BorderLink 1997

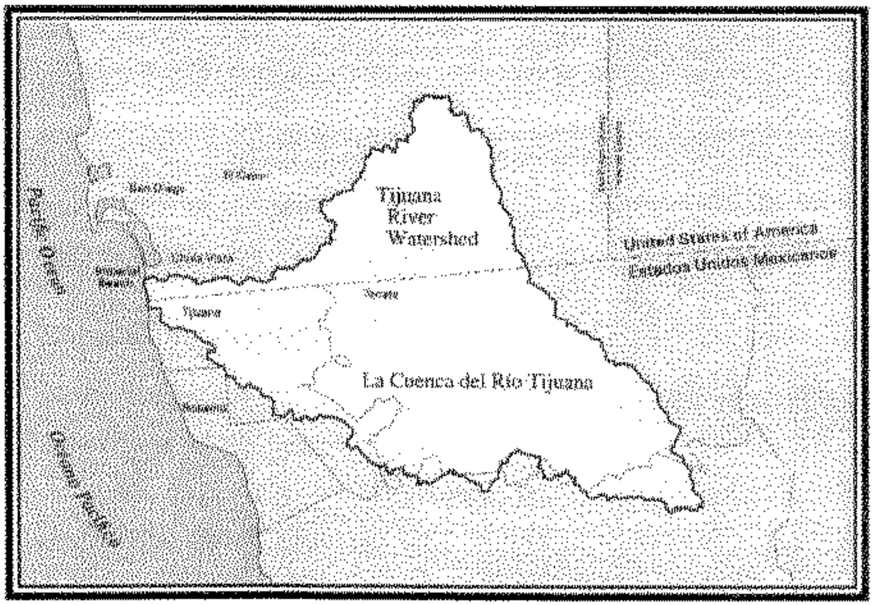
The Tijuana River Basin: Basic Environmental and Socioeconomic Data

edited by

Fernando Wakida

and

Karen Riveles



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Foreword

The following essays were written by graduate and undergraduate participants in the BorderLink 1997 summer program. Six students from San Diego State University (SDSU) and six students from the Universidad Autónoma de Baja California (UABC) worked together on binational teams to produce each of the essays. The faculty leader was Fernando Wakida of UABC. The project was financially supported through the Vice Rector's office of the Universidad Autónoma de Baja California and the Institute for Regional Studies of the Californias at SDSU.

The focus of this year's program was to study environmental, social, and economic characteristics of the binational Tijuana River Basin, located one-third in the United States, and two-thirds in Mexico. Research included library and internet sources as well as interviews with private and public sector agencies.

The main objective of the project was to identify information regarding water resources in the Tijuana River watershed and to understand the relationship among social, economic, and environmental factors in the basin. Socioeconomic data were collected, and the politics of land use and the main aspects of water resources were examined to determine possible impacts on the environment of the region. Studies that have been done on the water quality in the Tijuana River Basin were inventoried and the data were compiled into a number of tables.

The 1997 BorderLink was the fourth in the program. Previous efforts focused on strategies for marketing wine and tourism packages in Baja California (1993), the development of an economic profile for the San Diego-Tijuana region (1994), and the market for solid waste recyclables in the San Diego-Tijuana region (1996). In each of these, one or more faculty advisors worked with advanced students from both universities on a topic of regional importance. Not only does the research report generated at the end of the project serve as a useful document for students, researchers, and decision makers, but the experience of working as part of a binational team is invaluable for the student participants. BorderLink is a rich supplement to the core educational activities of UABC and SDSU and is an important step in developing the next generation of leaders for our binational region.

Paul Ganster

Chapter 1

Socioeconomic Analysis of the Tijuana River Basin

María Eugenia Jaramillo

Elena Lelea

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Introduction

An important part of the 1997 BorderLink Project was a socioeconomic analysis of the Tijuana River basin. This study examined the socioeconomic history of the region; the demographics and housing in Tijuana, Tecate, and San Diego; the water demands of each city; and the main economic activities in the watershed. Future population growth and economic activities are projected in order to determine an environmentally sound growth pattern for the binational region and identify the sectors that are consistent with economic and environmental sustainability. Population growth in the Tijuana River basin will affect the use of water by the residential and commercial sectors, and will have an impact on the environment.

This section describes the physical and economic aspects of the basin, the contrasts that exist within the binational region, and the dilemma of centralism within the Mexican political system. In addition, the demographics of the region are studied, including population growth, the economically active population, and housing availability. The demographic demand for water in Tijuana, Tecate, and San Diego County are examined. The cost of water is compared to the salaries within the region, and the cost of running water versus the cost of delivered water is considered. Economic activities in the Tijuana watershed are analyzed looking at the cost of water and amount used per economic sector, and the impact that each sector has on the environment. The economic activity that would be the most dynamic, water efficient, and have the least impact on the environment is discussed. Finally, the future demand for water in the region is reviewed, considering availability and allocation of the resource.

Physical and Economic Aspects of the Basin

The Tijuana River basin is 4,430 km^2 with two-thirds in Mexico and one-third in the United States. On the U.S. side of the border, the basin occupies 1,230 km^2 in San Diego County. In Mexico, the basin is 3,200 km^2 and includes parts of the municipalities of Tijuana and Tecate. The major bodies of water on the U.S. side of the basin are the Morena Reservoir, Barret Reservoir, and Cottonwood Creek. In Mexico, the Rodríguez Reservoir, Río de Las Palmas, Tecate River, Alamar River, and the Tijuana River form the Tijuana River basin. All rivers throughout the basin are seasonal. The region has suffered nearly six years of drought, therefore, San Diego County and the municipality of Tijuana rely almost entirely on imported water from the Colorado River. The city of Tecate is supplied by groundwater and also has access to Colorado River water. The water shortage in the municipality of Tijuana has not deterred industrial growth. However, when considering sustainable growth for Tijuana or San Diego, water supply is an important issue.

There is a larger population with more economic activity in the Mexican portion of the Tijuana River basin. The major economic activities in the municipality of Tijuana are commerce, industry, tourism, and some agricultural and livestock production. The industrial sector offers the most employment, and the commerce and tourism sectors generate the highest incomes (Clement and Zepeda 1993). Tijuana and Tecate are the major cities located in the Mexican portion of the basin. In the municipality of Tecate, Valle de Las Palmas is its largest rural community and has the potential to experience accelerated growth in the future because of its abundant supply of water.

The population on the U.S. side of the basin is smaller. The area consists of national forests, Indian reservations, San Ysidro, Otay Mesa, and Tecate. San Ysidro offers discount shopping centers, fast food restaurants, and money exchange houses that cater to the people crossing the border. In Otay Mesa, there are many warehouses affiliated with factories in Mexico. Land is used for small-scale agriculture but it is designated for future industrial use.

Contrast within the Binational Region

The economies of Tijuana and Tecate have been fueled by the dynamic economic activity of Southern California. There has been tremendous growth in the residential, industrial, and business sectors along the international boundary (Proffitt 1994). The industrial and business sectors of Tijuana have been driven primarily by foreign investment, and have grown faster than the capability of the municipality to deliver services to the growing population.

There is a lack of infrastructure to provide sewer service to the population and incomplete enforcement for monitoring illegal dumping by factories and businesses. These factors have a negative impact on the environment. Agriculture and industry on the U.S. side of the border also contribute to the contamination of the basin.

The majority of the population in San Diego County enjoys basic services such as running water, sewer service, paved roads, and access to public education. San Diego County has witnessed a demographic explosion in the last twenty years, but through public and private investment, the County has been able to meet the demand for service and infrastructure needs. When the basic needs of a population are met, issues such as environmental protection become important. Tijuana and Tecate continue to struggle to provide even minimal infrastructure and services, so other quality of life issues such as the protection of endangered species and wetlands do not have a high priority. For the protection of the environment to become a leading issue for Mexico, or other developing nations, the majority of residents must enjoy basic services such as potable water, sewer service, other infrastructure, and basic education. These differences in priorities between the United States and Mexico mirror the asymmetries between the two countries and make binational planning a challenge. The asymmetries are magnified on the border where a developing country and a country with the largest economy in the world meet face-to-face.

The Dilemma of Centralism in Mexico

Due to Mexico's centralized political system, the state and municipal governments do not completely control their finances (Rodriguez and Ward 1994). The taxes that the federal government collects from the municipalities are partially returned in the form of investment in infrastructure and services to the regions. However, only a modest proportion of taxes actually returns to the areas where collected. During the Salinas administration, only 16 cents for every dollar paid in taxes by the municipalities to the federal government was returned to the regional governments in the form of investment (Rodriguez and Ward 1994).

Municipalities receive funding from the federal government based on population levels and taxable industries (Rodriguez and Ward 1994). For the municipalities of Tecate and Tijuana, where a large sector of the economy consists of the largely untaxed maquiladora industry, this further aggravates the imbalance of funds redistributed into urban infrastructure and services, especially water. Therefore, the burden of constructing and maintaining infrastructure falls primarily on the regional governments while the federal government reaps the benefits of the booming economy of Baja California. Furthermore, the federal government frequently underestimates the population in the municipalities of Tijuana and Tecate, which reduces the total revenues transferred to the municipalities. This creates budget problems for the municipalities because they cannot provide services to the entire population that is expanding rapidly.

This dilemma of centralism can be seen in Tijuana's State Commission of Public Services 1996–2001 Development Plan. The plan offers an analysis of the supply and demand of potable water in Tijuana, but uses the official population statistics, which greatly underestimate the actual population of Tijuana. Using the smaller population figure, CESPT, which is obliged to use the official census figures, projects that Tijuana will enjoy an adequate supply of water until mid-2001. However, this underestimation of the population will create a water crisis in Tijuana in the immediate future. This exemplifies the problem that the regional government has in dealing with the federal government.

During the de La Madrid administration, there were political reforms that fostered decentralization and more autonomy for regional governments. The Salinas administration continued the reforms and recognized the victory of the National Action Party (PAN) in Baja California in the regional elections of 1989. Baja California was a forerunner in leading the nation to search for alternatives to the Institutional Revolutionary Party (PRI). The government elections on July 6, 1997, further demonstrated that the PRI is willing to allow regional governments to obtain more political autonomy.

Meaningful political reform in the Mexican federal government and continual decentralization are key to the fiscal health of the regional governments. This will generate confidence in the country's economy, which will lead to further private investment at the regional level in constructing and maintaining services and infrastructure to achieve sustainable growth.

Demographics

Tijuana's Population Growth

The municipality of Tijuana, Baja California, had a 1995 population of 1,106,489 residents, with an annual growth rate of 5.3 percent (INEGI 1995). By the year 2005, it is estimated that Tijuana will have a population of 1,863,729 residents. This growth will lead to an increased demand in services in the watershed, such as sewage facilities, potable water, and general infrastructure.

When planning for economic and urban development programs, the city must take into account the need for increased services and develop adequate strategies to ensure that the requirements of the residents in this dynamic watershed are met. Table 1.1 provides population projections for Tijuana through the year 2005.

Table 1.1. Tijuana Population Projection through the Year 2000

Year	Population
1997	1,106,489
1998	1,169,575
1999	1,238,538
2000	1,314,335
2001	1,398,227
2002	1,491,965
2003	1,598,028
2004	1,720,087
2005	1,863,729

Source: Population figures are estimated using a 5.3 percent annual growth rate, based on the 1995 INEGI statistics.

According to the estimates for total population, Tijuana is characterized by rapid population growth. By the year 2005, Tijuana's population will be some 58 percent larger than the current amount. This rapid growth is largely due to the constant flow of migrants from different states in the Mexican Republic, such as Sonora, Sinaloa, Jalisco, and Michoacán. These states have participated in the population growth of the City of Tijuana that has placed demands on the urban infrastructure. Because of the high migration rates, the native born population of Tijuana represents less than 50 percent of the total population. Some percentage of Tijuana's population, perhaps as many as fifty thousand people is "floating," consisting of people recently arrived who are in search of jobs or the opportunity to cross the border illegally.

Tijuana is a common destination for migrants and immigrants who are searching for a higher standard of living. They constitute the primary factor that supports the demographic composition of the city (COPLADEM 1996). The magnet of jobs in Tijuana and across the border and the lack of economy in many other parts of Mexico, account for this northward flow of migrants.

The migrant and immigrant population of Tijuana has not been calculated, but it has been estimated to be greater than thirty thousand people annually. These cross-border migrants have played an important role in the economy of Tijuana, creating links between the United States and Mexico. Therefore, the study of the population of migrants and the "floating population" should be analyzed in the context of the future socioeconomic development of Tijuana. The demand on existing infrastructure and the effect on urbanization, public works, and services must be examined.

As the population grows, expansion to the eastern portions of Tijuana will create transportation problems in the region. The demand for shorter routes for public and private transportation becomes more pronounced each day. Many boulevards and bridges have been constructed, as well as increased development of housing. The Plan de Desarrollo Municipal lists different strategies and objectives to satisfy the needs of the residents of Tijuana.

The demographic growth in the city of Tijuana should be differentiated by natural growth and by massive migration into the region. Natural growth results from the difference between the birth and death rates of the population. Migration is comprised of immigrants and has been a primary factor in the growth of the total population. The natural growth rate of Tijuana is less than the state and national average. Factors that influence this lower rate of natural increase include the metropolitan nature of the city, the high level of education, and perhaps the influence of the culture of the United States. Important structural characteristics of the population of Tijuana include a majority of young people and its urban nature, which result primarily from the low natural growth rates and the high immigration rates in urban zones (UABC 1996).

Tijuana's Economically Active Population

In 1995, the city of Tijuana had a population of 1,106,489 residents, of which 696,034 were included in the economically active population (PEA) (INEGI 1995). The secondary sector includes maquiladoras and manufacturers, the tertiary sector includes services and commerce, and the primary sector includes agriculture, livestock, and fishing. Table 1.2 shows that the greatest participation of the PEA occurs in the tertiary and secondary sectors. The smallest percentage is in the primary sector.

Table 1.2. Tijuana's Economically Active Population (PEA) by Sector

Primary Sector	70,299
Secondary Sector	215,771
Tertiary Sector	368,202
Unspecified	41,762
Total	696,034

Source: INEGI statistics (1995).

About 10 percent of the economically active population engages in primary activities. This sector constituted the same proportion of the PEA in the 1990s. The secondary sector generates 31 percent of the employment in the city, the tertiary sector employs 52 percent of the labor force, and 7 percent of employment is unspecified.

The diversification of the economic base and employment sectors is due to the growth of industrial employment, which has nearly doubled in less than ten years. The industrial sector has the highest turnover rate because of the rapid expansion of industrial employment, the low salaries, and the monotonous nature of the work.

The tertiary sector is the most dynamic in Tijuana's economy. Commerce and services will be one of the engines that spurs future economic growth in the urban space containing the Tijuana River watershed.

Tecate's Population Growth

The city of Tecate, Baja California, has a population of 80,000 and an annual growth rate of 5.3 percent (Romero 1997). By the year 2005, Tecate will have an estimated population of 120,925 residents. The increase in population will lead to an increased demand for services in the watershed, but on a smaller scale than in Tijuana. This is because the flow of migrants in Tecate is lower than in Tijuana. Also, the economy of Tecate is less dynamic than that of Tijuana.

The needs of the population are small when compared to Tijuana in terms of the demand for services such as potable water, sewage facilities, and general infrastructure. However, Tecate has grown in importance for the economy of Baja California due to the growth of the maquiladora industry on the outskirts of the city and the presence of the Tecate border crossing.

According to Marco Antonio Romero, a Tecate city official involved in economic development, future development projects will include the channelization of the Tecate-Tijuana River, and the construction of another border crossing about 500 meters east of the current Tecate border crossing. These developments will enable Tecate to engage in more commerce with the United States and with Tijuana. The economy will be more dynamic as the transport of merchandise and inputs for maquiladoras flow between the three cities. Maquiladoras are the economic growth engine in Tecate, commerce comprises a quarter of the economy, and agriculture plays a minimal part in the dynamic growth of this city.

Table 1.3 shows that the population of Tecate will grow from the current 80,000 residents to 120,925 in 2005. Within ten to fifteen years, the urban development to the east of Tijuana will reach Tecate. Then, the two cities will constitute a single, urbanized area.

Table 1.3. Tecate Population Projection through the Year 2000

Year	Population
1997	80,000
1998	84,240
1999	88,705
2000	93,406
2001	98,357
2002	103,569
2003	109,059
2004	114,839
2005	120,925

Source: Population figures are estimated using a 5.3 percent annual growth rate, provided by Marco Antonio Romero, in the Tecate Municipal Planning Department.

Current Urban Structure

Tecate is located in Mexico across the border from the city of Tecate in the United States. The topography of the area has determined the configuration of the city. Tecate is surrounded by a number of hills and mountains: El Cuchumá in the northwest, La Panocha to the northeast, and El Caracol and La Nopalera to the south. Tecate has an area of 1,573 hectares and houses 60,000 to 80,000 residents. The development of the city was based on a linear system along Federal Highway No. 2 that runs from Mexicali to Tijuana and Highway No. 3 that extends from Tecate to Ensenada. The tendency for growth in the urban space has varied as land has become available.

There have been two trends for urban growth. One has been toward areas with ideal living conditions, and another toward the southeast, which is a zone where the topography and steep slopes make urbanization difficult. General policies of consolidation, growth, conditional use, and ecological conservation are first-level strategies being proposed in planning the total central population of Tecate. These policies establish overall guidelines governing the use of the zones occupied by the population of the city. The second level of the strategy defines a detailed approach to the proposed urban structure under four basic headings: roadways, infrastructure, land use, and public facilities.

One of the most important objectives for the development of Tecate is to provide services at an intermediate level for residents. Another objective is to regulate growth in order to optimize the construction of infrastructure, public facilities, and services that improve the standard of living of residents. To realize these objectives, other factors must be taken into consideration. These include establishment of an urban zoning code, determination of policies and public works funding, participation of business sectors and society, formulation of an urban structure that is compatible with residential space, and increased transportation networks, sewage, and running water services.

Tecate has problems that are related to the physical environment. There is a scarcity of water resources, and existing aquifers are overexploited. The topography is unsuitable for urban development, with inclines of up to 30 percent and over in the south and southeast area. The soils contain diorite, granite, and intrusive and residual ignea. Faults and fractures exist where many human settlements are located, mainly in the southwest and southeast. The river and creeks that run intermittently within the urban area cause problems in the unchanneled parts of the city.

The physical expansion of Tecate has been of considerable magnitude. The urban area has increased 41 percent, reaching 1,573 hectares. Settlements have been established in the southeast part of the city, producing inappropriate growth because of the rugged terrain.

The expansion covers the surrounding areas of La Nopalera hill, along with the Descanso, Cucapah, and Emiliano Zapata colonias, and the Granjas Garzón and Maclovio Herrera settlements. Although 45 percent of the land reserved for urban development has been used, this represents only 22 percent of total growth of the city. Other settlements include the colonias of Santa Fe, Valle Verde, Lombardo Toledo, and El Rincón Tecate *(Programa de Desarrollo Urbano del Centro de Población de Tecate, B.C. 1993–2005* 1995).

Tecate's Economically Active Population

Tecate has a population of 80,000 residents, with 56,800 who are economically active in the primary, secondary, and tertiary sectors as well as in unspecified activities. Table 1.4 shows the economically active population in Tecate by sector. The secondary sector is the most active and includes the maquiladoras, industry, and manufacturing. The secondary sector is one of the most dynamic and prosperous sectors for the future of the economy of Tecate. The tertiary sector, which includes commerce, services, and tourism, is the second most active sector. The primary sector has the smallest percent of the economically active population and is of minimal importance to the economy of the city.

Table 1.4. Tecate's Economically Active Population (PEA) by Sector

Primary Sector	3,976
Secondary Sector	29,252
Tertiary Sector	7,100
Unspecified	16,472
TOTAL	56,800

Source: *Programa de desarrollo urbano del centro de población de Tecate, B.C. 1993–2005*, (1995) with PEA as 71 percent of total population.

San Diego Demographics

The population growth in San Diego is slower than in Tijuana and Tecate. The United States portion of the watershed contains a much smaller population than the Mexican portion. According to the United States Environmental Protection Agency (USEPA), in 1990 the population in the United States portion of the watershed was 80,649 (USEPA 1997). Applying the San Diego growth rate of 1.31 percent between 1990–1995, the watershed population in 1997 was estimated to be 88,342 (Ganster 1996). If the watershed region continues to grow at the current rate for the County of San Diego, it will contain 98,036 people by the year 2005. The portion of San Diego County residents in the watershed is small, around 3 to 4 percent, and the U.S. population of the watershed is approximately 3 to 4 percent of the total. It is likely that these relative percentages will continue in the future.

The San Diego portion of the watershed is relatively undeveloped. It contains parts of Imperial Beach, San Ysidro, Otay Mesa, and areas of East County. In the East County, the watershed includes the Campo and La Posta Indian Reservations, parts of the Cuyapaipe and Manzanita Indian Reservations, and some of the Cleveland National Forest. The United States Environmental Protection Agency describes the land use as follows: area in human use (urban and agriculture) is 5.27 percent; area in forest use is 64.25 percent; and area in crop use is 4.92 percent (USEPA 1997).

The San Diego portion has less environmental impact on the watershed than the Mexican side due to the low percentage of developed land and the relatively small population in the region. The San Diego/Tijuana Planned Land Use Map, produced by the San Diego Association of Governments (SANDAG) and the Dirección General de Planeación del Desarrollo Urbano y Ecología of the Municipality of Tijuana shows that heavy development of the U.S. side of the watershed is unlikely. The western portion, containing the lower part of Imperial Beach, is primarily zoned for parks/open space, urban recreation, and agriculture. The central portion, which contains San Ysidro and Otay Mesa, is mainly zoned for parks/open space, residential, commerce near the port of entry, and light industry. The Otay Mesa portion is entirely zoned for light industry (SANDAG and Dirección General de Planeación del Desarrollo Urbano y Ecología 1995).

The urban planning for this area does not promote increased settlement or commercial growth, despite past attempts to develop the area. During the 1960s, developers attempted to convert the Tijuana Estuary into a marina (Roper 1997).

The Watershed in the Context of Greater San Diego

The San Diego portion of the watershed falls within three major statistical areas (MSA) designated by SANDAG: South Suburban (MSA 2), East Suburban (MSA 3), and East County (MSA 6). Although these statistical areas expand beyond the watershed boundaries, they help describe the economic activities and demographics that affect the Tijuana River watershed.

Employment in the Watershed

Table 1.5. Employment/Labor Force Status (Persons Age 16+) in the MSA Regions along the Mexican Border Based on 1990 U.S. Census Data

	South Suburban % of Total	East Suburban % of Total	East County % of Total	San Diego County (%)
In Labor Force:	64.3	68.2	52.8	68.3
Armed Forces	4.5	2.1	.5	5.7
Civilian (employed)	55.2	62.4	49.2	58.8
Civilian (unemployed)	4.6	3.8	3.1	3.8
Not in Labor Force:	35.7	31.8	47.2	31.7

Source: San Diego County Census Profile, University of California, San Diego, 1997.

The San Diego regional employment information for the three statistical areas is shown in Table 1.5. The percentage of the population that is employed in the East Suburban section is nearly the same as the county average, but the other two MSAs in the watershed are lower than the county average. East County has the highest percentage of people that are not in the labor force because of the rural nature of the region. The proportion of the population in the labor force on the San Diego side of the watershed is higher than the Economically Active Population in Tijuana, which is 40 percent of its population. It should be noted, however, that direct comparisons between employment in San Diego and Baja California cannot be made because employment is defined differently in the two regions.

Employment by Sector

Table 1.6 contains data on the areas of economic activity in the different statistical areas. Although the top three economic sectors are similar to the San Diego County average, there are some stark contrasts between the statistical areas in the lower ranking industries.

Table 1.6. Employment by Economic Activity in the MSA Regions Based on 1990 U.S. Census Data (by percentage of employment in each MSA)

Industry	South Suburban % of total	East Suburban % of total	East County % of total	San Diego County % of total
Agriculture, Forestry, Mining	1.30	2.00	7.20	2.40
Construction	6.50	10.60	12.70	7.80
Manufacturing	15.10	12.60	7.10	13.80
Transportation/ Communications/Utilities	6.30	6.00	6.00	5.50
Wholesale Trade	4.00	4.00	2.10	3.90
Retail Trade	20.60	18.70	17.00	18.10
Finance, Insurance, Real Estate	6.50	7.60	5.00	8.10
Services	30.80	32.80	37.40	35.10
Public Administration	9.10	5.60	5.70	5.20

Source: University of California, San Diego, 1997.

Services and retail trade dominate as the top two sectors throughout the three statistical areas and match the San Diego County average. Manufacturing is the third largest in the South Suburban and East Suburban areas, and similar to the County average, but construction and agriculture/forestry/mining are the next largest employers in East County probably due to the rural environment. Another difference is in the South Suburban area, where public administration ranks fourth, which is higher than the other two areas and the San Diego average, where it ranks seventh. The higher percentage of public administration employment is probably due to the military presence in Imperial Beach and the border crossing administration. The finance, insurance, and real estate category ranks lower among the three areas than the San Diego County average. This contrast is consistent with the different levels of development among the sectors.

Different levels and types of development affect water consumption. Having information about industry can help determine water use in the region. Services and commerce tend to consume more water than industry. Future growth in these sectors will create a demand for water in the region. In the East County, agriculture is a larger industry than manufacturing and will demand less water. According to the City of San Diego Water Utilities Department, the estimated water use in its district is distributed as follows: residential at 57 percent, agricultural at 0.3 percent, public and other at 6.3 percent, industrial at 3.8 percent, and commercial at 32.5 percent (San Diego County Water Authority 1997). Commerce and services use a higher percentage of water than industry, but industry may produce more pollution in the river basin that may affect water quality. In conclusion, the limited growth and development in the region within the Tijuana River watershed should not heavily increase the demand for water.

