In Arizona, the range of this species is approximately bounded by the Gila River on the north, urban and agricultural development along the Colorado River on the west, and by bajadas and relatively coarse, alluvial, granitic soils immediately west of the Gila and Butler mountains to the east (Rorabaugh et al. 1987, Hodges 1995). Hodges (1995) estimated 550 km^2 (212 mi^2) of suitable habitat remains in Arizona. In this area, most records for the species are from areas of fine, often windblown, silica sand dominated by sparse stands of white bursage (*Ambrosia dumosa*), creosote (*Larrea tridentata*), and big galleta grass (*Hilaria rigida*) (Rorabaugh et al. 1987, Hodges 1995). The species shows a preference for and may be more abundant on sandy substrates as compared to desert pavement or hardpan surfaces (Muth and Fisher 1992, Rorabaugh et al. 1987), and in Arizona is most often found in areas of silica sand, rather than granitic sands and gravels (Hodges 1995).

The diet of the flat-tailed horned lizard consists primarily of ants, particularly from May to July (Parker and Pianka 1975; Turner and Medica 1982; Mark Fisher, Deep Canyon Desert Research Center, Palm Desert, California, pers. comm. 1992). The lizards are active primarily from mid-February to mid-November (Muth and Fisher 1992, Mayhew 1965). Some evidence indicates a late summer and fall period of dormancy in adults (Howard 1974), while juveniles may be active on warm days throughout the winter (Muth and Fisher 1992). Mean home range of telemetered flat-tailed horned lizards in Imperial County, California, was 4.7 acres (Muth and Fisher 1992). Females produce one or two clutches of eggs that hatch in July and August-September (Turner and Medica 1982, Muth and Fisher 1992, Howard 1974). Flat-tailed horned lizards construct burrows in which they hibernate in winter and escape high temperatures in summer (Muth and Fisher 1992, Rorabaugh 1994). Mean cloacal temperature of active flat-tailed horned lizards in California was 37.7^{o} C (Mayhew 1965). Maximum and minimum voluntary body temperatures are 41.0^{o} and 29.3^{o} C, respectively (Brattstrom 1965). Individuals become stressed when cloacal temperatures reach 45^{o} C or more (Mayhew 1965). Further information on the range, biology, and ecology of the flat-tailed horned lizard can be found in Muth and Fisher (1992), Turner et al. (1980), Turner and Medica (1982), Rorabaugh et al. (1987), Rorabaugh (1994), Norris (1949), Hodges (1995), and Mayhew (1965).

ENVIRONMENTAL BASELINE

The environmental baseline includes past and present impacts of all Federal, State, and private actions in the action area, the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early section 7 consultation, and the impact of State and private actions which are contemporaneous with the consultation process. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform to assess the effects of the action now under consultation.

In most formal section 7 consultations, the proposed action has not been initiated. This situation is different. Reclamation's operations and maintenance of its facilities in the action area represent ongoing projects, some of which have been in place for more than 50 years. The combined actions of numerous parties in addition to Reclamation over the last century and a half have already created a controlled, altered and much used river that bears only a limited resemblance to pre-development conditions. In order to completely assess the effects of the continuation of Reclamation's activities, it is necessary to examine the history of development along the Colorado River and the changes to aquatic, wetland and riparian habitats that resulted.

<u>Listed species/critical habitat:</u>

Bonytail Chub and Razorback Sucker

Historic Habitat Conditions on the Colorado River

Although the Spanish explorers and missionaries entered the region in the 1600-1700's, the history of significant human-induced change on the Colorado River can be said to have begun in 1823, the year the first fur trappers began to move into what would become Arizona. By 1824-26, trappers looking for beaver had reached the confluence of the Gila and Colorado Rivers (Davis 1973), and the serious exploitation of the river valleys had begun. Using information from the journals of early explorers and examining observable geography of the river, an approximation of the physical and habitat characteristics of the pre-development Colorado River can be made. While there are many historic sources of information describing the character of the project area, most do not provide details on physical conditions nor on the flora and fauna that would enable a mile-by-mile or year-by-year specific analysis of the river. The following discussions are based on anecdotal information from these historic sources (Davis 1973, Ohmart 1979), and on background information drawn from hydrology and fluvial geomorphology, to describe the historical system that likely existed (Simons et al. 1975). This discussion is not intended to be an exhaustive analysis of the formation and morphology of the Colorado River, but is intended as a starting point to assess the effects of river development activities.

For purposes of this discussion, the Colorado River in the action area was divided into two sections based on the different geographic features of each. The upper portion begins at Pierce Ferry and extends to the mouth of the Black Canyon. The lower portion begins at the mouth of the Black Canyon and extends to the SIB. The landforms and history of development in the two areas differ enough that the division is a logical one.

<u>Upper portion of the project area</u>

The upper portion extends approximately 90 miles south from Pierce Ferry to the mouth of the

Black Canyon. The escarpment that marked the lower end of the Grand Canyon, the Grand Wash Cliffs, are immediately upstream of Pierce Ferry, and changes in gradient and landform became apparent downstream from this point. Through the Grand Canyon, the river dropped at approximately eight feet per mile. Through the upper section of the project area, as the river began to level out, the river drop reduced to about three feet per mile (USBR 1946). The Colorado River cut through an area of alternating valley fills and mountains in this reach. Narrow canyons resulted from the mountains reaching the river channel. Rapids were largely restricted to these narrow canyon reaches. The open benches of the valleys provided a wider floodplain with some seasonally inundated bottomlands. Only one significant tributary, the Virgin River, entered the Colorado River in this portion of the action area. There were numerous desert washes that flowed during storm events and these had debris fans at their mouths. Probably the largest of these washes was Las Vegas Wash.

Physical characteristics of the narrow channel and wider floodplain areas were shaped by flow patterns. Water flowing out of the narrow Grand Canyon was contained in a wider and less steep channel through the valley fills and tributary basins of the upper portion of the action area. At high flows, water covered a wider area and was deeper and faster in the main channel area with shallower, quiet waters on the margins of the floodplain. Erosion and deposition of silts, sands and gravels by the flows affected bottomland topography and created or destroyed shoreline or mid-channel bars, islands, and other features. At lower flows, the river was flanked by these beaches and bars, existing in low-flow channels. It is possible that some meandering may have occurred throughout these reaches, especially in areas of available bottomlands or floodplain. If the sediment loads were high enough that deposition was actively occurring, sediment from easily eroded banks entered the system, and if the gradient was high enough, braided stream condition may have occurred. Braided conditions were likely limited by the availability of a wide channel area with floodplains throughout the reach. This availability also could have limited formation of backwaters and marshes, although there likely were side channels and eddies to function as quiet water habitats.

The narrow canyons separating the valley reaches were steeper and narrower, with rapids and higher water velocities. High flows presumably affected beach and channel bar topography in these reaches. Low flows were likely conveyed in the low flow channels. Depending upon the type of landform at the flood line through the reach (for example, a sheer cliff or talus slope), there could have been beaches or bars along the shorelines and possibly mid-channel bars if the river channel was wide enough. If the gradient and flow were sufficient, rapids could be found here also. Quiet water habitats were found in eddies and behind debris fans or associated with bars or deep pools.

There were two primary zones of riparian vegetation along the channels and floodplains. As is true today, substrates of silt, sand, gravel, cobble and rock, and stabilized talus were available for plants. The two zones can be briefly described as that above the normal flood line and that below the normal flood line. Plants characteristic above the flood line zone included catclaw acacia (*Acacia greggii*), western honey mesquite (*Prosopis glandulosa* var. *torreyana*), and netleaf hackberry (*Celtis reticulata*) (Turner and Karpiscak 1980). In the occasionally inundated area immediately below the normal flood line, these same plants might become established if floods did not reach them, but permanent colonization was not likely. The above the flood line zone was well represented in the canyon areas of the upper portion where there were talus slopes or other areas above the normal flood line; and its vegetation community would likely be found on the benches above the active floodplain.

