South Platte River
Segment 15 Water Quality:
A Historical Perspective

Prepared for:

Metro Wastewater Reclamation District
Denver, Colorado

Prepared by:

Camp Dresser & McKee Inc.
Denver, Colorado

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Introduction

1.1 Overview

In the early 1800s, the American West was characterized by some of the first Anglo-explorers as the Great American Desert. Published statements by explorers and travelers to the west which created, and at times exaggerated, the desert image include (Werner 1992):

> ***". . . these vast plains of the western hemisphere may become in time equally celebrated with the sandy deserts of Africa."***
>
> **Zebulon Pike 1810**

> ***". . . this was a barren region unfit for the habitation of civilized man."***
>
> **Stephen Long 1820**

> ***"On the fifth day. . . we saw, late in the afternoon, what we supposed to be a considerable stream, but on approaching it, we found to our mortification nothing but a dry bed of sand, into which the water had sank and disappeared."***
>
> **Francis Parkman 1846**

John Wesley Powell, who conducted several expeditions to the west in the 1860s and 1870s, perceived that the Great American Desert could be made more habitable by irrigation. But he recognized that water resources were limited, expensive to move, and that the overwhelming portion of the west could never be transformed. Powell stated in one of his writings "*when all the waters running in the streams found in this region are conducted on the land, there will be but a small portion of the country redeemed. . .*" (Reisner 1993).

The South Platte River has been characterized, historically, as a raging torrent one year and a dry sand bed the next (Silkensen 1992). Snowmelt induced runoff creates the greatest flows during the spring and early summer. Summer thunderstorms occasionally can cause disastrous flooding. Eisely (1989) characterizes the Platte as a ". . . *mile-wide roaring torrent of destruction* . . ." during spring floods and normally as ". . . *a rambling, dispersed series of streamlets flowing erratically over great sand and gravel fans . . ., a mile wide and an inch deep . . .*"

Perhaps Michener captures the essence of the South Platte River in his book *Centennial* (1974):

> ***"And finally there is the river, a sad, bewildered nothing of a river. It carries no great amount of water, and when it has some, it is uncertain where it wants to take it. No ship can navigate it, nor even canoe it with reasonable assurance. It is the butt of more jokes than any other river on earth, and the greatest joke is to call it a river at all. It's a sand bottom, a wandering afterthought, a useless irritation, a frustration, and when you've said all that, it suddenly rises***

up, aprils out to a mile wide, engulfs your crops and lays waste your farms."

James Michener 1974

Although Michener's description exaggerates the condition of the South Platte River of today, it does provide an insight to how the river was viewed by many of the early settlers to the Denver area. An understanding of the historical perspective of development along the South Platte River is important to understanding the ecological conditions that exist today.

Camp Dresser & McKee Inc. (CDM), their subconsultants, and the Metro Wastewater Reclamation District (Metro District) are engaged in a study to develop site-specific dissolved oxygen criteria for Segment 15 of the South Platte River. Segment 15 is a 26-mile reach extending from the Burlington Ditch Headgate, approximately two river miles upstream of the Metro District Central Treatment Plant, to a point immediately below the confluence with Big Dry Creek in southern Weld County. It is believed that present day dissolved oxygen issues and other water quality concerns in the river were influenced by the historical development of the South Platte River Basin. The purpose of this report is to provide a brief history of developmental activities that have occurred along and in the South Platte River and to demonstrate how these activities may have shaped the current riverine system.

To gather the necessary information for this report, an extensive literature review was conducted and several agencies in the Denver metropolitan area were contacted. Most helpful were the Colorado Museum of History and the resource library at the Metro District. Additional sources included the Colorado Department of Health (CDH), Denver Regional Council of Governments (DRCOG), Colorado State University and the United States Environmental Protection Agency (EPA), Region VIII. This historical review begins with the 1860s and extends to the present time period, with particular emphasis on those periods before and after primary treatment was implemented at the Denver Northside Treatment Plant, and after the Metro District's wastewater treatment facility became operational in 1966.

1.2 Report Organization

This report is organized into six sections. Section 2 provides an overview of the physical aspects of the basin including site description, geology, geomorphology, hydrology, general ecology and water quality. Section 3 focuses on early development (1860-1937) activities in the Denver metropolitan area that affected the South Platte River including industrial and commercial development, water management, and water quality. Section 4 describes the regionalization (1938-1990) of the Denver metropolitan area with regard to water quality planning. Subjects discussed in this section include the construction of the Denver Northside Treatment Plant and the Metro District (formerly the Metropolitan Denver Sewage Disposal District No. 1) Central Treatment Plant, and related impacts on water quality. Section 5 describes recent developments in improving the water quality of the South Platte River, specifically as it applies to Segment 15.

Section 2
South Platte River Basin

2.1 Description

The South Platte River Basin is located within the Southern Rocky Mountain Physiographic Province and the Colorado Piedmont Section of the Great Plains Physiographic Province (Nadler 1978). Beginning in the south central mountains of Colorado above the town of Fairplay, the South Platte River flows rapidly to the east down steep mountain grades and through the foothills (Figure 2-1

). Along its journey through the mountains, the river is impounded to form four major reservoirs, Antero, Spinney Mountain, Eleven-mile, and Cheesman. After exiting the foothills, the river flow again is slowed to form Chatfield Reservoir. Downstream of the reservoir, the river continues northward through and beyond the City of Denver, alternately losing water to municipal, industrial and agricultural demands and gathering water from return flows and tributaries. With increasingly diminished flow, the river negotiates an east turn toward Nebraska at the Cache la Poudre confluence. Eventually, the South Platte River joins with the North Platte River to flow into the Missouri and Mississippi Rivers.

The South Platte River as it flows through metropolitan Denver can be divided into two sections. The first section, from Chatfield Reservoir to just below the Fulton Ditch diversion structure, is best classified as transmontane; that is, the stream retains some of the characteristics of a mountain stream (e.g., cold water and cobble substrate). The river in this section travels through a highly industrialized area, receiving flow from numerous stormwater discharges, and effluent from municipal wastewater treatment facilities. River flow is supplemented by four tributaries, Bear Creek, Cherry Creek, Sand Creek, and Clear Creek, all of which drain the Denver metropolitan area. The second section, downstream of the Fulton Ditch diversion structure, possesses the characteristics of a high plains stream (e.g., meandering, reduced velocity and sandy substrate). This section of the river passes through primarily agricultural lands.

The Burlington Ditch diversion structure, located at the beginning of Segment 15 (Figure 2-2)

, often diverts almost all of the South Platte River flow to meet agricultural irrigation demands. This irrigation diversion is one of five located in Segment 15. In addition, a number of instream structures have been constructed to stabilize the channel grade and protect utilities. Most notably is the 88th Avenue drop structure which was originally built to protect a gas pipeline and recently (1988) modified to accommodate recreational boating. Upstream of the Burlington Ditch diversion structure, several instream structures have been installed to control channel erosion, improve river hydraulics, and enhance recreational opportunities (e.g., kayak chute at Confluence Park). Channelization and construction of grade control structures in this section have increased stream velocity and reduced the stream bank erosional tendencies of the river. This channelization is also prevalent downstream of the Central Treatment Plant where the river bank is riprapped to protect both the gravel ponds and the City of Thornton's water supply ponds from the eroding effects of the river.

The lower section of Segment 15, beginning just below the Fulton Ditch diversion structure, possesses the characteristics of a high plains stream, that is, the river meanders as it flows northeastward, has a substrate dominated by shifting sands, and braided channels. These

characteristics continue through Ft. Lupton. Much of the instream habitat in this section can be classified as a glide/run with intermittent riffles and infrequent pools. Three other irrigation diversions, the Brantner Ditch, Brighton Ditch, and Lupton Bottoms, are found downstream of the Fulton Ditch diversion structure. The Brantner and Brighton Ditch diversion structures each have a vertical drop greater than 6 feet forming a barrier to upstream migration of fish. In addition, the upstream pools created by these structures produce quiescent water which contains the lowest levels of dissolved oxygen found in the river. The Lupton Bottoms Ditch diversion structure has a vertical drop of less than 2 feet and is believed to affect upstream migration of smaller fish species.

Humans and livestock along this lower section have intruded upon the river, degrading bank stability and organically enriching the stream sediments. The dredging of gravel pits has interrupted flow and increased sediment loads, while intermittent channelization has disrupted the developing sinuosity of the river (Propst 1982). The river is channelized just upstream of the Brantner Ditch to protect graveling operations and agricultural lands. Downstream of the Brantner Ditch, the streambank has been confined with concrete rubble to protect the banks from erosion from the river and from surface runoff from adjacent agricultural fields. This surface runoff, as well as effluent from the South Adams County Water and Sanitation District wastewater treatment plant and the City of Brighton wastewater treatment facility, increase the nutrient loading to the river.

Downstream of the Brighton Ditch diversion structure, the river continually widens as it meanders through rich agricultural farmlands. The Lupton Bottoms Ditch diverts water from the river south of Fort Lupton for agricultural irrigation. Segment 15 ends at the confluence of the South Platte River and Big Dry Creek, just upstream of Ft. Lupton completing the 26 mile reach extending from the Burlington Ditch diversion structure.

2.2 Geology/Geomorphology

The current geological configuration of the South Platte River Basin was formed during the Mesozoic Era, approximately 100 million years ago. Beneath the inland sea that covered a large portion of what was to be the North American continent, the combined weight of sediment and water pressed down upon a relatively weak basin floor. The pressure, combined with a violent upsurge of magma from the mantle, bent more flexible layered rocks above until a massive mountain range emerged. This Rocky Mountain range spread from northern Canada almost to Mexico draining the inland sea as it lifted. While the Rockies rose, the South Platte River cut its way along the eastern edge of the mountains, capturing smaller rivers until they coalesced into one that flowed north then eastward over the plains where the sea once lay (Michener 1974). As the sea receded, it left little moon-colored shells along the river, inspiring the river's first known name, Moonshell (RMN 1984c). Later, French trappers renamed the river "*Riviere la Platte*" (broad shallow river). The braided (multichanneled) river was up to two miles wide in some places and so shallow in others it disappeared all together. "*Too thick to drink, too thin to plow, too shallow to sail on and too wide to shoot across... ,*" pronounced Charles Strobie, painter and explorer, known as Mountain Charlie. "*It would make a good river stood on edge,*" said 19th Century humorist Artemus Ward. Other, later descriptions would call it "*The Nile of North America,*" "*The Big Icky,*" and "*Denver's Sewer.*"

The South Platte River and its tributaries have removed most of the tertiary rocks from the Colorado Piedmont formation, leaving only narrow valleys for the river to flow through. During the Wisconsin Glacial period (approximately 11,000 years ago), ice flows ground rock formations into gravel terraces 90 or more meters thick, which, together with alluvium (to 90 meters), dune sand (to 30 meters), and loess (to 15 meters) were deposited along the South Platte River and its tributaries (USGS 1991a). These layers formed the flat plains at the foot of the Rockies that were later eroded by the path of the wandering South Platte River.