Housing

One of the most important means for evaluating the quality of life is the access to and availability of housing with services, such as running water and sewage connections. On both sides of the border, the tendency for development has been to expand from the urban cores. In Tijuana and Tecate, this tendency has resulted from the inability of municipal governments to manage the rapid population growth stemming from increased migration and industrial growth.

For these Baja California cities, urban planning is a new practice that was recently decentralized from the federal government. According to Hermila Tinoco of the City of Tijuana's Dirección General de Planeación de Desarrollo Urbano y Ecología, urban planning and zoning began as a result of the Urban Settlement Law of 1982. Between 1992 and 1995, the city also developed a legal instrument for urban development, specifying different zoning regions (Tinoco and Castellanos 1997). A similar planning process has been taking place in Tecate. Both cities are making efforts to catalogue different land areas within their municipalities and identify all natural resources. Their goal is to proactively plan development projects, like the Third Stage for the Río Tijuana, that include plans for housing land use.

In the past, the municipalities have been caught in a reactive pattern of development in which they granted land to squatters who had built their homes on unoccupied land without possessing a land title. Several limitations constrain municipal urban planning agencies from effectively managing growth and housing establishments. One problem is that municipalities often do not control all lands in the region since many are still under federal jurisdiction. In these instances, a lack of jurisdiction prevents cities from removing squatters from open lands without federal authorization (Clement and Zepeda 1993). The lag time causes rapid expansion and makes removal of people and their new homes difficult. Another problem is that development goals usually have a short-term orientation instead of a long-term strategy, due to their link to three-year municipal government terms. In addition, the municipalities usually lack sufficient funding and specific implementation plans for carrying out the development of improved infrastructure and housing (Clement and Zepeda 1993). Tecate, in particular, has suffered from municipal debt and a lack of funding.

In San Diego, the trend for housing developments has been an eastward expansion of large suburban communities with tract homes. This trend coincides with the development of large shopping centers that include mega-stores like Walmart and, therefore, require more land and water for landscaping and other facilities. Another consequence of this outward expansion is the deterioration of older neighborhoods. As a result, SANDAG officials are exploring possibilities for rejuvenating these neighborhoods to revitalize inner-city areas (SANDAG 1997). This revitalization would improve housing availability without eliminating open space and without further taxing the region's environment.

Tijuana's Housing

The present level of housing available in Tijuana does not meet the growing demand for homes. In 1990, the Mexican Census estimated that Tijuana had at least 161,338 homes. In 1997, the Dirección General de Planeación de Desarrollo Urbano y Ecología estimated that there were 267,258 homes (Tinoco and Castellanos 1997). Table 1.7 provides state government estimates of the housing shortage.

Of the homes available in Tijuana, 70 percent are owner-occupied, and only 30 percent are rented (San Diego Dialogue 1995). The Mexican government has established a number of institutions to plan and build low-income housing and provide infrastructure. One of these organizations is the Instituto del Fondo Nacional para la Vivienda de los Trabajadores (INFONAVIT), which was established in 1973. INFONAVIT is funded through direct deductions from the paychecks of workers to the Instituto Mexicano de Seguro Social (IMSS). This organization provides home loans to workers with 20-year terms. The monthly payments of the workers cannot exceed a certain percentage of their salaries (Klagsbrunn 1988). Another home loan agency is the Fondo para la Vivienda de los Trabajadores al Servicio del Estado (FOVISSSTE). Beneficiaries of these funds are affiliated with the Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE), a Social Security fund designated for state employees. Although these programs help increase the availability of housing, they are limited in the number of people they can serve. In order to receive benefits from these programs, workers must have jobs with benefits that pay social security. Most people in the Economically Active Population category do not have jobs with such benefits (Klagsbrunn 1988).

Table 1.7. Tijuana Land and Housing Deficit to the Year 2000
Based on Annual Production of Units

	Public	Private	Total	Total Demand	Annual Deficit	Deficit in Year 2000
Lots	3,205	--	3,205	5,477	2,272	11,360
Homes	1,278	2,382	3,660	10,436	6,770	33,870
Total	4,483	2,382	6,865	15,913	9,042	45,230

Source: *Monografía Socioeconómica de Baja California*, Universidad Autónoma de Baja California, 1996, and Gobierno del Estado de Baja California, 1996.

When comparing the involvement of these programs in home construction and improvement, the insufficiency of the programs becomes evident (Table 1.8). Whereas the annual demand for homes is 15,913, these programs are hardly able to serve 12 percent of that demand. Private developers also fill a small portion of the city's needs (Table 1.9). Thus, most of the housing constructed is self-help housing, built by the occupants from a variety of available materials.

Table 1.8. Tijuana Housing Units Completed by the Public Sector by Program, 1993

Program	Completed Housing Units	Housing Units in Progress	Housing Unit Improvement	Other	Total
FOVISSTE	--	--	4	4	8
INFONAVIT	1,230	--	--	368	1,598
State Real Estate Sales in Tijuana	--	203	71	--	274
Total	1,230	203	75	372	1880

Source: INEGI *Anuario Estadistico,* 1994.

The pressures of increased urbanization persist, and many sectors within the city are completely built out, mainly Playas de Tijuana, Otay, and Zona Centro. However, about 17 percent of the urban space contains empty lots and undeveloped areas (COPLADEM 1996). These empty lots run the risk of being "invaded" by migrants and low-income wage earners who cannot afford to buy homes, thus creating an increased strain on the already inadequate infrastructure and compounding environmental problems.

Table 1.9. Tijuana, Production of Houses by Private Developers, 1993–1995

Type	1993	1994	1995	Total	Average
Low-Income	0	2,914	1,348	4,262	1,421
Middle	613	464	654	1,731	577
Residential	97	127	929	1,153	384
Total	710	3,505	2,931	7,146	2,382

Source: *Monografía Socioeconómica de Baja California*, Universidad Autónoma de Baja California, 1996 and Comité de Planeación para el Desarrollo Municipal (COPLADEM), 1996.

According to figures from the Comisión Estatal de Servicios Públicos de Tijuana (CESPT) in April 1997 only 89.33 percent of Tijuana households had access to running water, while only 59.06 percent had access to sewage services. Data from the Comisión Federal de Electricidad (CFE) from January 1997, showed that 88.42 percent of Tijuana households had access to electrical energy. The families that are not served by the existing service infrastructure satisfy their needs by either pirating water and electricity illegally or by purchasing from water tank trucks (*pipas*). The people who lack access to sewage services contribute to environmental and health problems through improper disposal of untreated sewage.

Tecate's Housing

The dynamic growth in the Tecate region between 1970 and 1980 (5.15 percent per year) created a greater need for housing. In response to the growing population, housing units increased at an annual rate of 6.64 percent between 1980 and 1985. Since then, housing has been growing at a rate of 6.42 percent (*Programa de Desarrollo Urbano del Centro de Población de Tecate, B.C., 1993–1995* 1995). This production rate is larger than the 5.3 percent annual population growth rate. Currently, Tecate has approximately 17,644 houses. If the average household has 4.6 people, the existing supply of homes is enough to satisfy the demand of urban growth (Comisión Nacional del Agua 1996). However, the physical limitations restricting suitable land for development mentioned earlier will constrain further outward expansion in Tecate. Because there is an ample supply of housing, the housing assistance programs have focused less on producing finished units than in modifying and upgrading existing ones (Table 1.10).

Table 1.10. Housing Units Completed by the Public Sector by Program 1993

Program	Completed Housing Units	Housing Units in Progress	Housing Unit Improvement	Other	Total
FOVISSSTE	--	--	1	2	3
State Real Estate Sales in Tecate	--	34		--	48
Total	0	34	15	2	51

Source: INEGI, *Anuario Estadistico*, 1994.

According to Tecate's Urban Development Plan, 17 percent of households do not have access to running water and 35 percent lack access to sewage services (*Programa de Desarrollo Urbano del Centro de Población de Tecate, B.C., 1993–1995* 1995). The financial problems of the city will constrain its ability to build the necessary infrastructure to expand access to a larger portion of the population.

San Diego's Housing

The population residing in the western and central portions of the watershed tends to be transitory in nature, usually temporarily residing in South Bay areas. The border region in San Diego has a lower density of owner-occupied housing than elsewhere in the county, helping to explain the more transitory nature of the population. Due to the rural nature of the eastern region of the watershed in San Diego County, housing units are more scarce and probably more permanent. Of the housing units in San Diego, 99.8 percent have access to running water and 95.6 percent possess sewer connections (San Diego Dialogue 1995). The City of San Diego has implemented several home water conservation projects to help reduce water consumption. The 4.4 percent of the population without sewer connections will have a minimal impact on the environment of the region.

Water Needs of the Region

Table 1.11 includes a projection made by CESPT for water demand in cubic meters for the years 1997–2005.

Table 1.11. Total Water Demand in the City of Tijuana, Baja California, 1997–2005 in Cubic Meters by Sector

Year	Residential	Commercial	Industrial	Governmental
1997	5,548,016	832,202	817,208	299,893
1998	5,928,777	889,316	873,293	320,474
1999	6,346,606	951,991	934,838	343,060
2000	6,807,430	1,021,114	1,002,715	367,969
2001	7,318,979	1,097,847	1,078,066	395,621
2002	1,097,847	1,171,447	1,150,340	422,143
2003	8,364,831	1,254,725	1,232,117	452,153
2004	9,003,746	1,350,561	1,326,227	486,689
2005	9,755,635	1,450,162	1,436,979	527,332

Source: Interview with Ing. Carlos Machado of the Comisión Estatal de Servicios Públicos de Tijuana (CESPT). Data were projected to the year 2005 by Olivia Matus using linear regression analysis.

Tijuana is located in one of the most arid zones in Mexico. The large population in Tijuana, with a high annual growth rate, creates an increase in the demand for water in all sectors making water supply the most serious problem. The federal government built the Colorado River aqueduct in response to the increased water consumption in the region. According to CESPT, Tijuana will have enough water beyond the year 2000, but if the demand for potable water increases annually, more water connections to the existing Colorado River aqueduct may be needed. This may be necessary to ensure a potable water supply beyond the year 2000 for the developmental needs of the population. Similar to the water studies conducted to meet the international water quality standards, new studies should be done on the water that is unaccounted for or that is lost through the system. Without control of these unaccounted waters, the demand for water will increase much more than anticipated. Knowledge of reliable sources of water supplies can help increase investment in commerce, industry, and tourist developments in a way that permits economic development thereby generating jobs.

According to CESPT, there are currently 45,000 families or 20 percent of the population without direct water connections in the colonias. Therefore, each family must buy water from tank trucks (*pipas*) and pay $150 pesos to fill a 55-gallon container, of which approximately 30 liters per day are consumed. One container can last an average-sized family about two weeks. CESPT claims that it will be able to cover all of these families by the end of 1997. For those workers who make minimum wage or less, it could cost as much as 36 percent of their annual income to supply water to their families.

Tecate also faces a similar problem as water consumption increases as the population grows. Table 1.12 shows that the sector demanding the most water in the years 1997–2005 will be the residential sector.

Table 1.12. Total Water Demand in the City of Tecate, Baja California, 1997-2005 in Cubic Meters by Sector

Year	Residential	Brewery	Industrial	Commercial	Governmental	Cosmetics
1997	524,288	131,072	23,149	65,536	32,768	8,192
1998	115,281	52,135	43,673	27,688	25,657	5,350
1999	127,520	54,792	41,620	27,003	25,291	5,208
2000	114,768	49,314	37,459	24,303	22,763	7,188
2001	103,292	44,383	33,714	21,874	20,487	8,625
2002	104,490	45,158	34,710	22,455	21,004	9,488
2003	106,793	46,122	35,401	22,910	21,433	9,497
2004	107,590	46,441	35,606	23,049	21,566	9,022
2005	107,164	46,235	35,417	22,932	21,458	8,842

Source: CESPTE (1997). Data were projected to the year 2005 by Olivia Matus using linear regression analysis.

The brewery will be the next largest consumer of water. In third place, industry will demand the most water, commerce and government alternate in the next place, and the cosmetics sector will demand the least amount of water.

Tecate has a population of less than 100,000 residents and an annual growth rate of 5.3 percent (CESPTE 1997). The population growth will increase water demand in all sectors. If CESPTE satisfies the needs for potable water in the following years and meets all the city's water needs, this could lead to an increase in investment in commerce, industry, and tourism, which, in turn, would generate jobs and economic development.

In the public sector, Tecate needs resources in order to expand infrastructure. Without the necessary development of infrastructure, the city will not be able to cover the total demand for water. The need for water in all the sectors may continue to grow, but if the city lacks proper financing, the expanded supply of potable water will be delayed. This could result in an imbalance in the most significant activities of the municipality while impeding investment in the most economically mobile sectors. Tecate needs to encourage commerce and tourism to create economic development so that the city can obtain the necessary financing for constructing aqueducts to increase water supply access.

Economic Activities in the Tijuana Watershed

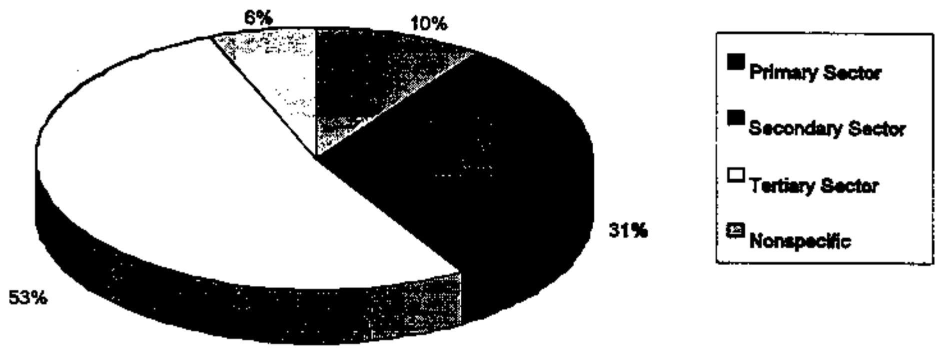
The impact on the Tijuana watershed caused by economic growth in the last twenty years has been significant. This section will discuss the principal sectors of Tijuana's economy, explain the growth of each sector and how they directly affect the environment, and describe the salaries of the workers in the region.

Analysis of Economic Sectors in Tijuana

The economy of Tijuana can be divided into three sectors: (1) agriculture, animal husbandry, and fishing; (2) manufacturing, industry, and textiles; and (3) services, commerce, and tourism. The primary sector employs 70,299; the secondary sector employs 215,771; and the tertiary sector employs 368,202 (INEGI 1995). The primary sector makes 31 percent of the PEA, and the tertiary sector is 51 percent of the PEA (INEGI 1995). Of the working population in Tijuana, 6 percent is in non-specific economic activities (Figure 1.1).

As Tijuana continues to grow, the economic activity in all three sectors expands. This expansion is most apparent in the primary and secondary sectors. The percentage of the PEA working in the primary sector in Tijuana has decreased over the last two decades, reaching a 25-year low in 1990. The decrease in primary employment is correlated with an increase in manufacturing. In 1980, about 17 percent of the PEA was employed in manufacturing. That number almost doubled in just ten years, reaching 29 percent of total employment by 1990. The percentage of people in nonspecific sectors has also decreased. In 1980, 33 percent of the economically active population worked in the nonspecific sector. That number decreased to 6 percent by 1995, as shown in Figure 1.1. These figures can be attributed to growth in the maquiladora industry (INEGI 1995).

Figure 1.1. Economically Active Population Per Sector



Source: INEGI, 1995.

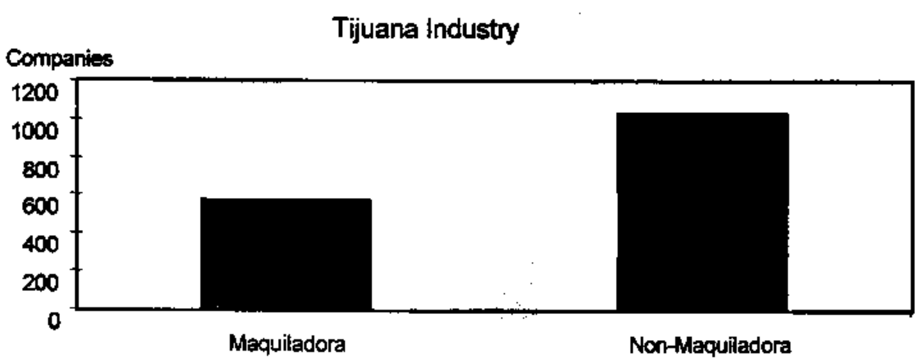
Industry

Transferring resources from the labor-intensive structure of the primary sector to the more capital-intensive structure of industry has placed a burden on the environment through the demand for resources and the creation of unwanted by-products. Some manufacturing plants produce large amounts of pollutants, therefore, government agencies are forced to set environmental standards. If heavy regulations are imposed on the companies, then it might become too costly for some companies to continue producing and they might be forced to leave. Yet, if there are no regulations, then a cost is imposed on the inhabitants of the area in the form of toxic waste and other types of pollution.

The fastest growing part of industry in Tijuana has been the maquiladoras. Maquiladoras are companies that import components for further elaboration and re-export. Maquiladora employment grew at an annual rate of 16.3 percent between 1980 and 1990. From 1980 to 1990, approximately 48.6 percent of the total number of jobs created in Tijuana were in the maquiladora industry (UABC 1996). Approximately one third of all industrial companies in Tijuana are maquiladoras (Figure 1.2).

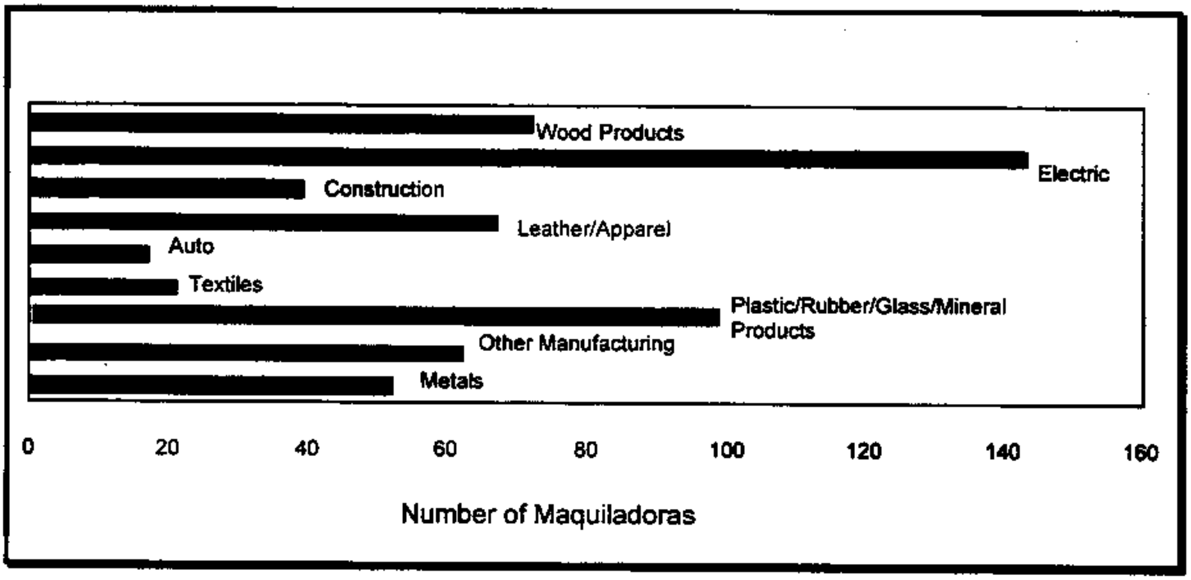
The maquiladora industry has had a positive impact on the economy of Tijuana. In addition to creating jobs for the growing population, the salaries paid by maquiladoras are higher than the national minimum wage and the corresponding minimal professional wage throughout the country (Clement and Zepeda 1993). In December 1996, each Tijuana maquiladora employee added 6,700 pesos to the Mexican economy, and the total value added by industry was 790,751,000 pesos in that month. Maquiladoras can be divided into eight categories as shown in Figure 1.3.

Figure 1.2. Number of Maquiladora and Non-Maquiladoras in the Industrial Sector



Source: *Monografía Socioeconómica de Baja California* Universidad Autónoma de Baja California, 1996.

Figure 1.3. Tijuana Maquiladora Categories



Source: Secretaría de Comercio y Fomento Industrial (SECOFI), 1996.

The manufacturing of electronic apparatuses and equipment and nondomestic electrical appliances is the largest, with 143 companies that employ 48,031 people. Companies that produce wood and plastic products are the next two largest, each employing approximately ten thousand people, and with a total of 72 and 63 plants, respectively. The total number of maquiladoras in Tijuana is 571 and employment is 100,489 (SECOFI 1996).

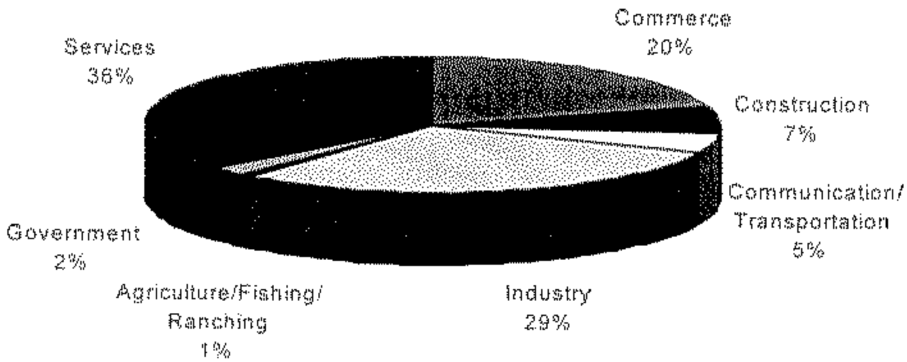
Larger companies are situated in industrial parks in the outskirts of Tijuana. There are 31 industrial zones in Tijuana: 15 centers and 16 parks. An industrial park is a geographic area that is clearly defined. Its topography and location facilitates industrial establishments based on a development program. This program considers urban infrastructure and sufficient services to propose the establishment of companies oriented toward industrial activities, services, and technological research and development. An industrial park must be registered with the Secretaría de Comercio y Fomento Industrial (SECOFI), a government agency that regulates the location and size for the industrial zones. The majority of these industrial zones are located in the east and southeast part of Tijuana. The average size of an industrial park is 48.1 hectares. There is a total of 624.8 hectares of developed industrial parks. The average size of an industrial center is 8.85 hectares, and there is a total of 176.9 hectares devoted to the centers.

The maquiladora industry is also important in Tecate. There are 88 maquiladoras that employ approximately eight thousand five hundred people. On the average, each employee in the maquiladoras adds 5,705 pesos per month to the local economy, and the total value added to the Mexican economy is 48,496,000 pesos (San Diego Dialogue 1995).

Commerce, Services, and Tourism

Tijuana has a strong concentration of commercial activities, tourism, and other services associated with a border economy. Commerce and services make up 20 and 36 percent, respectively, of the economic activity and have been a stable source of employment over the last twenty–five years. The tertiary sector has created the second largest amount of jobs and contributes the most value added (Figure 1.4).

Figure 1.4. Economic Activity in Tijuana



Source: INEGI, 1997.

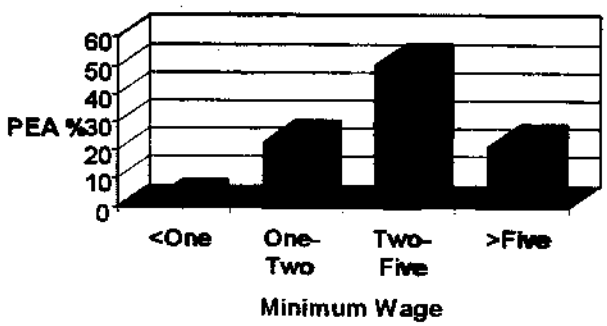
The commerce sector can be divided into three categories: 80 percent is in the form of small businesses, 10 percent is formal establishments without subsidiaries, and the remaining 10 percent is in the form of corporate restaurants, pharmacies, and clothing stores (UABC 1996).

It is difficult to accurately determine the number of commercial and service establishments due to the large percentage of companies that do not register with the Department of Commerce. There are 30,727 registered commercial and service companies in Tijuana. According to the Instituto Mexicano del Seguro Social (IMSS), the commercial sector employs 34,500 people. This number is a crude estimate, since it only reflects the number of employees from companies registered with IMSS. The IMSS estimates that 49,400 people work in the service sector. Although services and commerce employ the largest amount of people, the value added per capita for this sector is low because of the type of service performed, including border tourism.

Wages

The December 1997 minimum wage in Baja California was 26 pesos per day. Of the economically active population (PEA), 2 percent receives less than the minimum wage, 23 percent receives between one and two times the minimum wage, 50 percent receives between two and five times the minimum wage, and 22 percent receives more than five times the minimum wage. The commercial sector provides five times or more the minimum wage per day. The service sector employs the majority of workers making between three and five times the minimum wage per day. Workers in the maquiladora industry normally make about two times the minimum wage per day (Figure 1.5). The wages earned in Tijuana are high when compared to the rest of Mexico. This explains, in part, the large number of migrants coming to the area.

