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Sustainable Riparian Restoration - The Utilization of Sewage Effluent to Construct Wetlands along the Rio Grande: A String of Pearls Approach to Replenishment

Michael Earl Landis

University of Texas at El Paso, shadowmayor@sbcglobal.net

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SUSTAINABLE RIPARIAN RESTORATION - THE UTILIZATION OF SEWAGE
EFFLUENT TO CONSTRUCT WETLANDS ALONG THE RIO GRANDE
A STRING OF PEARLS APPROACH TO REPLENISHMENT

MICHAEL EARL LANDIS

Environmental Science and Engineering

APPROVED:

W. Shane Walker, Ph.D., Chair

Irasema, Coronado, Ph.D.

William L. Hargrove, Ph.D.

Julius J. Simon, Ph.D.

Benjamin C. Flores, Ph.D.
Dean of the Graduate School

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Michael E. Landis

2012

Dedication

This work is dedicated to my dear departed mother, Mary Louise Fuller Landis. For I truly see the world through her eyes. She taught me to always question, to seek laughter in the darkest of times, and to appreciate the little things in life that often are the most important.

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A STRING OF PEARLS APPROACH TO REPLENISHMENT

by

MICHAEL EARL LANDIS,
B.A. Biological Sciences, B.S. Civil Engineering, M.S. Civil Engineering

DISSERTATION

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for the Degree of

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Chair – Dr. Shane Walker, Dr. William Hargrove, Dr. Irasema Coronado, Dr. Jules Simon plus Dr. Vanessa Loughheed and Dr. John Walton

A special tribute must be paid to my wife, Catherine Ann for her support and her patience on this long and winding road. And to our children: Daniel Patrick, Aaron Ray, Zachary Quinton, and Rachel Clare - know that I have been blessed. We get to pick our mates in this world, but children come as they are. We couldn't be more fortunate in this regard.

I owe a special “Thank You” to Osvaldo A. Broesicke for his dedication and effort on the Sunland Park Wetlands proposal. He will make a fine engineer.

And I am most grateful for the help and support provided by the City of Sunland Park, especially the Utilities Section. Carlos Arellano in particular, went out of his way to help me with my research.

As can best be determined, the first to coin the phrase – “String of Pearls” is Dr. Jack Stanford, with the University of Montana and the Flathead Lake Biological Station.

Abstract

The Rio Grande, from Elephant Butte Dam to El Paso, has been transformed from a free-flowing wild river into a highly engineered irrigation system. The Rio Grande Project, authorized by Congress in 1905, mandated the Bureau of Reclamation to store and deliver water exclusively to farmers. The river, maintained by the International Boundary and Water Commission, has been straightened and channelized between levees. The laws and policies governing the use of the waters of the Rio Grande are prohibitive to ecological restoration. Prior Appropriation doctrine allows for the exclusive use of these waters.

One sustainable tactic for replenishing the denuded riparian corridor is the “string-of-pearls” approach, where specific sites are chosen for riparian restoration. Selected areas could be developed producing a sequence of wetlands, much like a string of pearls. These efforts must incorporate the environmental, social, and economic dimensions of sustainability to be truly effective.

As a case study, the City of Sunland Park, New Mexico has both land and water resources available for a constructed wetlands park. Their sewage plant discharges directly to the Rio Grande providing a steady, reliable stream of treated effluent that could be put to beneficial use. Migratory birds, indigenous flora and fauna, and people would again be drawn to the Rio Grande. In an economically disadvantaged area devoid of riparian features, a wetlands park could recreate one small green pearl in a landscape that was historically covered with riparian forests and wetlands. Potential benefits include improved water quality for the river, and the creation of an attractive park setting.

The goal of this investigation is to demonstrate the viability and sustainability of a constructed wetlands park utilizing treated sewage effluent. Cultivation of just one “pearl” could lead other communities to create new wetlands up and down the Rio Grande.

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Chapter 1: Introduction

1.1 Motivation

Picture a river valley in the desert; fertile and verdant. This valley is extremely productive, providing hundreds of millions of dollars in agricultural products. The irrigation works are managed efficiently and modeled upon the historic acequias (an ancient idea borrowed from the Old World Moors through their influence on the Spanish), or community ditch systems employed in northern New Mexico and Colorado. Waters applied to the fields drain back to the river from whence they came to be shared and reused by downstream farmers. The salts in the land are dissolved and flushed through the valley. Salinity levels remain stable and low. Today, the valley is greener in total than at any other period over the last several centuries. Upstream storage allows waters to be captured and held to provide water for the farms in times of drought. This valley can remain productive and sustainable as long as the snows arrive in the mountains to feed the river. It has become one of our nation's most spectacular success stories, a reclamation project where the river has been tamed, the desert seemingly conquered, and with crops being grown in abundance year after year.

Now picture a river valley in the desert; more a channel than a river. Gone are the meanders, oxbows, cienegas (marshes) and bosques (forested banks). Trapped between walls of levees, channelized and straightened, the river has become a giant irrigation ditch. The riparian character of this river has disappeared along with most of the wildlife previously found along its banks and in its waters, including sixteen species of native fish that have been extirpated (Stotz 2000). The river is turned on and off according to the plans of the farmers and river managers, and for many months each year the river bed runs dry. Little recreation occurs in this river. Many think the water is polluted and unsafe for fishing and swimming and most of all, for drinking. People of the valley no longer pay much attention to the river in their day to day lives. The notable exception occurs when fears arise during flooding events. Then fear of flooding runs high and the citizens clamor for bigger and higher levees to contain this nuisance river. But until the river is fully encapsulated in a giant pipe, there will always be those spots, few and far

between, where the old river makes an unexpected appearance. Some of the cottonwoods and willows that used to line the corridor of this valley sprout and thrive. The beaver is known to make an occasional appearance, only to be quickly trapped, but other critters and creatures formerly found in abundance have managed to eke out an existence between the farms and cities and people.

Picture these two rivers and the valleys they feed: one river providing valuable water that makes the valley a desert paradise, the other devoid of life and much of its original beauty. These two rivers, they are one in the same, the mighty Rio Grande flowing through the Mesilla Valley in southern New Mexico. A valley utilizing and diverting the flows of the Rio Grande as it passes through New Mexico on its way to Texas and eventually to the Gulf of Mexico.

This Rio Grande in southern New Mexico and far west Texas is neither “rio” nor “grande.” It is no longer a much of a river, nor is it large or fierce as its appellation would indicate. Controlled by dams and irrigation schedules, the water flows through a well manicured channel; treated exclusively as a commodity of conveyance for growing crops in the upper reaches of the Chihuahuan Desert.

For decades the riparian health of this river has languished under the whims and rhythms of the irrigation seasons. The public has grown fully accustomed to water arriving in the spring and being shut off in the fall. There has been little outcry over the state of our river. Environmental considerations were not part of the equation when dams were being erected and farmers and citizens were far more concerned with preventing flood damage and storing water for times of drought.

The fundamental question remains, what is a river? Common definitions include: a natural stream of water of usually considerable volume, a watercourse; or a large natural stream of water emptying into a large body of water, as an ocean or lake, and usually fed along its course by converging tributaries. Under these characterizations, it can be argued that the Rio Grande from Elephant Butte Dam through the El Paso Valley is hardly a natural river anymore. In fact, the Rio Grande in the Mesilla and El Paso Valleys has been transformed into a well-

managed irrigation ditch. These changes were deliberate, and part and parcel of this process has always been the ownership of the waters of the river.

Below El Paso, lies the two hundred mile stretch of river running from the Fort Quitman gaging station down to the border towns of Presidio, Texas and Ojinaga, Mexico. This sparsely populated and rugged section of the Rio Grande is known as the “Forgotten River”. Perhaps the portion of the Rio Grande conveyed from the Elephant Butte and Caballo Dams down to El Paso and Juarez; waters that fall within the Rio Grande Project operated by the federal Bureau of Reclamation, is deserving of a new epithet, “The Abused River.”

Engineering this river to suit irrigated farming needs has produced some remarkable results. The consequences of taming the Rio Grande are positive when water is viewed merely as a commodity; the farmers have a fairly reliable supply of water and flooding has been abated. The irrigation districts in New Mexico, Texas and Mexico have prospered. From a farming perspective, the Rio Grande Project is quite profitable, and controlling the river is necessary and justified. Ecologically, the river is managed as a large irrigation canal, as shown in Figure 1.



Figure 1 The Bed of the Rio Grande at the Start of the 2012 Irrigation Season

What is truly disturbing and much less acknowledged, are the severely negative effects. When examined from an ecological perspective, the river has been placed on life support: fish have been extirpated, wildlife is scarce and migratory birds have seen their traditional resting grounds eliminated. The human connection to the Rio Grande has been severed, and in an area encompassing a population of nearly two million people, only a very small number see the Rio Grande as a destination site, a place to enjoy the river and see what remains of the wildlife and amazing riparian beauty that can still be found in patches. The environmental situation is dire, and the socio-economic context surrounding the river is far more complex than the singular attitude regarding the river as a resource to be fully exploited.

1.2 Research Goals and Objectives

The Rio Grande is a victim of the Law of Unintended Consequences writ large. There exists a desperate need for projects designed to restore and replenish some semblance of riparian character back to what once was a wild and untamed river. The goal of this research is to develop a sustainable model for restoring riparian habitat along the Rio Grande, and This goal is accomplished by meeting the following objectives:

1. Examine and evaluate the history, policy, and ethics that led to the present unsustainable condition on the Rio Grande to clarify potential restoration solutions.
2. Evaluate the feasibility of creating wetlands utilizing treated sewage effluent, integrating the engineering, ecological, and economic aspects of sustainable riparian restoration.
3. Synthesize a string of pearls approach for restoration of the entire Rio Grande using the triple bottom line model of sustainability.

In order to address and investigate the broad range of issues tied to restoring the Rio Grande in a sustainable manner, this dissertation will be partitioned into three distinct chapters. First, the status quo is reviewed and critiqued. Second, a “single pearl” engineering, ecological,

and economic case study of Sunland Park, NM is provided. Third, is the synthesis of a sustainable restoration model for the entire Rio Grande. .

The efficacy of this model will hopefully evolve into a global system of restoration for the greater Rio Grande watershed, one pearl at a time. A truly sustainable outcome would be the cultivation of many constructed wetlands along the river, producing a “string of pearls” or restoration sites for a river currently bereft of any significant riparian habitat.

Chapter 2: The Law of Unintended Consequences and the Roadmap to Replenishment

2.1 Introduction

While the waters of the Rio Grande below Elephant Butte Dam are effectively managed for irrigation purposes, a steep price has been extracted on the riparian corridor. The results of the established policies have produced severe habitat losses, disconnections between different ecosystems, and a tragic loss of biodiversity. The present situation is not conducive to any semblance of a healthy ecological landscape and is not a sustainable legacy for future generations.

2.2 Problem Statement

Given that the riparian ecology has been decimated by our engineering efforts to control the Rio Grande for agricultural purposes, are there effective restoration strategies that can be implemented for this river below Elephant Butte Dam? A truly sustainable effort must account for the social and economic dimensions of development and not focus solely on the ecological.

2.3 Goals and Objectives

Restoring and reclaiming the native riparian habitat along the Rio Grande in Southern New Mexico and Far West Texas using sustainable and integrated management techniques is the overarching goal of this research. The objectives of this research are to:

- (1) Provide a review of the historical conditions and degradation of the Middle Rio Grande including the laws and policies that have brought forth these effects;
- (2) Evaluate the needs for restoration and sustainable management of native riparian habitat;
- (3) Propose practical solutions for restoration and replenishment incorporating the social, economic, and ecological dimensions; the three pillars of sustainability.

2.4 Historical Conditions & Degradation of the Rio Grande

2.4.1 Historical background of the Rio Grande

There have been a number of accounts and reports on the Rio Grande dating back to the time of the first Spanish explorers in the 16th century. When Europeans came upon the Rio Grande of the El Paso and Mesilla Valleys, they saw a diverse, patchy landscape covered with large groves of cottonwoods and thick stands of willows. The meanders in the river and the oxbows that were cut-off from the main river channel were numerous and full of an abundance of marshes filled with reeds (Gallegos, 1927). The aquatic and terrestrial landscape was home to many large mammals such as wolves, deer, turkeys, and even bears. Only the deer remain and their numbers along the Rio Grande are few. Hundreds of vertebrate species abounded, including many types of fish. The river was viewed by many a traveler emerging from the Chihuahuan desert from Mexico as a paradise (Bartlett, 1965).

Historically, the flows of the river were somewhat ephemeral. Prior to the advent of intensive irrigation and to construction of the Rio Grande Project, the Rio Grande below El Paso generally experienced biannual seasonal flows. From April through June, snow-melt runoff from southern Colorado and northern New Mexico delivered a majority of the annual flows. In the summer monsoon months of July to September, flash-floods from tributary arroyos provided substantial inflows to the main river channel. Over the centuries, the climate of the Upper Rio Grande has experienced alternating wet and dry cycles lasting several decades. These long cycles have sometimes been interrupted by acute periods of drought or flooding. Historical accounts from the last 350 years highlight some of these jagged disparities.

An 1811 description by von Humboldt describes one such drought period:

“The inhabitants of Paso del Norte have preserved recollection of a very extraordinary event which took place in 1752. The whole bed of the river became dry all of a sudden for more than thirty leagues above and twenty leagues below the Paso for several weeks,” about 130 miles in total (Stotz, 2000).

Conversely, during a notable wet period in 1598, the Spanish expedition led by Don Juan Oñate encountered a lush river valley at the Paso del Norte with wide marshes, an abundance of fish and fowl, and fresh flowing water (Scurlock, 1999).

The Rio Grande was a much different river prior to the incursion of dams and large scale irrigation systems. Cottonwood forests and swamps, oxbow lakes, and thriving wildlife are described over the centuries. Interestingly, the river was deemed ephemeral for certain periods when the bed would run dry for weeks and months at a time. But what people recall quite clearly about the river starting in the 1800's are the great floods - not just for the inundation of farmlands, but the blanketing of cities like Albuquerque and Juarez for several weeks on end. These reports provide an important and useful timeline denoting the changes witnessed on the Rio Grande and how current conditions on the river compare with previous eras, particularly before the construction of large dams like the Elephant Butte Dam. Sadly, the wild and untamed Rio Grande of the past has become a relic, and most of the riparian habitat has been destroyed.

And some warnings went unheeded. Indications that there might be water supply problems were recorded in an official report from Major O.H. Ernst, U.S. Army Corps of Engineers, to the Chief of Engineers, 1889:

“At El Paso... the water ceases to flow and except at detached pools the bed becomes entirely dry. The diminution of flow is probably due to evaporation and to the abstraction of portions of it for irrigation purposes. In my judgment, the stream is not worthy of improvement by the General Government.” Annual Reports from the War Dept. 1889 US Printing Office.

The General Government decided otherwise.

2.4.2 Exploitation of the Rio Grande

Over-extraction of water, dams, and the western water laws negating the long-held philosophy of Nature's Law or Common Law inherited from the British are the key forces affecting the health of the Rio Grande. Throughout history, water (especially rivers) has been treated as a common resource. From Roman times to the Magna Carta to the European

migration into the New World, the rivers were held as part of nature to be enjoyed by all and owned by none. Traditionally, water was held as a usufruct, a substance to be shared and used by all without ownership, much like the air that we breathe. As this idea migrated to the United States, it was codified under the ideas of British Common Law and nearly identical laws were espoused by the Spanish and French colonies as well. A compendium of these laws and ideas is covered by the National Organization for Rivers (NORS) in their National Rivers report: “Public Ownership of Rivers in the United States – Rivers and the Public Trust Doctrine”, updated through 2012. From the earliest times, this concept of public ownership held firm with the belief that rivers were divine or god-given, and that all people had the right to enjoy them and use them including the banks of these rivers, for dwelling, for fishing and for commerce. These laws and attitudes governing water were drastically altered with the discovery of gold and other precious minerals in the western United States. In 1872, the General Mining Act (Mining Law of 1872) codified a system of property rights secured through mining claims based upon location and time in the order of claims filed. Mining interests dictated that the same idea should be applied to the waters needed to conduct mining operations. And thus it came to pass that the Western Water Law of “first in time, first in right” (Holland and Hart LLP, 2007), or Colorado Law;~~or~~ more formally the Prior Appropriations Doctrine, came into being.

Since then, water in the western states has been commoditized for beneficial uses only, at great expense to the ecosystems dependent on flowing rivers and streams. In New Mexico, all waters are appropriated based upon the time the right to those waters was secured. The New Mexico Water Dialogue updated report of 2012 (UNM School of Law, 2012), describes the history of how laws governing water quality were enacted and the failings of states to address problems of water quality and quantity. In New Mexico, unappropriated waters do belong to the public, but most of the flowing rivers have been fully appropriated or “claimed”. As problems with pollution and river flows between states became more and more acute, the inability of States to solve these issues led to the Federal government stepping in to govern many complex issues related to both water quantity and water quality.

2.4.3 Water management and governance

The first disputes within the Rio Grande watershed centered on flow. The codification of the Prior Appropriation Doctrine settled in-state claims as to who would receive their appropriation first. Deliveries between the States of Colorado, New Mexico, and Texas were also a matter of contention. The formation of a Rio Grande Compact in 1938, overseen by a Federal Commissioner, was required to force the states to share the Rio Grande “equitably”. This sharing of surface flows was based upon an index of flows derived from gaging stations accounting for Colorado flows into New Mexico. The combined flows were measured at Embudo, New Mexico; the site of the very first USGS gaging station established in 1888. New Mexico deliveries to Texas (actually the portion of New Mexico and Texas supplied by the Rio Grande Project) are measured at the San Marcial gaging station above Elephant Butte Reservoir. Delivery requirements are based upon measured flows and an agreed upon schedule or index for the amounts of water each state is allowed to deliver to farmers, and their delivery obligations to downstream states. The Compact stipulates that in the event of a spill at Elephant Butte Dam, all credits and debts are erased. Spills or water flowing freely over the crest of the dam spillway have only occurred during three periods: in May of 1942, from 1985-1988, and for the two year period of 1994-1995 (USBR, 2009).

This was not the case, however, for Mexico. As highlighted in the Legal Hydrograph by the Bureau of Reclamation (USBR, 1996), the Mexican government sued the United States to insure that they would receive a fair share of the river. During the mid-1890’s no water made its way down to Ciudad Juarez. The Mexican government blamed this situation on the extensive irrigation farming in the lower Colorado and upper New Mexico regions. Their contention was that the United States allowed upstream farmers to essentially use all of the Rio Grande flows for a period of three years 1894 – 1896 to the detriment of farmers in the El Paso Valley (IBWC stream gage historical record of the Rio Grande). Resolution was formalized in the Convention between the United States and Mexico for the Equitable Distribution of Waters of the Rio Grande. The Treaty was signed in 1906 but legally enacted in 1907; informally it is known as

the 1906 Treaty. Thus, an international treaty and the subsequent Rio Grande Compact of 1938 between Colorado, New Mexico, and Texas settled the major disputes over questions of water quantity or flow. Water quality problems would require a completely new level of enforcement, also by the Federal Government.

The following list of policies, laws, and Acts of Congress have impacted the flows of the Rio Grande to the greatest extent:

Prior Appropriation Doctrine of New Mexico: First legally declared in the 1891 New Mexico Territorial Supreme Court Case *Trambley vs. Luterman*, it was later codified into the 1907 water law. The defining law for water use in New Mexico, it designates appropriation of waters based upon order of claims, and those beneficial uses for which appropriated waters may be applied. New Mexico remains the only western state that does not statutorily recognize in-stream flow as a beneficial use (UNM, 2012). In essence, the State has not formally declared that water for the Rio Grande is of beneficial use. This non-ruling has left the door open for such applications, as the State has not declared water for rivers to be explicitly non-beneficial.

Reclamation Act and the Rio Grande Project: The formation of the Reclamation Service (later to become the Bureau of Reclamation) in 1902 authorized the Secretary of the Interior to seek sites in the western states where rivers could be dammed to provide sustainable supplies of water for irrigation projects. The idea followed the general suggestion by the explorer John Wesley Powell who determined that the river flows in the west and particularly the southwest were not steady enough to provide for irrigation needs throughout the growing season. In 1905, the Rio Grande Project was authorized resulting in the construction of the Elephant Butte Dam, and later the Caballo Dam. Upon its completion in 1916, Elephant Butte Dam was the largest concrete structure in the world (Autobee, 1994).

Treaty of 1906: This agreement for the equitable distribution of waters between the United States and Mexico settled a lawsuit brought by Mexico against the U. S. for failure to deliver any appreciable water during the late 1800's. Part of the treaty specified that the

construction of the Elephant Butte Dam would be used to hold these waters for delivery to Mexico (USBR, 1996).

Miscellaneous Purposes Act of 1920: This Act allows for water to be used for purposes other than irrigation in Reclamation projects. The end users have generally been municipalities and the act states that there must be no other source of water available, and that the application of the water must not be detrimental to the irrigated lands for which it was originally intended. A case can be made that voluntary in stream flows could be purchased and applied to the river under this act (USBR, 1996).

Rio Grande Compact between Colorado, New Mexico, and Texas: Approved by Congress in 1938, this interstate compact equitably apportions the flows of the Rio Grande based upon an index of runoff measurements. The Compact monitors flows of the river between each state with accounting provisions for shortages and credits from year to year. The Compact does not specify how each state is to use their waters, and in keeping with the law of the west, the water accounting is specifically focused on irrigation farming in the Rio Grande watershed.

The next three laws describe the Federal Government's efforts to keep our waters fishable and swimmable (water quality), and protect our wildlife (species preservation).

The Clean Water Act of 1972: An amendment to the Federal Water Pollution Control Act of 1948, the Clean Water Act as it is known governs the discharge of pollutants into the "Waters of the United States". The Act set water quality standards for surface waters and in its initial form, called for the elimination of all water pollutants by 1985. A laudable goal, it has never come close to being a reality. Among the direct benefits for the Rio Grande were the strict limits placed on water quality parameters like biological oxygen demand (BOD) and total suspended solids for sewage discharged into rivers. The regulation of non-point source pollutants has remained the most difficult aspect of fulfilling the intent of this law, in part because non-point pollutants are difficult to ascertain.

Endangered Species Act of 1973: The purpose of this act is to protect and recover species in danger of extinction. The act also specifically addresses the recovery of ecosystems

these species require to survive. Within our river watersheds, the Fish and Wildlife Service administers this program, and they often find themselves at odds with the Bureau of Reclamation, the Army Corps of Engineers and other water management agencies. The best known example along the Rio Grande is the ongoing Silvery Minnow recovery program.

The National Environmental Policy Act of 1969: NEPA, as it is known, is an environmental act governing the actions of the Federal government and any actions undertaken using federal funds. Its intended purpose is:

To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

In combination and in total, these laws and many minor laws not mentioned, demonstrate a philosophical shift in thinking about water management in the western United States. The divine gift of water and rivers was by long-standing tradition, a part of nature that falls under the realm of Natural Law. The doctrine of Natural Law held that water was a common property. Codified by the Romans, the rivers were public and *aqua profluens* (flowing water) could not be owned or possessed. From the English, the principle of riparian water rights continued this philosophy of waters being held in common with extraction of waters limited solely to the owners of riparian lands adjacent to rivers. As a Divine gift, water was not to be owned like a commodity, and all people were able to enjoy the opportunities presented by rivers and lakes. Philosophers have relied upon the concept of divine creation as a framework for the natural world. The values we place on natural resources and nature itself come from this sense of the sacred, that it is “god-given.”