2.3 Hydrology

Historically, the water flow of the wide, braided South Platte River has been seasonal in the extreme. Late spring and early summer snow melt caused extensive yearly flooding of the basin before 1860. However, late summer and winter found very little or no water in many sections of the channel. In July of 1842, the expedition of John C. Fremont, a lieutenant in the Corps of Topographical Engineers, found the river "*. . . fifty to one hundred feet wide, sunk some thirty feet below the level of the prairie, with perpendicular banks, bordered by a fine of green cottonwood, but not a drop of water.*" In the year 1874, settler Harry A. Pettee recollected that on the eastern plains, "*. . . there were times that the river was practically dry, and at times it had a little spurt of running water caused by rains or something of that kind, but I don't remember of there being any water to amount to anything any time during that year. . . there was no year except at times of flood when you could not cross back and forth every day. . . There was one year there, I think it was in June, we cut on the north side of the river, and when we came back the river was full, there was a flood sometime during the day.*" (NCT 1917).

It is likely that the South Platte River historically supported a fish population consistent with these intermittent flows. The present fish community developed with the controlling mechanisms that gave the river its perennial status. Today, were it not for the discharge from the Central Treatment Plant and groundwater recharge from agricultural activities, there would be little water in the river to support aquatic life, water fowl, and recreational activities during many periods of the year.

The Central Treatment Plant effluent typically constitutes more than 90 percent of the river's flow in Segment 15 nearly nine months a year. The Central Treatment Plant discharge (ranging from 65 to 220 mgd) varies throughout the day based on the water use patterns of the people in the Metro Districts' service area. This causes daily changes in the flow regime of the river, as well as seasonal ones, that can create adverse conditions for aquatic life. Habitat may be available for spawning at one time of the day, but may be high and dry at another time.

The principal sources of groundwater within the South Platte River Basin are the alluvial aquifers along the river, the High Plains aquifer in eastern Colorado, and the Denver Basin aquifer system underlying the South Platte River Basin. The alluvial aquifer, historically recharged by precipitation and leakage from streams, is unconfined and hydraulically connected with the river along its mainstem and major perennial tributaries. More recently, water recharge has been aided by reservoirs and ditch leakage and by percolation of applied irrigation water diverted from the river and its tributaries. The High Plains aquifer is generally unconfined, with local confinement by lenses of clay and silt. The Denver Basin is recharged in outcrop areas by rainfall, snow melt, and streamflow. Discharge from all three aquifers takes place through wells, seeps, springs, stream discharge, and evapo-transpiration (USGS 1991b).

Precipitation in the South Platte River Basin varies erratically from year to year as evidenced by periodic droughts extending from one to several years. Besides yearly precipitation differences, there are intra-basin differences in precipitation. Annual precipitation at Greeley is reported to be approximately ¾ of that at Julesburg, with precipitation increasing again in the foothills and mountains. Denver precipitation averages 13 to 14 inches annually.

2.4 Ecology/Water Quality

Little is known of the ecological history of the South Platte River Basin before the 1800s. However, the ecosystem along the front range has changed since 1860 from that of a grassland to one of urban, industrial and agricultural development. From historical accounts, vegetation in the form of trees or woody growth was scarce along the South Platte before 1860. Edwin James, botanist, of the Steven H. Long expedition of 1819-1820 (Silkensen 1992) noted that, "*We passed several extensive tracts nearly destitute of vegetation.*" The popular "Parsons' Guidebook" of William B. Parsons, entitled *The New Gold Mines of Western Kansas*, stated that, "*There is no wood of any account between O'Fallen's Bluff [in Nebraska] and Fort St. Vrain [a trading post north of Denver]*" (Parsons 1858). Cottonwood trees were described as "*remote from one another*" and many travelers complained of the lack of wood for fuel. The region was dominated by shortgrass and mid-grass prairie species (e.g., wheatgrasses, needlegrasses, grama grasses, bluestems, and fescues). As travelers approached the mountains, the vegetation appears to have increased in quantity and diversity.

The relative abundance and historical distribution of native fish in the South Platte River before 1880 were poorly known. D.S. Jordan's (1891) fish collection efforts in the late 1800s is the best source of historical data on the fish community in the South Platte River (Lewis and Saunders 1985). His data shows that twelve species of fish were known to the South Platte River at that time. Several others followed in the footsteps of Jordan (Ellis 1914; Li 1967; Goettl 1982), but none was as detailed as Propst's work in the 1980s, almost 100 hundred years later. Propst (1982) concluded from the historical records and his collections, that 29 native fish species and 12 non-native fish species have occurred in the South Platte River system. Of the 29 native species, three disappeared from the river before the turn of the century (Lewis and Saunders 1985).

Many of the non-native fish introduced into Colorado early in the 20th century were game fish to support recreational fishing. The Colorado Division of Wildlife has continued this practice over the last 20 years; along with both historical and more recent introductions of predator-type fish, the native fish community may have been negatively impacted. The common carp was introduced into Colorado (Ellis 1914) in 1882, and probably competed for habitat and resources, possibly displacing some of the native fish.

Prairie communities generally contained many species of mammals, including deer mice, black-tailed prairie dog, black-footed ferrets, prairie vole, white-tailed jackrabbits, striped skunk, elk, pronghorn antelope, and buffalo. Native birds commonly found in this region included meadowlarks, various grouse, hawks, and sparrows. Reptiles and amphibians traditionally found here included bull snakes and rattlesnakes, some toads, and lizards.

The mountain communities contained a combination of coniferous (pine, spruce, and fir) and deciduous (aspen) forests. Dominant animal species included raccoon, red squirrel, least chipmunk, beaver, flickers, red-winged blackbird, black-capped chickadee, mule and white-tailed deer, and black bear. The Rocky Mountain wolf, now under consideration for reintroduction, ranged throughout the Rocky Mountain region.

Bluestein and Hendricks (1975) speculated what the virgin water quality of the South Platte River in the mountain areas would have been, based on their knowledge of mountain streams. They estimated the dissolved oxygen concentration statistically at 8 mg/L (milligrams per liter), fecal coliform at 5 mpn/100 mL (most probable number per 100 milliliters), nitrate-nitrite at 0.1 mg/L, TDS (total dissolved solids) at 75 mg/L, and temperature at 10 C.

It is suspected that water quality of the South Platte River in the plains region was affected by warmer temperatures (lower dissolved oxygen) and higher concentrations of suspended sediments. Prior to 1860, South Platte River flow and water quality was probably not affected by groundwater or influenced by its intermittent plains tributaries (Bluestein 1975).

Before the 1860s, little was known about the link between water quality and illness. Louis Pasteur first discovered the microbe in the 1860s. John Snow, a scientist of the 1840s, was able to relate an outbreak of typhoid to a contaminated well. An eruption of cholera, in 1849 in the town of Julesburg, was attributed to contamination of the South Platte River and its aquifer by settlers in the first wagon trains heading west over the early trails near Julesburg (Post 1970). It is possible that John Simpson Marsh, a trapper and trader who settled near the confluence of the South Platte River and Cherry Creek in the autumn of 1857 (Shoemaker 1981), may have been one of the last persons to be able to draw drinking water directly from the South Platte River at Cherry Creek. Gold was discovered the next summer on Cherry Creek sparking a gold rush and a massive influx of immigrants. The population of Denver grew rapidly, changing the quality of the South Platte River forever.

From the 1860s until the late 1930s, the South Platte River was a major conduit for raw domestic and industrial waste. This long period of degraded water quality must have affected the composition, distribution and abundance of fish in the South Platte River (Lewis and Saunders 1985). Rare or sensitive species were probably lost from the river as it flowed through and past the Denver metropolitan area. Li (1967) concluded that historical water pollution was a likely contributor to the reduced abundance of some fish species in selected portions of the South Platte River. In combination with the long period of degraded water quality and the severe alteration of the physical habitat, the ecological integrity of the South Platte River must have suffered significantly.

In summary, before the gold rush of 1858, the South Platte River was an intermittent stream that probably supported some fish species. With urbanization beginning in the late 1800s, the river took on a perennial flow regime. This urbanization also exhausted the river's assimilative capacity for pollution which most likely led to the loss of some resident species. Today, the flow regime in the South Platte River, particularly in Segment 15, is highly controlled by irrigation and flood control facilities and is dominated by the Central Treatment Plant effluent nearly nine months a year. Recent field studies by the Metro District (CDM 1993c,d) indicate that fish species diversity and fish population have increased during the 1980s and 1990s, but some species may not have returned.

Section 3
Development (1860-1937)

Between 1860 and 1937, tremendous growth occurred along the front range of Colorado. The early influx of settlers responded to the news of rich gold ore deposits found on Cherry Creek and in the Clear Creek basin. Along with these miners, came a need for support services (food, transportation, etc.) attracting even more people to the area. As the ore deposits were depleted in the late 1800s, the miners turned toward agriculture, prompting a demand for water along the front range.

3.1 Industrialization/Commercialization

The South Platte River's earliest known commercial use was that of a monetary source for nomadic Indian tribes, the Ute, Arapahoe, Cheyenne, Apache, and Comanche, who used the moon colored shells from its bed for barter and decoration. Beginning in the eighteenth century, explorers, trappers and traders entered the region. The first commercial edifice, Fort St. Vrain, located 40 miles north of present day Denver, was built after the Louisiana Purchase in 1803. The fort, a trading post that served the white and Indian trappers of the American and Hudson Bay Fur Companies (Klemme) in the 1830s and 1840s, was part of a trio of forts along the South Platte River. As the fur bearing animals were trapped out, the trading posts declined, and by the 1850s, the fur trading industry had crumbled.

Right on the heels of the short lived fur industry came the second phase of South Platte River commercialization: mining. Gold was discovered on Cherry Creek and Clear Creek in the late 1850s. The rush of miners to the South Platte River and its tributaries dramatically increased population in a short period of time. As the population grew with the mining industry, transportation became a major partner in the development of the South Platte River Basin. Attempts were made to develop shipping commerce through navigation of the South Platte River in scows and barges. The unpredictability of the river soon caused vessels to dwindle in size to canoes and dinghies (Shoemaker 1981).