Figure 1.5. Tijuana Wages, 1997



Source: INEGI, 1997.

Conclusion

Sustainable Growth through Meaningful Political Reform

The July 6, 1997, first time governor elections in Mexico City changed the country's political format. For the first time since its conception over sixty-five years ago, the PRI must contend with a system of checks and balances supported by political pluralism in the Chamber of Deputies. This continuation of political decentalizaion offers further autonomy and fiscal responsibilities to the regional governments. The meaningful political reform will bring additional transparent elections, such as those of 1997. With an open government and clean elections, peoples' confidence in Mexican institutions will increase.

Confidence in the political and economic institutions is required to encourage private investment. This type of investment will come from both multinational corporations investing for profit and from direct individual investment from Mexicans and North Americans. The investments by individuals also improve services, infrastructure, and quality of life in the region where they live. This is the type of binational private investment required to build crossborder linkages needed to fully develop the economic potential of the region. The binational investment will build economic crossborder linkages not only in the form of traditional development in the manufacturing and electronics sector, but also in financial institutions, such as the banking industry and the insurance sector.

Long-term plans for this growth are being considered in Tecate and Tijuana/San Ysidro. In Tecate, plans exist to construct a second border crossing to the east of the current border crossing site. This plan stems from the idea to expand the facilities at the port of Ensenada to accommodate the increased traffic related to NAFTA and global trade, and to relieve the demand at the port of Long Beach. This plan will allow the creation of crossborder linkages among the areas in the form of more services, financial, insurance, and tourist industries. A larger scale plan for the formation of a duty free zone is being considered at the San Ysidro border crossing. The duty free zone would consist of hotels, restaurants, and other tourist industries. However, the duty free zone would primarily consist of banking and financial centers as well as insurance agencies. This type of industry is required to fully exploit the binational region. The prospects for the Tijuana-San Diego region achieving these types of developments has been demonstrated by the ability of Asian investment to grow from manufacturing centers to major financial centers (Otero 1996). The Tijuana region has the capacity to convert from a manufacturing center to a financial center because of the experienced work force of the region, high level of education, and feasible infrastructure that can lead to sustainable growth in the financial sector (Otero 1996).

Water and Economic Growth

For growth to occur in the financial and insurance sectors, the region will need to depend almost entirely on water supplied by the Colorado River. As water service deregulates on both sides of the border, there will be an opportunity to buy water on the open market. The energy sector has begun this process of deregulation (Sweedler, et al. 1995). While this may increase the availability of water in the region, economic activities that would be the most feasible in this dry climate should be considered.

The industrial and commercial sectors of Tijuana pay more for their water than the residential sector. The fact that the residential sector pays less may lead to wasteful water practices on the part of the residents. The supply for water in Tijuana will exceed its demand by 2001, therefore, serious water conservation and alternative development must be addressed. The region must consider not only what type of development it will choose, but also how much further the region can grow. If the region continues to grow at the same high rate, it will continue to attract migration that will further exacerbate the water supply and treatment problems.

The Effects of Economic Growth on the Basin

The region is economically dynamic with expanding sectors in not only manufacturing, but also in the financial and insurance sectors. This increase in economic growth rates has led to a lack of basic water and sewer services. Sewage waste and the contamination from improper disposal of hazardous and solid wastes are detrimental to the environment. The environment has already been contaminated due to the rapid population growth in the region. Economic and social growth must be restrained to prevent further damage to the ecosystem of the Tijuana River basin.

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Chapter 2

Politics of Water Management in the Tijuana River Watershed

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Teresa Téllez Girón

Introduction

The objective of this analysis was to identify the institutions and policies that dictate the planning and management of the Tijuana River watershed and its resources. In order to understand the watershed management and planning issues, various existing and projected land uses were identified within the Tijuana River watershed. These land uses were identified to provide a description of the current regional setting affecting the watershed and water quality implications associated with future growth. The following analysis also describes existing water demand and projected capacities needed to adequately provide water service for use within the watershed.

A watershed is defined by natural characteristics such as its ridges, slopes, canyons, tributaries, and man–made structures. All activities within a watershed or drainage basin are significantly linked to each other. For instance, massive grading activities resulting in the rapid depletion of slope vegetation can have severe down slope environmental impacts such as erosion and sedimentation buildup along lagoons or rivers. Upstream urban development on slopes or canyons can also result in potential problems such as chemical pollutant runoff and/or discharge of agricultural and industrial effluents. Sewage contamination and flooding are the most dominant problems that face residents in the Tijuana River watershed. Since the 1930s, sewage contamination has existed in the Tijuana River watershed as a result of rapid population growth, coupled with an inadequate infrastructure system in the growing Tijuana area. Given the topographical setting of the watershed, untreated sewage flows directly into the United States through the Tijuana River or through north–draining gullies and canyons such as Smuggler's Gulch and Goat Canyon. Raw sewage streams contaminate surface waters and nearshore ocean waters as well as ecological preserves such as the Tijuana River National Estuarine Research Reserve in San Diego.

For the purpose of understanding the characteristics of the Tijuana River watershed and the political institutions that provide water management in this watershed, students from both the Universidad Autónoma de Baja California (UABC), Tijuana campus, and San Diego State University (SDSU) conducted an intensive research project. A number of questions were posed during this investigation, including: (1) How is the Tijuana River watershed defined? (2) What are the physical characteristics of this area? (3) Who provides water management oversight in the area? and (4) How can the natural resources within this area be preserved?

Management Oversight

A complex and multijurisdictional system exists within the United States and Mexico with responsibilities ranging from the management of water resources, to land development issues, to the protection of natural resources within the watershed. The Tijuana River watershed is managed by respective U.S. and Mexican local, state, and federal legislative bodies, as well as a binational commission known as the International Boundary and Water Commission (IBWC) in the United States, or the Comisión Internacional de Límites y Aguas (CILA) in Mexico. A century–old organization, the Commission's functions were expanded in 1944 to incorporate the resolution of boundary water and sanitation problems including the study of projects for hydroelectric generation plants, storage dams, and flood control.

The legal framework for water management in Mexico is based on the Political Constitution, which determines that, "The nation holds at any time, the original water and land rights, and that, therefore, it will have the right to impose public interests over private property, as well as to regulate the exploitation of those elements suitable for appropriation, and to take care of its conservation" (Secretaría de Agricultura y Recursos Hidráulicos). The federal, state, and local agencies with water resources responsibilities in the Tijuana-Tecate region include the following:

- Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP): This federal environmental agency is responsible for enactment of Mexico's General Ecology Law providing for the protection, restoration, and conservation of natural resources. It also is responsible for the coordination of bilateral environmental programs and projects.

- Comisión Internacional de Límites y Aguas (CILA): This binational agency has been responsible for bilateral water sanitation projects along the border for over fifty years, and boundary arbitration for over one hundred years.

- Comisión de Servicios de Agua del Estado (COSAE): The primary functions of the agency include the operation of aqueducts and special water-related projects (Proyecto Hidroeléctrico–Tecate), as well as federal programs.

- Comisión Nacional del Agua (CNA): Established in 1989, this federal agency coordinates with state and local agencies for the provision, storage, and distribution of potable water and wastewater systems. According to the National Water Law, the principal functions of the CNA are to develop and implement the National Hydrological Plan; to preserve and conserve surface and groundwater in accordance with Mexican environmental laws; to oversee the expenditure of federal funds to construct public infrastructure projects; and to promote the efficient use of water, authorize direct surface water discharges, and implement appropriate measures to control and prevent water contamination.

- Comisión Estatal de Servicios Públicos de Tijuana (CESPT): This state agency is responsible for the provision of water and wastewater services to the City of Tijuana.

- Dirección General de Planeación de Desarrollo Urbano y Ecología: This agency coordinates and provides technical assistance to municipal offices and governmental agencies with land development issues. It also implements programs for the conservation of ecological resources.

In addition to Mexico's federal agencies, the following agencies provide water management oversight in Tecate:

- Comisión de Servicios Públicos de Tecate (CESPTE): Responsible for the provision of water and wastewater services for the city of Tecate, Baja California.

- Secretaría de Planeación y Desarrollo Urbano: Oversees growth management and land development issues within the municipality of Tecate. Coordinates with the Public Works Department for urban and infrastructure improvement projects within the city.

In California, the following types of agencies provide water service and supply:

- Municipal (City of San Diego)
- Regulatory and Planning Bodies (San Diego Regional Water Quality Control Board)
- Irrigation Districts
- Municipal Water Districts

There are 14 cities in San Diego County, of which two– the City of San Diego and the City of Imperial Beach– are located within the Tijuana River watershed. Unincorporated land east of Otay Mesa falls within the local jurisdiction of the County of San Diego or the federal jurisdiction of the Bureau of Land Management (BLM). In the eastern portion of the watershed, large tracts of land fall under the ownership of the Cleveland National Forest or the reservations of various Native American tribes such as the Campo, the La Posta, the Cuyapaipi, and the Manzanita.

The United States Environmental Protection Agency sets federal standards for water quality and treatment based upon the Clean Water Act. It has no powers over water quantity or sources. The 3 year–old U.S. EPA office in San Diego was created as a result of NAFTA–related border environmental concerns.

Water is imported to San Diego through the State Water Project and the Colorado River Aqueduct. The Metropolitan Water District of Southern California (MWD) wholesales water from the Colorado River Aqueduct and California's State Water Project (SWP) to its member agencies such as the County Water Authority (CWA) of San Diego. In San Diego County, 23 retail member agencies purchase water from the CWA, and retail the water to consumers within their districts. Wells and reservoirs are mainly supplementary sources of water in San Diego County. The CWA provides approximately 90 percent of the water used in its service area during an average year. CWA owns and operates the five large–diameter, gravity–fed pipelines in two main aqueduct corridors that deliver the imported water. However, water treatment and storage facilities are not owned nor operated by the CWA, as these functions are performed by the retail member agencies. The CWA's retail member agencies specifically within the Tijuana River watershed are the City of San Diego, the Tia Juana Valley County Water District, and the Otay Municipal Water District.

The Regional Water Quality Control Board (RWQCB) regulates wastewater treatment plants through National Pollution Discharge Elimination System Permits (NPDES). The RWQCB regulates the discharge of wastewater to water bodies or onto the land. The degree of treatment necessary before discharging wastewater depends on the relevant groundwater or surface water quality standards and objectives. These standards and objectives are promulgated by the Regional

Board and are based on beneficial uses of the ground or surface waters and the relevant statutory requirements.

State and federal policies required for the administration of water resources include the California Environmental Quality Act; the Federal National Environmental Policy; the Federal and State Endangered Species Act; the Federal Clean Water Act (CWA); the State Porter-Cologne Act; the Safe Drinking Water Act (SDWA); the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

Land Use Characteristics within the Watershed

Natural Characteristics

Two main tributaries, the Cottonwood Creek in San Diego and the Las Palmas River in Tijuana, form the Tijuana River. Upon crossing the border, Cottonwood Creek becomes the Alamar River. Arroyo las Calabazas and Arroyo Seco form the Las Palmas River. From the merging of the Río Alamar and Río de las Palmas in Tijuana, the river flows westerly approximately eleven miles before discharging into the Pacific Ocean, south of Imperial Beach in San Diego County. As the river channel extends north across the international boundary of the United States and Mexico, it traverses through a wide floodplain and continues westward into the Tijuana River estuary. From the point of confluence in Mexico, where the Tijuana River begins at an elevation of 215 feet above sea level, there is a gradual downhill slope for the next 11 miles. At the international border, the valley cut by the river has a width of 1.5 miles and opens to 3 miles at the Pacific Ocean (Herzog 1990).

Urban Uses

The Tijuana River watershed consists of a total area of 4,460 km^2, with approximately 1,236 km^2 (1/3) in San Diego County and 3,224.05 km^2 (2/3) located in the municipalities of Tecate and Tijuana. The area includes mixed urban development in the cities of Tijuana and Tecate, with rural land uses in the outskirts of the cities. Undeveloped land zoned for future development and infrastructure for tourism is included in this category. Urban uses under this category include approximately 10 percent of the land in the watershed (Table 2.1).Table 2.1 shows that approximately 10 percent, or 442 square kilometers (60,000 acres) of the watershed, is comprised of urban development, while agriculture use makes up 6 percent, and the remaining 83 percent of land is open and undeveloped.

Most of the developed area is concentrated within the cities of San Diego and Tijuana. According to the Plan Estratégico de Tijuana, the Municipality of Tijuana has approximately 1,584.48 square kilometers of land, of which 14 percent (or 249.03 square kilometers) are currently developed. Mixed residential and commercial uses are concentrated within the western and central portion of the city. To the east, land use includes mixed residential, industrial, and public use such as the Abelardo L. Rodríguez International Airport. Large, open-space parks are limited to Morelos Park in Tijuana. Ecological preserve areas include the Cerro San Ysidro located east of the airport, Presa Abelardo L. Rodríguez, Cerro Colorado, and Cerro de la Abeja to the south.

Table 2.1. Current Land Use in the Tijuana River Watershed

Land Use Type	Area (km^2)	% Total	Land Use	Area (km^2)	% of Use	% Total
Urban	442.0	9.960	Urban	210.9	47.7	4.700
			Suburban	96.8	21.9	2.200
			Settlements w/ urban development	30.7	6.9	0.700
			Settlements w/o urban development	86.4	19.5	1.999
Agriculture	263.0	5.900		85.7	33.0	1.900
			Irrigated land	177.0	67.0	3.990
			Dry farming			
Livestock/ Ranch	1.6	0.036	Cattle	1.6	100.0	0.036
Natural Vegetation	3698.0	83.300	Shrub land	996.0	26.9	22.400
			Chaparral	2562.0	69.3	57.700
			Forest	52.0	1.4	1.170
			Agrarian Vegetation	88.0	2.4	1.980
				17.0	3.8	1.400
Other Uses	34.5	0.800	Bare	14.5	42.0	0.300
			Bodies of water	19.0	55.1	0.400
			Bank material	1.0	2.9	0.020
Total	4439.1	99.996		4438.6		99.826

Source: Chavez, 1996.

Land use in San Diego County within the Tijuana River watershed consists of regional parkland, such as the Border Field State Park and the Tijuana River National Estuary Research Reserve. Both of these are adjacent to the border beach area. Military and Immigration and Naturalization Service (INS) activities are also located in this area including the Imperial Beach Naval Auxiliary Landing Field (NOLF) at Ream Field. Land uses in the Otay Mesa region include industrial parks, the Brown Field Airport, and agricultural. Sparse development exists further east in the communities of Dulzura, Morena, Live Oaks Spring, and Campo. These land uses are included in unincorporated county land and in the Dulzura and Mountain Empire Region community plans.

Agricultural Areas

Agricultural land use includes farming and cattle ranching. Crops harvested in the watershed include barley, grapes (vineyards), olives, alfalfa, onions, carrots, tomatillos, peppers, peaches, wheat, and oats. As shown in Table 2.1, agricultural uses within the watershed comprise an area of 263 square kilometers, or almost 6 percent of the total area.

One of the concerns with agricultural activities in the watershed is the potential for groundwater contamination that exists through fertilizer and pesticide use since the water quality of agricultural runoff is not regulated. The potential for aquifer contamination and, therefore, well-water contamination in the watershed can have serious health repercussions and is an issue of concern.

Livestock/Ranch Areas

Intensive livestock land uses such as dairy farms are predominantly located on the eastern edge of Tijuana in the El Florido community. The majority of the watershed to the east of Tijuana, along the valleys and sierras (higher mountain ranges), includes cattle ranching and livestock grazing. As shown in Table 2.1, this land use occupies an area of 1.6 km^2. In San Diego, there are agricultural areas next to the border in the Tia Juana Valley County Water District in addition to horse raising.

Mining

One land use that is seldom mentioned is sand mining for clay and pottery production. Sand is mined in Tijuana as well as Tecate. This contributes to the further erosion of the land, depleting the aquifers' ability to recharge, in addition to upsetting the natural environment. Small quarries and sand and gravel mining operations are scattered throughout the watershed. Their environmental impacts are not known.

Natural Vegetation

The natural vegetation of the watershed is comprised of chaparral and forest and coastal scrub, including disturbed vegetation as a result of past agricultural uses. Chaparral includes the following vegetation types: Parry pinyon pine (*Pinus quadrifolia*), junipers (*juniperus sp.*), and jeffrey pines (*P. jeffreyi*). Sparse communities of riparian vegetation are located in the eastern regions. Chaparral has coverage of 3,698 km^2. Coniferous forest is located in the high parts of the mountain range and covers 52 km^2.

Future Land Use/Changes

With the *Plan de Desarrollo Municipal de Tijuana, 1996–1998*, Tijuana has projected the development of over 90 percent of the land within its municipality (COPLADEM, 1996b). The land consists of large tracts of federally owned land as well as private lands. In accordance with the Urban Development Program 1993–2005 for Tecate, future growth is projected in the industrial, commercial, and residential sectors. Since the majority of the urban zone is developed, growth of undeveloped portions of land primarily extends to the south.

Description of the Tijuana River Watershed

Hydrological Resources

The Tijuana River watershed encompasses a drainage area of 1,731 square miles in California and Mexico, of which 462 square miles lie within San Diego County. The Tijuana River is formed at the confluence of Río de las Palmas, Río Alamar, and Cottonwood Creek in Tijuana. Tributaries and water impoundments located in the Tijuana-Tecate zone include the Río Alamar to the north, Arroyo las Calabazas in the Sierra Juárez to the south, Río de las Palmas, and Río Tijuana. Smaller tributaries include la Ciénega, Arroyo Seco, and Arroyo El Florido. The Tijuana River flows northwesterly through Tijuana for about five miles to the International border, drains westerly for approximately six miles, discharging into the ocean. Tributaries that flow across the border into Mexico include Campo Creek and Río Tecate. A number of smaller canyons including Smuggler's Gulch, Smith Canyon, and Goat Canyon flow from Mexico across the border into the Tijuana River valley. The Morena and Barrett dams on Cottonwood Creek in San Diego and the Rodríguez Dam on the Río de las Palmas create significant impoundments on the Tijuana River drainage system. Water from the Barrett Reservoir is diverted to the Otay Hydrographic Unit via the Dulzura Conduit, then Dulzura Creek, which leads to the Lower Otay Reservoir. The Tijuana River watershed does not have naturally occurring bodies of water.

The San Diego-Tijuana region is generally arid and receives approximately ten inches of rainfall per year near the coast, ranging up to more than thirty inches per year in the mountains. Most stream flows within the region are intermittent or ephemeral. Numerous reservoirs, such as the Morena, Barrett, and Rodríguez dams have been constructed to capture surface runoff water and store the local fresh water resources of the region. Ninety percent of the mean annual precipitation occurs during the six-month period between November and April.

The Abelardo L. Rodríguez Dam is located in the City of Tijuana and has a storage capacity of approximately 137 million cubic meters, at a height of 100 meters. The dam is currently below its storage capacity. Additional dams in the Tijuana-Tecate region include the Carrizo Dam, with a total storage capacity of 40 million cubic meters. It currently serves both the cities of Tijuana and Tecate.

Within San Diego, water storage in the Tijuana River watershed includes Barrett Dam, with a storage capacity of 46.8 million cubic meters, and the Lake Morena Dam, at 62.9 million cubic meters. In comparison to the Rodríguez and Carrizo dams, the Lake Morena and Barrett reservoirs are located in an area with greater annual rainfall. Annual precipitation is approximately 202.30 mm at Rodríguez Dam, which contrasts with 508.00 mm at Morena Lake. The difference in precipitation results in high water levels at the dams located in the mountains. Approximately 14 million cubic meters are stored annually at these sites. Morena Reservoir covers an area of 3,250 acres at a height of 3,000 feet (1,417 m), making it the highest and most remote of San Diego's reservoirs.

Water Demand by Sector

Tijuana

As previously mentioned, water supply to the City of Tijuana is generally provided by CESPT. Water demand and consumption is discussed below by land use sector.

- Residential uses include single and multifamily residential uses and accounts for 74 percent of the total demand.
- Industrial uses include both light and heavy industrial uses, and are dominated by maquiladoras in the Tijuana-Tecate region. Industrial uses account for 10.9 percent of the total demand.
- Commercial uses account for 11.1 percent of the total demand. This type of land use includes the large tourist industry in the Tijuana region.
- Public use includes local, state, and federal government uses and accounts for 4 percent of the total demand.

Tecate

Water consumption for the City of Tecate is shown in Table 2.2 as calculated by the Comisión Estatal de Servicios Públicos de Tecate (CESPTE).

Table 2.2. Water Consumption for the City of Tecate

May 1997	Consumption in m^3 (%)
Residential	61.6
Brewery	20.4
Industrial	6.0
Commercial	5.9
Public	5.4
Hydrants	0.9

Source: CESPTE, 1997.

As seen in Table 2.2, the brewery in Tecate is a major consumer of water. Although it appears that the brewery uses a disproportionate amount of water, the numbers are deceptive. Not only is Tecate's population much smaller than Tijuana and San Diego, but the brewery is also one of the largest employers in the region.

San Diego

Demand for water in the service area of the San Diego County Water Authority is divided into two sectors: municipal and industrial (M&I), and agricultural. Municipal and industrial use constitutes 81 percent of San Diego's regional water consumption. This category includes water used for residential landscaping, human consumption, and other domestic purposes. Agricultural water is used mainly for crop irrigation and makes up the remaining 19 percent of water demand (San Diego County Water Authority 1992).

M&I water consumption is divided into four user groups: residential, commercial, industrial, and public/other. Among municipal and industrial users, the residential sector consumes 54 percent, commercial 13 percent, industrial 4 percent, and public/other 10 percent (San Diego County Water Authority 1992).

Water Cost

Water costs for the cities of Tijuana and Tecate are based on the Income Law for the state of Baja California. The water costs, as published by the official registrar, are shown in Table 2.3.

Table 2.3. Water Cost by Sector

Location	Use	m^3	Cost ($) per m^3
Tijuana	Domestic	0 to 5 Monthly minimum	*$ 12.93
		6 to 15 per month	2.59
		16 to 20 consumption per month	2.94
		21 to 30 "	5.97
		31 to 40 "	7.67
		41 to 50 "	8.79
		51 to 60 "	10.22
		61 and higher	10.30
	Commercial, Industrial, and Public	0 to 5 Monthly minimum	*$ 49.85
		consumed	9.97
		31 to 1000, "	10.22
		1001 and higher	10.42
Tecate	Domestic	0 to 5 Minimum payment	??
		5 to 10 per m^3 consumed	
		10 to 15 "	
		16 to 20 "	
		21 to 30 "	
		31 to 40 "	
		41 to 50 "	
		51 to 60 "	

		61 and higher	
	Commercial Industrial, and Public	0 to 5 Minimum Payment	*$ 72.95
		6 to 10 per m3 consumed	5.68
		11 to 15 "	5.68
		16 to 20 "	5.68
		21 to 30 "	5.68
		31 to 40 "	9.48
		41 to 50 "	9.48
		51 to 100 "	9.48
		101 to 500 "	10.05
		501 to 1000 "	10.05
		1001 to 10,000 "	10.05
		10,001 and higher	10.05
San Diego (Otay Water District)	Residential Water Rate (at 21 units or above, all units 0-21, are billed at $1.65/HCF)	0 to 5 units	$1.01/HCF
		6 to 25 units	1.65/HCF
		26 to 35 units	1.79/HCF
		36 to 50 units	2.11/HCF
		51 and above	2.62/HCF
	Agricultural	Treated Water (Not certified under Municipal Wastewater Department's (MWD) interim agricultural water program	$1.76/HCF
		reated Water (Certified)	1.45/HCF
	Industrial and Commercial	Treated Water	$1.76/HCF
		Reclaimed Water	1.50/HCF
City of San Diego	Residential Water Rate	Single Family Residential Treated Water	
		0 to 10 units	$1.379/HCF
		11 and up	1.561/HCF
		(other than single family) Treated Water	1.435/HCF
	Agricultural	Treated Water	$1.435/HCF
		Reclaimed Water	434.00/acre foot
			562.50/acre foot
	Industrial and Commercial Water Rate	Treated Water	$1.435/HCF
		Reclaimed Water	562.50/acre foot

*Mexican currency (Nuevo Pesos), San Diego prices are in U.S. dollars. HCF= hundred cubic feet.
Source: Tijuana: *Periódico Oficial del Estado de Baja California* July 1, 1996; Tecate: *Periódico Oficial del Estado de Baja California* September, 1995; San Diego: San Diego County Water Authority, September 1996.

Water Volume by Origin

- Abelardo L. Rodríguez Dam is located in the southeastern portion of the City of Tijuana. It receives downstream flows from the Tijuana and Las Palmas rivers. It was built in 1936 and has a total capacity of 137 million m^3.

- El Carrizo Dam is an earthen dam located near Tecate. Water from the Lower Colorado River is brought in via the Colorado River-Tijuana Aqueduct (ARCT) over mountains 4,000-5,000 feet high, which significantly adds to its cost. However, there are hydroelectric power reclamation sites for power generation once the water journeys downhill. It has a storage capacity of 40 million m^3.

- Morena Dam It was built in 1910 and is located in San Diego County at an elevation of 1,417 meters. The water is from the controlled drainage area of 295.13 km^2, and is fed by Cottonwood Creek. It has a storage capacity of 62 million m^3. The mean precipitation is 508 mm.

- Barrett Dam It was built in 1921 and is located in San Diego County. It is fed by Cottonwood Creek. Water comes from a controlled drainage area of 652.40 km^2. The storage capacity is 55 million m^3.

Corte Madera Lake is situated in the northeasternmost area of the watershed. This small lake is relatively inaccessible and is not used for water supply purposes for San Diego.

