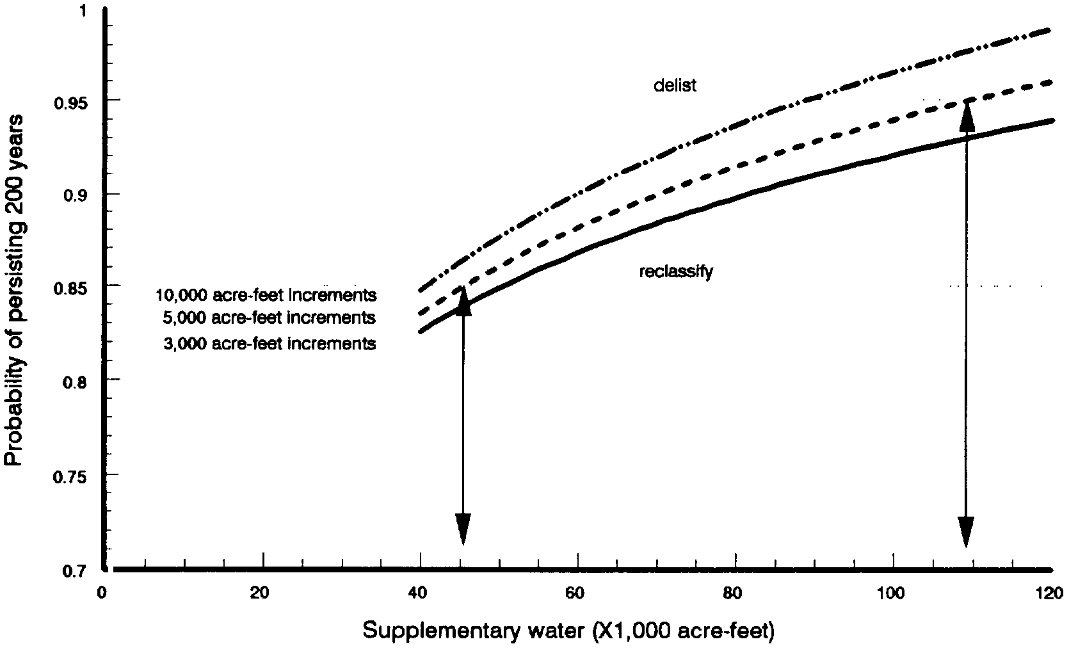

FIGURE C-2. Cui-ui persistence probability associated with different annual rates of acquiring supplemental water for the lower Truckee River. This assumes that larvae survival rate is 0.002 and acquisition activities begin in 1994.

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