March 2003

City of Gustine

Sanitary Sewer System Master Plan Update Final Report

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Objective

The objective of this planning study is to assess the City of Gustine's (City) collection system for retrofit, upgrade, and expansion needs based on previous studies, new structures, computer modeling, and the 2002 General Plan.

Study Process Overview

This planning process included (1) information gathering, (2) an engineering study, and (3) a series of City Council planning workshops. Information collection included a review of the 1990 Sanitary Sewer System Study performed by Bedesen-Cardoza-Andrews Inc. (BCA, 1990), as-built construction drawings, and planning documents including the current City of Gustine General Plan land use phasing maps prepared by the Merced County Association of Governments (MCAG). The engineering analysis compiled these data and using a computer model of non-storm system flows, modeled existing and projected conditions. The model also evaluated multiple expansion options to meet projected system flows. The workshop process included City Council and staff workshops to review and discuss the expansion options.

Introduction

The City sewer system currently conveys an average of 1.18 million gallons per day (mgd) of domestic and industrial wastewater to the City Wastewater Treatment Facilities (WWTF). Figure 1 is a probability plot of total system sewer flows as recorded at the WWTF influent headworks. Daily flow variation is primarily due to seasonal factors (summer irrigation) and rain event inflow. The industrial contribution, which comprises 40 to 60 percent of the total flow, is primarily from 3 agricultural and dairy processing operations within the City limits. These industrial flows have little seasonal variability and have only minor peaks over the course of the day.

The fluctuation in WWTF flow rate over the course of an average (dry weather) day is shown in Figure 2. The WWTF influent daily flow curve has mild peaks in the mid-morning (10 AM) and late evening (8 PM). This two-peaked "diurnal" curve is typical for domestic sewage flows. The City peaks are dampened compared to the typical municipal treatment plant influent because of the significant influence of the constant industrial input.

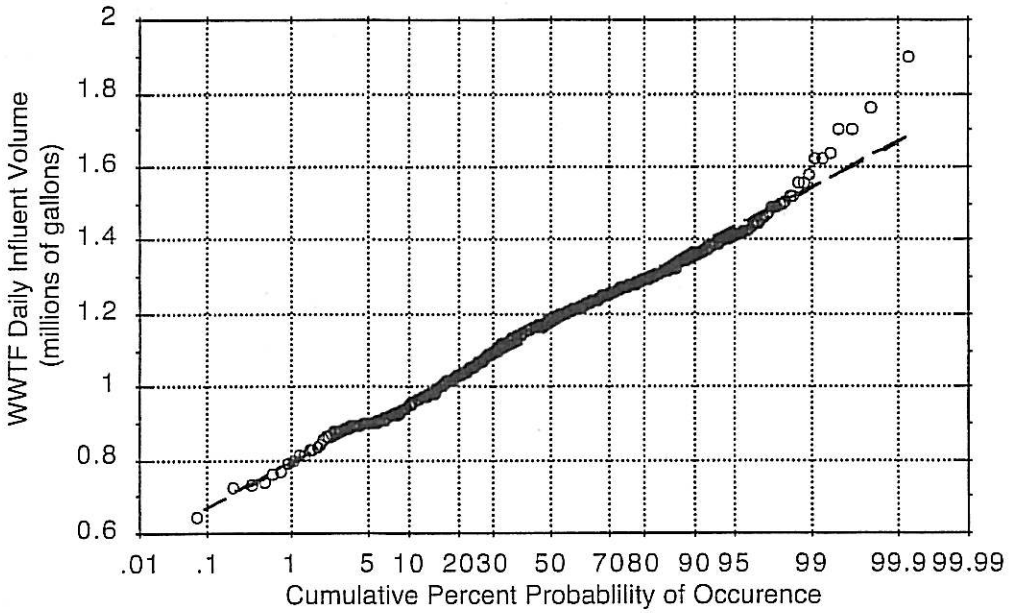

Figure 1. Probability Plot of WWTF Influent Daily Volume

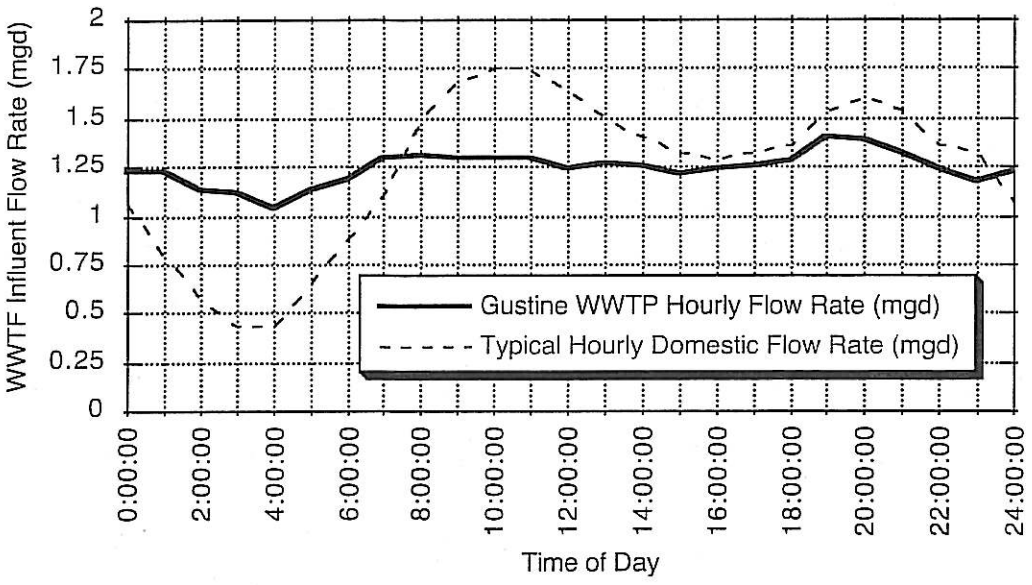

Figure 2. Daily Flows for Gustine WWTF & Typical 1.2 MGD Municipal WWTF

Existing Service Area and Sanitary Sewer System

The current service area of 709 acres, shown in Figure 3, is roughly bordered by the CCID channel to the west, Hunt Road to the east (including subdivision just east of Hunt Road and south of Carnation Road), Sullivan Road to the south, and Highway 140 to the north (including Gustine High School and residential estate development). The sewer system is comprised of approximately 22.3 miles of trunk and lateral sewers varying in diameter from 6 to 24 inches. The exact construction material of each pipe is unknown, but presumed to be a mixture of vitrified clay, concrete, asbestos cement, and PVC. The main 24-inch trunk line along Carnation Road to the treatment plant is constructed of vitrified clay.