Groundwater sources include the following:

- Tijuana and Alamar rivers: There are around thirty water wells that deliver approximately 80 liters per second (lps) of water. The monthly groundwater supply is 146,000 m^3.

- Tecate groundwater is extracted from the Tecate Creek with a total of 21 water wells. Surface water is provided via the Presa El Carrizo, which is pumped through pipelines to the Cuchumá water treatment plant. Water capacity is 53,514 m^3.

Imported Water

The Colorado River has been an increasingly important source of water, providing the region with 85–90 percent of its water needs on a regular basis. This is especially true in Tijuana, where precipitation has been low since the floods of 1993–94. A rapidly growing population compounds this drought. These facts ensure that water levels in the Rodríguez Dam stay low. At present, the dam's water is used only as an emergency source. The Colorado River Aqueduct provided San Diego County with about 400,000 acre-feet per year of water in 1995 and 1996.

Water Wells in the Watershed Area

The availability of water wells is based on data from the *Estudio hidrológico del Estado de Baja California* for 1995 (INEGI 1995). Mexican law requires approval and certification for the creation of wells (Table 2.4).

Table 2.4. Water Wells in the Tijuana River Watershed

Valley	No. of wells	No. of Domestic Wells	No. of Water Springs	Extraction by Volume
Tijuana	100	310	0	18.0 million m^3
Tecate	58	12	0	6.0 million m^3
Las Palmas	48	47	4	6.5 million m^3

Source: *Estudio hidrológico del estado de Baja California*, INEGI, 1995.

In San Diego, the county does not provide data on the numbers of wells within the watershed area. However, a permit is required for a well to be dug, but there are no restrictions on drawing amounts for wells on private property. According to the EPA, the individual well owner is primarily responsible for the safety of water drawn from the well and not subject to the same regulations as are public water systems.

Protected Watershed Area

There are few municipal ecological reserves in the cities of Tijuana and Tecate. There are seven protected regions within the state, but none include parts of the Tijuana watershed, not even Parque Nacional Constitución 1857, although it borders the southeastern area of the watershed. Tijuana has two large urban park areas. Morelos Park has a land coverage of 320 hectares and Amistad Park is approximately 242.939 m^2 in size.

There are an additional 53 registered parks in Tijuana. These are generally small pockets of parkland with minimal vegetation and few recreational amenities. Public park space includes a total of 867,109 m^2. A regional ecological park measuring 1,800,000 m^2 is located in the southern portion of Tijuana. The total area of park space in Tijuana is 3,800,000 m^2 (COPLADEM, 1996b). Within the municipality of Tecate, there are no official open space preserves.

San Diego

The San Diego portion of the Tijuana River watershed consists largely of federally protected areas. At the federal level, there is the Cleveland National Forest, the Bureau of Land Management areas, and the Tijuana National Estuarine Research Reserve. Additional parklands include Lake Morena and Barrett Dam.

In all of San Diego County, government owned land accounts for 54 percent or approximately 1.45 million acres. Of that land, 51 percent is federally owned, 40 percent is owned by the state, and 9 percent is owned by different public agencies.

Table 2.5. Parklands in the United States Portion of the Tijuana River Watershed

Location	Jurisdiction	Area	Date Founded
Cleveland National Forest	Federal	120,188.08 ha.	N/A
Border Field State Park	California	160.00 ha.	1971
Tijuana National Estuarine Research Reserve	Multiple	2,513 acres/1,024.00 ha.	1982
BLM-Otay Mountain/Kuchama Cooperative Management Area	Federal		N/A
Morena Lake Park	San Diego		N/A

The Tijuana River estuary has become one of the last functional wetlands in Southern California. California leads the nation in depletion of its wetlands. The National Oceanic and Atmosphere Administration (NOAA), a Commerce Department agency of the United States government, has designated the estuary as one of the 22 units of the National Estuarine Research Reserve System (NERRS). The Tijuana River has experienced channelization, damming, and sedimentation in both the United States and Mexico (Gregory, et al. 1996).

Aquifers

Groundwater in the region is generally of poor quality due to limited rainfall and use of imported Colorado River water for irrigation. Groundwater resources are mostly concentrated within three areas: Tecate, Valle de las Palmas, and the Alamar River and Tijuana River (Table 2.4). There are 47 wells within the Tijuana portion of the watershed. In the 1970s, these wells provided 385 liters/second (lps) of water, decreasing to 135 lps in the 1980s. In the 1990s, high salinity contents were detected in most of the water wells. For this reason, only 10 water wells are currently in use, extracting water at 95 lps. Groundwater supplies in San Diego County are minimal due to the geology of the region. In Tecate, Baja California, water use was heavily dependent on groundwater resources from Tecate Creek. This source of water began to diminish during the 1970s, at which time CESPTE identified the availability of additional groundwater sources in the Valle de las Palmas aquifer.

In Tecate, a number of water wells are located throughout the city as well as in the outskirts between San José and the Cañada San Javier. CESPTE is currently undertaking a groundwater study to evaluate the availability of future groundwater resources near the Rumorosa area (CESPTE 1997).

Table 2.6. Water Aquifers in the Tijuana River Watershed

Aquifer	Total	Infrastructure			Use (m^3 x 100)			
		Wells	Domestic	Springs	Agriculture	Public	Domestic	Industry
Tijuana Zone	621	135	486	0	8.00	5.00	1.00	10.00
Tecate Zone	69	69	0	0	1.00	2.67	0.33	2.0
Valle de las Palmas	48	48	0	0	5.00	0.00	1.50	0.0

Source: Comisión de Servicios de Agua del Estado (COSAE), 1997.

Public/Private Water and Wastewater Treatment Projects

Tijuana Wastewater Treatment Service Programs

The City of Tijuana was initially developed within the floodplain of the Tijuana River and upon Spooner's Mesa to the west. The first municipal sewage system consisted of a septic tank with a capacity to serve 500 inhabitants and was constructed in the river floodplain in 1928. Potable groundwater was pumped for sale to nearby communities, such as San Ysidro and Coronado. By the mid-1930s, Tijuana's population exceeded 5,000 and its excess wastewater flows had begun its cycle of contamination of groundwaters in the Tijuana River valley north of the border. By 1935, a new effluent chlorinating septic tank system was constructed in Tijuana with a capacity for 5,000 inhabitants. Through 1963, Tijuana's water supply originated from groundwater and rainwater storage in the Rodríguez Dam in the tributary of the Tijuana River (RECOM 1994).

In 1984, Mexico's environmental ministry (known then as SEDUE), prepared plans for the Integrated Project for Potable Water and Sanitary Sewer of Tijuana, funded in part by the Inter-American Development Bank (IADB). The Integrated Project provided for utilization of a Colorado River aqueduct to provide drinking water sufficient to supply Tijuana's needs to the year 2010, in addition to new and upgraded sewage conveyance and treatment facilities. By 1987, Mexico had improved Pump Station One to a design capacity of 2,628 lps, constructed a 42-inch force main (pipe), and improved the San Antonio de los Buenos treatment plant. However, the rapid population growth in Tijuana has continuously exceeded the capacity of the sewage treatment facilities. Until 1990, the interim measures completed by both Mexico and the United States failed to provide adequate sewage conveyance and treatment service.

In order to safeguard the Tijuana River valley and surrounding areas from water pollution originating in Tijuana, the U.S. Government, through the IBWC, initiated discussions with Mexico for development of an international wastewater treatment plant. Through funding from the U.S. Environmental Protection Agency (U.S. EPA), the IBWC is constructing a 25–mgd (million gallons per day) advanced primary/secondary treatment plant for wastewater, as part of a potential phased–in 100–mgd (4,380 lps) plant. This plant is located in the Tijuana River valley, in the United States. The state of California, through the City of San Diego, is also providing state defensive measures grant monies for planning, design, and construction of the project.

Currently, raw sewage from areas of Tijuana that lack sewage facilities, collects in the Tijuana River. During dry weather, sewage flows of up to 13 mgd can be collected, via a diversion in the concrete-lined channel of the Tijuana River in Tijuana. The raw sewage is then pumped through the city municipal pipeline to Pump Station One, which then goes to the San Antonio de los Buenos Treatment Plant. Excess flows are discharged into a 30-inch diameter emergency connection to the San Diego municipal treatment system and are treated at the Point Loma Treatment Plant. Other renegade wastewater flows enter the United States from north-draining canyons and gullies, and during dry weather, are pumped back into the existing Tijuana system.

The Comisión Nacional del Agua and the state of Baja California have developed the Wastewater Treatment and Reuse Plan for Tijuana based on three factors: (1) the current and projected population, (2) land use data and maps, and (3) current technology for wastewater treatment plants. In order to understand Tijuana's total wastewater discharges, the 30 sub-basins were mapped on a topographical map, including the 16 urban sectors of the city, the drainage system, and the population data. Based on these factors, data on both water and sewage demand have been obtained.

According to the Wastewater Treatment and Reuse Plan for the state of Baja California, future water demand will be highest for landscape irrigation uses, such as parks and greenbelts. An inventory of these existing uses was conducted to establish a ratio of park area per person. The study indicates a ratio of $6m^2$/person and 0.40 liters/second/hectare. Based on an annual projected growth rate of 5.06 percent, the City of Tijuana will require a wastewater service capacity of 1,813 liters/second by the year 2005, and 2,350 lps by 2010. Table 2.7 identifies projected water demands for landscape irrigation use for the years 2000 through 2020.

Table 2.7. Projected Water Demand for Parks and Greenbelts

Year	2000	2005	2010	2013	2015	2020
IrrigationWater Demand/lps	401	519	662	769	844	1,068
Wastewater Treatment Demand/lps	1,412	1,813	2,350	2,750	3,063	4,013
Total	1,813	2,332	3,012	3,519	3,907	5,081

Source: Municipalidad de Tijuana, 1995.

Sewage pump station No. 1 (PB 1) and its associated sewage conveyance lines provide wastewater delivery needs for Tijuana. The current capacity of this facility is 1,800 lps. The wastewater treatment plant at San Antonio de los Buenos has a current capacity of 750 lps. Its treatment capacity will be increased to 1,100 lps within the next year. Projected wastewater treatment capacity is 1,850 lps of which 348 lps are expected to be available for irrigation use/reuse.

There is also a small pilot water reuse plant to generate reclaimed water for urban green areas. Located on a slope above the Tijuana River, Ecoparque is seeking funds from NADBank for expansion.

Water/Wastewater Infrastructure Setting

Existing and Proposed Sewage System

The sewer infrastructure system of Tijuana is currently suffering as a result of the rapid, unplanned urbanization, and the rapid increase in population. In response, the Municipality of Tijuana has produced urban and land use development plans. Land use development is guided through the implementation of the *Plan de Desarrollo Municipal de Tijuana* (COPLADEM 1996a). The city is currently conducting intensive land use studies to identify and map land uses through the use of Geographical Information Systems (GIS). Urban planning for the adequate provision of public infrastructure occurs in the developed areas of the municipality such as the Zona del Río.

A third phase of development is proposed along Zona del Río, including mixed commercial uses, office use, greenbelts, and a water treatment plant. However, the eastern and southern sectors of undeveloped land in Tijuana are still subject to irregular land settlement by squatters or migrants from the interior of Mexico. Often, irregular settlements are established in environmentally critical or sensitive areas such as steep slopes or flood plains, resulting in massive land disturbance, erosion, and flooding conditions during severe rainstorms.

The sustained economic growth of maquiladoras and the commercial sector will continue to attract an influx of migrants to the border region. Based on a review of the current land use map for Tijuana, the City lacks future preservation plans for open space or ecological parks, with the exception of the Abelardo Rodríguez dam area. According to the Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP), the area surrounding the dam has been zoned for future use as an ecological preserve. Stakeholders in the surrounding dam area include supporters and opponents of this project.

Tijuana-Tecate

Urban growth and the topographical setting in Tijuana severely limit the extension and provision of services in Tijuana. However, agencies such as CESPT are moving forward with infrastructure improvement projects. These include upgrading the conveyance system and operating Pump Station No. 1 that is located adjacent to the border, and provides continuous service. This pump station has a capacity of 25 million gallons per day (IBWC 1996). As a condition of the construction of the International Wastewater Treatment Plant, Mexico has committed to ensuring the proper operation of the San Antonio de los Buenos Wastewater Treatment Plant. As shown in Table 2.8, there are a total of 157, 832 sewage connections in Tijuana, or 59.06 percent of the population coverage.

Sewage improvement plans will be required to provide for future service. The following laws and plans mandate these improvements: the Proyecto de Ley de Agua Potable y Alcantarillado, the Proyectos de Reglamentos Administrativos y de Servicios, and the Proyectos de Manuales de Procedimientos y de Servicios.

Table 2.8. Existing Sewage Service for Tijuana

Indicators of Sewage Treatment	Number of Connections
Sewage Connections	157,832.00
Sewage Service Coverage (%)	59.06

Source: CESPT, 1997.

As shown in Table 2.9, future sewage infrastructure projects in Tijuana will require a minimum investment of US$63,164,354 by CESPT. Table 2.10 identifies the number of existing sewage connections and total service coverage, which is 76.11 percent for the City of Tecate.

Table 2.9. Proposed Sewage Improvement Plan, Tijuana

Concept	Description	Investment
1. System of Connectors	Construction of a 840.29 km. sewer system to serve up to 129,653 household discharges and 78.03 km of new connectors.	47,004,35
2. Treatment Plants	Construction of plants with a capacity of 530 lps. Tecolote-La Gloria Treatment Plant with a capacity of 140 lps. Monte de los Olivos, with a capacity of 340 lps, and La Morita, with a capacity of 50 lps.	$16,159,999
Total		63,164,354

Source: CESPT, 1997.

Table 2.10. Existing Sewage Service System for Tecate

Indicators of Connections	Total Connections
Number of Sewage Connections	10,546.00
Service Coverage	76.11%

Source: CESPTE, 1997.

Aqueducts and Management Systems

Water supply for the City of Tijuana is provided through the Colorado River. Water is conveyed through the Colorado River-Tijuana Aqueduct (Acueducto Río Colorado–Tijuana, ARCT). The aqueduct was constructed in 1975 and serves a total population of 1,200,000 inhabitants in the City of Tijuana. It has a water capacity of 4,000 lps. Beginning in the northern portion of Baja California, the aqueduct extends from Irrigation District No. 14, in the Valley of Mexicali, through several valleys and the mountainous region of La Rumorosa via pumps. It then flows by gravity into El Carrizo Dam and continues toward the El Florido Drinking Water Treatment Plant. From there, Tijuana is supplied with water through two main pipelines. One extends into the Mesa de Otay water tank, and the other into the Aguaje de la Tuna water tank and the Colonia Obrera pumping station.

The ARCT covers 147 kilometers from the Pump Station PB-0 to the Colonia Obrera pump station. The ARCT has a capacity to convey a flow of 4.0 m^3/sec. The aqueduct has six pump stations and it reaches an elevation of 1,060 meters. From each pump station, there are four pipelines with diameters from 54 inches to 84 inches. The water lines extend to the El Carrizo Dam, which has a storage capacity of 40 million m^3. Water lines also extend to the El Florido station, located at 250 meters above sea level.

Table 2.11. Aqueduct System in the Tijuana River Watershed

		Characteristics					
No.	Name	No. of Pumps	Capacity (H.P)	Flow (m^3/sec)	Length (km)	Diameter (inches)	Tubing (material)
1	Rodríguez Dam Aqueduct	3 wells	1500	2.000	8.00	48	Ductile Iron
2	Carrizo-Cuchumá Aqueduct	3	125	0.070	.05	10	PVC
3	Las Auras-Tecate Aqueduct			0.350	10.80	20	Steel
4	ARCT (Tijuana-Colorado River Aqueduct)	6 pump stations		4.000	147.00	54 and 84	

Source: COSAE, 1997.

Another aqueduct system consists of the Abelardo L. Rodríguez Dam–El Florido Plant Aqueduct. This system has a conveyance capacity of 2,000 lps. In 1994, approximately 2,032.54 lps were extracted from the Rodríguez Dam, of which 1,636.54 lps were extracted through the Rodríguez–El Florido Aqueduct and 396 lps from the adjacent water system (COSAE 1997).

In Tecate, water is supplied by the Carrizo-Cuchumá o Hawaiano Aqueduct. This system has a conveyance capacity of 100 lps. Water is extracted from the El Carrizo Dam, which includes a pump station and 10–12 inch water lines (COSAE 1997). The Carrizo-Cuchumá system is only used during peak periods due to high operation costs (CNA 1996). The Río Tijuana Aqueduct conveys water to Tecate, through the Las Auras Aqueduct, with a discharge to La Nopalera water system. Table 2.11 contains a description of the aqueduct system in the Tijuana River watershed.

Potable Water Plants

Tijuana has two potable water plants that provide water service to over 45 percent of the population. The potable water plant at the Rodríguez Dam, has been improved to a pumping capacity of 750 lps. Due to the current water shortage at the dam, only 650 lps of water can be extracted. The availability of water supply from this dam is limited by seasonal rainfall, which averages only 10 inches per year, and therefore, does not provide a reliable source of water. It is utilized only as a summer supplemental supply or in case of emergency.

The El Florido water treatment plant, with a capacity of 4,000 lps, primarily serves the City of Tijuana. It has two treatment modules of 2,000 lps each. It is projected to have sufficient service capacity until the year 2010 (CESPT 1996). Tijuana provides potable water to approximately 95 percent of the city, either through pipes or water trucks. The city expects to have an adequate water supply until the year 2002.

There is a project underway to provide water to the Tecate-Tijuana area by way of a secondary aqueduct system parallel to the existing ARCT (Tijuana-Colorado River Aqueduct). This is hoped to sustain the region and its growth for a number of years more.

There are two potable water plants in Tecate, the Cuchumá and La Nopalera, as described in Table 2.12.

Table 2.12. Potable Water Plants, Tecate

Source	1-10	11-20	21-30	Total
Cuchuma	20,315	33,202		53,317
La Nopalera			33,773	33,773
Total				87,080

Source: CESPTE, 1997.

There are no potable water plants in the San Diego portion of the watershed. However, there are many within the region of San Diego County.

Existing and Future Water Infrastructure Projects

Water Treatment Plants in Tijuana

Tijuana currently has only one operating wastewater treatment plant, the San Antonio de los Buenos Treatment Plant, six miles south of the border, southwest of downtown Tijuana. It is located along the Tijuana-Ensenada coastal area, near Punta Bandera. It receives effluent from Pump Station No. 1. The wastewater treatment plant, which began operations in 1987, has an optimal treatment capacity of 1,100 lps, but often treats only 750 lps. The San Antonio de los Buenos uses a three-lagoon treatment process. It has a direct ocean discharge with treated wastewater released at the waterline. In contrast, Pump Station No.1 has a current capacity of 1,350 lps. The excess effluent is mixed with treated effluent and discharged into the ocean.

San Antonio de los Buenos Treatment Plant can currently handle 17 mgd, but there are plans to increase its capacity by 25 mgd, for a total of 42 mgd. However, the current effluent flows are already approximately 40 mgd. Sewage flows will increase in the future both through contained population growth and additional residences becoming hooked up to the sewage service.

Only a small share of the treated effluent is reclaimed and reused for irrigation at the new, nearby golf course, Real del Mar. Reclaimed water costs approximately $ 0.447 per cubic meter.

Projects recently approved for funding by the North American Development Bank (NADBank) include the Parallel Conveyance System and Rehabilitation of the San Antonio de los Buenos Plant, Tijuana; Ecoparque, Tijuana; and the South Bay Reclamation Plant, San Diego. These projects were certified by the Border Environment Cooperation Commission (BECC), which is a bilateral organization created by an agreement parallel to the North American Free Trade Agreement (NAFTA). This organization was set up to help border communities in the U.S.-Mexican border region develop and finance needed environmental infrastructure projects.

The Parallel Conveyance System and Rehabilitation of the San Antonio de los Buenos Treatment Plant is an US$18 million project that includes the construction of a pump station and a 16-kilometer pipeline system to allow the City of Tijuana to manage its sewage flows. The project will help fund needed repairs to the existing conveyance system, as well as provide for an additional pipeline to San Antonio de los Buenos. It will help avoid sewage runoff into the Tijuana River. Also, it will serve as a complement to the International Wastewater Treatment Plant in San Diego that will begin operation in mid–1998. It also includes the rehabilitation and expansion of the wastewater treatment plant at San Antonio de los Buenos, increasing the quality of the ocean-discharged effluent. The funding of US$16 million is provided by USEPA via NADBank. CESPT will be constructing the plant.

Ecoparque is a US$170,000 project that consists of the expansion of a pilot project set up to treat wastewater to secondary standards for green area irrigation reuse. Approximately twenty-one thousand residents of the Mesa de Otay area are expected to benefit from this project.

The South Bay Reclamation Plant is a US$99.6 million project that will allow treated wastewater in the southern part of the Metropolitan Wastewater System to be reused in San Diego, Imperial Beach, Chula Vista, National City, and areas outside of San Diego County. The plant has an initial treatment capacity of 7 million gallons per day (mgd) with expansion capabilities. The project is expected to decrease the burden of the treatment facility at Point Loma, and lessen the City's use of imported primary water for certain secondary activities.

Wastewater Treatment Plants in Tecate

The City of Tecate has one wastewater treatment plant with a capacity of 300 lps. Water from the treatment plant has a direct discharge to the Tecate river. The existing Tecate Brewery has its own wastewater treatment plant and a water reclamation plant. Reclaimed water is used for irrigation purposes only.

Wastewater Treatment Plants in San Diego

Within the Tijuana River watershed on the U.S. side, there is only the International Wastewater Treatment Plant, which is destined to treat wastewater from Tijuana. The facilities at Point Loma have the only other major wastewater treatment plant, but it is located outside the basin. The majority of wastewater generated by water users in San Diego's part of the watershed is sent to the Point Loma treatment plant, although there is one small facility in Campo, in the upper basin in San Diego County. Point Loma does not serve the eastern area of the watershed, including private residences and Indian reservations. Most of these areas utilize septic tanks.

The Point Loma treatment plant receives wastewater from San Diego, Tijuana, and 15 other cities. It has the capacity to treat 180 mgd, discharging treated effluent through a pipe 4.5 miles into the ocean at a depth of 320 feet. The plant utilizes advanced primary treatment rather than the secondary treatment mandated by the United States Congress. The City of San Diego signed an "agreement" that serves as an exemption from complying with the 85 percent total suspended solids (TSS) requirements.

On July 8, 1990, the United States and Mexico agreed to build an international treatment plant on the U.S. side of the border to treat sewage flows that have consistently exceeded the capacity of Tijuana's existing sewage collection and treatment system (IBWC 1990). The Tijuana River cleanup agreement required collection, treatment, pumping stations, and the establishment of a sewer system. Prior to this, there had been only septic systems. The purpose of Minute 283 was to restore the environmental quality of the Tijuana River valley, the estuary, the beaches, and the life of its residents by building the wastewater treatment plant.

The South Bay International Wastewater Treatment Plant (SBIWTP) is under construction by the United States government in cooperation with the Mexican government. The plant is located on a 75-acre site west of San Ysidro, at the intersection of Dairy Mart and Monument roads. Construction of this project began July 15, 1994. Phase 1, site preparation, was completed in February of 1995. Construction of the advanced primary treatment phase began June 1995 and was completed in 1997. The South Bay Land Outfall has also been constructed. The last phase, the South Bay Ocean Outfall, should be completed by the summer of 1998.

Although both countries share in the operation and maintenance of the SBIWTP, the United States will pay for the installment of secondary treatment equipment that is required in the United States. In addition, the United States is responsible for the finance, construction, operation, and maintenance of the ocean outfall, used for disposing of treated effluent into the Pacific Ocean, which is not required by Mexican standards.

There are connections to the SBIWTP from the main Tijuana effluent pumping station (Pump Station No. 1), and two canyon diversions at Smuggler's Gulch and Goat Canyon. In addition, the SBIWTP has connections to the South Bay Land Outfall, which feeds into the South Bay Ocean Outfall, and to the Tijuana Emergency Connecting Sewer to Point Loma's treatment plant.

Financing of the plant comes from a total US$400 million from the U.S. and Mexican governments, with supplemental funding assistance from the City of San Diego for the South Bay Ocean Outfall (pro rata share, 40 % = US$60 million). Original figures placed the total cost of the treatment plant at US$305 million, with US$239.4 million from the United States federal government, US$16.8 million from Mexico, and US$5.3 million from the State of California. The contribution from Mexico is lower because of its lower standards of wastewater treatment, where no secondary treatment is required. The labor costs would have been lower if Mexico had constructed the plant, since it does not require a three-mile pipe into the ocean for discharges.

The U.S. Environmental Protection Agency administers the majority of the project's funding and serves as the overall coordinator. The U.S. and Mexican sections of the IBWC serve as mediators for the boundary and water treaty resolutions, the design and construction manager of the International Wastewater Treatment Plant, and the design manager of the South Bay Ocean Outfall. The City of San Diego's Metropolitan Wastewater District (MWWD) is the construction manager for the South Bay Ocean Outfall. The State of California State Water Resources Control Board (SWRCB) is the technical advisor to the SBIWTP policy committee.

An Environmental Impact Statement (EIS) was submitted for the construction and operation of the SBIWTP. The Supplemental Environment Impact Statement (SEIS) was provided to examine the possibility of early primary treatment completion and possible early discharge without secondary treatment in 1998. There has been a secondary SEIS that examined alternatives for a less expensive secondary treatment method using ponds.