The Pikes Peak and Leavenworth City Express Company (a stagecoach line) established a 600 mile route from Kansas that stimulated growth along the South Platte River. By 1859, the Denver city directory listed 27 retail and 12 wholesale establishments, 23 saloons, four billiard parlors, four 10-pin alleys, 11 restaurants, eight hotels, two livery stables, four lumber yards, one news depot, two theaters, nine real estate and mining claim agents, and 14 each physicians and lawyers (DPS 1941). Miscellaneous industries included ceramics, explosives, and timber products manufacturing. In 1865, a Board of Trade was organized to lure the railroad to Denver, its efforts resulted in the laying of track for the Denver Pacific and Kansas Pacific railroads.

By the 1890s, the metal mining industry had reached its zenith with a production of gold, silver, copper, and lead of $50 million annually. Mining production dropped to $14 million a year by 1921. The businesses that handled mining machinery moved to Denver as the mining communities in the mountains lost population. Nonmetals mining of gypsum, clay, lime, building stone, sand, gravel, mica, and cement continued to be of importance in the basin. As the metal mining industry waned, more miners turned to farming.

The first water appropriation occurred with the digging of an irrigation canal in the South Platte River Basin on the Cache la Poudre c1840 by Antoine Janis (Eschner 1981). Some radishes, the first fresh vegetables grown in the Denver area, were served in June 1859, and later that year, the first wheat was harvested (DPS 1941). The principal crops grown in the South Platte River Basin became hay and forage, wheat, sugar beets, potatoes, barley, dry beans, corn, oats, rye, sorghums and other grains, and seed. With agriculture came the need for food processing plants and small manufacturing to provide the implements and accessories needed for farming, from feed bags to tools for irrigation dams (Colorado Interstate Gas Co. 1960).
By the 1880s, the South Platte River was bordered by smelters, stockyards and meat packing plants, planing mills, quartz mills, grist mills, and saw mills. There was a paper mill, two woolen mills, and five breweries, (buildings of two of the breweries, The Zang Brewery and the Tivoli can still be found along the river) (DPS 1941). All of these industries were discharging their untreated process water into the South Platte River.

Ranching flourished in the late 1800s and early 1900s, but by the 1930s there was a general decrease due to settlement and fencing of range lands, although it was still considered a major industry. The Denver Stockyards was established along the South Platte River near Globeville, and served as a staging area for livestock brought to market. Starting in the 1920s, petroleum and natural gas activity along the river was on the increase.

3.2 Water Management

3.2.1 Appropriation Doctrine

To understand the use and development of water resources in Colorado, it is necessary to have an awareness of water rights as they apply to the western United Stated (U.S.). In the U.S. there are two basic doctrines which are the basis of water use: (1) the riparian doctrine, wherein the right of water use comes from the ownership of riparian lands (those along the watercourse) and (2) the doctrine of prior appropriation, which permits the diverting of water from the stream banks without regard to ownership of land contiguous to the stream, and even though the diversion diminishes the natural flow downstream. Appropriation recognizes the right to divert the water away from the stream by works for the application of water to any beneficial use. These water doctrines have their roots in ancient Babylon, Egypt, and Rome. These civilizations' extensive use of limited water resources, and complex legal statutes concerning those resources, allowed them to flourish. The downfall of these ancient civilizations has been attributed in some part to the decay of their water facilities (Black 1960).

The western United States based its use of water on the doctrine of prior appropriation. The first American consideration of the question of riparian vs. appropriation doctrine was presented before the California State Supreme Court in 1855. The court's decision was that in the case of water appropriations "*first in time was the first in right*" (5 California 140, 63 Am Dec. 113 1855). There followed a string of legal decisions, like the Desert Land Act of 1877, expanding the appropriation doctrine and establishing the subjection of junior appropriators to senior appropriators, and the authority of states to decree cessation of diversion due to preference of use.

The importance of water to semi-arid Colorado, and the increasing complexity of appropriations of the limited supply, required laws combined with countless decisions of legal interpretation. At the adoption of the Colorado State Constitution in 1876, provisions in the form of Article XVI, Sections 5 through 8 dealt with water appropriations, rights-of-way, and rates, affirmed the "*first in time, first in right*" doctrine in Colorado. The state constitution also established a priority of appropriation, giving domestic purposes first rights, followed by those of irrigation (Colorado Constitution, Art. XVI, Secs. 5-8). There followed innumerable cases dealing with the role, definition, and use of tributary waters, designated beneficial uses, surface vs. subsurface water rights, "riddance" waters, supply sources, overflow from lakes during high water, percolating waters, "made" waters, and non-tributary waters, even to the extent of covering water previously used by trees that had been cut down (43 U. of Colo. L. Rev. 473 (1972) Phreatophyte Eradication as a Source of Water Rights in Colorado as reported in Trelease 1975). In 1902, the Federal Reclamation Act caused a boom in irrigation development in Colorado. With its passage, the federal government entered into the financing of large scale irrigation projects in the west (Trelease 1975).

One of the most significant pieces of water legislation was enacted in Colorado in 1937. It authorized the establishment of the Colorado Water Conservation Board (CWCB) to appraise and inventory the State's water resources. These responsibilities included development of programs for water resource conservation, utilization, and control; formulation and further a continuing State policy with respect to inter- and intra-state water development programs and problems; and promotion of water projects. In this capacity, the CWCB could conduct investigations, make surveys and studies, review and make official State comments on projects' reports of Federal agencies, and cooperate with other interested and affected groups to attain these principal objectives (Black 1960).

3.2.2 Irrigation

As population, and industrial and agricultural demands for scarce water resources grew, accommodations for these demands in the form of diversion, storage, treatment and regulation also increased. Water management of the South Platte River began with small crude diversions in the flood plains followed by expansion to a network of larger canals for development of the higher bench lands. After 1860, the greatest use of surface water was for municipal and irrigation purposes.

Increasing population and demands for water led to the development of water provider organizations. By 1870, agricultural interests and other water users had begun to organize into cooperatives to subsidize the construction and expansion of an elaborate network of canals. In that year, municipal users formed Denver City Water Company to build a water pumping plant on 15th Street to serve the 4,759 inhabitants of Denver. By 1880, the natural flows of the South Platte River were over-appropriated (Denver Water News 1940d).

Running out of water to appropriate along the South Platte River and its tributaries, water users looked across the mountains for more. The first transmountain diversion to bring more water into the basin, the Skyline Ditch, was put into use in 1893.

About this same time, the South Platte Canal and Reservoir Company was formed to build the first of many large reservoirs, including Lake Cheesman. Its purpose was to capture the 1,796 square miles of watershed draining into Goose Creek. Two attempts were made to build Cheesman Dam. The first attempt, made in 1900, was wiped away by a spring flood before completion. The second dam, completed in 1905, was 212 feet high, 39 feet long at the bottom, and ¼ mile at the top. But water needs still continued to grow (Denver Water News 1940d).

By 1934, the irrigated area in the South Platte River Basin was 1,225,423 acres. The estimated mean annual water supply stood at 1,650,00 acre feet, of which, 1,500,000 was mountain runoff and 150,000 plains runoff. The estimated mean annual consumption was 1,350,000 acre feet and estimated outflow 300,000 acre feet (Colorado State Department of State Engineer 1934).

By acquiring additional water rights and constructing Elevenmile Canyon Dam in 1935, Denver was able to increase its use of the South Platte River. But non-ending demand for new water supplies caused Denver to look over the mountains to the western slope for additional sources. To augment Denver's supply, the first transmountain water was diverted from the Colorado River through the Moffat railroad tunnel system in 1936. Most reservoirs constructed after the 1930s were for municipal supplies, flood control, and recreation.

3.2.3 Impacts on Groundwater

In the late 1800s, a curious phenomenon began to occur in the basin. The hydrology of the South Platte River was changing. The change was confirmed in the biennial State Engineer's Report of 1883-1884, "*It is claimed that the flow of water in the Platte River through this district is much more uniform than formerly, which is undoubtedly true, and is due to the effect of the irrigating canals on the stream above, by reducing its flow in the flood season. After high water, its natural flow is increased by the return into the stream of a portion of the water, which is commonly called 'seepage'.*" (Silkensen 1992)

By 1885, the water table contours of the basin showed a distinct gradient toward the South Platte River. Farmers, noticing these return flows to the river caused by their irrigation, made additional diversions to use this new found source of water. Each year, the increased irrigation augmented the natural flow of the river. By 1908, irrigation seepage had caused a permanent flow of 2-3 cubic feet per second (cfs) at the head of Peterson Canal near Ovid (NCT 1917), making the return flow to the South Platte from irrigation water 20 percent by 1922.

Groundwater resources were being developed as irrigation waters infiltrated the water table. These sources were used at first primarily for municipal and stock watering purposes. The first irrigation well, dug in 1910, was followed by 500 others through 1930 (Bluestein 1975).

3.2.4 Flood Control

The change of the South Platte River from an intermittent to a perennial stream due to irrigation return flows had a major impact on the entire basin (Nadler 1978). Previously the channel would widen with each successive flood. Now there was a continuing decrease in the width of the channel; the sinuosity increased and the width to depth ratio decreased. During periods of drought through the 1900s, the vegetation was able to encroach on the receded river bed, not allowing it to return to its former width nor allowing the braided channels to move due to the anchoring of the islands by the vegetation (Nadler 1978).

The change was analogous to a climatic change. Vegetation became denser and similar to that of more humid regions. Velocities of flood waves were reduced and their erosive effect mitigated by the expanding plant growth along the river. Each year the period that the river was "dead" decreased. The narrowing of the channel had a significant impact on the frequency of recurrent seasonal flooding, especially on developed floodplains.

Appreciable or severe flooding had always occurred in the Denver area along the South Platte River and Cherry Creek. The greater volume, 100-year floods, carried an average of approximately 30,000 cubic feet per second into Denver. Mr. Putman, a sheepherder, remembered that, "*. . . in 1876, the river was the highest we had ever known it previous to that time, . . . I had camped on the river bottom lands, and while I was informed by an old settler that I would probably get flooded out some day, I thought I would take chances. . . All the settlers along the Platte Valley proper in that vicinity (Seventy Meadows) were compelled to abandon their residences and were flooded out. I moved my tricks and trinkets up on the hill close by and camped there for a short time, then moved back into the house and in about ten days the water came up again and drove us out again*" (NCT 1917). The earliest attempts to mitigate flood damage were to offer advice to stay out of the usual flood areas, or to construct retarding dams, such as the Castlewood Dam to temporarily hold back the high water and flatten the flood peaks (Denver Post 1933a,b).

