City of Willcox

Willcox, Arizona

Natural Gas System Study

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This document prepared under my supervision - Bradley B Bean, Arizona registered professional engineer, 40733. Attested by my seal.

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Introduction...

The purpose of this report is to document a portion of a study that was performed for the City of Willcox ("the Owner") natural gas distribution system. This portion of the study consisted of developing a computer model of the existing gas system and development of various scenarios to evaluate the current and potential future capacity of the system.

The Owner contracted with WC Scoutten ("the Client") to provide various services as part of a study of the Owner's natural gas system. As part of those duties, Bradley B Bean, PE ("the Contractor") was contracted by the Client to build a model of the Owner's gas system and to perform various analysis using the model. All data collection and coordination with the Owner was performed by the Client.

The Contractor's firm specializes in design and analysis of natural gas systems, and provides specialized software for performing those tasks. For this study, the system model was developed and analyzed using the Contractor's GASWorkS™ 9.0 network modeling software.

The model development process and results of the various phases of the project are briefly described in the Summary section. The detailed process and results are described more fully in later sections of this document.

Summary...

General...

The Owner's system consists of a "high" pressure supply line and a lower pressure "distribution" system. The supply line is served by a single Town Border Station. The Town Border Station is supplied by a tap from the gas supplier (El Paso Natural Gas). The supply line serves the distribution portion of the system through a single Regulator Station. The supply line is owned and operated by the Owner, however the operating pressure of the line is controlled by the supplier. The nominal operating pressure of the supply line is 100 Psig. The distribution system nominally operates at a pressure of 28 Psig. The study did not include analysis of the operating equipment at the Town Border Station or the Regulator Station.

Model Development...

The model development of the existing gas system was performed through electronic and manual conversion of data provided by the Owner and Client. The model included both the piping configuration and location of the attached customers. The piping portion of the model was generally created by importing data from an electronic map of the City's system. The customer portion of the model (location and demand) was created by a combination of data import and manual methods.

The result was that a customer feature was placed near its physical location based on address and assigned a demand value by extracting data from the City's billing system.

Individual customer demands were taken from peak usage data for the January 2010 billing period. These values, in combination with total peak system flows were used to establish a prorated demand factor for the system for a peak demand period. Of the data provided, the highest system demand occurred on February 3, 2011.

The model results were generally checked against field results reported by the City's staff. The check was performed to ensure that the model results reasonably predicted the performance of the actual system operating behavior. Other than load data, no documented operating data was available for this check, however based on the staff's observations, the check indicated that the model results reasonably matched the field values.

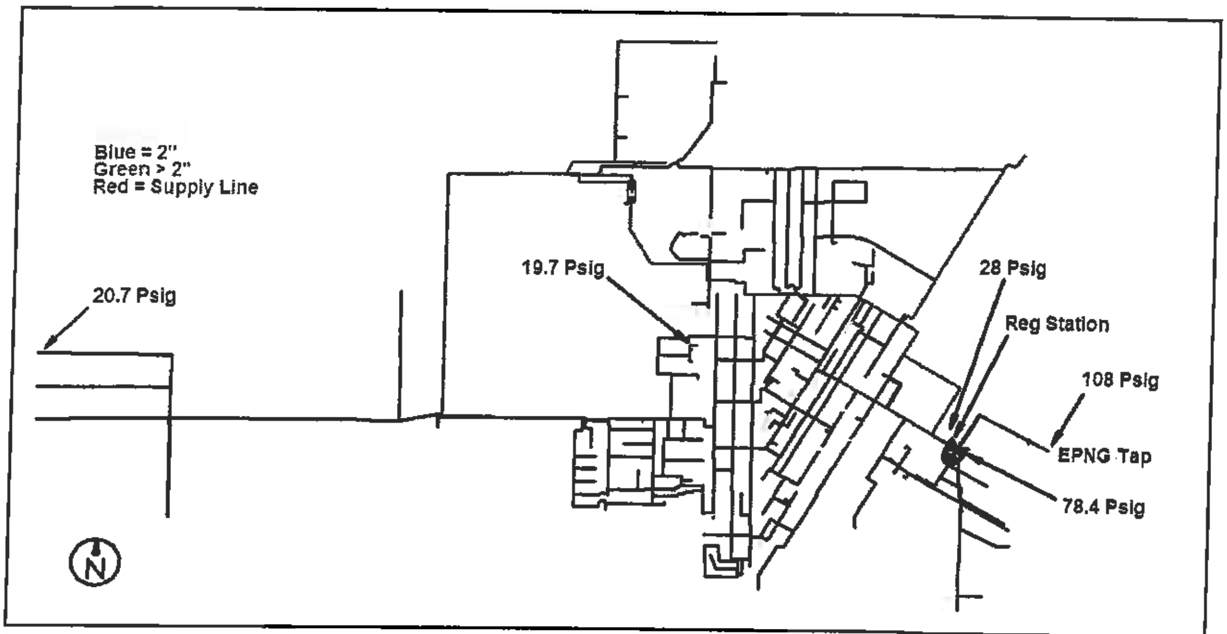
Starting with the verified model, various scenarios were developed to review the system's capacity under various operating configurations. The scenarios included review of the system performance at recent peak conditions, determination of the maximum overall demand increase that the current system could adequately support, and a review of the system's performance after all steel piping is replaced with plastic piping (assuming a same size replacement). No specific growth areas were identified or included in the analysis.