The plant has been initially approved for a capacity of 25 mgd (millions of gallons per day, or 1,100 lps) of advanced primary treatment, with an ability to handle an additional 50 mgd, if needed. It is designed to be expandable to 100 mgd. The U.S. standards are used for the quality of ocean discharges. Residual sludge will be disposed of in Mexico, according to Mexican federal standards, since the plant will be treating Tijuana's sewage.

An advanced primary treatment method will be used at the binational plant. Through this method, raw sewage is screened to remove floating debris and other particulates. Chemicals are then added to the wastewater in a concrete basin called a Primary Sedimentation Tank (PST) to accelerate the settling of wastewater solids. Advanced primary treatment produces twice the amount of settled sewage sludge than conventional treatment.

The plant will have a future capability for secondary treatment. Secondary treatment includes a biological process that introduces microbes to break down the remaining organic matter. The secondary treatment facility using the method of activated sludge, as well as canyon collectors have already been designed.

An environmental concern regarding the wastewater conveyed to the SBIWTP from Mexico is the presence of toxic contamination. A commitment from Mexico was required for an industrial pretreatment program for the removal of these toxic elements from wastewater before reaching the SBIWTP. Testing is being done on the wastewater of the City of Tijuana for the existence and amounts of toxic elements. The test results will determine exactly what pretreatment methods are needed.

The water treated at the SBIWTP will be discharged into the Pacific Ocean. In addition, the City of San Diego's new South Bay Water Reclamation Plant, adjacent to the SBIWTP, will discharge water into the Pacific Ocean when reclaimed water is not used during the low water demand period in the winter. Discharges will be monitored to ensure that the treated wastewater meets California State Ocean Plan and federal water quality standards.

There are two main conveyance pipes for the SBIWTP, the South Bay Land Outfall and the South Bay Ocean Outfall. The South Bay Land Outfall was completed early in the project and is a 12-foot diameter reinforced concrete pipe, running for 2.3 miles parallel to the border. Connected to it is the South Bay Ocean Outfall, which is jointly owned by the City of San Diego and the IBWC. The ocean outfall will have an average daily flow capacity of 174 mgd and a peak flow capacity of 333 mgd. The City of San Diego has purchased use for up to 40 percent of outfall capacity, which is 74 mgd, or 133 mgd peak, for discharge from the South Bay Water Reclamation Facility and from future wastewater treatment facilities to be built in the South Bay area. The remaining outfall capacity will be used by the new SBIWTP.

The ocean outfall has a drop shaft reaching 160 feet below sea level, with an 11-foot diameter underground tunnel 19,000 feet long. From the South Bay Land Outfall, to roughly 13,500 feet offshore, the ocean outfall will surface and continue along the sea floor, ending in a Y-shaped diffuser approximately 3.5 miles offshore at a depth of about 95 feet. The ocean outfall should be completed by mid-1998, with an estimated total cost of US$140 million out of a total US$400 million budget for the plant.

Funds of about US$16 million, limited to what Mexico would have paid to construct a treatment plant at its Río Alamar location to treat wastewater to Mexican standards, has been allotted to expand the sewage collection system and construct additional works necessary to collect and convey the sewage from Tijuana. The plant began treating the wastewater of Tijuana in 1997. It is expected to handle the sewage treatment needs of Tijuana in conjunction with the San Antonio de los Buenos plant until the year 2000. If the growing population exceeds the capacity, the full capability of the binational plant could be put to use.

Infrastructure improvements to the Tijuana sewage system have included a large-scale pumping plant, force main, conveyance channel, wastewater treatment facilities, a river diversion structure, and interceptor-collection systems for sewage flows from areas in Tijuana that lack sewage facilities. Defensive measures in the United States have included an international outfall, an emergency connection to the City of San Diego sewer system, temporary holding ponds, and interceptor-return-to-sender systems for sewage flows from unsewered areas in Tijuana. Although these interim measures have been effective on a short-term basis, they have not kept pace with the growth of Tijuana, resulting in continued flows of untreated sewage into the United States.

Conclusion

Water is a scarce and essential commodity in the San Diego-Tijuana–Tecate region. The availability of water in the Tijuana River watershed is severely limited due to lack of rainfall. Water supply from this resource is affected by the rapid urbanization experienced in the region as well as by the quality of downstream water flows associated with this growth. The lack of adequate sewage infrastructure further aggravates water supplies in the Tijuana River watershed.

Tijuana's most significant problems include the lack of sufficient water supply, storage, and wastewater treatment for future uses. Water supply issues threaten the region as a whole. Rapid urban growth and industrialization continue in the Tijuana–Tecate-San Diego region. The maquiladora sector is growing in an easterly direction within the Tijuana River watershed.

There appears to be a lack of national and international coordination among key decisionmakers at the local, state, and federal level. Based on the information obtained during this research, it appears that current water service is disproportionately allotted to industrial and commercial users. State agencies whose primary goal is to promote the economic growth of Baja California do not readily provide relevant information regarding the lack of water infrastructure.

Irregular settlements and migration patterns continue to occur, but at a slower rate than the previous decades. It is unknown whether current land use management policies and zoning restrictions in the Municipality of Tijuana adequately address this issue. The population of Tijuana is expected to surpass that of San Diego by the year 2050. Also, it is expected that Tijuana's urban core will cover 108,000 acres by the year 2013.

Issues associated with groundwater are expected to increase as wellwater becomes a source for storage of fresh water. The contamination of aquifers via human activity such as sewage runoff and fertilizer and pesticide use is a concern for the environmental health of the region. As water becomes more expensive in the future and dam-water evaporation rates become an issue, aquifers may be looked at as a potential storage unit. International groundwater issues are still unresolved due to difficulty in quantifying impacts and assessing water availability and amount drawn. The Tijuana River watershed cannot support urban growth without imported water.

San Diego is looking for alternative water sources to lessen its dependency on a single supplier. The Imperial Irrigation District (IID) of Imperial Valley, California, and San Diego have attempted to finalize a water deal. One of the obstacles is that of conveyance. The Metropolitan Wastewater District of Southern California (MWD) is working with the two areas to determine a fair price for the IID's water. Although the MWD and the IID obtain water from the same source, the Colorado River, the IID water will cost less than the MWD's water. However, the California Water Plan Update (p.368) states that even if California implements water management options, which have already been investigated and analyzed, there will still be an annual shortage of 1.6 to 3.6 (MAF) million–acre–feet in average years and a 2.5 to 4.5 MAF deficit in drought years by the year 2020. A main problem is that the Colorado River's total annual allocation of 17.5 MAF, among seven states and Mexico, is more than the average annual flow of the Colorado River of 14 MAF.

The Border Environment Cooperation Commission (BECC), as a binational political organization, could play an important role in funding water treatment solutions for the Tijuana River watershed. There are talks of additional treatment plants in the future to resolve wastewater conflicts. In Mexico, industrial waste standards have recently been set. The federal government in Mexico is decentralizing, thereby empowering the states and municipalities. The Mexican government is attempting to redistribute resources and opportunities through the new federalism policies. This decentralization process is meant to increase efficiency, equality, and democratic decisionmaking. Eventually, it should enable local authorities in Tijuana and Tecate to more effectively address water and other environmental concerns in the Tijuana watershed.
Although there has been general drought conditions in this region, there is potential for an upcoming wet season. Meteorologists predict that "El Niño" may provide wet weather conditions that may temporarily recharge some aquifers as well as replenish local dams. However, unusually wet weather may also bring unwanted consequences such as flooding.

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Chapter 3

Analysis of Water Quality in the Tijuana Watershed

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Introduction

The objectives of this section are to analyze surface water and groundwater quality within the Tijuana River watershed. Official sources and research studies carried out by regional universities and research centers were reviewed to identify possible sources for water pollution.

Rapid industrial growth and extraordinary increases in population result in aggravated problems under many circumstances, but especially within a border region. The U.S.-Mexican border near the Tijuana River has experienced expansive growth with direct effects on the environmental quality of the area, especially to water quality. The contamination of water resources is of great concern to the governments of the United States and Mexico and society, in general. The Tijuana River watershed is a shared region that requires comprehensive planning to address water quality concerns within the watershed that are associated with land use issues in both the United States and Mexico.

Governments on both sides of the border have initiated and increased measures to control and improve water quality. These range from establishing indicators to assess water quality to unique applications that reduce or eliminate impacts from point sources, wastewater treatment plants and industries, and nonpoint sources such as urban or agricultural runoff. The following is a summary of water quality information that has been collected for groundwater, surface water, and identified sources of pollution within the Tijuana River watershed from the various governmental and nongovernmental organizations involved in water quality management.

Although this research is comprehensive, there are other sources and organizations that may maintain water quality information. An extensive effort was made to report all water quality data and data sources. However, some sources may have been overlooked due to their less obvious nature or difficulties in acquiring their information. Therefore, this report is not a complete synopsis, but offers an excellent reference for historical water quality data and currently available sources of water quality data, pollutant sources within the watershed, and an analysis of water quality within the watershed.

Surface Water Quality in the Tijuana River Watershed

Tijuana

The International Boundary and Water Commission (IBWC) and its Mexican counterpart, the Comisión Internacional de Límites y Aguas (CILA) are a longstanding binational organization addressing water sanitation issues as well as other related matters. IBWC/CILA have monitored the Tijuana River regularly for total and fecal coliform for a number of years. They have also been responsible for many other water quality studies and special projects.

The Environmental Impact Statement (EIS) for the International Wastewater Treatment Plant (IWTP) is a comprehensive document that summarizes most of their water quality data collected to date, as well as additional data that address environmental impacts.

In April of 1990, a water–monitoring program for the Tijuana River was initiated to evaluate the wastewater flows to be treated at the proposed IWTP. The program information is available in the Environmental Impact Study. Water quality samples were taken at two locations: Tijuana Pump Station No. 1, within Mexico, and from the Tijuana River near the border on the U.S. side. Samples were taken for 30 consecutive days at each location and were analyzed for a number of constituents. Pollutant loadings were calculated using an estimated 10 mgd (438 lps), and these results are displayed in Table 3.1. Estimated loadings from the Tijuana River for lead and cyanide were elevated at an estimated 40 kg/day and 150 kg/day. However, no detectable concentrations of mercury, selenium, arsenic, or cadmium were found during this sampling period. A referenced study completed in 1990, showed evidence that some parameters, such as biochemical oxygen demand (BOD), have increased significantly as sewage flow level in the river have increased (IBWC and U.S. EPA 1996). Some pollutants appear to have remained unchanged. Some of the results are shown in Tables 3.1 and 3.2.

Table 3.1. Pollutant Loading of the Tijuana River (at 10 mgd) 1990 and 1995

	1990	1995
Substance	Kilograms/Day	Kilograms/Day
Total Nitrogen	1,246.0	0
BOD	4,953.0	3,221.0
COD	11,515.0	9,122.0
TSS	8,113.0	66,162.0
Aluminum	118.0	378.0
Cadmium	*	0.4
Chromium	1.5	2.9
Copper	4.4	4.4
Cyanide	0.4	0.8
Lead	1.1	1.0
Magnesium	2,195.0	0
Manganese	10.6	37.2
Mercury	0	0.1
Nickel	2.5	1.1
Selenium	*	3.3
Silver	0.4	0.2
Zinc	3.8	53.5
Arsenic	0	1.7
Antimony	0.4	1.

* Data not available.

Source: International Boundary and Water Commission and U.S. Environmental Protection Agency, 1996.

According to an analysis implemented, wastewater from Tijuana can be defined as strongly domestic with industrial contributions. This strength of the wastewater appears to be reduced by 50 percent on weekends (RECOM 1994).

Table 3.2. Pollutant Loading at Pump Station No. 1 (at 10 mgd) 1990 and 1995

	1990	1995
Substance	Kilograms/Day	Kilograms/Day
Total Nitrogen	2,208.00	0
BOD	11,953.00	13,285.0
COD	31,255.00	31,075.0
TSS	12,974.00	10,068.0
Aluminum	24.30	29.7
Cadmium	0.05	2.8
Chromium	1.30	1.0
Copper	6.50	3.7
Cyanide	0.30	0.8
Lead	1.70	1.0
Magnesium	1,754.00	0
Manganese	4.70	4.4
Mercury	0.10	0.1
Nickel	1.40	0.5
Selenium	0	3.1
Silver	0.40	0.2
Zinc	10.40	35.7
Arsenic	0	1.7
Antimony	0	1.2

* Data not available.

Source: IBWC and U.S. EPA (1996).

Tables 3.3 and 3.4 have data from the Comisión Nacional del Agua (CNA) monitoring programs between 1995 and 1997 and from a study reported in Trava and Ganster (1985). Accordingly, a significant reduction in the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels indicates a clear improvement in water quality in the 10 years elapsed between the two studies. Total Dissolved Solids (TDS) values have also decreased.

Table 3.3 Analysis of Water Quality in the Tijuana River 1985

Parameters (mg/L)	Jan	Feb	March	April	May	June	July	Aug	Average
Total dissolved solids	1,730.00	1,620.00	1,960.00	1,800.00	1,890.00	1,780.00	1,880.00	1,950.00	1,826.00
BOD	286.00	———	295.00	268.00	398.00	280.00	270.00	260.00	284.00
COD	860.00	681.00	595.00	973.00	1,161.00	977.00	722.00	1,075.00	881.00
Ammonia-N	33.60	47.90	34.40	43.70	37.20	40.10	40.90	37.80	39.50
Phenols	0.18	0.06	0.08	0.18	0.01	0.07	0.09	0.07	0.09
Detergents	23.30	23.10	27.50	30.70	27.50	24.30	37.30	6.30	25.00
Oils and fats	21.00	367.00	96.00	30.00	21.00	20.00	11.00	665.00	153.90
Cd	0.01	0.01	0.02	0.01	0.02	0	0	0.03	0.01
Cr	0	0.24	0	0	0.05	0	0.25	---	.07
Cu	0.03	0.62	0.27	0.61	0.22	0.42	0.36	0.11	.39

Pb	0.06	0.08	0.07	0.04	0	0.14	0.18	—	.07
Ni	0.37	0.10	1.07	1.26	0.44	0.98	1.98	1.07	0.91
Zn	0	0	0.90	0.18	0.22	1.39	0.31	0.12	0.39

Note: The authors do not mention the sampling site(s).

Source: Trava and Ganster, 1986.

Table 3.4. Water Quality of the Tijuana River

Parameters	Units	StandardValues	1995	1996	1997
pH		5.0-9.0	6.60	7.96	8.40
Temperature	°C	Natural Conditions +2.5	19.00	21.91	21.60
DO	mg/L	4.0	8.94	12.43	16.79
BOD	mg/L		28.27	24.33	19.00
COD	mg/L		49.00	104.09	101.40
$N(NH_3)$	mg/L		1.00	2.03	
PO_4 (ortho)	mg/L	0.1	0.62	.02	0.56
Alkalinity	mg/L	400 (as $CaCO_3$)	264.00	397.73	375.20
TSS	mg/L	500	78.00	82.28	52.20
TDS	mg/L	500	835.00	1,528.63	1,476.00
VDS	mg/L		108.00	189.25	147.60
Conductivity	mhos/cm	No	1,410.00	2,445.00	2,308.00
Total coliforms	nmp*100ml				
Fecal coliforms	nmp*100ml		3.4E+05	5.0E+06	4.8E+05
Streptococcus	nmp*100ml				

Note: DO: Dissolved Oxygen; BOD: Biochemical Oxygen Demand; COD: Chemical Oxygen Demand; TSS: Total Suspended Solids; TDS and VDS: Total and Volatile Dissolved Solids.

Source: Comisión Nacional del Agua, 1997. Water Quality Standard CE-CCA-001/89.

Table 3.5 shows water quality data for the Rodríguez Dam. A comparison to available water quality standards (as indicated by Mexican Ecological Criteria for Water Quality [NOM CE-CCA-001/89] for water supply) indicates a generally acceptable water quality. An increase in the average values for the total dissolved solids and fecal coliform is observed for 1996, exceeding the standard parameters.

Table 3.5. Water Quality Data for the Abelardo Rodríguez Dam, 1994–1997

Parameter	Standard Value	Unit	1994	1995	1996	1997
pH	5.0-9.0		8.23	8.30	8.02	8.05
Temp	Natural Conditions + 2.5	°C	21.00	21.50	20.64	18.20
DO	4.0	mg/l	9.18	8.90	8.86	11.85
BOD		mg/l	1.00	2.90	5.06	3.40
COD		mg/l	22.00	21.50	31.90	35.80

N (NH_3)	5.0	mg/l	<0.05	<0.05	0.05	
PO_4 (ORTO)	0.1	mg/l	0.02	<0.01	0.02	0.03
Alkalinity	400 (as $CaCO_3$)	mg/l	165.00	180.30	220.73	305.20
TSS	500	mg/l	21.00	33.80	33.27	21.60
TDS	500	mg/l	549.00	470.50	522.36	656.80
Conductivity	NO	MHOS/cm	759.00	788.80	930.25	1,116.20
Total Coliforms		NMP/100ml		154.80	2,327.00	0
Fecal Coliforms	1000	NMP/100ml	44.00	69.60	2,332.55	0
Streptococcus		NMP/100ml		23.00	2,233.18	46.67

Note: There are some nonquantitative amounts. All the data are the average values.

Source: Comisión Nacional del Agua, 1996. Water Quality Parameter CE-CCA-001/89.

Many of the parameters evaluated were above the allowed standard values. According to the data, water quality in the Tijuana River has improved in recent years; nevertheless, there are still values that exceed water quality standards. The level of fecal coliform has been the primary pollutant of interest in the Tijuana River. Fortunately, the levels of fecal coliform have decreased, as well as the incidences of increased levels. However, violations of the fecal coliform water qaulity standard still occur and remain a critical issue. Fecal coliform levels in the Tijuana River are lower than in upstream tributaries, including contributions from the Tecate River.

Tecate

Tables 3.6 through 3.11 show the results obtained for the Tecate River (Lozano 1995). The physical-chemical parameter values of some sampling sites such as Rinconada and Rancho La Puerta are near to the water quality of sewage for that year. A pattern of assimilation of pollutants was observed as water quality tended to improve downstream. The pH results were within the standard parameter.

Table 3.6. pH Results for the Tecate River

	Sampling Site						
Date	Rin. Tecate	La Puerta	Cuchuma R.	Encinos	Toll booth	Max. Std.	Min. Std.
10/26/93	7.6	7.5	7.7	6.5	6.8		5.0
11/26/93	8.8	7.5	8.4	8.0	8.1	9.0	5.0
2/5/94	7.8	7.5			8.1	9.0	5.0
4/7/94	8.0	7.7	7.2		8.1	9.0	5.0

Note: All dates are between the standard limits.

Source: Lozano, 1995.

Table 3.7. Total Solids in mg/l for the Tecate River

Date	Sampling Site Rin. Tecate	La Puerta R.	Cuchuma R.	Encinos	Toll booth	Standard
10/26/93	9,520	7,556	3,568	929	85	1,000
11/26/93	1,810	1,636	2,116	1,751	1,436	1,000
2/5/94	8,240	7,105	NS	NS	486	1,000
4/7/94	917	1,164	997	NS	642	1,000

Note: NS: no sampling
Source: Lozano, 1995.

Very high levels of total solids were found at Rinconada Tecate and Rancho la Puerta, but downstream sites showed reduced levels through dilution and hydrodynamics. This parameter is an indicator of large amounts of organic and inorganic material deposited along the river.

The parameter of Oil and Grease (CE-CCA-001/89) does not indicate any specific level, but data from Table 3.8 shows high levels of oil and grease in Rinconada Tecate and Rancho La Puerta.

Table 3.8. Oil and Grease in mg/l for the Tecate River

Date	Sampling Site Rin. Tecate	La Puerta R.	Cuchuma R.	Encinos	Toll booth
10/26/93	66	23	7	2	<1
11/26/93	103	70	21	14	5
2/5/94	89	60	NS	NS	<1
4/7/94	62	19	5	NS	<1

Note: NS: No sampling.
Source: Lozano, 1995

Table 3.9 shows a high level of Chemical Oxygen Demand (COD) at most of the sites. A level above 250 mg/l is similar to weak but untreated domestic wastewater and most of these sites showed high COD levels that are associated with Total Solids and strong discharges of organic matter.

Similar to COD, biochemical oxygen demand (BOD) levels were high and the general water quality was equivalent to that of untreated domestic wastewater. The extreme difference between COD and BOD gives some indication that the source of oxygen demanding matter is not entirely from a domestic source. It is likely that the high COD levels are the result of higher strength industrial wastewater being released to the Tecate River. Although ambient BOD levels vary, the high BOD levels at all the sites indicate extreme situations. It is not likely that any of these sites could have the assimilative capacity to handle these elevated BOD levels without severe biological impacts.

Table 3.9. COD in mg/L for the Tecate River

	Sampling Site				
Date	Rin. Tecate	La Puerta R.	Cuchuma R.	Encinos	Toll booth
10/26/93	1,005	704	302	302	101
11/26/93	618	1,388	354	354	435
2/5/94	824	635	NS	NS	54
4/7/94	889	667	364	NS	200

Note: NS: No Sampling
Source: Lozano, 1995.

Table 3.10. BOD in mg/l for the Tecate River

	Sampling Site				
Date	Rin. Tecate	La Puerta R.	Cuchuma R.	Encinos	Toll booth
10/26/93	198	177	91	42	23
11/26/93	227	210	123	67	79
2/5/94	246	184	NS	NS	49
4/7/94	17	131	101	NS	61

Note: NS: No Sampling
Source: Lozano, 1995.

Table 3.11. Surfactants in mg/l for the Tecate River

	Sampling Site					
Date	Rin. Tecate	La Puerta R.	Cuchuma R.	Encinos	Toll booth	Standard Parameter
Oct./26/93	3.2	1.9	0.3	0.3	0.3	0.5
Nov./26/93	2.9	1.3	0.4	0.4	0.4	0.5
Feb./05/94	1.6	1.3	NS	NS	<0.1	0.5
Apr./07/94	1.2	0.5	0.3	NS	<0.1	0.5

Note: NS: No Sampling
Source: Lozano, 1995.

The allowed standard value for surfactants in Mexico is 0.5 mg/l. Rinconada Tecate and Rancho La Puerta showed a very high level. However, by following the river course, the level drops to within the allowed parameter. Surfactants are associated with detergent use, and the high levels are likely the result of industrial and domestic sources.

Table 3.12 shows water quality data from the CNA monitoring in the Tecate River. The values are the averages of general monthly sampling. The sampling site was not identified. The values do not indicate any general trend, but there was great variation in the average values of COD and BOD. BOD levels ranging between 200 to 400 mg/l are extremely high, but also indicate a consistent problem likely associated with the release of untreated wastewater. The extremely low DO levels, below 3.0 mg/l, indicate the impact of the high BOD levels and also a destroyed biological environment. High COD levels describe a pollutant source of a high strength or industrial nature. The majority of other pollutants indicate an area extremely affected by untreated wastewaters.

Similar results were seen in the study carried out by Lozano and the data from CNA. The contamination within the Tecate River might be due to discharges from local industries and the Tecate Wastewater Treatment Plant.

Table 3.12. General Water Quality of the Tecate River

Parameter	Unit	Standard values	1994	1995	1996	1997*
PH		5.0 - 9.0	7.26	7.33	7.05	7.80
Temperature	°C	Natural conditions +2.5	18.20	20.00	18.09	18.83
DO	mg/L	4.0	1.86	0.90	2.87	0
BOD	mg/L		311.60	202.67	362.50	382.50
COD	mg/L		1,194.40	155.00	783.41	1,055.83
$N(NH_3)$	mg/L		12.82	-	12.30	-
PO_4 (ORTHO)	mg/L	0.1	1.85	2.22	2.54	3.49
Alkalinity	mg/L	400 (as $CaCO_3$)	522.40	569.75	643.27	669.83
TSS	mg/L	500	618.60	334.00	357.00	436.50
TDS	mg/L	500	1,132.60	750.00	1,280.73	1,756.83
Conductivity	mmhos/cm	no	1,186.00	1,498.50	2,038.75	1,852.83
Totals coliforms	nmp*100ml					
Fecal coliforms	nmp*100ml		4.3E+06	5.7E+06		
Streptococcus	nmp*100ml					

*Average value January to June

Source: Comisión Nacional del Agua, 1997. Water Quality Standard CE-CCA-001/89.

Data for Carrizo Dam are shown in Table 3.13. Phosphates and total suspended solids (TSS) exceeded the allowed standard for some years in which data were obtained. However, total dissolved solids decreased in the last year and their level is within the allowed parameter of the standard mentioned earlier (NOM CE-CCA-001/89).

The data obtained from CNA and the Lozano study indicated an increase in BOD due to a high concentration of organic matter. The analytical data showed poor water quality at the first two sampling sites: Rinconada and Rancho La Puerta. Although the Lozano study was completed prior to construction of the wastewater treatment plant, the more recent data from CNA show that the water quality of the Tecate River is still very poor.

Alarming levels of fecal coliform also exist. These could be explained by the fact that disinfection in the treatment of effluent discharged by the Tecate Wastewater Treatment Plant is not required. This indicates an extreme public health concern particularly for those who have close contact with the waters of the Tecate River.