Plants characteristic of the below flood line zone include Fremont cottonwood (*Populus fremontii*), several species of willows (*Salix* spp.), arrowweed (*Pluchea sericea*) and, where conditions allowed, cattail and reed (*Phragmites communis*) (Turner and Karpiscak 1980). The plant communities in this zone were subject to frequent inundation and washout during high flows. However, reestablishment was generally rapid where suitable substrates existed (Rosenberg et al. 1991).

Flows over the course of the year varied tremendously (USBR 1946, Carlson and Muth 1989). Highest flows were in April to June, coinciding with the spring runoff from the Upper Basin tributaries. Rising flows during this period flooded the bottom lands along the river channel, depositing sediments in shall water areas. The spring-summer flows passed through the narrow canyons at high velocities and significantly higher stages than flows at other times of the year. Flows decreased over the summer, with some higher flows possible due to local rainfall events in the watershed areas of the Grand Canyon tributaries or the Virgin River. Lowest flows were seen from October to March, at which time the river generally remained within low flow channels. Winter rainfall events resulted in shorter duration higher flows that could be quite significant. While the pattern of flows remained the same each year, the actual flow levels would vary based on rainfall, snowpack, and other factors. Daily variations were observed and could be traced to local rainfall events but were generally not large or consistent in occurrence (Turner and Karpiscak 1980).

Sediment loads in the river were highest during the May-June and August-September periods, with the latter period having the higher levels (Turner and Karpiscak 1980). Sediment was deposited in areas of lower velocity, building banks, beaches and bars; but sediment was removed from areas subject to higher velocities or erosive forces. Higher flow levels or velocities would erode some deposition areas and create or augment others. The inflow into this part of the river provided a source of new sediments coming from upstream sources. The addition of these materials to the system allowed for the maintenance of beaches, banks and bars as sediments were carried downstream out of the area.

The combinations of flows and geology in this portion of the river created a mosaic of habitat options for fish. In the main channel, the interaction of flows and bed composition created a variety of stream bed configurations. Significant differences in depth and current velocity over short distances could occur (Simons et al. 1975, Leopold 1969) and could change with flow rate. Ripples, dunes, antidunes and chutes and pools were features of the river bed that resulted from the interaction of flow and riverbed composition (Simons et al. 1975). Although the flow velocity could be quite high in the main channel, the stream bed configurations allowed for some areas with a reduced current velocity. Examples of these areas would be those immediately downstream of underwater dunes. Creation of islands or mid channel bars also could reduce velocities and create a lower velocity retreat in the side channel, chute, eddy, backwater or slough areas located between the island and the shore. There is considerable variation in current velocity depending upon where along a bar or island the measurement is taken. The riffle-pool sequence provided for deep pools separated by shallow crossings, or alternate bars with the pools located against the concave bank of bends (Simons et al. 1975). Eddies also formed at the detritus fans of the washes and in the lower reaches of tributaries. The watered tributaries also provided some different habitats, being generally smaller and carrying lower flows than the main river. In wider areas, high flows caused inundation of floodplain and bottomland areas, creating slower moving, shallow, water areas that, while ephemeral, were extremely important habitats for refuge and food for native fish species.

Although the load of sediment in the river varied, and thus to an extent light transmission varied, there was little in the way of planktonic plants or animals or rooted aquatic vegetation in the main channel. The shifting instability of the substrate further precluded rooted plants, and was not conducive to aquatic invertebrates. Chironomids and oliochaetes likely were the dominant invertebrates (Carlson and Muth 1989). The slower water areas, where the river was clearer and silts formed the substrate, likely supported a more varied invertebrate fauna, possibly with planktonic plants and animals being more numerous (as they are today in similar habitats) (Minckley 1979, Ohmart et al. 1988). Depending upon age and structure of the area, rooted plants might have been present, but there is little information to suggest this was common in the upper portion of the river.

The riparian areas along the river provided much of the organic input needed to support the aquatic resources. This contribution came in two forms, the first from invertebrate production that entered the river as drift, and the second from leaves and woody material that decomposed in the shallow waters and provided food and substrate for invertebrates and algae. Additional woody or other plant debris was brought into the mainstem from the tributary washes or the Virgin River. Backwaters and marshes or slow-moving areas concentrated organic materials, but there was no barrier to downstream transport of organic compounds.

Given the unstable nature of the river channel throughout this upper portion of the project area, substantial areas of riparian vegetation would not, at first, be expected to occur. However, this was not the case. A large population of beavers was found in the early 1800's in this area along the river (Davis 1973). It is known that in 1853, trees cut by beavers ended up as driftwood used by the Aubry party to construct rafts for crossing the Colorado River near the site of Hoover Dam.

In his diary, Aubry noted that by next morning, the rafts had been destroyed by the beavers chewing on the lashings. Both cottonwood and willow then, as now, grew rapidly and were adapted to periodic inundation and elimination through erosion. The constantly renewed stands were sufficient to support sizeable beaver populations. Beaver did not have to cut all the trees they needed, because erosion of upstream riparian areas brought trees to them. The width and flows of the Colorado River in this area likely precluded development of many beaver dams, although side channels and sloughs might have been temporarily blocked off by beaver dams. These beaver-created backwaters augmented the uncommon backwaters and marshes created by the river itself.

Water quality was as important a component of the available habitat as the physical structure. Sediment (as already mentioned) was a major component of both habitat and physical structure. Water temperatures varied both daily and seasonally during any year, with wide fluctuations possible, especially in shallow waters (Minckley 1979, Carlson and Muth 1989). Total dissolved solids concentrations and components were also variable; evaporation losses may have concentrated these ions in some backwater shallows possibly causing some overall downstream increases. Oxygen depletion was not likely a problem in this upper portion of the project area due to the relative lack of deep, isolated backwaters with large amounts of organic material and the prevalence of flowing water conditions that provided for oxygenation of the water.

Lower portion of the project area

The lower portion of the project area is approximately 300 miles long. Unlike the upper portion of the project area, the lower portion was moderately well recorded by explorers, scientists and settlers prior to and during early development. Downstream of Black Canyon, the Colorado River flowed through broad alluvial valleys created by river action (Rosenberg et al. 1991). The only constraints on the river's movement were periodic bedrock areas; these bedrock areas created minor canyons, separating the basins (Hely 1969). Three such areas were the area above the present site of Imperial Dam, the canyon where Parker Dam would be built, and Topock Gorge. These canyon areas constrained river flow and in form and function resembled canyons found further upriver. At certain flows, currents could be quite high with whitewater rapids. Two major tributaries, the Bill Williams and the Gila Rivers, enter the lower portion of this part of the project area. In addition, there were many desert washes and associated debris fans.

