Hydraulic Analysis Comparing Efficiency of One and Two-Zone Pressure Water Systems

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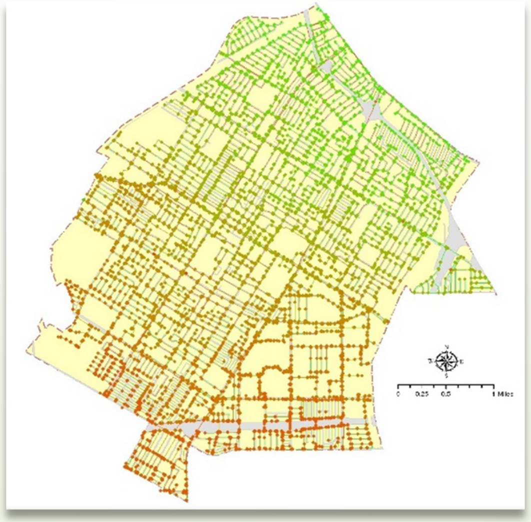
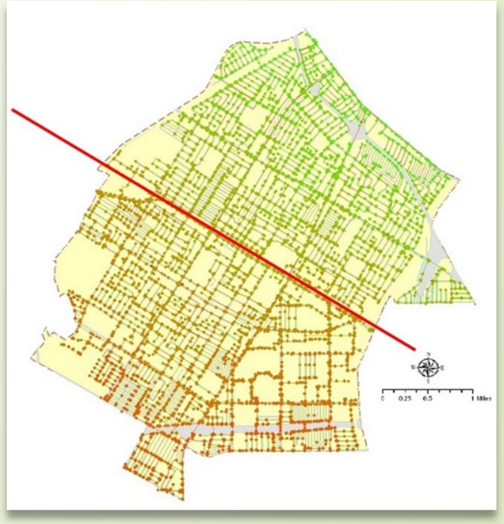


- Energy
- Pressures
- Implementation

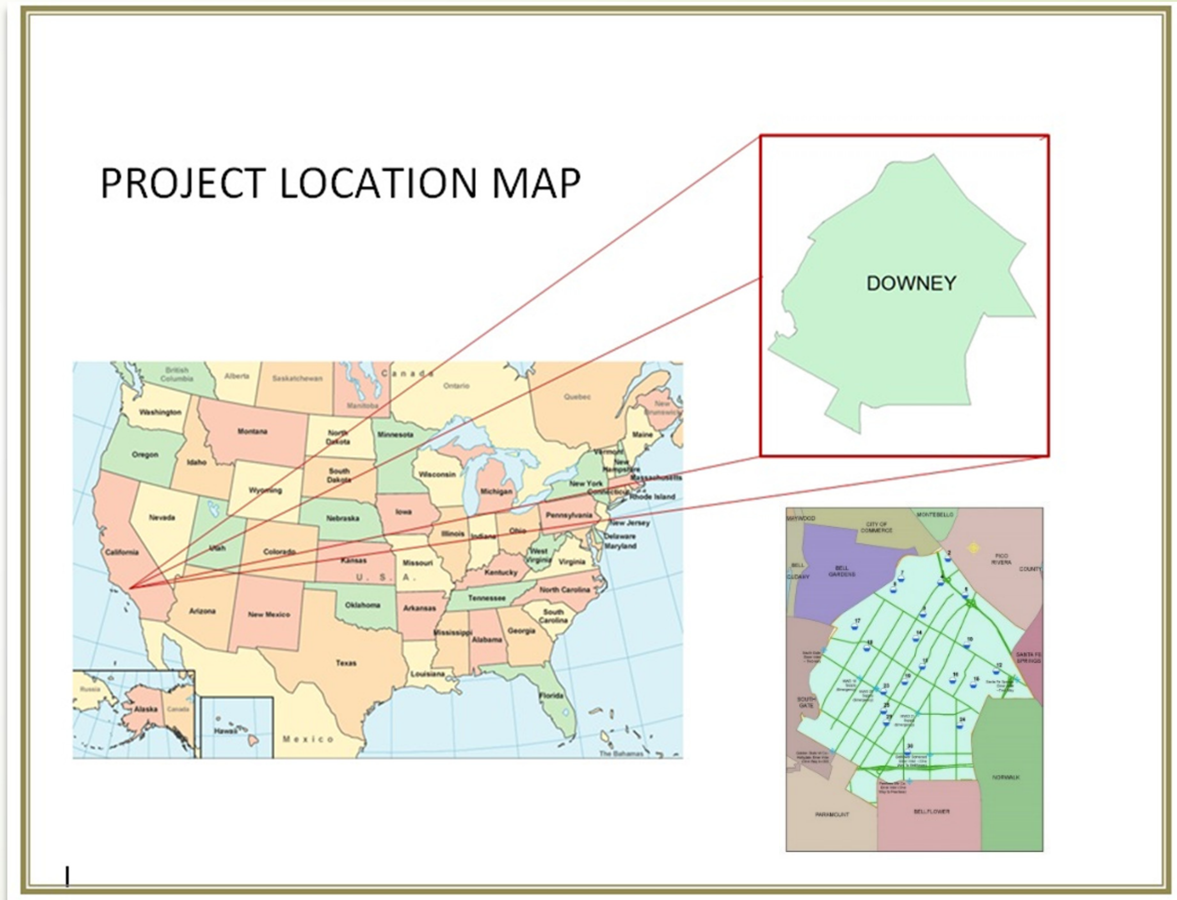


Agenda

- Background (Geography, Topography, Water Distribution System, Problem Description)
- Project objectives
- Project approach methodology, existing model updates and a comparative analysis
- References
- Questions

Background

- Overview of City of Downey
  - Location – 12 miles south east of downtown Los Angeles
  - Area - 12.8 Sq. miles
  - Population - 113,000
  - Topography, elevations range from 140 ft. to 85 ft. above sea level gives a total relief of 55 ft.
  - Primary drinking water purveyor
  - Five emergency connection with other water agencies

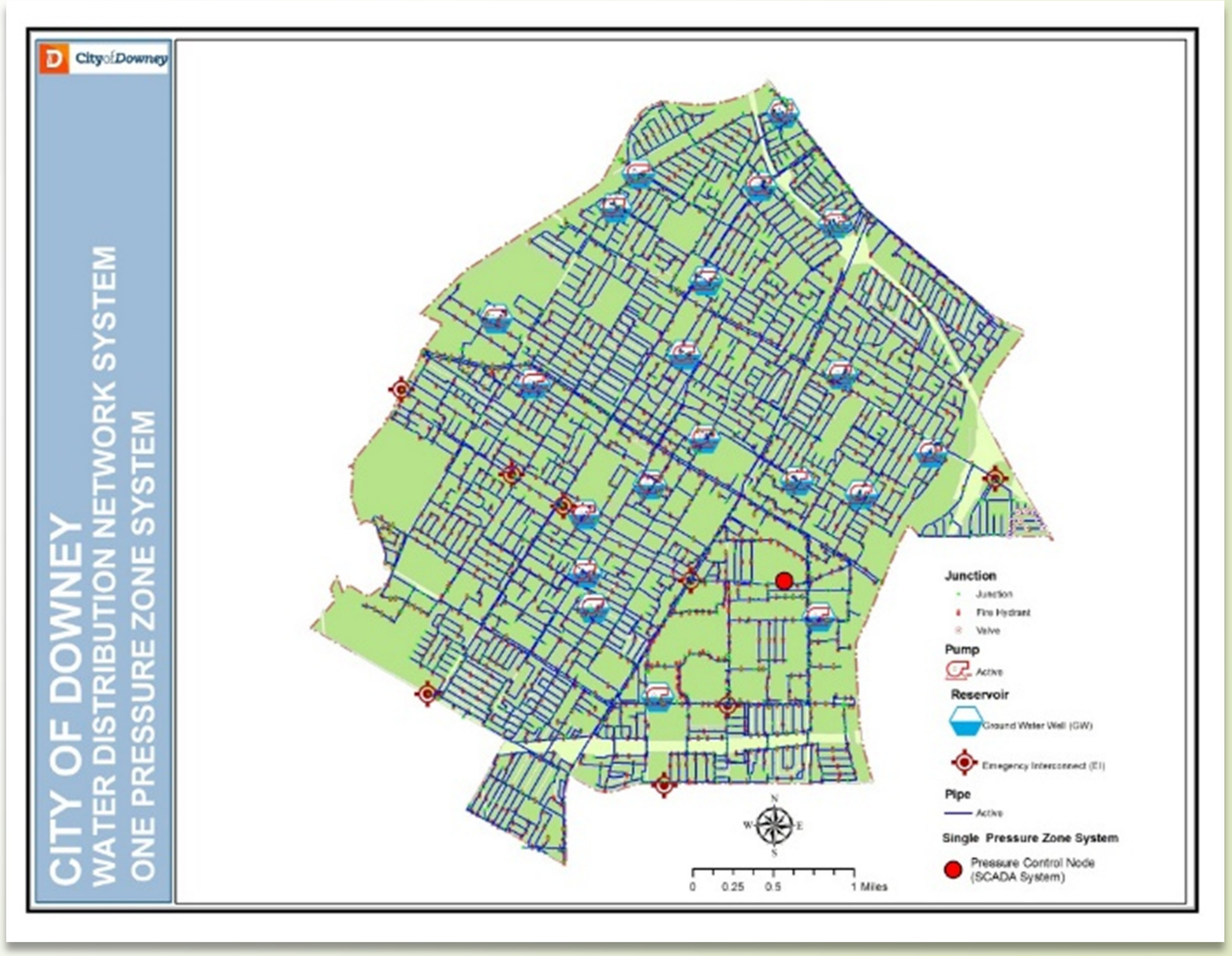


onlineatlas.us(n.d.)