Detailed descriptions of the various scenarios are described later in this document.

Model Results...

When modeling the system for conditions associated with the February 3, 2011 peak period, the system appeared to generally perform adequately from a hydraulic viewpoint. No actual operating issues were reported by the Owner's staff, and the model results did not indicate any likely issues.

For the peak period analysis, the outlet of the Town Border Station was assumed to be 108 Psig and the overall system flow was assumed to be 63 Mcfh. The outlet of the Regulator Station was assumed to be 28 Psig. Under these conditions the model indicated that the system's low pressure point would be about 19.7 Psig located near the service to the High School. The pressure at the west end of the system along Airport Road would be about 20.7 Psig. The inlet to the Regulator Station was anticipated to be 78.4 Psig. Assuming that the overall system demand was near a peak value, these values are within acceptable industry operating standards.



Existing System - 02/03/2011

When modeling the system to determine the maximum overall growth in demand that the system could adequately support, the results indicated that the overall system demand could be increased by about 27 percent based on the existing system configuration, and about 16 percent after all of the existing steel distribution mains are replaced with plastic material mains. That means that the demand or load of all of the customers could be increased equally by these amounts, while maintaining adequate supply pressures through out the system. Of course this actual scenario would not generally occur. However, the results provide a general indication of whether the system can adequately sustain additional growth, and provides a magnitude of how much growth potential the system has. Using the lower value of 16 percent as the limit for any demand increase, the potential for long-term demand growth should be considered somewhat limited.

For the complete system replacement analysis, all of the remaining distribution piping was replaced with equal sized polyethylene piping. It appears that the past replacement policy generally followed this trend. Replacement of steel pipe with equally sized plastic pipe generally results in a reduction in system capacity because the wall thickness of the new plastic pipe is much greater than the wall thickness of the existing steel pipe, resulting in a much smaller inside pipe diameter. The results of the replacement model indicate that after complete steel replacement, under conditions similar to the recent peak demand conditions, that system low pressure point would be about 18 Psig, compared to the current 20 Psig or so. This is within acceptable industry standards. The overall allowable system growth was reduced under this scenario as reported above.

Overall the results of the various analysis scenarios indicate that from a hydraulic viewpoint the existing system has sufficient capacity to provide adequate service during peak conditions, and has the potential to sustain slight growth without requiring modification.

Model Development...

The following describes the detailed model development process.

Assumptions & Notes:

Model Development - Assumptions & Notes...	
No.	**Description**
1	The Client provided an electronic drawing file containing a depiction of the mains associated with the gas piping system. The file also contained base map information such as street, property, and road right-of-way lines, and street names. This additional information was used as a background to the piping configuration. The file was dated September 7, 2011.
2	The drawing file contained information about the piping connectivity, pipe sizes, and material types. The pipe connectivity and sizes in the model were assigned based this information. The pipe hydraulic length in the model was assigned to the drawn length of the segment. A fuzzy tolerance of 1 foot was used during the import process. Pipe ends that fell within this tolerance of each other were "snapped" together.
3	A GIS shape file containing building locations and address numbers was acquired from the county and provided by Client. This file was used to determine the location of potential customers. The file was dated October 12, 2011.