The alluvial materials of the valley floors allowed the Colorado River to meander through the floodplain and bottomlands. The cycle of erosion and deposition created, and eventually destroyed, a series of terraces along the banks of the river (Grinnell 1914). These terraces were prone to varying degrees of inundation, depending upon the runoff level of the particular year and height of terraces above the river channel. Deposition of sediments in the channel itself created islands and bars, and the river could take on a braided configuration. Bars and islands were similar in form and function to the same forms upstream. The erodibility of the materials in the terraces and the force of the river flows created cut banks several feet high in some areas (Ohmart 1979). Flow dynamics led to the creation of oxbow lakes when meanders were cut off from the main channel. These lakes were not permanent, and their life span depended upon the availability of water which might reachonfigurations. Deeper backwater lakes with good water connections to the river or the river water table yet outside the area of frequent inundation might have lasted longer. In the 1800's, some of these larger backwaters were permanent enough features that they had been named by settlers (Ohmart et al. 1975). Most backwater lakes were not large, and changed rather quickly to marshes, then to terraces or were completely filled in by single flood events. While in a geologic sense, these backwater lakes were transitory, their life spans could be 50 to 70 years (Ohmart et al. 1975). Such life spans were not inconsequential and allowed for the development of habitat features to support fish and other aquatic life. The large numbers of beaver found along the river, with their small dams, also created backwaters. These dams would likely be washed out by the yearly high water events. Another type of backwater was even more ephemeral and may have been much more common along the river. The lowest terraces of the river were flooded during late spring and early summer. For native fish, these flooded bottomlands provided feeding and refuge areas from the high flows in the main channel. The presence and extent of these temporary lakes (sloughs) were noted by explorers and Native Americans, who fished these areas with nets and traps (Ohmart 1979).

The presence of abundant riparian vegetation in many places along the river was reported by many diarists. Riparian tree and shrub communities were established on the terraces, bars and beaches along the river and could extend several miles back from the active channel. The specific type of vegetation present depended upon how high above the normal flood line the terrace or beach was located (Grinnell 1914, Rosenberg et al. 1991). The highest terraces if not inundated, supported thickets of western honey mesquite with an understory of various shrubs. On the lower terraces, arrowweed was found in drier locations, with willows dominating the inundated areas.

Many historical accounts describe the presence of marsh vegetation and give the impression that considerable marshland existed. This may have been true in some specific areas, such as at the confluence with the Gila River and at times with the Bill Williams River. Marsh development along the rest of the river in the lower portion of the project area was limited. Shallow marshes would fill in quickly during floods, and were susceptible to drying out as the river shifted away from them. Several accounts mention the presence of marsh vegetation (reeds or "tules") away from the tributary confluences but not with any sense of real abundance (Davis 1973, Ohmart 1979). Marshes could develop at the lowest terrace where flood waters persisted over long periods or where the water table was at the surface. Marsh vegetation such as cattail, bulrushes (*Scirpus* spp.) and reed were found in these areas. Reeds were so abundant in some areas that they could in some instances stabilize the sediments along the banks of the active channel (Ohmart 1979).

As discussed earlier, cottonwoods and willows are fast growing species of trees adapted to the frequently flooded bottomlands (Rosenberg et al. 1991). These communities were subject to erosion of substrate, prolonged inundation that could kill trees, or relocations of the channel that isolated these vegetative communities from the water needed for proper growth and maintenance. Such communities were "short-lived" because of these factors. While some areas, especially those in the canyons or other river reaches lacking significant floodplain, did not support extensive riparian vegetation, many other places did. Early diarists noted the presence of everything at various times and places along the river from a scarcity of any trees at all, to dense willow and cottonwood thickets, to gallery forests (Davis 1973, Ohmart 1979). There was sufficient wood in the cottonwood, willow and mesquite areas to support steamboats, ranching, mining, domestic use and other activities along the river for many years. Also noted was the rapid regeneration of the cottonwood-willow forest after cutting or other disturbance (Davis 1973, Grinnell 1914, Ohmart 1979).

Flow patterns through the lower portion of the project area were not significantly different from those in the upper portion, although the times of peak flows might be shifted to slightly later in the year. Highest flows were in the late spring to early summer, with decreasing flows from summer to spring. Rainfall events on the Bill Williams watershed might provide a brief inflow peak during the summer or winter rainy seasons. Flows from the Gila River were substantial and could be a significant part of the flow to the Sea of Cortes that maintained the marsh and riparian habitats below the SIB. Both drought and high flood years could be devastating to the backwater, marsh and riparian communities along the river.

Especially during the high flow months (late spring to early summer), when significant erosion of the terraces was taking place, the sediment loads carried by the river were extremely high. This sediment built bars and islands in the channel and in the inundation areas, and raised the heights of the terraces after each event. It also filled in marshes and backwaters during flood events. The amount of sediment coming into the system each year, combined with the relocation of existing sediments, caused aggradation in some areas, while active erosion occurred in others (Minckley 1979). During periods of lower flows and in areas of quiet water, the water became significantly clearer.

As in the upper portion of the project area, the riparian vegetation communities provided a significant amount of organic material to support the system. The river channel itself, with its shifting sand/silt bottom supported a limited invertebrate fauna. Plankton growth in the more turbid main channel was depressed by turbidity. Invertebrate drift in the main channel was largely dependent upon the terrestrial insects from the riparian communities. In backwater areas, the deposited sediment formed a soft substion and clearer water, and provided increased invertebrate, plankton and algal populations. Aquatic plants could also root and grow in these areas. The inundated bottom lands provided an important source of organic material to the system. As with the upper portion of the project area, there were no barriers to downstream transport of organic compounds.

Water quality was an important issue in aquatic habitats in the lower portion of the project area.

Salinities and total dissolved solids in the water were increased by high evaporation rates. Isolated waters could quickly become uninhabitable for most aquatic organisms. Several diarists mentioned seeing white salts or other material on the ground surface of some dry banks or sloughs. Air temperatures were very high in the summer, and water temperatures, especially in shallow areas with little inflow, could reach 30° C (Carlson and Muth 1989). Oxygen depletion in backwaters and marshes was very possible during the hot summer months.

There were a variety of habitats available to fish in the lower portion of the project area. Main channel pools and runs, side channels, eddies, oxbows, bars and islands were located throughout the reach. There were limited amounts of canyon type habitats, but a greater abundance of sloughs, lagoons, other inundation areas and backwaters than in the upper portion of the project area. Even more so than the upper portion, habitats in this lower portion were very physiologically demanding. Tolerance for high temperatures, high salinities, and low oxygen was needed to get through the difficult periods. High flow events reshaped the floodplain and available habitats in ways that canyon bound reaches did not usually experience.

Native aquatic species

Of the ten native fish species in the Colorado River in the area of interest, only two are involved in this consultation. The bonytail chub and razorback sucker were common to abundant in the Colorado River prior to 1823, and some information documenting their decline in the years leading up to the present day is available. There are two areas of interest; the first is related to abundance, the second to habitat use and availability.

Early estimates of fish abundance are very unspecific. The diarist period spans several decades and normal population cycles and seasonal abundance in a particular area combined with drought and flood effects compound errors in any estimates. Variously, diarists described "few" or "many" fish of several types (Davis 1973, Ohmart 1979) present in a variety of locations along the river. In some cases, we can determine which native fish were discussed. For example, when diarists referred to "salmon," they probably meant Colorado squawfish. References to suckers could have been razorback suckers or flannelmouth suckers (*Catostomus latipinnis*). Similarly, "trout" could have been bonytail or roundtail chubs or something else.