Table 3.13. Water Quality Data for Carrizo Dam, 1994–1997

Parameters	Units	1994	1995	1996	1997
PH		8.03	8.1	7.94	8.12
Temperature	°C	19.00	20.2	18.73	17.60
DO	mg/L	8.65	8.9	8.74	9.72
BOD	mg/L	<1.00	2.1	2.73	0
COD	mg/L	17.00	16.0	13.82	21.00
N(NH3)	mg/L	<0.05	0.0	0.06	0
PO4(orto)	mg/L	0.02	0.0	0.02	0
Alkalinity	mg/L	155.0	184.7	187.18	182.80
TSS	mg/L	12.00	13.5	24.73	13.20
TDS	mg/L	944.00	795.8	874.00	943.20
Conductivity	mmhos /cm	1,033.00	1,139.5	1,442.7	1,429.60
Totals coliforms	nmp*100ml		371.2	7,205.82	0
Fecal coliforms	nmp*100ml	88.17	82.5	271.00	0
Streptococcus	nmp*100ml			2,361.27	0

Note: *There are some nonquantitative amounts. 1997 data are the average value from January to May.
Source: Comisión Nacional del Agua, 1997.

San Diego County

The objective of the study on mass emission of selected contaminants from the Tijuana River into the Southern California bight was to measure the concentration of selected constituents in runoff samples from the largest channels in Southern California and to estimate the mass carried to the ocean. Samples were collected from eight channels during wet and dry-weather flows, and annual loads of contaminants delivered to the ocean were estimated.

Discharge from the Tijuana River was 2 percent of total gauged runoff to the Southern California bight during the 1987 water year (10.2 x 10^6 m^3) and 6 percent of total gauged runoff during the 1988 water year (40.2 x 10^6 m^3). Discharge during the two-year study was 24 percent and 94 percent of the long-term annual mean (1950–1988: 42.9 x 10^6 m^3). Discharge during high flows (>0.5 m^3/s) occurred 7 percent of the days in 1987 and 24 percent of the days in 1988, and accounted for 48 percent and 82 percent respectively, of the annual river discharge. Most of the discharge from the river occurred from January through April.

Twenty-seven runoff samples were collected from storms in October 1987, January 1988, and April 1988. Discharge during these storms was 1–15 percent (0.4–6.0 x 10^6 m^3) of the annual discharge volume. Two nonstorm samples were collected in September and December of 1987. Twenty-nine samples were analyzed for suspended solids, 28 samples for trace metals, and 27 samples for chlorinated hydrocarbons. The concentrations of all constituents were positively correlated with flow and suspended solids. The volume of discharge from the Tijuana River increased by 300 percent from 1987 to 1988; mass emission estimates increased by the same amount.

Table 3.14. Estimates of Mass Emission of Selected Contaminants from the Tijuana River, 1986–1988

Year	Vol (x $10^6 m^3$)	SS (x 10^3 kg)	Cd (kg)	Cr (kg)	Cu (kg)	Ni (kg)	Pb (kg)	Zn (kg)
9/86 - 8/87	10.2	43,883	52	1,870	4,231	1,178	10,051	11,706
9/87 - 8/88	40.2	173,270	205	7,385	16,706	4,653	39,684	46,221

Source: Cross, Schiff, and Schafer, 1992.

During the past century, urbanization has had a dramatic impact on the landscape of Southern California. Rivers and streams have been extensively modified to conserve water for a growing population and to control floods. Urbanization increases the quantities of pollutants that reach rivers and streams. The type and concentrations of pollutants in runoff are determined by the degree of urbanization, types of land use, densities and types of vehicular traffic and animal populations, atmospheric quality, municipal cleaning practices, and specific storm characteristics. Most river discharge and contaminant transport in Southern California happens during winter storms that occur intermittently and unpredictably. Data from Table 3.3 show that a large amount of lead is being discharged into the river, but information from the South Bay International Wastewater Treatment Plant Environmental Impact Statement shows different results.

Table 3.15. Basic Water Quality Parameters for Morena Reservoir

			Year		
Parameter	1993	1994	1995	1996	1997
Temperature (°C)	17.70	17.10	17.00	17.30	16.30
Dissolved Oxygen (mg/l)	9.00	8.43	9.53	8.17	9.5
pH	8.40	8.50	8.80	8.50	8.70
Conductivity (mmhos)	428.00	484.00	469.00	515.00	544.00
Total Dissolved Solids	0.27	0.28	0.30	0.33	0.35
Oxidation-Reduction Potential (mV)	280.00	294.00	253.00	278.00	389.00

Source: City of San Diego, 1997 *Barret and Morena Reservoir, Basic Water Quality Profiles (1993-1997).*

Table 3.16. Basic Water Quality Parameters for Barret Reservoir

			Year		
Parameter	1993	1994	1995	1996	1997
Temperature (°C)	16.60	18.80	19.00	19.50	18.40
Dissolved Oxygen (mg/l)	7.42	8.98	8.88	8.98	9.08
pH	7.40	8.60	8.40	8.50	8.40
Conductivity (mmhos)	409.00	521.00	457.00	513.00	542.00
Total Dissolved Solids	0.26	0.33	0.29	0.33	0.35
Oxidation-Reduction Potential (mV)	273.00	255.00	242.00	309.00	366.00

Source: City of San Diego, 1997

Tables 3.15 and 3.16 show water quality data for Morena and Barret resevoirs. They were obtained from the Water Quality Laboratory of the City of San Diego. Data shown in the tables are the average values at the level of the streambed at the dam.

Although only a few parameters were obtained from the Morena and Barret reservoirs, water quality appears to be in good condition as indicated by high levels of dissolved oxygen. The type and amount of activity in the watershed offers evidence that there are no significant sources of water quality impairment. Therefore, the indicative nature of the water quality parameters depicts the water quality for reservoirs under these conditions, with no strong shift in trend to show any problems. The pH levels appear somewhat high as well as the conductivity values; however, they appear normal, considering the hydrogeological nature of the area, and are within acceptable levels.

Special Studies and Monitoring at the Tijuana Estuary and Nearshore Area

The objective of this section is to summarize and update different studies that have been compiled for the Tijuana River estuary to better understand the nature of pollution within this zone. This zone is the most studied area in the watershed.

City of Imperial Beach

The City of Imperial Beach monitors water quality from several stormwater outlets under a draft metropolitan-wide National Pollutant Discharge Elimination System (NPDES) permit for stormwater control. This program started on a monthly basis in February 1995. Two of these stormwater outlets drain into the Tijuana River watershed. They are identified under the names of E-1 and F-1, and drain into the Tijuana River estuary. Unfortunately, very little numeric water quality data are available. This is because, under the draft agreement of NPDES, water chemistry will be analyzed only if a visual inspection warrants further investigation. The parameters measured are pH, chlorine, detergent, copper, and phenols, which are typical pollutants associated with urban runoff. Some of the data obtained from these reports are shown in Table 3.17.

Table 3.17. Stormwater Quality Data in Imperial Beach

Site	Date	pH	Chlorine	Detergent	Copper	Phenol
E1	May 25, 1995	8.5	1.5 ppm	1.20 ppm	--	--
	October 20, 1995	--	--	0.75 ppm	2.0 mg/l	0.0 mg/l
	February 23, 1996	7.7	1.5 mg/l	1.00 ppm	0.5 mg/l	0.5 mg/l
F1	October 20, 1995	---	---	1.75 ppm	0.2 mg/l	---

Source: City of Imperial Beach, 1997.

In addition, John Powell & Associates, Inc., conducted a study associated with the City of Imperial Beach's Illicit Connection Illegal Discharge Detection Program in September 28, 1993. Three grab samples yielded the results on Table 3.18.

Table 3.18. City of Imperial Beach Stormwater Grab Samples, 1993

Site	pH	Chlorine	Detergent	Copper	Phenol
E1	8.5	0.1 mg/l	0.25 mg/l	0.0 mg/l	0.0 mg/l
F1	7.6	0.0 mg/l	1.00 mg/l	0.0 mg/l	0.0 mg/l

Source: City of Imperial Beach, 1997.

Data available show that, with the exemption of a value of copper in 1995, the parameters measured are within acceptable values. However, illegal discharging is a nonpoint source of pollution for the Tijuana River estuary.

The United States Environmental Protection Agency tracks water quality data nationally from diverse sources in a system titled STORET. The STORET retrieval was received for the watershed of the Tijuana River. Although significant data were available from the United States Geological Survey (USGS) and the State Water Resource Control Board (SWRCB), no data were available after the 1980s.

Mussel Watch and Toxic Substance Monitoring

The State Water Resource Control Board (SWRCB) is divided into nine regions within California. The Tijuana River watershed is overseen by the Region 9 Regional Water Quality Control Board (RWQCB). The SWRCB oversees two statewide monitoring programs: State Mussel Watch (SMW) and Toxic Substance Monitoring (TSM). Sampling has continued for the Mussel Watch program and the TSM for over 10 years. The SWRCB is also responsible for submitting the water quality assessment report and/or Clean Water Act 305(b) Report.

The Mussel Watch program was developed as an effective method of assessing coastal and near inland waters. The program involves the maintenance and collection of mussels at coastal sites followed by the analysis of various contaminants. Although the Mussel Watch program analyzes many organics and metals, not all are pertinent to this project. Table 3.19 displays data for wet metals concentrations in mussels sampled at a site at or near the mouth of the Tijuana River.

The Toxics Monitoring Program was initiated in 1976 in order to assess waters throughout the state where water quality impacts are suspect or possible. The RWQCBs assist in citing TSM sites, while the resulting data are used by various agencies, including the California Environmental Protection Agency, in order to manage and coordinate water quality improvements. Water quality data were retrieved from the SWRCB Internet website and the 1992-1993 annual report. Only one sampling site was within the Tijuana watershed and the Tijuana estuary, described as "San Diego Station located on the northern arm of the Estuary near the terminus of First Street in the City of Imperial Beach." Pertinent data are illustrated in Table 3.20, which has been reproduced from the TSM 1992-93 Report. Table 3.20 displays similar data for metals in wet samples for analyzed fish.

Some of the metals levels reported in the State Mussel Watch and Toxic Substances Monitoring programs are in excess of appropriate standards and have resulted in the State assessing the Tijuana River as not meeting designated uses. As mentioned, much more data have been collected from both the SMW and TSM program.

Table 3.19. Mussel Watch Data for Metals in Wet Samples, mg/kg

Station Name	Date	Ag	Al	Cd	Cr	Cu	Pb	Zn
Zuñiga Jetty	Jan	0.286906	96.39788	0.940711	0.339511	1.636600	0.556611	33.47230
Zuñiga Jetty	Jan 85	0.148629	64.65548	0.765399	0.266999	1.613926	0.646673	29.18008

Zuñiga Jetty	Jan 86	0.168461	62.32902	0.712430	0.296050	1.517876	0.478073	31.33736
Imperial Beach/Pier	Jan 84	0.302325	84.96028	0.275500	0.246500	1.246999	0.497785	28.42478
Imperial Beach/Pier	Dec	0.730000	130.00000	0.200000	0.300000	2.000000	0.409999	34.00000
Tijuana River/Imperial	Feb 85	0.196042	56.82093	0.872717	0.210518	1.370599	0.282281	26.03631
Tijuana River/Imperial	Jan 86	0.190713	113.4972	0.907962	0.352887	1.158169	0.404680	25.46116
Tijuana River	Jan 84	0.153219	87.65048	1.081179	0.282478	1.249721	0.298779	26.31912
Mexican Border	Jan 86	0.108499	56.09140	0.580784	0.259315	1.061750	0.326584	21.89576

Source: Rasmussen, 1995. *State Mussel Watch Program 1987-1993 Data Report.* Sacramento: State Water Resources Control Board, California Environmental Protection Agency.

Table 3.20. TSM Metals Concentrations for Wet Samples, mg/kg

		Common Name	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Tijuana Estuary	Apr 84	Striped Mullet						-0.02				
Tijuana Estuary	Apr 84	Striped Mullet						-0.02				
Tijuana Estuary	Apr 84	Striped Mullet	2.9	2.9	0.4	-0.04	85.00		-0.10	0.20	6.09	32.00
Tijuana Estuary	Apr 84	Striped Mullet	0.79	1.60	0.06	-0.04	27.00		-0.10	0.10	3.20	25.00
Tijuana Estuary	Jun 85	Longjaw Mudsucker	-0.02	0.69	-0.01	0.05	0.40	-0.02	0.10	-0.10	-0.20	15.00
Tijuana Estuary	May 86	Opaleye						0.07			0.23	
Tijuana Estuary	May 86	Opaleye	0.07	0.92	0.08	-0.02	4.09		-0.10	0.20		18.00
Tijuana Estuary	May 86	Pacific Staghorn Sculpin	-0.02	0.25	-0.01	0.03	0.97	0.03		0.10	0.28	12.00
Tijuana Estuary	Jul 87	Diamond Turbot						0.07			0.33	
Tijuana Estuary	Jul 87	Diamond Turbot	0.15	5.90	0.05		22.00		-0.10	-0.10		58.00
Tijuana Estuary	Jun 88	Longjaw Mudsucker						0.08			0.19	
Tijuana Estuary	Jun 88	Longjaw Mudsucker	0.05	1.20	0.02	-0.02	4.69		-0.10	-0.10	-888.00	14.00
Tijuana Estuary	Jun 89	Longjaw Mudsucker						0.07		-888.00	0.19	-888.00
Tijuana Estuary	Jun 89	Longjaw Mudsucker	0.04	1.29	0.03	-0.02	4.40		-0.10	-0.10	-888.00	17.00
Tijuana Estuary	Jun 92	Longjaw Mudsucker	-0.02	1.39	-0.01	0.12	0.76	0.04	-0.10	0.10	0.28	20.00

Note: -0.02 = below detection

Source: State Water Resources Control Board Web Site, TSM 1992–1993 Report.

Coliform Monitoring at the Tijuana River, Estuary, and Coastal Area

The San Diego County Department of Environmental Health collects and tracks coliform data at several sites including Dairy Mart Road, Imperial Beach Pier, Tijuana River Mouth, Borderfield State Park, and Goat Canyon.

Of the five descriptive sites mentioned, Dairy Mart Road and Goat Canyon stand out with extremely high total coliforms (TC) and fecal coliforms (FC) due to the constant sewage overflow into the Tijuana River. However, analysis of data at the mouth of the Tijuana River downstream from the Dairy Mart site indicate significant reductions in both TC and FC. This may be the result of a "filtering" process in the estuary from vegetation, sedimentation, or biological degradation. In addition, changing tides and seawater intrusions likely dilute coliform levels.

The sites along the coast are Imperial Beach Pier, Borderfield State Park, and the Tijuana River Mouth. Although there are some high levels, the data show that they are generally within the allowed standards for recreational use: 1000 colony forming units (CFU)/100 ml for TC and 200 CFU/100 ml for FC. From July 1990 to June 1995, there were approximately seventy-five days in which the TC standard of 1000 CFU/100 ml was exceeded. This resulted in beach closures. The days when coliform counts were high can be attributed to rain, which carries the sewage from further up the river on the Mexican side, or from occasional spills due to breaks in the sewage transport system. The complete coliform data are shown in Appendix 1 (San Diego County Department of Environmental Health 1997).

Microbiological Water Quality of the Tijuana River Estuary

The aim of the microbiological study was to characterize the degree and spatial nature of microbial contamination of the Tijuana estuary during both wet and dry weather under a range of tidal conditions (Gersberg et al. 1994). An additional objective was to determine whether salinity measurements could be used to predict the level of microbial contamination at sites throughout the Tijuana estuary.

Eleven monitoring stations in the Tijuana River and estuary were used in order to assess spatial variation of microbial contamination and salinity. Resulting data indicate that mean levels of the fecal indicator bacteria are very high after rain events, also that mean levels are much lower at all estuary sites during the year.

During wet weather, both mean TC and FC levels in surface waters at all sites in the estuary greatly exceed suggested federal guidelines for recreational waters of 1000 CFU/100 ml for TC and 200 CFU/100 ml for FC. The highest mean values in the estuary (1.4–6.8 x 10^6 CFU/100 ml TC and 1.3–4.7 x 10^5 CFU/100 ml FC) occurred at the river sites during low tide. At high tide, during wet weather, there is some amelioration of bacterial contamination that is particularly pronounced at the Ocean Mouth site, where the mean TC and FC levels are 3,920 and 247 CFU/100 ml, compared to mean levels of 4.432 x 10^6 and 1.423 x 10^5 CFU/100 ml at low tide.

Mean levels of both total and fecal coliforms range from 2.4×10^3–5.0×10^4 CFU/100 ml for TC and 4.5×10^2–5.7×10^3 CFU/100 ml for FC in the Tijuana River during dry weather (low tide) and are similar to indicator levels in dry weather flows of Southern California storm drains.

Fresh water flows into the estuary are dominated by contaminated Tijuana River water, while tidal flows deliver more or less uncontaminated ocean waters. Hence, indicator levels should decrease as salinity increases within the estuary.

The data obtained from this study indicated that there is and will continue to be a profound effect from rainfall and runoff water on the water quality of the Tijuana estuary. Even after the International Wastewater Treatment Plant is constructed and working, high loading of fecal microorganisms by the Tijuana River from nonpoint sources in the watershed will continue to contaminate the Tijuana estuary (Gersberg et al. 1994).

Heavy Metals in Sediments and Fish at the Tijuana River Estuary

Gersberg, Trindade, and Norby of SDSU conducted a study to assess toxic heavy metal levels of cadmium (Cd), chromium (Cr), copper (Cu), zinc (Zn), lead (Pb), and nickel (Ni) in the sediments of the Tijuana River and estuary. Fifty sampling stations within the estuary and river were established, and sampling was conducted during May of 1988.

Results from the sites in the river and the northern section are shown in Appendix 2. The results indicated a general pattern of relatively low concentrations of heavy metals in the northern part and higher levels in the southern section of the estuary, as well as at sites upstream in the river. The influence of tidal conditions and releases of sewage or excess stormwater drainage likely contribute to this discrepancy in metals levels.

The highest metal concentrations in sediments were found near Goat Canyon (site 39–45). There was no apparent trend in the river sampling where results from sites 1 and 2 at Dairy Mart Road were variable to other sites (8 and 9 at Saturn Street). Cadmium values ranged from 3.52 mg/kg (site 40) to 0.05 mg/kg at site 22 (at the mouth).

Sites exceeding an objective of 1 mg/kg Cd were considered polluted in this study. They included sites 4–8, 11, 12, and sites 38–42, 44, and 45. A variable amount of sewage flowed continuously into the Tijuana River, but only the concentration of cadmium seemed to be high in the sediment of the river and estuary. In fish, only lead was present at a level higher than the international standards, but it seemed not to be a significant risk for human health.

The general trend for heavy metal levels was lower concentrations in the northern section with higher levels in the southern section and in the estuary and river. The highest levels of heavy metals were found in the United States near the Tijuana bullring. These were attributed to occasional wastewater releases into Goat Canyon. Cadmium concentration levels were as high as 3.52 mg/kg in a nearby site (Gersberg et al. 1989).

Heavy Metals and Acid Volatile Sulfides in the Sediments of the Tijuana River Estuary

A study conducted in 1996 analyzed heavy metal and acid volatile sulfides (AVS) in the sediments of the Tijuana River estuary (Meyer 1996). AVS is a popular method of determining the extent to which metals are bound as sulfides and may be subsequently less bioavailable. This study stated that water in the Tijuana River contained untreated industrial waste from Tijuana. Mean heavy metal concentrations in the water of the Tijuana River are as follows: 0.069 ppm Cd; 0.055 ppm Cr; 0.281 ppm Cu; 0.321 Ni; and 3.745 ppm Pb (Trindade 1988). Probable pollutant sources were considered to be the metropolitan areas of San Diego and Tijuana. Sampling sites in the Tijuana River estuary were: (1) Sludge Pond, (2) Upper Oneonta, (3) Middle Oneonta, (4) Lower Oneonta, (5) Tijuana River, (6) Old Tijuana River, (7) Horse Trail, and (8) South Beach. Samples were taken in January and February of 1996.

The study involved sediment core samples with analysis of heavy metals in the bottom, middle, and top portions of sediment cores. Table 3.21 summarizes the core section and the range of metal concentrations found at the numerous sites.

Table 3.21. Sediment Core Samples for Heavy Metals

Sediment Core Level	Metal	Site Number for Lowest Conc.	Range, Lowest Conc. (ppm)	Site Number for Highest Conc.	Range, Highest Conc. (ppm) (Site)
	Cd	1, 2, 4, 5 & 6	0.8	8	4.7
Bottom	Cu	7	3.3	1	39.5
Bottom	Pb	4	1.3	1	46.3
Bottom	Ni	3	5.5	8	20.8
Bottom	Zn	4	14.5	3	134.1
Middle	Cd	4	0.7	8	9.5
Middle	Cu	4	0.7	1	54.5
Middle	Pb	8	6.0	7	126.9
Middle	Ni	2	5.8	7	37.3
Middle	Zn	4	23.3	1	130.0
Top	Cd	3, 4, 5, & 8	0.8	1	15.8
Top	Cu	4	0.9	1	304.5
Top	Pb	4	11.3	7	112.7
Top	Ni	4	8.3	7	158.3
Top	Zn	4	18.9	1	402.0

Source: Trindade, 1988.

Within the top 2.5 cm of the core sediments, site 1 had the highest metal concentrations, while top section heavy metal concentrations at site four were consistently as low. Individual results of metal concentrations in core samples are displayed in Appendix 3. The data clearly indicate a decrease in metal concentrations with decreasing depth of core samples, showing a nonhomogenous distribution of metals.

At the time of the study by Meyer, sediment quality standards had not been adopted in the state of California. Therefore, the extent of contamination is difficult to define. In fact, the lack of scientific detail concerning sediment toxicity is a major impetus behind similar studies in order to define effective methods in determining bioavailibility of metals in sediments. However, California uses the Apparent Effect Threshold (AET) approach for assessing contamination of marine and estuarine sediments. Although there are no official standards, the State Water Resource Control Board (SWRCB) may engage in enforcement action based on these procedures. However, comparison of the Southern California AET concentrations with the mean sediment concentrations from this study yields only one value in excess. The mean nickel concentration in top sediments core subsample at site 1 (Sludge Pond) was 112.41 ppm while the Southern California AET concentration was 99 ppm. Subsequently, although the Tijuana estuary has been subject to considerable metals contamination, most of the concentrations are below what the state of California considers harmful to the environment. Stormwater runoff from the area surrounding the Tijuana estuary may be a more important source of heavy metal contamination than freshwater flows crossing the U.S.-Mexican border.

Heavy Metals in Sediments, Biota, and Water of the Tijuana River and Estuary

A particular focus of the study titled "Heavy Metals in Sediments, Biota, and Water of the Tijuana River and Estuary," was the analysis of cadmium, chromium, copper, nickel, lead, and zinc in the sediments of the Tijuana River and estuary as illustrated in Table 3.22 (Trindade 1988). The possibility exists that these metals may be accumulating by physiological processes in the sediments, and then bioconcentrating in the food chain. Furthermore, the spatial heterogeneity of the heavy metals throughout different areas of the Tijuana River and estuary might help define the important sources of metals to the ecosystem. Heavy metals are not biodegraded and, when delivered to an ecosystem, tend to accumulate and increase in concentration.

Table 3.22. Heavy Metal Values of Three Studies in the Tijuana River Estuary

Study	Cd	Cr	Cu	Ni	Pb	Zn
City of San Diego 1984 (water) (ppm)	0.057	0.33	0.051	0.009	0.020	0.043
Toxic Substances Monitoring Program 1984 (fish liver) (mg/kg)	0.140	<0.04	84.000	<0.100	0.200	33.000
San Diego Regional Water Quality Control Board (fish muscle) (mg/kg)	0.360	1.10	5.930	1.630	1.750	2.530

Source: Trindade, 1988.

The source of metals in the Tijuana River and estuary include nonpoint sources such as agricultural and urban runoff, natural processes–mainly by the dissolution of minerals that are then carried in the water–and discharge of wastewater. The amount of foreign and domestic industry in Tijuana, coupled with the fact that there is no industrial pretreatment, indicates that a major source of the metals to the estuary may be the raw wastewater from the city of Tijuana. Urban runoff is another contributing factor as a source of metals.

Table 3.23. Mean Levels of Heavy Metals in Tijuana Wastewater

Metal	Mean Influent Level (mg/l)
Cr	0.193 (12)
Cu	0.460 (12)
Ni	0.095 (12)
Pb	0.231 (12)
	0.508 (12)

Note: Numbers in parentheses represent the number of trials.
Source: Trindade, 1988.

Tijuana River Watershed Toxics Data Project

The Tijuana River Watershed Toxics Data Project was completed to address development of a database for transboundary chemicals, pollution, and environmental tracking (Gregory et al. 1996). Some complexities involved in a mutual database between the United States and Mexico were discussed, including language differences and spelling as well as the wide range of names associated with many chemicals in both Mexico and the United States.

The report lists a collection of agencies and organizations in the United States and Mexico that report or track some sort of environmental data. Furthermore, the report addresses development of a Geographic Information System (GIS). Many of these organizations that were within the San Diego-Tijuana region were consulted for available water quality data (Gregory et al. 1996).

Chemistry, Toxicity, and Benthic Community Conditions in Sediments of the San Diego Bay Region

This work is the result of efforts by the National Oceanic and Atmospheric Administration (NOAA), the California State Water Resources Control Board (SWRCB), the Department of Fish and Game, among other organizations. The work concerns the status of three major bodies of water in the San Diego area, including the Tijuana River estuary (Anderson et al. 1996). The objectives of the study were to determine the presence or absence of adverse biological effects, determine the degree of impacts and severity of sediment contamination, determine the spatial extent of the impact, and determine the relationship between toxicants and measures of effects.