Model Development - Assumptions & Notes...	
No.	**Description**
4	An Excel spreadsheet containing various customer information was provided by the Client. The address values in the file were matched against the building locations. Where a match was found, the associated customer number (CUST_NO) was manually assigned to that location to indicate that it was a gas customer. The values in the USE field in the spreadsheet were assigned to the PER UNIT LOAD values for the associated customer in the model. The file was dated October 26, 2011.
5	After completing the customer assignments, the assigned PER UNIT LOAD values were used to obtain prorated usage values for each customer using an automated routine. The prorated value represents the proportion of the total load used by each individual customer. Using this method, each customer is assigned a proportion of the total system demand in terms of a factor. During the solution process, the model DESIGN FACTOR value is set to a desired total system demand, this demand value is then applied to each customer based on their proportional value. In general, when adding customers to the model in the future, the PER UNIT LOAD for the new customer should be either assigned as a representative usage factor value similar to the prorated usage factors and the APPLY DESIGN FACTOR option selected. Or, the PER UNIT LOAD for the new customer should be assigned to an appropriate actual demand value and the APPLY DESIGN FACTOR option not selected. The representative usage factor for a customer can be determined by dividing the actual or estimated peak monthly usage in Ccf by 201874 Ccf.
6	Where a connection was indicated at an intersection, the pipes were assumed to be connected using full opening tees or control devices. Where no connection was apparent, the pipes were assumed to pass through the intersection without connection.
7	The Town Border Station and Regulator Station were manually entered into the model based on the locations provided by the Client.

Model Development - Assumptions & Notes...	
No.	**Description**
8	The GASWorkS node features (the connections or terminations of the pipes in the model) were automatically assigned progressive numbers during the import process. Nodes representing the supply and regulator inlet and outlet locations were manually assigned descriptive names.
10	Certain common model data was assumed as follows: Specific Gravity = .6 Dynamic Viscosity = .000007 Lbm/Ft-sec Heating Value = 1000 Btu/Cf Base Pressure = 14.73 psia Base Temperature = 60 Fahrenheit Flowing Temperature = 40 Fahrenheit Average Elevation = 4250 Feet Pipe Efficiency = .95
11	The Appendix lists the pipe size/type values and inside diameter values that were assumed in the model. A standard schedule wall thickness was used for all steel pipe. The SDR value used for plastic pipe is shown in the Appendix.
12	The IGT-Improved pipe flow equation was used for all portions of the system. This equation is suitable for the encountered operating pressures and conditions.
13	Supercompressibility was not considered due to the relatively low operating pressure range.
14	The Town Border Station outlet pressure value was set at 108 Psig for the base model, and at 100 Psig for the potential growth models. The node representing the Town Border Station was named "EL_PASO". The normal Regulator Station set pressure was assumed to be 28 Psig for all models. The nodes representing the inlet and outlet of the Regulator Station were named "DRS_IN" and "DRS_OUT" respectively.
15	Individual system valves were not included in the model. However, all system valves were assumed to be fully open.

Model Development - Assumptions & Notes...	
No.	**Description**
16	Dimensional units for the model were assumed as follows: Diameter = Inches Length & Elevation = Feet Volumetric Flow Rate = Mcfh Viscosity = Lbm/Ft-sec Temperature = Fahrenheit Pressure = Psi (gauge or absolute as appropriate)
17	The DESIGN FACTOR value was set at 63000 for the base model. This value represents a recent peak hour value of 63 Mcfh which occurred at 7:00 AM on February 3, 2011.
18	Equivalent length values for valves and fittings were assumed to be negligible and were not included in the model.
19	Sufficient data was not available to calibrate the model. However the Owner reported that the distribution system pressure does not normally drop below 17 Psig under peak conditions. The location of the low pressure measurement was not provided.
20	The capacity of the Town Border Station and Regulator Station were assumed to be sufficient for all modeled scenarios.