Fish were common in the diet of Colorado River tribes (Miller 1955, Davis 1973, Ohmart 1979). Capture methods recorded in historic accounts included traps, nets, and hook and line using cactus spine hooks (Palmer 1878). In the 1700's, catch rates for setting nets and traps in lagoons near what is now Yuma was estimated at 37 pounds of fish an hour (Eixarch 1977 in Ohmart 1979). That was at the start of the lagoon fishing season in February. Records up to 1911 reveal Colorado squawfish, razorback suckers and bonytail chubs ran up into irrigation canals near Yuma in such numbers that they clogged the outlets and had to be pitchforked out and used for fertilizer (Miller 1961, Minckley 1965). Observations of fish in the highly turbid waters of the mainstem were unlikely, and attempts to capture fish under these conditions had little chance of success. In 1914, Grinnell captured razorback suckers and bonytail chub in a backwater in the spring and observed Colorado squawfish moving upstream but stopped below Laguna Dam in April. Not many people recorded abundance of fish in the river during the pre-development and early development periods. Fish might have been more or less abundant than the records show and may have been only easily noticeable at certain times and places. The general conclusion reached by various researchers is that the razorback sucker and Colorado squawfish were abundant in the pre-development period and the bonytail chub was at least common (Dill 1944, Miller 1961, Minckley 1979).

The available information is not sufficient to determine how these native fish species might have been seasonally distributed in the available habitats of the action area. More recent information is available from the Upper Basin on the habitat use of these fish. Although conditions are not entirely the same between the two Basins, it is reasonable to use the life history information summarized elsewhere in this document and provided in other sources to gain an understanding of how these native fish seasonally used the habitats available to them in the pre-development baseline of the LCR. Minckley (1979) provided a discussion of habitat use in his work that is herein incorporated in summary.

The bonytail chub became rare long before scientists were able to fully assess its habitat requirements. In the Upper Basin, it is assumed to be a mainstem species, utilizing pools and eddies (Minckley 1973, Vanicek 1967) rather than fast flowing areas. The physical adaptations seen in body form are thought to address the problems of moving around in a fast flowing system in order to reach slower water areas and to deal with floods (Minckley 1973). These types of slow-water habitats were widely available through the project area. Grinnell (1914) captured bonytail chubs with razorback suckers in a backwater in early spring; therefore these habitats were used to some extent by native fish. The ability of bonytail chubs to successfully survive in small hatchery ponds and large reservoirs may be related to use of and adaptations to backwaters in the wild. We know very little about spawning behavior or spawning habitat in rivers, although from the reservoir data (Jonez and Sumner 1954, Wagner 1955) it is surmised that gravel and similar hard substrates were used. Spawning in bonytail chub is in late spring to early summer, later than that for the razorback sucker. There is no information on any type of bonytail chub spawning migrations, although they were taken in irrigation canals. Habitat needs for juvenile fish are not known. Young bonytail chubs feed on invertebrates taken from the substrate. Sub-adults and adults also utilize floating food items, particularly terrestrial insects. The extensive riparian areas along the Colorado River would have provided a source of insects to the river. Water quality issues in the backwaters and sloughs presumably affected seasonal use of these habitats.

Based on present information from the Upper Basin, habitats for the razorback sucker are generally slower moving portions of the mainstem, and, when available, inundated bottomlands and sloughs. Spawning takes place in the spring, starting (in Lake Mohave) in January or February and running until April, with staging beginning as early as November (Minckley et al. 1991). There are records suggesting that spawning migrations occurred (Minckley et al. 1991). Some fish may not have migrated at all but used the nearest gravel fan available. These migrations may have been the cause for entrainment in irrigation canals. Spawning areas required a harder substrate than the shifting sand of the river bed. Gravel bars and debris fans at the mouths of desert washes provided the necessary features and these were not uncommon along the river (Loudermilk 1985). In the Upper Basin, spawning behaviors have been observed in mainstem reaches with flat water, backwaters and creek mouths usually with gravel to cobble substrates. Similar habitats were available in the project area. The spawning period took place just before and at the start of spring floods. The newly inundated bottomlands would then be available for the young of the year fish as feeding and refuge areas. Young of the year razorback suckers were found not only in inundated bottomlands but also in backwaters and tributary mouths (Smith 1959 and Taba et al. 1965 *In* Minckley et al. 1991). Young razorback suckers apparently moved downstream after hatching (Minckley et al. 1991) but the optimal distance between spawning areas and rearing areas is not known. The lower portion of the project area was well supplied with the inundated bottomlands n other places of quiet water (Minckley et al. 1991). Inundated bottomlands were used until water levels dropped enough to dry them up. In the absence of backwater type habitats, razorback suckers used deep pools, areas behind obstructions, slow-moving side channels, runs, and the areas of lower velocity behind underwater dunes (Minckley et al. 1991). All of these habitat types were available in the project area. Although razorback suckers do not generally reside in fast-water canyon areas, these areas did not necessarily constitute a barrier to passage, and individuals ranged through the entire reach. Research from the Upper Basin indicates that some, but not all, razorback suckers have significant non-spawning movements.

Water quality in backwaters and inundated bottomlands may have been a problem for young and adult razorback suckers using these areas. Movement to the main channel quiet water habitats may have occurred as conditions deteriorated. Grinnell noted numerous carp (*Cyprinus carpio*) and catfish (*Ictalurus punctatus*) in clear water lagoons and sloughs but did not mention observing any native fish there. However, both razorback and bonytail were captured in a backwater where there were both carp and catfish (Grinnell 1914). Both of these non-natives are potential predators on native fish.

Human Uses of the Colorado River

Early uses: pre-1823

Early uses of the Colorado River in the action area had effects more on the local than regional scale. Clearing and use of inundated bottomlands for subsistence agriculture by Native American peoples did reduce riparian vegetation in localized areas. Use of cottonwood, willow and mesquite for domestic purposes also reduced the amount of riparian vegetation on a local scale. Maintaining agricultural fields prevented the regrowth of riparian vegetation, but where possible, both cottonwood and willow regenerated very rapidly along the river. The mesquite portion of the riparian forests, although slow growing, was an important source of food for the Native American people. It is not likely that activities they undertook significantly reduced the acreage of this vegetation community.

Effects to the river channel from Native American activities were limited. There were no significant diversions made from the river and floodwaters provided much of the irrigation needed. Protective stands of riparian vegetation were removed for agricultural terracing or other uses and thus were susceptible to erosion during high flows; but the amount of erosion is difficult to estimate. No levees or bank stabilization or training structures were in place. River functions were controlled by natural forces. There were no barriers to fish movement through the Colorado River, up the Gila River or down to the Colorado River delta except those resulting from natural river dynamics.

During the period of Spanish exploration and mission development, the LCR was used as a travel corridor. Cattle and burros were introduced to the region sometime in this period and likely grazed along the river, affecting riparian and emergent aquatic vegetation.

Populations of the razorback sucker, bonytail chub and Colorado squawfish were exploited for food by the Native Americans. These fish were actively sought and may have been seasonally more susceptible to capture (Ohmart 1979). One diarist in 1776 noted that catches of 37 and more pounds of fish per hour were made using traps and nets in lagoons (Ohmart 1979). The sizes of the fish populations varied due to environmental factors, with no evidence overharvesting. During this period, no non-native fish or invertebrate species were introduced into the LCR.

Initial development: 1823-1909

Early activities by the trappers and explorers had limited effects on the river environment. Removal of beavers may have had effects on the numbers of small backwaters, but the extent of this is not known, and beaver populations rebounded after trapping declined in the 1830's. Permanent settlements emerged adjacent to military posts, ferry points, mines, and farming/ranching areas.

The need for ferry service across the Colorado River to allow passage to California, the development of mines near the river, and the need for a way to deliver supplies to military posts and other settlements along the river and the interior of Arizona led to the development of navigation companies. Steamboats would collect cargo from sailing ships or steamships at the ports down in the delta and transport the materials up the Colorado River as far as Callville (submerged by Lake Mead after 1935) (Leavitt 1943). At the height of the period, about 35 trips per year upriver from Yuma were made by the steamboats (Leavitt 1943).