Table 3.24. Information Summarized by the Report for the Tijuana River Estuary

Parameter/ Concentration or Measurement	Southern Section	Samples per Total Sampled Central Section	Northern Section
Copper in Sediment			
0–18.7 ppm below TEL		6/6	
18.7–106.2 ppm below PEL			1/1
106.2–660 ppm below PEL	4/4		
Zinc in Sediment			
0–124 ppm below TEL	1/4	6/6	
124–271 ppm below PEL			1/1
271–1600 ppm above PEL	3/4		
Mercury in Sediment			
0–0.13 ppm below TEL	3/4	6/6	1/1
0.13 - 0.696 ppm below PEL	1/4		
0.696–3.5 ppm above PEL			
High MW PAH			
0–655.34 ppb below TEL	5/5	8/8	2/2
655.34–6676.14 ppb below PEL			
6676.14–56500 ppb above PEL			
Low MW PAH			
0–311.7 ppb below TEL	3/5	7/8	
311.7–1442 ppb below PEL	2/5	1/8	½
1442–27200 ppb above PEL			½
Total PCB			
0–21.55 ppb below TEL	5/5	8/8	2/2
21.55–188.79 ppb below PEL			
188.79–1380 ppb above PEL			
Total Chlordane			
0–2.26 ppb below TEL		8/8	
2.26 - 4.79 ppb below PEL	3/3		1/1
4.79 - 160 ppb above PEL			
Amphipod Toxicity (Lab Controls)			
Toxic	2/2		2/2
Nontoxic		2/2	
Urchin Development Toxicity			
Undiluted(Toxic)	2/2		2/2
(Nontoxic)		2/2	
50% Dilution(Toxic)			
(Nontoxic)	2/2	2/2	2/2
25% Dilution(Toxic)			
(Nontoxic)	2/2	2/2	2/2
Amphipod Toxicity Reference Envelope with all Stations			
48 - 100% Survival	3/5	9/9	
0 - 48% Survival	2/5		2/2

Source: Anderson et al. 1996.

Although the majority of the sampling was performed in the San Diego and Mission bays, equivalent data are available for the Tijuana River estuary. Random sampling blocks were designated to determine the monitoring stations. These randomized blocks were described as Southern, Central, and Northern sections of the estuary. Separate chemical analysis was performed on sediment samples as well as pore water samples. Similarly, toxicity testing was performed with various test organisms. Some pertinent results of the study are presented in Table 3.24.

This comprehensive study concluded that several "hot spots" exist that require further study and action. However, the priority areas were concentrated in the San Diego and Mission bays. Elevated pollutant levels in the Tijuana estuary were mostly attributed to past and current industrial activity at or near the estuary (Anderson, et al., 1996).

Based on the studies that have been completed, particular pollutants appear to be more of a concern than others are. Zinc is the metal that consistently has the highest concentrations. However, this is not unusual considering the sources, the geochemistry, and relatively lower toxicity of zinc. Lead is another metal that consistently showed elevated levels. Cadmium and nickel both received special attention in some studies, but were not consistently found at elevated levels.

In 1988, wastewater samples indicated the following gradation in concentrations: Zn> Cu> Pb> Cr> Ni, while Tijuana estuary samples indicated: Cr> Cd> Cu> Zn > Pb> Ni> (Trinidade 1988). In 1989, the concentration gradations found were: Zn>Pb>Cu>Cr>Ni>Cd in the Tijuana River; Zn>Pb>Cr>Ni>Cu>Cd in the estuary; and Zn>Pb>Cr>Cu>Ni>Cd at the mouth of the river (Gersberg et al. 1989). In 1996, data on core samples generally followed the following concentration pattern: Zn>Ni>Cu>Pb>Cd for the bottom; Zn>Pb>Ni>Cd>Cu for the middle; and Zn>Pb>Ni>Cu>Cd for the top of the core samples (Meyer 1988).

These data confirm that the metals in highest concentration in the Tijuana River estuary are Zn and Pb. However, lower concentrations of more toxic metals, for example cadmium, may pose a similar, if not greater, problem. The predominant source of metals in the estuary consistently comes from the southern section of the estuary due to drainage from Smuggler's Gulch and Goat Canyon.

Groundwater Quality

The Comisión Nacional del Agua (CNA) is divided into three geohydrological zones within the Mexican part of the Tijuana River watershed. These include Valle de Tijuana, Valle de las Palmas, and Valle deTecate.

Groundwater quality in terms of Total Dissolved Solids (TDS) varies from fresh to salty water, with a concentration between 200 to 11,000 mg/l. The values for 1980 in Valle de Tijuana for TDS were between 500 and 3000 mg/l. Groundwater quality in the southeast section of this valley was poor with values between 1000 and 3000 mg/l and the rest were 2500 mg/l (INEGI 1995). In 1992, the TDS were between 200 and 2500 mg/l in Valle de Tecate. TDS values in Valle de las Palmas were between 1000 and 4000 mg/l. According to the Palmer-Piper triangular diagrams, the chemical families of these are sodic, magnesic with a tendency to calcic-bicarbonate chloride (INEGI 1995).

Table 3.25 shows the water quality data for June 1992 from wells that are used for water supply in the city of Tecate. General groundwater quality, as seen in Table 3.25, is considered to be acceptable within the Mexican Parameters (NOM-127-SSAI-1994). But, when comparing them to the U.S. EPA standards, some parameters, such as total solids (TS) and dissolved solids (DS), are below the standard.

Table 3.25. Physical-Chemical Analysis of Water Supply Wells of Tecate

Parameter	Temp. °C	pH	Conductivity mcmhos	Ca ppm	Mg ppm	DS ppm	TS ppm	Mn ppm
Source								
PB 7 well	24.5	7.5	1,265	181	181	772	772	0.022
Sepanal 2	24.3	7.6	1,168	167	173	698	698	
Cuauhtémoc 1 well	24.5	7.5	1,166	186	134	703	703	
Cuauhtémoc 2 well	24.4	7.8	1,155	190	134	712	712	
Cuauhtémoc 3 well	24.4	7.6	1,088	164	118	660	660	
Cuauhtémoc 4 well	24.3	7.6	1,191	170	156	719	719	
Cuauhtémoc 5 well	24.6	7.6	1,233	162	162	763	763	
PB 15 well	24.4	7.3	1,623	227	245	999	999	
PB 11 well	24.3	7.6	1,155	186	134	695	695	
PB 11 well	24.8	7.6	1,145	170	128	691	691	
PB 14 well	24.7	7.8	1,073	155	128	585	585	
PB 6 well	24.8	7.8	1,028	150	124	568	568	
Serrano well	24.7	7.3	819	156	108	520	520	
Brewery well								
PB 12 well	24.9	7.5	1,064	148	122	686	686	
PB 13 well	24.7	7.3	1,121	212	140	685	685	
River 1 well	24.5	7.6	1,060	164	138	638	638	
River 2 well	24.6	7.4	1,063	158	130	609	609	
River 3 well	24.5	7.5	1,054	152	130	607	607	
Cold Water well	25.3	7.3	588	101	70	328	328	
Wells for load of tank truck								
PB 2 well	24.4	7.5	1,060	162	140	640	640	
PB 4 well	24.6	7.6	1,020	150	120	560	560	
Cuchuma Drinking Water Treatment Plant.								
Cuchuma raw water	26.2	8.0	1,458	203	151	887	887	
Cuchuma treated water	26.3	7.8	1,468	199	155	886	886	
Standard Quality I		7.0 to	-	250	125	500	500	

		9.0							
Quality II		6.5 to 8.5	-	300	-	1,000	1000	0.150	

Note: Standard Quality Y- Water Quality Criteria, EPA 440/S 86-001 Standard Quality II Secretaria de Salud, Norma Oficial Mexicana NOM-127-SSAI-1994.

Source: CESPTE, 1997.

San Diego County

The sustained groundwater pumping of the 1950s, at rates twice the average annual natural recharge or safe yield, resulted in a groundwater decline of 23 to 30 feet (7 to 9 m) or more in the Tijuana River valley. By the early 1960s, groundwater table elevations across much of the valley had fallen below sea level. Due to this lowering of the groundwater table, highly saline groundwater from underline and adjacent marine sediments and sea water began to invade and to degrade the alluvial aquifer. This salt water degradation contributed to the decline in demand for Tijuana River valley groundwater in the 1960s. As consumption eventually became less than natural recharge, the resulting annual surplus of supply began to overcome years of accumulated deficits, and water levels began recovering as early as the mid 1960s.

Today, the quality of groundwater in the Tijuana River valley is still characterized by high sodium chloride and high total dissolved solids. These high salinity levels prevent the current use of well water for irrigation of salt-sensitive crops cultivated within the valley. As a result of lowered groundwater levels and seawater intrusion, groundwater TDS concentrations along the coast have exceeded 27,000 milligrams per liter (mg/l) (a standard TDS content generally ranges between 1000 and 1500 mg/l). In the Department of Water Resources Bulletin 106-2, the Tijuana River valley groundwater was rated generally inferior for domestic use due to its high sulfate and high fluoride concentrations (State of California 1967). It was also rated generally inferior for irrigation purposes because of high electrical conductivity, high chloride levels, and high percentage of sodium in the Spooners Mesa area. In addition to seawater intrusion, the poor quality of the groundwater is also attributed to leakage of sodium chloride from the San Diego Formation, irrigation return, and groundwater movement from beyond the international boundary (State of California 1967).

Nevertheless, the Water Quality Control Plan for the San Diego Basin designates municipal and domestic supply, agricultural supply, and industrial service supply as beneficial uses for the groundwater east of Hollister Street. These beneficial uses do not apply west of Hollister Street (IBWC and U.S. EPA 1996).

Groundwater elevation and quality data were received from the California Department of Water Resources. However, most of the data were from the 1950s and 1960s, when the groundwater was heavily used and degraded. Due to the lack of use of lower Tijuana River groundwater because of excessive salinity and overdrawing, as described earlier, the groundwater quality was not documented for a number of years. Collection of water quality data resumed in 1995, and is currently the responsibility of the Tia Juana Valley County Water District (TJVCWD). Planning documents have been prepared and a great deal of conductivity (salinity) data have been collected to assess and model the groundwater of the Tia Juana River Valley. Some of the conductivity data are illustrated in Table 3.26. Comparing the historic and current groundwater quality is not very useful, since the water quality, particularly salinity, is dictated by the coastal infiltration and overdrawing of groundwater. Future use of data is being applied as a planning tool for assessing the use and storage of groundwater in the Tia Juana River Valley.

Table 3.26. Groundwater Quality Data for the Tia Juana River Valley Gathered in April 1993

Well Id.	TDS	Pb	Ag	Se	Al
3	1,897	.410	1.65		
6	6,880	.038		.014	
9	1,911	.010		.012	38.5
13	1,979	.029		.016	
14	1,584	.037		.017	
20	2,347	.014		.017	

Source: Tia Juana Valley County Water District, 1997.

In addition to coliform data gathered in coastal areas, the land use section of the San Diego County Department of Environmental Health collects information on groundwater, including the eastern part of the watershed in the United States. Coliform testing for groundwater wells are usually done by the department with a pass /fail result. This information is not being collected within a database. However, nitrate data are also collected when construction of wells is completed and at other times. These data are being recorded within a database by the land use section. The data received include groundwater nitrate data for all of San Diego County. Unfortunately, the data are not searchable to identify locations only in the Tijuana watershed. For the purposes of this study, sites in the towns of Potrero, Campo, and Pine Valley were selected for analysis. According to County Department of Environmental Health data, there are 113 sites (Campo 79, Potrero 23, and Pine Valley 11) where nitrate levels were less than 25 ppm (most of them with no nitrate concentration). Conversely, there are only 18 sites (Campo 12, Potrero 5, and Pine Valley 1) where nitrate levels were 50 ppm. In addition, the land use section also collects total dissolved solids information for wells. However, like coliform data, this information is not in a database (San Diego Department of Environmental Health 1997).

Prevention and Control of the Contamination of Water Bodies

Water Quality of Discharges from Wastewater Treatment Plants in the Watershed

This section reviews the water quality of wastewater treatment plant discharges within the watershed. The principal wastewater treatment plants associated with the watershed are the plant located in Punta Bandera, the new International Wastewater Treatment Plant in the United States at the border, and the Tecate Wastewater Treatment Plant. There are small-scale, low technology wastewater treatment operations at ranches in residential areas within the watershed, including a documented site in Campo in the United States. Most of these small-flow treatment systems have little or no water quality impacts in the watershed.

Tijuana

Water quality data from 1991 to 1996, for the Tijuana wastewater treatment facility at Punta Bandera were examined. Although this plant is not in the watershed, most of the wastewater it treats comes from the watershed. As to the general evaluation of water quality during and after treatment at Punta Bandera, the following tables show that most of the parameters are well above the allowed standards. A decrease in the quantity can be observed. In some of the data, the value for the discharge at sea exceeds the capacity of the treatment plant. The plant does not have the capacity to treat all the wastewater being generated from the city of Tijuana. When water arrives at the treatment plant, nearly half of it is separated into a channel where it is diverted to the end of the treatment and is just chlorinated. Treated water is then mixed with untreated water at the lagoons, and higher levels of nearly all the parameters can be seen. The new International Wastewater Treatment Plant will divert some of this excess wastewater so that the Punta Bandera plant will be able to manage and properly treat the total amount of water that reaches it.

There was also a high level of Chemical Oxygen Demand (COD), as can be seen in Table 3.27. The allowed parameter for COD in Mexico from treated wastewater discharges is 100 mg/l, and every one of the points exceeds this parameter. The data show a decrease in COD levels from 1991 to the present.

The allowed standard for Biological Oxygen Demand (BOD) is 50 mg/l, and all the data shown in Table 3.28 indicate amounts higher than should be allowed, but there is a decrease in BOD levels from earlier years to the present.

Levels for oil and grease are much higher than the allowed standard value of 10 mg/l, as can be seen in Table 3.29. The data from 1996 show a very clear decrease from levels from 1992, which means that less grease and oils are being discharged into the sewer system. The standard parameter for oils and grease could not be located.

The same tendency that is occurring for other parameters can be seen in Table 3.30 for total solids. There is a general decrease from 1991 to 1996, but a higher level for discharge to the sea than there is for wastewater after being treated at the plant.

The pH parameter is the only one that has not exceeded its standard parameter of 6 to 9. It has been a constant value of 7.2 to 7.7 from 1991 to 1996 as can be seen in Table 3.31.

Table 3.27. Chemical Oxygen Demand at Punta Bandera Treatment Plant

COD (mg/L)			
Year	Affluent	Plant	Sea
1991	616	247	*
1992	522	242	240
1993	496	324	315
1994	523	375	384
1995	509	266	372
1996	491	237	381

* Data not available.

Source: CILA, 1997.

Table 3.28. Biological Oxygen Demand at Punta Bandera Treatment Plant

BOD (mg/L)			
Year	Affluent	Plant	Sea
1991	328	102	100
1992	277	89	92
1993	275	186	185
1994	271	189	201
1995	252	116	166
1996	245	99	156

Source: CILA, 1997.

Table 3.29. Oil and Grease at Punta Bandera Treatment Plant

Oil and Grease mg/L			
Year	Affluent	Plant	Sea
1992	280	187	185
1993	106	64	66
1994	124	94	123
1995	132	73	97
1996	51	23	43

Source: CILA, 1997.

Table 3.30. Total Solids at Punta Bandera Treatment Plant

Total Solids mg/L			
Year	Affluent	Plant	Sea
1991	1,668	1,495	1,494
1992	1,625	1,491	1,463
1993	1,440	1,264	1,377
1994	1,651	1,463	1,504
1995	1,412	1,224	1,332
1996	1,444	1,188	1,353

Source: CILA, 1997.

Table 3.31. The pH at Punta Bandera Treatment Plant

pH			
Year	Affluent	Plant	Sea
1991	7.2	7.2	7.3
1992	7.5	7.5	7.7
1993	7.3	7.2	7.5
1994	7.4	7.3	7.4
1995	7.3	7.5	7.5
1996	7.4	7.4	7.5

Source: CILA, 1997.

The standard parameter for ammonia-N was not located, but one point stands out in Table 3.32. The discharge to the sea in 1995 was eight times higher than the amount recorded for other groups.

Table 3.32. Ammonia-N at Punta Bandera Treatment Plant

Ammonia-N (mg/L)			
Year	Affluent	Plant	Sea
1994	37.3	35.2	35.2
1995	34.8	33.4	299.8
1996	29.3	24.1	27.7

Source: CILA, 1997.

Surfactants, also called detergents, have an allowed standard value of 5 mg/L. The data indicate higher levels than there should be, as seen in Table 3.33. There is a decrease in 1996 from the values in the data from several years earlier.

Table 3.33. Surfactants at Punta Bandera Treatment Plant

Surfactants (mg/L)			
Year	Affluent	Plant	Sea
1994	20.4	18.7	18.9
1995	17.9	14.9	21.0
1996	18.5	10.7	12.2

Source: CILA, 1997.

Tecate

Table 3.34. Water Quality Data of the Tecate Wastewater Treatment Facility June 30, 1997

Parameter	Influent	Effluent	Max allowed*
pH	7.4	7.2	6 to 9
Total Suspended Solids mg/L	362.0	43.0	40
Oils and Grease mg/L	<20.0	<20.0	20
Ammonia-N mg/L	18.0	19.6	15
COD mg/L	732.0	182.0	140

* Maximum allowed values by CNA of discharges for this plant.
Source: Comisión Estatal de Servicios Públicos de Tecate, 1997.

The data shown in Table 3.34 indicate an efficient treatment at the Tecate Wastewater Treatment Plant. Nevertheless, results for COD were slightly higher than the allowed parameter. However, the plant has an efficiency of 75 percent in terms of COD removed. Other parameters of interest, such as BOD, and surfactants were not included in the data obtained.

San Diego County

No major NPDES dischargers exist on the U.S. side of the Tijuana River watershed. In the upper U.S. part of the watershed in the United States, populations and water resources are sparse. Therefore, most wastewaters are treated with septic tanks or low technology wastewater treatment. In the lower section of the watershed, where populations and industrial activity increase, most wastewater is pumped out of the watershed and discharged via the Point Loma Wastewater Treatment Plant. The El Campo ranch is an example of a low flow NPDES discharger within the watershed. Data were available for this discharger from the Department of Environmental Quality. Table 3.35 shows discharge data for the El Campo Ranch Wastewater Treatment Plant. Even though the small El Campo plant is within the Tijuana River basin, the data obtained indicate water quality within the expected parameters.

Table 3.35. El Campo Ranch Effluent Monitoring Report (mg/L)

Month	TDS	SO_4	BOD	TSS	Surfactant	NO_3	pH
March \ 91	693.0	169.0	41.5	17.3	0.14	0.0	7.6
June	703.0	88.0	29.4	133.0	0.14	31.0	7.5
September	700.0	86.0	44.8	22.5	3.00	<0.1	7.6
December	59.4	69.0	93.2	20.0	0.24	0.4	7.4
March \ 92	688.0	78.0	24.7	10.0	0.50	47.8	7.8
June	663.0	75.0	27.0	25.8	0.52	64.7	7.6
September	755.0	70.0	13.9	22.8	0.40	102.0	7.9
December	828.0	116.0	15.0	20.7	0.50	95.0	8.0
March \94	630.0	80.0	20.4	-	-	71.3	8.0
June	636.0	48.0	4.9	-	-	25.7	7.6
September	738.0	78.0	8.3	-	-	66.0	7.6
December	774.0	79.0	216.0	-	-	110.0	8.0
March \ 95	624.0	62.0	9.2	-	-	62.0	7.9
June	686.0	82.0	14.1	-	-	45.0	7.8
September	706.0	60.0	79.0	-	-	<0.6	8.0
December	650.0	65.0	21.9	-	-	100.0	7.8
June \96	668.0	64.7	25.2	-	-	77.1	7.2
December \96	822.0	59.2	17.8	-	-	115.0	7.8

Source: Reams, George provided data at personal interview. County Department of Public Works Wastewater Management Division, 1997.

Registered Discharges in the Tijuana Area

Article 27 of the Mexican Constitution identifies national waters in Mexico as those in the territorial seas as determined by international law; internal marine waters lagoons and estuaries that are permanently or intermittently connected with the sea; interior natural lakes that are connected to water currents; rivers from their headwaters whether permanent, intermittent, or torrential to the river mouth at the sea, lake, lagoon, and estuary within Mexico; the effluent of rivers that serve as the internal or national boundaries; the waters of lakes, lagoons, and estuaries that are crossed by international borders; springs discharging into maritime zones, riverbeds, shores of lakes, lagoons, or estuaries within Mexican territory; mine drainage; and all water courses, riverbeds, shorelines of interior lakes and other currents as established by law (Wakida 1996).

Table 3.36. Registered Discharges to National Waters and Others

Receiving Body of Water	Number
Absorption Well	17
Garden Watering	5
Pacific Ocean	2
Matanuco Creek	5
Alamar Creek	2
Superficial Infiltration	1
El Florido Creek	5
Lagoon	1
Unknown	10

Source: CNA, 1996.

Table 3.36 contains data obtained from industries in the Tijuana region that discharge their wastewater to bodies of water other than the municipal sewer system. Table 3.36 shows the number of discharges registered by Comisión Nacional del Agua (CNA) in the Tijuana region and the body of water receiving these discharges.

An analysis of the data of 48 industries found that 25 percent of them pretreat their wastewater, 17 percent have plans to do the same, but the majority, 58 percent, have nothing planned. However, when analyzing the actual volume of water, 49 percent of the wastewater is treated and producers of 48 percent of the volume have plans to treat the water. No plans exist for treatment for 3 percent of the volume (CNA 1996).

Contaminated Zones with Potential Risk to Pollute Surface and Groundwater in the Tijuana Area

According to the PROFEPA files, there are some sites in Tijuana that have a pollution problem that can affect nearby water bodies. These sites include the Industrial Zone (Mesa de Otay), Cañón del Padre, and El Florido (Alco Pacífico).

Industrial Zone (Mesa de Otay)

A study was conducted between 1992 and 1993 where samples were taken from three discharges not made into the sewer system in the industrial zone (Sepúlveda 1994). It was found that the parameters for oil and grease, COD, detergents, sedimentable solids, and some metals like iron, chromium, and lead were above the maximum parameters allowed (Sepúlveda 1994).

The data obtained indicate that most parameters are above the allowed value, according to international standards for wastewater quality. The highest levels were oil and grease, COD, surfactants, and suspended solids. This shows that there was no discharge control. The complete data are shown in Appendix 4 (Sepúlveda 1994).

El Florido (Alco Pacífico)

Alco Pacífico was a company that worked on recuperating lead from wasted batteries. The process included battery reception, battery breakdown, recuperation of acids, plastic recuperation, melting oxides and lead plates, and molding and storing of lead ingots. This process generated hazardous waste, such as lead scoria, lead oxides, acidulated water, and melting ashes.

At the site, about fifteen thousand tons of metal scoria were found, as were five hundred thousand tons of metal waste. In all, there were approximately 11,000 m^3 of material broken down into fine fragments arising from the process of baking and refinement. Part of this material was dispersed by action of wind and rain.

According to a study done by a private firm, Levine-Fricke, it was determined that the freatic layer had not been contaminated with heavy metals. Some soil samplings showed concentrations of antimonium, arsenic, cadmium, copper, lead, and selenium above the established limits according to the Ecological Technical Norm NTE–CRP–011/88; these contaminants were found at a depth less than 0.60 m from the surface in the southern part of the site (PROFEPA 1992).

Cañón del Padre

The western part of the Cañón del Padre has encountered problems with contamination generated by several sources that include clandestine trash dumping sites, both domestic and industrial, and untreated wastewater directly discharged to the canyon by the Industrial City "Nueva Tijuana" (PROFEPA 1992).

The area has serious ecological problems. It was detected that some of the discharges from companies did not comply with water quality standards. Also, a continuing deterioration of the soil exists because of ongoing clandestine trash dumping.

In October 1990, an analysis of samples taken in Cañón del Padre was done in the United States by Quality Assurance Laboratory. The samples were taken from a site that was described, but could not be located on a map by the researchers. In three days of sampling, small quantities of heavy metals were detected, confirming the existence of industrial waste. The parameters for

BOD, COD, iron, detergents, oils and grease were high. It was not specified under which norm or standards this conclusion was reached.

In an analysis done by Mexicali Laboratory, six points were sampled, but their locations were not identified on a map. The samples were taken from wells 1, 2, 3, and 4; sediments at Ejido Chilpancingo; and a stream located at Ejido Chilpancingo. The analysis indicated that the wells' water quality is within the allowed standards for domestic use regarding physical and chemical parameters, wastewater, and heavy metals.

Trace Metal Accumulation in Soil in Nueva Tijuana Industrial City and Bordering Regions

Five samplings were carried out in Nueva Tijuana, the industrial zone of Mesa de Otay, to determine the geoaccumulation levels of metals in the soil (Temores 1995). Trace levels of metals were detected in two of the sites. The following order of geoaccumulation was determined from the results: Cd>Cu>Cr>Pb>Ni>Zn (Temores 1995).

This highly contaminated soil could pollute the aquifer through rainwater that infiltrates the soil and carries these trace metals into the aquifer layer. There were high levels of zinc and lead as trace metals in the samples taken. In the level of geoaccumulation, cadmium and copper had the highest levels. Appendix 5 shows the mean concentration and the geoaccumulation of trace metals in Nueva Tijuana and the adjacent region.