This idea is easy to understand in areas where water is abundant, like most of Europe and the eastern United States. But even in arid climates, this view predominated. Islamic Sharia law stipulates that water must be shared, and that since water is a gift from god, no one man can deny another the right to use available water (Dellapenna, 2009).

Newer laws and particularly environmental regulations intended to preserve and protect our waters directly conflict with these older established laws and precedents. The impairment and imperilment of our nation's waterways caused by industrial, agricultural, and domestic wastes led to enactment of key environmental laws and regulations. These new regulations were in direct response to our treatment of our lakes and rivers as giant sewerage and plumbing systems. Not only was water quality impacted, but the endangerment and extirpation of species was the greatest unforeseen tragedy. The public's demand that these unsustainable practices be curtailed is what led to the enactment of laws to protect our environment. Recurring fires on the Rouge River in Detroit and the Chicago River were not unusual. It was the June 1969 fire on the Cuyahoga River that truly ignited the ecological movement in America. Caused by debris and the indiscriminate dumping of solvents, the Cuyahoga had suffered through a series of fires going back to the late 1860's. Primed by the January oil spill in Santa Barbara, the fire of 1969 energized the American public. Tolerance for dumping wastes into our nation's waterways had surpassed the breaking point. The people and Congress took decisive action to halt these polluting practices.

For centuries, rivers have been used as dumping grounds for industrial wastes, sewage, and other runoffs. In the post WWII expansion of the United States, many of our rivers were under siege, indeed some even caught fire. The old usufruct notion that rivers should be enjoyed by the common man was under assault. The public demanded change and a series of wide ranging Federal regulations were enacted to keep our rivers and lakes "fishable" and "swimmable" (Percival *et al*, 2009). The original intention of the Clean Water Act (CWA) was to eliminate all discharges of pollutants into our rivers and lakes by 1985. "Clean Water Act at 30" is a report on the failings of the laudable goals of the Clean Water Act and why so many of our rivers have yet to be designated as fishable and swimmable (Bazel, 2003). The text, *River Ecology and Man* (Oglesby *et al*, 1972) provides a glimpse into the severe pollution levels within our rivers and lakes faced by our nation in the late 1960's and early 1970's. The pull between economic interests and ecologic health was being debated and looking for solutions that would

satisfy the greatest good for our waterways was the emphasis of water policy experts. Initial attempts to keep waters fishable and swimmable under the Federal Water Pollution Act of 1948 did not grant sufficient enforcement authority to the Federal Government. The States were left in charge of dealing with water pollution abatement, to little effect. Commerce, industrialization, and economic concerns held priority over the state of many of our nation's rivers.

From a water quality perspective, the Rio Grande in southern New Mexico is not imperiled by industrial or chemical pollutants. Though the river is laden with silt and sand, the major concern for human contact is fecal coliform bacteria (IBWC Clean Rivers 319 report, 2010).

All discharges from sewage treatment plants are required to meet regulated requirements for maximum daily loadings. Overall, they are not a problem on the Rio Grande as indicated by the number of violations recorded (EPA-ECHO, 2012). The majority of bacterial appear to come from avian sources and from drainage discharges.

Salinity is also a major concern, especially in the distal end of the Mesilla Valley. Salt build-up is a much bigger concern for the El Paso Valley than the Mesilla Valley. The source of salts is now thought to be of geological origin from saline groundwater intrusion at the bottoms of valleys along the Rio Grande, specifically at San Acacia, Elephant Butte, Seldon Canyon, and the El Paso (ASARCO) narrows (Phillips *et al*, 2009). The flows of salts through the system is generally in a balance, with 710,000 tons of total dissolved solids entering the system from Elephant Butte Reservoir, and 700,000 tons of salt exiting the Rio Grande Project at the end of the El Paso County and Water Improvement District No. 1 (Miyamoto, 1995). Essentially, the Rio Grande Project is experiencing rising salinity levels at the bottom of the Mesilla Valley and within the El Paso Valley. The sources of these salinity increases are connate saline intrusions and the application of groundwater in El Paso that have a higher TDS content than the surface waters of the Rio Grande. However, what remains the defining factor impacting the riparian corridor is the altered hydrograph. The impacts of dams and diversions on the flow regime have been devastating, and the engineering measures of straightening and channelizing the river

perhaps even more so. These structures and policies have relegated the river to nothing more than a delivery system for irrigation. The dams are investments in concretizing the idea that the Rio Grande requires taming and control exclusively for the purposes of farming and flood control.

Surface water resources are in peril across the planet. The Pacific Institute has released a series of biennial reports on our fresh water sources with an emphasis on rivers and lakes (Gleick, 2008). The vascular systems of our continents are choked, polluted, and subject to increasing demands. In the United States, as with most of the world, a majority of water is used for agricultural purposes. In a 2002 Watersheds report, “The Truth About Land Use in the United States” (Wuerthner, 2002), the impacts of agriculture within the lower 48 states are abundantly clear. Water use, especially in the western United States, is predominantly agricultural, over 80% in most places, and the amount of ecological destruction caused by farming far exceeds the impacts of urbanization and industrial infrastructure.

For the State of New Mexico, the Utton Law Center of the University of New Mexico prepares papers detailing the status of water resources within the state for upcoming legislative sessions e.g. Water Matters Water Issues for Members of the 51st New Mexico State Legislature - 1st Session (UNM, 2012). The Center analyzes groundwater extraction, river exploitation, and the potential effects of climate change and drought for elected officials and policy makers to use as a guide for future water resources decisions. Together these sources provide a glimpse of water conditions on a global, national, and regional scale demonstrating the commonalities of water problems across the globe and some of the unique issues we are facing on the Rio Grande.

2.4.4 Current unsustainable conditions of the Rio Grande

How the Rio Grande in Southern New Mexico and Far West Texas came to its present state is a direct result of taming and controlling its flows for the purposes of irrigation, flood control and power production. Massive engineering projects have been employed to this purpose, specifically: The Rio Grande Project implemented by the Bureau of Reclamation, was

authorized by Congress in 1905. The division of waters to be stored in the reservoir between Mexico and the United States was settled with the signing of the treaty for sharing the waters of the Rio Grande in 1906. The Project resulted in the construction of two major storage dams and six diversion dams for irrigation deliveries.

Elephant Butte Dam was completed in 1916, and currently holds approximately 2.1 million acre-feet of water (2.5 billion cubic meters), or just under three years inflow into the reservoir when averaged over the life of the project. Initial storage was 2.6 million acre-feet, but nearly 20% of capacity has been lost due to sedimentation. Periodic sediment surveys indicate that the dam will remain viable for several centuries. The dam is 301 feet high and 1,674 feet long. Power generating facilities were added to the dam in 1940. Elephant Butte Dam was the first and foremost barrier on the main stem of the Rio Grande. All of the waters for the Rio Grande Project are held by the Bureau of Reclamation and these waters are fully appropriated to lands within the downstream irrigation districts.

Caballo Dam and Reservoir were authorized in 1936 and the dam was finished in 1938. The dam was built as a flood control structure to handle any overflows from Elephant Butte Dam twenty five miles upstream, and inflows from the Black Range through the Percha Arroyo. Storage capacity is 340,000 acre-feet, and the reservoir was used in the past to allow for operation of the power house at Elephant Butte beyond the end of the irrigation season. All of the irrigation deliveries in the Rio Grande Project emanate from Caballo Dam.

In addition to the two main dams, Elephant Butte and Caballo, four diversion dams, Percha, Leasburg, Mesilla, and American Diversion direct waters from the river into irrigation canals and channels. An extensive delivery and drainage system, 141 miles of laterals, 462 miles of laterals, and 457 miles of drains make up the 205 mile long Rio Grande Project.

The American Diversion Dam is situated on the international boundary line and is operated by the International Boundary and Water Commission. The remaining waters of the Rio Grande/Rio Bravo are split between Texas and Mexico for the irrigation districts in the El Paso Valley.

The Rio Grande Canalization Project operated by the International Boundary and Water Commission was authorized in 1936. Its purpose is to ensure equitable deliveries of water to Mexico and the United States. The project extends from Percha Diversion Dam to the International Dam in El Paso, a distance of 105 miles. The Project also serves as a flood control structure with levees placed on both sides of the river channel for most of the Mesilla Valley. The Canalization Project restricts the flows of the Rio Grande to less than 3,000 cubic feet per second in the river channel and 10,000 cubic feet per second inside the levees (85 and 283 cubic meters per second).

Below the American Diversion Dam, the waters delivered to the United States are diverted from the Rio Grande into the American Canal Extension Project, essentially depriving the river corridor of any irrigation flows below El Paso. The American Canal dumps into the Riverside Canal in Socorro, Texas, where drainage waters eventually find their way back to the remnants of the Rio Grande and the Boundary Rectification Project. The Rectification Project, begun in 1933 and completed in 1962, straightened out the meandering river while apportioning equal parts of land to Mexico and the United States. From El Paso to the Fort Quitman gaging station, the Rio Grande was initially 155 miles long. Rectification produced a much shorter and straighter river at 86 miles in length. The Chamizal National Memorial was dedicated in 1966 to commemorate the end of the border dispute along the Rio Grande in the El Paso Valley. The Rectification Project was the engineering solution to the long standing dispute over the U.S. – Mexico border as stipulated in the 1848 Treaty of Guadalupe-Hidalgo at the end of the Mexican-American War.

The historical character of the unfettered Rio Grande has been transformed into a channelized conveyance system. The dams and irrigation schedules have produced a river that is more a giant plumbing system, than a wild and scenic river. Ecologically, the bosques (wetlands) and oxbows have disappeared, and suitable habitat for migratory birds along with native flora and fauna has greatly diminished. Of the 29 species of native fish that historically were found in the Mesilla Valley, as many as 22 have been extirpated (Parametrix, 2010).

The dearth of wetlands from below Caballo Dam to El Paso is a direct consequence resulting from policies dictating that all water in the upstream reservoirs should be designated solely for irrigation and contracted municipal purposes; thus no in-stream or environmental flows are reserved for the Rio Grande. The delivery and timing of releases from the dams have produced a levee bound river system that is opened and shut-off like a spigot. Riparian habitat restoration is desperately needed in this area. Migratory birds travelling the Rio Grande corridor have few opportunities for stopovers in open water areas. The nearest “wetland,” Rio Bosque Park in El Paso, only receives treated effluent during the non-irrigation season, generally from November to February - the surface water at the Bosque Park is at best, intermittent and unreliable.



Figure 2 Riparian Corridor upstream of ASARCO smelter

The United States Supreme Court holds that rivers are public and have been since ancient times in civilized societies (Percival *et al.* 2009). Roman law held that running waters were common to all men; that rivers and ports are public places with the right to fish and transport goods common to all men. The reasoning for this law was that it followed the Laws of Nature. The right to use the banks of rivers as well as the river itself was recognized as part of this law. This policy was enforced throughout Europe and reaffirmed by the Magna Carta of 1215.

Royalty had secured some portions of rivers for their private use, and this practice was overturned on the basis of the Roman idea of Laws of Nature, established by divine providence (National Organization for Rivers Report, 2012). This ruling was transfixed to be immutable. Spanish and French laws concurred with Roman law declaring that the right to use rivers for fishing and commerce, including the banks of rivers were public and common to all (Dellapenna, 2009). The Colonies of the United States kept with these laws. The rivers of the country were free-flowing, often very large, and provided immense fishing grounds at their estuaries. French and Spanish colonies acted similarly. Jurisdiction over water rights did not become an issue until westward expansion led to the discovery of gold and silver in the mountains and rivers of the west, past the 100th meridian line where annual rainfall was less than 20 inches per year and rivers ran low in the summer month or even intermittently.

Mining struck the first major blow to the tradition of Nature's Law and the notion that water was a part of the commons as men clamored for gold and silver. Claims to lands with potential mineral resources required a marking and registration denoting not only the place, but just as importantly time. This locking of land for one's use lead to the radical idea of extending the same consideration towards the water needed to conduct the intended mining operation. The importance of establishing a claim for a parcel of land was rendered useless if the water needed for mining was diverted and consumed upstream. On small rivers and creeks, a mining operation could consume a large portion of the available flowing water. A claim filed on Monday, might not be workable if an upstream claim filed on Tuesday extracted too much water. In order to secure the water necessary for mining such claims, the right to use available surface waters on those claims came to be tied to the land in what is generally known as the "first in line, first in right" rule of water law or more formally as the Prior Appropriation Right. Legally established in Colorado in 1872, and similar to the rights given to miners in the California Gold Rush, this doctrine was based on the scarcity of water available and the need to tie water rights to adjacent lands. In the same vein, the Homestead Act of 1862 allowed for farmers to establish a first right

to public lands, and in those areas where surface waters were accessible, similar claims to the rights of the river followed suit.

The essential feature of Prior Appropriation law is the codification of an appropriation date and allocation amount for each user. Senior rights trump junior rights in times of drought and allocations are treated like mortgages that can be bought and sold. The central principle for the allocation of water is the concept of beneficial use. Defining the uses for which water can be extracted from western rivers is the limitation that prevents the vicissitudes of speculation and non-utilitarian transfers. Across the western United States and within New Mexico, beneficial use of appropriated waters includes mining, agricultural, industrial, and municipal applications. Ecological uses and in-stream flows are not considered by New Mexico as a beneficial use.

This complete and total abandonment of Riparian Water Law or the Law of Nature is the critical impetus that led to the exploitation and degradation of the Rio Grande. Fostered in our pursuit of mineral and agricultural wealth, it is an idea founded upon greed and the philosophy that Manifest Destiny trumps the divinely inspired Natural Laws. Due to the scarcity of water available, the race was set to appropriate every drop and to ensure that none was wasted on non-beneficial uses, including the in-stream flows that are obviously necessary for riparian habitat. The 19th century thinking behind these actions was deemed logical and just at the time. Western water laws and New Mexico water law was hardly nefarious in intent. What couldn't be forecast were the repercussions often realized much later, a phenomenon aptly described as the Law of Unintended Consequences. The adage was encapsulated in its modern form by Robert Merton in 1936 and later simplified by Barry Commoner in The Closing Circle, 1971.

The expansion of the railroads across the west, the harvesting of vast timber reserves, the migration of farmers to the Rio Grande Valley and the hunt for gold, silver and copper, all greatly impacted the demand for water from the river. The effects of timber harvesting still impact the upland watershed as the soils have lost their ability to store and hold water. Snow melt runoff is accelerated when lands are cleared of forests and roadways are cut into the landscape.

As a result, senior and junior water appropriations were established that remain to this day. As long as the allotted waters are put to beneficial use as defined in the appropriation, those waters can be extracted for commercial purposes in perpetuity.

The second and perhaps even greater impact of dividing up water rights comes from the fact that the flows of the Rio Grande were often unreliable for irrigation purposes. Like the Colorado and other western rivers, the Rio Grande is dependent upon snowfall in the Rocky Mountain Ranges during the winter months. As the snow melts, a new season begins and spring runoffs increase until the end of May or early June in most years. During the summer months, the flows diminish until the summer monsoons return. By fall, the river is much smaller and trickles until the next spring when the cycle begins anew.

The fact that the Rio Grande is seriously in trouble is highlighted by groups concerned with the health of our rivers and ecosystems. Specifically, the American Rivers watchdog group is one of the leading organizations focused on protecting and restoring our nation's rivers and streams. In 1993, this group listed the Rio Grande as one of the ten most endangered rivers in the United States. The primary areas of concern were endangered species of fish, pollution levels, invasive species, and over extraction of water throughout the entire watershed. In 2003, the Rio Grande was listed again among the ten most endangered national rivers; the re-listing prompted by the fact that the river no longer flowed to the Gulf of Mexico (American Rivers, 1993 & 2003). The mouth of the Rio Grande was occluded due to a lack of flows. This cause for alarm further elicited a response from the World Wildlife Fund (WWF) for Nature (WWF 10 Rivers most at Risk) who issued an alarming report listing the Rio Grande/Rio Bravo as one of the ten most endangered major rivers in the world. These reports and a myriad of studies and investigations by agencies, universities, and non-governmental organizations (Lougheed and Rodriguez, 2008; Stromberg, 2001; Everitt, 1998, Bilbe 2006; Skancke, 2007) support the same general conclusion – that the Rio Grande is currently operated in an unsustainable way, and the ecological damage is severe and in some cases, possibly permanent.

2.5 Evaluation of Sustainability

2.5.1 Sustainable environmental management and restoration

Rachel Carson's groundbreaking work "Silent Spring" published in 1962, was a wake-up call for the public to take notice of environmental problems. Her book is considered to be the start of the modern environmental movement. The death of songbirds in our residential areas struck a chord with the American people. The devastating effects of our polluting industries and agricultural methods, the disregard for our natural resources, and the death of many of our waterways led to a clamor for restoration. Attendant to these needs, new voices were heard proclaiming a more radical approach to better define how we fit into the natural world and our part in it. The idea that we were all collectively at fault, and must work together, was proposed by many. The environmental condition of the nation was not tenable, and a more sustainable approach for providing our food, energy, and materials was deemed necessary. A leading voice for this effort was the late Barry Commoner; his seminal book, "The Closing Circle" (Commoner, 1971) made the argument that several important connections were not well understood. Chief among them was his "First Law of Ecology", which states that all things sharing a common environment are interconnected and interdependent. We cannot simply disregard the wastes we generate, as they will accumulate and come to rest throughout the environment, often with deleterious effects. The Ethics of Sustainability text, (Kibert, *et al.*, 2010) describes how an enormous shift in our thinking is required to solve our environmental problems. The ethical choices we select are paramount to building sustainable solutions. For solutions to fit truly within the construct of sustainability the social, economic, and environmental dimensions must be considered. Integration of the social and economic dimensions into an environmental framework is necessary criteria for evaluating the success of

any restoration project. This triple bottom line (TBL) philosophy was first introduced by John Elkington in 1997 for the corporate world. This concept has broadened to include the greater sustainability realm and the three pillars of “people, planet, and profit” have evolved into the more general, “social, environmental, and economic’ dimensions of sustainability. One criticism of this approach is the treatment of each pillar as a co-equal leg, which ignores the hierarchical relationships as they pertain to the environment as a whole. The two diagrams below highlight this discrepancy. The first shows an interconnected relationship between the three pillars, a view favored by traditional economic analysis where value is measured in terms of dollars. The second shows the economic and social aspects of our world as part of the greater environment. This nested representation better reflects those non-dollar aspects of indirect costs and benefits like environmental degradation, and the utter dependence on the environment for society and the economy. The environment is not a part of this philosophical diagram; it is the whole, with embedded realms of society and commerce.

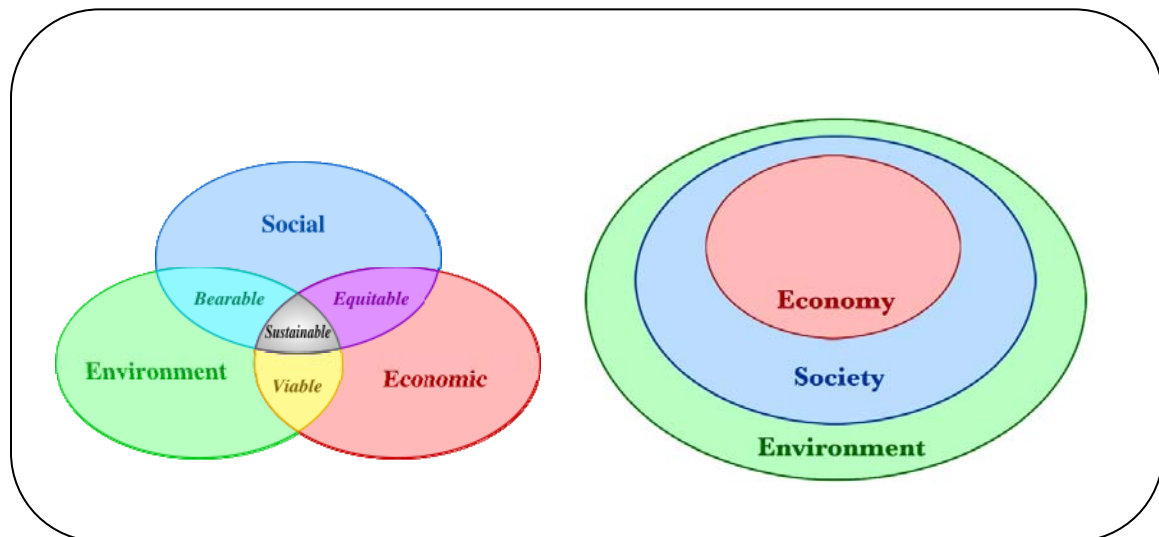


Figure 3 Triple Bottom Line 3-Legged & Nested Venn Diagrams

What isn't strongly emphasized is our obligation to correct the errors of previous generations. Restoration is the common term used to describe actions directed towards enhancement of our environment, when replenishment may be a more accurate characterization. Having dominion over nature does not give us the right to leave our unsolvable problems for future generations to correct. The consideration of future generations and the legacy we leave are important questions that weren't clearly addressed in the previous century. We do have a moral obligation to the future generations yet to come. Our duty is not just to the living, but to those who will be forced to clean-up the messes we leave behind.

Probably the most widely known definition of sustainability comes from the Brundtland Commission report (sponsored by the United Nations) from 1987 on Our Common Future:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Missing from this definition is the requirement that reparations are presently required for the damages that have already been performed in the past. It is incumbent upon us to begin restoration of the environment where possible and to set a framework for this to be a continual and sustainable process. For the section of the Rio Grande in New Mexico and even the channelized portion below Elephant Butte Dam, there are several groups planning to implement restoration projects.

The Paso del Norte Watershed Council helped sponsor a Watershed Integrated River Restoration Plan for the Rio Grande from Elephant Butte Dam down to Fort Quitman, Texas. This 200 mile long stretch of river is channelized and now runs between flood control levees. Much of the native habitat has disappeared and the plan outlines specific sites where restoration efforts appear feasible. In partnership with this plan and parallel to it is the El Paso – Las Cruces Watershed Wetlands Action Plan, sponsored by the New Mexico Environmental Department, Surface Water Quality Bureau. The draft was released for comment in 2006, and the state has identified the water quality and water quantity obstacles that need to be surmounted before establishing wetlands in southern New Mexico. Similarly, there exists a state-wide program, the

New Mexico Wetlands Program run by the New Mexico Environmental Department. The goal of this program is to protect and restore New Mexico's remaining wetlands and riparian areas while increasing the number of self-sustaining, naturally functioning wetlands and riparian areas to benefit New Mexico's future. Their focus on the future and sustainability is encouraging.

Each of these plans highlights the potential opportunities to establish new wetlands and makes general recommendations on the protection and restoration of existing wetland sites. Yet specific actions and projects are not listed. For example, the Southwest Environmental Center (SWEC) has helped to create the Picacho Wetlands and the Mesilla Valley Bosque State Park in conjunction with the State of New Mexico and the City of Las Cruces. The La Mancha Wetlands project is currently under construction.

While the state wetland plan calls for the construction of two new wetlands per year, partnerships and outside help are listed as necessary for this undertaking. These partnerships, contracts, and agreements take time to implement, and the lack of funding from outside partners could certainly stall any progress on the New Mexico wetlands front. Tribute is made to the necessity of monitoring water quality, but though the state plans and others are a move in the right direction, they are toothless in that no specific projects have been selected.