Background

- Overview of Downey's water distribution network
  - Groundwater sources
  - Central basin aquifer
  - Service connections 21,500
  - No. of active groundwater wells 20
  - Average daily demand 10.2 MGD
  - Total pipe length in miles – 260
  - No. of valves – 3,800
  - No. of fire hydrants – 1,850
  - System pressure varies from

    north (48 psi) to south (98 psi)
  - Water system well operations are managed by SCADA



Background

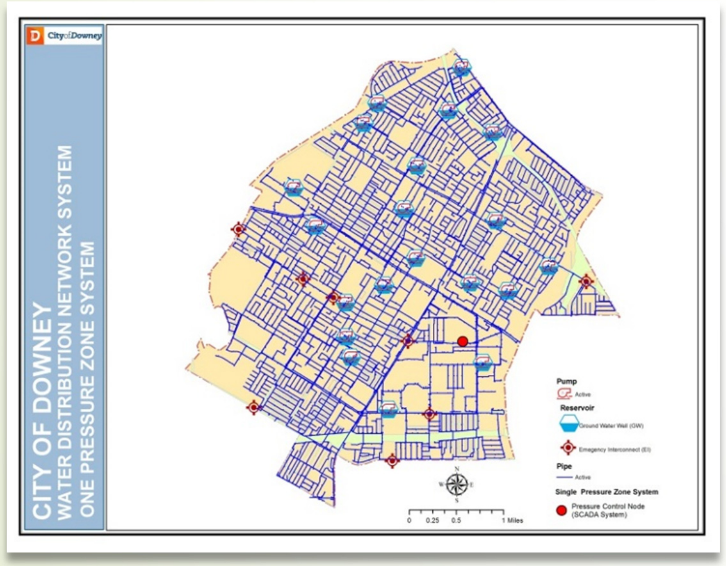
- Problem description
  - High costs of pumping energy rates. Annual energy cost for operating 20 wells is about $1.4 million
  - There is about 50 psi difference between north and south portion of the City
  - Existing system is configured as 1 Zone system and the wells are controlled from a single monitoring node
  - Well pumps run more frequent to stabilize the system pressure

Next Topic

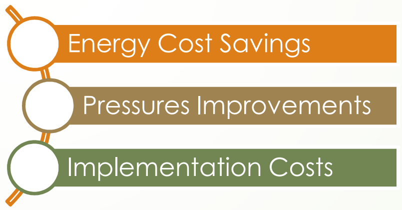
- Background (Geography, Topography, Problem Description)
- **Project Objectives**
- Project Approach Methodology and Analysis
- References
- Questions

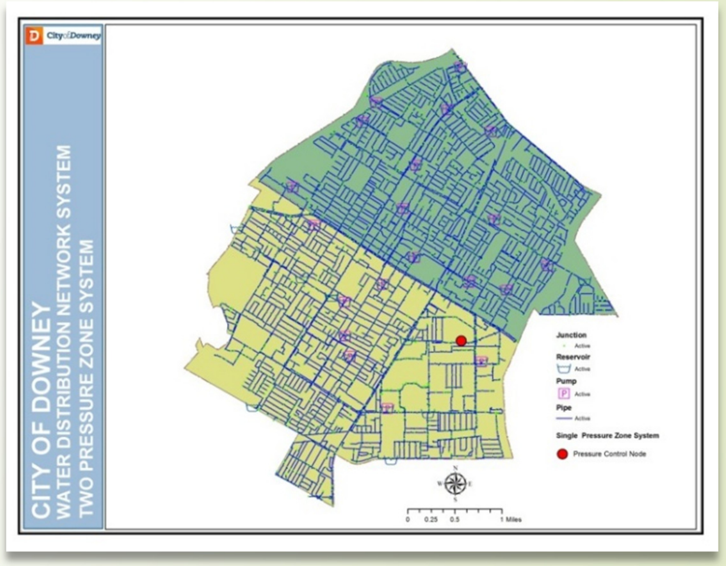
Project Objectives

- This project will quantify the improvements in terms of energy conservation and pressure variability by moving to a two zone system, and to determine the payback period.



Existing Condition





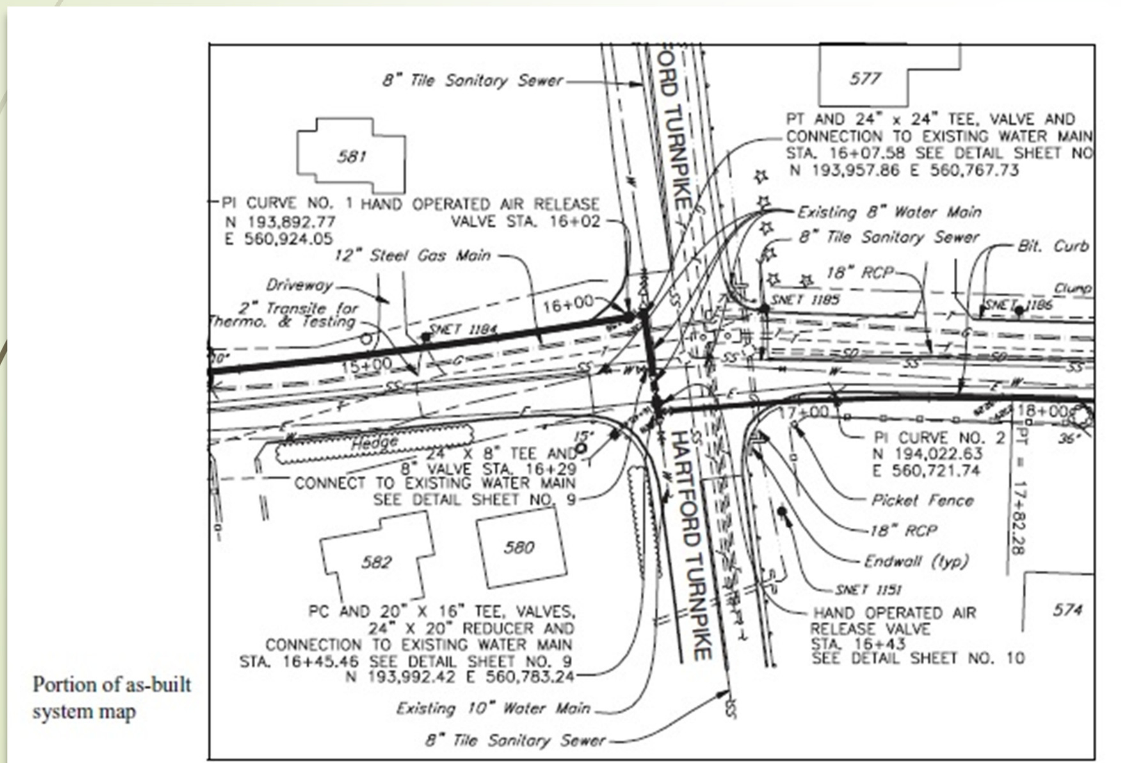
Project Goal

Next Topic

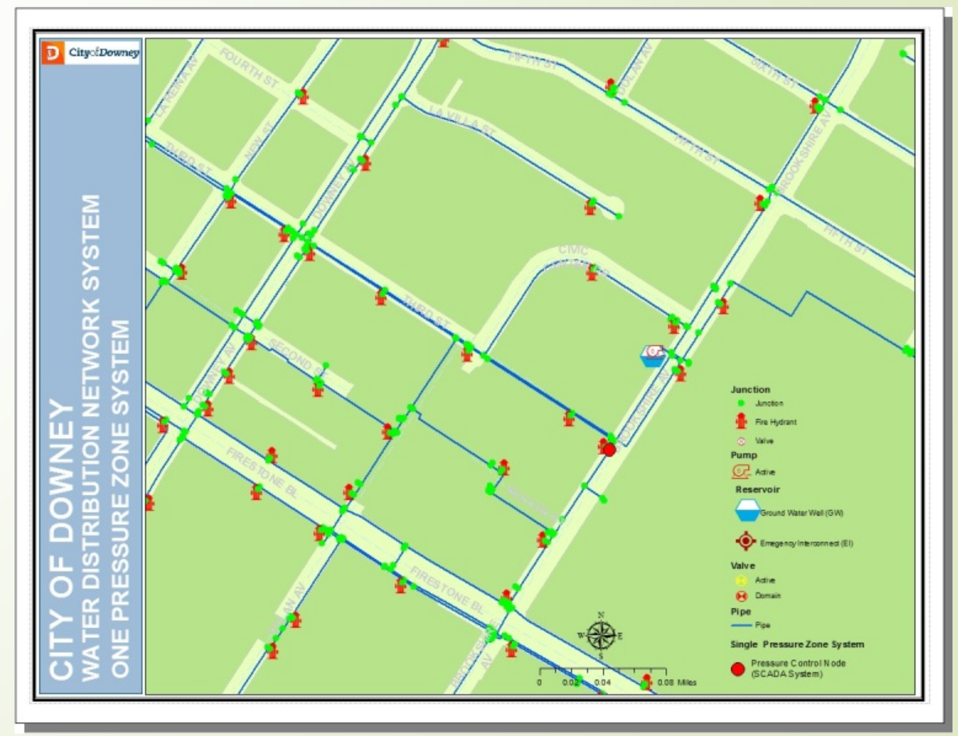
- Background (Geography, Topography, Problem Description)
- Project Objectives
- **Project Approach Methodology and Analysis**
- References
- Questions