The first major project to deal specifically with flood control along the South Platte River came in response to the flood of 1921. Mayor Stapleton turned his attention to a major renovation of the South Platte through Denver for flood control and land reclamation. The banks of the river were built up to 15 feet high and reinforced, the river bed was deepened, the channel changed in several places by removing curves. A channel change at Globeville, frequently impacted by flood waters, removed a curve where the river overflowed regularly several times a year, causing damage to property.

New river banks were built from 13th to 8th Avenues, also places of high water overflow. At 3rd Avenue the river was widened and a new wall of curbing stones was constructed. At the south city line, more than a mile of bank was constructed and the river widened. These efforts proved successful, because a flow recorded during the spring of 1929 at a dam south of Alameda showed that although the flow was greater than that of the flood of 1921, "*. . . there was not so much as a damp cellar*" (Denver Municipal Facts c1930).

The importance of flood control was temporarily de-emphasized until 1933, when Cherry Creek experienced a major overflow. The response to the flood was to build more retarding dams. Cherry Creek Dam was originally built above Sullivan in 1934 with financial assistance from the Federal government. The dam was 45 feet high, with an opening in the center, sized to allow only as much flow into the creek channel as it could carry. Additional flood control measures implemented included the removal of several curves on the South Platte River; banks were riprapped and raised; and new channels were excavated. Dry Creek southeast of Englewood was straightened where it entered the suburbs (Denver Post 1935). While too much water was a short-lived and intermittent problem, too little water was a continual problem.

3.3 Water Quality

As previously mentioned in Section 2.4, scientists suspected, but could not prove the connection between drinking water and disease before the discovery of the microbe in 1860. Statistics of disease incidence were, of course, kept by public health departments, permitting tracking of the occurrence of water pollution indirectly. The earliest systematic attempt to accumulate water data nationally was begun by the United States Geological Survey in 1900. USGS Report No. 74 of 1902, entitled "Water Resources of the State of Colorado" contained water supply and irrigation data of the states streams and rivers (USGS 1902). Attempts by the USGS at water quality monitoring were spotty through 1914 and it wasn't until 1931 that permanent monitoring networks appeared.

The burgeoning mining population of the basin in 1859, had one answer to waste removal: the South Platte River. The river would take all the waste away. In the late 1800s, as the banks of the South Platte River teemed with slaughter houses, rail yards, and other industries, the river expanded its role as a convenient sewer. The refuse from the business district was hauled down to the river via horse drawn closed tanks and dumped into the water. The odor from the waste was most offensive in working class neighborhoods near the smelters, around the railroad yard, and along the river, but it was noticed throughout Denver.

Health concerns were voiced. At the April 16, 1874 City Council Meeting, Dr. William R. Whitehead, Chairman of the Health Committee, submitted a report which included the analysis of four water samples taken from wells near the South Platte River. The analysis showed from one to twenty grains of "*putrid matter per gallon of water*" (1 grain per gallon = 17.1 milligrams per liter). Dr. Whitehead warned that "*. . . in the course of a few years, we may be made to drink from the Platte River, diluted with the excremental filth and foul drainage of the most populous parts of Denver*" (Denver Board of Water Commissioners 1874).

In an attempt to control stream pollution, penalties were established for discharging obnoxious substances, such as, "*refuse matter from slaughter house or privy, or slops from eating houses, or any other fleshy or vegetable matter which is subject to decay in the water. . . ,*" but the odor from refuse became so bad that the city finally began construction of sewer lines (Dorsett 1986) sometime after 1872 (Shoemaker 1981). By the mid 1880s 250 miles of sewer lines were in place. By 1886, the City's sewer lines were collecting from 3,050 water closets and 3,226 kitchen sinks. The untreated effluent flowed through the system directly into the river. The contents of the pipes were discharged near 27th Street, furnishing polluted water for irrigation use further on down the river (Shoemaker 1981). Unfortunately, a side effect of the contaminated irrigation water was that as it moved deeply into the ground, it polluted the aquifer. In 1918, Henry M. D'Votie, Superintendent of Canal 2 of Greeley, reported, that, near Greeley, wells as deep as 125 feet did not bring good water (Manuscript 1918).

Concerns over disease, odor, and rodents were ever more frequently voiced as industrial pollution along the South Platte River became manifest. In 1898, a report in the Denver Times stated that "*A most curious phenomenon was visible . . .on the north side [of the Platte] in the vicinity of Zang's brewery . . . fishes by the thousands, jumped from the shallow Platte and endeavored to reach the shore. The peculiar whitish hue that the river assumed terrified some of the men employed at Zang's. They argued that the fish could not be persuaded to leave the river unless there was something in the water that would exterminate them . . . it [a milky substance] is supposed to have come from the paper mills near Overland Park, some five miles away*" (Times 1898). A local publication called Field, Fellows and Hinderlich, in December 1907, reported that the water in the Rocky Mountain Ditch from Clear Creek "*. . . is not desirable for domestic purposes as it carries considerable slimes from the stamp mills*" (FFH 1907).

Ever growing discharges to the South Platte River Basin brought greater water pollution, and water pollution brought health problems. In 1890, 287 deaths per 100,000 from typhoid were reported. When mechanical filters were installed at drinking water treatment plants in 1893, the deaths fell to approximately 58. Further attempts to treat the water with hypochlorite dropped the deaths to 21 in 1911, and between 1923 and 1932, deaths fell to two when chlorine was added (Your Municipal Water System 1934).

The Denver Water Department began systematic sampling of Denver's drinking water in the early 1900s. Samples were taken from tap water and analyzed by the City's laboratory and results were confirmed by the City Board of Health (Swan 1938). Unfortunately, research has been unsuccessful in locating the data sheets of those analyses, but others are readily available. Some sampling appears to have been in response to outbreaks of disease.

Pollution concerns regarding water still focused mainly on drinking water quality and great pains were taken to protect the watershed that supplied drinking water to Denver. Dilution of sewage remained the preferred method of instream water quality control, but in times of low flow, this was a problem.

In the late 1920s, in response to requests by scientists to begin regular sampling of the South Platte River near Denver, the Colorado State Board of Health (CSBH) began conducting water quality studies of its own. The Biennial Report of the CSBH in 1926-1927 warned that "*. . . untreated domestic sewage discharged into the streams by the cities on their [the South Platte and her tributaries] banks, together with the industrial wastes discharged by the sugar factories, constitutes too heavy a load of putrescible organic matter to be assimilated by the small flow of water during the fall*" (CSBH 1926).

The polluted river water used downstream for irrigation of crops, was causing intestinal disease in the inhabitants of the South Platte River valley below Denver. The use of untreated wastewater on irrigation crops caused an increase of typhoid fever, amebic dysentery and infectious diarrhea, deadly to infants, whenever the vegetables were consumed (Chapman 1934a,b; Hall 1933). A report of the State Division of Public Health in 1932, published the analytical results of samples taken from the Burlington Ditch. These results showed that dissolved oxygen was at 4.7 ppm; oxygen demand was at 139.00 ppm. The report estimated that the average outflow of domestic sewage from outfalls located at the Burlington Ditch, near the H & M Meat Company, and outfalls on each side of 47th Street was 46 million gallons (State of Colorado Division of Public Health [CDPH] 1932a). The report stated that *E. coli* was found on vegetables irrigated with sewage laden water, the irrigation water itself was found to contain *E. coli*, and that the dilution factor in the South Platte River at Denver was only about 50 percent.

Bacteriological analysis showed that the total bacteria count in the irrigation water downstream of Denver was extremely high, decreasing 20 miles below Denver, but raising a second time at Brighton. Chemical analysis showed that the river two miles below Denver was almost devoid of dissolved oxygen and that in the Burlington Ditch the dissolved oxygen was zero. Dissolved oxygen decrease, and increases in oxygen demand between Mississippi and the 45th Avenue Bridge above the city outflow, proved that many private sewers were not connected to the city's system. As a result, the river at this location was essentially serving as an open sewer. It wasn't until ten miles downstream from Denver that the river began to improve in quality due to re-aeration (CDPH 1932b). The report concluded that the contaminated irrigation water delivered from upstream at Denver was the cause of many cases of typhoid fever and dysentery, especially among children. The Division recommended a sewage treatment plant; scientists and concerned citizens agreed. A $3.0 million bond issue was passed by the City and County of Denver to construct the Denver Northside Treatment Plant.

The expectations of Denver's populace to the new Denver Northside Treatment Plant were that when the effluent was mixed with the low flow of the South Platte River it would "*be free from objectionable sights and odors, . . . not too greatly depress its soluble oxygen content nor too greatly increase its biochemical oxygen demand, . . . not kill the fish, and . . . contribute to the water only a minimum of danger from human intestinal pathogens*" (Hall 1933).

Although not much information was found in literature regarding effects of poor water quality on the fish community during this time period, it is not difficult to comprehend that the ecological integrity of the river was being compromised for the sake of development. This degradation in water quality may have eliminated many of the native fish species in the South Platte River in the Denver metropolitan area and downstream.

Section 4
Regionalization (1938-1990)

4.1 The Denver Northside Treatment Plant

The first wastewater treatment plant in Denver, the Denver Northside Treatment Plant (DNTP), was constructed in 1936, and began operation in May 1938, with a capacity of 50 mgd. Its function was to remove solids from Denver's wastewaters by screening, grit removal, primary sedimentation, and filtration. The filtered effluent was discharged to the South Platte River. Waste solids or sludge, was treated via anaerobic digestion and dewatered on sludge drying beds (CDM 1974).

Initially the plant provided a 65-70 percent removal of biochemical oxygen demand (BOD) and 85 percent removal of suspended solids. The Colorado Board of Health required the BOD not to exceed 40 mg/L at that time, but the plant was discharging effluent of about 100 mg/L BOD. The difference was being met by dilution with river water. Even as the system came on line, it was evident that it was inadequate to the task. Various water diversion systems were to be implemented by 1940 to assist with dilution in the river as a means of quality control (Swan 1938).