Modifications to the system facilities made since the 1990 BCA study include:

1. Construction of the Borrelli Ranch pump station,
2. Build-out of the Borrelli Ranch development 1 & 2,
3. Build-out of the Southport development,
4. Build-out of the Rosewalk development, and
5. Replacement of the 8-inch Railroad Avenue sewer line with 10-inch line in 2000

A more frequent clean-out schedule of the identified problem lines in the system was also implemented beginning in 1990. Interviews with Environmental Management Services (EMS, contract operator for the City) indicated no system overflow or significant line problems. However, maintenance staff did indicate that the Highway 33 (South Avenue) and Meredith Avenue lines present the greatest problems with regard to capacity and clean-out issues.

Projected Growth Pattern

Sewer infrastructure development and improvement are generally required to support anticipated growth. The 1990 Sanitary Sewer Master Plan used the 1985 General Plan as the basis for assuming large areas of projected development to the east of town towards the WWTF. The most current General Plan land use phasing map (MCAG, 2002), shown in Figure 4, does not project residential development of this area. The current General Plan map includes residential development in the areas to the north and south of town. The area directly to the east of town is projected for manufacturing and controlled industrial development. Significant industrial development is projected to the northeast of present-day Gustine.

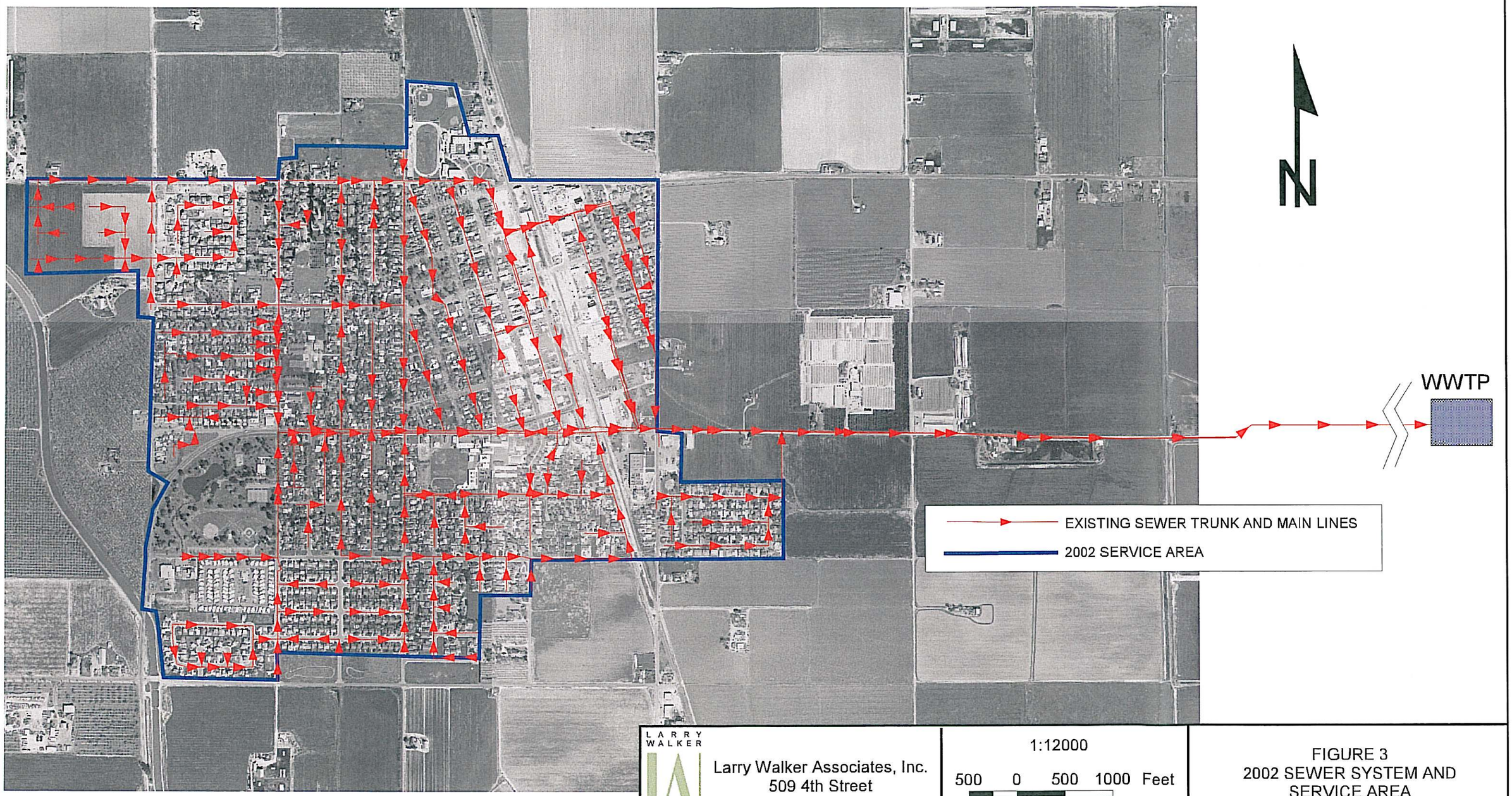

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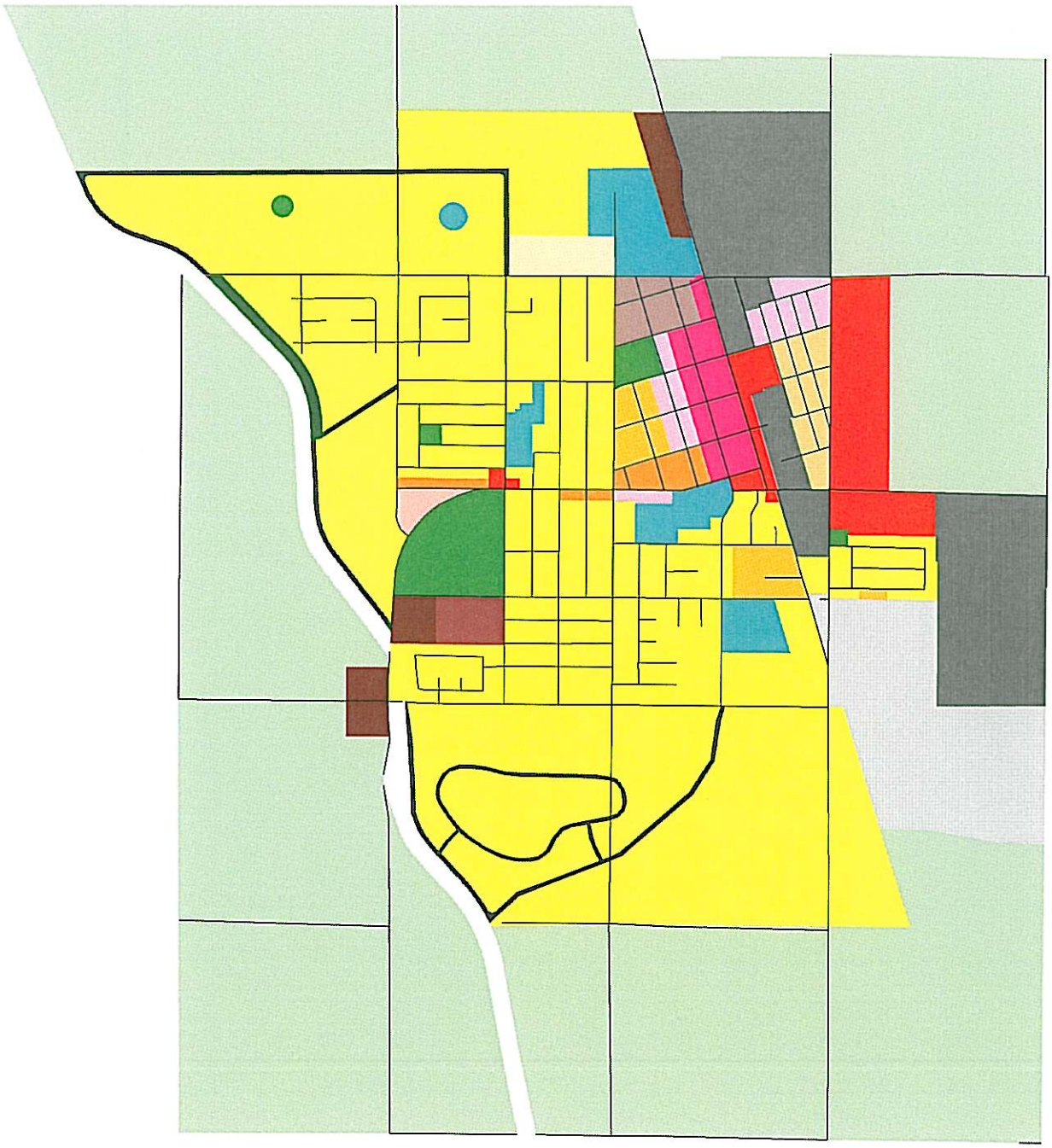
FIGURE 3
2002 SEWER SYSTEM AND SERVICE AREA

July 24, 2002



RESIDENTIAL ESTATE
LOW DENSITY RESIDENTIAL
MEDIUM DENSITY RESIDENTIAL
HIGH DENSITY
MOBILE HOME PARK
PLANNED DEVELOPMENT

RETAIL BUSINESS DISTRICT
OFFICE
NEIGHBORHOOD COMMERCIAL
MIXED USE
HIGHWAY COMMERCIAL
GENERAL SERVICE COMMERCIAL

PARK
SCHOOL
GREENWAY
MANUFACTURING/INDUSTRIAL
CONTROLLED INDUSTRIAL
AGRICULTURE/COMMERCIAL

General Plan Phasing
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FIGURE 4
LAND USE PHASING

July 24, 2002

Study Methods