Stromberg (2001) highlights a critical component missing from many wetland and restoration plans – flow. Restoring our rivers and reestablishing some native riparian ecology on the Rio Grande requires water, preferably natural river water, if possible. The Prior Appropriation Doctrine makes it difficult to allocate water for the river, since this is not typically deemed a “beneficial use”. Short of overturning more than a century's worth of water rights precedent, finding ways and methods to restore and build new wetlands requires a new, diversified strategy.

2.5.2 Proposed Methods for Restoration

How to achieve sustainable replenishment of our watersheds in an environment where water is scarce, resources are limited, and people are either polarized or indifferent, is the

daunting task facing many restoration projects. Economics, environmental justice issues, community involvement, and aesthetics all play important roles in the attempts to bring nature back to the river.

David Schaller's essay (2004), "Beyond Sustainability: From Scarcity to Abundance" compels society to probe deeper questions necessary to define "sustainability". His arguments are much in line with the Laws of Ecology espoused by Barry Commoner. Real sustainability requires long term thinking where financial economy is integrated with nature. Environmental, social, and economic challenges are all interconnected. Sustainability projects and plans must be founded on an ethical framework built upon obligation to ourselves and future generations. In this view, the prevailing idea that sustainability is tied to scarcity and austerity is abandoned. Nature is to be emulated as much as possible, and we have been myopic in how much we miss the enormous abundance and diversity already present in the environment we are working in. Rather than doom and gloom, Schaller calls for us to think anew and look to nature for inspiration.

Finally, in an effort to describe the wetland situation in the United States, the Federal government conducted an extensive review and analysis of our wetlands as a collective effort by a number of federal agencies led by the Fish and Wildlife Service, "Status and Trends of Wetlands in the Conterminous United States 1998 to 2004" (Dahl, 2006). Surprisingly, the total number and acreages of wetlands increased during this period. This report is crucial to our understanding of our nation's wetlands, and where trends are running negative or positive. It is always important to have a trustworthy baseline of information from which to begin, and the view of our government on this issue has come a long way from the days of the old Soil Conservation Service of the 1930's through the 1960's where the government was on track to "drain every swamp". That swamps are now often called wetlands, is proof of the power of new thinking.

Who speaks for our rivers? Is it the environmental organizations, the farmers, concerned citizens, or communities adjacent to the river? Each of these groups may have deep concerns

over the degradation of our nation's (and even the world's) rivers, but where are their voices heard? Who has a say in how we manage our water resources? What right do we have to plunder our rivers to the point where they no longer function as rivers, but more as giant plumbing systems?

These questions are particularly critical in the arid southwestern portion of the United States. Great rivers like the Colorado, the Rio Grande, and the Salt River for example are highly managed and controlled. Here the rivers are controlled and employed for the beneficial uses of energy production, flood control, irrigation, and for supplying water to meet municipal and industrial needs. And unlike the great rivers of the central plains and eastern seaboard where flows escape to the sea, in the southwest water that makes it to the ocean is somehow seen as “lost”.

2.5.3 Supplemental flows for intentional flooding

One possibility yet to be attempted within the Rio Grande Project involves the application of supplemental flows to cause overbank flooding of the Rio Grande between the levees. During normal irrigation operations, the majority of the delivery waters remain within the main river channel. Higher flows spill out onto the floodplain and are viewed from an agricultural perspective as wasteful. However, there are current efforts to change this view, particularly over the last decade.

The International Boundary and Water Commission is currently in the process of creating riparian habitat as specified in the U. S. Section of the Rio Grande Canalization Project Environmental Impact Statement. The goal of the project is to maintain flood control and delivery capability while providing environmental enhancement where possible. The alternatives considered in this approach include the implementation of no-mow zones along the floodplain, the planting of native trees and shrubs to establish riparian vegetation and the creation of wetlands at the outfalls of drains along the Rio Grande.

The final piece of this plan involves the use of controlled water releases for overbank flows for targeted restoration sites. By initiating flow patterns that mimic spring runoff conditions, conditions will be more favorable for the establishment of native riparian vegetation like willows (*Salix* spp.) and cottonwoods (*Populus* spp.).

These flows would only be required during the spring months of March through May to coincide with the normal snowmelt hydrograph. During the summer monsoon months of July and August, the Rio Grande Project is often flooded for short durations as storm flows within the watershed find their way into the river channel and swell the river to the point where the Bureau of Reclamation must suspend deliveries to avert flooding. This results in the releases from Caballo Dam being shut off or greatly diminished during these flood events for a period of hours or days, depending on the severity and duration of the storm event.

For example, if an overbank flow of 5,000 cubic feet per second (cfs) was desired in May, and the normal discharge to the irrigators was 1,500 cfs at the time, an additional 3,500 cfs would be released on top of the normal irrigation flow for several days. The aspects associated with providing overbank flows have been studied and the likely spots where overbank flooding would produce some regeneration of riparian habitat have also been mapped.

What has remained difficult to ascertain, is the availability of the water required to carry out this endeavor. Currently, it is not thought that such efforts would be possible, nor necessary on an annual basis. More study is needed to evaluate what time periods would optimize the application of overbank flows. Achieving overbank inundation every three or five or even seven years could certainly aid in developing more riparian zones along the Rio Grande.

Non-governmental organizations like the Las Cruces Audubon Society have been soliciting voluntary water transfers from farmers to the river for riparian restoration purposes. In addition to voluntary agreements, the leasing of water on a year-to-year basis is also being pursued. How the current laws and policies will affect any of these overbank flow schemes is yet to be resolved. Opponents may decry the use of any waters for “non-beneficial” application.

Similar to this approach, mechanisms are in place where the U. S. Government, via the Bureau of Reclamation could purchase water from farmers on a short term basis to accomplish these same goals. Unlike the Middle Rio Grande Restoration Project where the Federal Government was forced to pay for water to ensure the survivability of the endangered silvery minnow (*Hybognathus amarus*), a similar effort below Elephant Butte and Caballo Dams could be voluntary and preemptory. The requirements for ensuring certain levels of flows within a river have historically been driven by the Endangered Species Act and other requirements of the Fish and Wildlife Service to maintain ecological balance. In regards to ecological harm, water management agencies like the Bureau of Reclamation, the Army Corps of Engineers, and the International Boundary and Water Commission have generally not acted in a preventive manner, hamstrung by budget constraints and a lack of foresight. Responses to emergencies come long after the time for precautionary actions has passed. Preliminary steps that could have been taken to prevent these crises are often viewed improperly (at that time) as being too costly or even unnecessary. Unfortunately, when crises situations arise, agencies are forced to act as dictated by various environmental protection laws, and these required actions can become quite costly. The inability of Federal Agencies to act on potential ecological problems is driven by western state's laws defining beneficial use, and the political power of those holding water rights to keep all of their water secure. This status quo inevitably leads to a crisis management mode of action, rather than a more sensible approach that could stave off impending problems with preventive releases of waters.

It remains unsettled whether the application of Rio Grande Project waters onto the floodplains is in keeping with the definition of beneficial use for project waters. Should a legal determination be made allowing for irrigation waters to be applied to floodplains, not on farm lands, but instead within the river itself, the Miscellaneous Purposes Act of 1920 would likely be the legal authorization for conducting the transfers of project waters. This Act allows Reclamation Projects to provide water for municipal, industrial, and other miscellaneous purposes.

The idea of overbank flooding has been pushed and pursued by many people both within and outside of Federal Agencies for over a decade on the Rio Grande. The ongoing drought only compounds this problem. When water supplies are low, it is hoped that some farmers may desire to forego farming for a year and offer to supply some water toward an overbank release, or as in the past, they may prefer to transfer that same water to their fellow farmers. Some farmers will be reluctant to see any water applied outside of their irrigation district boundaries and will view any overbank proposal as an encroachment on their ability to farm in future years. Their biggest fear is that a re-authorization of the Rio Grande Project will result in some of the irrigation water stored in Elephant Butte being permanently redirected to provide riparian flows for the river and not the farms.

Risk-averse agencies, afraid to raise the ire of irrigators, are reluctant to act with foresight and deal with potential calamities propitiously. Water users, fearful of any application of water for environmental reasons, are reluctant to relax their monopoly hold on water. Collectively, there is a strict adherence to the status quo. Our long-running inability to deal with ecological degradation stems from a constipated mind-set, unwilling to seek common solutions and to try new ideas for replenishing our ecosphere.

2.5.4 A String of Pearls Approach

Restoration of the Rio Grande riparian corridor appears to be a nearly impossible task. All of the water in the river is stored solely for irrigation purposes, and the State Law prohibits the application of water for the benefit of nature and rivers. Attempts to fix the river have run up against the seemingly impenetrable obstacles of dams, laws, tradition, and indifference. The search is on for finding those specific sites suitable for generating one spot of riparian growth in the hopes that others may sprout up elsewhere, creating a mosaic of wetlands, patches of green along a denuded river channel. These sites have been likened to a “string of pearls”. If enough pearls are produced, eventually a string will be formed providing a semi-connected landscape of riparian networks throughout the Rio Grande Basin. Where to set these pearls is the subject of

much investigation. One specific approach that holds great promise is the use of effluent from waste water plants situated on the river to create constructed wetlands along the banks of the Rio Grande. These flows are steady and not dependent upon the flows released from dams, or the flows emanating from irrigation drains. In fact, the flows are steady even in times of drought.

One pearl is all that is needed to start this process. The prime site would be a waste water treatment plant that discharges to the river, with available land in a setting that would be favorable to the community and the water users as well. The City of Sunland Park, New Mexico at the distil end of the Mesilla Valley offers a prime opportunity to generate one pearl in what could become a string of wetlands throughout the region.

To create a wetland using water that is currently discharged to the river in an economically disadvantaged border community near the center of city government presents us with a great chance to replenish the riparian character of the mighty Rio Grande in a way that may truly be considered sustainable by generations yet to come.

2.6 Conclusions

Using ample evidence from the past descriptions of the Rio Grande and its riparian character, it is clear that the river has been drastically changed. These changes, while beneficial to farmers and cities, have come at a great expense. The ecological condition of the Rio Grande has deteriorated to the point where changes must be made. The present water management policies are not sustainable. The truth is that our progress comes with an environmental price. These costs are not always discernible in terms of dollars, but the environmental and social costs remain nonetheless. Ignoring these expenses has been easy to do, as managing the Rio Grande for flood control and irrigated agriculture has produced an enormous economic boon to the residents of the Rio Grande watershed. The effects of these actions have been decades in the making, and are now rising to the forefront of concerns; concerns not just for the riparian corridor, but for a more sustainable and ~~the~~ equitable use of our nation's waters.

How we came to this point is due to the fact that water in the southwest is limited. In response, people opted out of the traditional view that rivers are common property and that appropriation of water for beneficial use was necessary. This became manifest in the Prior Appropriation Doctrine. The singular effect of this philosophical shift was a diminution of flows within the river, both temporally and quantitatively. The justification for this shift in thinking was purely economical. Social “justice” was meted out only for those with a claim to the “public’s waters”. To better control and manage the flows of the Rio Grande, dams were constructed with the first major dam at Elephant Butte. This marked the first great obstruction on the river.

The second great impingement upon the Rio Grande was the dumping of sewage, wastes, and agricultural runoff by-products. Over the last fifty years, environmental laws have been established to prevent the discharge of these pollutants into the Rio Grande and other rivers. The degradation of water quality caused an awakening, and the public demanded that restoration of our waterways become a priority.

Finally, restoration actions were taken, albeit on a much smaller scale in the Rio Grande watershed. Some of these have worked better than others. In order to facilitate a sustainable constructed wetland, new thinking is required to produce a system that is sustainable both economically and environmentally. An integrated ethically driven approach is needed to restore the Rio Grande. The needs of the community, irrigators, public officials, scientists as well as engineers, must be recognized and articulated clearly before any such project is launched. The old thinking that got us to where we are now cannot solve the problems we are encountering. A new level of thinking is required.

This quandary was summed up by the philosopher Nicolo Machiavelli who stated:

“There is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order, this lukewarmness arising partly from fear of their adversaries, who have the laws in

their favor; and partly from the incredulity of mankind, who do not truly believe in anything new until they have had the actual experience of it.”

Sustainability, this idea of striving to meet this generation’s need without impacting the ability of future generations to do the same, can be viewed as applying the brake pedal to a runaway train. Often left out of this discussion is the fact that the tracks may be headed in the wrong direction. The 1st Law of Ecology (Commoner, 1971) reminds us that everything is connected to everything else. There is but one ecosphere for all living organisms and what affects one, affects all. Unfortunately, the harmful effects can be long-reaching and multi-generational.

But what of the effects we are left to deal with from previous generations? The “sins” of our fathers are vested upon the world we inhabit. Ecological degradation and resource exploitation beliefs become ingrained and codified. What is required, and rarely mentioned in the sphere of sustainability is the obligation each generation has towards restoration and replenishment. It may not be enough to simply apply the brakes. Sometimes the old tracks must be ripped up and a different course be chosen. Not only do we owe the future the right to meet their own needs, but it is incumbent upon us all to right the wrongs of the past where possible, else we too are negligent. But in this case, our negligence is not due to our ignorance, but rather by our deliberate choice to “pass the buck” and not take responsibility. In many ways, this is more reprehensible than a blind plundering of our natural world. To choose not to act when possible is to present an irresponsible act as rational and acceptable, further inculcating the false sense of sustainability merely being a look to the future while ignoring the consequences of our past and present water policies. One can argue that this is the similar path we have chosen when dealing with our nuclear waste. After generating these wastes for over six decades in the United States, we have yet to find a suitable method to store these toxins, let alone dispose of them “forever”. Apparently, our coming generations will hopefully be better suited to clean up our mess.

Finally, it is the beauty of wetlands that may do more to change how people view the Rio Grande than any lawsuit over water rights, or social justice demands for access to surface water. The beauty of a natural river when compared to an irrigation ditch is clearly self-evident. If enough wetlands were to be created along the Rio Grande corridor, perhaps more farmers and citizens would find the idea of putting water back into the river more palatable. By showing the attractive setting provided by a constructed wetland, it may be the pursuit of beauty, more than truth or justice that can bring about an effective strategy for managing the Rio Grande in a more sustainable way. Judgment on our effectiveness is left to our posterity.

Recommendations: The Federal, State, and local agencies charged with managing the waters of the Rio Grande must accept the fact that this river has been mismanaged both ecologically and socially. Our current policies are not sustainable. Beneficial use has been too narrowly defined, allowing for irrigation practices that neglect the health of the riparian environment and those communities with ties to the river.

Correcting the damages caused by the systemic abuse of the Rio Grande requires multiple restoration projects. These long-term efforts will eventually become part of a new water management policy; one that considers sustainability and future generations.

Local communities have a significant role in coordinating and implementing projects for replenishing our nation's fourth longest river. The nexus between people and the river has been severed, and a reconnection of communities with their water and nature is fundamental to making the Rio Grande healthy and beautiful again.

Chapter 3: The Environmental, Social, and Economic Dimensions of Sustainability

3.1 Introduction

The Rio Grande Project managed by the Bureau of Reclamation delivers waters of the Rio Grande effectively to the farms in the Mesilla and El Paso Valleys. The river channel itself has been straightened and confined between levees. What once was a wild, meandering river has become a well-managed irrigation ditch. Most of the riparian corridor has been destroyed. The loss of habitat is severe and the few wetland areas remaining are disconnected. The current situation is not ecologically sustainable. Future generations may see our use of this river solely for agricultural purposes as a tragedy.

Restoring the river is a daunting task. Water is delivered exclusively to farmers who own the rights or claims to their water. Dams and irrigation schedules present obstacles that are intractable. One tactic that shows great potential is the “string-of-pearls” approach, where specific sites are chosen for riparian restoration. Rather than attempting to “green” the entire river, selected areas will be developed producing a sequence of green spots, much like a string of pearls. Treated effluent from sewage plants is a sustainable and reliable source of water that could easily be put to good use in constructing wetlands.

The concept of using constructed wetlands for water treatment arose from observations of natural wetlands removing contaminants from watersheds. In these systems, biological, physical, and chemical processes reduce contaminants naturally (e.g., solids settling, microbial oxidation, anaerobic decomposition, denitrification, adsorption, and precipitation). For constructed wetlands, a broad range of contaminants can be treated, and selected design parameters can target specific pollutants to produce high quality effluent for discharge to receiving water bodies. Aspect ratios, depth of cells, hydraulic residence time, and the amount and type of plants and aquatic organisms are selected based on the treatment goals.

The first step when considering the construction of a wetlands site is the planning phase. Site selection, landscape geography, treatment level desired, and aesthetics are preliminary

considerations that need to be clearly defined at the beginning. The U.S. Department of Agriculture, Natural Resource Conservation Service provides the following from their Engineering Field Handbook (NRCS, 1992):

“A conceptual planning phase is essential. Wetlands can be designed in a variety of system types and configurations to meet specific wastewater needs, alternative sites are often available, and a variety of local, native plant species can be chosen. Every site is unique and the design of a constructed wetland system will be site-specific. The planning phase consists of characterizing the quantity and quality of the wastewater to be treated, determining the discharge standards to be met, selecting the site, selecting system type and configuration, and specifying the design criteria to be met by the detailed engineering plans. Economic factors include the land area required, the type of water containment, the control and transport of water through the system, and vegetation. Setting and prioritizing the objectives of the wetland system is key to the creation of a successful system. The characteristics of a local natural wetland should be used as a model for the constructed wetland, modified to fit the needs of the project and the specifics of the constructed wetland site.”

3.2 Goals and Objectives

Considering the complex political system governing water rights along the Rio Grande, the arid climate, and the stressed economic condition of the region, the goal of this paper is to evaluate the feasibility of constructing a wetlands park in Sunland Park, New Mexico. The park would represent one pearl in a string of pearls for restoring the Rio Grande riparian corridor.

The objectives of this paper are to evaluate and design:

- (1) physical and hydraulic conditions necessary for such a park;
- (2) sustainable ecological conditions, including native biological species and effects on water quality; and
- (3) economic expenses.

3.3 Literature Review

Natural wetlands and constructed wetlands have been the subjects of numerous studies. Academic investigations from the natural sciences focus on the biological and ecological processes, while engineers and chemists investigate the fate and transport of contaminants and water flows. Landscape ecologists and architects take a larger view, and seek to understand the role of wetlands in the surrounding environments. Political scientists, philosophers, and sociologists investigate the role of wetlands with the larger environment and surrounding human communities. The goal of holistic sustainability brings all of these disciplines and others together into a truly interdisciplinary study. Indeed, the philosophy of sustainability has been crucial to the long-range and broader views required when evaluating the need for, and the effectiveness of constructed wetlands.

3.3.1 Physical and Hydraulic Design Principles

There are many books and studies on the design and construction of wetlands. In the previous century, the use of surface wetlands was first applied in Europe (1912), in part as a cost saving measure for treating municipal wastes. A majority of the wetlands constructed in Europe were subsurface vegetation beds not susceptible to freezing in the winter months. In the United States, the wetlands movement did not begin in earnest until the 1970's. The EPA Constructed Treatment Wetland System Description Performance Database (2000) lists 150 constructed wetlands in treating municipal wastes from wastewater treatment plants. (Some may no longer be operational.)

Designing wetlands is a field of extensive study; pioneers in this realm include the authors of the texts described here. In Treatment Wetlands by Dr. Kadlec and Dr. Knight (1996), a thorough engineering analysis is provided. The modeling of nutrient and contaminant removal based on influent characteristics is carefully explained. The size of the wetland cells, the depth and residence time are key design criteria. The classic equations for removal rates of nitrogen and BOD5 are the result of their work, and have subsequently become standards in this field.

More recent design texts and manuals rely upon their equations as foundations for analysis of treatment efficiencies.

Natural Systems for Waste Management and Treatment by the professional engineers S. C. Reed and R. W. Crites, and Middlebrooks, E. J. (1998) is similar to the Treatment Wetlands text and provides an updated formula for the removal rates of phosphorus and fecal coliform bacteria. The standard equations are dependent upon a number of factors, but in general allow for an effective analytical tool for designing wetlands dealing with respect to these pollutants. Reed also provides a general equation for determining the rate of suspended solids removal. These equations were derived, in part from the Manning equation for open channel flow and have come to be known in the world of wetlands construction as the “Kadlec equations” and “Reed methods” for calculating the influent and effluent water qualities. The work of these authors and other experts like Dr. Tchobanoglous are compiled in an encyclopedia of wetland design published by the EPA (2000), EPA Manual Constructed Wetlands Treatment of Municipal Wastewater. This manual is a compendium of research findings and refinements and is considered the standard reference for design questions and problems.

In addition to the design references listed previously in Wetland Design Principles, other sources used for this feasibility analysis include: Modeling the Hydraulic Characteristics of Artificial Wetlands by G. A. Jenkins of Australia and several journal papers by Economopoulou, and Tsihrintzis. These reports build upon the earlier works of Kadlec, Reed and Knight and continue the pursuit of the pollutant removal modeling. In 2004, Economopoulou and Tsihrintzis provided a guide for applying design principles to meet water quality requirements.

There are general recommendations from each of these texts on the designs best suited to treat a range of pollutants. For most wetlands, there are a select group of pollutants that are problematic, and the design criteria employed will determine the optimal reduction or polishing levels that can be achieved overall.

3.3.2 Ecological and Biological Design

Designing and managing wetlands requires the understanding of the biological systems operating within the area. From microbiology to macro-biology, a grand view of the biota involved and recognition that the wetlands are a working system is absolutely necessary.

The EPA Free Water Surface Wetlands for Wastewater Treatment Technological Assessment of 1999 describes the importance of planning and sizing of wetlands to fit within the existing landscape. Chapter 6 of this manual, “Lessons Learned and Recommendations” identifies the importance of constructed wetlands for multiple benefits and public access. The addition of information signs, interpretive centers and educational seminars is critical to public participation and attraction to the wetland site. While deep open water cells may be engineered for specific pollutant removal processes, these “ponds” also attract water fowl and aquatic life that also attract people.

Campbell and Ogden in their book, Constructed Wetlands in the Sustainable Landscape (1999) tell of the “waterworks gardens” project in Kings County, Washington south of Seattle. The wetlands are described as a combination of treatment functions and artwork into a “single public accessible project” (p. 218). The entire project was led by Lorna Jordan, an artist. This emphasizes the importance of planning, design, and working with the landscape topology and ecology of any proposed wetland project, and the possibilities that go beyond the rectangular cells often selected by engineers.

The EPA Technological Assessment Free Water Surface Wetlands for Wastewater Treatment referenced previously addresses the potential nuisances associated with wildlife without examining the ecological purpose of attracting wildlife as a benefit in a chapter titled “Environmental Impact”. Sadly, the manual says too little of the potential for wildlife habitat and restoration of indigenous fauna that wetlands can so readily provide.

Within the Rio Grande watershed, a World Wildlife Fund publication, *Creation of a Chihuahuan Desert Bi-National Wetland: A Feasibility Assessment* (2008) by Loughheed and Rodriguez, map potential wetland sites along the Mexican border with Texas. While noting the

potential for pollutant removal, key to these sites is the fact that habitat for birds, native plants, animals and other aquatic organisms can be established in an area where many of these species flourished in the past.