By 1941, the filtration process had to be discontinued because of cost and operating problems (HEW 1966). In 1948, in an effort to keep up with area growth, the plant was expanded to 75 mgd and the filters were converted to chlorine contact tanks, to provide disinfection of the effluent prior to discharge to the river. In spite of these improvements, a 1949 study of the variation in loading on the South Platte River by discharge of the plant effluent, showed a distinct correlation between plant discharge and high biochemical oxygen demand (USPHS 1950). The report suggested that enhanced stream flows via timed discharges from existing reservoirs would be effective pollution abatement, but also pointed out that this solution held little promise "*inasmuch as the water resources of the Basin are already highly developed principally for irrigation purposes,*" (USPHS 1950). The report concluded that DNTP needed increased capacity and a higher degree of treatment to further improve South Platte River water quality.

After World War II, the metropolitan area expanded rapidly, with much of the growth occurring in unincorporated areas between older established ones. Sprawling suburbia quickly outstripped the ability of private investors to finance water systems required for development. To address this problem, the State of Colorado passed enabling legislation to establish the "Water and Sanitation District" concept. The concept provided a method to create a quasi-municipal entity with taxing power to finance and develop water and sanitation systems in the unincorporated areas (DRCOG 1969).

In 1947, the state legislature created the new Department of Public Health, concurrently empowering it to issue orders, adopt rules and regulations, and to establish standards for public health law enforcement. County, city-county, and multiple county health units were also established, but as separate governmental entities subject to Colorado health laws. The creation of these institutions produced a difficult water quality management problem, for while each jurisdiction was local, the pollution problems were regional. In the absence of central jurisdiction, these local health units had not only to cope with their own pollution problems but also pollution from upstream and downstream neighbors had to be considered.

By 1949, there were 45 separate sewer systems along the main stem and tributaries of the South Platte River providing a variety of sewage treatment to their customers (USPHS 1950). By the late 1950s, due to explosive population growth, sewage treatment and disposal had become a major problem. With the enactment of new and more stringent water pollution control laws, a decision was made to form a regional wastewater treatment agency, rather than to try to comply with new laws on a costly individual basis.

In 1957, the Sabin (named after Dr. Rena Sabin, a health reform advocate) State and Local Health Department laws were enacted establishing a standard for domestic sewage (defined as containing human excrement) (Nichols 1972). Effluent standards were established at sewage discharges and which could not contain more than 0.5 milliliters per liter settleable solids, 75 parts per million suspended solids, 50 parts per million settleable solids BOD. These standards made secondary treatment necessary for compliance (HEW 1966). The 1966 HEW study showed that the DNTP was discharging partially treated sewage, digester supernatant, and digested sludge to the river, quickly depriving the Burlington-O'Brian Canal of dissolved oxygen and releasing a septic stream into Barr Lake producing intolerable odors, especially in the spring.

In 1964, the primary treatment at DNTP was further expanded to 106 mgd and a 90-inch diameter conduit was constructed to convey plant effluent to the new secondary treatment facilities operated by the Metropolitan Denver Sewage Disposal District No. 1 (MDSDD) (see Section 4.2). Sludge drying and disposal were eventually discontinued at the DNTP and a new digested sludge pump station and twin 8-inch sludge lines were constructed for pumping digested sludge to the MDSDD plant (CDM 1974). In 1978, DNTP primary treatment facilities and solids handling process were upgraded to include grit washing and dewatering, screenings dewatering, and sludge pumping and digestion system improvements.

In 1984, the operation of the DNTP and the ownership of Denver's common interceptor system (those interceptor sewers handling wastewaters from Denver plus suburban communities) were transferred to the MDSDD (Wingate 1990). In 1987, the completion of the new primary treatment capacity at the MDSDD Central Treatment Plant allowed the DNTP to be closed.

4.2 Metropolitan Denver Sewage Disposal District No. 1

In 1960, the Metropolitan Sewage Disposal Districts Act of Colorado was passed to allow the formation of districts to "*acquire, construct, own, hold, and operate a sewage disposal system to intercept, receive, transport, treat, and dispose of the outfall of sewer systems of municipalities*" (Wingate 1990). The MDSDD was organized in 1961 for the purpose of constructing and operating a wholesale wastewater transmission, treatment, and disposal system to serve most of the Denver metropolitan area. At the time of the District's creation, there were 26 separate sewage treatment facilities in the metropolitan Denver area alone. By 1964, the Metropolitan Denver Sewage Disposal District No.1, entered into a Sewage Treatment and Disposal Agreement with 13 member municipalities. Additional municipalities (including water and sanitation districts) joined the MDSDD over the next 10 years.

In 1984, MDSDD's functions were reorganized to absorb many of the City and County of Denver's wastewater facilities and 25 suburban customers who had contracts for sewage treatment with Denver. By agreement, Denver transferred 113 miles of common interceptor sewers and operation of its 106 mgd DNTP to the MDSDD (Wingate 1990). By 1990, 20 member municipalities were represented on the Board of Directors. In May of that year, the MDSDD changed its name to Metro Wastewater Reclamation District (Metro District).

The Metro District began operation of its Central Treatment Plant (North Complex) in 1966. The plant included screening, grit removal, primary sedimentation, activated sludge, secondary sedimentation, and chlorination. Primary and secondary treatment design capacity for the plant in 1971 were 24 and 117 mgd, respectively (Bluestein 1975). Sludge was dewatered and incinerated with residue disposed at the Lowry Landfill. More stringent air quality restrictions and performance problems caused the incinerator to be shut down and all sludge to be transported to Lowry for incorporation into the soil. In a cooperative research effort with Colorado State University, a program for possible recycling of liquid sewage sludge for fertilizer and soil conditioner was explored.

More stringent state effluent discharge standards, population growth, and equipment problems caused the plant to become non-compliant in 1973. In order to provide more capacity and return to compliance, the South Complex was built in 1976. This addition included eight anaerobic digesters for sludge stabilization and secondary treatment facilities which used pure oxygen in the activated sludge process. By 1976, the Central Treatment Plant consisted of two parallel treatment systems, the North Complex and the South Complex. Each treatment system includes preliminary treatment, primary treatment, secondary treatment, and disinfection facilities. Solids from the North and South Complexes are combined for anaerobic digestion and dewatering for subsequent land application.

The discharge permits issued to the Metro District in December 1986 and January 1987 by EPA and the Colorado Department of Health (CDH), established new discharge standards for partial ammonia removal based on predicted plant performance, as opposed to a permit that established discharge standards based on the water quality of the receiving stream. The ammonia limits were to reduce the extent of improvements required at the Central Treatment Plant while the Metro District monitored the water quality of the South Platte River. The purpose of the water quality monitoring was to determine the need for the permit to contain more stringent effluent standards. The requirements were to become effective with the Metro District discharge permit renewal in 1992. The permits also required treatment processes be provided to reduce chlorine concentrations in the effluent (dechlorination facilities were constructed in 1988, with full dechlorination on line in November 1988). Construction was initiated to add nitrification/denitrification facilities to the North Complex to meet EPA and CDH mandated criteria for ammonia. These facilities became operational in October 1990.

4.3 Water Quality

According to the 1949 census, approximately 618,000 persons were being served by sewer systems that discharged raw or treated sewage into the South Platte River system. About 80 percent were served by primary treatment plants and 11 percent had secondary service; 69 percent of the total serviced community was located in the Denver area. Pollution in the South Platte River Basin was limiting the river's usage for irrigation, recreation, and industrial purposes, and was creating a local nuisance. Although the City and County of Denver constituted the largest single sewage disposal problem, acute sewage problems were also located downstream of Boulder, Golden, and Greeley.

Public Health Service investigations in 1948-1950, and the Colorado State Department of Public Health study of 1956 on Barr Lake, concluded that the DNTP effluent comprised 58 percent of the total streamflow below Denver to Kersey during the summer and 73 percent of streamflow during the winter. The lowest dissolved oxygen conditions and highest biochemical oxygen demand values on the South Platte River, excluding the effects of sugar beet processing wastes, were found downstream of Denver. The average dissolved oxygen in the river during the summer seasons ranged from 3.5 to 8.0 mg/L; average BOD ranged from 5 to 35 mg/L. High sludge deposits were also reported throughout the river system.

A study performed by a group from the U.S. Department of the Interior, Federal Water Pollution Control Administration from Cincinnati, Ohio in 1961-1963, found that streamflow increased 50 cfs from 310 to 360 cfs; total bacteria increased 25,500,000 per 100 milliliters (mL), from 12,000,000 to 37,500,000; coliform bacteria increased 2,400,000 per 100 mL from 100,000 to 2,500,000; BOD increased 84 parts per million, from 6 to 90; Total Dissolved Solids (TDS) increased 120 parts per million, from 430 to 550; and dissolved oxygen decreased 3.5 parts per million, from 7 to 3.5. The study samples were collected over a 25 mile stretch of the river starting 0.2 miles above the DNTP (Nichols 1972).

Systematic studies of bacteria in vegetables and fruits irrigated with sewage-polluted water were initiated in July 1948. Summary results showed that the coliform density of the soil was the same as that of the irrigation waters. Leafy vegetables showed coliform levels equal to or greater than the irrigation water used on them, and root crops, such as carrots, showed high densities of coliform bacteria. "*There are no generally accepted criteria by which the relative safety of irrigation waters may be determined. Sewage treatment requirements and acceptable standards of bacterial purity for waters used for irrigation purposes are now largely a matter of judgment and experience. The use of water in the basin should be governed to a considerable extent by the amount and the quality of water required for irrigation purposes*" (USPHS 1950). But Rule 20 of "Regulations Relating to Sanitary Engineering, Public Water Supplied, Water Purification Plants, Sewer Systems, and Sewage Treatment Plants" under the Colorado State Division of Public Health Laws, Rules and Regulations (Revised 1942), Colorado State Board of Health, Denver, Colorado stated "*No domestic sewage nor water containing domestic sewage in an amount and condition such that bacteria of the coli-aerogenes group (coliforms) are present in quantities of ten or more per cubic centimeter, shall be used to irrigate or be permitted to overflow any fruits or vegetables for human consumption, the edible portions of which grow in the ground or above it within one foot of the surface, except with the written permission of the State Board of Health obtained as hereinafter provided.*" The limiting value for coliform content of water used for irrigation was 1,000 per 100 milliliter, however, the rule was unenforceable and there was doubt as to its legality.