As part of this study, sewer capacity analyses were performed using collection system data (developed in 1990, 2001, and 2002), General Plan projections, and proprietary modeling software. This Master Plan update is based on the population and land use projections from the current General Plan land use phasing maps (MCAG, 2002). Collection system data were compiled into a Geographical Information System (GIS) that is compatible with other existing electronic mapping "layers" of the City maintained by MCAG. These maps of the sewer system, sewer service areas, and land use areas were then imported into a sewer capacity modeling program (Hydra 6.1). Separate model runs were performed to compare and calibrate to current conditions and to assess future conditions according to land use phasing in 2010 (phase 1) and 2020 (phase 2). Outputs from the model and maintenance staff observations were used to develop recommendations for sewer system inspection, improvement, and expansion.

Data Collection and Compilation

Sewer system data were compiled from a previous sewer analysis (1990), as-built drawings from new development, interviews with City and sewer maintenance staff, and new survey data collection (2001/02). Sewer system data from the 1990 study were available in hard copy format only. These data included a schematic map used for the 1990 study and as-built drawings from new development. Following compilation of these data, a survey crew from Stoddard & Associates, Inc. (Stoddard) was subcontracted to perform additional field survey data.

Bedesen-Cardoza-Andrews 1990 Sewer Master Plan

The BCA 1990 study identified lines half full of sludge, surcharging of maintenance holes, inter-connections between existing lines, abandoned lines, gravel and debris in the system, and difficulty in determining conveyance routes. Exact locations of these problem areas were not specified in the report. The 1990 study generally noted a number of "overflow" connections between parallel pipes as well as split junctions where flow is diverted to more than one pipe. However, the report noted that the existing 1990 system, with the exception of the Railroad Avenue line, was adequate to handle existing flows. Flow conditions (volume and peaking) have not changed significantly since the 1990 report.