Project Approach Methodology and Analysis

- Existing City's hydraulic model
  - Last updated with consumption data in 2009
  - GIS Layers, engineering record drawings and as-builts
  - InfoWater Software
  - Hydraulic Model Simulation



A typical Asbuilt/ Engineering Record (Walski, 2003)



GIS Feature Classes

Data Collection

- Water meter consumption data for 2014 for each household
  - Billing data stored with 100 CF units
  - Gallons Per Minute(GPM) conversion
  - Total number of meter nodes 21,789
  - Assessor Parcel Number, relate with parcels GIS layer
  - Demand node allocation
  - Sample records from finance billing system

Table

WaterConsumption_2014

OBJECTID *	ID	Strno	Fract	Street	Type_	Unit	ZIP	Meter_No	Read_Date	Land_Use	Cons	acct1	acct2	metsize	units	waterusage
1	698340	107	111	STONEWOOD MAL	<Null>	125	90241-3905	0001323988	3/10/2014	Commer	808	2405-464	002	2	19	77.76
3	698340	107	111	STONEWOOD MAL	<Null>	125	90241-3905	0001323988	6/30/2014	Commer	473	2405-464	002	2	19	77.76
4	698340	107	111	STONEWOOD MAL	<Null>	125	90241-3905	0001323988	8/26/2014	Commer	476	2405-464	002	2	19	80.09
7	698341	113	121	STONEWOOD MAL	<Null>	<Null>	90241-3905	0001323920	3/10/2014	Commer	1096	2405-463	003	2	3	77.76
10	698341	113	121	STONEWOOD MAL	<Null>	<Null>	90241-3905	0001323920	8/26/2014	Commer	918	2405-463	003	2	3	80.09
11	698341	113	121	STONEWOOD MAL	<Null>	<Null>	90241-3905	0001323920	10/20/2014	Commer	828	2405-463	003	2	3	1895.91
13	698341	102	148	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001323923	3/10/2014	Commer	910	2405-466	002	2	10	77.76
14	698341	102	148	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001323923	5/5/2014	Commer	781	2405-466	002	2	10	77.76
15	698341	102	148	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001323923	6/30/2014	Commer	869	2405-466	002	2	10	1933.02
17	698342	102	148	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001323923	10/20/2014	Commer	747	2405-466	002	2	10	80.09
18	698342	102	148	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001323923	12/23/2014	Commer	844	2405-466	002	2	10	1932.92
21	698342	206	272	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001324114	6/30/2014	Commer	10	2405-499	002	2	4	77.76
22	698342	206	272	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001324114	8/26/2014	Commer	11	2405-499	002	2	4	80.09
23	698342	206	272	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001324114	10/20/2014	Commer	11	2405-499	002	2	4	21.21
25	698342	274	292	STONEWOOD MAL	<Null>	EVEN	90241-3905	0001323922	3/10/2014	Commer	93	2405-497	002	2	15	190.13

94141 (0 out of 94150 Selected)

WaterConsumption_2014

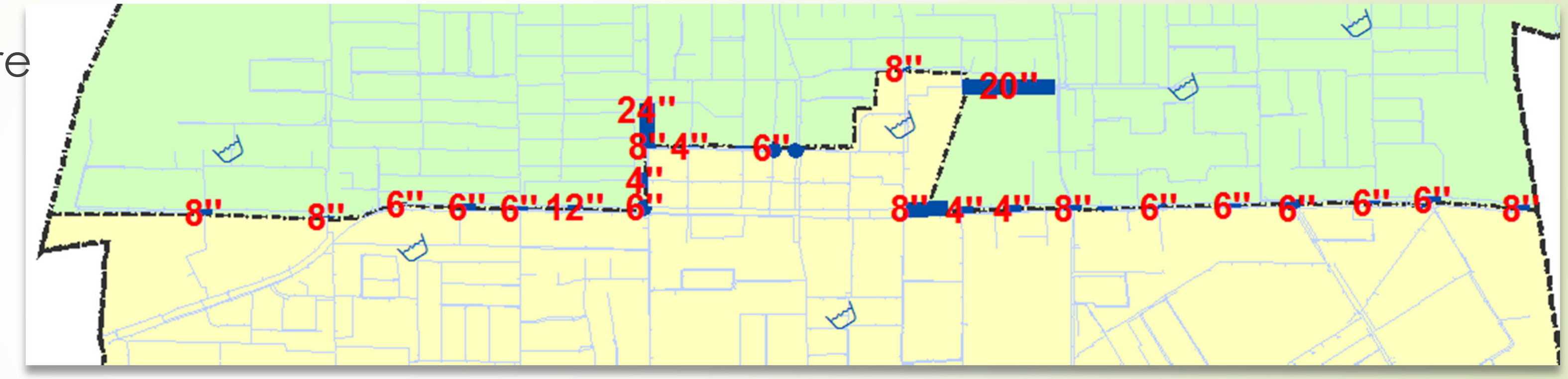
Data Collection

- Well pumps field test
  - Southern California Edison (Electrical purveyor)
  - Frequency of tests
  - Updates to Model

WELL	Location	Pump hp	Latest Pump Test			Elevation
			Well Cap	@ PSI	kW	
4	8040 Allen Grove	350	2881	59.2	224	139
11	11051 Brookshire	450	3028	68	374	120
16	9156 Cecilia Ave	200	1573	60.7	115	119
17	7237 E. Pellett	75	669	71.8	52	116
30	9131 Imperial Hwy	125	850	78.5	66	96
8	7442 Lubec Ave	100	1106	53.5	86	134
14	10505 La Reina Ave	100	811	69.3	63	125
24	9643 Washburn Ave	100	314	71.8	33.9	106
23	8201 Stewart and Gray	100	776	71.4	65	113
10	10001 Haldon Ave	150	1194	71	99.2	129
18	7538 Burns Ave	150	1382	71.9	116.4	115
2	7932 Telegraph Rd	100	536	55.1	46.8	147
25	12120 Downey Ave	150	1249	72.5	98	108
9	9856 Paramount Blvd	100	811	69	68	130
29	12240 1/2 Planett	125	1367	57	96	106
12	10228 Lesterford	175	1714	74	137	126
15	10636 Casanes Ave	125	1095	74	91.5	118
5	9034 Stoakes ave	75	635	60	49	143
19	11523 Dolan Ave	100	903	72	68.5	114
7	7440 Suva Ave	100	787	70.7	70	133
Yard	9252 Stewart and Gray					107
	Century & Lakewood					88

Zone Boundary Conditions

- Two boundary conditions
- Optimal pipe segments
- Straight line division (First trial)
- Final 2 zones boundaries
- Total pipe segments for closure