Mosquito control is always an important consideration when building a wetland, especially if a park setting is the goal. The use of fish and bats to control larvae and adults has been applied in other wetlands, but for designs that inhibit the growth of mosquitoes, Dr. William Walton has written extensively on this topic, covering years of empirical studies of many wetland sites. His publication (Walton, 2003), is but one excellent example of his work and theories. Other papers and publications by Dr. Walton are listed in the references section. Another valuable source for mosquito control is the brochure by Emily Biebighauser published in 2006; Construct a Healthy Wetland – Destroy Mosquitoes. This brief set of guidelines highlights the strategies that can be employed in managing a wetland successfully for vector control with an emphasis on natural methods to combat mosquito growth. Some wetland sites prefer to use chemical poisons to target mosquitoes, others have introduced bacteria that are toxic to mosquito larvae, but the overall emphasis is predicated on planning and design (Sarneckis, 2002). Sarneckis concludes that vegetation and design aspects of constructed wetlands are considered to be major factors contributing to mosquito growth. The elimination of habitat favoring mosquito breeding and growth, like standing water and thick vegetation, are precautionary measures that have proven to be quite effective.

In addition to the biology and ecology of any wetland system, consideration must be paid to the question of wildlife. Build it, and they will come. Creatures large and small will be attracted to wetlands. While many would like to see ducks and geese and other waterfowl swimming in the park, few wish to attract the same numbers of skunks, coyotes, and even bullfrogs. How to control and manage for animal access and removal, if necessary, is a practical component of wetland management. Having a wildlife management plan is part of operating and maintaining a healthy wetland. For example, gophers and other burrowing animals can wreak havoc on levees and dykes and can cause extensive damage requiring expensive repairs.

Alternatively, wetlands can provide habitat for keystone animals like bald eagles (*Haliaeetus leucocephalus*) in the Rio Grande Basin, and Sandhill Cranes (*Grus canadensis*) at the Bosque del Apache National Wildlife Refuge (*woods of the Apache*). Endangered species like the southwestern willow flycatcher (*Empidonax traillii extimus*) may find suitable habitat, if not for breeding, certainly for stop-overs on their migration. The well-known and admired animals help to attract attention, people, and economic benefits to constructed wetland sites (Gelt 1997).

3.3.3 Sustainability – The Community, Ecological Economics and the Aesthetic

The most famous and the most successful constructed wetlands referenced in the United States are those that work for the community as well as nature. The Tres Rios Project in Phoenix, the Arcata Wetlands in Humboldt County, California, and the Las Vegas Springs Preserve are three notable examples of wetlands designed to benefit nature and attract people cohesively. By creating a park setting, a greater interest is generated, including the utilization of these wetlands as areas for academic research.

Research is crucial to understanding how our human waste-streams are affecting the environment. Endocrine disruptors, persistent chemical compounds associated with pesticides, herbicides, and personal care products are topics of great interest. How, and to what levels can a wetland system alleviate some of these pollutants is not fully understood and will be an issue to be monitored for decades to come.

The economic benefit of constructed wetlands is difficult to ascertain. Many of the benefits are indirect, and not easy to quantify monetarily. The net impact of a single wetland may be small by itself, but if that single wetland acts as a seed to promote other wetlands, and the ecological landscape of the watershed shifts towards a more natural and inviting setting for people wishing to spend time outdoors, the overall impacts can be quite large.

While the costs of building and maintaining constructed wetlands can be determined, calculating the indirect benefits attached with increased visitation, education, and community

pride are systematically quantified in the application of ecological economics. Professor Robert Costanza, in his pioneering work, Ecological economics: The science and management of sustainability (1991), argues that the external and indirect costs and benefits associated with nature have long been left out of traditional economic analysis, and that doing so is not an acceptable method for sustainability evaluations. Cumberland *et al* (1997) point out the fact that viewing the economic benefits through the traditional lens of standard economics measures is quite limited. The value of the natural environment far surpasses the value of humankind's entire economic output. Yet in traditional GDP-type analyses, the external costs of pollution, social injustice, and the extinction of species are relegated to trivial dollars and cents issues. This classic economic view limits our ability to approach sustainability holistically.

The string of pearls approach is actually more of a watershed or systems configuration. Rather than creating habitat at a singular site like an estuary or river bend, each pearl when combined into a string of pearls becomes part of an assembly or series of wetlands. This creates a much larger scale of riparian type habitat. The connections and nexus with the river and adjacent communities is a type of synergism. The whole becomes greater than the sum of its parts. Collectively, the string represents the missing riparian corridor as is the case with the Rio Grande. The value of human interaction and interest in these wetland pearls cannot be overstated. The environmental is integrated into the social fabric and economic realm by reason of its existence. And the first and foremost quality of each pearl is its beauty, for that is the true source of its attraction.

One pearl changes the aesthetic of the immediate area. A string of pearls instills beauty on a landscape or eventually watershed scale. If successful in one location, other communities will wish to follow suit.

Wetlands help to foster positive recognition and bring substantial educational value to their host communities. A new sense of community heritage for Sunland Park, New Mexico will (hopefully) emerge from the development of this wetlands park. A profound and transformative

identity with the Rio Grande may be inculcated in the young people residing in this former colonia and economically distressed community on the U.S. – Mexico border.

3.4 Feasibility of a “String of Pearls”: case study of Sunland Park, NM

3.4.1 Background

The critical lens through which this wetlands conceptual design will be evaluated is the principle of sustainability. Using this standard, considerations beyond the usual engineering and ecology requirements (such as the precautionary principle, social justice concerns, the distributional principle, and ecological economics) must be included into this larger sustainability perspective. This framework includes challenges and needs that are too often neglected when undertaking construction projects, even environmental projects. The scope of this idea is more comprehensive than simply improving the water quality of the effluent discharged to the Rio Grande through engineering measures, or ecological attempts to provide new riparian habitat, or even assisting a poor border community with development; this present research seeks to address why it is ethically sound and indeed appropriate to eventually apply this idea to an entire watershed – the Rio Grande from top to bottom. The idea of sustainability also infers that to maintain the status quo, to accept the present condition, is a negligent position, one that is insufficient. We must also seek to replenish and restore that which has been degraded. In terms of riparian habitat on the Rio Grande, sustainability begins with restoration.

The Rio Grande serves as receiving water for sewage plant effluents from Colorado through El Paso and downstream to the Gulf of Mexico. From Albuquerque to El Paso, there are over a dozen wastewater facilities discharging treated sewage effluent into the Rio Grande. Currently there are a number of wetland areas (EPA Environmental Compliance & History Online listings of NPDES permits - <http://www.epa-echo.gov/cgi-bin/ideaotis.cgi>) along the Rio Grande, but at this time there are no functioning constructed wetlands in place for polishing wastewater treatment plant effluent being discharged into the river.

The New Mexico State Engineer has the legal authority and statutory responsibility to “supervise, measure, appropriate, and distribute” the waters of the state (New Mexico Statutes Annotated (NMSA) 1978, § 72-2-1), including surface waters (NMSA 1978, §§ 72-5-1 through 37), and ground waters, (NMSA 1978, §§ 72-12-1 through 28), in accordance with the prior appropriation doctrine, as established by state law, NM Constitution at XVI; NMSA 1978, § 72-1-2. Once the effluent reaches the Rio Grande it becomes water of the river. During the irrigation season, these waters fall within the purview of waters released for the Rio Grande Project managed by the Bureau of Reclamation. These flows are apportioned between the three irrigation districts of New Mexico (EBID), Texas (EPCWID No. 1), and District No. 9 in Juarez, Mexico. In the non-irrigation season, flows below Caballo Dam, whether drainage returns, storm flows, or treated sewage effluent are non-accountable waters and free to be used by the irrigation districts at their discretion.

Sunland Park, New Mexico straddles the Rio Grande at the bottom of the Mesilla Valley. South of the City, the Rio Grande winds its way through the Asarco narrows, exiting into the Texas and Mexico borderlands, eventually reaching the Gulf of Mexico, 1,200 miles downstream. The City’s boundaries include the only portions of New Mexico situated south of Texas. It is a relatively poor, though rapidly growing border community with an estimated population approaching 15,000 and a mean annual income of only \$23,171 (U.S. Census Bureau statistics for 2010). It is considered to be a disadvantaged border community with 47% of its residents living below the poverty line. According to Border Environment Cooperation Commission (BECC) Infrastructure Needs Report of 2009, nearly 100% of its citizens are provided water and wastewater services through the public utilities department. The City’s waste water treatment plant (WWTP) collects and treats all the sewage from Sunland Park and the neighboring community of Santa Teresa. The failed wastewater treatment plant at Santa Teresa, (to be renamed the Sunland Park North facility) is in the process of being upgraded and will soon be able to treat up to 2.7 million gallons per day. This should alleviate the influent loading generated by Santa Teresa which adds approximately 800,000 gallons per day to the

Sunland Park WWTP. The Sunland Park wastewater treatment plant discharges its effluent (NPDES Number NM0029483; EPA Registry ID 110011027174) less than six miles upstream of the intakes at the Robertson Umbenhauer (Canal Street) Surface Water Treatment Plant in El Paso, Texas. Annually, the City of El Paso obtains 40-50% of its drinking water from the river, except for low-flow years during drought periods. Quality of wastewater treatment discharges is of critical importance in light of indirect potable reuse.

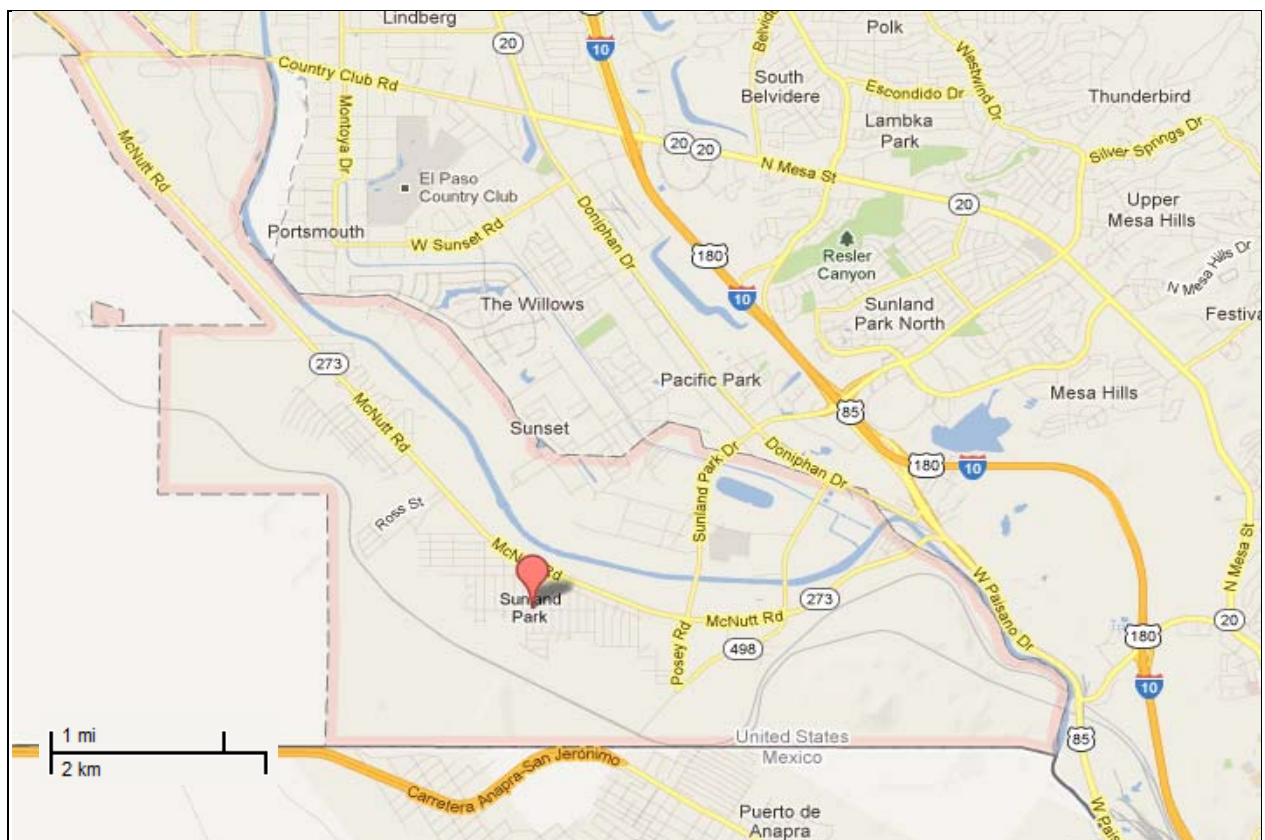


Figure 4 Map of Sunland Park, New Mexico

The City of Sunland Park, New Mexico is exploring the idea of utilizing their treated sewage effluent to create a wetlands park along the Rio Grande riparian corridor. This feasibility study is an evaluation of the City's proposal, and is intended as a preliminary design for the constructed wetlands project. Should such a project be funded in the future, it is anticipated that

this report will provide the framework necessary for construction to commence. The goal of this project with the City is to create cost-effective and sustainable treatment wetlands in the form of a public park to be enjoyed by local citizens and visitors from abroad. Utilizing this water to create a wetlands park could be of great benefit for both the community and the riparian environment.

Currently, the secondary effluent from the Sunland Park WWTP discharges up to 2 million gallons per day (MGD) directly to the Rio Grande through a single pipe. This effluent is required to meet all Clean Water Act and National Pollutant Discharge Elimination System permit requirements set by the Environmental Protection Agency and administered by the New Mexico Environment Department – Surface Water Quality Bureau. The effluent generally meets all Clean Water Act requirements and EPA Total Maximum Daily Loading 303(d) listed limits. There have been a few instances of exceedances, and polishing wetlands could provide a suitable buffer to alleviate acute conditions of overloaded WWTP discharge violations. Generally, the effluent from this plant surpasses the specified guidelines for biochemical oxygen demand (BOD 5-day), total suspended solids (TSS), E. Coli bacteria, residual chlorine and toxicity test for *Daphnia pulex* (water flea) and *Pimephales promelas* (fathead minnow). Other regulated characteristics of the effluent include turbidity and the presence of foams and oils.

The City of Sunland Park Waste Water Treatment Plant was issued its most recent National Pollutant Discharge Elimination System (NPDES) permit (NM0029483) on October 1, 2007 and is in the process of acquiring a renewal after September 30, 2012. The City resides in EPA Region 6, which is headquartered in Dallas, Texas. The Surface Water Quality Bureau of the New Mexico Environment Department (NMED) is the state regulatory agency charged with ensuring compliance with the NPDES permit standards.

Table 1 Permit Limits for NM0029483: Sunland Park Wastewater Plant Discharge Limits

Name	Limit		Limit		Limit
		(lb/day)	Basis	(mg/L)	
Aluminum	monthly	0.131	average	0.058	Average
Ammonia as N	monthly	monitor	average	Monitor	Average
BOD, 5-day, 20 deg. C	monthly	227	average	30	Average
BOD, 5-day, 20 deg. C	monthly	68.4	average	30	Average
Coliform, fecal general	monthly			500	Average
E. coli, thermotol, MF, MTEC	monthly			126	Average
Flow, in conduit or thru treatment plant	monthly	monitor	average		
Flow, in conduit or thru treatment plant	monthly	monitor	average		
LF P/F STATRE 48HR ACU DAPHNIA PULEX	quarterly			Monitor	Minimum
LF P/F STATRE 48HR ACU PIMEPHALES PROMELA	quarterly			monitoring only	Minimum
Mercury	monthly	0.000453	average	0.00033	Average
NOEL LETHAL STATRE 48HR ACU D. PULEX	quarterly			Monitor	Minimum
NOEL LETHAL STATRE 48HR ACU PIMEPHALES	quarterly			Monitor	Minimum
Phosphorus	monthly			Monitor	Average
Solids, total suspended	monthly	227	average	30	Average
Solids, total suspended	monthly	68.4	average	30	Average
Total Residual Chlorine	monthly			0.019	Maximum
Total Residual Chlorine	monthly			0.099	Maximum
pH	monthly	min = 6	max = 9		

The Sunland Park WWTP NPDES permit requires that the WWTP effluent discharged to the Rio Grande be monitored for the following characteristics: biochemical oxygen demand, 5-day (BOD₅), total suspended solids (TSS), E. Coli bacteria, total residual chlorine, whole-effluent toxicity, and effects on Daphnia pulex (water fly) and Pimephales promelas (flathead minnow) species. In general, the effluent is meeting all Clean Water Act requirements as specified under the NPDES permit. Currently, weekly samples are collected to monitor BOD, TSS, and E. coli levels. The EPA Enforcement and Compliance History On-Line (ECHO) website lists the parameters that are monitored including residual chlorine levels and flow measurements.

In 2008 the Sunland Park WWTP effluent was tested twice for mercury and aluminum and yielded average readings of 0.155 µg/L and 0.02 µg/L, respectively. Subsequent monitoring for mercury and aluminum was deemed unnecessary.

Table 2 EPA Safe Drinking Water Act Maximum Contaminant Levels (MCL)

Primary Contaminants	mg/L	Secondary Contaminants	mg/L
Arsenic	0.01	Aluminum	0.05 - 0.2
Copper	1.3	Chloride	250
Lead	0.015	pH	6.5 - 8.5
Mercury	0.002	Sulfate	250
Nitrate	10	TDS	500

Similarly, in 2008 ammonia levels in the influent and effluent were compared. The level of ammonia present in the influent was 42.6 mg/L and the average effluent level was 0.5 mg/L. No further testing is recorded, though the presence of ammonia does directly affect the toxicity tests performed on *Daphnia* and *Pimephales* species, and should the ammonia levels become much higher, this could impact the BOD levels of the effluent.

For this study, the Utilities Division of Sunland Park generously provided the records of their own laboratory data recorded from samples collected and analyzed on site. Appendix 1 lists flows, BOD, TSS, and Coliform levels for 2008 through April of 2011. The five major pollutants of concern for this NPDES permit are BOD₅, nitrates, fecal coliform counts, phosphates, and total suspended solids. The WWTP effluent at Sunland Park contains very low levels of the nutrients nitrogen (ammonia) and phosphorous. The City is required to sample for these chemical constituents every five years, as nutrient loading is not an issue for this particular plant. Nitrogen levels are consistently less than 5 mg/L and phosphorous is less than 2 mg/L. The Clean Water Act standards list anything above 30 mg/L for nitrates and phosphates as in violation of the Total Maximum Daily Loading (TMDL) rates deemed environmentally unacceptable for discharge to the Rio Grande. The TMDL calculation and monitoring is performed by the Las Cruces office of the New Mexico Surface Water Quality Bureau. In

summary, the WWTP at Sunland Park has little phosphorous in the influent, and nitrogen is not problematic. The levels of treatment achieved at the WWTP are quite clean as to be expected from a secondary treatment system dealing primarily with domestic sewage.

For the four year period of 2008 through 2011, the average BOD₅ concentration of the effluent was 4.7 mg/l. This is an effective treatment level for influent that starts above 350 mg/L which is typical for raw sewage in the United States. TSS effluent averaged 4.8 mg/l over these four years with an average influent level above 360 mg/L entering the WWTP. The treatment train at Sunland Park is effective at lowering the levels of these pollutants prior to discharge to the Rio Grande. The fecal coliform counts average well below the 126 coliform forming units (cfu) maximum allowed for this stretch of the Rio Grande. There have been spikes in bacteria, and retesting has shown these to be temporary or related faulty sampling with each follow-up sampling meeting the required limits.

Figure 5 shows the average monthly flows experienced at the Sunland Park WWTP for four years, 2008 through 2011. Each year, there is an increase in effluent during the summer months of July through September. In 2011 this trend continued through October. It is believed that this increase resulted from a faulty effluent meter (conversations with Carlos Arellano, CRRUA foreman for the Water Utilities). Inflows at the WWTP have never exceeded the design capacity, and the maximum daily treatment is estimated to be approximately 7,500 cubic meters per day (CMD) or 2 MGD, just below the limit for the WWTP. The average daily flows for each year has been steadily increasing, as indicated by the average daily flows for the years listed: 1.51, 1.58, 1.70, and 1.76 million gallons per day for 2008, 2009, 2010, and 2011 respectively.

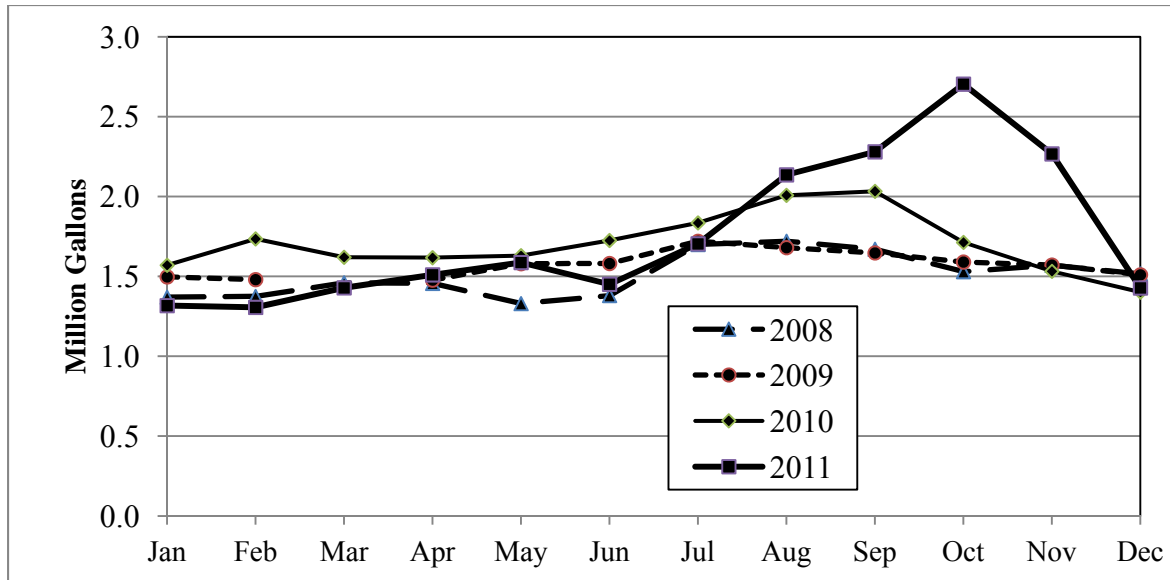


Figure 5 Treated Effluent Discharge - Average Daily Flow

The graph shows that the plant was running at or above capacity (allegedly) for October of 2011. When the Sunland Park North WWTP (formerly the Santa Teresa WWTP) expansion and replacement project comes on line, it is expected to treat up to 1.6 MGD or 6,000 CMD. Currently, up to 500,000 gallons per day is being sent to the Sunland Park WWTP. This extra inflow is a cause for serious concern, and has produced notable spikes in TMDL's like TSS and coliform bacterial counts. The primary treatment facility at Santa Teresa only treats 300,000 gallons per day before the effluent is sent to Sunland Park.