Development Process:

The process used to the develop the model of the system is summarized in the following table.

Model Development - General Process...	
Task	**Description**
1	*Main Piping Conversion* - The line work representing the main piping was imported into GASWorkS from the Client supplied CAD drawing file using the GASWorkS DXF file import routine. Before importing, the CAD drawing file was saved as a DXF (Drawing Exchange Format) file. When the file was processed by the import routine, a pipe feature was created for each entity found on the specified layers. The pipes were placed in their "geographic" location using the coordinates assigned to each line end and deflection point. A node was automatically placed at the end of each of the linear features. The nodes were automatically assigned an arbitrary number. Where a geographically coincident node was located, the previously created node was used and the pipes were "snapped" together. Vertex (deflection) points were placed at each of the graphic vertices found in the file. The pipe sizes, were assigned manually based on the sizes designated in the drawing file.
2	*Imported File Clean-Up* - After importing the main piping line work, moderate clean-up was required. Some of the items that required reconciliation and revision included deletion of redundant pipes, breaking of pipes not broken at intersections, and cleaning up pipe ends that were not "snapped" together. Where unusual conditions were encountered, the Client was asked to provide an interpretation. Corrections were made accordingly.
3	*Manual Main Entry* - The western portion of the system, basically all of the mains along Airport Road west of Interstate 10, were manually entered. An image of the area was extracted from Google Maps. The image was appropriately scaled and used as a background to trace the mains over.
4	*Address Import* - The GIS shape file provided by the Client was imported to identify potential customer locations. The file contained point features as well as attribute information including the street address for each location. The file was processed using the GASWorkS Customer SHP file import routine.

Model Development - General Process...	
Task	**Description**
5	*Customer Identification Number Assignment* - The addresses in the customer information (billing) file were compared to the previously imported address locations. Where a match was found the associated customer number was manually assigned, indicating that location as a gas customer. Where an address appeared in the customer information file and did not appear in the imported address locations, a new customer feature was added at a representative location. Where no matching address was included in the customer information file, no customer number was assigned.
6	*Customer Load Assignment* - The format of the customer information file supplied by the Client was not conducive to immediate use by GASWorkS. The format of the file was modified to allow use by GASWorkS. After reformatting, the revised file was "linked" to the model and the individual customer demands were assigned to the matching customer. Once assigned, an automated routine was used to prorate the loads as described in the Assumptions and Notes section.
7	*Regulator Station Entry* - The Regulator Station was manually entered based on information provided by the Client.
8	*Final Model Preparation And Verification* - After completing the above tasks, the model was checked to ensure that the configuration reflected the actual system configuration, and that the results generally appeared appropriate. Model calibration was not performed.

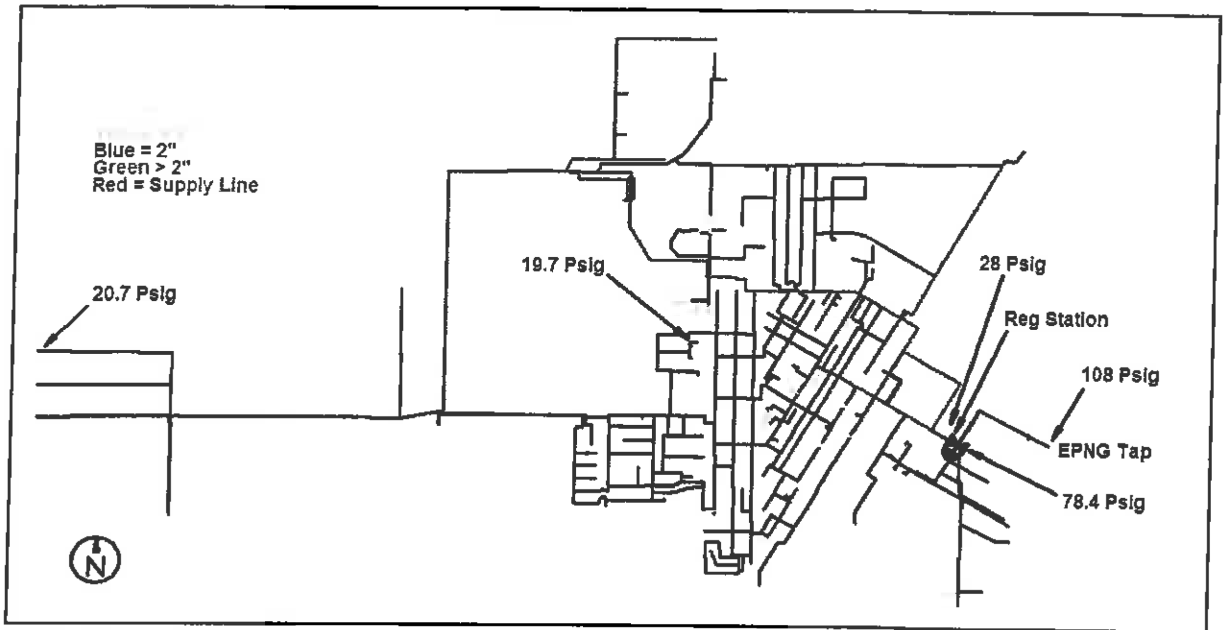
Statistics:

The statistics for the model of the City's existing system are shown in the following figure and table. These values reflect the item counts for the "base" model. A complete model summary is included in the Appendix.

Model Statistics - *Mesa System...*

Item	System
Pipe Count	476
Node Count (Pipe connections & terminations)	425
Customer Count	2090
Supply Points	1 Gate Station (TBS) Total Flow = 63 Mcfh
Regulator Elements	1 Station DRS flow = 63 Mcfh
Total Pipe Length	244,700 feet or 46.3 miles
Pipe Size Summary	Sizes ranged from ½ inch PE to 4 inch steel. (See the Appendix for a complete summary)
Low Pressure Value	HP (100 Psig): 78 Psig at the inlet to the Regulator Station LP (28 Psig): 19.7 Psig near service to the High School

The results reflected in the base model are representative of how the system would perform under the estimated "peak" demand and specified operating pressure conditions.



Existing System - 02/03/2011

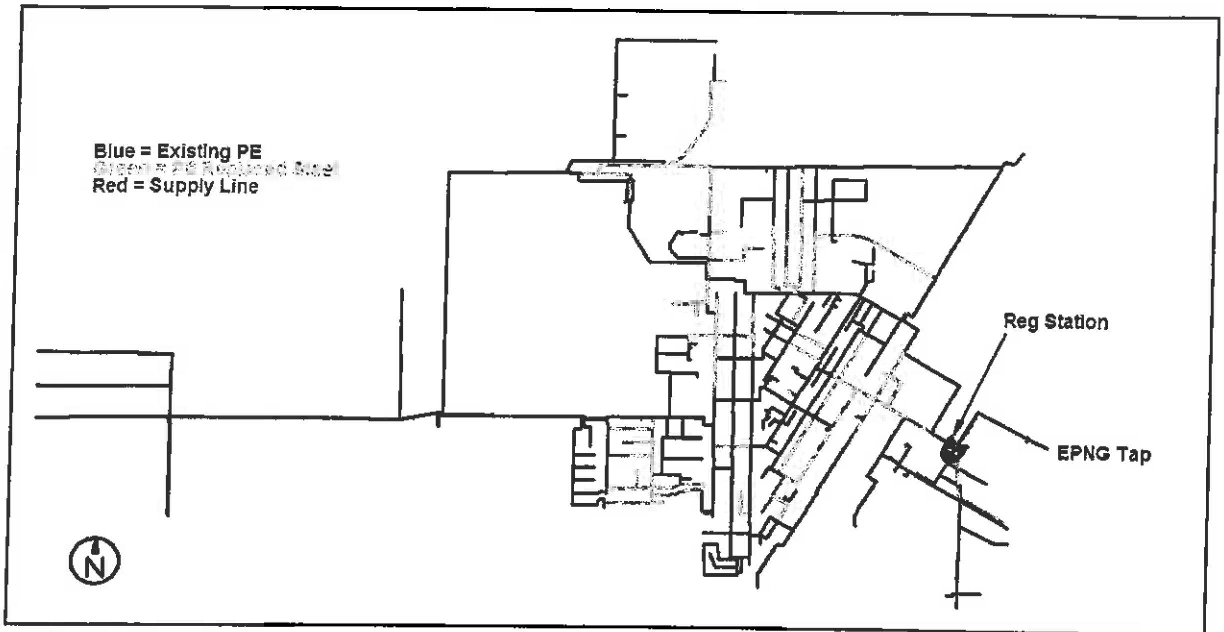
Capacity Study...