Stoddard Associates 2001-2002 System Survey

In general, the 2001 field survey confirmed the geometry and elevation data from the 1990 study and the as-built drawings from new developments. During this process, some minor discrepancies between the information sources were noted. The surveyed maintenance holes were visually observed for damage or

problematic flow conditions. Follow-up surveys in December 2001 and April 2002 were used to resolve discrepancies and to photograph maintenance holes. Some maintenance holes along Carnation Road have been paved over or covered, making identification of survey points impossible. The survey crew identified two isolated flow condition problems. The maintenance hole in the 12-inch line at Third Avenue along the alley between Fourth and Fifth Streets was filled with sludge and debris. The existence of a parallel line and the odd connection arrangement of this 12-inch line indicate that the line is likely abandoned. The maintenance hole at the beginning of the 6-inch line along Wallis Avenue at West Avenue was surcharging the connecting upstream line. Several maintenance holes were observed to have debris, including bricks from the maintenance hole rims. A GIS-based map of the sewer lateral and main system was prepared and includes sewer invert elevation and manhole rim elevation information.

The scope of this update study did not include the remote video camera inspection (TV inspection) of lines to identify the specific condition of pipes or an infiltration and inflow (I/I) analysis to assess the affect of water infiltration or stormwater runoff inflow on sewer capacity.

Sewer Capacity Model Development

The sewer capacity model combines the physical description of the sewer system with sewage flows based on land use and service area information. Model assumptions were based on land use definitions (housing density) and typical per capita domestic contribution as shown in Table 1. The model outputs include the steady-state (at design flow) time-series hydrographs, hydraulic profiles, and other hydraulic data for each modeled pipe length. Four scenarios were considered based on current conditions, anticipated development of Borrelli Ranch, and the phased land use plan:

1. Current conditions – 2002. This scenario was primarily used for calibration and verification of the model.
2. Current conditions and complete build-out of the Borrelli Ranch development.
3. General Plan Phase 1 conditions – 2010. New residential development in the "Planned Development" land use allows for a range of housing densities. A least-dense and a most-dense build outs were considered.
4. General Plan Phase 2 conditions – 2020. New residential development in the "Planned Development" land use allows for a range of housing densities. A least-dense and a most-dense build outs were considered.

Table 1. Wastewater Flow Assumptions

Residential Land Use	***Housing Unit Density per Acre***	***Persons per Housing Unit*** [a]	***Flow per Person (gal./day)*** [b]
Pre-1990 Low Density Residential	3.5[c]	2.79	75
Low Density Residential	4[d]		90
Medium Density Residential	6.1[e]		75
Medium/High Density Residential	10.1[e]		75
Mobile Home Park	8.6[c]		75
Residential Estate	1.5[d]		120
Planned Development – Highest Density	2.6[f]		90
Planned Development – Lowest Density	1.4[f]		90
Commercial and Institutional Land Use	***Persons per acre***		***Flow per Person (gal./day)*** [g]
School	per school (200-300)[h]		15 – H.S. 10 – K-9
General Service Commercial	25[h]		15
Retail Business District	25[h]		15
Office	50[h]		15
Mixed Use	28 Res.[d,b] 25 Vis.[h]		75 – Res. 15 – Vis.
Manufacturing/Industrial Land Use Contributor	***Assumed Daily Contribution (mgd)*** [i]		
Morningstar	0.32		
Hillview	0.08		
Land-O-Lakes	0.2		
Nut processing	0.003		
Miscellaneous Land Use	***Person per Acre***[h]		***Load per Person***[h]
Highway Commercial	1		15
Park	1		15

(a) Gustine Data from US Census Bureau 2000 Census
(b) Metcalf and Eddy. Wastewater Engineering Treatment. Third edition, 1991.
(c) Calculated based on current parcel density
(d) Average value in 2002 General Plan
(e) Minimum value in 2002 General Plan
(f) Based on 2002 General Plan Residential Land Use Calculator. Housing unit density is based on the unimproved (i.e., no right of way or open space) land area.
(g) Tchobanoglous and Schroeder. Water Quality. 1987
(h) estimated
(i) Average daily flow from 2000-01.

Land Use Data

Land use data were provided by MCAG. Residential land use definitions of housing density were used to develop a sewage flow for each service area. The sewage flow is determined as a residential, visitor (i.e., office or other business), or commercial flow. Residential and visitor flows are calculated by multiplying the population by the assumed daily per capita load. Populations were developed based on the building density and persons per building assumptions shown in Table 1. Average flows were used for the listed commercial dischargers. Each land use also has an assumed "diurnal curve" to estimate the hourly variation in flow rate and peaking conditions over the course of an average day.

Service Area Data

Service areas are the sewer-served areas specific to individual pipes (i.e., the area drained to a specific lateral line). These areas are analogous to watersheds for naturally draining areas and are often referred to as sewersheds. Each service area drains to only one pipe, but a pipe can have contributions from more than one service area. The City sewer models are comprised of 122 to 197 service areas, depending on the projected land use assumptions. These areas were estimated using the layout of the sewer pipe network, as built engineering drawings, and visual inspection of key geographical features and infrastructure.

Infiltration and Inflow

Infiltration and inflow (I/I) can have a significant effect on municipal sewer systems. Infiltration is the leakage into the system from a high groundwater table or other water sources. Inflow is the leakage into the system directly from stormwater runoff (open manholes, overflows from storm sewers, direct roof drainage connections, etc.).

Infiltration is modeled as a constant flow into the system at a rate relative to the development density. Based on WWTP influent and industrial flow records, infiltration is highest during the summer irrigation periods and accounts for approximately 100,000 gallons of daily flow.

Inflow cannot be sufficiently considered until the problem areas or system defects are identified through a targeted study. However, the general magnitude of inflow can be determined by analyzing treatment plant influent and rainfall data. For this study, treatment plant daily influent volumes were regressed against daily rainfall totals and tested for statistical significance to determine if inflow effects are significant. Inflow effects were not directly considered in the model. During rainfall events inflow was observed to contribute up to 700,000 gallons in a single day. Instantaneous peaking of system flow greater than 3 mgd was also observed during rainfall periods. Flow rate peaking due to inflow is considered in this report by making conservative assumptions about required capacity (i.e., pipes that flow less than half full at the peak dry weather design condition have capacity to convey storm peaks without system overflows).