3.4.2 Physical and Hydraulic Design

Between the Sunland Park WWTP and the riverbank of the Rio Grande, there are several acres of city-owned land readily available for the creation of a constructed wetland. This proposed multipurpose wetlands park will be designed to provide a variety of potential benefits including enhancement of the City's landscape, polishing wastewater to improve water quality prior to its discharge to the Rio Grande, flood control management, wildlife conservation, recreation, education, and research. The proposed area is located near Racetrack Drive and McNutt Road, north of the City library and administrative buildings, along the south side of the Rio Grande riverbank, as shown in Figure 6. The rectangular structure due east of the WWTP is

the Sunland Park administrative complex which includes the police station, city hall, courthouse, and utilities section. The outfall from this plant into the bed of the Rio Grande is located at: 31.475523 N and 106.332625 W, just west of the big cottonwood tree (circled). The barren land between these facilities and the Rio Grande is suitable and available for siting the proposed wetland cells. These wetlands are expected to become a green attraction site and center for learning about the environment, the water cycle, biological processes, and the treatment of our waste-streams.



Figure 6 Google Map of Sunland Park, NM and

The placement and site selection of any constructed wetlands is determined by the topography, availability and costs of the land. The primary economic advantages of this site are availability and cost. The City owns the land in question and has no other use for the proposed pilot site at this time. The flatness is actually a favorable condition for construction as this simplifies the excavation of cells and build-up of levees around the wetlands for containment.

There is easy access to the area, with land available to store excavated materials and any necessary sand, gravel, and stones imported for construction. The lack of infrastructure adjacent to the site will also assist with the ease of liner placements. Based on these qualities, the site is ideal for this project. The fact that this wetland is located next to Racetrack Drive and will be viewed by the public as they travel to the nearby Sunland Park Racetrack and Casino, or Western Playlands Amusement Park will help to showcase these restoration efforts on the banks of the Rio Grande. Public awareness can only be increased by placing these wetlands in a highly visible spot, next to a heavily trafficked bridge and only one mile from the proposed border crossing between Sunland Park, and Anapra, Mexico.

The main channel of the Rio Grande is typically relatively dry during the non-irrigation season. The relatively low flow that can be seen meanders from bank to bank within the riverbed. The floodplain on the north extends to the levee which appears as a dirt road (the road is on the top of the levee). To the south of the river, there are no levees in this section of river and Highway 273, or McNutt Road acts as the barrier to the floodplain.

The Pilot Site shown on the map is approximately 1 hectare or just over 2 acres in area. With the levees and access paths and piping lines, there is ample room for a wetland of this size. The topography is nearly level for most of the floodplain. Appendix A.8 shows the elevations relative to the satellite map. From the two juxtaposed images, it is apparent that there is little to no slope within the pilot site, and that flows through the wetlands will depend upon changes in hydraulic head between the successive cells. The recommended slope for the bottom of constructed wetlands is 0 to 1% or one foot of drop for every one hundred feet of linear cell footprint. For the site selected, the elevation of the land surface is flat. There is less than two feet of elevation drop from the highest to the lowest elevations measured. For purposes of excavating wetland cells and constructing berms, this piece of land is ideal.

3.4.3 Modeling of Pollutant Removal

Typically, design theory for constructed wetlands focuses on the loading rates and removal rates of pollutants (e.g. nitrogen/ammonia and phosphorus) utilizing kinetic rate constants for biological extraction/production and resulting removal efficiencies.

Three distinct equations are used for this design process, and the five pollutants of concern are total suspended solids, BOD₅, nitrogen, phosphorous, and coliforms. The first two equations are 1st order exponential decay equations, derived from the general form: $N = N_0 e^{-\lambda t}$ for standard first order reactions. The third equation is an empirical solution derived from measurements taken in constructed wetlands. It is arithmetic and provides only a general solution for the removal of suspended solids. Temperature, BOD, nitrogen, phosphorus, bacterial loadings, and TSS removal rates are calculated by employing the general equations:

- (1) $\frac{C_e}{C_i} = e^{-K_T t}$ For BOD5 and Nitrogen removal rates, (Reed – 1995)
- (2) $\frac{C_e}{C_i} = e^{\frac{-K_l}{h_l}}$ Coliform and Phosphorus removal rates, (Kadlec & Knight – 1996)
- (3) $\frac{C_e}{C_i} = [0.1139 + 0.00213(\text{HLR})]$ for TSS removal rates, (Knight – 1995)

Where:

C_e and C_i are effluent and influent concentrations mg/L

K_T and K_l are rate constants with T for temperature and l for hydraulic loading

h_l hydraulic loading defined as Q/A or inflow/surface area ($\text{m}^3/\text{d}\cdot\text{m}^2$ or m/d)

(HLR) is the hydraulic loading rate in centimeters per day (cm/d)

Table 3 Pollutant Removal Equations & Rate Constants for Constructed Wetlands

Pollutant	Equation	Rate Constants	Units
BOD-5	(1)	$K_T = 0.678(1.06)^{T-20}$	d^{-1}
Fecal Coliform	(2)	$K_I = 0.3$	md^{-1}
Nitrogen	(1)		
<i>Nitrification</i>	(1)	$K_T = 0.0389T$ for $0^\circ < T < 1^\circ C$	d^{-1}
		$K_T = 0.1367(1.15)^{T-10}$ for $1^\circ < T < 10^\circ C$	d^{-1}
		$K_T = 0.2187(1.048)^{T-20}$ for $T > 10^\circ C$	d^{-1}
<i>Denitrification</i>	(1)	$K_T = 0.023T$ for $0 < T < 1^\circ C$	d^{-1}
		$K_T = 1.15^{(T-20)}$ for $T > 1^\circ C$	d^{-1}
Phosphorus	(2)	$K_I = 0.0273$	md^{-1}
Equation (1) by Reed et al. (1995), Equation (2) by Kadlec and Knight (1996)			

Influent BOD levels at treatment wetlands are usually above 10 mg/L and nitrogen levels can be higher. The average BOD level of the Sunland Park WWTP is less than 5 mg/L and ammonia is very low at less than 0.5 mg/L (as N).

For the City of Sunland Park effluent, BOD, TSS, and coliform bacteria are the pollutants of concern. The removal rates for BOD and Coliform pollutants are evaluated in Tables 4 and 5. Table 3 lists the equations used to perform these calculations.

Table 4 BOD removal rates for various temperatures and HRT's - From Equation (1)

$K_T = .678(1.06)^{(T-20)}$ From Equation (1) in Table 1				
Influent Level	HRT days	Effluent Levels in mg/L		
BOD _i mg/L		T = 0°	T = 25°	T = 40°
10 mg/L	t = 2	6.6	1.63	0.13
10 mg/L	t = 3	5.3	0.66	0.01
10 mg/L	t = 4	4.3	0.27	0
10 mg/L	t = 5	3.5	0.11	0
% Percent Reduction in BOD Levels	t = 2	34.5%	83.7%	98.7%
	t = 3	47.0%	93.4%	99.9%
	t = 4	57.1%	97.4%	100.0%
	t = 5	65.3%	98.9%	100.0%

At colder temperatures, it takes more time to remove BOD as expected with any kinetic reaction. When the ambient temperature approaches 25 degrees, effective removal is achieved at the end of 3 days. Under warmer conditions, two days HRT is sufficient for BOD removal. Therefore, from the data presented in the chart, an HRT of 3-4 days should efficiently polish the incoming BOD levels to less than 5% of initial concentrations. In colder weather, the process is much slower though the effluent from the wetlands would still be cleaner than what is currently discharged to the Rio Grande. See Figure 7.

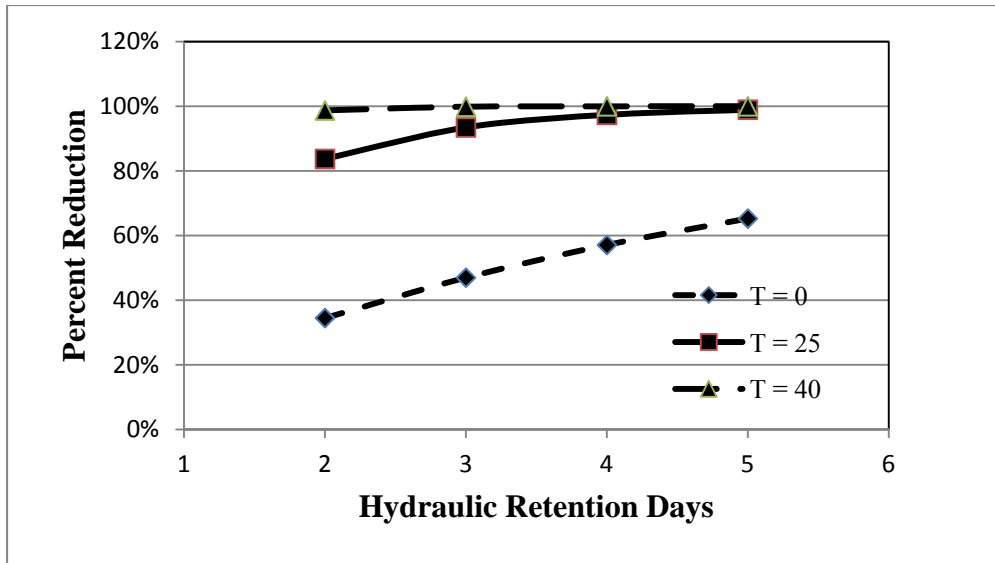


Figure 7 Sensitivity of BOD Reductions to Temperature and HRT

For coliform bacteria and phosphorous removal rates, equation (2) is employed. The following chart is based on an average inflow of 300,000 gallons per day, or 1136 cubic meters per day. This is 20% of the average daily influent over past four years. The calculations are based on wetland cell depths of: 1.2, 0.9, and 0.3 meters, or 48, 36, and 12 inches. Hydraulic Residence Times of 2, 3, and 4 days are used to calculate the surface areas and these hydraulic loading rates.

Table 5 Coliform, Phosphorous & TSS removal rates for various HLR's - From Equation (2)

From Equation (2) in Table 1			
$K_1 = 0.3$ for coliform & 0.0273 for phosphorous; HLR in centimeters for TSS			
HLR (cm/day)	Percent Reduction of Pollutants		
	Fecal Coliforms	Phosphorous	TSS
30	63.2%	8.7%	82.2%
20	77.7%	12.8%	84.4%
15	86.5%	16.6%	85.4%
12	91.8%	20.3%	86.1%

For Coliforms, the greater the surface area present, the better the reduction of bacteria. As with coliform removal rates, the lower the hydraulic loading rate, the greater is the reduction of phosphorous levels. Total suspended solids reduction changes little with the hydraulic loading rates as settling and flocculation occur at a rapid rate. The design strategy for maximizing coliform and phosphorous reduction rates is to create wetland cells with maximum surface area (less depth) while simultaneously maximizing retention times for the reduction of other pollutants. Temperature is not a factor in reducing the levels of pollutants listed in Table 3.

3.4.4 Hydraulic Design

Hydraulic design theory is applied to determine the optimum configuration of wetland cells to remove pollutants and to provide for the sustainment of wetland or riparian vegetation. Length to width ratios, slope, hydraulic residence times and hydraulic loading times, flow rates and vegetative density are all variables considered in the design.

The efficiency of pollutant removal and hydraulic design limitations will be evaluated for the WWTP effluent (influent to the wetlands). Fortunately, the effluent is secondary-level treated discharge that is relatively clean, the pollutant levels are low. Polishing the effluent from the WWTP should not be a limiting factor in the design of the cells and an HRT of more than 4 days shows little improvement on the efficiency of pollutant removals.

This affords the opportunity to explore a greater range of hydraulic designs, as the removal of pollutants will not be the driving factor in the operation of the wetlands. For this reason, the wetlands will be referred to as polishing wetlands, rather than treatment wetlands. A broader focus, less concentrated on pollutant reduction, allows for other important considerations to enter into these design calculations: restoration of riparian habitat for migratory birds, development of a scenic attraction for the enjoyment of visitors, and development of an educational center for water resources.

For constructed treatment wetlands the recommended length to width ratio ranges from 2:1 - 5:1, while cell depths can be as little as 0.3 m or ~ 1 foot up to 2 meters for the deepest

ponds. Hydraulic residence times are on the order of 2 to 6 days. Open water zones are usually designed at no more than 20% of the surface area, but have been designed as high as 50% in certain sites. Because the influent to the proposed wetlands is already treated, the hydraulic residence time required is less, and the use of deeper cells and more open water areas will not dramatically impact the levels of pollutants to be discharged to the Rio Grande.

Figure 8 shows the reduction of pollutants calculated over a period of days. The hydraulic retention time runs from 2 to 5 days. The hydraulic loading rate is based upon the total HLR for the three combined cells configured as shown in Table 3.

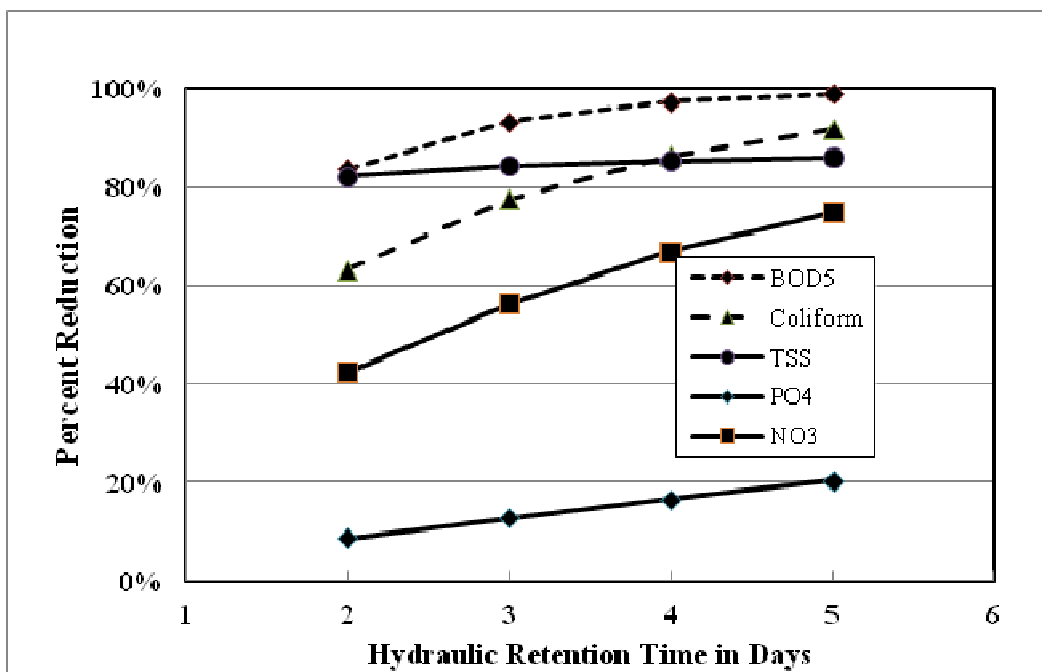


Figure 8 Hydraulic Retention Time vs. Percent Reduction of Pollutants

The reduction of phosphate increases with time, but overall removal rates are projected to be low for the practical range of hydraulic loadings. Phosphorous is a conservative nutrient primarily removed by adsorption. Biological uptake is very slow. A seven-fold increase in wetlands area would be required to reduce influent levels by 50%. However, phosphorous levels are not a concern for this particular sewage plant. The reduction of nitrates and coliforms are enhanced with longer retention times. The percent reduction for TSS and BOD is significant

with brief retention times (better than 80%) and additional time after four days does not significantly yield better results. A retention time of 4 or 5 days would be optimum, as longer periods won't result in any significant pollutant reduction, except for phosphorous which is already very low.

Analysis for sizing this pilot-scale wetland is based upon the average daily inflow rate of 300,000 gallons per day (gpd), or 1136 cubic meters per day. This flow rate was chosen as it represents nearly 20% of the average influent treated at the WWTP each day. With an inflow of 300,000 gpd a wetland nearly 1 hectare or 2 acres can be created. If such a pilot scale wetland proves feasible, further expansions to handle all of the effluent generated at the WWTP could be done on a modular basis, using the pilot site as a template. Other wetland additions would not be identical geometrically, but the retention times, depth of cells and incorporation of trails and viewing areas would be engineered in a similar fashion. Only the scope would increase, as the dimensional analyses would remain fairly constant. A full build-out would only require a larger scale after refining and adjusting for issues encountered at the pilot wetland.

Three cells are utilized in this preliminary wetland design. The hydraulic retention time for the three cells combined is 4 days. This provides enough time for better treatment of nitrates and bacteria. The first cell is the deepest at 1.2 meters (4 feet) and holds 40% of the total volume. For an inflow of 300,000 gpd and a retention time of 4 days, the total volume of water is 1,200,000 gallons or 4,544 cubic meters. Thus, the first cell will hold 1,818 cubic meters. The surface area for this first cell is 1,515 square meters and a 30 by 50 meter configuration conforms closely to the golden ratio.

The second cell is 0.9 meters (3 feet) deep and holds 30% of the volume, or 1,363 cubic meters. It has a surface area identical to the first cell and will also be 30 by 50 meters, or 1,500 square meters.

The final cell is 0.3 meters (1 foot) deep and like the second cell holds the remaining 30% or 1,363 cubic meters of water. This cell has the greatest surface area at 4,544 square meters. Configuring this cell to resemble a golden rectangle yields a 55x85 square meter cell.

Together, the three cells running in series provide a deep open water space where solids and suspended materials can settle, a medium deep cell with some open water and submergent vegetation; and a shallow cell for emergent vegetation with a much greater surface area. The total surface area for the three cells is approximately 7,573 square meters or 1.9 acres.

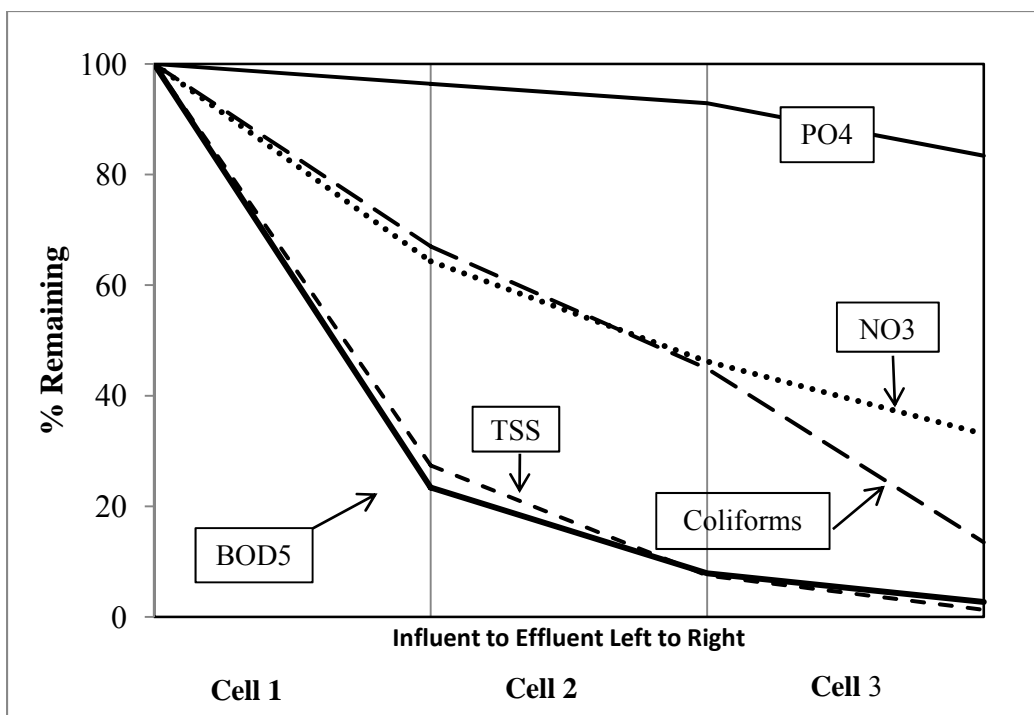


Figure 9 Percent Pollutant Reduction by Wetland Cells

The figure shows the calculated polishing levels expected for each treatment cell and the wetlands as a complete system. TSS and BOD levels drop off dramatically within the first cell. Coliforms and nitrates are reduced with time and phosphates are generally conservative. It should be noted that the estimation for TSS removal is overstated. The equation is arithmetic $C_e = C_i[0.1139 + 0.00213(HLR)]$ and in the form of: $C_i(a + bx)$. Multiples of this equation representing the treatment levels achieved from cell to cell produce a formula that becomes a cubic in terms of the coefficients. For TSS the actual reduction for the wetlands is expected to be closer to 85% and not 97% as shown in the figure.

3.4.5 Salinity and Flows

Constructed wetlands will not increase the total mass load of salts discharged to the Rio Grande. Evapotranspiration will result in some water loss, and the salinity concentration of the polished effluent emanating from the wetlands will slightly increase. However, compared to the salinity and salt loadings that exist in the Rio Grande and coming from the Montoya Drain one mile downstream of the WWTP, the increase in salinity will have no appreciable effect on the overall salinity levels for the Rio Grande watershed. The following table compares salinities for the WWTP return flows with the drain returns from the Montoya Drain and the total dissolved solids recorded at the Courchesne gaging station.

The total amount of salts entering and leaving the Sunland Park Waste Water Treatment Plant will not change. For comparison purposes, if half of the water was “lost” to evapotranspiration (a 50% loss is a large over-estimate, it is typically less than 10%, as described in the next section), then the remaining effluent would have twice the salt concentration or salinity. The NPDES permit for discharge allows for up to 2000 TDS, well within the expected value of salinity expected from the wetlands.

The following chart shows the salts delivered by the Montoya Drain and the Rio Grande under dry, average, and wet conditions, for both the non-irrigation and irrigation seasons. The Sunland Park WWTP discharges an average of 3 tons of salt per day. On the whole, the Montoya Drain carries nearly 250 tons of salt each day during the irrigation season and the Rio Grande carries more than 1300 tons of salt per day. Statistically, the salt load from the Sunland Park WWTP amounts to 0.2 – 0.4% of the total salt load.

During the non-irrigation season, when no releases are made from Elephant Butte and Caballo reservoirs, Sunland Park WWTP discharge is actually much lower in salinity than the return flows discharging from the Montoya Drain. The Montoya Drain adds 248 tons per day, the Rio Grande carries 1,354 tons per day and the Sunland Park WWTP adds 3 tons of salt per day. In summary, the overall impact on water losses and salinity increase of the effluent after coursing through the wetlands will be negligible.