The main goal of the project was to use the system model developed in the previous tasks, to review the system's ability to provide adequate service under various scenarios. The approach to this part of the project was to first evaluate and identify any weakness in the existing system performance. This was done using the verified model as a basis. The regulator and supply pressures were reset to their nominal values. No significant issues were discovered.

Next the demand on the existing system model was increased until the system's low pressure points were less than acceptable values. When this limit was reached, the associated demand reflected the maximum overall increase in load that the system could support. For analysis purposes it was assumed that the minimum allowable operating pressure for the distribution system was 14 Psig with a Regulator Station set (outlet) pressure of 28 Psig. And that the minimum allowable operating pressure for the supply line was 50 Psig with a supply pressure at the tap of 100 Psig. The maximum capacity of the system for this scenario was 80 Mcfh or about 27 percent greater than the recent peak period demand used for the base model analysis.

Using the maximum demand model as a basis, a model was developed in which all of the existing steel pipe segments within the distribution system were replaced size for size with polyethylene plastic pipe. Again the maximum capacity that the system could support was determined. In this case the maximum demand was slightly less than the previously determined value, this was expected as the inside diameter, and thus the carrying capacity, of the plastic pipe is less than the same sized steel pipe. Using the previously mentioned pressure criteria, the maximum capacity of the system for this scenario was 73 Mcfh or about 16 percent greater than the recent peak period demand used for the base model analysis. The replaced main segments are highlighted in the figure on the following page.

When required, the steel supply line could be replaced using high density polyethylene plastic. As part of the polyethylene replacement model, the 4 Inch steel supply line was replaced with 4 Inch plastic. The model indicated that a 4 Inch plastic line could not provide adequate pressure to the inlet of the Regulator Station under peak conditions. If the steel supply line were replaced with plastic, it would need to be replaced either with a 6 Inch plastic line, or a combination 4 and 6 Inch plastic. In order to determine the proportions of 4 Inch and 6 Inch, the type and configuration of the equipment installed at the TBS and Regulator Station would need to be known and reviewed.



Existing Steel Mains To Be Replaced By Plastic

Consideration & Observations:

The following table lists some observations for the City's consideration.

Considerations & Observations...	
Item	**Description**
1	No specific growth areas or increased demands were provided for analysis. If in the future the City gains information about specific growth potential, for example a new subdivision or redevelopment project, construction of a significant new building, or replacement of significant gas fired equipment, those loads can easily be applied to the model to determine the impact on the system's performance.
2	One initial concern was with the performance of the western portion of the system. This portion of the system is comprised of a fairly long one-way feed 2 inch plastic main. Although intuitively this appeared to have potential issues, the model results indicated that there were no hydraulic issues with that portion of the system. However if additional load growth occurs in that area, an additional feed into the area would enhance that portion of the system from an operational viewpoint. The long one-way line is vulnerable to damage, and will eventually limit the amount of growth that can be sustained in the area that it serves. Perhaps a loop line from the north could be considered if growth continues.
3	The equipment at the Regulator Station was not reviewed as part of this analysis. The capacity studies assumed that the station capacity was sufficient to supply the additional demand associated with the distribution system. This may or may not be the case. Eventually a review of the station capacity should be performed to ensure that the station is adequate for both existing and potential future demands. Depending on the equipment installed at the Regulator station, the minimum allowable operating pressure for the supply line used in the capacity studies may need to be revised, and the model results recalculated.
4	Similar to the long one-way feed on the west side of the system, the supply line on the east side of the system is also a long one-way feed. There is nothing inherently unsafe or undesirable about this type of configuration, however it does carry a certain risk if the line sustains some sort of damaged that is sever enough to cause the line to be shutdown. Obviously this would affect the feed to the City and in most cases would result in a complete loss of service for the City's customers. That said, from a hydraulic viewpoint there is no indication that the line has any performance issues. Assuming that the line is in adequate operational condition, most damage to buried gas lines occur from third party excavation or water or drainage way washouts. If it is not already doing so, the City should consider keeping extra vigilant surveillance of any excavation activities and the condition of any water/drainage way crossings