By far the major effect of the river steamboats was the harvest of cottonwood, willow and mesquite for fuel. Fuel stations were set up along the river and most of the suitable trees were used up by 1877 when railroads largely replaced steamboats for carrying cargo. Regeneration of the forests occurred naturally, although we do not know if the extent of cutting and the type of trees taken had any significant effect on the mosaic of riparian community age structure along the river as a whole. These uses might have set succession back over a large area and possibly affected erosion of lower terraces.

Docking facilities likely had little to no effect on the river itself and such structures likely had to be replaced following high flows. The river steamboats had a very shallow draft and could operate in a few feet of water. When they did go aground, there was local disturbance to the immediate areas during efforts to refloat the boats. These effects were transitory. Between 1869 and 1903, at least six surveys evaluated the potential for channel improvements to improve navigability. Only two, one in 1884 for channel work between Mohave and El Dorado Canyon, and another in 1892 for a levee along the Gila River, actually determined channel improvement projects were feasible (Leavitt 1943). The channel improvements in 1884 likely had little to no lasting effect to the river. However, the construction of the Gila River levee was tied to a larger pattern of effects from settlements along the banks of the river.

In 1877, Thomas Blythe made the first application for diversion of water from the LCR to the Palo Verde Valley in California. Other diversions for irrigation in the Yuma and Gila Valleys in Arizona and the Palo Verde and Imperial Valleys in California followed. Some of this new agricultural land was located along the terraces of the river and replaced the mesquite and cottonwood-willow forests. However, significant amounts of agricultural development were in fertile valleys away from the river itself.

The beginnings of significant agricultural development along the river affected the extent and location of the riparian forests and their ability to regenerate. Riverside lands converted to agriculture were lost to riparian vegetation as well as to potential marshes and backwaters. There might have been changes to local erosion and deposition patterns due to the cleared terraces, but the extent and meaning of these are not known. Construction of diversion structures did not create large, permanent barriers to movements of fish or water, and did not result in reservoir formation. Their barrier effect was greatest during periods of drought or seasonal low water. During high flows, these diversion barriers would often be destroyed.

Efforts to protect agricultural fields from flooding resulted in the first of the levees along the river. The first levees were placed near Yuma in 1902 (COE 1982). With the strength of the high flows of the river, the success of these structures was dubious at best.

The amount of total Colorado River flow diverted during this period increased as the irrigated acreage increased. The actual diversion depended upon the river flow at the time. During high flows, the percent diverted may not have been significant. Diversions during moderate periods may have been locally more significant, but the degree of effects to overall aquatic habitats is not known. At low flows, if the diversion was capable of taking a majority of the water, it could partially dewater the downstream segment of the river. The extent of this dewatering may not have been widespread.

Perhaps the most significant effect of human activities and development in the watershed of the LCR between 1823 and 1909 was the sequence of events that led to the inadvertent diversion of the Colorado River to the Salton Sink in November 1905. Overflows of the river to the sink were nords exist for such flows in 1840, 1842, 1852, 1859, 1862, 1867, and 1891 (Ohmart 1979). The 1905 overflow was different, and resulted from a series of natural causes overlying significant changes to the watershed, a discussion of which follows.

The Gila River was the largest tributary to the Colorado River in the project area. Reports from the early diarists indicated that the river was perennial with large marsh and riparian areas associated with it (Davis 1973, Ohmart 1979, Rea 1983). By the middle of the 1800's, the number of livestock grazing on the Gila River watershed began to increase dramatically. The drought cycle that began in the 1860's did not reverse that trend, and overgrazing of the range became more and more significant. By the time of the drought of 1891-1893 (Hastings and Turner 1965), adverse effects to both upland and riparian vegetation, loss of surface flow and the initiation of arroyo cutting had occurred along at least the middle reaches of the Gila River. By the end of the 1800's, the channel and riparian floodplain had been adversely affected to the extent that flood events were more erosive and moved faster through the system. In November, 1905, a very large winter rain-caused flood event went down the Gila River and joined the Colorado River's similarly high flow. A few miles below the confluence, the combined rivers broke through a cut and flowed west down the Alamo Canal, north along the Alamo river, and into the Salton Sink. Unlike previous overflows, the entire capacity of the Colorado River was diverted. This situation continued until November 1906 when the river was diverted back into its channel. About that same time, another winter rain flood came down the Gila River and may have contributed to the failure of the repairs and the flow returned to the Salton Sea. The Colorado River was not finally returned to its channel again until February 1907.

At the end of this period of development, there were some changes to the river in terms of age structure and extent of the riparian forests, in both the cottonwood-willow and mesquite. There may have been some losses to backwaters and marshes from conversion of those lands to agriculture, but use of the very low lying lands for agriculture was not practicable given the periodic flooding. There were some changes in flows due to diversions, and these had some effects that are difficult to quantify and may not have been regionally significant. There were no man-made barriers to movement within the system. The Gila River had been significantly affected by watershed conditions and dry cycles and may have lost much of its native fish value, and use of the Gila Basin by fish in the Colorado may have been compromised. The inadvertent diversion of the entire flow of the Colorado and Gila Rivers to the Salton Sea was both a natural and human development related event, and it created a large lake, something that had not been recently present in the system. That inadvertent diversion also had some effects on physical habitats of the Colorado River below the diversion and to the delta and the biotic resources there. These effects would be related to the reduction in flows through the areas and changes in salinity patterns where there was a tidal effect from the Sea of Cortez.

In addition to looking at the physical effects to the river, the presence of carp after 1885 and channel catfish after 1892 complicate the analysis. The information available on the status and distribution of non-native fish populations in the late 1800's is almost entirely anecdotal.

The development of the floodplain terraces for agriculture eliminated their value as riparian, marsh and backwater areas for fish habitats. With the placement of levees, floodwaters could no longer reach these important habitats, thus even seasonally inundated areas could be lost. Changes in erosion patterns due to lack of vegetative cover and the placement of levees may have had effects on erosion and deposition on downstream habitats. The placement of diversions may have been a temporary barrier to movement, but it is likely that most significant migrations took place during high water periods when functions of such barriers were inconsequential. The effect of actual water diversions varied greatly, largely dependent upon local water conditions. Where water levels were already low, removal of some portion of the water could result in a fish kill if the habitat dried up or water quality declined due to evaporation. At some point, the loss of fish could have been significant. Losses to young fish, perhaps even whole cohorts, could occur. The removal of water for irrigation would be of special concern during drought years when water levels were already low.

Overall, water quality in general did not change much. There may have been some increase in total dissolved solids and salinity from increased irrigation returns, but the proportion of these returns was still small. Continued evaporation of water during low water periods and droughts likely had more effect on water quality.

The presence of carp and channel catfish in the Colorado River in the late 1800's is documented, but the extent of their presence and the size of their populations is not fully understood. We do know they were observed in clearer water areas such as backwaters (Grinnell 1914), but their use of the main channel habitats is unknown. Both species use main channel habitats in other rivers, and physical conditions in the Colorado River were not so severe as to preclude this possibility. Drought and low water conditions put stress on these introduced fishes as well as on the native species. Both carp and channel catfish are resilient species, capable of surviving in difficult environments. Whether the largely unmodified habitats of the Colorado River were fully usable by these species is unknown.

At the end of this period, 1823-1909, populations of all three native fish remained abundant or at least common in the Colorado River in the project area despite a fish kill late in the 1800's caused by "alkali" water from the Gila River (Sykes 1937 in Minckley 1979). Significant numbers of razorback suckers and bonytail were recorded in the Salton Sea as well (Miller 1961, Minckley 1983). Despite drought and flood, no noteworthy declines in the populations were observed, although we do not have any information on the age structure of the populations at the end of the period.