It can be determined that water is the main method of propagation for heavy metals in the analyzed zones due to discharges that are not conduced to the municipal sewer system and that later come in contact with soil in these areas (Sepúlveda 1994). In these same areas, there are several vegetable crops and human settlements. This implies a toxicological risk, be it from direct human contact with the trace metals or through indirect contact from bioabsorption in the locally produced crops (Temores 1995).

Due to the variability in the collection of water quality data—from special studies to continuous monitoring and technical and administrative differences in monitoring in the United States and Mexico—it is very difficult to understand trends in water quality. There are more recent efforts, for example in the Border XXI program, to establish a consistent monitoring program with established indicators to access trends. Despite the lack of consistent data, some generalizations can be made. The majority of the pollutant sources in the watershed come from Mexico. However, this is not an obvious situation since the explosion in population and industry has been primarily on the Mexican side. In fact, a great deal of the runoff of the watershed on the U.S. side is diverted outside the watershed through water transfers from Barret Lake to the Otay Reservoirs. This limits most of the impact from the United States to the lower section of the watershed.

Based on the frequency of pollutants monitored, fecal coliform and certain heavy metals are primary pollutants of interests. Fecal coliform data have been highlighted more for water quality for recreational activities associated with the beaches near the outlet of the Tijuana estuary.

Conclusion

In recent years, water contamination in the Tijuana watershed has been a subject of great interest because of its effects on aquatic ecosystems and public health. For this reason, governmental authorities and the public have to participate in the prevention and control of water contamination. That is why it is necessary for the authorities to force industries to comply with the discharge standard. Authorities should encourage a higher public participation in these issues.

The data analyzed showed that there has been an improvement in water quality in the Tijuana River, as well as the wastewater from Tijuana in terms of heavy metal concentrations and organic matter. The Mexican environmental agencies have enforced, in a more effective way, the wastewater quality standards for industries. This improvement though, has not happened in the Tecate River, where data showed that the water quality is poor. The Tecate Wastewater Treatment Plant has only recently been placed in service.

Stormwater runoff seems to be one of the major sources of heavy metals in the Tijuana River estuary. The studies analyzed showed that zinc had the highest concentration in the Tijuana River estuary.

To assure better water quality, government agencies in Mexico, such as Dirección General de Ecología, of the state of Baja California, are enforcing laws established to protect the environment, including water quality. Industries are being pressured to properly pretreat their wastewater prior to discharge into the municipal sewer system. An improvement in water quality was observed, as well as better relations among the different agencies on both sides of the border.

APPENDIX 1

Table 1. Coliform Values at the Tijuana River and Nearshore Area

Site	Date	Total Coliform	Fecal Coliform
Tijuana river mouth	02-Jul-90	5,400	490
Tijuana river mouth	02-Jul-90	5,400	490
Tijuana river mouth.	05-Jul-90	<20	
Tijuana river mouth	05-Jul-90	<20	
Tijuana river mouth	09-Jul-90	20	20
Tijuana river mouth	09-Jul-90	20	20
Tijuana river mouth	16-Jul-90	5,400	1,700
Tijuana river mouth	16-Jul-90	5,400	1,700
Tijuana river mouth	23-Jul-90	80	80
Tijuana river mouth	23-Jul-90	80	80

Tijuana river mouth	30-Jul-90	<20	<20
Tijuana river mouth	30-Jul-90	<20	<20
Tijuana river mouth	06-Aug-90	490	110
Tijuana river mouth	06-Aug-90	490	110
Tijuana river mouth	13-Aug-90	<20	
Tijuana river mouth	13-Aug-90	<20	
Tijuana river mouth	20-Aug-90	20	20
Tijuana river mouth	20-Aug-90	20	20
Tijuana river mouth	27-Aug-90	80	20
Tijuana river mouth	27-Aug-90	80	20
Tijuana river mouth	04-Sep-90	5,400	1,300
Tijuana river mouth	04-Sep-90	5,400	1,300
Tijuana river mouth	17-Sep-90	20	<20
Tijuana river mouth	17-Sep-90	20	<20
Tijuana river mouth	24-Sep-90	80	80
Tijuana river mouth	24-Sep-90	80	80
Tijuana river mouth.	08-Oct-90	<20	
Tijuana river mouth.	08-Oct-90	<20	
Tijuana river mouth	15-Oct-90	203	140
Tijuana river mouth	15-Oct-90	203	140
Tijuana river mouth	22-Oct-90	20	20
Tijuana river mouth	22-Oct-90	20	20
Tijuana river mouth	29-Oct-90	5,400	3,500
Tijuana river mouth	29-Oct-90	5,400	3,500
Tijuana river mouth	05-Nov-90	50	<20
Tijuana river mouth	05-Nov-90	50	<20
Tijuana river mouth	13-Nov-90	50	20
Tijuana river mouth	13-Nov-90	50	20
Tijuana river mouth	26-Nov-90	790	790
Tijuana river mouth	26-Nov-90	790	790
Tijuana river mouth	03-Dec-90	20	20
Tijuana river mouth	03-Dec-90	20	20
Tijuana river mouth	10-Dec-90	790	330
Tijuana river mouth	10-Dec-90	790	330
Tijuana river mouth	17-Dec-90	50	20
Tijuana river mouth	17-Dec-90	50	20
Tijuana river mouth	07-Jan-91	>=240,000	>=240,000
Tijuana river mouth	07-Jan-91	>=240,000	>=240,000
Tijuana river mouth	14-Jan-91	330	330
Tijuana river mouth	14-Jan-91	330	330
Tijuana river mouth	22-Jan-91	230	230
Tijuana river mouth	22-Jan-91	230	230
Tijuana river mouth	28-Jan-91	490	490
Tijuana river mouth	28-Jan-91	490	490
Tijuana river mouth	04-Feb-91	20	20
Tijuana river mouth	04-Feb-91	20	20
Tijuana river mouth	11-Feb-91	80	80

Tijuana river mouth	11-Feb-91	80	80
Tijuana river mouth	19-Feb-91	230	230
Tijuana river mouth	19-Feb-91	230	230
Tijuana river mouth	25-Feb-91	330	110
Tijuana river mouth	25-Feb-91	330	110
Tijuana river mouth	04-Mar-91	1,700	330
Tijuana river mouth	04-Mar-91	1,700	330
Tijuana river mouth	11-Mar-91	490	490
Tijuana river mouth	18-Mar-91	20	<20
Tijuana river mouth	18-Mar-91	20	<20
Tijuana river mouth	22-Mar-91	>24,000	16,000
Tijuana river mouth	22-Mar-91	>24,000	16,000
Tijuana river mouth	27-Mar-91	>=24,000	>=24,000
Tijuana river mouth	27-Mar-91	>=24,000	>=24,000
Tijuana river mouth	28-Mar-91	>=24,000	>=24,000
Tijuana river mouth	28-Mar-91	>=2,4000	>=24,000
Tijuana river mouth	08-Apr-91		
Tijuana river mouth	08-Apr-91		
Tijuana river mouth bottle #17870	15-Apr-91	80	<20
Tijuana river mouth bottle #17870	15-Apr-91	80	<20
Tijuana river mouth	23-Apr-91	<20	
Tijuana river mouth	23-Apr-91	1,300	490
Tijuana river mouth	23-Apr-91	<20	
Tijuana river mouth	23-Apr-91	1,300	490
Tijuana river mouth	07-May-91	5,400	490
Tijuana river mouth	07-May-91	5,400	490
Tijuana river mouth	13-May-91	20	<20
Tijuana river mouth	13-May-91	20	<20
Tijuana river mouth	20-May-91	5,400	170
Tijuana river mouth	20-May-91	5,400	170
Tijuana river mouth	28-May-91	<20	
Tijuana river mouth	28-May-91	<20	
Tijuana river mouth	03-Jun-91	170	50
Tijuana river mouth	03-Jun-91	170	50
Tijuana river mouth	10-Jun-91	20	<20
Tijuana river mouth	10-Jun-91	20	<20
Tijuana river mouth	17-Jun-91	80	20
Tijuana river mouth	17-Jun-91	80	20
Tijuana river mouth	24-Jun-91	20	<20
Tijuana river mouth	24-Jun-91	20	<20
Tijuana river mouth	01-Jul-91	70	40
Tijuana river mouth	01-Jul-91	70	40
Tijuana river mouth	08-Jul-91	800	230
Tijuana river mouth	08-Jul-91	800	230
Tijuana river mouth	03-Sep-91	<20	
Tijuana river mouth	03-Sep-91	<20	

Tijuana river mouth	17-Sep-91	40	20
Tijuana river mouth	17-Sep-91	40	20
Tijuana river mouth	28-Apr-92	110	70
Tijuana river mouth	28-Apr-92	110	70
Tijuana river mouth	04-May-92	300	300
Tijuana river mouth	04-May-92	300	300
Tijuana river mouth	12-May-92	40	20
Tijuana river mouth	12-May-92	40	20
Tijuana river mouth	12-Aug-92	<20	
Tijuana river mouth	12-Aug-92	<20	
Tijuana river mouth	19-Apr-93	200	500
Tijuana river mouth	19-Apr-93	200	500
Tijuana river mouth	18-May-93	40	<20
Tijuana river mouth	18-May-93	40	<20
Tijuana river mouth	25-May-93	<20	
Tijuana river mouth	25-May-93	<20	
Tijuana river mouth	25-Jun-93	U	
Tijuana river mouth	25-Jun-93	U	
Tijuana river mouth	20-Jul-93	>=16,000	5,000
Tijuana river. mouth	20-Jul-93	>=16,000	5,000
Tijuana river mouth	26-Jul-93	>=16,000	9,000
Tijuana river mouth	26-Jul-93	>=16,000	9,000
Tijuana river mouth	30-Aug-93	170	20
Tijuana river mouth	30-Aug-93	170	20
Tijuana river mouth	19-Jan-94	>=16,000	>=16,000
Tijuana river mouth	19-Jan-94	>=16,000	>=16,000
Tijuana river mouth	25-Apr-94	2,400	800
Tijuana river mouth	25-Apr-94	2,400	800
Tijuana river mouth	23-Jun-94	<20	
Tijuana river mouth	23-Jun-94	<20	
Tijuana river mouth	27-Jun-94	20	20
Tijuana river mouth	27-Jun-94	20	20
Tijuana river mouth	25-Jul-94	20	20
Tijuana river mouth	25-Jul-94	20	20
Tijuana river mouth	29-Aug-94	<20	
Tijuana river mouth	29-Aug-94	<20	
Tijuana river mouth	11-Apr-95	5,000	1,700
Tijuana river mouth	11-Apr-95	5,000	1,700
Tijuana river mouth	24-Apr-95	<20	
Tijuana river mouth	24-Apr-95	<20	
Tijuana river mouth	10-May-95	>=16,000	16,000
Tijuana river mouth	10-May-95	>=16,000	16,000
Tijuana river mouth	17-May-95	500	300
Tijuana river mouth	17-May-95	500	300

Tijuana river mouth	22-May-95	9,000	2,400
Tijuana river mouth	22-May-95	9,000	2,400
Tijuana river mouth	19-Jun-95	230	230
Tijuana river mouth	19-Jun-95	230	230

Source: San Diego County Department of Environmental Health, 1997.

Appendix 2

Table 1. Heavy Metal Concentrations in Surface Sediments (3 centimeters of the surface) of the Tijuana River and Sites of the Northern Part of the Estuary

Site	Number	Cd	Cr	Cu	Ni	Pb	Zn
Tijuana River	1	0.05	4.23	4.41	3.76	8.17	21.09
	2	0.16	5.47	6.10	4.81	6.73	20.93
	3	0.71	17.86	22.22	14.11	59.13	125.70
	4	1.12	9.88	10.08	7.43	25.66	62.17
	5	2.02	13.14	17.11	13.37	35.07	90.63
	6	1.43	14.53	15.20	11.95	22.85	69.84
	7	1.06	25.27	24.66	19.31	54.44	125.58
	8	1.18	21.67	34.07	12.07	56.40	203.61
	9	0.79	9.72	12.63	7.92	67.93	66.59
	55	1.48	17.75	19.96	17.75	16.27	81.34
Tijuana River Mouth	22	0.05	2.83	0.88	0.96	1.42	4.77
	23	0.11	2.51	0.73	1.15	1.85	4.22
	24	0.09	2.83	0.60	1.34	1.64	10.33
	52	0.11	2.25	1.04	0.97	1.51	5.73
	53	0.14	2.95	1.38	1.30	1.72	6.72
Tijuana River Estuary	10	0.55	5.39	4.39	6.22	12.43	6.87
North part	11	1.85	9.15	12.20	10.46	8.48	29.47
	12	1.78	16.46	34.80	18.76	44.55	89.69
	13	0.17	6.29	2.11	2.30	3.62	8.74
	14	0.12	5.02	1.36	1.58	2.89	5.83
	15	0.42	10.19	8.99	7.03	14.24	37.77
	16	0.17	5.87	2.71	2.42	4.22	9.98
	17	0.14	7.38	2.14	2.36	6.19	10.07
	18	0.18	3.02	1.42	1.35	3.43	7.77
	19	0.15	6.99	2.08	2.27	3.77	7.08
	20	0.14	4.14	2.46	1.95	3.49	9.95

	21	0.09	0.43	1.43	1.77	1.99	4.56
	51	0.13	3.89	1.02	1.08	3.04	5.64
	54	0.20	7.40	2.52	2.00	4.13	10.85

Note: All the values are in ppm (mg/kg) dry weight
Source: Gersberg, Trindade, and Norby, 1989.

Appendix 3

Table 1. Heavy Metal Concentration in Surface Sediments (3 centimeters of the surface) of the Southern Part of the Estuary

Site	Cd	Cr	Cu	Ni	Pb	Zn
25	0.05	2.38	0.99	1.32	1.80	5.31
26	0.09	3.50	0.69	1.24	1.80	5.49
27	0.28	5.99	4.41	3.62	7.29	22.84
28	0.92	16.71	15.38	12.90	24.00	52.20
29	0.43	4.69	2.74	3.75	4.40	13.74
30	0.43	4.46	3.54	4.18	5.81	18.09
31	0.20	4.95	2.31	2.78	4.13	8.17
32	0.23	2.95	1.65	2.61	3.30	8.27
33	1.01	10.28	10.20	11.06	14.41	47.94
34	2.30	21.37	17.04	51.89	37.64	119.45
35	0.94	6.71	10.32	7.58	27.49	52.34
36	0.86	24.09	17.67	13.99	28.49	74.72
37	0.70	21.36	20.57	12.54	24.35	131.27
38	1.66	13.57	25.30	22.68	21.62	93.86
39	2.58	21.89	19.22	43.86	26.69	102.80
40	3.52	32.04	25.18	28.52	33.27	124.21
41	2.74	24.97	20.82	27.64	25.81	114.69
42	1.32	23.05	22.67	19.41	57.70	136.26
43	0.92	24.65	23.88	19.03	49.23	140.15
44	3.22	23.11	17.68	18.42	34.90	97.65
45	2.91	22.23	15.05	15.53	21.94	81.60
46	0.12	2.66	2.78	1.83	4.26	20.86
47	0.20	3.75	4.52	2.28	7.12	15.54
48	0.09	2.56	3.38	1.61	6.56	15.24
49	0.35	7.77	8.83	5.45	18.25	34.89

Source: Gersberg, Trindade, and Norby, 1989.

Table 2. Heavy Metal Concentration (dry weight) of Bottom Core Subsamples

Sampling Date	Site Number	Lead (ppm)	Copper (ppm)	Nickel (ppm)	Zinc (ppm)	Cadmium (ppm)
1/15/96	1	21.3	8.30	9.50	33.30	0.80
1/28/96	1	46.3	39.50	15.80	62.00	4.50
2/06/96	1	6.3	5.80	13.30	30.80	0.80
1/15/96	2	30.0	24.50	7.00	93.30	0.80
1/28/96	2	16.3	27.00	15.80	98.30	3.30
2/06/96	2	6.3	27.00	15.80	97.00	2.00
1/15/96	3	32.5	27.00	12.00	120.80	2.00
1/28/96	3	14.1	27.80	9.80	128.00	0.80
2/06/96	3	34.5	31.70	5.50	134.00	4.30
1/15/96	4	1.3	4.50	7.00	14.50	0.80
1/28/96	4	1.3	2.00	7.00	17.00	0.80
2/06/96	4	10.0	14.50	10.80	59.50	4.50
1/15/96	5	3.6	17.40	19.80	69.80	4.30
1/28/96	5	37.5	8.25	5.75	45.75	0.75
2/06/96	5	13.3	8.30	11.20	46.60	0.90
1/15/96	6	27.4	24.50	9.00	112.60	3.10
1/28/96	6	32.5	19.50	13.25	77.00	3.25
2/06/96	6	4.8	4.30	11.40	42.40	3.10
1/15/96	7	10.7	4.30	7.90	34.00	1.90
1/28/96	7	15.0	7.00	9.50	43.30	0.80
2/06/96	7	10.0	3.25	8.30	44.50	3.30
1/15/96	8	17.5	27.00	20.80	970.00	3.30
1/28/96	8	23.7	24.50	13.9	108.70	4.70
2/06/96	8	11.3	23.30	7.00	110.80	5.80

Source: Meyer, 1996.

Table 3. Heavy Metal Concentrations (dry weight) of Middle Core Subsamples

Sampling Date	Site Number	Lead (ppm)	Copper (ppm)	Nickel (ppm)	Zinc (ppm)	Cadmium (ppm)
1/15/96	1	33.8	35.8	28.30	62.0	2.00
1/28/96	1	13.8	54.5	30.80	129.5	8.30
2/06/96	1	38.8	47.0	33.30	125.8	7.00
1/15/96	2	26.3	29.5	22.00	125.8	0.80
1/28/96	2	25.6	21.8	33.00	97.0	5.80
2/06/96	2	15.0	47.0	5.80	110.8	4.50
1/15/96	3	31.3	29.5	24.50	100.8	0.80
1/28/96	3	35.0	29.5	15.75	102.0	0.75
2/06/96	3	28.8	32.0	32.00	104.5	3.30
1/15/96	4	23.8	6.7	28.10	101.9	4.31
1/28/96	4	14.3	0.7	25.70	23.3	0.70
2/06/96	4	20.2	6.7	18.60	48.3	1.90
1/15/96	5	20.0	14.5	19.50	65.8	2.00
1/28/96	5	25.0	32.9	22.10	69.8	1.90
2/06/96	5	28.8	7.0	22.00	39.5	0.80
1/15/96	6	31.3	20.8	25.80	109.5	5.80
1/28/96	6	35.5	24.5	33.70	96.8	2.10
2/06/96	6	36.3	18.3	22.00	72.0	3.30
1/15/96	7	11.3	12.0	14.50	28.3	2.00

1/28/96	7	20.0	7.0	27.00	34.5	0.80
2/06/96	7	126.9	8.9	37.30	53.5	8.90
1/15/96	8	6.0	17.4	24.90	83.4	5.40
1/28/96	8	17.5	15.8	20.80	80.8	0.80
2/06/96	8	28.8	28.3	25.80	109.5	9.50

Source: Meyer, 1996.

Table 4. Heavy Metal Concentrations (dry weight) of Top Core Subsamples

Sampling Date	Site Number	Lead (ppm)	Copper (ppm)	Nickel (ppm)	Zinc (ppm)	Cadmium (ppm)
1/15/96	1	112.5	304.5	158.30	402.00	12.0
1/28/96	1	51.3	244.5	139.50	402.00	15.8
2/06/96	1	70.0	65.8	39.50	234.50	10.8
1/15/96	2	36.3	29.5	34.50	123.30	2.0
1/28/96	2	13.1	32.8	34.20	123.00	8.1
2/06/96	2	47.5	30.75	38.25	118.30	4.5
1/15/96	3	50.0	28.3	33.30	117.00	0.8
1/28/96	3	33.8	22.0	32.00	110.80	4.5
2/06/96	3	31.3	32.0	40.80	123.30	2.0
1/15/96	4	30.0	0.9	23.40	18.90	2.4
1/28/96	4	11.3	2.0	8.30	42.00	0.8
2/06/96	4	18.8	8.3	30.80	45.80	2.0
1/15/96	5	56.4	25.3	25.30	113.70	0.9
1/28/96	5	45.0	32.0	38.30	142.00	0.8
2/06/96	5	17.5	3.3	23.30	53.30	2.0
1/15/96	6	23.8	25.8	29.50	114.50	7.0
1/28/96	6	26.3	19.5	29.50	72.00	2.0
2/06/96	6	22.5	15.8	27.00	75.80	3.3
1/15/96	7	22.5	7.0	22.00	35.75	0.9
1/28/96	7	21.3	10.8	19.50	35.80	3.3
2/06/96	7	23.1	5.9	34.20	27.80	4.6
1/15/96	8	26.2	38.8	38.80	110.20	5.5
1/28/96	8	43.8	22.0	32.00	100.80	0.8
2/06/96	8	20.0	22.0	33.80	105.80	3.3

Source: Meyer, 1996.

Appendix 4

Table 1. Sepúlveda Study (1994) Zone A

Period	Parameter	% above maximum allowed norms
Dec / Jun 1992	Oils and grease	95.5
	Conductivity	23.0
	COD	91.0
	Dissolved oxygen	46.0
	pH	0.0

	Dissolved solids	37.0
	Sedimentable solids	64.0
	Suspended solids	100.0
	Temperature	0.0
	Iron	73.0
	Manganese	37.0
	Copper	9.0
	Nickel	4.5
	Chromium	2.3
	Zinc	4.5
	Lead	9.0
	Detergents	100.0

Period	Parameter	% above maximum allowed norms
Feb/Jun 1993	Oils and grease	100.0
	Conductivity	19.0
	COD	82.0
	Dissolved oxygen	*75.0
	pH	0.0
	Dissolved solids	12.0
	Suspended solids	87.0
	Sedimentable solids	25.0
	Temperature	0.0
	Iron	87.0
	Manganese	0.0
	Copper	12.5
	Nickel	0.0
	Chromium	25.0
	Zinc	0.0
	Lead	25.0
	Detergents	100.0

* Represents percent below the minimum required.

Table 2. Sepúlveda Study (1994) Zone B

Period	Parameter	% above maximum allowed norms
Dec/ Jun 1992	Oils and grease	91.0
	Conductivity	14.0
	Dissolved oxygen	*82.0
	pH	4.5
	Detergents	100.0
	Dissolved solids	14.0
	Sedimentable solids	60.0
	Suspended solids	32.0
	Temperature	4.5
	Iron	81.0
	Manganese	4.5
	Copper	0.0
	Nickel	0.0

	Chromium	28.0
	Zinc	0.0
	Lead	22.0
	COQ	100.0

* Represents percentage below the minimum required.

Table 3. Sepúlveda Study (1994) Zone C

Period	Parameter	% above maximum allowed norms
Dec/Jun 1992	Oils and grease	100
	Conductivity	9
	COQ	95
	Dissolved oxygen	90
	pH	14
	Detergents	100
	Dissolved solids	9
	Sedimentable solids	73
	Temperature	0
	Iron	68
	Manganese	27
	Copper	0
	Nickel	0
	Chromium	50
	Zinc	0
	Lead	32
	Suspended Solids	100

Appendix 5

Table 1. Mean Concentration (mg/kg) of Trace Metals in Soil Samples from the Nueva Tijuana Industrial City, and Adjacent Regions

Zone	Cr	Zn	Cu	Pb	Cd	Ni
A	10.00	80.00	14.00	20.96	0.177	20.66
B	9.50	94.40	14.00	19.99	0.202	25.82
C	16.00	79.00	20.00	27.71	0.730	25.02
D	7.50	65.90	112.60	27.42	0.737	25.88
E	17.80	72.50	14.50	27.76	0.718	27.06
F	12.00	112.40	18.00	24.96	0.515	24.42
G	15.90	144.50	29.10	70.27	0.458	22.98
H	16.70	55.40	12.00	26.61	0.271	24.52
I	51.70	164.00	56.70	61.53	0.649	57.93
J	40.50	151.26	46.00	85.20	0.818	45.31

Source: Temores, 1995.

Table 2. Rate of Geoaccumulation (I.G.) of Trace Metals in Soil Samples from the Nueva Tijuana Industrial City, and Adjacent Regions

Zone	Cr	Zn	Cu	Pb	Cd	Ni
A	1.00	1.00	1.00	1.00	1.00	1.00
B	1.00	1.00	1.00	1.00	1.00	1.00
C	1.64	0.90	1.42	1.35	3.85	1.07
D	0.77	0.75	8.04	1.34	3.88	1.11
E	1.82	0.83	1.03	1.36	3.78	1.16
F	1.23	1.28	1.28	1.22	2.72	1.05
G	1.63	1.65	2.07	3.43	2.41	0.98
H	1.71	0.63	0.85	1.29	1.43	1.05
I	5.44	1.88	4.05	2.55	3.43	2.49
J	4.15	1.73	3.28	1.15	4.32	1.94

Source: Temores, 1995.

Table 3. Location of Sampling Sites

Site	Location	Description
Zone A	Nido de las Aguilas Hill	4 km northeast of Industrial City
Zone B	Fraccionamiento Magisterial	2 km northeast of Industrial City
Zone C	Boulevard Industrial	Mesa de Otay
Zone D	Cañon Industrial Tokabi	Between Tobaki and Cokin Industries
Zone E	Behind Opticas Industries	Canyon along the dry riverbed
Zone F	South part of Cokin Industries access to Ejido Chilpancingo	Water discharge
Zone G	Eastern part of Glenn Industries	Water discharge
Zone H	Farming area Las Granjas	Behind Glenn Industries
Zone I	Las Granjas	South of farming area
Zone J	Section of the Alamar River	South of Ejido Chilpancingo

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