Status Report on (I&I) Reduction Program

The following information is provided in response to the City Council's request for a status report on the City's infiltration and inflow (I&I) reduction program.

First some definitions, taken from *Existing Sewer Evaluation & Rehabilitation*, American Society of Civil Engineers/Water Pollution Control Federation, 1983:

- Infiltration is water entering a sewer system and service connections from the ground through such means as defective pipes, pipe joints, connections, or manhole walls.
- Inflow is water discharged into a sewer system and service connections from such sources as roof drains, yard and area drains, foundation drains, manhole covers, cross connections from storm sewers, surface runoff, or drainages.
- Excessive I&I is the quantity of I&I which can be economically eliminated from a sewer system by rehabilitation as determined by a cost-effective analysis that compares the cost of rehabilitation to the costs for transportation and treatment of the I&I.

Status of I&I Reduction

In a report titled *Infiltration/Inflow Study for the City of Rapid City, South Dakota,* completed in April, 1994 by the Alliance of Architects and Engineers, twelve sections of sanitary sewer line were identified as experiencing high infiltration. (A summary of the 1994 report is contained in Appendix A.) Table 1 below, taken from the 1994 report, lists the 12 sections with high I&I, the amount of infiltration in million gallons (MG) per year, and the current status of replacement or rehabilitation. The first nine sections were deemed to have excessive I&I, i.e., the costs of rehabilitation were less than the costs of transportation and treatment, and were recommended for replacement or rehabilitation. (It was determined that elimination of I&I from the remaining three segments was not cost effective.) The segment locations are shown on the attached map.

TABLE 1

Segment No.	Infiltration per Year (MG)	Replacement / Rehabilitation Status	Infiltration Removed (MG)
1	47.3	Done	47.3
2	120.9	On Long Range CIP	
3	73.1	On 5 Yr CIP for 2006	
4	13.1	Done	13.1
5	60.4	Done	60.4
6	26.3	Done	26.3
7	5.3	In RVSD system	
8	23.7	Done	23.7
9	1.6	On 5 Yr CIP for 2005	
10	15.6	On Long Range CIP	
11	21	On Long Range CIP	
12	11.4	In RVSD system	
Totals	419.7		170.8

Since 1994, significant amounts of I&I has also been removed by reconstructing additional segments of the sanitary sewer system in conjunction with other infrastructure projects such as street reconstruction. In those situations where the sewer fund can cost share for resurfacing, mobilization/demobilization, etc., removal of I&I becomes cost effective. Those segments are listed in Table 2 below with an estimate of the amount of infiltration removed, and are also shown on the attached map. The amount of infiltration is estimated on the basis of: 1) visual observations of depth of clear water flow made at the time of reconstruction, and 2) on minimum pipe slopes. The estimates are believed to be conservative, that is, actual measurements made by flow meters would likely show higher amounts of infiltration.

TABLE 2

Segment No.	Infiltration Removed (MG)
101	5
102	10
103	5
104	30
105	15
106	5
107	25
108	5
109	15
110	5
111	50
112	5
113	15
114	40
115	30
116	15
117	15
118	25
Total	315

The amount of I&I removed from the sanitary sewer system since the 1994 I&I study is 170.8 MG per year from the 1994 recommendations plus 315 MG per year from additional reconstruction projects for a total of 485.8 MG per year or an average of 1.33 million gallons per day (MGD).

The excerpts from McLaughlin Water Engineers' Facilities Plan contained in Appendix A discuss the impact of I&I on the water reclamation facility expansion.

Future Projects & Programs for I&I Reduction

Recommendations for further I&I reduction include:

1) Complete the rehabilitation of the remaining 3 projects within the City's system from the 1994 list;
2) Work with RVSD to reduce I&I in their system (Segments 7 and 12);
3) Initiate a pilot project to determine the most cost effective technique(s) to seal manhole chimneys;
4) Initiate a pilot project to determine the most cost effective technique(s) to seal manholes located in the gravel alluvium along Rapid Creek;
5) Initiate a pilot project to determine the most cost effective technique(s) to reduce discharges to the sewer system from service lines including foundation drains and basement sumps. Consider allowing seasonal (winter time) discharges only, constructing storm sewers to receive clear water discharges from foundation drains and basement sumps, and/or constructing groundwater drain systems to lower the water table.