Dam construction: 1909-1954

This period marked the first significant regional changes to the LCR from water development activities. By 1913, as additional lands were converted to agriculture, both along the river and in the more remote valleys, irrigated acreage from the Virgin River to the boundary with Mexico totaled 367,000 acres, 53,000 of which were along the river itself. By 1927, 95,000 acres of irrigated land were found along the river. The water supply of the Colorado River was estimated and divided for human uses among the Basin States and Mexico, thus setting the parameters for development (USBR 1946).

In 1909, Laguna Dam was completed and provided a diversion point for water to off-river lands in Arizona and California. Silt was trapped behind the dam and water was backed up for several miles, inundating and drowning riparian vegetation (Grinnell 1914) and creating a large, slack-water habitat in certain seasons. It also acted as a barrier to fish passage at least at some seasons. Grinnell (1914) recorded that Colorado squawfish were staged below the dam in April. Laguna Dam was built strictly as an agricultural diversion and did not create a significant reservoir pool to store water or control the floods of the Colorado River.

The decision to construct Hoover Dam was driven by the need to control the floods that damaged agricultural lands and facilities. The number and extent of levees along the banks of the river were not sufficient to control the river and required expensive maintenance and strengthening (USBR 1946). The closure of Hoover Dam in 1935 definitely had the most significant physical effects to the river in the project area of any action before or since.

Hoover Dam significantly altered the natural hydrograph of the river. High spring and summer flows were captured and stored and the water released later in the year in a controlled manner to provide sufficient water for irrigation needs and to meet other downstream obligations. The early 1930's were drought years, with flows in 1931 and 1933-37 all below average (USBR 1946, Hely 1969). The worst year was 1934 with an annual flow of only 6,573,000 acre-feet (COE 1982), less than half of long term average flows. Flows at Yuma in August, 1934 reached a low of 18 cubic feet per second (Dill 1944), and the adverse effects to aquatic and riparian habitats and fish populations must have been tremendous. After this difficult period, a normal hydrograph was not resumed in the LCR. Starting in 1935, flows below Hoover Dam were controlled by releases made to provide flood control, water storage for irrigation and power needs. Flows to provide for the natural river hydrograph were not considered in the development of Law of the River documents.

These changes to the natural river flows significantly altered the fish habitats available. Without high spring and early summer flows, there was a reduction in inundated bottomlands and flows through backwaters and marshes. Erosion and deposition altered fish migration or spawning cues based on rising water levels and did not follow previous patterns. Access from the lower reaches of the river to the upper reaches and the Grand Canyon was completely prevented by Hoover Dam, severing migration routes and isolating portions of each of the fish populations from each other. Lower water levels may have left some spawning and nursery backwater sites dry. The river's ability to meander and to create or destroy backwaters and marshes was reduced with the reduction in flows. Water availability to higher terraces was minimized. Without the threat of floods, additional terrace lands containing riparian vegetation could be converted to agriculture. Levees could be constructed to more easily contain the water remaining in the river.

The closure of Hoover Dam also created a large reservoir, Lake Mead, on the mainstem of the river, inundating miles of river, riparian areas and the associated habitats with hundreds of feet of water. Reservoir shorelines had little chance to develop riparian areas due to the fluctuations in water levels caused by the operation plans. Lake Mead became a sediment trap. Sediment laden waters coming out of the Grand Canyon slowed when they reached portions of the river affected by reservoir elevation and thus sediments were deposited (Hamblin and Hardy 1969, Turner and Karpiscak 1980). Raising and lowering the reservoir level alternatively eroded and deposited these materials within the reservoir and its area of influence upriver. Such river dynamics created areas where riparian vegetation could develop, but these water fluctuations also could retard the development of these areas.

Because the sediment was trapped in Lake Mead, water released from Hoover Dam was clear. The released waters picked up sediment from the river bed below the dam and carried it downstream, causing a net movement of sediment out of the system because the input of fine material into the system was now limited to desert washes and this input did not balance the output. The clear water and progressively armored substrates extended further down the Black Canyon each year (Moffett 1942). Once Lake Mead filled, the water released was also significantly colder than at the inflow from the Grand Canyon and water temperature varied little over the year, maintaining a range of 22° to 16° C (Moffett 1942, Dill 1944, Allan and Roden 1978).

Before 1940, two additional dams had been added to the river. Parker Dam formed another complete upstream barrier to fish, further inundated riparian vegetation and riverine aquatic habitats, created a large reservoir, regulated water flows, and allowed for a large, and fairly constant diversion from the Colorado River by the Metropolitan Water District of Southern California. Just as with the upper end of Lake Mead, a delta began to form at the head of Lake Havasu as sediment was deposited. A large marsh area was created; yet large areas of riparian vegetation were also destroyed to create Topock Marsh. As Lake Havasu does not fluctuate to the extent Lake Mead does, there were more opportunities for new riparian and marsh habitats to develop in its delta area. Water released from Parker Dam was clear and erosive, carrying deposited sediments upstream, but it was not a cold tailrace. The much smaller Imperial Dam was much less of a barrier, but did trap sediment behind it and significantly increased the size of the ponded area resulting from Laguna Dam. Additional areas of riparian vegetation were lost, but the larger slack-water area provided for backwater-type habitats. Water diversions for California and Arizona were made from Imperial Dam, replacing diversions from Laguna Dam.

The last large dam, Davis Dam, was completed in 1950 and finally closed in 1954. This created Lake Mohave, which drowned out another large valley and miles of riverine habitats and backed up the Black Canyon to the tailrace of Hoover Dam. Davis Dam has a cold tailrace; sediment transport below the dam created another clear, armored channel. Davis Dam was also a complete upstream barrier to fish movement. Between the effects of the three large dams, the Colorado River was no longer a connected series of habitats, reachable from any part of the system. Much of the upper portion of the action area had been converted to reservoirs. The northern area of the lower portion had also been converted to reservoirs, but the southern portion was still riverine, although flows were almost completely controlled by releases from the dams.

During this period, several other projects for irrigation diversion came on line. Headgate Rock Dam was completed in 1946 to provide irrigation water to the Colorado River Indian Tribes. Morelos Dam was completed in 1950 to provide irrigation water to portions of Mexico. The Gila Gravity Main Canal (1939), All-American Canal (1940), Siphon Drop (1941) and Coachella Canal (1948) transported Colorado River water to farms in Arizona and California. These actions contributed to the additional fragmentation of habitats and alteration of flows.

The small reservoir behind Imperial Dam in no way compared in size or depth with Lake Havasu behind Parker Dam, Lake Mohave behind Davis Dam, or the enormous Lake Mead behind Hoover Dam. But Imperial Reservoir was probably the largest "backwater" ever known along the Colorado River. Like the ponded area behind Laguna Dam, water backed up more or less permanently onto the lower terraces, drowning out cottonwoods, willows and some mesquite. Miles of river, bottomlands, terraces and uplands were inundated by Havasu, Mohave, and Mead. New habitat was created, a lake-like reservoir, that had not been present on the mainstem before.

In addition to being sediment traps, the large reservoirs also trapped organic material and dissolved nutrients. Waters released from the dams did not contain the same level of organic material that would provide for primary productivity in the downstream backwaters. The reduction of riparian vegetation inundated by reservoir pools and due to agricultural development further diminished the amount of organic input to the system. Irrigation returns contained higher levels of dissolved solids, organics from fertilizers, pesticide and herbicide residuals and caused an overall reduction in the quality of the water remaining in the river.