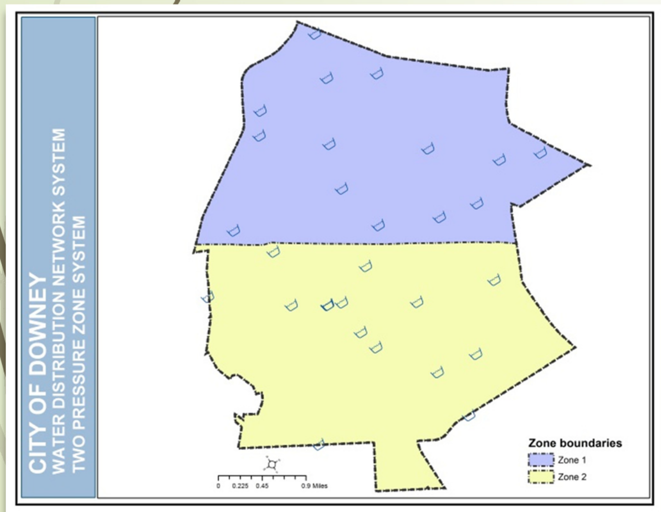


Figure (a) Dual zones boundary well flows not balancing

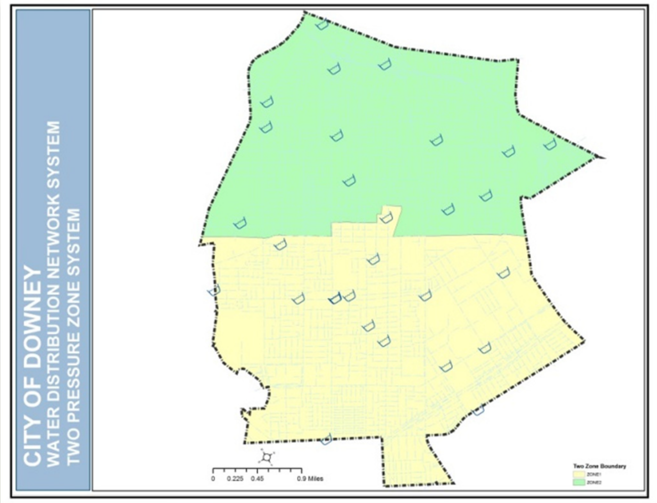


Figure (b) Dual zones boundary well flows balancing

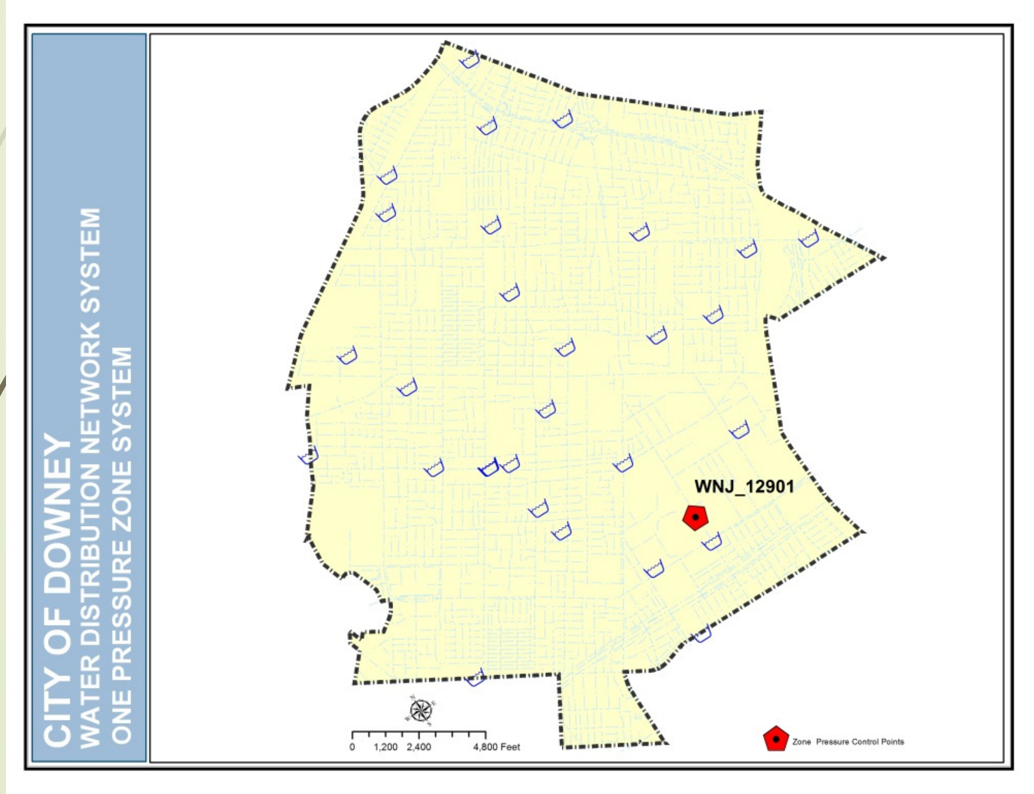
VALVE DIAMETER SIZE	NO OF PIPES TO BE CLOSED	MATERIAL
4"	5	CI
6"	12	CI
8"	8	AC
10"	1	CI
12"	2	CI
20"	2	CI
24"	2	CI
Total Number of Pipes to be Closed	32	

Number of pipe segments closed

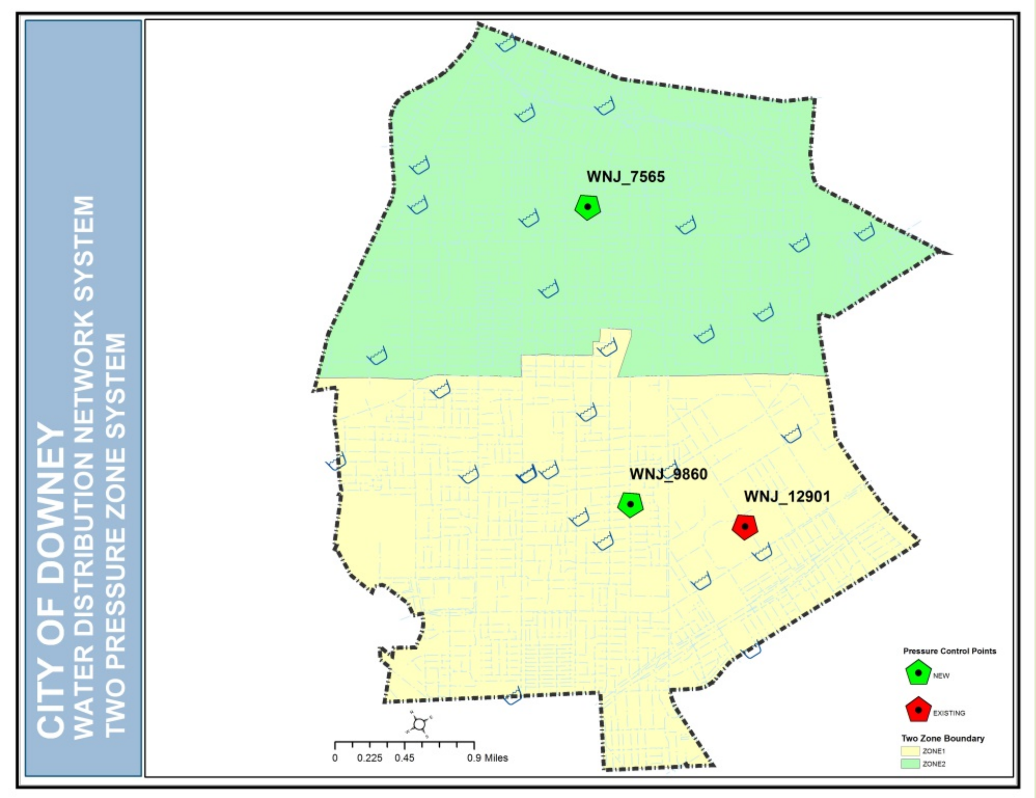
Pressure Control Nodes Location Selection

- 1 Zone analysis
  - Pressure control node 12901
  - Control node location

- 2 zones analysis
  - North Zone
    - Pressure control node 7565
  - South Zone
    - Pressure control node 9860



1 Zone



2 Zones

Well Pumps Operations Sequencing Order

- Wells start/stop sequence order list
- Existing 1 zone system sequence order
- 2 zones sequence order updates to hydraulic model

1 ZONE WELL PUMPS SEQUENCING	
Well #	SEQUENCE
16	1
17	2
30	3
08	4
14	5
24	6
23	7
10	8
18	9
02	10
25	11
09	12
29	13
12	14
15	15
05	16
19	17
07	18
04	24 Hr.
11	24 Hr./VFD

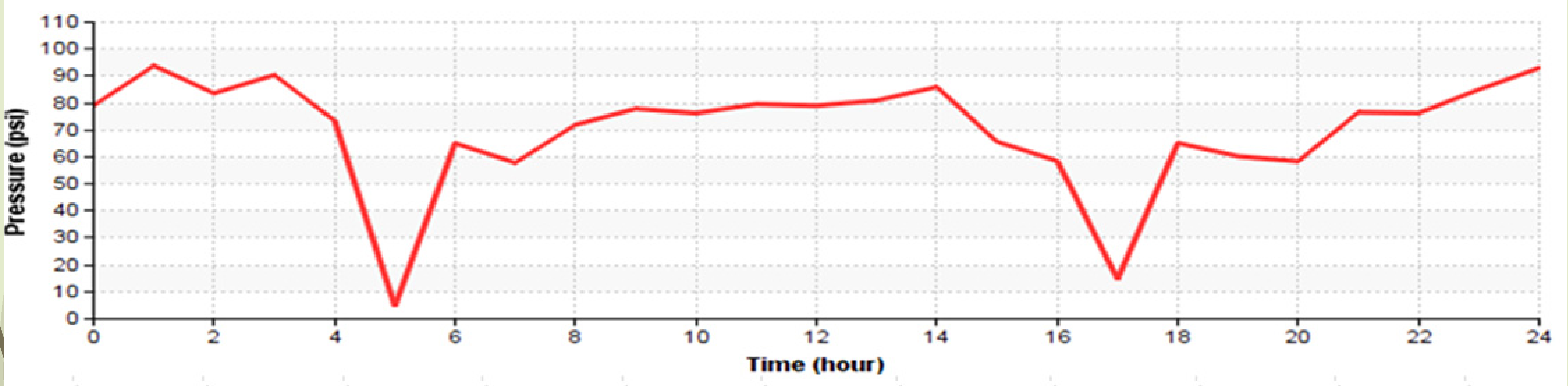
1 Zone

2 ZONES WELL PUMPS SEQUENCING				
ZONE 1			**ZONE2**	
Well #	**Well Pump Sequecning**		**Well #**	**Well Pump Sequecning**
04	Always Running		**11**	Always Running
16	Always Running		**30**	Always Running
14	Always Running		**24**	Always Running
08	Always Running		**18**	Comes on next
10	Always Running		**25**	After 18
02	Comes on next		**23**	After 25
17	After 02		**19**	After 23
09	After 17		**29**	After 19
12	After 09			
15	After 12			
05	After 15			
07	After 05			