From 1950-1963, the amount of secondary treated wastewater in Colorado nearly doubled. Untreated discharges were reduced by 38 percent. For the year 1953, in the state of Colorado as a whole, 44 municipalities were discharging untreated wastes, 56 were providing primary treatment only, and 37 were providing secondary treatment (Nichols 1972). The major industrial discharger was the sugar beet industry, with a waste stream population equivalent of 1,530,000, attributed to seasonal wastes. Significant contributions were also made by the canning, dairy, and meat processing industries. Findings of the 1942 Joint Committee of the Sanitary Engineering Division and the Irrigation Division of the American Society of Civil Engineers on the Salvage of Sewage indicated that sewage treatment of sugar beet wastes to reduce BOD and TSS by 85 percent, followed by chlorination, would render the wastewater satisfactory for irrigation purposes (USPHS 1950). The Public Health Service also recommended treatment of wastes from the sugar beet processing industry at processing plants located throughout the South Platte River Basin north of Brighton to reduce pollution load on receiving streams by about 80 percent.

In 1961, William N. Gahr of the Colorado Department of Public Health presented a speech to the 128th Meeting of the America Association for the Advancement of Science in Denver. He stated that a portion of the South Platte River in northeast Metro Denver had suffered severe damage because of "*refined gasoline, domestic sewage and industrial waste*" which impacted domestic water supplies, rendered economic losses, and resulted in much inconvenience. He went on to recite several instances of groundwater pollution (Gahr 1961).

By 1963, the pollution problems of the South Platte River Basin had grown to such proportions that Governor John Love called for a conference to investigate them. The purpose of the conference was to locate the sources of pollution that were producing an adverse effect upon water quality; to determine the physical, chemical, and biological responses of the river to pollution; to compute the waste load reductions necessary to obtain desired water quality and to recommend water quality control measures needed to effect the desired waste load reduction. The findings from the conference lead to the development of a pollution abatement program (FWPCA 1966).

The results of the findings and recommendations of the investigations were presented at the second session of the South Platte Conference in 1966. The findings showed that coliform densities exceeded standards for most of the South Platte River and its tributaries, and presented a health hazard to all persons who came in contact with river water. Oxygen demand and resulting low dissolved oxygen levels, were causing near septic conditions in many segments of the river. Suspended and settleable solids had destroyed most aquatic plants and animals and resulted in sight and odor nuisance conditions. Further, pollution in the South Platte River had affected groundwater supplies, a source of domestic water supply. The conference recommended that all wastes discharged to the South Platte River Basin streams be subject to secondary treatment; that certain industries provide pretreatment for their wastes before discharging the effluent into the sanitary sewer system; that others provide treatment prior to discharge into the streams or use preventative measures in the form of berms or ponds to prevent contamination of the stream; and that stream augmentation be part of the pollution process (FWPCA 1966).

In 1969, studies by the Water Pollution Control Division of the Colorado Department of Public Health showed that almost all water drawn from the South Platte River had fecal coliform agents usually found in raw sewage. The study also found acetate, cyanide, selenium, iron, lead, hydrogen sulfide, nitrates, and phosphates in unacceptable concentrations in the river (Denver Post 1969b).

Reports of pollution in the form of accidental spills, untreated discharges, trash dumping, and wildlife hazards were seen frequently in the newspapers: "*Odor of Oil is Heavy Over New Bike Path*" (Rocky Mountain News 1978), "*Acid Spill Kills Fish in South Platte River*" (Rocky Mountain News 1972b), "*Pollution Aides Order Car-Wash Crackdown*" (Rocky Mountain News 1969), "*Stapleton Cited as Top Polluter of Platte*" (Rocky Mountain News 1970b). As these problems arose, attempts were made to address them and prevent recurrence. To address the problem of railroad yard oil seeping into the South Platte River, catch basins, an interceptor, and absorbent booms were used to try to stop the seepage. Unfortunately the soil had absorbed so much oil over the century of the railroad's presence, that the attempts to recover the oil were unsuccessful (Rocky Mountain News 1978).

EPA (1972) in a study of water quality of the South Platte River, concluded that the South Platte River from the Central Treatment Plant outfall to Fort Lupton was severely degraded by the organic pollutant load from the Denver metropolitan area. The report showed improvement from the 1964-1965 studies, but there was still degradation. The organic load from industrial wastes had been reduced 87 percent due to the connection to municipal systems or the construction of industrial wastewater treatment facilities; but the results of the evaluations of municipal wastewater treatment facilities showed that Brighton, South Adams County Water and Sanitation District and the Metro District achieved less than 80 percent BOD removal and inadequate disinfection. The sugar beet industry was still the largest source of industrial pollution in the basin, followed by the oil and refining companies, meat packing plants, railroads, and gravel mining.

The study found that the segment from Exposition Avenue to York Street, classified as a warm-water fishery, had waste sources including numerous storm sewers, and minor industrial discharges. Raw sewage was found entering the river at 47th Avenue and Franklin Streets resulting in fecal-coliform densities averaging 13,000 per 100 mL. This raw sewage was creating sludge banks downstream from those discharges. The rest of the river from York Street to the state line was classified for industrial and irrigation use (EPA 1972).

The Metro District's Central Treatment Plant was implicated to be the major waste source in this reach. EPA contended that adequate treatment was not provided for BOD, nor suspended solids removal, and, there was inadequate disinfection as shown by low chlorine residuals and high bacterial densities. The inadequate primary treatment at DNTP was significantly affecting secondary treatment efficiency at the Central Treatment Plant. The study recommended expansion and improved efficiency of the Central Treatment Plant (EPA 1972). Also, in 1973, the City and County of Denver began a five year program to upgrade DNTP facilities to improve plant performance (CDM 1974).

In 1972, an accidental dumping of 200 gallons of concentrated sulfuric acid from a chemical plant raised concerns about the fish in the river. The acid lowered the pH level to 3 instead of its usual 7 to 8 at W. 13th Avenue and Zuni Street. EPA noted that fish were killed as far as three miles downstream from the point of the spill. Under orders from the Department of Health and Hospitals, the chemical company was subsequently required to dump all its wastes into a holding pond (Rocky Mountain News 1972c).

EPA subsequently proposed a plan to improve water quality of the South Platte River upstream of Denver to allow uses for full-contact recreation, (swimming) and a drinking water supply. The objective was to cut fecal coliform levels in half by December 1973. In addition, the EPA plan called for improving the water quality downstream of Denver to the state line, to permit the development of a warm water fishery and a drinking-water supply. EPA endorsed state water quality standards and required compliance by the end of 1976. EPA also required the state to change its definition of beneficial uses to include fishery resources and recreation (Denver Post 1972).

In 1974, the Platte River Development Committee, a coalition of government, commercial interests, and private citizens, actually began clean up of the banks of the South Platte River in Denver. Four demonstration sites were turned from trash dumps into greenbelts and parks (Rocky Mountain News 1974a; Shoemaker 1981).

Despite these successes, it was found that stormwater pollution was also a problem. Legislation such as the 1966 Federal Clean Water Restoration Act, and the 1972 Federal Pollution Control Act Amendments placed new and stronger emphasis on stormwater pollution. Runoff from precipitation and snowmelt were found to contribute suspended solids, chemical oxygen demand, coliform bacteria, and lead in concentrations equal to or greater than those same pollutants from secondary effluent from an equivalent sized area. Suggestions to lessen stormwater pollution included air pollution control, solid waste management, erosion control, chemical controls, catch basin cleaning, improved effectiveness of street sweeping, and control measures to reduce the quantity or rate of stormwater runoff, e.g., onsite storage, porous pavements, and treatment of urban stormwater (Bennett 1978).

The river was still being used as a dump. Slabs of concrete, cars, tires, refrigerators, even the shells of cement trucks could still be found on its banks (Rocky Mountain News 1984c). Pieces of sheet insulation found in and near the river were traced to a lumber firm (Rocky Mountain News 1984b).

In 1980, the Colorado Water Quality Control Commission began setting numeric pollution limits for the South Platte River and its tributaries (Rocky Mountain News 1980). By 1985, water quality models were being used to determine the effects of pollution in the South Platte River. The USGS and the cities of Littleton and Englewood reported the results of a study on the effects of the Bi-City Wastewater Treatment Plant (BWWTP) effluent on the river along a 14.5 mile reach. Two groups of simulations were used. In one group, effluent discharge and 5-day Carboneous Biological Oxygen Demand (CBOD) concentrations were varied in the model; the other group had a varied effluent concentration of total nitrate nitrogen and total ammonia nitrogen. The results showed that when 5-day CBOD effluent concentrations increased, the minimum simulated dissolved oxygen concentrations downstream were lowered. Simulations made with different amounts of total nitrogen in the nitrate and ammonia form showed that as more nitrification took place within the BWWTP, lower total ammonia-nitrogen concentrations occurred in the river. Using a range of pH values, unionized ammonia concentrations were modeled to be higher than the existing temporary stream standard during warm water conditions (USGS 1985).

In 1986 and 1987, the Metro District received its discharge permits (federal and State) for the Central Treatment Plant. The permits required the Metro District to upgrade its wastewater treatment facilities to meet recently adopted stream standards for Segment 15. Of particular importance to the Metro District were the requirements to improve the treatment process to meet the newly adopted dissolved oxygen, chlorine, and ammonia standards for Segment 15. Additionally, the Metro District, through a requirement by EPA Region VIII, was to initiate biological and chemical monitoring in Segment 15 at selected locations. This information was to be used to evaluate the biological integrity of the river and gather data for the development of a site-specific water quality model. The model was to be used to evaluate the proposed improvements to water quality from the Central Treatment Plant and to determine what additional improvements should be made to ensure dissolved oxygen and unionized ammonia levels were not being exceeded in the river.

In conjunction with this work, the Metro District initiated their Incremental Assessment Program to evaluate the improvements to water quality and the biological integrity of the river. Under this program, the Metro District collected water quality data and biological data (fish and macroinvertebrates) prior to dechlorination, after dechlorination; prior to partial nitrification in the North Complex, and after partial nitrification was online. The purpose of this program and the ensuing studies was to determine the incremental improvements to water quality and aquatic life after each process was modified, to evaluate which improvement(s) had provided the greatest benefit, and to determine if additional nitrification at the plant would be necessary to achieve desired water quality conditions.

The Colorado Water Quality Control Divisions' 1986 annual report identified Segment 15 of the South Platte River as being moderately impaired by low dissolved oxygen, fecal coliforms, unionized ammonia and heavy metals. This report was followed by another report in 1989 by the Denver Regional Council of Governments (DRCOG) which stated that water quality in Segment 15 had shown an improvement in quality within the previous five years due to steps taken by the Metro District to improve effluent water quality. McMahon, et al. (1993) in their studies for the USGS and the Metro District, found that the groundwater seepage to the river is being stripped of dissolved oxygen as it flows upward through the bottom sediments. The rate at which this groundwater flows into and out of the sediments is dependent upon the variation in effluent discharge rates at the Central Treatment Plant. The USGS studies also concluded that surface waters cycling through oxygen stripping bottom sediments may have an impact on dissolved oxygen concentrations in the overlying surface waters.