As noted previously, at the heads of Lakes Mead and Havasu, the slowing of river flows deposited sediment loads and created depositional deltas. Riparian vegetation could establish on portions of these sites, but its persistence was variable and linked to management of reservoir levels. At what is now Topock Marsh at the head of Lake Havasu, deposition of sediment raised water levels and drowned out mesquite bosques on the upper terraces. Marshes also formed at the confluence of the Colorado River and Bill Williams, now in Lake Havasu. The total area of new marshes may have been larger than that previously known on the river. The creation of these new habitats resulted in the deliberate introduction of additional non-native fish species. Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), and black crappie (*Pomoxis nigromaculatus*) were introduced into Lake Mead to provide a sport fishery. Rainbow trout (*Oncorhynchus mykiss*) were stocked into the tailrace of Hoover Dam for the same purpose. Additional stockings of these species were made in other locations on the river. Red shiners (*Notropis lutrensis*) were also introduced as forage fish. Populations of these new species, along with the carp, channel catfish and other non-native species accidentally introduced, expanded throughout the radically altered system. Dill (1944) reported that the spread and increase in size of non-native fish populations did not occur until after the completion of Hoover Dam.

Populations of native fish underwent significant declines early in this period. Razorback suckers were thought to be holding their own in reservoirs (Miller 1961), and populations in Lake Mead were larger than those in the newly completed Lake Mohave (Wallis 1951). In the Colorado River below the big reservoirs, razorback suckers became rare (Minckley and Deacon 1968, Minckley 1973). Bonytail chub were reported as at least common in the early 1940's in Lake Mead (Moffett 1943 in Wallis 1951), but were much less common in the 1950's (Wallis 1951, Jonez and Sumner 1954). In Lake Mohave, the bonytail was observed more often (Jonez and Sumner 1954, Allan and Roden 1978), but it was still considered rare. There is limited information on the river below the dams, but locals told Dill (1944) that the once common bonytail chub was now rarely seen. The Colorado squawfish populations in the project area were essentially gone by the 1950's. Significant declines were noted in the 1930-1935 period (Miller 1961) with a few caught in the system until the late 1940's (Moffett 1942, Dill 1944, Wallis 1951, Jonez and Sumner 1954, Allan and Roden 1978, USFWS 1980).

Rather than focussing on one or another of the changes (physical or biological) to the river as the definitive cause for the declines in native fish populations, it is more likely that a combination of circumstances was responsible. While specific data on abundance and age structure are lacking, available anecdotal information does not indicate any precipitous increases or decreases in observed native fish population levels prior to the 1930's. From a habitat perspective, there had been some changes due to diversions, development of agricultural lands, and other effects to the watersheds prior to this period. Changes in water quality and the beginnings of nutrient retention in reservoirs could also be a factor. As far as flows in the river, overall, in the period 1897-1930, average discharge of the Colorado River was 15,297 acre-feet at Lees Ferry (USBR 1946), which is higher than the long term average of 14,400 acre-feet. Years with sufficient flows at the right time to have successful spawning and recruitment must have occurred within that period, allowing for maintenance of varied age structures in the populations. We do not accurately know the extent or expansion of non-native fish species and their status at the start of the period.

After the construction of Hoover Dam, the resultant changes to the Colorado River in the project area dramatically altered physical conditions. Those altered conditions came after another short drought cycle, with the river never returning to its pre-1930 condition. Non-native fish populations increased (Dill 1944), including additional species introduced to the river. While all fish species, native and non-native, were stressed by the drought situation, once that stress was relieved, the physical conditions that were restored were not the historic ones. Despite being adapted to a widely fluctuating, physically demanding aquatic habitat, the native Colorado River fish were specialized to function within those conditions.

For example, the rise of the river in the late spring and early summer may have been a cue to initiate spawning activity for Colorado squawfish (USFWS 1991). Without that cue, because of the storage of high flows behind Hoover Dam, maturation and spawning might have been impaired. The precise locations of spawning areas for the three native species prior to dam construction are not known. Closure of the dams isolated portions of the populations from each other, and from essential habitats, presumably including historic spawning locations. Essential habitats might also have been inundated during reservoir formation. For the Colorado squawfish and perhaps razorback sucker, migratory routes to spawning areas might have been blocked by Hoover Dam. Passage for larvae downstream to rearing areas in the few remaining inundated bottomlands was similarly hampered. Expansion of non-native fish populations into the remaining backwaters, the main channel and the reservoirs increased the level of predators, something the native fish had not had to cope with before. Ordinarily, predators have a pattern of behaviors that prey species develop defenses against. Prey species faced with new predators using different patterns generally do not fare well unless they can quickly adapt.

The declines in the populations of razorback suckers and bonytail during the period 1909-1954 were not as dramatic as those of the Colorado squawfish, but they were significant and largely occurred for the same reasons. As with Colorado squawfish, large numbers of adult fish were lost in irrigation canals and never returned to the river but were carted off to be used as fertilizer (Miller 1961). Both species persisted in reservoirs at the end of the period but the riverine populations were depleted.

It is significant to note that razorback suckers did manage to have several years of recruitment to the population trapped in Lake Mohave. Reports after the dam had closed indicated the population was not as large as that in Lake Mead (Wallis 1951). Data from captured fish from Lake Mohave in the next period showed there had been recruitment to the population at least from 1937 to about 1957 with a "peak" in the late 1940's to early 1950's (McCarthy and Minckley 1987). Recruitment after the mid-1950's for both the bonytail chub and the razorback sucker has been virtually nonexistent. Recent reports of the presence of spawning razorback suckers in Lake Mead has raised questions as to the source and age of these fish.

Channel modification: 1954-1996

The large dams on the Colorado River provided for controlled releases of water when needed and prevented large floods. The dams did not, however, exert the same measure of control over what effect the released water had in the river channels. Meanders and braided channels continued to be formed. Sediment loads were carried downriver and deposited at the head of Lake Havasu and behind Imperial Dam.

The Colorado River Front Work and Levee System provided Reclamation with the responsibility for managing the Colorado River and its floodplain. This responsibility dates back to 1925, but the most significant law was that of 1946 which authorized funding to Reclamation to manage the river. This included operating the Front Work and Levee System, constructing and improving protective structures and drainage systems, improving and straightening the river channel and conducting investigations and studies pertaining thereto. The purposes of these activities fall into three main categories. The purposes for physical conditions were flood control, sediment control, water savings, navigational improvement, and river regulation. The economic purposes were salinity control, improvement of drainage on adjacent agricultural lands, enhanced land values, and recreation and recreational development. Environmental goals were protection of the environment and fish and wildlife preservation (USACOE 1982).

Starting in 1902, levees were constructed along the river to protect agricultural developments (USACOE and BR 1982), but until the threat of high floods was addressed, control of the river was not practicable. With the construction of the large dams along the river, it became more feasible to address additional control of the river.

Reclamation's BA addresses the placement of levees and bank stabilization structures, as well as the amount of dredging necessary to maintain channels and settling basins from Davis Dam to the SIB. Minckley (1979) includes information on the amount of channelization per r A description of the existing (1996) works under this program is included in the BA and will not be repeated here.

Bankline stabilization and dredging programs were intermittently undertaken by Reclamation from 1951 onward. The physical control of the river was achieved by bankline stabilization, training structures, channel realignment and levee construction. Dredging operations were important to channel realignment, sediment control, and environmental enhancement and mitigation. By 1996, 167.46 miles of bankline stabilization and 113.8 miles of levees lined the river from Davis Dam to the SIB.