A complete I/I study would include flow monitoring at various points in the system during rain events to assess the location of problem areas and video inspection of identified problem areas. The study would first focus on probable areas of significant I/I including the lines along Carnation Road, older areas of town, and at cross connection points. Such analysis is outside of the scope of this plan update. However, once the system defects are known and rainfall and inflow data are collected, the model can be modified to consider inflow effects. The 1990 study did not consider I/I directly.

Model Calibration

The existing conditions (2002) were used to calibrate the model. The most significant assumptions for the model are the per capita sewage flow and the diurnal curves for each land use. These two inputs were adjusted to calibrate the total volume and the WWTF influent diurnal curve, respectively, of the overall system. The model was calibrated by regressing the predicted model hourly flow against observed flows at the treatment plant. The regression was optimized for best fit on average conditions and several observed days of "normal" (dry weather) flow. Wet weather and seasonal effects were not considered as variables in the model. As such, the modeling variables (per capita contributions and land use diurnal contribution patterns) represent average dry weather flows. However, for design and improvement purposes a factor of safety is applied to ensure that the system will be able to handle projected flow variability. An overly conservative model (e.g. using the maximum daily flow or the 95th percentile flow) would inaccurately represent a complex system with inherent variability by building-in multiple factors of safety. Additionally, it is assumed that some defects will be located and corrected by the City to maintain system integrity and minimize inflow.

The model inputs were then modified to consider the 2010 and 2020 General Plan-based flow projections and proposed system improvements. Description data for each model scenario are summarized in Table 2.

Table 2. Summary Data for Model Runs

Model Scenario	***Modeled Sewer System Average Daily Flow (mgd)***
Current Conditions	1.18
Current Conditions + Borrelli Ranch Build-out	1.23
General Plan Phase 1 w/ low density Planned Development	2.15
General Plan Phase 1 w/ high density Planned Development	2.25
General Plan Phase 2 w/ low density Planned Development	2.27
General Plan Phase 2 w/ high density Planned Development	2.43

Results

The results of the model analysis generally support the diurnal pattern, peaking factor, and problem area findings in the 1990 study, as well as recent maintenance staff observations. New residential development impacts the sewer system more than manufacturing, industrial, or commercial development, as residential development would be upstream of the existing system and would greatly increase the total area served. Proposed industrial and commercial development is further downstream in the system and can be connected to main trunk lines that currently have significant (>50%) additional downstream capacity. Future development will "stress" the main trunk lines including North Avenue, Linden Avenue, South Avenue, Meredith Avenue, and Railroad Avenue.

The model results revealed problem segments in particular lines wherever line surcharging (i.e. the hydraulic grade line (HGL) is above the crown of the sewer pipe) occurred at design flow. Manhole surcharging (HGL above the manhole rim elevation) was not noted in any of the model runs, but could occur when wet-weather inflow conditions are considered.

Current Conditions

The average daily influent flow at the WWTF during 2000-2001 was 1.18 mgd. The average flow rate was 1.24 mgd on days reporting detectable rainfall. A statistical significance was found between rainfall and WWTF influent rate indicating that the system is impacted by I/I. The peak daily average flow rate of 1.9 mgd occurred during a day with detectable rainfall. Based on influent flow records, instantaneous peaks exceed 3 mgd (the highest reading on the paper recorder) several times a year.

Line surcharging was noted at connections to the 12-inch line on Carnation Rd and the 6-inch line on North Avenue to the alley between Fourth and Fifth St. However, this may only be due to inaccurate connection assumptions or "complicated" hydraulic conditions that the model cannot process. Additional line surcharging may be evident when considering inflow during rain events.

Future Conditions

Complete build-out of the Borrelli Ranch development is the near-term scenario. Longer term future conditions include General Plan Phase 1 (2010) and General Plan Phase 2 (2020). Daily system flow projections for all scenarios are presented in Table 2.

Line surcharging is a general indication that the capacity of a line has been exceeded. Line surcharging was not observed in the model outputs for the Borrelli build-out scenario. However, residential development will lead to capacity problems in the medium- and long-term development phasing scenarios. Industrial development is projected to be a significant contributor (an additional 800,000 gpd by Phase 1 build-out), however, if connection points to the existing

system are chosen to optimize capacity, line surcharging conditions could be avoided.

Sewer system segments projected to surcharge (i.e., full pipe flow) or be more than half full (depth of flow divided by pipe diameter is greater than 0.5) under 2010 and 2020 flow conditions are listed in Table 3 and identified in Figure 5. Residential density assumptions did not significantly affect the number or location of projected line surcharges or the number of pipes projected to have less than 50% capacity available. The results in Table 3 and Figure 5 are for both the low and high density projections.

Table 3. Line Capacity Issues for Current System under Projected Medium- and Long-Term Future Flows

SURCHARGING	
2010	*2020*
North Avenue 6-inch line from West Avenue to the alley between 4th and 5th Streets	North Avenue 6-inch line from Sycamore Avenue to alley between 4th and 5th Streets
Alley between 4th Street and 5th Street 6-inch line from North Ave to 2nd Avenue	Alley between 4th Street and 5th Street 6-inch line from North Ave to 2nd Avenue
	Railroad Avenue 10-inch line
	South Avenue 12-inch line from Ash Avenue to 24-inch junction
MORE THAN HALF FULL	
2010	*2020*
South Avenue 12-inch line from Linden Avenue to 24-inch junction	South Avenue 12-inch line
Linden Avenue 8-inch line north of South Avenue to Brenda Avenue	Linden Avenue 8-inch and 10-inch lines
Carnation Road 12-inch line	Carnation Drive (all lines)
Meredith Avenue 8-inch line	Meredith Avenue 8-inch line
Railroad Avenue from South Avenue to Wallis Avenue	