4.4 Water Management

4.4.1 Overview

The continued development of South Platte River Basin water resources impacted the regime in the South Platte River as it flowed through the Denver metropolitan area. Further development of surface water supplies for drinking water, commercial and industrial development, flood control facilities, and gravel mining operations considerably changed flow conditions in the river.

In 1940, the major water usage in the basin was for agricultural purposes. A population of approximately 418,000 was being served from surface water supplies. By 1950, the basin water resources, consisting of surface, ground and transmountain diversions, supplied about 2,800,000 acre feet of water for municipal, industrial (including manufacturing and railroad use), agricultural, and hydro-electric purposes.

Surface water supplies to Denver included those from the South Platte River and Fraser River. Approximately 70 percent of the supply came from the South Platte River together with Bear Creek and Cherry Creek, from the intake at Platte Canyon, Bear Creek intake at Morrison, and the Cherry Creek infiltration galleries at Sullivan (USPHS 1950). The biggest water project of the century to augment supply to the South Platte River Basin was the Colorado-Big Thompson Project. Begun during World War II with Federal Funding, this massive project included 13.1 miles of tunnel excavated through the Continental Divide. Its purpose was for irrigation supplementation (Tyler 1992).

For further municipal supply augmentation, expansions were made to the Fraser River collection system; the Ralston and Gross Reservoirs were constructed for storage and regulation of flow diversion. The Vasquez Tunnel was completed for diversion of headwaters of the Williams Fork River to the Fraser River collection system; and enlargement of Williams Fork Dam and Reservoir,

originally constructed in 1938, provided replacement water to the Colorado River to meet downstream senior requirements while Denver was diverting from its junior rights on the Fraser, Williams Fork, and Blue Rivers. In 1963, construction was completed on Dillon Reservoir and the Roberts Tunnel to again expand Denver's system.
Two Forks Dam had been on the list of recommended projects since the late 1930s. However, pressure by environmental groups in the late 1980s and early 1990s encouraged EPA to veto permits required for its construction. Conservationists wished to see the South Platte River, as it runs between Cheesman Reservoir and the Two Forks site, protected and left as a free-flowing river. Others said the dam would provide for more recreational opportunities if it were built, not to mention the additional water storage potential (Rocky Mountain News 1989b). In 1989, approval for this storage project was denied.

4.4.2 Commercial and Industrial Development

During the period from 1939 to 1964 agriculture was a primary activity in the South Platte basin. But by the late 1940s and early 1950s, manufacturing and attendant peripheral service industries began to be the major employers, as better farming methods and less land in production provided fewer employment opportunities in agriculture (Colorado Interstate Gas Company 1960).

Because the central South Platte River valley developed as a railroad hub just before the turn of the century, a broad range of industrial activities related to that industry such as ore mills, foundries, and fuel depots grew up along the South Platte River during the middle third of the 19th century. As the valley around the South Platte River through Denver became more industrialized, it became less aesthetically attractive, and it became a more convenient location for landfills. Four landfills were located in the area between East 22nd Street and East 27th Street. Research indicates that the landfills were operating in the 1950s before widespread use of most hazardous organic compounds.

In the late 1960s, the central valley in Denver was ten miles long, one mile wide and comprised ten percent of the city's land area. The river divided Denver nearly in half. The river valley had several problems in addition to flooding and pollution. The internal street system was inadequate, and circulation was complicated by extensive rail facilities and tracks. New and old industrial and residential functions were intermingled. Much of the land was vacant or improperly used.

Dumping of burned trash along the South Platte River was common. Most of the valley was unattractive and provided a poor physical environment. Consequently, it was generally avoided by people and business. "*It is an unsightly and uneconomic scar across the center of the city*" (DCUD 1966). Drop structures, constructed to allow diversion of irrigation water throughout the course of the river, disrupted the flow and increased the flood potential. The river banks were poorly maintained and nearly all protective and attractive vegetation had been removed from the channel and surrounding areas. "*The social environment in the valley is among the poorest in the city except for several of the more cohesive neighborhoods. People living and working in the valley have less cultural and recreational opportunity than people in any other section of the City. The valley, in general, is an undesirable area of the City in which to live and work*" (DCUD 1966).

4.4.3 Flood Control

The U.S. Army Corps of Engineers (COE) had been investigating and implementing flood control methods since 1931 (COE 1984). Their first efforts centered around the control of flooding on Cherry Creek. The restoration of Castlewood Dam and the construction of a reservoir on lower

Cherry Creek were authorized twice by the Flood Control Acts of 1941 and 1944. The Cherry Creek Dam was completed in 1953 and controlled 385 square miles of the Cherry Creek watershed. Its storage capacity was 177,000 acre feet.

Other projects of the COE included completion of the Kelly Road Detention Dam in 1954 to provide flood protection for portions of Aurora and Denver. Corps-suggested projects during this time included Chatfield Dam and Reservoir, Mount Carbon Dam and Reservoir, and Sand Creek Basin dams. The Bureau of Reclamation recommended Two Forks Dam and Reservoir, and assorted smaller projects on Cherry Creek, Plum Creek, Bear Creek, Clear Creek, and North and South Boulder Creeks. Other watershed projects for flood and erosion control were either completed or proposed by the Soil Conservation Service throughout the basin (ICRPC 1967).

Despite all planning and enhancement of water control projects, the specter of the 100 year flood still haunted the basin. On June 16, 1965, more than 14 inches of rain fell on portions of the Plum Creek watershed in a few hours creating extreme flood conditions (150,000 cubic feet per second) in the South Platte River resulting in widespread and costly damage to Littleton, Englewood, Sheridan, and Denver. The most severe damage was from widespread inundation, crest action, and damming action of debris at bridges. Every bridge south of Colfax Avenue was damaged. The bridge-dams caused the debris-laden waters to spread out around them into the cities, damaging and destroying residences, commercial and industrial buildings, and threatening disease. Parts of Interstate Highway 25 were buried by tons of silt from the 12 feet of water that had covered them. Although there was widespread flooding, structural damage throughout the area was minimal. Direct and indirect damages were estimated at $325 million. Cherry Creek Dam was credited with the prevention of $130 million in flood damage.

Plans for a dam above Littleton at the South Platte-Plum Creek confluence had been approved by the United States Congress in 1950, following recommendations by the COE in 1945, but no funds had been appropriated. Following the 1965 flood, the construction of a dam at that location to prevent a similar occurrence naturally garnered public approval. Funding was provided, and the construction of the Chatfield Dam was initiated with completion in 1975 (SSMRPD 1982). The completion of Bear Creek Dam and Lake on Bear Creek (previously called Mount Carbon Dam and Reservoir), about eight miles from its confluence with the South Platte River, occurred a few years later.

Following the 1965 flood, large scale flood control study plans for the South Platte River from Littleton through Denver were initiated and proposed, but relegated to the files by the time a new entity, the Greenway Foundation, came on the scene (Shoemaker 1981). The Greenway Foundation proposed and implemented aesthetic improvements coupled with flood control facilities to the South Platte River along its reaches through Denver and along Cherry Creek.

In further efforts to manage the river and continue the work begun by the Greenway Foundation, the Urban Drainage and Flood Control District, in 1983, along with 14 local sponsors and 7 project advisors, began another master drainage planning study of the South Platte River from Chatfield Reservoir to Brighton. The objective was to develop a plan to optimize the uses of the river corridor. The goals of the study were to reduce future flood damage, to exploit the potential of the river corridor for parks and recreation, and improve wildlife habitat and riparian vegetation. The plan, finished in 1985, contained several elements. The Phase A report supplied detailed engineering, recreational, and landscaping research and analysis of several alternatives. The Phase

B report consisted of two volumes showing the preliminary engineering design and the recreation plan for the selected alternative (UDFCD 1985).

Recent studies of flood control on the river have increasingly been coupled with the need to improve water quality to the extent that aquatic life may be restored. However, there are conflicts between flood control practices and aquatic life use potential. For example, fish habitat structures such as dams (to create pool habitats), boulders, etc., could possibly decrease the channel's capability to handle flood stage flows (ERT 1985).

4.4.4 Gravel Mining

Gravel mining has been a major economic force in the South Platte River Basin since the early 1900s. In 1907, the USGS Mineral Resources of the United States reported that in 1906, sand production was 48,206 tons, but gravel production was zero. One year later, 51,951 tons of sand was produced and 16,102 tons of gravel was mined (USGS 1907). By 1956, the importance of the industry caused the USGS to review gravel production by county. Adams County was the largest producer of sand and gravel in the state of Colorado. That year, a river sand and gravel deposit at the junction of Clear Creek and the South Platte River five miles north of Denver motivated the founding of the Inland Sand & Gravel Co. The company's plant was designed to handle an input of 300 tons per hour and average 100 tons per hour of finished products. It had the first large hydraulic dredge in the area. The dredge was the only one operating at that time on the South Platte River north of Denver (USGS 1955-56).

Gravel production on the South Platte River continued to increase. Total gravel tonnage for Colorado in 1956 was over 15 million tons (USGS 1955-56). By 1979, the amount of sand and gravel sold or used by producers in Colorado was nearly 26 million tons (USGS 1980). The largest producers of sand and gravel in the South Platte basin were Mobile Pre-Mix Sand and Gravel, Flatiron Sand and Gravel, and Cooley Gravel with production sites all along the corridor of the Platte.

In the 1970s, during a period of heightened environmental awareness, a proposal to extract sand and gravel in the Denver metropolitan area was met with heated public controversy. The proposal brought about the sharpest conflict ever over land-use decisions, apportioning land among urban use, sand and gravel recovery, and scenic preservation (USGS 1980).

The main concern regarding pollution from the gravel mining industry at the time was the silting resulting from the unregulated drainage discharge from the mine tailings. Settling ponds were generally in use and dilution by the streams was thought to reduce the concentration of the waste constituents to practically negligible proportions. Gravel mining criteria and standards had been developed along with the 1985 flood control plan to provide for protection of the river in Adams County. Management and criteria enforcement were required to ensure that gravel mining did not result in damage to structures or channel degradation in times of flooding (UDFCD 1985).