Table 6 USDA/USGS Data from the Courchesne Gage 1936-1994
(Based on Monthly Measurements)

Salinity and Flows in Rio Grande	TDS	AFPD	MGD	Tons per Day TPD
Average	1109	1126	375	1734
Maximum	3894	11900	3967	64416
Minimum	641	5	2	5
Sunland Park WWTP	500	5	1.57	3
Percent of Total (avg)		0.4%		0.2%

Comparison of Montoya Drain and Rio Grande Salts and Flows for Dry, Average, and Wet years from Boyle Engineering Report for IBWC, 1998

Montoya Drain

	TDS	MGD	TPD	TDS	MGD	TPD
Dry 1971	1356	12	68	1377	12	69
Avg 1980	1739	22	160	1352	44	248
Wet 1988	1878	27	211	1288	58	312

Rio Grande

Dry 1971	1733	85	614	1045	143	623
Avg 1980	1335	138	768	733	433	1354
Wet 1988	1042	282	1225	686	671	1919

Comparison of 1980 flows for Montoya Drain and the Rio Grande

	Drain	River	Ratio	
TDS	1352	733	1.8	The drain is nearly twice as salty and carries 10% of the flow and accounts for 20% of the salt
MGD	44	443	0.1	
TPD	248	1354	0.2	

TDS = Total Dissolved Solids (mg/L); AFPD = Acre-feet per Day; MGD = Millions of Gallons per Day; TPD = Tons per Day

Pan Evaporation Rates for this area are above 100 inches per year. Specifically, at Caballo Reservoir, the State of New Mexico table of evaporative losses lists the annual average evaporation at more than 107 inches or 2720 millimeters. The amount of evapotranspiration (in inches) for three crops grown by the Elephant Butte Irrigation District: Pecans – 29.4; Alfalfa – 51.5; and Cotton – 26.3 inches, indicates that the evapotranspiration rates are typically 50% of pan evaporation rates at best (Skaggs and Samani, 2006). The EPA Manual for Constructed Wetlands Treatment of Municipal Wastewaters suggests that ET rates may be as high as 70-80% of pan evaporation rates for fully vegetated systems. Using straight pan evaporation as a conservative estimate, an annual rate of 107 inches or 2.72 meters represents the maximum anticipated total evapotranspiration rate:-

Table 7 Pan Evaporation Rates inches per month - Caballo Reservoir & Jornada Range
New Mexico State University State Climate Center Office

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
4.42	5.10	8.56	11.37	13.59	14.80	13.08	11.35	9.26	7.27	4.78	3.48	107.06
2.50	4.18	7.24	10.06	11.94	12.85	10.88	9.53	7.82	5.71	3.61	2.50	88.82

For the wetland design, with an average influent of 1136 cubic meters per day, a total of 414,924 cubic meters will flow through the system. The surface area of the wetlands is 7573 square meters, and the pan evaporative loss averages 2.72 meters giving a volume of water evaporated of 20,600 cubic meters, or just under 5% of the total flow each year. This will account for the total amount of water lost for this pilot investigation as the cells will be lined and impermeable for this design.

The magnitude of water loss from different surfaces generally occurs as follows: Pan evaporation > open water > saturated soil > riparian vegetation > upland vegetation > dry soil. Open water evaporation is approximately 70% of pan evaporation rates for the desert southwest (King and Bawazir, 2000).

The amount of salts entering the Rio Grande will not change due to evaporation; only the concentrations will increase, albeit minimally. The total load of salts in the Rio Grande at El Paso is more than the loading expected from 500 WWTP's (1734 tons per day vs. 3 tons per day) similar to the Sunland Park facility. Salt concentration is not an issue of concern.

3.4.6 Biological and Ecological Design

The final component, equally important to any of the other parameters, is plant selection. Purchase, procurement and planting costs are specific to the location, climate and purpose of the wetlands. For wetlands, there are a number of nurseries supplying different types of vegetation depending on location, depth of water, and aesthetic requirements. Incorporating indigenous plants is fundamental to working for a sustainable ecosystem, and fortunately, many of the plants found in natural southwestern wetlands are ubiquitous and inhabit riparian wetlands along the Rio Grande. Harvesting some of these plants is a common method of local environmentally concerned organizations.

A plethora of wetland plant species are found throughout the desert southwest. The following table lists some of the prominent types utilized at two well-known and actively studied constructed wetland sites; Sweetwater in Tucson and Tres Rios in Phoenix. Most of these plants are now found naturally in the Mesilla and El Paso Valleys. The extent to which these plants are indigenous and others invasive is not always clear. The categories of plant types are listed first:

Trees are great enhancements for any wetland park, especially in a desert climate. Planting native cottonwoods and willows in the area around the wetland cells and along the bank of the Rio Grande will provide much needed habitat for birds and animals. Care should be taken not to plant trees too close to the cells as shading can impede the effectiveness of pollutant removal and roots can damage levees and liners.

Table 8 Preferred Wetland Plant Species for Constructed Wetlands Park

<u>Category</u>	<u>Species & Common Name</u>
Bulrushes	<i>Schoenoplectus americanus</i> (Chairmaker's bulrush) <i>Scirpus microcarpus</i> J. (Panicked bulrush)
Forbs	<i>Ambrosia psilostachya</i> (Cuman ragweed) <i>Anemopsis californica</i> (Yerba manza) <i>Helianthus annuus</i> (Common sunflower) <i>Suaeda frutescens</i> (Seepweed) <i>Heliotropium curassavicum</i> (Salt heliotrope) <i>Sesuvium verrucosum</i> (Salt purslane)
Grasses	<i>Distichlis spicata</i> (Saltgrass) <i>Echinochloa crus-galli</i> (Barnyardgrass) <i>Leptochloa fusca</i> ssp. <i>fascicularis</i> (Bearded sprangletop) <i>Muhlenbergia asperifolia</i> (Scratchgrass)
Rushes	<i>Scirpus americanus</i> (American Three-square Bulrush) <i>Scirpus californicus</i> (Giant Bulrush)
Sedges	<i>Carex emoryi</i> Dewey (Emory's sedge) <i>Carex Microptera</i> Mack (Smallwing sedge)
Shrubs	<i>Baccharis salicifolia</i> (Seepwillow)
Trees	<i>Salix exigua</i> (Coyote or Narrowleaf willow) <i>Populus deltoides</i> (Rio Grande Cottonwood) <i>Salix gooddingii</i> (Gooding's willow) <i>Prosopis pubescens</i> (Screwbean mesquite)

Burrowing animals are always a concern for wetlands. Badgers, squirrels, and rabbits can wreak havoc on constructed sites, and maintenance is required to keep their burrows from affecting the operations of the wetlands.

Of great benefit to a constructed wetland setting is the presence of bats. These mammals help keep insect populations in check and are a natural vector control for mosquito borne illnesses.

The greatest threats to humans presented by the placement of a wetland next to a population center are mosquitoes and the diseases they spread. In this part of the Chihuahuan Desert, there have been reported cases for Dengue Fever, West Nile virus, and encephalitis along the U. S. – Mexico border. Equine virus affects horses and this is a specific concern due to the proximity of the wetland to the Sunland Park Race Track. It should be noted that Dona Ana County Vector Control actively sprays the backwaters and marsh areas between the racetrack and the Rio Grande to suppress the spread of the equine virus as well as to prevent human contraction of other diseases delivered by mosquitoes.

In order to abate the issue of mosquito populations arising from the wetland park, several strategies can be simultaneously employed to combat the spread of disease. The placement of gambusia or other minnows that feed on mosquito larvae are an effective method for controlling some of the population. Similarly, the presence of bats helps to greatly reduce the number of mosquitoes. Finally, engineering measures such as the use of vertical walls in each cell, rather than the more traditional low slope sides can reduce those areas of slow moving waters where breeding occurs. By keeping the flows through the cells steady and ensuring that the water is moving, a lot of mosquito growth can be controlled. Deep open water cells with vertical walls provide an easy means to limiting the spread of mosquito borne diseases.

This is more difficult in shallow cells that are covered in vegetation. The key to reducing mosquito eruptions is to ensure that the water is moving at a fairly consistent rate. Standing water is required for mosquitoes to successfully lay their eggs and hatch their larvae, and moving water precludes their efforts to breed. The utilization of submerged propellers and sprayers to

promote mixing and water movement have been used effectively in many wetlands and lagoons. Taken together, a multi-pronged approach is recommended for the control of mosquitoes at the proposed wetland park.

3.4.7 Economics

Guidelines for engineering design and construction are presented in Table 9:

Table 9 Engineering and Construction Parameters

Parameters	Values
Inflow	1136 cubic meters per day or 300,000 gallons per day
Cell Sizes and Number	3 cells 1.2 m (4 ft), 0.9 m (3 ft) and 0.3 m (1 ft) deep
Aspect Ratio	Golden Ratio $\sim 1:1.618 \phi$
HRT	4 days total
Earthwork	$\sim 7,500$ cubic yards or $\sim 5,800$ cubic meters
Size of Liners	$< 100,000$ square feet
Piping and Valves	1000 feet 14 inch pipe; 120 feet 8 inch pipe
Plants	Native plants to be used to the extent possible

The hydraulic residence time of four days for an inflow of 1136 cubic meters per day, requires a total volume of 4,544 cubic meters. Surface area for the three cells combined is 7,573 square meters or 81,515 square feet; equal to 1.87 acres or 0.76 hectares. The three cells combined will require nearly 7,500 cubic yards of soils to be excavated. At least 90% of this soil can be used for the construction of levees and roadways associated with this wetland design. The remaining soil can be put to use as a flood levee to direct overbank flows from the river and runoff flows from storm events away from inundating the wetland site. The costs for these parameters are provided in a general sense and are not precise or exact.

The amount of liner necessary for the three cells including covering the heel side of each cell levee is less than 100,000 square feet. For the sake of this project, 100,000 square feet of 30 millimeter Polyvinylchloride liner has been chosen. This is a standard in the industry, and available from a manufacturer in Arizona. PVC liners cost less than many other liners. The price for this amount is close to 40 cents per square foot or about \$40,000 for the liner. The liner and the earthwork are the two most costly engineering tasks involved with this and most other wetlands (land acquisition is not a factor for this particular site).

Equipment and labor costs are based on local El Paso rates, and for a project this size (relatively small when compared to major construction projects) the overall bill for these efforts is in the \$45,000 to \$65,000 range.

Piping, valves and other ancillary equipment needed for these wetland cells amounts to less than \$15,000 based on standard industry rates.

The total cost for wetland construction can best described as a range of likely prices. The EPA Manual for Constructed Wetlands examined nine specific wetland sites and it was determined that a formula relating size directly to cost was not possible. Of the wetlands examined two were similar in size to the proposed Sunland Park wetland project: Ouray, Colorado and Mesquite, Nevada. The Ouray wetlands included the purchase of land (\$55,000) and had a total price of \$108,000 for 0.9 hectares; the Mesquite wetlands did not employ a liner and the 1.9 hectare site cost over \$500,000.

Based upon preliminary data and cost comparisons for excavation work in the El Paso area, price of liners available, and estimates on appurtenances and plants, it is likely that the pilot scale wetland can be constructed for less than \$250,000.

Table 10 Construction Costs for Sunland Park, New Mexico Wetlands Park

<u>Category</u>	<u>Unit Costs</u>	<u>Quantity</u>	<u>Cost (\$)</u>
Excavation	\$4 per cubic yd	10,000	\$40,000
Compaction	\$5 per cubic yd	2,000	\$10,000
Rip-rap	\$30 per sq yd	600	\$18,000
Gravel	\$20 per cubic yd	600	\$12,000
Liner 30 mil PVC	\$0.40 sq ft	100,000	\$40,000
Plumbing			
Piping			
12 inch RCP	\$30 per LF	1,000	\$30,000
8 inch PVC	\$25 per LF	200	\$5,000
Valves	\$650 - \$2,800	12	\$12,000
Structures	\$4,500	4	\$18,000
Plants average cost	\$1.50 per plant	5,000	\$7,500
Subtotal			\$192,500
Misc 15%			\$28,875
<u>TOTAL</u>			<u>\$221,375</u>

The costs listed in the table are conservative. For example, the price per plant listed at \$1.50 is taken from the La Mancha Wetlands Report (Parametrix, 2010) where the average plant price was \$0.75. The excavation and compaction costs may be over-priced for this area given that much of the soil is loamy sand and alluvial deposits which may be suitable for compaction on site *United States Department of Agriculture*. (n.d.). Retrieved July 30, 2011, from Web Soil Survey: <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.

Reinforced concrete pipe was chosen for its strength, durability, and low cost. For one thousand linear feet, there may be a reduction in price. The liner chosen is PVC. While the State of New Mexico regulations call for a minimum of 40 millimeters thickness, this is primarily for waste lagoons associated with dairy operations. As the effluent is already meeting NPDES

requirements, a relaxation of this standard is deemed likely for this application. Whether a liner is actually required or not, has yet to be decided by the Surface and Groundwater Bureaus of the New Mexico Environmental Department. Because this is a pilot project, it is best to err on the side of caution and plan for the installation of a liner.

The prices given for valves and structures (manifolds and weirs) are also higher than expected. However, for this analysis higher costs were used to establish a realistic ceiling for this project. Altogether, the actual price for this wetlands could be several tens of thousands of dollars less than the total of \$221,375 tabulated. This results in a capital cost of \$0.74 M per MGD treated and a unit operating cost of \$0.14 per thousand gallons (kgal) treated over a 15 year life.

3.5 Conclusions

There are several reasons why this concept is deemed worthy of a feasibility study. The opportunities and advantages for the City of Sunland Park include:

- Availability of City land adjacent to the WWTP and the Rio Grande
- Effluent already permitted for discharge to Rio Grande
- Implementation of low-tech, low-cost method for polishing effluent
- Less costly than traditional WWTP infrastructure
- Environmentally attractive for birds, riparian flora and fauna, and human visitors
- Provides a ready-made “laboratory” for future academic study
- Promotes public education on water issues (nexus with adjacent library)
- Establishes wetlands in a channelized river system
- Socially just project for a poor and disadvantaged border community
- Visually pleasing green space for the public to enjoy in a eco-park setting
- Puts “free” water to beneficial use
- Enhancement of Rio Grande water quality (less nitrogen, BOD/COD)
- Visually pleasing to passers-by, a form of free advertisement

- Establish an attractive centerpiece for the City's Municipal Center
- UTEP CERM recognition - community involvement & resource management
- High potential for integration with alternative energy sources – solar and wind energy for aeration, filtration and pumping
- The cultivation of a single pearl in a string of pearls

The construction of a wetlands park in Sunland Park is technically feasible. Wetlands provide a low cost method for polishing waste water effluent. Total suspended solids, BOD₅, nitrogen, and coliforms are all reduced by more than 75% for the proposed wetlands park. Evapotranspiration loss is less than 95 and the total salt contribution to the Rio Grande would be less than 0.4%.

The effluent discharges directly to the river and should an emergency dictate that flows be halted into the wetlands an existing diversion pipeline is available.

Constructed wetlands treating the entire discharge from the sewage plant could create a total of twelve new acres of open-water habit. This would be a significant level of restoration and replenishment for the Rio Grande watershed and for the citizens of Sunland Park, New Mexico.

For every one million gallons of effluent discharged to the Rio Grande, at least six acres of actual wetlands could be created similar to the designs presented: three deep, three medium, and three shallow cell each. With the additional lands required for trails and berms, at least seven acres of wetlands can be built to handle every one million gallons of treated effluent per day.

Recommendations: Farmers and federal agencies too often see restoration of the environment as a thinly veiled movement to acquire “their” water rights. The Bureau of Reclamation and the International Boundary and Water Commission find themselves responding to NEPA requirements, Endangered Species Act crises and pressures from environmental groups as consequences of their previous policies.

Restoration pathways that do not involve the taking of water from irrigators are far more likely to be implemented. Utilizing treated sewage effluent to create wetlands prior to the flows reaching the Rio Grande is one example of putting water to beneficial use for the environment and the communities that would not impinge upon the needs of farmers.

Federal, State, and local agencies should embrace and assist with this “string of pearls” approach to sustainable restoration. It is a feasible, forward-looking and locally focused strategy that could provide mitigation credits for the impacts of our river management programs.

Chapter 4: The String of Pearls Approach to Riparian Restoration – One Pearl

4.1 Introduction

Evaluation of the unsustainable practices of our current society can result in a pessimistic perspective. Topics like ecosystems losses, species decline, water scarcity, climate change, disease migration, and socio-economic disparity can be disheartening. Scarcity, limits and carrying capacity are descriptives used to emphasize the severity of our problems. This mode of thinking that has set us upon the path of unsustainable exploitation is not helpful for discovering potential solutions. It is understandable that some may be discouraged by the daunting tasks required of mankind to truly seek a more sustainable future. Limiting our consumption, our expansion into the natural world and the water we use are all austerity measures that may seem apparent at first. But, there is another, more hopeful point of view, which requires a paradigm-shift. David Schaller proposes another way to look at the problem:

“I believe there is an austerity all right, but it is an austerity of imagination. All of it is fueled by the premise of scarcity in nature. I propose that there is an abundance to nature that, in our ignorance and even arrogance, we are only beginning to fathom. In fact, it would be arrogance to claim even that much. Our microbiologists, botanists, biologists, mycologists, wood chemists and geneticists are only now scratching the surface of this great diversity and plenty. What we don't understand, we can't possibly explain, value, or protect” (Schaller, 2003).

The “string of pearls” approach to riparian restoration utilizes sources of water that are readily available, even abundant. Using existing effluent streams will not conflict with water users already given the right to divert the Rio Grande. Constructed wetlands are a relatively low-cost method for polishing treated sewage and enhancing the quality of water discharged to the river. And finally, the wetlands would be both ecologically and economically beneficial, especially when indirect costs and benefits are calculated for using water in this way. Socially, it is fitting to bring some beauty and investment to water resources previously regarded as waste discharges, especially in a poor border community like Sunland Park that has for too long been neglected.

4.2 Goals and Objectives

Considering the “triple bottom line” perspective of sustainability, how are the three pillars of sustainability (environmental, economic, and social) integrated into the construction of a wetlands park?

This replenishment effort must and can come from the bottom up, not the top down. A truly sustainable approach accounts for a wide variety of factors – poverty, justice, economics, replenishment, beauty, and reproducibility. The final outcome must be much broader in range than merely improving water quality or restoring riparian ecology. Accomplishing these sustainability goals will require meeting these three objectives:

- 1) to establish a case for our obligation to restore the environment when it is in our capacity to do so.
- 2) to demonstrate economic and social sustainability. Analysis of this project will be in terms of the Distribution Principle and Ecological Economics.
- 3) to make a clear synthesis of the string of pearls idea with sustainability, obligation to future generations, and how a restoration effort is the pathway to transforming sewage into a scenic wetlands.

4.3 ENVIRONMENTAL SUSTAINABILITY

Environmental ethics have significance for the value of non-human nature. Biodiversity, landscape ecology, and the genetics of evolutionary processes are all affected by our non-sustainable practices as humans. Just as the preservation of species is important to the overall health of the planet, so too is the need to maintain the environment that makes future evolutionary strides possible. Saving endangered species from extinction is insufficient; we must maintain and restore healthy ecosystems to allow for repopulation and recovery of dynamic equilibrium. Caring for and restoring riparian wetlands within the Rio Grande corridor is a task not just for our present generation but for those generations, human and non-human yet to come.

“The time has come to link ecology to economic and human development. When you have seen one ant, one bird, one tree, you have not seen them all. What is happening to the rain forests of Madagascar and Brazil will affect us all.” — Edward O. Wilson

A string of pearls approach to riparian restoration can bring about the restoration of the Rio Grande ecology one pearl at a time. Each wetland created will become a new gene bank for the species that inhabit these areas. Biodiversity is proportional to the number of wetlands available, and creating a wetland park in Sunland Park, New Mexico is but one important step towards restoring the natural character of the Rio Grande. While one pearl may not be biologically significant, several pearls acting as a string along the Rio Grande corridor can contribute significantly to the environmental sustainability of a major desert river.

4.3.1 The Nested Triple Bottom Line

The Triple Bottom Line (TBL) is a model for representing three dimensions of sustainability: environmental, economic, the social. Historically, these three dimensions were treated like legs to a stool, with each dimension being somewhat independent of the other. Over time, the idea of an integrated TBL was developed in which each of the three dimensions is interwoven and interconnected.

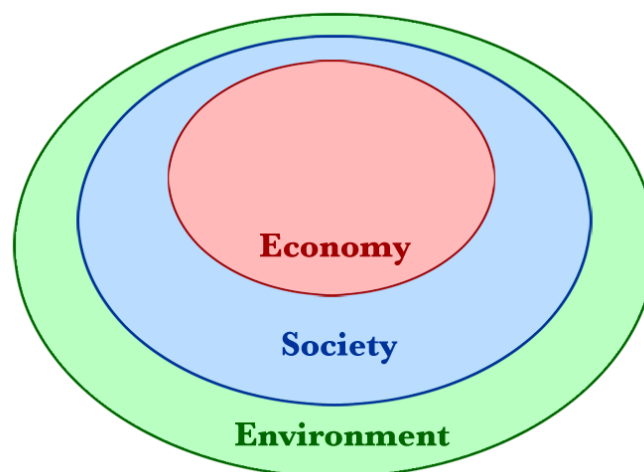


Figure 10 Nested Triple Bottom Line - Everything resides in the Environmental Dimension

A wastewater wetland park situated next to the Rio Grande will produce a number of benefits beyond the obvious restoration of riparian ecology and the polishing of sewage effluent. Well designed wetlands can serve as education centers for people to learn about ecosystems like the Rio Grande and its watershed. The placement of trails and signage for viewing wildlife greatly enhances the discovery process. By considering the human element in the construction of wetlands, we can foster the development of a positive connection to the ideas of restoration and replenishment. Additional economic benefits, both direct and indirect will provide even more value to an economically poor community. The wetlands park will positively stimulate the environment, the society, and the economy.

4.3.2 The Unheeded Precautionary Principle

The governance of the Rio Grande by State and Federal statutes insures that waters are put to beneficial use for the greater good of the people. Agencies of the states and federal governments are obligated to act on behalf of the general population. Yet, the beneficiaries of these laws and policies are the few who hold water rights. Maintaining the health of the environment itself was not considered to be an important benefit when dividing up the waters of the Rio Grande. The Bureau of Reclamation claims that the waters of the Rio Grande Project are “fully appropriated”, with each drop of water tied to the lands that fall within the irrigation districts. Environmentalists claim that the river is “over-appropriated” with no provisions for in-stream flows or for environmental benefits. Irrigators with established water rights are allowed to use the waters of the river, but what about those citizens residing next to the river? Those without a voice in how the Rio Grande is shared are victims of the “law of unintended consequences”, attributed to Robert Merton in its modern form; a familiar negative outcome when the precautionary principle (United Nations Earth Summit, 1992) is discarded.

4.3.3 Obligations to Future Generations

Whether it's another application of the Golden Rule, or simply following the old Boy Scout maxim – “Leave every camp site cleaner than when you found it,” the philosophical underpinnings of sustainability focus on the truly least among us, those yet to come. Our future generations will inherit the messes and successes we leave behind. Much of our environmental damage will require restoration in the future.

In the text, The Ethics of Sustainability (Kibert et al. 2010), the philosophical ideas for framing the idea of sustainability are explored. The views of Kant, Bentham, Norton, and Rawls are summarized in the following paragraphs as they pertain to justice and sustainability. In fairness to the earlier philosophers, sustainability was not the prominent topic during the nineteenth century as it is today.

Kant's deontological ethics holds to defining correct rules and duties to obey those rules. His categorical imperatives and universal principles propose that if an action is not good for all of the people, then that same action cannot be good for a single actor to do. People have intrinsic values and rights, which are moral claims that certain categories of persons can make on others who are duty bound to respect those claims.

Utilitarianism, as launched by Jeremy Bentham, holds that what is ethical is that which creates the greatest good for the greatest number of people.

Bryan Norton argues from a pragmatist perspective that well-reasoned actions that achieve practical and urgently needed environmental and social improvements are the best course of action.

In each of these philosophical views, we can see our obligation to treat the coming generations with the same accord we give to the living generation. Kant's belief in rights and what is good for all must be good for one can be expanded to include our progeny. Similarly, the greatest good for the greatest number of people would imply that what we do today should account for the much larger numbers of people to come. And urgent and decisive actions as espoused by Norton will have immediate effects to be passed on to the future.