2 Zones

1 Zone System Pressures (psi) at Control Node 12901

- System pressure analysis using EPS for a 24 Hours period
- Summer peak day flow scenario
- Valleys depict the lowest pressure (High Demands)

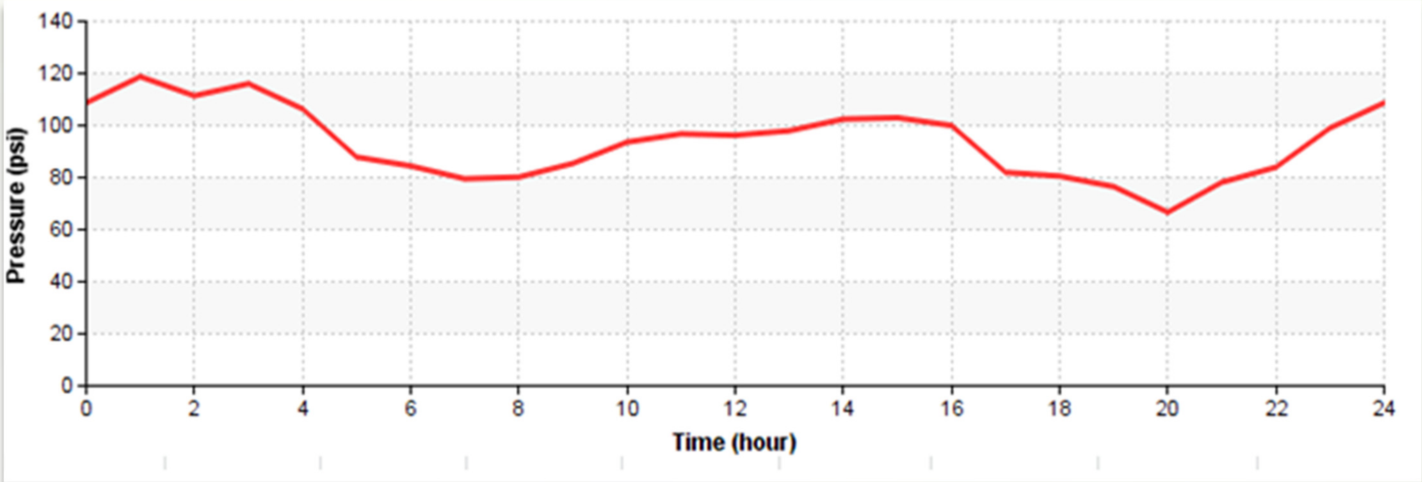


Summer peak day flow scenario was used to perceive the highest demand flow in the system to visualize the pressures

1 Zone

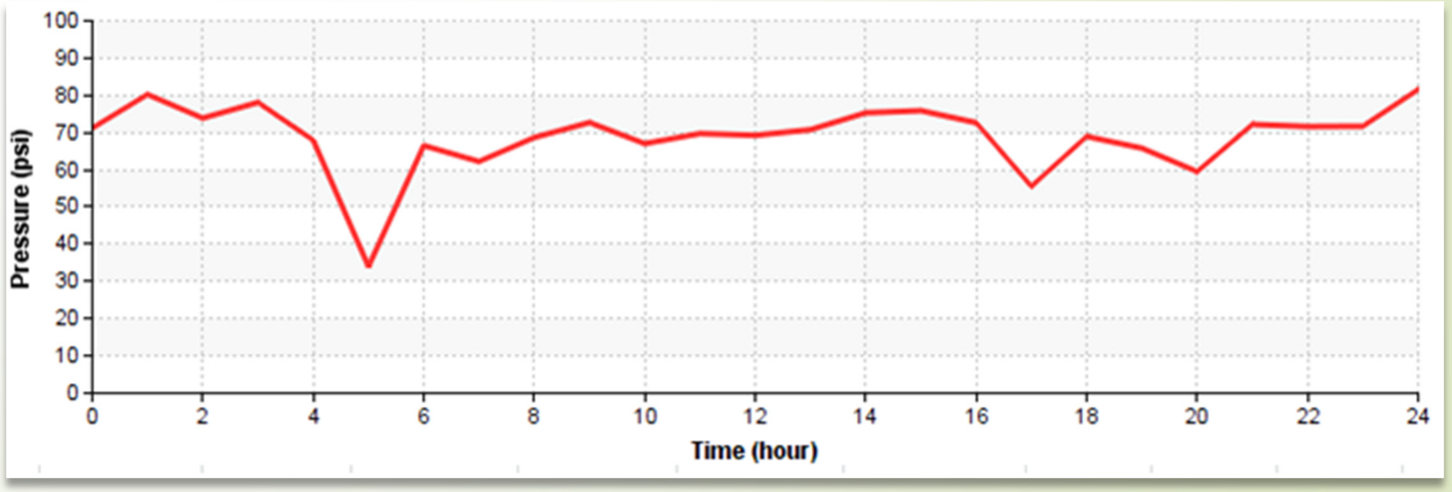
2 Zones (North and South) System Pressures(psi)

- North zone
  - System pressures stabilized
  - No valleys with low pressures



North Zone Control Node 7565

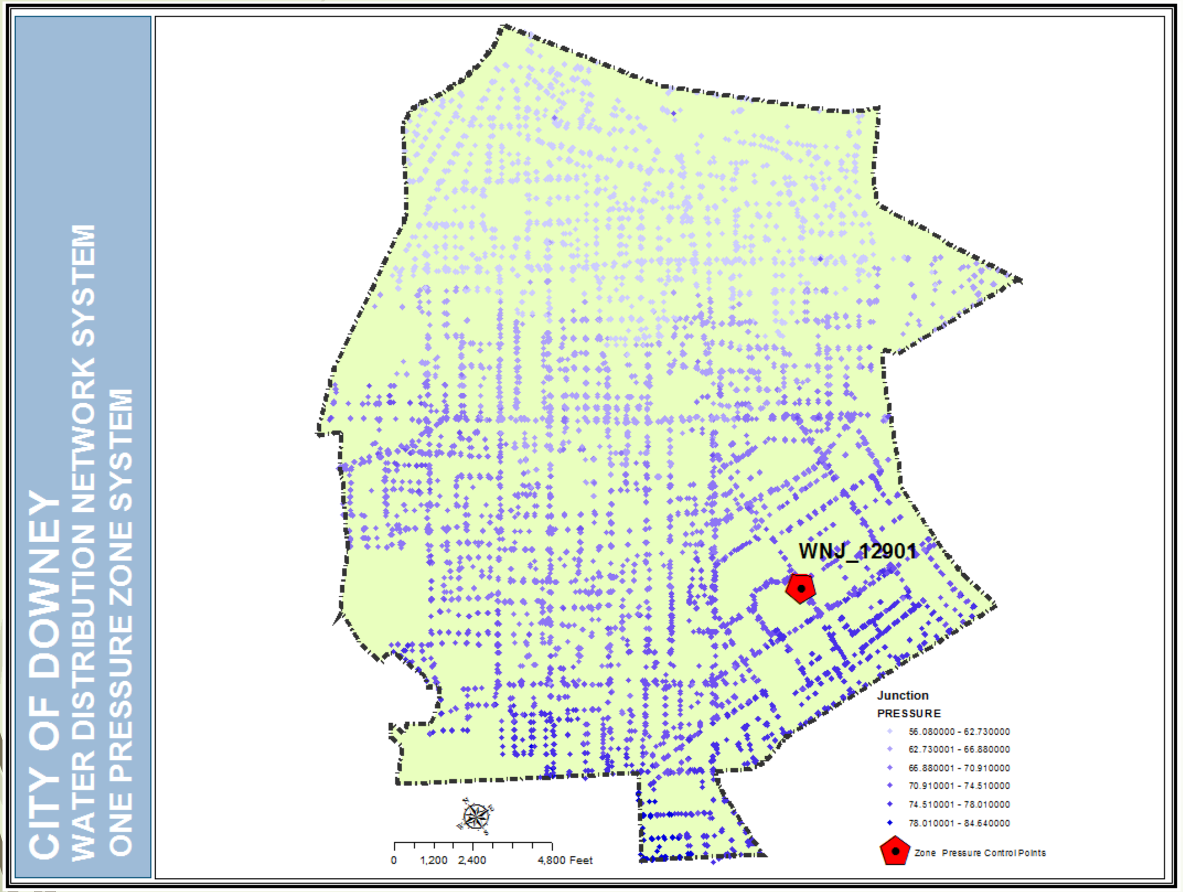
- South zone
  - System pressures stabilized
  - One valleys with improved pressures