Basis for Water Reclamation Facility Expansion

In 1996 the City contracted with Process Applications, Inc., Fort Collins, CO to assess the design of the WRF to determine if the major unit processes were capable of treating then current wastewater flow and pollutant loads to the levels required by the facility's discharge permit. The assessment utilized a formal process developed by the US Environmental Protection Agency called a Comprehensive Performance Evaluation (CPE) which also evaluates the operations, maintenance and administration of the facility. The resulting report, titled *Results of Comprehensive Evaluation for the City of Rapid City, South Dakota Water Reclamation Facility*, March 1996, concluded that:

"In summary, the major unit process evaluation shows that, except for the chlorine contact basin, the plant unit processes are rated at close to the current annual average flow rate (10.2 mgd) for the plant. The rotating biological contactors are the most limiting process in the plant. Their rating was based on meeting a "worst case" ammonia nitrogen limit of about 1.2 mg/L. Although the plant has a design capacity of about 13.5 MGD, permit requirements have become more stringent, resulting in overall reduced plant capacity. Based on these major unit process evaluation results and the steady population growth rate, the City should begin evaluating alternatives for providing additional plant capacity."

The *Facilities Plan for Rapid City Water Reclamation Facility*, 2000 by McLaughlin Water Engineers also contains an evaluation of the WRF's capacity in a section titled Current Plant Capacity which states:

"The facility currently experiences stable operations at flow rates of 10 MGD and BOD loadings of 17,100 lb/d. The effect of higher hydraulic loading on the plant performance is reflected in Figure III-10. The effect of higher organic loading on plant performance is reflected in Figure III-11. The existing facility is fundamentally sound, although in need of upgrades and repairs in certain areas. With some exceptions, the existing facilities are expected to continue to be serviceable through the 20-year planning period. *Additional capacity is required to serve the growing population in the service area, and expansion of the service area* (emphasis added).

The current hydraulic capacity of the plant is 20 MGD. At flows in excess of this amount the weir in the clarifiers become submerged."

In a section titled Increased Capacity Requirements, the Facility Plan concludes:

"Based on the projected wastewater flows, loadings and anticipated wastewater discharge criteria, the plant expansion should provide for the following:

- Increased average flow capacity of 2.2 MGD
- Increased peak day flow capacity of 5.0 MGD
- Increased peak hour capacity of 10 MGD
- Increased average organic load capacity of 5,200 lb/d
- Increased average TSS load capacity of 5,200 lb/d"

Figure 1 – WRF Service Area Population, Figure 2 – Number of Water Accounts, and Figure 3 – WRF Annual Influent BOD Loadings show trends supporting the decision to expand the WRF's treatment capacity.