Figure 5. Model Results Indicating Sewer Line Surcharging and Reduced Additional Line Capacity

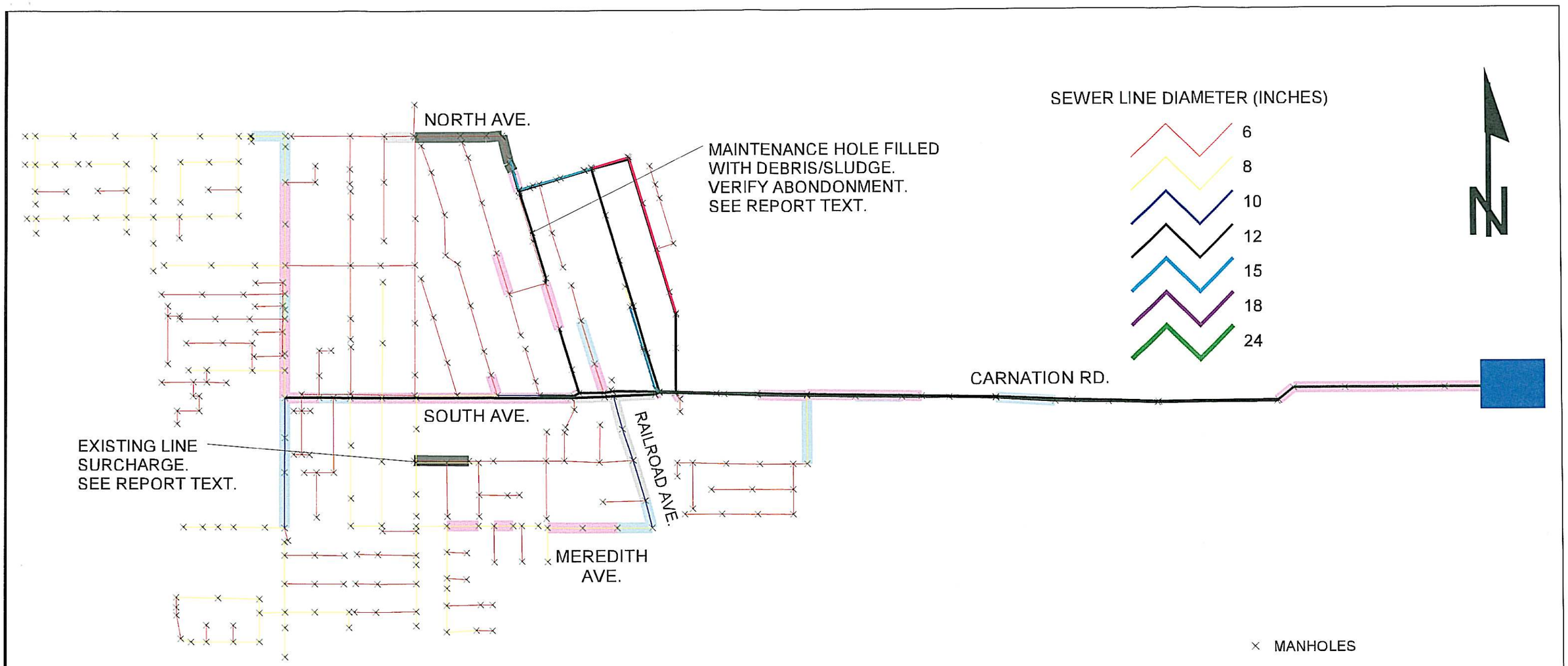

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FIGURE 5
MODEL RESULTS INDICATING LINE SURCHARGING AND REDUCED ADDITIONAL CAPACITY

July 24, 2002

Over the course of the planning period, surcharging would progress in a number of lines as development occurs. The newly upgraded Railroad Avenue line would surcharge under the 2020 scenario. In addition to the Railroad Avenue line, the 12-inch main trunk along South Avenue, the line under the alley between 4th and 5th Street, and the 6-inch North Avenue lines would surcharge or "bottleneck" under the 2010 and 2020 build-out scenarios without any system improvements. A bottleneck is the general term used to identify capacity-critical and potentially problematic lines where flow is under pressure. Meredith Avenue would also have capacity problems during high flow periods in the 2020 scenario. The Linden line was identified in the 1990 study as having potential capacity problems. Surcharging is not expected in this line until the modeled 2020 build-out. The surcharging on the line running under the alley between 4th St. and 5th St. and a few other isolated cases of line surcharging were identified in the modeling, however, these may only be due to connection assumptions that were made, and are not considered significant.

Lines that transmit more than half their capacity will likely be surcharged for periods during storm events. However, the impact of wet-weather inflow cannot be precisely quantified without additional data on the location and magnitude of inflow sources.

Although the model does not perform a thorough evaluation of pump performance and capacity, both lift stations (Brentwood and Borrelli) appear to have sufficient capacity for current conditions and build-out of Borrelli Ranch. If additional connections are made to these lift stations, a more thorough analysis would be required. Future development may require additional pump sub-stations to lift sewer flows into the existing system.

Recommendations

Recommendations are classified into ongoing system maintenance and assessment work and sewer system improvements and expansion options to meet anticipated system needs. The current condition of the existing lines is also of concern as there has not been an inspection of most of the lines and there have been anecdotal observations of line and manhole deterioration. Four system improvement and expansion options are presented as technically feasible options. These recommendations include projected costs for their full implementation. The system improvement and expansion recommendations are based on projected conditions and significant growth within the City sphere of influence. A recommended option was selected based on City input regarding anticipated growth pattern and an engineering analysis of the most cost efficient and technically efficient use of existing system infrastructure.

System Maintenance and Assessment

It is recommended that the City institute a systematic program for preventing sewer overflows by enhancing operation and maintenance strategy.