There was some concern about the many gravel pit lakes along the Adams County stretch of the South Platte River particularly in the vicinity of 88th Avenue and 104th Avenue. The concern was that the thin earthen dams separating the gravel pits from the river could break, creating flooding conditions downstream (Rocky Mountain News 1984a). There were also concerns about the flood plain in the vicinity of these gravel pits.

Gravel pit lakes were found to provide good habitat for fish and wildlife, and recreational opportunities. Numerous pocket parks located along the river used gravel pits as a resource; some were stocked with fish by the Colorado Department of Wildlife. Studies of aquatic wildlife using gravel pit lakes found that three characteristics of gravel pits influence duck use: surface area, mean bank height-to-surface area ratio (a higher bank tends to block the duck's view), and mean density index of submerged food plants (especially in the fall). While summer use by adult ducks was negligible, the gravel pits offered migratory habitat. Studies found marginal vegetation around the gravel pits. Recommendations included using the lakes for migratory habitat for dabblers and divers, and for mallard brooding and molting habitat (Blomberg 1982).

Section 5
Recent Developments and Conclusions

5.1 Water Quality

Current major water quality issues of the South Platte River include the effects of point and nonpoint sources receiving-water biology, sediment and nutrient loading, heavy metals, organic chemicals, and bacteria. Also of concern is the degradation of groundwater from point and nonpoint land use sources; deterioration of groundwater quality as a result of induced infiltration of degraded surface water; the effects of present and past mining practices on the biological and chemical quality of the river; and the naturally occurring trace elements and radionuclides in groundwater (USGS 1991b). These issues, along with other physical changes and the altered flow regime, make the South Platte River unique. Harris (1993) concluded that the South Platte River is indeed unique, as it has two watersheds (or sources of headwaters): one which drains the mountains, and the other which drains the homes, business, and farms of the Denver metropolitan area.

Data over the past 25 years shows significant improvement in water quality of the South Platte River below the outfall of the Metro District's Central Treatment Plant. This segment of the river has been traditionally one of the most impacted in terms of quality, and has undergone extensive studies in the last eight years. As discussed previously, the Metro District has undertaken an extensive sampling program to evaluate the ecological integrity in Segment 15 of the South Platte River. This work has been conducted in conjunction with major plant improvements at the Central Treatment Plant, which have measurably improved the water quality in Segment 15. In recognition of these efforts, the Metro District was given a special award for environmental progress by EPA in 1992.

In 1992, the Metro District began the Segment 15 Studies and Improvements Project to help determine the causes of low levels of dissolved oxygen in certain areas of Segment 15 and evaluate methods to eliminate dissolved oxygen problems in the river. The Nitrification Alternatives Study of 1991 explored alternatives which would solve the dissolved oxygen problem without necessitating the construction of nitrification/denitrification facilities at the South Complex. The Nitrification Alternatives Study concluded that ponding in the vicinity of the 88th Avenue was causing a significant dissolved oxygen sag. The compliance schedule in the Metro District's NPDES permit mandated predesign and final design of stream channel modification to eliminate this dissolved oxygen sag (CDM 1992b). In addition, the Metro District conducted effluent management studies to evaluate alternative reuse strategies which would improve dissolved oxygen levels in Segment 15, and provide member cities with a water resource benefit (CDM 1994).

Biological field studies (i.e., habitat and community structure), were conducted to determine if low dissolved oxygen in the river or other conditions were negatively impacting the fish community.

Laboratory studies were also performed on resident fish species to determine their tolerance to diel fluctuations in dissolved oxygen, which mimicked the diel dissolved oxygen variation in the river. These studies were conducted for early and adult life stages of the fish.

5.2 Current Limitations to Aquatic Life in Segment 15

There have been major improvements in the water quality from point sources in the South Platte River over the last 25 years. These improvements have created positive changes in the fish community. Other factors, such as habitat and flow regime, may now be the controlling factors affecting the fish community in Segment 15.

Aquatic habitat in the segment is limited due to steep banks. These river banks are sometimes protected from erosion with riprap consisting of discarded concrete and abandoned automobiles. This bank protection increases the velocity of the river, limiting the available habitat for aquatic life. The river also experiences a diel (24 hour) variation in stage height with respect to flow. Discharge of effluent from the Metro District is high during the day and low at night resulting in alternating creation and elimination of habitat for aquatic life and the resuspension of organic matter. The river in the upper segment flows through a narrow channel consisting of a cobble-gravel substrate. The lower segment has a wide-meandering stream with shifting sand bottom. This broad sand bottom limits the development of diverse benthic macroinvertebrate and algal communities, both of which are important food sources for other, higher level, aquatic organisms. As the groundwater flows upward through the sediments into the river, the segment is affected by the stripping of dissolved oxygen (USGS 1993).

The dominant substrate type within Segment 15 was found to be fine gravel/sand. Although limited, the presence of aquatic vegetation was found to be well distributed throughout the segment. Snags and debris were found on an average of 9.4 items per mile (CDM 1992a). A flooding event in late August 1992, demonstrated the dynamic changes that can occur during times of high water. Snags were transported downstream of the segment, single channels were formed where secondary channels had formerly been dominant, areas previously having high density of aquatic vegetation were swept clean, bed material shifted from sand/fine gravel to coarse gravel and vice versa. Habitat types within local areas changed dramatically as a result of this flood event (CDM 1992a).

The uniqueness of Segment 15 habitat has allowed for the colonization of those species that are present in the river today. Goettl (1982) concluded in his study that water quality in the South Platte River was adequate to support good fish populations, but that the habitat was not sufficient to support desirable game species (e.g., largemouth bass). Similarly, Fausch and Schrader (1987) indicated in their study that limitations in habitat quality have affected the biotic integrity of fish communities in front range rivers, more so than water quality. More recent studies conducted by CDM, et al. (1993c) suggest that habitat, river flow regime, and barriers to fish migration are limiting factors for a diverse fishery in the South Platte River, particularly in Segment 15.

5.3 Current Uses Segment 15

The South Platte River, with its many tributaries, crosses a number of political boundaries which leads to a problem of interagency coordination. The Greenway Foundation, a private group, was formed to facilitate river revitalization for recreational uses. The foundation works with several agencies having jurisdiction along the river and has fostered cooperation. The foundation's major accomplishment has been to acquire riverside open space for recreational and wildlife use, thereby curtailing urban encroachment on the river corridor. The work of the Greenway Foundation has been upstream of Segment 15. Downstream in Segment 15, Adams County has extended the improvements through the addition of bike paths and installation of parks and access areas.

A recent study conducted by the Metro District on waterfowl use downstream of the Central Treatment Plant discharge, concluded that numerous migratory waterfowl were using this reach of the river during the winter months (WEST 1993). Along with the higher water temperatures, the nutrients being discharged in the effluent have stimulated algal growth in the river, providing an excellent food supply for waterfowl. The large number of waterfowl have attracted numerous birdwatchers to the area. The Colorado Division of Wildlife considers this area an important staging area for winter waterfowl.

The South Platte River corridor, as it traverses the Denver metropolitan area, has undergone significant changes in the last ten years to accommodate the recreational desires of its citizens. The bike pathway that parallels the river has become a popular attraction, and has increased visitor use to the river. Channel modifications have created areas for kayaking and rafting. Although the users of river may find enjoyment from these new recreational opportunities, it is not without impact (e.g., streambank protection to protect bike paths) to the aquatic and riparian wildlife that use the river.

5.4 Conclusions

The South Platte River Basin as it appears today was formed in the Mesozoic Era of geologic time. The South Platte River's headwaters lie near Fairplay in the south central mountains of Colorado. After descending to the plains near the city of Littleton, the river moves north past Denver then east to Nebraska where it meets the North Platte River to form the Platte River. Before the influence of man in the basin, the stream flow of the South Platte was seasonal in the extreme with flooding in the spring and early summer that spread out over a wide and braided river bed. During the late summer, fall, and winter, near drought conditions resulted in little or no flow to the plains regions of the river. With the advent of massive irrigation projects by early settlers, the hydrology of the South Platte River changed from an intermittent to that of a perennial stream. This change was caused, in part, by return flows from infiltration of irrigation waters and from water storage projects which allowed release of the stored waters in times of low flow. Rapid development of the basin in the late 1800s created a greater demand for water supply for projects utilizing transmountain water resources and necessitated increasingly complex water legislation to manage limited resources.

Water quality concerns through the 1930s focused mostly on drinking water supplies; during this time the water quality of the river suffered from discharge of untreated or partially treated wastewater. Vociferous protests were made over the quality of the water as it flowed past Denver downstream to other communities, but it was not until the late 1930s that the first wastewater treatment plant was constructed. From the time of construction of the first wastewater treatment plant in 1937 to the present, the ability of the community to deal with pollution in the river has lagged behind the legislative and environmental necessity to do so. Scientific analysis techniques improved from the 1880s when water pollution was measured in "grains of putrid matter per gallon" to sophisticated computer modeling to forecast pollution impacts and management strategies. Wastewater treatment techniques advanced from simple primary treatment to nitrification/denitrification in order to control the ammonia content of the receiving waters.

Water quality control is progressing toward a total river management philosophy which attempts to take into account water quality, water quantity, aquatic resources, aquatic and riparian wildlife habitats, as well as the impacts of flood control methods and streambed stabilization activities. In addition to all the components of water quality mentioned above, is the overriding factor of water appropriation. The development of the arid west was built on the necessity to share and manipulate its precious liquid resource; present and future pollution control measures must take appropriation into consideration.

The South Platte River is unique. It drains a watershed that historically has seen intense development and use; in turn there has been a significant impact on the aquatic resources of the river system. Although Segment 15 is an effluent-dominated stream, the current perennial flow regime has offered some benefits over the historical intermittent flow regime. The fish community present in Segment 15 today is probably just as diverse as it was prior to the arrival of early settlers into the region. Although some of the fish species present today may be different, many of the species observed in the late 1800s are still present. Some species found downstream of Segment 15 (e.g., red shiner, bigmouth shiner, brassy minnow) may have been present historically, but the long period of poor water quality plus habitat modifications may have contributed to their demise in this segment. Although these species are found downstream of Segment 15, the placement of irrigation diversion dams may have prevented them from moving upstream into the segment.

Future development in the South Platte River Basin should be based upon sound management decisions that consider both the needs of the public and of the river. By developing a sound approach to watershed management with an understanding of the uniqueness of this watershed, the ecological integrity of the South Platte River will continue to improve, providing a most valuable resource for all.

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