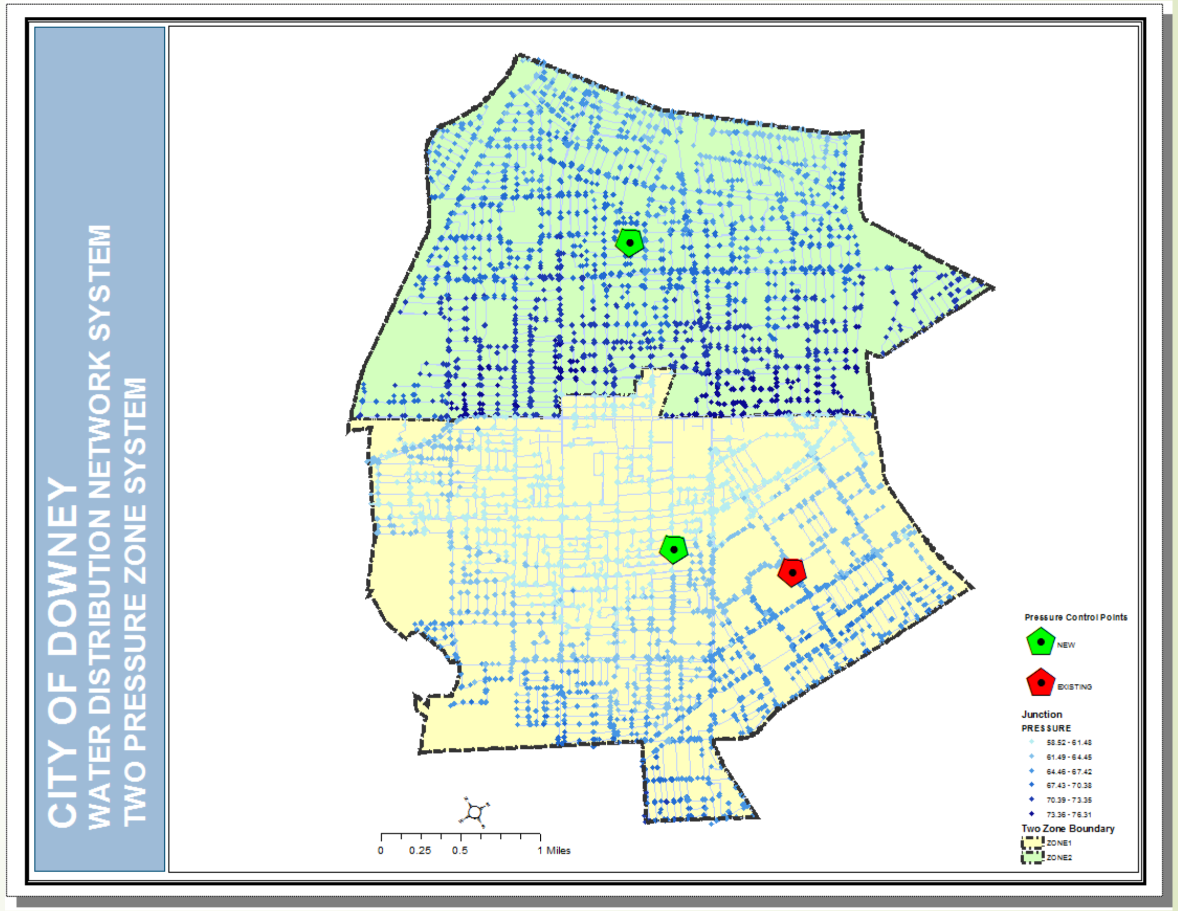
South Zone Control Node 9860

1 Zone and 2 Zones Pressure Variations

- 1 zone pressures range from 56 psi to 85 psi
- 2 Zones pressures pattern much improved