Considerations & Observations...	
Item	**Description**
	along the supply line route.
5	Although the City is responsible for the "operation" and maintenance of the supply line, it apparently does not have control over the actually operating pressure of the line. It appears that Maximum Allowable Operating Pressure (MAOP) of the line may have been occasionally exceeded. The MAOP of the line is 100 Psig. It appears that at times the operating pressure of the line may have been as high as 110 Psig. The MAOP is an operational limit established by the regulatory code (CFR 49 Part 192.619). Slightly exceeding the MAOP will not necessarily result in damage or failure of the affected facilities. In fact, the code allows the value to be exceeded by up to 10% under certain equipment failure conditions. However normally, the operating pressure of the associated facility should not exceed the MAOP. This is as issue the City should probably address with El Paso Natural Gas.
6	The potential capacity increase of 27 percent which the existing system could sustain, sounds somewhat impressive. However this value cannot be sustained as the system replacement continues. The capacity increase of 16 percent, associated with the complete plastic replacement model, is more representative of the long term capacity increase that the system could sustain. Not knowing how close the recent (February 3, 2011) peak demand was to the actual maximum system demand, at this level, the system capacity might be considered close to its maximum limit. If required, the system's capacity could be increased by raising the operating pressure of the distribution system. Depending on the Maximum Allowable Operating Pressure of this portion of the system, increasing the operating pressure may require a formal uprating. Increasing the operating pressure of the distribution portion of the system, may affect the capacity of the supply line by increasing the minimum required inlet pressure to the Regulator Station. These issues should be more fully evaluated when considering replacement of the supply line.
7	Sufficient data was not available to "calibrate" the model results to reflect actual field values. The model indicated that the lowest anticipated system pressure would be about 20 Psig under peak conditions, the Owner's staff reported observing past pressures as low as 17 Psig. Although this anecdotal data allows the model results to be "verified" as reasonably representative of the anticipated system performance, this data is not Sufficient to allow the model be tuned or calibrated. If should be understood that the modeled and actual field results will be similar but not the same.

Appendix

Contents of Appendix...

Model Summary...

The following summarizes the data features associated with the base model.

Pipe Summary...		
Size/Type	**Inside Diameter, Inches**	**Length, Feet**
1P - SDR 11	1.020	1,684
1S	1.049	478
1/2P-CTS - SDR 7	0.429	421
1.25P - SDR 10	1.271	436
2P - SDR 11	1.885	120,892
2S	2.067	52,781
3/4P - SDR 11	0.814	546
3P - SDR 11.5	2.808	602
4S	4.026	27,277
4P - SDR 11.5	3.621	38,058
Total =		244,709

System Summary...

Total Node Count: 427
Total Pipe Count: 478
Total Customer Count: 2090

Known Pressures: 2
Unknown Pressures: 425
Known Loads: 426
Unknown Loads: 1
Total Knowns: 428
Total Unknowns: 426
Number Of Nodes Turned Off: 0
Nodes Connected Only To Turned Off Pipes: 0
Known Temperatures: 427

Unknown Temperatures: 0
Known Gas Properties: 0
Unknown Gas Properties: 427

Design Factor: 63000.000
Total All Flows In To The System: 63.045 Mcfh
Total All Flows Out Of The System: 62.939 Mcfh
Difference In Total Flows: 0.106 Mcfh

Element Summary...
Compressors: 0
Fittings: 0
Pipes: 477
Regulators: 1
Valves: 0
Wells: 0
Attribute Valves: 0
Number Of Closed Elements: 0

Customer Summary...
Total Customer Count: 2090
Total Customer Unit Count: 2090
Total Turned-Off Customers: 0
Total Customers Assigned To 'From' Node: 0
Total Customers Assigned To 'To' Node: 0
Total Customers Assigned To 'Both' Nodes: 2090
Total Load Into System: 0.000 Cfh
Total Load Out Of System: 0.998 Cfh