But perhaps the clearest sense of duty to the future comes explicitly from John Rawls:

Each generation must not only preserve the gains of culture and civilization, and maintain intact those just institutions that have been established, but it must also put aside in each period of time a suitable amount of real capital accumulation. This saving may take various forms from net investment in machinery and other means of production to investment in learning and education. (Rawls, 1999)

This is a clear indication that an investment in the future may yield results not to be enjoyed by the current generation, and that this is, in part, the chain of inheritance whereby today's generation received the benefits (and problems) from yesterday's generations labors. The payoffs are beyond the horizon, the ultimate form of delayed gratification.

These philosophical perspectives support the conceptualization of sustainability:

The Whistler 2020 (Canada) sustainable community movement describes sustainability as "... a minimum condition for a flourishing planet in the long term."

"Leave the world better than you found it, take no more than you need, try not to harm life or the environment, make amends if you do. " (Hawken, 2007)

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (The Brundtland Commission, 1987).

And as a caveat, we are reminded by David Schaller (2004) that:

Solutions grounded in the premise of scarcity will never result in sustainability.

4.4 SUSTAINABLE ECONOMICS

Traditional measurements of economic growth have held an inverse correlation with environmental health. Expanding economies translate into ecological degradation. These exploitations of the environment are often left off of the ledgers of economic accountings. All too often, the costs incurred are referred to as "indirect" costs or shared burdens. When examined from the viewpoint of the three integrated dimensions of sustainability, the

conclusions of the traditional economists may seem absurd. There is no “other” environment to handle our wastes. Barry Commoner states this idea concisely in his “second law of ecology”: “Everything must go somewhere” (Commoner, 1971). The atmosphere, landfills, and our waterways are convenient dumping grounds for wastes and yet, they are part of the same environment which we all depend upon to sustain us. As a warning to our exploitative ways, Commoner’s “fourth law of ecology” reminds us that: “There is no such thing as a free lunch.” There are consequences to our actions; the damming and diversion of the Rio Grande solely for agriculture has wreaked havoc on the native riparian ecology.

Unsustainable growth is a malignancy on the earth’s ecosystems. The practice of conventional economics is concerned primarily with economic profit and limitless resource consumption. Conversely, the implementation of holistic ecological economics strives to achieve the explicit goals of sustainable scale (not growth), fair distribution, and the efficient allocation of resources. While “green economics” might not necessarily advance the idea of ecosystems services, it does seek to prevent the over-appropriation of our natural resources. A critical aspect to green economics is the social awareness that accompanies its effectiveness.

Ecosystem services are not quite the same as green economics, which focuses more on the efficient use of renewable resources and providing products with much lower environmental (external) costs. Ecosystem services look directly at the benefits afforded to us by the simple existence of the natural environment. In contrast to the “tragedy of the commons”, ecosystems services analysis includes the abundance and “wealth of the commons”, so long as we keep our exploitative interests at bay. In fact, as the natural world is consumed by our traditional economic drive for growth, the ecosystems services sector should be increasing in value according to the laws of supply and demand. The last few acres of Amazon rainforest or Great Plains grassland, or Rio Grande wetlands could become very valuable when the price of exploitation is internalized and not relegated to an abstract realm outside of the standard economic sphere.

Capitalism, when engaged in conventional economics, clashes directly with the concept of sustainability on several issues, but especially in the role that ecosystems play in the economy. Neoclassical economics is quite deficient in meeting the guidelines of sustainability. An economy that protects natural and social systems is not part of the usual profit-centered, market-driven framework.

4.4.1 Tragedy of the Commons

Garrett Hardin wrote “The Tragedy of the Commons” in 1968 following what Aristotle had written two millennia before: “That which is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest.” Protecting any commons – especially the global commons is not an easy task. Myopic self-interests interfere with our obligations to sustain the public goods. Social justice, and the good of society as a whole, is an ideal that we can only approach, and never fully achieve. Like sustainability, it is a “path to be walked, not a destination to be reached” (Kibert, 2010).

Decoupling is the separation of economic production from environmental exploitation. Nature is treated as an externality, an abstraction of the real places where wastes are sent and resources are extracted. In standard market analysis, as the scarcity of a product increases, so does the price in keeping with the relationships between supply and demand. However, when a cost is “hidden” or de-coupled, the price of a product remains artificially low.

The external costs of traditional economic analysis are subsidized by the environment, absorbing the costs of growth, without the pressures of consequence. Ecosystem impacts are unpriced and treated as inconsequential. Unsustainable goods are cheaper due to hidden subsidies paid for by the environment, the community, and future generations (Hawken, 2007). Only when it becomes too late, does the realization that we have exceeded the carrying capacity of the environment come to the fore. Such is the case with many of our environmental problems from global warming, over fishing our oceans, and the endangerment of birds by our profligate use of pesticides. Short-term profits are accrued at the expense of sustainability. The harsh

reminder for not realizing or actualizing the costs borne by the environment comes back to haunt us by the stark term, the tragedy of the commons.

Just as traditional economics exploits the environment by externalizing costs heaped upon the environment, so too are there social costs not accounted for. The exploitation of poorer communities by placement of polluting industries and waste collection facilities is well known. This is just another example of externalizing costs to create a shared burden. “Shared” is a euphemism for the less fortunate among us bearing the brunt of our collective growth; a system of privatized or privileged profit, at the expense of social or environmental costs.

4.4.2 Wealth of the Commons

In its truest sense, a commons is a governance system for using and protecting “*all the creations of nature and society that we inherit jointly and freely, and hold in trust for future generations.*” (Daly, 1996)

Ecological economics uses the approach of internalizing what had previously been externalized costs. The term “ecosystem services” is employed to highlight the idea that all economic measures fall within the greater environment, and have social impacts as well. The nested interconnected Venn diagram of the Triple Bottom Line (as shown in Figure 1) models this viewpoint clearly. Ecosystem services also open the door to a new paradigm economics. The services provided by the environment, while previously ignored, can be significantly larger than previously imagined. An investigation by Costanza (1997) concluded that the entire global ecosystem had a net worth of approximately 33 trillion dollars, nearly twice the entire GDP of mankind. These services include the cleansing of our environment, providing raw materials, habitat for other species, and enjoyment by the human race. Other not so obvious services include pollination, nutrient cycling, soil formation, genetic resources, and recreation.

A special form of ecological wealth comes from the cultural services provided where many populations are intricately tied to the landscape and ecology of the lands they inhabit. Cultural traits and traditions come from this interdependency. This is true of mountain tribes,

boreal cultures, island communities, and people of the deserts who dwell near rivers. Unfortunately, this connection to the Rio Grande has nearly disappeared for the average citizen of the Paso del Norte region. For example, fishing, swimming, and other forms of recreation that are common to other riverside urban centers are largely absent in this region.

Finally, there is the ecological service rendered by regulation of climate. Both the hydrosphere and atmosphere provide temperature regulation and precipitation controls that can be affected by the destructive and unsustainable pursuit of growth and profit. This is the tragedy of the global commons.

Building a wetlands park in the heart of Sunland Park would enrich the common lands that now sit idly between the city library and the Rio Grande. The ecological services provided include a cleansing of effluent prior to joining the Rio Grande and valuable habitat for wildlife. It is fair to anticipate that bird watchers, local citizens, and field trips by local schools will contribute some measure of economic gain for the city as well.

4.4.3 The Restoration Economy

Economic development activities can be placed into three distinct categories: new development; maintenance, and restorative development. Restorative development is defined as: that mode of economic activity that returns property, structures, or objects to an earlier condition, transforms them into a healthier and/or more functional condition, or replaces an unsalvageable structure without consuming more land (Cunningham, 2002).

Restoration, the largest economy that few are aware of, is more commonly recognized by the public as downtown historic renovations, redevelopment of office buildings, and the construction of wetlands. This expanding field is spawning new professional disciplines, generating businesses, new fields of research, and technological advancements. It has been estimated that restorative development may soon surpass even new development. Over \$400 billion in 2001 was budgeted for restoration projects, both public and private in the United States alone (Cunningham, 2002).

Small and large cities along the Rio Grande can be part of this important trend when strategic funding is accrued and decisions are made to construct wetland parks. No new land is being developed as the floodplain is simply a neglected portion of the river channel. The string of pearls approach is one more branch of the restorative economy.

4.4.4 The Distributional Principle and Reciprocity

Sunland Park is a poor city that “hosts” a large landfill operation. The landfill is situated within the Rio Grande watershed, rather than on top of the adjoining mesa. Originally an illegal dumping site, the landfill evolved into a managed facility that previously housed a medical waste incinerator. A majority of the wastes buried in the landfill originated in El Paso and from U. S. owned maquiladoras in Mexico. The landfill was expanded in the 1980’s for purposes of fee generation and for convenience reasons, including cheap land and easy access. Opponents within the city have continued to fight the operation of the dump, and many see this as an environmental and social justice issue for a city comprised of low-income people of color.

In her plea for the poor and disadvantaged of the world, physicist and environmental activist Vandana Shiva (1999) observes that “Giving people rights and access to resources so that they can regain their security and generate sustainable livelihoods is the only solution to environmental destruction and the population growth that accompanies it.” In the same vein, the Brundtland Commission proclaimed, decades earlier, that “inequality is the planet’s primary ‘environmental’ problem.” Both Dr. Shiva and the Brundtland Commission insist that social justice is not at odds with protecting the global commons. “Indeed, social justice is the only thing that can save it” (Kibert, 2010).

In a just society, Rawls (1999, p. 10) argues, basic civil rights are upheld and the social advantages of education and economic opportunity are equitably shared. Justice also requires the fair distribution of social disadvantages, such as environmental risks. This Distributional Principle in turn requires a fair distribution of power and decision-making abilities, as these

(political) goods determine how and to whom other social advantages and disadvantages will be distributed.

The Prior Appropriation Doctrine gives owners of water rights exclusive use of surface waters in the Mesilla Valley. In effect, this is an unequal sharing of resources, and in terms of social justice, a lack of reciprocity. The rule of law is not always just. We certainly have the capacity to manage and control the Rio Grande, and according to the laws of the land, we also have the right. But whether we are justified in doing so has become a contentious issue, pitting environmentalists and a portion of the public against the farmers and those agencies managing the waters of the United States. Challenging water laws is a long, conflict-driven fight, especially in the west.

4.4.5 Community Pride

Community pride comes from having a beautiful site associated with the local area that attracts visitors from afar. Knowing your town or city is viewed favorably by residents and visitors adds greatly to the sense of self-worth, and the social dimension of being a part of a beneficial enterprise. While the economic benefits are easily appreciated, the sense of beauty often holds a deeper, more significant influence. For a low-income border community, like Sunland Park, having a beautiful wetland in the midst of their city center to attract visitors goes a long way towards promoting a feeling of deserved pride and accomplishment. The pride of being part of a greater restoration and sustainability effort could reinforce support and investment in the communities along the Rio Grande.

4.4.6 The Beauty of Nature

The Bosque del Apache presents a prime example of what a managed wetlands can become to both the environment and the public at large. According to the Fish and Wildlife Service, over 165,000 visitors were drawn to the 57,000 acre refuge in 2011. The Refuge brings in \$13.7 million annually from non-residents to the three counties of Socorro, Bernalillo, and Sierra; along with \$4.3 million in regional tax revenue and directly supports nearly 100 jobs

outside of the refuge area. In 1941, fewer than 20 Sandhill Cranes (*Grus Canadensis*) wintered in the Bosque del Apache area and today their numbers are closer to 20,000 (FWS, 2012). Our nation's refuges are wonderful symbols of sustainable areas set aside for environmental purposes that have generated huge economic benefits (more than \$4 billion annually) and provided local economies with jobs (over 32,000) and a renewed sense of local pride.

A solution that doesn't pit irrigators against the public, farmers against environmentalists, and people against their government would be optimal and far more likely to be implemented. This is why the string of pearls approach to replenishment holds such great promise. The construction of wetlands using sewage effluent doesn't create a large conflict over existing water rights, the water is treated as a waste, and the general public is the recipient of the benefits, not just the few privileged water rights holders.

A sense of obligation to work towards sustainability for the sake of the future rather than the doom associated with staving off pending disaster promotes the sense that the best reward for a voluntary action without a payoff is the satisfaction that comes from doing what is right and just - doing for others and not just for one's self.

Finally, the solutions to water management in the 21st Century will require a high level of interdisciplinary collaboration and broad public engagement. Here also, nature serves as a model for the benefits of collaboration and cooperation, or social capital, in society, as opposed to the specialization and hyper-individualism of the 20th Century. Networks of conversations and pilot projects will serve as the foundation for creative invention and enhancement of the "Common Wealth" (Nelson, 2012).

4.5 Conclusions

Environmental problems are often too narrowly defined and restricted by conventional thinking reliant upon traditional analyses. Solutions fall short even when interdisciplinary, integrated management frameworks are employed. Innovative alternatives are perceived as

threatening to the established experts, especially when local communities are given control over their own destiny.

True sustainability involves replenishment for the misdeeds of the past, and an investment for the next generation with payoffs beyond our current lifetimes. The great challenge is to hand over a better, cleaner world to our children's children; or do unto the next generation what you would like the old generation to have done for us. This is not meant to be a condemnation of our negligent ways, but an awakening to the realm of other possibilities.

Environmental justice requires us to replenish and restore our local ecologies to the greatest extent possible. Where our laws and policies preclude some of these efforts, innovative solutions to these vexing roadblocks are required, such as the string of pearls strategy proposed in this research.

Creating new habitat and polishing sewage effluent simultaneously is beneficial to the greater Rio Grande riparian ecology. We are obligated as rational caring people to sustain and enrich the biodiversity within the troubled Rio Grande watershed; it is imperative. The cumulative effects of multiple pearls along the river could be transformational.

There is a wealth in the commons that remains untapped. Opportunities for riparian restoration can be found that do not involve fighting for the control of water. Building a wetland park is just one step towards developing a restorative economy. Success breeds more success and eventually one successful wetland will spawn more of the same.

Effective ecosystem management on a sustainable basis necessitates the involvement of local communities. For wetland parks approved for feasibility analysis, the citizens should be empowered with full partnership for every phase of the project. This includes site selection, park and wetland design, plant selection and placement, placement of viewing stands and seating areas, and even maintenance. The driver of sustainability projects must be the public's interests. Too often, a project is presented in finished form by outside experts, and the local people are forced to live with the decisions made by others. Social justice requires local control. To "think

globally and act locally” is, perhaps, the most effective mechanism for transformation, restoration, and sustainability.



Figure 11 Major Cities on the Rio Grande Watershed

The effluent discharges from the sewage plants for major cities within the Rio Grande corridor is nearly 200 million gallons each day. According to the EPA Environmental Compliance History Online website, these are the average discharges for the following cities:

Albuquerque – 53 MGD; Las Cruces – 8 MGD, El Paso – 70 MGD, Del Rio – 4 MGD, Laredo – 18 MGD, McAllen – 10 MGD, and Brownsville – 14 MGD. Combined, these cities alone discharge 177 million gallons of treated effluent per day.

In chapter 2, it was determined that a polishing wetlands system would create approximately 7 acres of wetlands for each million gallons discharged daily. If all the effluent from these cities were diverted into polishing wetland cells, over 1,200 acres of new wetlands could be created. If just 50% of this effluent was put to this use, that would still produce enough for over 600 acres of riparian habitat.

Federal agencies like the Bureau of Reclamation and the International Boundary and Water Commission are required to create wildlife habitat when their structures and projects impact native wildlife and especially threatened or endangered species. The formation of wetlands from sewage effluent could greatly help these agencies meet their needs.

Polishing wetlands are different than wildlife refuges which often need broad shallow ponds rather than deep water cells. The annual effluent from the municipal wastewater treatment plants reaching from Albuquerque to Brownsville is 64 billion gallons per year (244 million cubic meters) or 198,000 acre-feet. Using the irrigator's allotment of three acre-feet per acre (the normal application for the Rio Grande Project) this is enough water to fill 66,000 acres of new refuge sites with three feet of water every year.

To think globally and act locally may be the best we can do. Or in this particular case, to think about the entire Rio Grande Watershed and start with one constructed wetlands, one green pearl. We must not ignore the restoration challenges that lie before us.

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Glossary

A&E	Architectural and Engineering – Refers to the Formal Design of a facility
AFPD	Acre-Feet per Day Volume measure for water with 1 acre-foot of water = 325,851.43 gallons. Three AFPD ~ 1 MGD
AK	Agua Variant Soil - soil type designation consisting of fine sands and loam found in floodplain areas
AOI	Area of Interest
ASARCO	American Smelting & Refining Company site in west El Paso at the narrows.
Bm	Bluepoint Loamy Sand - soil type designation found in alluvial fans
BOD ₅	(Biochemical Oxygen Demand) A measure of the oxygen consumed during degradation of organic and inorganic materials in water. BOD ₅ = Five day biochemical oxygen demand – a standard used for TMDL's.
CWA	Clean Water Act
cfu	(Colony Forming Unit(s)) A laboratory unit indicating the number of living bacterial present in a sample per volume of water
EBID	Elephant Butte Irrigation District
ECHO	(Enforcement and Compliance History On-line) An EPA website housing data for all NPDES permits and record for any violations of those permits.
EPA	United States Environmental Protection Agency
EP No. 1	El Paso County Water Improvement District No. 1
ET	Evapotranspiration – the amount of water loss to the atmosphere due to evaporation and respiration, the sum of the physical and biological processes that move water from a liquid to a gaseous phase for a given parcel of water.
FWS	(Free Water Surface) An open water area in a constructed wetland
GWQB	(Ground Water Quality Bureau) A division of NMED tasked with monitoring and protecting the ground waters (aquifers) in New Mexico.
HLR	(Hydraulic Loading Rate) A measure of a volume of water applied to a land area with units of volume per area per time or simple depth per time e.g. feet per day

HRT	(Hydraulic Residence Time) A measure of the average time that water occupies a given volume or how long a plug of water takes to travel through a water system
IBWC	International Boundary and Water Commission
MCL	Maximum Contaminant Level from the Safe Drinking Water Act (SDWA)
MGD	Million(s) Gallons per Day where 1 MGD ~ 3 Acre-feet per day
NH ₃	Ammonia or Nitrogen present as ammonia
NMED	New Mexico Environment Department
NO ₃	Nitrate or Nitrogen present as nitrate
NPDES	(National Pollutant Discharge Elimination System) A permitting program to control water pollution regulated by the EPA and individual States.
NRCS	(Natural Resource Conservation Service) Formerly the Soil Conservation Service the NRCS is a division of the USDA charged with conducting and recording soil surveys.
PFR	(Plug Flow Reactor) Velocity profile of water moving continuously through a system like water flowing through a pipe. The flow is continuous as opposed to a Batch Flows which are interrupted periodically.
ppm	Parts per million, usually expressed as milligrams (mg/L) per liter for water
SDWA	Safe Drinking Water Act
SSF	(Sub-Surface Flow) Wetlands with water flowing below the surface are SSF wetlands. Vegetation beds are planted above the subsurface flow zones.
SWQB	(Surface Water Quality Bureau) A division of NMED tasked with monitoring and protecting the surface waters in New Mexico.
TBL	Triple Bottom Line – The Economic, Social, and Environmental aspects of sustainability.
TDS	(Total Dissolved Solids)
TMDL	(Total Maximum Daily Load)
TPD	Tons per Day
TSS	(Total Suspended Solids) A measure of the total amount of filterable material in a given water sample.
USBR	United States Bureau of Reclamation

USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WWTP	Wastewater Treatment Plant or sewage treatment facility

Spanish Language Terms used in this Dissertation and their English translations

<i>Acequia</i>	- A community run irrigation channel or ditch. The origin of the word is Moorish or Arabic <i>al-sāqiya</i> .
<i>Colonia</i>	- <i>Undeveloped low income communities along the U.S./Mexican border</i>
<i>Ciudad</i>	- City, as in Ciudad Juarez.
<i>Bosque</i>	- Woods, tract of land planted with trees and brushwood: forest, grove; any woody place. The Bosque del Apache Wildlife Refuge.
<i>El Paso</i>	- The pass or crossing. Designated as a place where Spanish travelers crossed the Rio Grande on their way to northern New Mexico.
<i>Jornada</i>	- A journey or march, travel by land. The Jornada del Muerto means the trail of death. This 100 mile trail bypassed the Rio Grande north of Las Cruces for a straighter route to the Pueblo regions of Albuquerque. There was a lack of water, grasses for grazing and firewood for most of this dangerous stretch of desert.
<i>Maquiladoras</i>	- Assembly plants in Mexico where products are manufactured in the Free Trade Zone by low-wage (compared to the U.S.) workers.
<i>Mesilla</i>	- A small table. Or in this case, the small valley floor extending from Seldon Canyon above Las Cruces down to the narrows at El Paso.
<i>Rio Bravo/Rio Grande</i>	- Big, or bold, or fierce, or wild river.