Depending upon placement, the effects of levees can be minimal or significant. If placed at the outer edge of the floodplain, there is likely to be little to no effect except in the instance of a flood for which portions of the floodplain are beyond the levee. Since levees tend to reclaim lands from the floodplain for development purposes, their placement can narrow or otherwise restrict the floodplain. Assuming that levees remain in place during high water, flows through the narrowed floodplain are likely to be deeper and faster than if the channel were wider. Erosion and deposition patterns are likely to be different and may significantly alter the channel morphology. Depending upon the degree to which the channel has been narrowed, there may be increased deposition of materials at the lower end of the levee if water is allowed to spread out into a wider channel past that point. Marsh and riparian vegetation may establish here, and at low flows water may pond up on the upstream side. Marshes and backwaters nearest to the active channel are always more at risk of being adversely affected by high flows because they are subjected to more frequent high flows. The areas affected may be altered due to the inability of the river to spread out over a wider area. There is opportunity for new marsh and backwaters to form, but they may be subject to shorter life expectancies since they may be affected by more destructive floods more often. The marshes, backwaters and riparian forests behind the levee are almost entirely lost. Any remaining areas would lose accessibility to the river. With reductions to backwaters, marshes, and riparian areas, there is less organic material input to the system and fewer places to retain it. There are also fewer places for young and adult fish to find slow water areas except perhaps at downstream deltas.

Bank stabilization and placement of training structures have significant effects on flow patterns and create a new, straighter, channel for the river. Transport of water is made more efficient by decreasing the distance needed to travel, reducing turbulence due to shoreline heterogeneity and increasing velocity of the water (Minckley 1979). Currents may be almost uniformly swift with the straight channel configuration. Rock rip-rap and training structures prevent movement of the active channel and reduce the available sediment load from "unprotected" banks.

Once channelized, the river may cut a deeper channel due to the action of water on the bottom sediments (Minckley 1979, Ohmart et al. 1988); the same effect may be created mechanically by dredging. In either case, the result is a dropping of the water table which dries up marshes and backwaters and eliminates riparian vegetation if the water goes deeper than the roots can reach (Minckley 1979, Ohmart et al. 1988). In the interest of water conservation, additional riparian trees were removed (Ohmart et al. 1988), and the remaining backwaters were reduced in size or eliminated using dredge spoil to decrease the water surface area (Minckley 1979). In the new stabilized channel, there is considerable shifting of the bottom sediments under the new velocity regime, with subsequent adverse effects to navigation as sandbars move around. With limited input of fine materials, the silt and sand is eliminated and gravel/cobble/rock substrates may dominate as they do below the large dams. Diversity of main channel habitats is reduced considerably.

As part of river control projects, backwaters and marshes immediately adjacent to the river channel are often closed off from the river by a stabilized bank or dike. Water percolating through the bank provides some freshening for these areas, but it may not be sufficient to offset high evaporation rates that reduce water quality. Backwaters and marshes that have only percolation inlets are isolated and thus not available as habitat for fish and other aquatic organisms in the main channel and do not contribute much in the way of organic materials to the system. Backwaters and marshes with more open inlet structures are available as habitat and can provide organic material to the system.

Bankline stabilization has effects to fish habitats along shorelines as well. Rip-rapped shores reduce heterogeneity of bank and near-shore habitats available for fish (Minckley 1979). Uncut banks with riparian vegetation provide sheltering habitats in rootwads (Moffett 1942, Ohmart et al. 1988) and, if vegetated with emergent vegetation, are also diverse habitats (Minckley 1979).

The combination of controlled discharges from the dams, bank stabilization and dredging of the channel, and diversion of water from the system does not allow for the natural formation of new backwaters and marshes by the action of the river. Backwaters and marshes that survived the channel work are slowly aging out of existence (Ohmart et al. 1975). There has been an increase in backwater and marsh acreage behind Imperial Dam and Parker Dam at the Bill Williams delta and Topock Marsh. Yet, these areas are subject to normal aging and effects of the river. As an example, several areas above Imperial Dam have been lost as backwaters over the last few years in part due to high flows of the early 1980's transporting large amounts of silt into them.

As part of the mitigation for the various river control projects, Reclamation has undertaken to improve and enhance backwater and marsh areas. These are to offset losses to wildlife habitats lost from Reclamation's operations and have been designed to provide fish and wildlife habitats. Dredging, dike construction and other mechanical techniques are used to create these areas. Studies on main channel (Minckley 1979) and backwater habitats (Tash 1975, Kennedy 1979) have been done in concert with these mitigation activities.

Water levels in controlled situations fluctuate on a daily, weekly and seasonal basis. Fluctuations are largest below the large dams and attenuate as the water moves downstream. Shallow backwaters and marshes may be dewatered or replenished by the fluctuations. If insufficient water reaches these areas, water quality problems may limit their usefulness to fish.

Reductions in organic input from the floodplain riparian areas coupled with entrapment of organic materials in the large reservoirs may affect productivity. Reduction in shallow areas in the channel and of marshes and backwaters also reduces the amount of quiet water areas where primary production can occur. These areas have higher concentrations of plankton (Marsh and Minckley 1985) and benthic invertebrates (Minckley 1979) than does the shifting sand of the main channel. Where main channel substrates are composed of larger materials, benthic invertebrate populations rise and there is considerable growth of algae on the substrate. These types of areas, with their generally clearer water, are new habitats to the river.

There may be some changes to historic water temperature patterns as a result of river control activities. Seasonal and diurnal fluctuations were the historic norm. Fluctuating water levels and partial isolation of backwaters from the mainstem may allow some backwater areas to become warmer or cooler than they would have under historic circumstances. Especially below Davis Dam, the channelization of the river and the fluctuating nature of the releases influence the distance downstream that cold water effects are felt.

Other water quality parameters are affected more by actions on the river other than river control structures. Large increases in salinity resulting from water use and re-use may have greater effects in backwaters with insufficient fresh water exchange. Combined with high evaporation rates and fluctuating water levels, the situation exists for less than optimal conditions for fish survival.

In summary, the efforts to control the Colorado River have resulted in losses to floodplain riparian areas, and alterations in the way backwaters and marshes develop and age. Dam construction may have increased the total acreage of marshes along the river, thus offsetting some marsh losses. As for backwaters, maintenance of the existing ones relies on human intervention; natural formation of backwaters is improbable. What backwaters are still extant may be isolated from the mainstem and thus not available to fishes in the main river. Others are in the process of aging out of existence. While some remediation and conservation efforts have resulted in retaining or creating backwaters and marshes, channelized reaches of the mainstem are less diverse habitats for fish (Beland 1953, Minckley 1979). Many of the remediation and conservation efforts are described in **Table 9**.

As for introductions of non-native fish to the system, there are now 44 species of fish recorded from the LCR. Of that number, nine are native species, and 33 are non-native. Of the non-natives, 13 are "hypothetical," which leaves 20 species of non-native fish known from all or part of the lower portion of the action area (Minckley 1979). There may be additional species in Lake Mead not included in these records.

For the native fish species, most of the river control activities came well after declines in their populations were observed. Yet, river control efforts do appear to have played a part in creating a habitat more conducive to non-native species than native ones. Information in Minckley (1979) and summarized by Ohmart (1988) on fish habitats and habitat use showed that while different species might be selective, the multi-species, non-native fish fauna occupied virtually every available habitat along the river. This includes what remained of the types of habitats historically used by the native fish, as well as the newly created habitats such as rip-rapped banks. This is not surprising given the range of species present and their habitat flexibility. There are few relicts of the historic Colorado River left in the managed water delivery system the river has become.