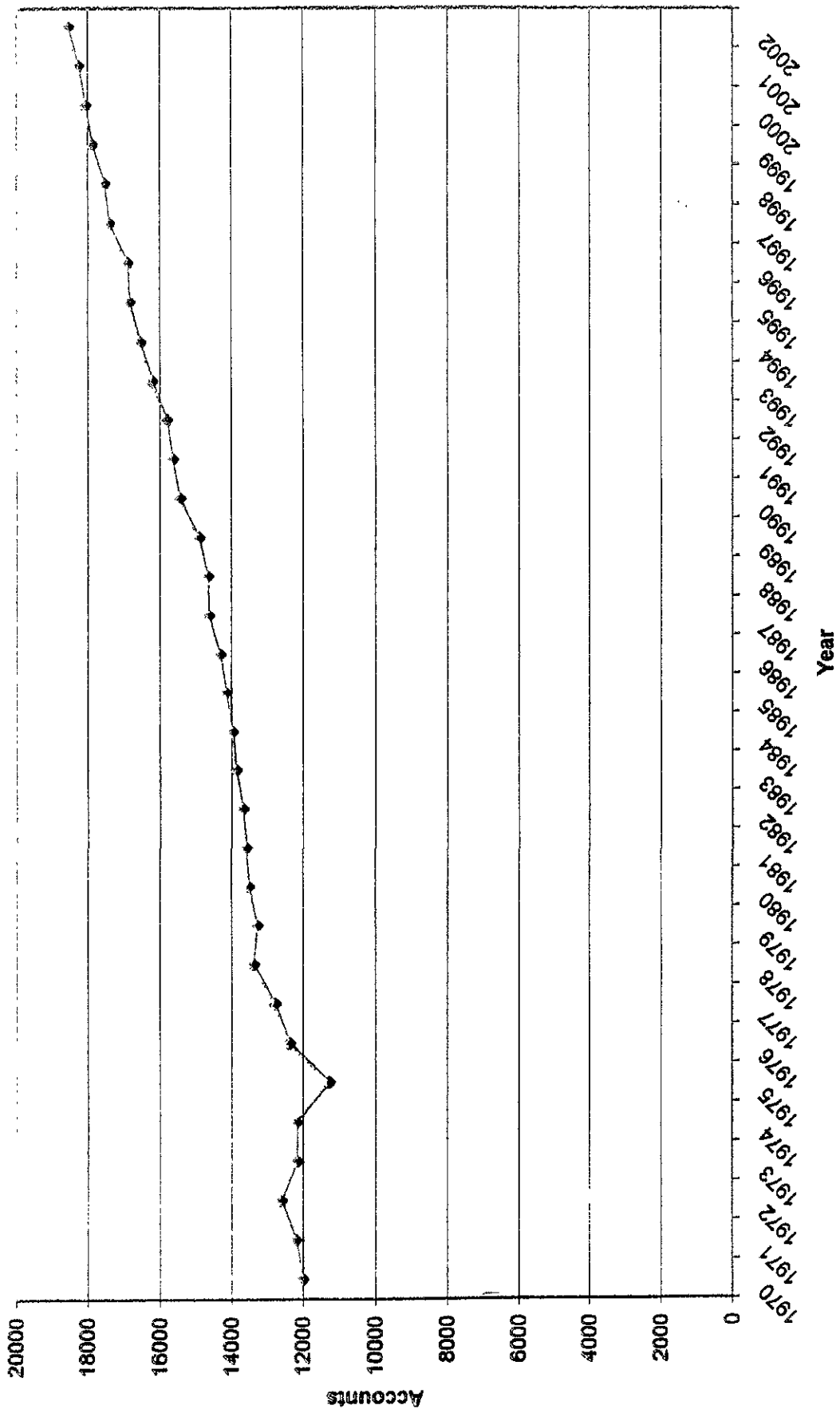


Figure 2 - Number of Water Accounts

Figure 3 - Rapid City WRF Annual