Continued weekly cleaning of the Railroad Avenue and Linden Avenue lines is recommended along with additional cleaning of the Meredith Avenue line and the South Avenue/Carnation Road line. Additional lines should be video inspected as soon as possible according the following priority list:

1. South Avenue 12-inch line
2. North Avenue 6-inch line
3. Alley between 4th St. and 5th St. 6-inch line from North Avenue to 2nd Avenue.
4. Alley between 4th St. and 5th St. 12-inch line easterly line from 2nd Avenue to 4th Avenue. This line is not connected to the line listed in item #3 above and is likely abandoned. This line should be cleaned-out and investigated and possibly decommissioned to prevent further sludge and debris collection.
5. Carnation Road (all lines)
6. Wallis Avenue 6-inch line. The maintenance hole invert at West Avenue is significantly lower (3.3 feet) than the next downstream maintenance hole causing the collection of water and potentially debris. This should be confirmed and then corrected by rerouting and decommissioning the line. This section of line is the initial segment of line with no upstream contribution, besides user connections. If the problem is not corrected the production of hydrogen sulfide gas will be an odor nuisance and lead to the more rapid decay of the line. The maintenance hole at West Avenue also has a higher probability of surcharging according to modeling results.
7. Meredith Avenue 8-inch line
8. Linden Avenue north of South Avenue 8-inch line
9. Linden Avenue south of South Avenue 10-inch line

The investigations should be done in conjunction with the newest survey data and system map to confirm the configuration and elevation data. A maintenance schedule should be developed so that all lines are systematically cleaned out and video inspected over the course of the next planning schedule (2010). The data collected (video, inspection notes, and survey results) should be reviewed, and archived so that it is available for future planning and engineering work.

Survey and inspection data should be used to develop a prioritized task list for line replacement and repairs. Tasks could be completed on the list as funds became available.

Both the Borrelli and Brentwood pump stations should be evaluated more thoroughly to confirm operation parameters (float switch elevations, wet-well volume, etc.) used in the sewer system model. Additionally, a more thorough engineering review of pumping station capacity is necessary before further development occurs in the service area of these pump stations outside of the Borrelli development.

A targeted I/I study should be completed in conjunction with the storm drain master planning effort. This study will focus on identifying defects and inflow entry points within the system as well as assessing the magnitude of inflow. In particular, the Carnation Road lines, the South Avenue lines, the Linden line, and other older lines in the downtown area should be examined for I/I problems. Additionally, deteriorated maintenance holes should be rehabilitated to minimize inflow.

Mid- and Long-Term Improvements

Mid- and long-term improvements were developed through a series of public workshops with the City Council. The workshop process included the preparation and review of three draft planning documents that identified four collection system planning options. Through the workshop process, the City Council identified the final collection system improvements. The objective of the improvements is to provide for the anticipated growth in the immediate future as well as the long-term needs as established in the General Plan. The recommended collection system improvements are intended to provide sufficient capacity to match these projected growth patterns. The improvements are summarized in Figure 6 and consists of the following "construction" elements:

- Replace of North Avenue 6-inch line
- Construction of a "bypass" line from North Avenue to the 15-inch Second Avenue line
- Connect Borrelli pump station to discharge to the North Avenue line
- Construction of a new 12 or 15 inch main trunk that runs along Sullivan Road (E-W) and then connects to the Carnation Road line east of East Avenue
- Construct 12 or 15 inch main trunk line north of town between Fentem Road and Worthington Road (E-W) and then along Highway 33 (N-S) to the 15-inch existing line

Actual build-out of the General Plan will occur incrementally, however, main line construction and improvement can be separated into three stages. The first stage is meant to relieve capacity issues on South Avenue by re-routing flow from the Borrelli Ranch development at the northwest side of town along an upgraded North Avenue line. The line retrofit carries flow to the east side of town to a new bypass line, and then on to lines where there is more capacity. The second and third stages are the installation of new collection system facilities (12 or 15 inch main lines) to the north and south of town. The line to the south of town would likely be constructed first and is referred to as "stage 2" development. The new line retrofit would carry residential development to the south of town and the controlled industrial in the southeast of town. The new line to the north of town would likely be constructed last in the final stages of the General Plan build-out.