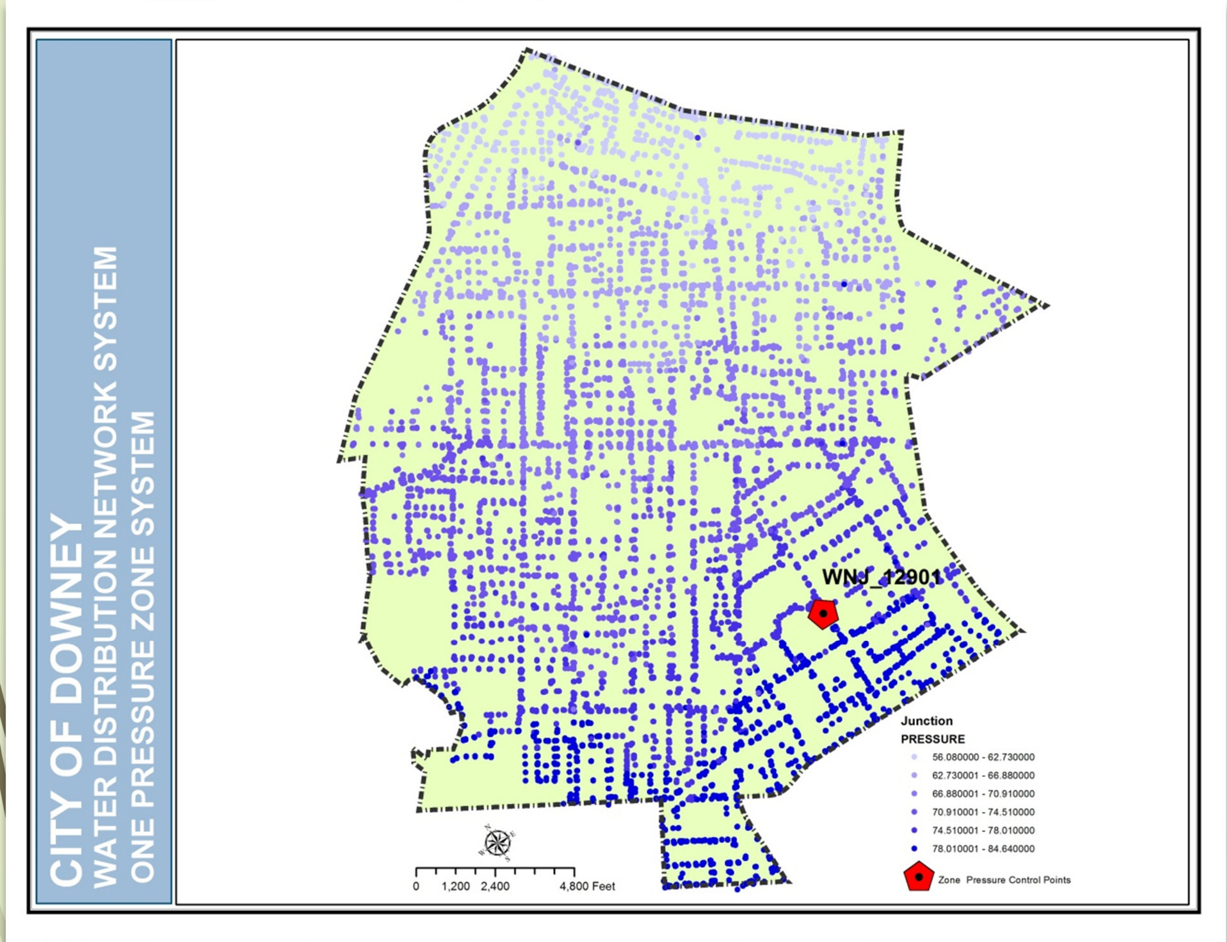
1 Zone

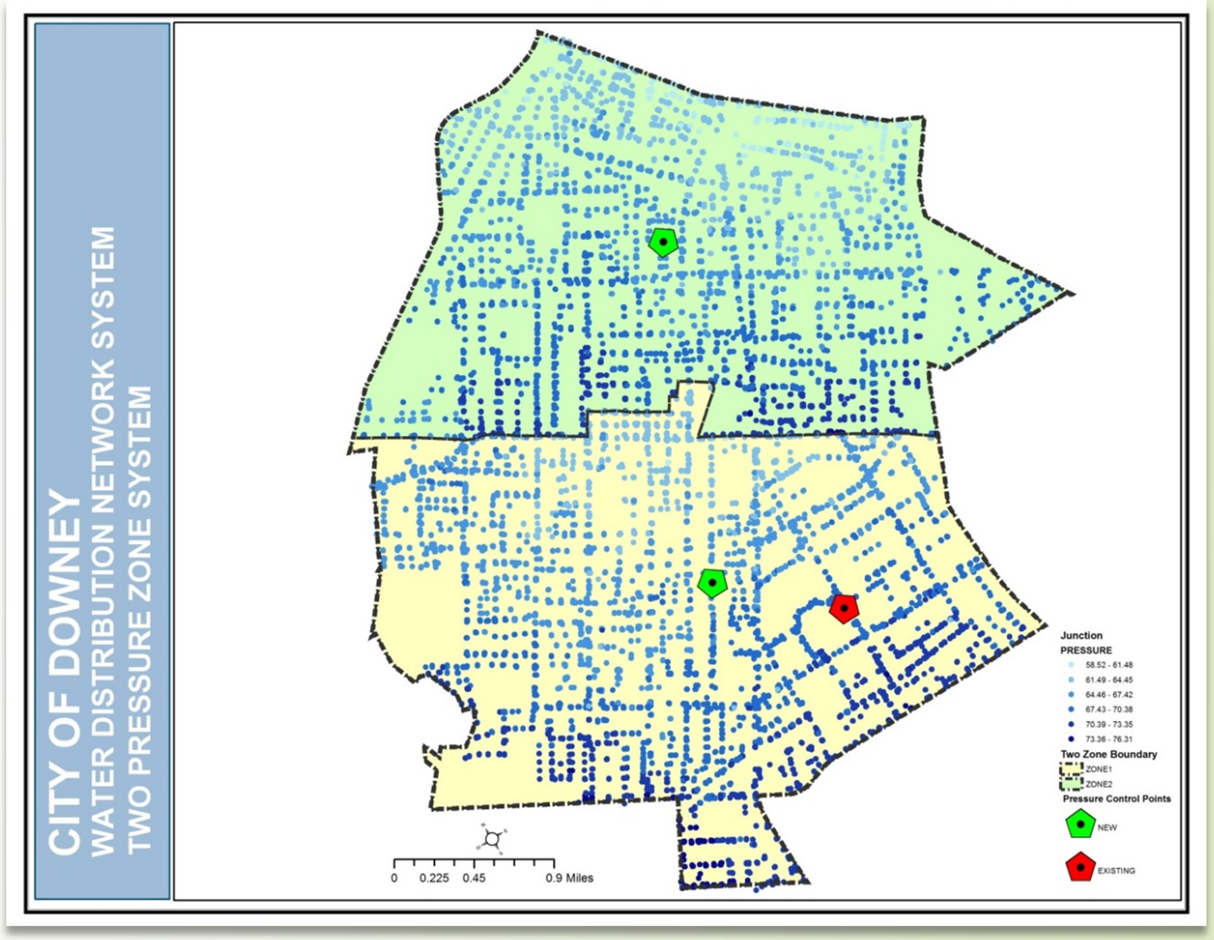


2 Zones

6:00 AM Time Stamp

1 Zone and 2 Zones Pressure Variations





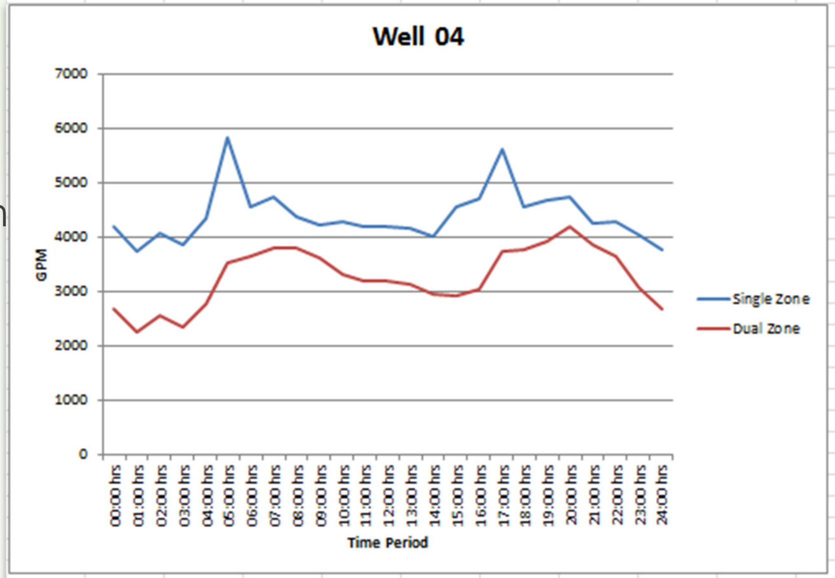
1 Zone

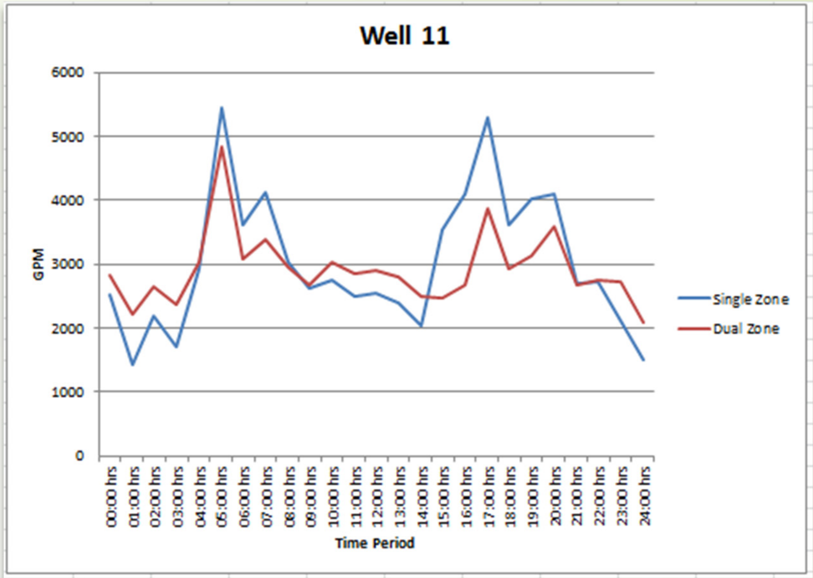
2 Zones

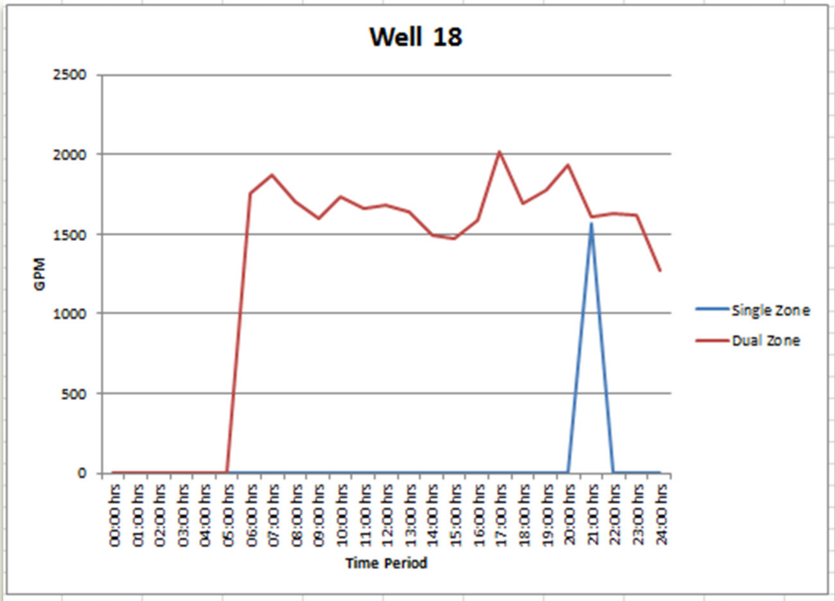
18:00 Time Stamp

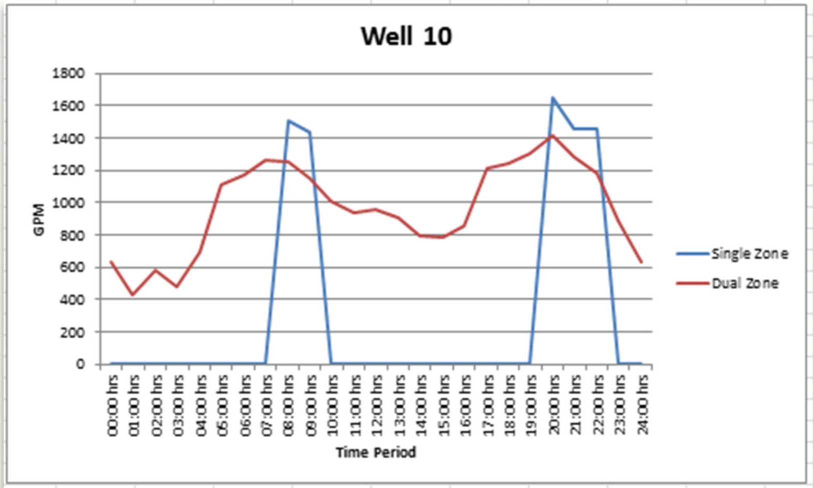
One and Two Zones Flow Comparison

- Larger Pumps (500 hp &450 hp)
  - High flows in (blue) 1 zone system
  - Lower flows (red) in 2 zones system
- Smaller Pumps (100 hp & 160 hp)
  - Intermittent flows in 1 zone system
  - Better support in 2 zones system









Pump Energy Consumption Calculations

Pump motor affinity law

Power is proportional to cube of water flow

P1 = Edison tested energy wattage in kWh

Q1 = Edison tested discharge or flow in GPH

P2 = Hydraulic model energy at a given time (unknown)