Influent BOD Loadings

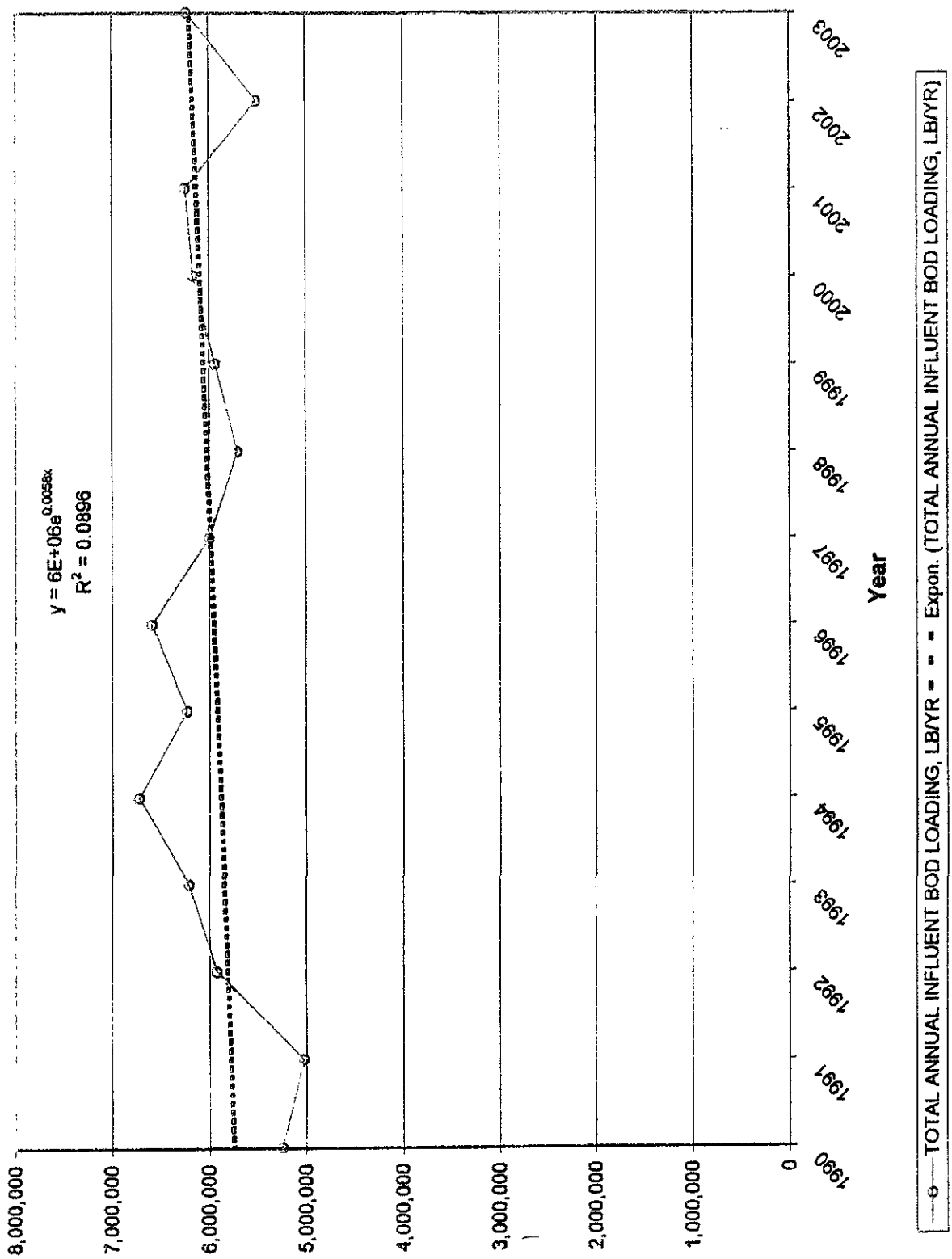
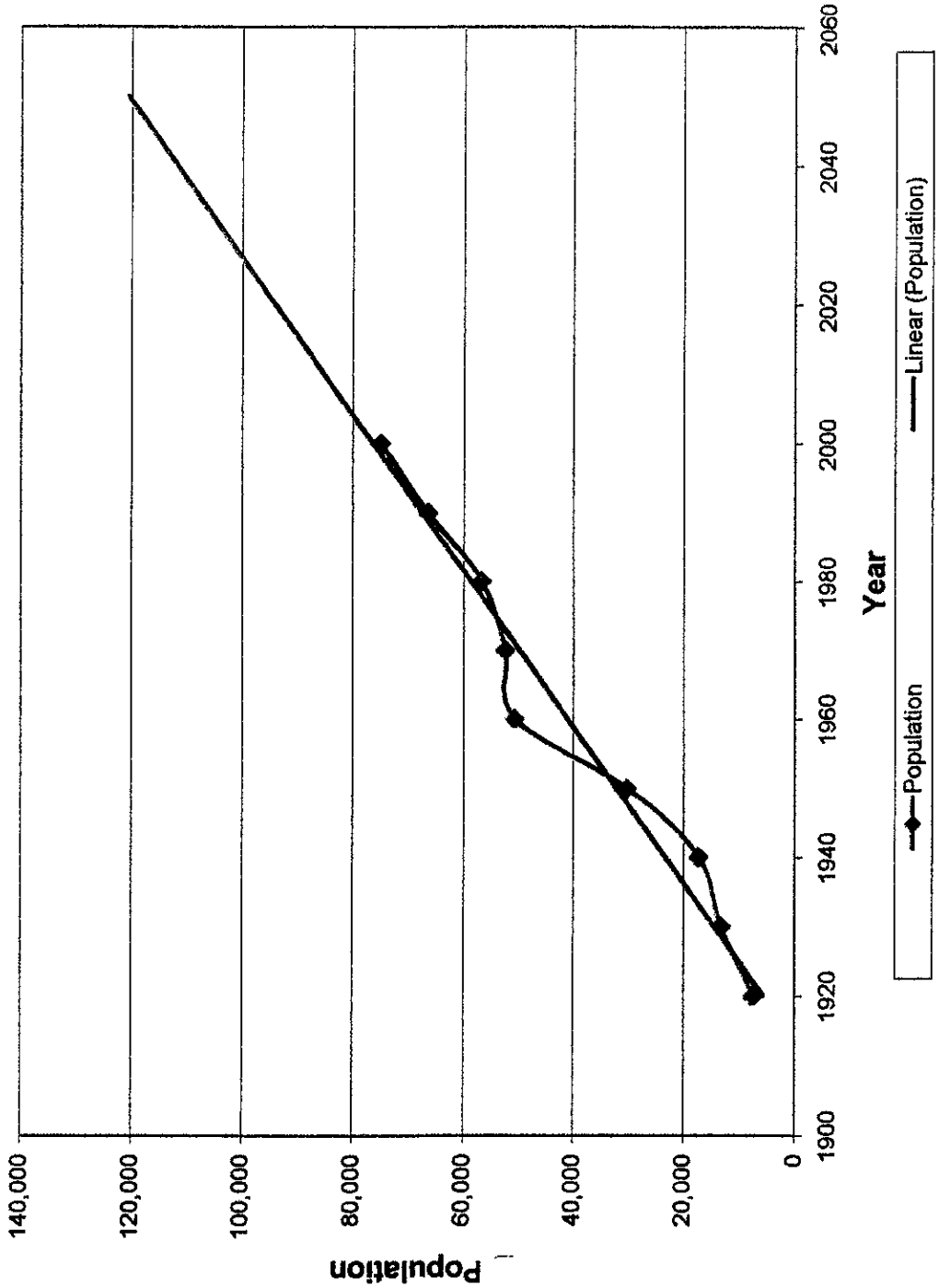