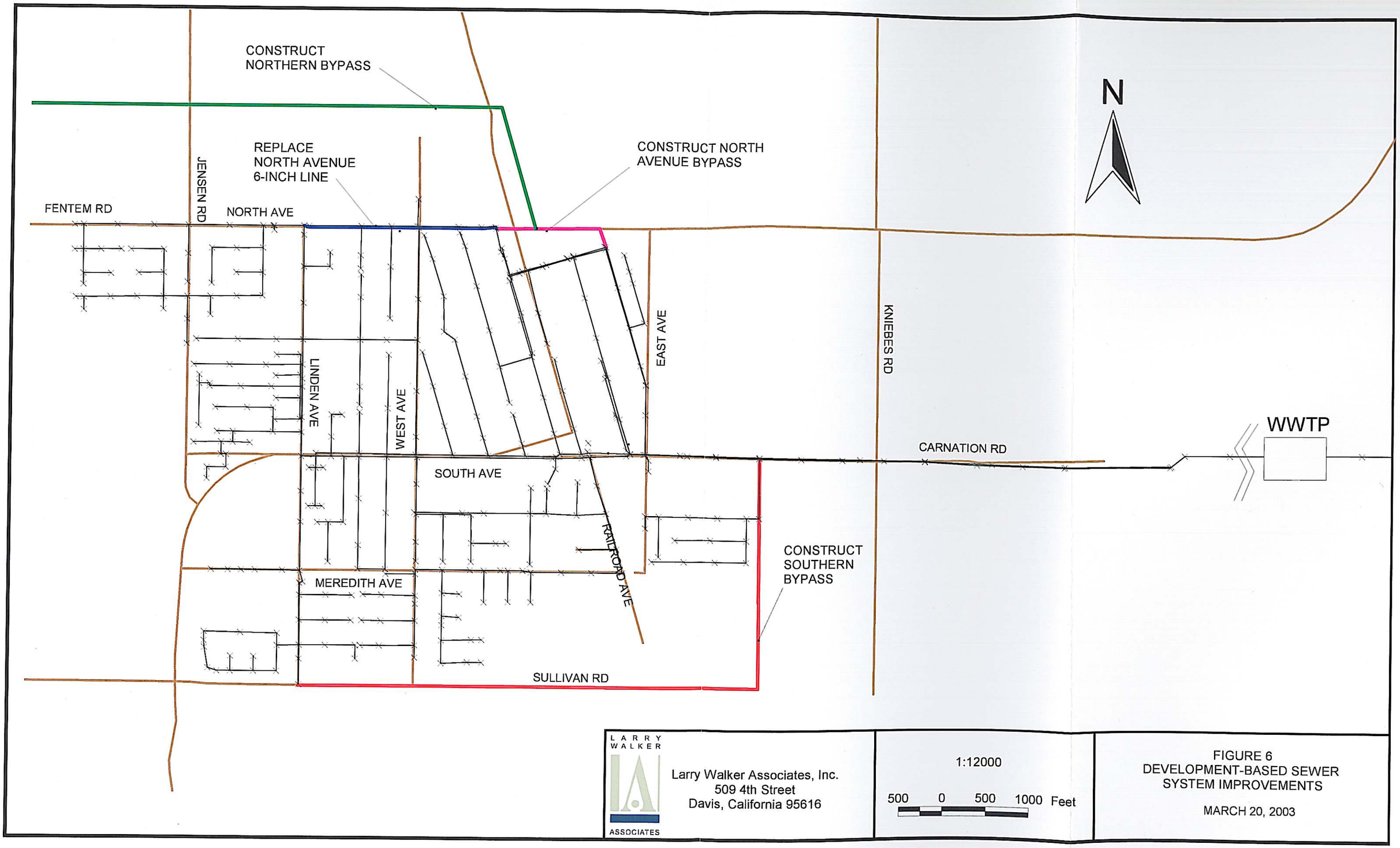

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FIGURE 6
DEVELOPMENT-BASED SEWER
SYSTEM IMPROVEMENTS

MARCH 20, 2003

The initial North Avenue improvements and "bypass" are necessary to relieve the potential capacity problems associated with development of the area to the west of Linden Avenue, as is anticipated. A more detailed engineering analysis of this line improvement and bypass construction is necessary to ensure that the proposed alignment will not interfere with other utilities. Additionally, the collection system model should be run prior to any specific significant development to ensure that the capacity is available. This phase of improvements will allow a significant amount of growth both north and west of town.

The proposed new sewer line along Sullivan Road would allow for the anticipated development south of town. This line could be routed to connect to the Carnation Road 24-inch line in a number of ways that would minimize the amount of right-of-way needed and to provide the lowest construction costs. The alignment shown in Figure 6 generally meets these criteria, but can be modified to allow for coordination of construction of other facilities (stormwater or water) or to further minimize construction cost. Specific development plans may also benefit from a different alignment.

The proposed new sewer line to the north of town between Fentem Road and Worthington Road is likely the third phase of infrastructure development. As development increases towards the end of the planning period the carrying capacity of the new North Avenue line will diminish and this new line will likely be necessary.

A detailed engineering design for all improvements and expansion should also consider the size of pipe that is installed. Model runs indicate that 12-inch lines would provide sufficient capacity, but do not account for I/I effects over the lifetime of the pipes. Pipes should not be sized too large so as to reduce the minimum (scour) velocity below what is necessary to keep solid materials suspended.

These phasing scenarios are based on development projections through the planning period and could change if actual development did not follow the anticipated growth pattern. The projected costs for all stages of the master plan are included in Table 4.

Table 4. Projected Collection System Expansion Costs

Stage	Description of Modification	Line Diameter (inches)	Total Length	Unit Cost ($/ft) (a)	Total Capital Cost ($1000s) (b)	Year	Projected Future Total Cost ($1000s) (c)
1	Replace North Avenue 6-inch line	12	2,130	$114.69	$244	2006	$267
1	Construct bypass from North Avenue to 2nd Avenue	12	1,500	$114.69	$172	2006	$188
1	Connect Borelli PS discharge to North Avenue				$29	2006	$32
				Stage 1 Sub-total:	$445		$487
2	Construct new 12-inch line along Sullivan Road (E-W) and between Hunt and Kniebes Roads (N-S)	15	8,000	$139.43	$1,115	2015	$1,844
2	Bore under RR for bypass line				$73	2015	$123
				Stage 2 Sub-total:	$1,188		$1,967
3	Construct new 12-inch line between Fentem and Worthington Roads (E-W) and along Hwy 33 (N-S)	15	7,750	$139.43	$1,081	2020	$1,786
3	Bore under RR for bypass line				$73	2020	$121
				Stage 3 Sub-total:	$1,154		$1,907

(a) *Includes Pipe (VCP), Manholes (9-12' D @ 267' spacing), Repaving, General conditions @ 10 %, OH& P @ 15%, and Engineering/Contingency @50%*

(b) *January 2003 dollars*

(c) *Projected future costs based on discount rate of 3% per year.*

Conclusions

Sewer system capacity in the City is sufficient for the current level of development and full build-out of the Borrelli Ranch development. Industrial users contribute a significant fraction of the total system flow, however, current and planned industrial facilities are generally downstream in the system and have a spatially limited impact on the system. Industrial flows also fluctuate less than typical domestic flows over the course of a day.

Residential development, as projected in the General Plan, is then the primary driving force for sewer system expansion and improvements because of the spatial expansion and upstream nature of residential development. Assuming there were no modifications to the existing sewer system, the proposed residential development to the north of Fentem Road would primarily impact the lines on North Avenue, Linden Avenue, and South Avenue. Proposed residential development South of Sullivan Road would primarily impact the Meredith Avenue, Railroad Avenue, and the South Avenue lines. The Carnation Road lines will likely surcharge (flow under pressure) during storm events if I/I inputs are not corrected.

Although future manufacturing, commercial, and controlled industrial land use development will contribute significant sewage flows to the system, these developments are planned for areas where existing capacity is available. However, these new non-residential connections to the system may require some on-site sewer line construction by the area's developer to reach the appropriate connection point.

The sewer system will require upgrades and/or expansion to meet the needs of projected development. The improvements developed in this plan, as shown in Figure 6 and listed in Table 4, are based on the a collection system computer model, General Plan growth and land use projections, and a series of City Council workshops.