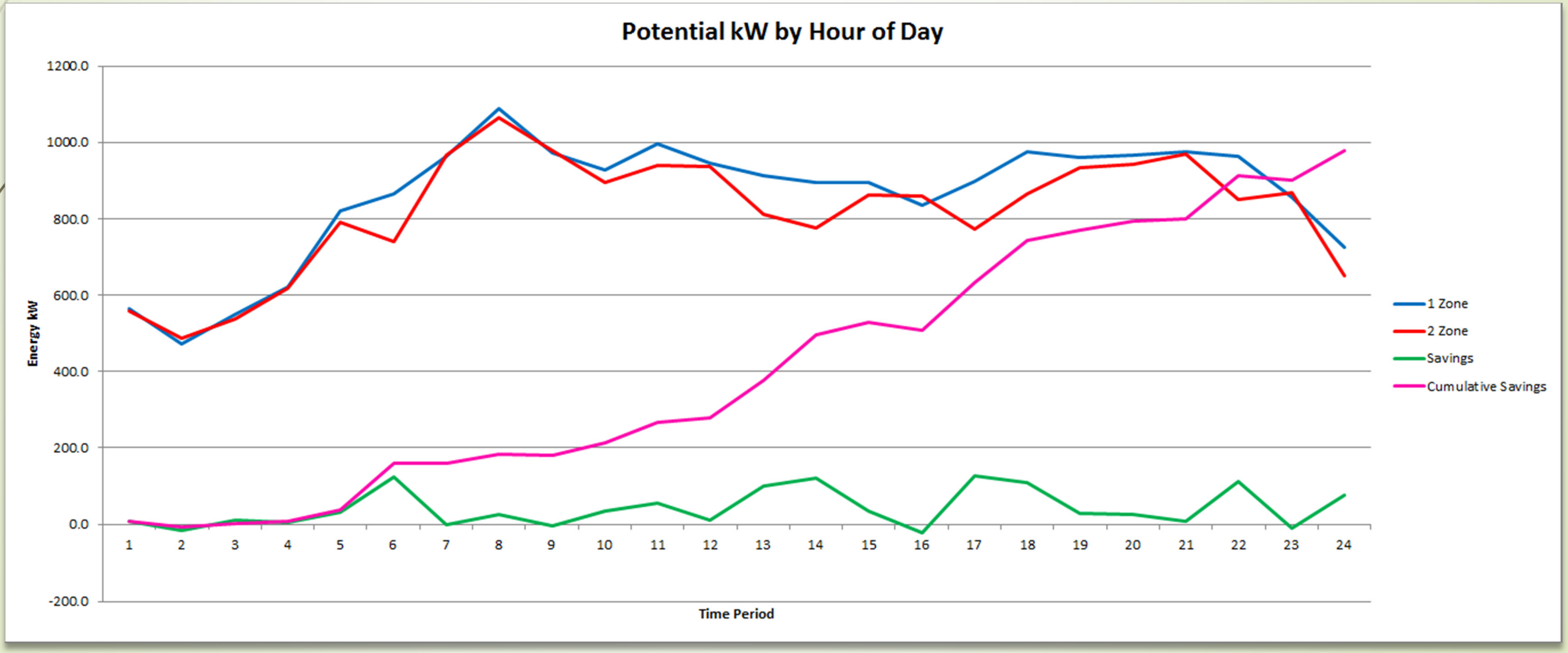
Q2 = Pump flows at a given time period from hydraulic model

P1/P2 = (Q1/Q2)^3

P2 = P1*(Q2/Q1)^(1/3) in kWh

Single and Dual Zone Energy Comparison(kW)

- Blue color line, energy consumption in 1 zone system
- Red color line, energy consumption in 2 zones system
- Green color line, energy savings over 24 hours period
- Purple color line cumulative energy savings



Pump Energy Savings in Dollar Amount

- Annual average demand used for conservative totals
- Lowest tier rate of $ 0.11092 per kWh
- Total annual savings $120,720

Water System Average Daily Flow		10,202 GPM	Water System Summer Peak Day Flow	13,074 GPM
	Pump hours per day	Peak Electrical Demand	Annual kWh @ Peak Demand	Annual kWh @ Average Demand
			kWh	kWh
Single Zone	175 hours	1,316 KW	12,874,175	6,213,121
Dual Zone	220 hours	855 kW	10,928,812	5,124,761
			kWh	
		Totals Savings	1,945,363	1,088,360

Average day flow scenario was taken to perceive to use minimum tier rate to foresee minimum possible savings

Energy cost savings per year

Edison Energy Rate per kWh		Total Energy Savings (kWh)/Year	ToTal Costs
$ 0.11092		1,088,360	$ 120,720.89

Dual Zone Implementation Payback Recovery Analysis

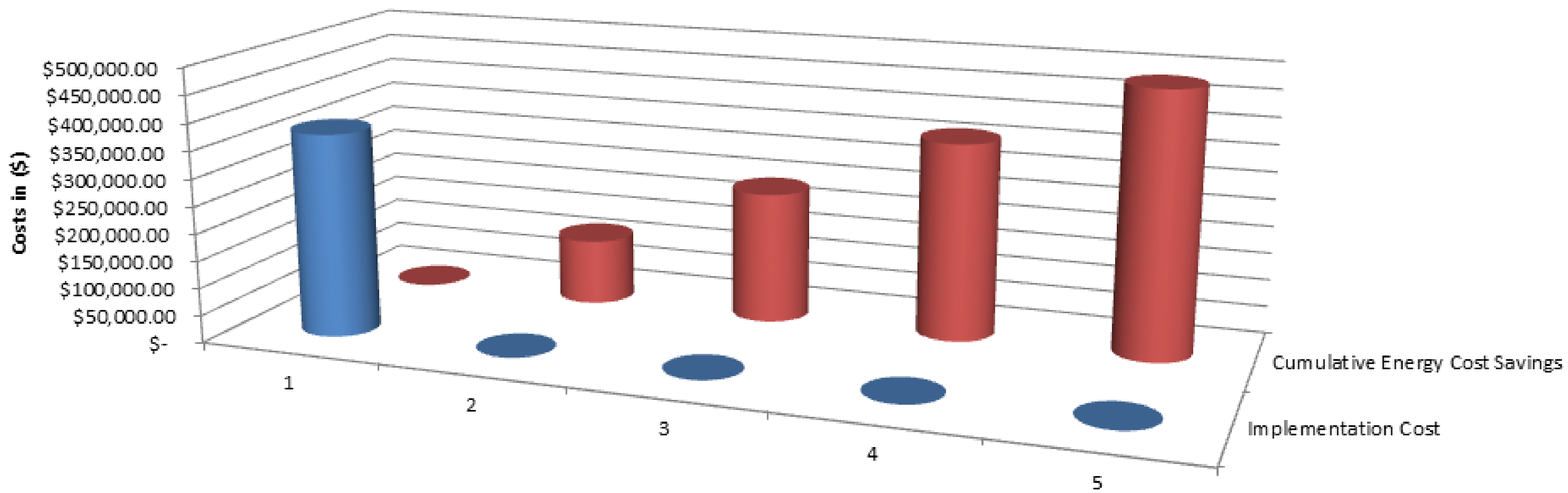
- Implementation cost figures from Utilities Division
  - Valve material and labor costs
  - SCADA monitoring nodes setup
- Total implementation costs $373,000
- Total annual savings $120,720
- Payback Period 3.09 years

VALVE DIAMETER SIZE	NO OF PIPE SEGEMENTS TO BE CLOSED	PIPE MATERIAL	IMPLEMENTATION COSTS/ VALVE (CONSTRUCTION & MATERIAL)	TOTAL COSTS
4"	5	CI	$ 5,000.00	$ 25,000.00
6"	12	CI	$ 6,000.00	$ 72,000.00
8"	8	AC	$ 7,000.00	$ 56,000.00
10"	1	CI	$ 10,000.00	$ 10,000.00
12"	2	CI	$ 12,000.00	$ 24,000.00
20"	2	CI	$ 18,000.00	$ 36,000.00
24"	2	CI	$ 25,000.00	$ 50,000.00
				$ 273,000.00
SCADA MODIFICATIONS	2 STATIONS		$ 100,000.00	$ 100,000.00
			Total Implementation Costs	$ 373,000.00

Payback recovery time

Net Pay Back Analysis	Costs
Total Impelementation Costs	$ 373,000.00
Total Energy Savings per year	$ 120,720.89
Number of Years for Cost Recovery	3.09

Cost Benefit Analysis



	1	2	3	4	5
Implementation Cost	$373,000.00	0	0	0	0
Cumulative Energy Cost Savings	0	$120,720.89	$241,441.78	$362,162.67	$482,883.56

Year

Summary of Results

- Local pressures in the 2 zones system improved
- Over $120,000 in energy savings
- Payback recovery time of 3.09 years for the estimated installation costs

Next Topic

- Background (Geography, Topography, Problem Description)
- Project Objectives
- Relationship between Water Distribution System, GIS, and Hydraulic Modeling
- Hydraulic Modeling Concepts
- Project Approach Methodology and Analysis
- **References**
- Questions

References

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Acknowledgements

Advisor - Dr. Patrick J. Kennelly

Questions?