Figure 1 - Rapid City WRF Service Area Population



APPENDIX A

The *Facilities Plan for Rapid City Water Reclamation Facility*, 2000 by McLaughlin Water Engineers contains the following summary of the 1994 and 1997 I&I studies and discussion of I&I as it relates to the water reclamation facility expansion:

An *Infiltration/Inflow Study for the City of Rapid City, South Dakota* was completed in April, 1994 by the Alliance of Architects and Engineers of Rapid City. An important finding of this study was that flows entering the WRF exceeded total water production for the service area by about 1.7 mgd, even in periods of low groundwater, that is, the winter months. This was labeled the year-round, or "constant" infiltration. In addition, sewers located in the alluvial deposits along Rapid Creek, including creek crossings, were a major contributor to infiltration, but not the only contributor identified in the study. Sediment in sewer lines, generally thought to be a qualitative indicator of infiltration, was found to be a widespread problem, and an improved sewer cleaning program was recommended. The study calculated a theoretical I&I of 815 million gallons per year, which was the amount that WRF effluent exceeded water production, and actually measured 85 % of that value with its flow monitoring program. "Constant", or year-round, I&I was found to be almost 80 % of the total I&I. A cost effectiveness analysis was performed and a list presented of sewer segments that were cost effective to replace. The study indicated that replacing those lines would eliminate 45 % of the total infiltration. In our experience the impact of private service lines and the ability of groundwater to migrate to the weakest links in a sewer system can make significant reduction of I&I difficult.

In October, 1997, CETEC Engineering Services, Inc. prepared a *Summary Report, Southeast Rapid City Infiltration/Inflow Study, for the City of Rapid City.* The study area was a 1300-acre urbanized area in Southeast Rapid City. The three- to four-block "problem area", where most sewer backups were occurring during heavy rainfall, was centered around the intersection of East Meade Street and Hawthorne Avenue, where two major trunk sewers join.

This study found that two-thirds of the 1.6 mgd average daily dry weather sewer flows in the study area was groundwater infiltrating or being pumped from basement dewatering systems. The sewers were also found to be severely impacted by storm water inflow and rainfall induced infiltration. Peak flows of four to eight times average flows in trunk sewers were recorded during two storm events. Seven to ten percent of total rainfall volume entered the sewer system during and after these rain events - two to three times the expected average - according to the study report. The study found that up to 90 % of groundwater infiltration is from private service lines, either from leaking service pipes or basement dewatering systems. Also, manhole covers and private service lines were suspected to be the main sources of storm water inflow in the study

area, and inflow originated from numerous widely distributed small sources rather than a few major sources. The City has embarked on an I&I control program to address these issues.

The study recommended upsizing much of the trunk sewer system in Southeast Rapid City, in the area most affected by surcharging during storm events. It was further recommended that the City implement demonstration projects within the study area to further analyze I&I problems. It was suggested that consideration be given to further I&I flow reduction in lieu of lower priority trunk sewer replacement.

The two previous I&I studies have outlined cost effective programs for eliminating part of the excessive I&I and preventing costly sewer backups. I&I reduction is an elusive goal, and many studies have been done in other cities across the country to determine the most cost effective approach. It appears that the consensus is that replacing a small percentage of the worst sewer lines and reducing inflow are cost effective, but system-wide I&I reduction programs do not result in savings in treatment costs sufficient to offset the expense to rehabilitate the entire collection system. Certainly, as older clay or concrete pipe is replaced with PVC by attrition, new construction uses service saddles, and stricter building standards preclude some of the worst I&I from private services, the I&I problem will be reduced.