Appendix

A.1 PAN EVAPORATION RATES FOR NEW MEXICO

New Mexico Monthly Average Pan Evaporation Rates in Inches

		J	F	M	A	M	J	J	A	S	O	N	D	Total
ABIQUIU DAM	1957-2005	0	0	6.06	7.43	9.95	11.39	10.52	8.9	7.23	5.3	3.13	2.22	72.13
AGRICULTURAL COLLEGE	1892-1959	3.01	4	7.89	10.2	8.65	13.99	12.33	11.16	8.31	6.28	4.35	2.89	93.06
ALAMOGORDO DAM	1939-1975	3.73	4.35	8.21	11.3	12.88	14.43	13.66	11.59	9.17	7.19	4.89	3.46	104.86
ANIMAS	1923-2005	3.87	4.91	8.29	10.78	12.36	14.25	11.6	11.07	8.54	6.71	4.69	3.61	100.68
ARTESIA 6 S	1914-2005	4.38	3.03	7.25	7.66	12.11	13.13	10.86	10.44	9.36	6.34	3.12	0	87.68
BITTER LAKES WL REFUGE	1950-2005	2.67	3.93	6.82	9.6	11.31	12.62	11.88	10.16	8.02	5.85	3.53	2.5	88.89
BOSQUE DEL APACHE	1914-2005	3.21	4.2	7.76	10.2	11.61	13.13	11.56	10.36	8.03	6.25	3.66	2.54	92.51
BRANTLEY DAM	1987-2005	4.65	0	8.62	11.77	14.61	15.46	14.19	12.22	9.88	7.97	5.77	4.34	109.48
CABALLO DAM	1938-2005	4.42	5.1	8.56	11.37	13.59	14.8	13.08	11.35	9.26	7.27	4.78	3.48	107.06
CAPULIN NATL MONUMENT	1966-1979	0	0	0	0	9.08	10.57	9.71	9.18	7.65	0	0	0	46.19
CLOVIS 13 N	1929-2005	3.83	4.12	6.63	8.72	10.15	11.45	11.65	9.55	7.64	5.78	3.95	3.21	86.68
COCHITI DAM	1975-2005	0	4.14	6.44	8.48	11.07	12.95	12.38	10.62	8.91	6.29	3.94	2.79	88.01
CONCHAS DAM	1938-2005	0	0	7.35	8.88	10.29	11.69	11.37	10.06	8.24	6.18	4.04	2.79	80.89
EAGLE NEST	1937-2005	0	0	0	4.91	7.67	7.83	7.07	5.87	5.3	4.31	0	0	42.96
EL VADO DAM	1923-2005	0	0	3.61	5.43	7.46	8.84	8.52	6.91	5.66	3.84	1.72	0	51.99
ELEPHANT BUTTE DAM	1917-2005	3.47	4.87	8.61	12.22	14.94	16.37	14.15	12.05	9.78	7.7	4.91	3.34	112.41
ESTANCIA	1914-2005	0	0	3.26	6.79	8.56	9.27	8.61	7.1	5.6	3.82	2.62	0	55.63
FARMINGTON AG SCIENCE	1978-2005	0	0	0	7.97	10.06	12	12.52	10.7	8.15	5.41	0	0	66.81
FLORIDA	1939-1992	3.54	4.81	8.1	10.94	13.03	14.8	11.84	10.1	8.51	6.58	4.57	3.11	99.93
GALLUP RANGER STN	1966-1975	0	0	0	6.61	9.31	12.12	10.5	8.7	7.95	5.07	2.2	0	62.46
JEMEZ DAM	1953-2005	0	0	0	9.91	12.27	13.95	14.29	11.45	9.8	6.72	3.65	0	82.04
JORNADA EXP RANGE	1925-2005	2.5	4.18	7.24	10.06	11.94	12.85	10.88	9.53	7.82	5.71	3.61	2.5	88.82
LAGUNA	1914-2005	0	0	0	8.47	9.33	11.98	10.76	8.88	6.83	5	1.98	0	63.23
LAKE AVALON	1914-1979	4.49	5.33	9.42	12.36	14.31	15.16	14.14	12.33	9.25	7.26	4.68	4.2	112.93

LAKE MC MILLAN	1941-1949	0	0	0	13.78	8.14	14.26	13.38	13.45	10.35	6.15	0	0	79.51
LOS LUNAS 3 SSW	1923-2005	1.87	2.81	5.27	7.77	9.74	10.49	10.06	8.67	6.58	4.64	2.75	2.45	73.1
NARROWS	1948-1964	3.09	5.67	7.62	11.07	13.37	15.44	13.07	11.42	9.97	7.2	4.32	2.64	104.88
NAVAJO DAM	1963-2005	0	0	0	6.58	9.1	11.07	11.24	9.66	7.22	4.74	0	0	59.61
PORTALES 7 WNW	1934-1960	3.26	4.57	8.24	8.85	10.72	12.16	10.44	9.28	7.95	5.98	4.15	3.53	89.13
ROSWELL WSO AIRPORT	1893-1972	0	0	0	11.29	0	15.87	12.11	12.63	7.92	6.97	4.66	4.51	75.96
SANTA FE	1867-1972	0	0	3	7.28	8.73	10.93	9.95	8.26	7.15	5.1	2.5	0	62.9
SHIPROCK	1926-2005	0	0	0	7.84	10.57	14.44	13.17	10.8	9.8	6.54	0	0	73.16
SOCORRO	1914-2005	0	0	4.83	7.09	9.17	9.35	8.56	7.57	5.73	4.14	0	0	56.44
STATE UNIVERSITY	1959-2005	3	4.33	7.4	9.9	12.03	12.91	12.05	10.34	8.14	6.17	3.85	2.79	92.91
SUMNER LAKE	1921-2005	0	0	7.33	10.22	12.35	13.54	13.36	11.16	9.02	6.97	4.92	3.17	92.04
TUCUMCARI 4 NE	1904-2005	0	0	0	9.83	11.53	13.11	13	11.13	8.96	6.74	0	0	74.3
UTE DAM	1965-2005	4.38	4.91	7.53	8.78	10.75	10.49	10.92	9.42	7.56	6.68	4.98	3.04	89.44

A.2 SUNLAND PARK NPDES PERMIT



REGION 6
1445 ROSS AVENUE
DALLAS, TEXAS 75202-2733

NPDES Permit No NM0029483

AUTHORIZATION TO DISCHARGE UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Clean Water Act, as amended, (33 U.S.C. 1251 et. seq; the "Act"),

City of Sunland Park
1000 McNutt Rd., Suite D
Sunland Park, NM 88063

is authorized to discharge from a facility located at 1000 McNutt Road in Sunland Park, Dona
~~Ana County, NM. The discharge will be to receiving waters named Rio Grande in Segment No.~~
20.6.4.101 of the Rio Grande Basin,

the discharges are located on that water at the following coordinates:

Outfall 001: Latitude 31° 47' 54" North, Longitude 106° 33' 24" West,

in accordance with this cover page and the effluent limitations, monitoring requirements, and other conditions set forth in Part I, Part II, Part III, and Part IV hereof.

This permit supersedes and replaces NPDES Permit No. NM0029483 issued March 29, 2002.

This permit shall become effective on October 1, 2007

This permit and the authorization to discharge shall expire at midnight, September 30, 2012

Issued on September 13, 2007

Prepared by

Miguel I. Flores
Director
Water Quality Protection Division (6WQ)

Isaac Chen
Environmental Engineer
Permits & Technical Section (6WQ-PP)

A.3 Elevation Map



Sunland Park

3653 to 3654	3666 to 3667
3654 to 3655	3667 to 3668
3655 to 3656	3668 to 3669
3656 to 3657	3669 to 3670
3657 to 3658	3670 to 3671
3658 to 3659	3671 to 3672
3659 to 3660	3672 to 3673
3660 to 3661	3673 to 3674
3661 to 3662	3674 to 3675
3662 to 3663	3675 to 3676
3663 to 3664	3676 to 3677
3664 to 3665	3677 to 3678
3665 to 3666	3678 to 3679

These elevations
Were provided by
Osvaldo Broesicke
with the University
of Texas, El Paso
(UTEP) in part for
the Paso del Norte
Watershed Council
and the UTEP
Center for
Environmental
Resource
Management
(CERM). The
elevations were

taken from a mobile
GPS system
covering over 1000



A.4 SURFACE WATER QUALITY STANDARDS

New Mexico's Water Quality Standards (WQS) define water quality goals by designating uses for rivers, streams, lakes and other surface waters, setting criteria to protect those uses, and establishing provisions to preserve water quality.

2.3 Water Quality Standards

General standards and standards applicable to attainable or designated uses for portions of the Lower Rio Grande watershed that were surveyed in this study are set forth in sections 20.6.4.13, 20.6.4.97, 20.6.4.98, 20.6.4.99, and 20.6.4.900 of the standards for Interstate and Intrastate Surface Waters (NMAC 2006). Surface specific standards for the Lower Rio Grande watershed are set forth in sections 20.6.4.101, 20.6.4.102, and 20.6.4.103, and read as follows:

20.6.4.101 RIO GRANDE BASIN - The main stem of the Rio Grande from the international boundary with Mexico upstream to one mile below Percha dam.

A. Designated Uses: irrigation, marginal warmwater aquatic life, livestock watering, wildlife habitat and primary contact.

B. Criteria:

(1) The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses except that the following segment-specific criterion applies: temperature 34°C (93.2°F) or less.

(2) At mean monthly flows above 350 cfs, the monthly average concentration for: TDS 2,000 mg/L or less, sulfate 500 mg/L or less and chloride 400 mg/L or less.

C. Remarks: sustained flow in the Rio Grande below Caballo reservoir is dependent on release from Caballo reservoir during the irrigation season; at other times of the year, there may be little or no flow.

[20.6.4.101 NMAC - Rp 20 NMAC 6.1.2101, 10-12-00; A, 12-15-01; A, 05-23-05; A, 12-01-10]

20.6.4.102 RIO GRANDE BASIN - The main stem of the Rio Grande from one mile below Percha dam upstream to Caballo dam.

A. Designated Uses: irrigation, livestock watering, wildlife habitat, primary contact and warmwater aquatic life.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criteria apply: the monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less.

C. Remarks: sustained flow in the Rio Grande below Caballo reservoir is dependent on release from Caballo reservoir during the irrigation season; at other times of the year, there may be little or no flow.

[20.6.4.102 NMAC - Rp 20 NMAC 6.1.2102, 10-12-00; A, 05-23-05; A, 12-01-10]

20.6.4.103 RIO GRANDE BASIN - *The main stem of the Rio Grande from the headwaters of Caballo reservoir upstream to Elephant Butte dam and perennial reaches of tributaries to the Rio Grande in Sierra and Socorro counties, excluding waters on tribal lands.*

A. Designated Uses: *irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, secondary contact and warmwater aquatic life.*

B. Criteria: *the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses.*

C. Remarks: *flow in this reach of the Rio Grande main stem is dependent upon release from Elephant Butte dam.*

[20.6.4.103 NMAC - Rp 20 NMAC 6.1.2103, 10-12-00; A, 05-23-05; A, 12-01-10]

20.6.4.104 RIO GRANDE BASIN - *Caballo and Elephant Butte reservoir.*

A. Designated Uses: *irrigation storage, livestock watering, wildlife habitat, primary contact and warmwater aquatic life.*

B. Criteria: *the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criteria apply: the monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less.*

[20.6.4.104 NMAC - Rp 20 NMAC 6.1.2104, 10-12-00; A, 05-23-05; A, 12-01-10]

A.5 Calculation of Pollutant Removal Rates: BOD; N; Coliforms, P, TSS

		T = 0	T = 25	T = 40
BOD	$K_T = .678(1.06)^{(T-20)}$	0.211404	0.907317	2.174438
	1.6 t = 1.6		1.451707	
	2 t = 2	0.422807	1.814634	4.348876
	3 t = 3	0.634211	2.721951	6.523314
	4 t = 4	0.845614	3.629268	8.697751
	5 t = 5	1.057018	4.536585	10.87219
For BOD initial = 100			23.417	
	t = 2	65.520	16.290	1.292
	t = 3	53.035	6.575	0.147
	t = 4	42.929	2.654	0.017
	t = 5	34.749	1.071	0.002
% Reduction			76.6%	
	t = 2	34.5%	83.7%	98.7%
	t = 3	47.0%	93.4%	99.9%
	t = 4	57.1%	97.3%	100.0%
	t = 5	65.3%	98.9%	100.0%
Nitrification		$K_T = 0.2187(1.048)^{(T-20)}$		
Initial = 100		T = 0	T = 25	T = 40
	$K_T =$	0	0.276475	0.558566
	1.6		64.252	
	2 t = 2	100.000	57.525	32.722
HLR	3 t = 3	100.000	43.630	18.718
0.75	4 t = 4	100.000	33.091	10.707
0.75	5 t = 5	100.000	25.098	6.125
0.25			35.7%	
	t = 2	0.0%	42.5%	67.3%
0.15	t = 3	0.0%	56.4%	81.3%
	t = 4	0.0%	66.9%	89.3%
	t = 5	0.0%	74.9%	93.9%
Denitrification		$K_T = 1.15^{T-20}$		
	$K_T =$	0	2.011357	16.36654
	1.6		4.003	
	2 t = 2	100.000	1.790	0.000
	3 t = 3	100.000	0.240	0.000
	4 t = 4	100.000	0.032	0.000
	5 t = 5	100.000	0.004	0.000
			96.0%	
	t = 2	0.0%	98.2%	100.0%
	t = 3	0.0%	99.8%	100.0%
	t = 4	0.0%	100.0%	100.0%
	t = 5	0.0%	100.0%	100.0%

For Fecal Coliform

Initial = 100	h_i	$K_1 = 0.3$	% Reduction
t = 2	0.30	36.78797	63.2%
t = 3	0.20	22.31304	77.7%
t = 4	0.15	13.53355	86.5%
t = 5	0.12	8.208514	91.8%
	0.75	67.03202	33.0%
	0.25	30.11945	69.9%

For Phosphorus

Initial = 100	h_i	$K_1 =$	%
		0.0273	
t = 2	0.30	91.30178	8.7%
t = 3	0.20	87.24064	12.8%
t = 4	0.15	83.36014	16.6%
t = 5	0.12	79.65225	20.3%
	0.75	96.42545	3.6%
	0.25	89.65512	10.3%

TSS Removal by Reed et. al 1995

$$C_e = C_o[0.1139 + 0.00213(\text{HLR})]$$

Where HLR is in cm/d

HLR m	HLR cm	For input = 100	Removal %
0.30	30	17.78	82.2%
0.20	20	15.65	84.4%
0.15	15	14.585	85.4%
0.12	12	13.946	86.1%
	75	27.365	72.6%
	25	16.715	83.3%
	60	24.17	75.8%

Percent reduction for Parameters for T = 25

HRT	BOD	Coliform	TSS	PO4	NO3
2	83.7%	63.2%	82.2%	8.7%	42.5%
3	93.4%	77.7%	84.4%	12.8%	56.4%
4	97.3%	86.5%	85.4%	16.6%	66.9%
5	98.9%	91.8%	86.1%	20.3%	74.9%

A.6 Calculations for Determining Cells Sizing for HRT = 2,3,4, & 5 Days

Pilot Wetlands HRT = 4 days Q = 300,000 gpd ~ 1136 m³/d Volume = 1.2 MG ~ 4542 m³

Calculations for HRT of 2,3,4 & 5 days				Three Cells 4', 3', & 1' deep with 40%, 30%, 30% volume per cell					
1136	HRT	Volume	Area	h _i	h _i (cm)				
	2	2272	3787	0.30	30			Feet	Meters
	3	3408	5680	0.20	20			4	1.2
	4	4544	7573	0.15	15			3	0.9
	5	5680	9467	0.12	12			1	0.3
	C1 & C2		1515	0.75	75				
	C3		4544	0.25	25				
			Surface		2:1				
HRT = 2	Cell	Volume	A	Square	shape	General	Golden		
40% Vol	1.2	909	757	28	19	20X40	22X35		
30% Vol	0.9	682	757	28	19	20X40			
30% Vol	0.3	682	2272	48	34	35X70	37X61		
Total		2272	3787						
HRT = 3	Cell	Volume	Surface A	Square	2:1 shape	General	Golden		
40% Vol	1.2	1363	1136	34	24	25X50	27X43		
30% Vol	0.9	1022	1136	34	24	25X50			
30% Vol	0.3	1022	3408	58	41	40X80	46X74		
Total		3408	5680						
	Depth		square m						
HRT = 4	Cell	Volume	Surface A	Square	2:1 shape	General	Golden		HRT
40% Vol	1.2	1818	1515	39	28	30X60	30X50	1500	1.6
30% Vol	0.9	1363	1515	39	28	30X60	30X50	1500	1.2
30% Vol	0.3	1363	4544	67	48	50X100	55X85	4675	1.2
Total		4544	7573		62	60X120		7675	
Acres			1.87 ~ 2			70X110		1.9 ~ 2	
								~81500 sq ft	
HRT = 5	Cell	Volume	Surface A	Square	2:1 shape	General			
40% Vol	1.2	2272	1893	44	31	30X60	34X55		
30% Vol	0.9	1704	1893	44	31	30X60			
30% Vol	0.3	1704	5680	75	53	55X110	60X96		
Total		5680	9467						

A.7 EPA REPORT ON THE SUNLAND PARK WWTP

Pollutant Loading Trends Report

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Enforcement & Compliance History Online (ECHO)

You are here: [EPA Home](#) [Compliance and Enforcement](#) [ECHO](#) [Search Data](#) Pollutant Loading Trends Report

ECHO Pollutant Loading Trends Report



The data source for this report is the [DMR Pollutant Loading Tool](#) which uses discharge monitoring data to display yearly discharges. [Click Here](#) to see more information about this facility, view facility loading calculations or report errors.

Facility Permits and Identifiers

[Data Dictionary](#)

STATUTE	SYSTEM	SOURCE ID	FACILITY NAME	STREET ADDRESS	CITY	STATE	ZIP
CWA	ICP	NM0029483	SUNLAND PARK WASTEWATER PLANT	1000 MCNUTT ROAD	SUNLAND PARK	NM	88063

Facility Characteristics

[Data Dictionary](#)

STATUTE	SOURCE ID	FACILITY STATUS	SIC CODE
CWA	NM0029483	Major	4952

Effluent Characteristics

[Data Dictionary](#)

YEAR	AVERAGE PATHOGEN CONCENTRATION (per 100ml)	MAXIMUM PATHOGEN CONCENTRATION (per 100ml)	AVERAGE TEMPERATURE (F)	MAXIMUM TEMPERATURE (F)	AVERAGE DAILY FLOW (MGD)	TOTAL ANNUAL FLOW (MG)
2007	80.28	220	-	-	1.45	2,778
2008	18.56	63.44	-	-	1.51	1,662
2009	5.03	27.36	-	-	1.57	1,717
2010	3.60	15.03	-	-	1.65	1,803
2011	2.69	11.78	-	-	1.70	1,868

Effluent Pollutant Discharge by Weight (lbs)

[Data Dictionary](#)

YEAR	TOTAL DISCHARGED (lbs)	METALS DISCHARGED (lbs)	NITROGEN DISCHARGED (lbs)	ORGANICS DISCHARGED (lbs)	PHOSPHORUS DISCHARGED (lbs)	PRIORITY POLLUTANTS DISCHARGED (lbs)	SOLIDS DISCHARGED (lbs)	TOP POLLUTANT BY POUNDS	AMOUNT DISCHARGED BY TOP POLLUTANT (lbs)
2007	90,461	161	19,108	41,617	-	0.20	29,390	BOD, 5-day, 20 deg. C	41,617
2008	33,683	-	-	12,646	-	-	21,036	Solids, total suspended	21,036
2009	65,356	-	-	33,586	-	-	31,771	BOD, 5-day, 20 deg. C	33,586
2010	43,152	-	-	23,171	-	-	19,982	BOD, 5-day, 20 deg. C	23,171
2011	30,182	-	-	14,685	-	-	15,497	Nitrogen	20,171

Effluent Pollutant Loading by Toxic Weighted Pound Equivalent (TWPE)

[Data Dictionary](#)

YEAR	TOTAL DISCHARGED (TWPE)	METALS DISCHARGED (TWPE)	PRIORITY POLLUTANTS DISCHARGED (TWPE)	TOP POLLUTANT BY TWPE	AMOUNT DISCHARGED BY TOP POLLUTANT (TWPE)
2007	147	33.05	23.42	Total Residual Chlorine	92.43
2008	0.01	-	-	Total Residual Chlorine	0.01
2009	0.00	-	-		-
2010	0.00	-	-		-
2011	0.00	-	-		-

Total Discharged (lbs)

[Data Dictionary](#)

POLLUTANT NAME	2007	2008	2009	2010	2011
Aluminum	160	-	-	-	-
Ammonia as N	19,108	-	-	-	-

BOD, 5-day, 20 deg. C	41,617	12,646	33,586	23,171	14,685
Mercury	0.20	-	-	-	-
Solids, total suspended	29,390	21,036	31,771	19,982	15,497
Total Residual Chlorine	185	0.01	-	-	-

Total Discharged (TWPE)[Data Dictionary](#)

POLLUTANT NAME	2007	2008	2009	2010	2011
Aluminum	9.62	-	-	-	-
Ammonia as N	21.21	-	-	-	-
BOD, 5-day, 20 deg. C	-	-	-	-	-
Mercury	23.42	-	-	-	-
Solids, total suspended	-	-	-	-	-
Total Residual Chlorine	92.43	0.01	-	-	-

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A.8 LINER REQUIREMENTS FOR NEW MEXICO

NEW MEXICO ENVIRONMENT DEPARTMENT GROUND WATER POLLUTION PREVENTION SECTION SYNTHETICALLY LINED LAGOONS - LINER MATERIAL AND SITE PREPARATION GUIDELINES

Purpose: These guidelines represent minimum liner material and site preparation requirements for wastewater treatment, storage and evaporation lagoons. These requirements do not apply to lagoons storing hazardous wastes or high strength waste. The Ground Water Quality Bureau may impose additional requirements (e.g., double-lined lagoons with leak detection) for facilities discharging hazardous or high strength waste to lagoons through the development of specific Discharge Permit conditions for such facilities.

Liner Material Requirements:

- 1. The liner shall be chemically compatible with any material that will contact the liner.*
- 2. The liner material shall be resistant to deterioration by sunlight if any portion of the liner will be exposed.*
- 3. Synthetic liner material shall be of sufficient thickness to have adequate tensile strength and tear and puncture resistance. Under no circumstances shall a synthetic liner material less than 40 mils in thickness be accepted. Any liner material shall be certified by a licensed New Mexico professional engineer and approved by the New Mexico Environment Department (NMED) prior to its installation.*

Lagoon Design and Site Preparation Requirements:

- 1. The system shall be certified by a licensed New Mexico professional engineer and approved by NMED prior to installation.*
- 2. Inside slopes shall be a maximum of 3 (horizontal): 1 (vertical), and a minimum of 4 (horizontal); 1 (vertical).*
- 3. Lagoon volume shall be designed to allow for a minimum of 24 inches of freeboard.*
- 4. The liner shall be installed with sufficient liner material to accommodate shrinkage due to temperature changes. Folds in the liner are not acceptable.*
- 5. To a depth of at least six inches below the liner, the sub-grade shall be free of sharp rocks, vegetation and stubble. In addition, liners shall be placed on a sub-grade of sand or fine soil. The surface in contact with the liner shall be smooth to allow for good contact between liner and sub-grade. The surface shall be dry during liner installation.*
- 6. Sub-grade shall be compacted to a minimum of 90% of standard proctor density.*
- 7. The minimum dike width shall be eight feet to allow vehicle traffic for maintenance.*
- 8. The base of the pond shall be as uniform as possible and shall not vary more than three inches from the average finished elevation.*
- 9. Synthetic liners shall be anchored in an anchor trench in the top of the berm. The trench shall be a minimum of 12 inches wide, 12 inches deep and shall be set back at least 24 inches from the inside edge of the berm.*
- 10. If the lagoon is installed over areas of decomposing organic materials or shallow ground water, a liner vent system shall be installed.*
- 11. Any opening in the liner through which a pipe or other fixture protrudes shall be properly sealed. Liner penetrations shall be detailed in the construction plans and record drawings.*
- 12. A synthetic liner shall not be installed in temperatures below freezing.*
- 13. The liner shall be installed or supervised by an individual that has the necessary training and experience as required by the liner manufacturer.*
- 14. All manufacturer's installation and field seaming guidelines shall be followed.*
- 15. All synthetic liner seams shall be field tested by the installer and verification of the adequacy of the seams shall be submitted to NMED along with the record drawings.*

Vita

Michael E. Landis was born in Trona, California. The first son of William and Mary Landis, he received his bachelor's degree in Biological Sciences from the University of California at Santa Cruz in 1987, and his second bachelor's degree, in Civil Engineering from Arizona State University in 1994. He received a master's degree in Civil Engineering from the University of Texas at El Paso in 2002. Mr. Landis served five years of active duty service in the United States Air Force from 1984 through 1989, and seven years in the Arizona Air National Guard from 1989 to 1996 as an Avionics Technician. He is a retired from the United States Army Reserves. He served as an engineer in Operation Iraqi Freedom (OIF3) in 2005. Prior experiences include working as a consulting hydrologist for aquifer storage and recovery projects, and as an environmental engineer working for the Department of the Army at Fort Bliss. Presently, he is employed with the Department of Interior, Bureau of Reclamation as a Planning Engineer. His work centers on all aspects of water resources associated with the Rio Grande, including groundwater monitoring, drought management, water quality issues, conservation and effluent reuse, desalination, and riparian-endangered species problems. His wife is Catherine A. Landis, and they have three sons Daniel, Aaron, Zachary, and one daughter Rachel. The Landis family has resided in El Paso since 1996.

Permanent address: 4016 Tierra Santa Place
El Paso, Texas, 79922

This dissertation was typed by Michael E. Landis.