With daily flows of greater than 120 gallons per capita per day (gpcd) during periods of high groundwater, the WRF is classified as having significant I&I. For 1996 and 1997, the wastewater flows were 150 and 160 gpcd respectively. However, these were very wet years, with some significant rainfall events resulting in excessive I&I. The average annual flow over the previous four years, 1992 through 1997, was 130 gpcd and we believe it to be more representative. Excessive I&I is defined by the EPA document *Construction Grants, 1985* as the quantity of I&I which is more economical to remove than to transport and treat. A cost effectiveness analysis has already been performed by the Alliance of Engineers and Architects in their April 1994 I&I Study for the City of Rapid City, described above. It appears that the Rapid City WRF meets the State's requirements for I&I reduction if it implements the sewer line replacements recommended in the 1994 study.

An analysis of the infiltration and inflow (I&I) to the sewer system was performed in order to assess its current impact and to project the potential impact of I&I correction programs on the future wastewater flow rates. The I&I contribution is estimated to be a minimum of 4.5 MGD and can exceed 25 MGD. The analysis was based on two methods: 1) analysis based on average organic loading and monthly flows, and 2) an analysis of diurnal flow records and wastewater quality during nighttime low flow periods.

The average daily flow (based on monthly averages) for the 5-year period between January 1992 and December 1997 were illustrated in Figure III-1. The effects of precipitation and increasing groundwater levels can be seen in the increasing flow rates, and especially the flow rates for the wet months of June and July. The average daily flow for that 5-year period was 10.0 MGD. This represents a wastewater flow of 139 gallons per capita per day (gpc/d). The average daily flow for 1995, the "typical year", was 10 MGD with a standard deviation of 1.76 MGD.

The first analysis of I&I was based on the 5-years of data referenced above. It consisted of calculating an I&I flow rate by generating an estimate of the "pure sewage" component of the wastewater and subtracting it from the total wastewater flow. It was assumed that I&I does not contribute to the BOD loading and that "pure sewage" has a BOD of approximately 380 mg/l. As discussed below, the average organic loading to the facility over the 5-year period was 17,100 lb/d. This is illustrated in Figure III-3. On this basis "pure sewage" component is approximately 5.4 MGD. This corresponds to 75 gallons of "pure sewage" per capita per day. Therefore, on an average flow basis the I&I component is approximately 4.6 MGD. This approach is illustrated in Figure III-4. From this figure it can be seen that the I&I contribution can exceed 11 MGD during wet months of wet years. On the basis of historic records of plan flows in excess of 30 MGD, the I&I at times probably exceeds 25 MGD. A second approach in the analysis of I&I was to examine diurnal flow variations. Two conditions were evaluated for a year with average precipitation: a typical day during a dry month, and a typical day during a wet month. January 10, 1994 was selected as a representative day for the "dry" condition. The hourly flows are illustrated in Figure III-5. It can be seen that even during the hours of lowest flow, wastewater flow never fell below approximately 5.5 MGD. June 27, 1994 was selected as a representative day during a wet month. Flows for that day are illustrated in Figure III-6. During that day the flow never fell below 6.0 MGD. Due to the length of the trunk sewer, the effects of low flow period in the center of Rapid City do not reach the plant for approximately 2 hours. Some early morning sewage flow from residences near the plant contributes to the flow during the 5:00 AM to 6:00 AM period. Therefore, the low flow period does not represent a period of pure I&I.

In order to determine the sewage component during the low flow periods, wastewater samples were collected on October 2, 1998 and analyzed for BOD. At a flow of 6.17 MGD the BOD was 32 mg/l. This corresponds to approximately 0.5 MGD of "pure sewage" and reveals that the I&I was approximately 5.6 MGD. (This data was also evaluated on the basis of the average BOD of 205 mg/l, with the result that there was approximately 1.0 MGD of average wastewater and 5.2 MGD of I&I.) This method generally' confirmed the analysis conducted above.

Rapid City has undertaken an I&I correction program which addresses both the existing system and new construction. Due to the size and age of the wastewater collection system and the long trunk sewer, it is anticipated that the I&I correction program will have limited effect on the

existing system but that I&I will be controlled for new infrastructure. It was assumed that the I&I correction program for the existing system can result in a 5 percent reduction in I&I, or approximately 0.2 MGD. It was further assumed that new population served (22,000 residents) will contribute 100 gallons per capita per day of wastewater, or 2.2 MGD. This corresponds to 75 gpcd or 1.65 MGD of "pure sewage", and 25 gpcd or 0.55 MGD of I&I. Therefore, the net increase in I&I is projected to be 0.35 MGD by the year 2018, resulting in an average I&I of approximately 5 MGD.