Nitrification Control in the Distribution System to Reduce Resource Requirements

—

Lean Six Sigma Black Belt Project
by
pHishbone out of H_2O

January 25, 2018

CITY OF Tulsa
A New Kind of Energy

Project team

- Team members:
  - Melissa Gray, Project Manager, LSS black belt candidate
  - Stefanie Hunter, LSS black belt candidate
  - Eric Lee, LSS black belt candidate
  - Eric Parker, LSS black belt candidate
  - Benita Becton, LSS green belt
  - Jhoanna Murray, LSS green belt

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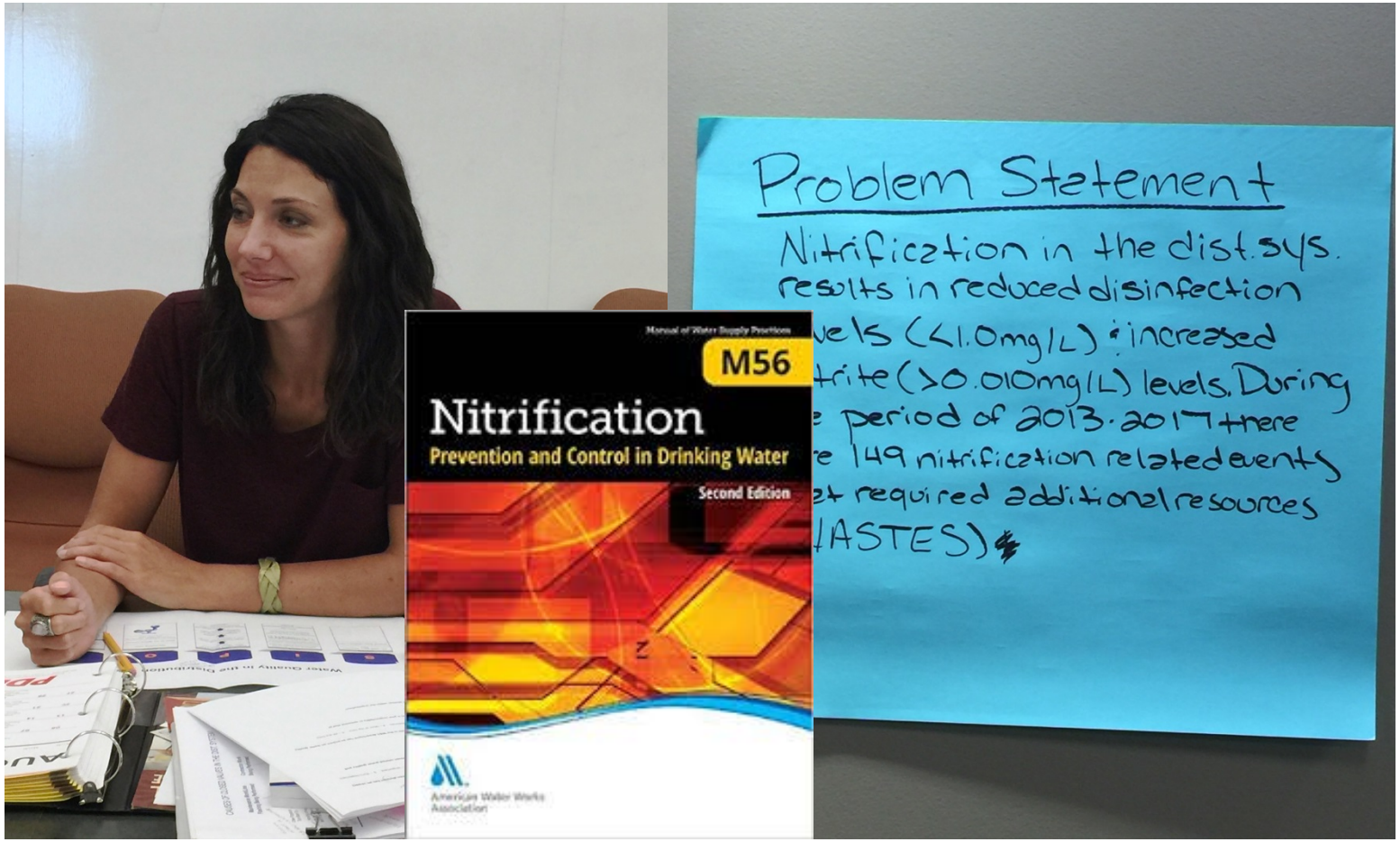
Training and project

- Classroom training conducted August 1st through August 31st
  - Conducted by Walter Miller and Mark Reid through Oklahoma City Community College
- Project team met each Thursday afternoon from September 2017 to January 2018
- Benita Becton and Jhoanna Murray were added to the team as the project progressed



Define Phase

Project selection and process

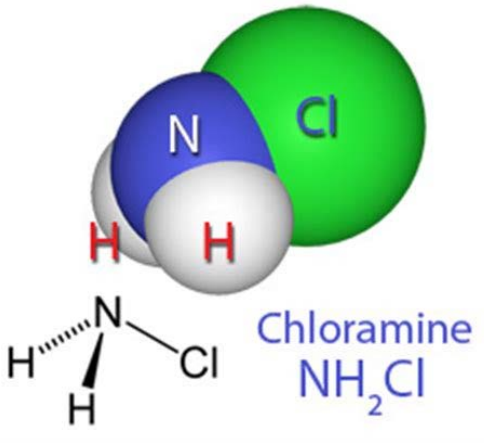
- Nitrification Control in the Distribution System to Reduce Resource Requirements
  - Historical data related to nitrification in the distribution system was analyzed to determine if there were opportunities available to reduce the amount of resources required to respond to water quality events that required additional resources

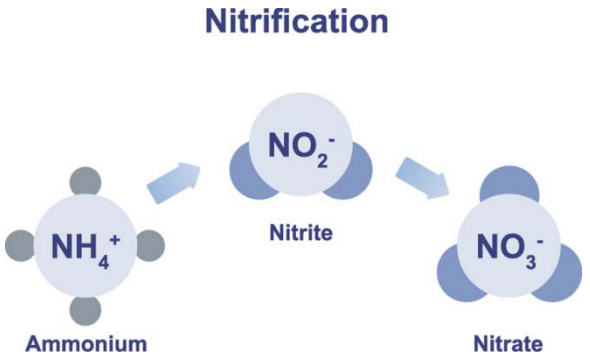
History

- In July 2012, the City of Tulsa switched from chlorine to chloramines for secondary disinfection of the water distribution system.
- The switch was to ensure compliance with the EPA's Stage 2 Disinfectants and Disinfection Byproducts Rule.
- The regulation reduces the risk of disinfection byproducts that can form when free chlorine combines with naturally occurring organic matter in the water.

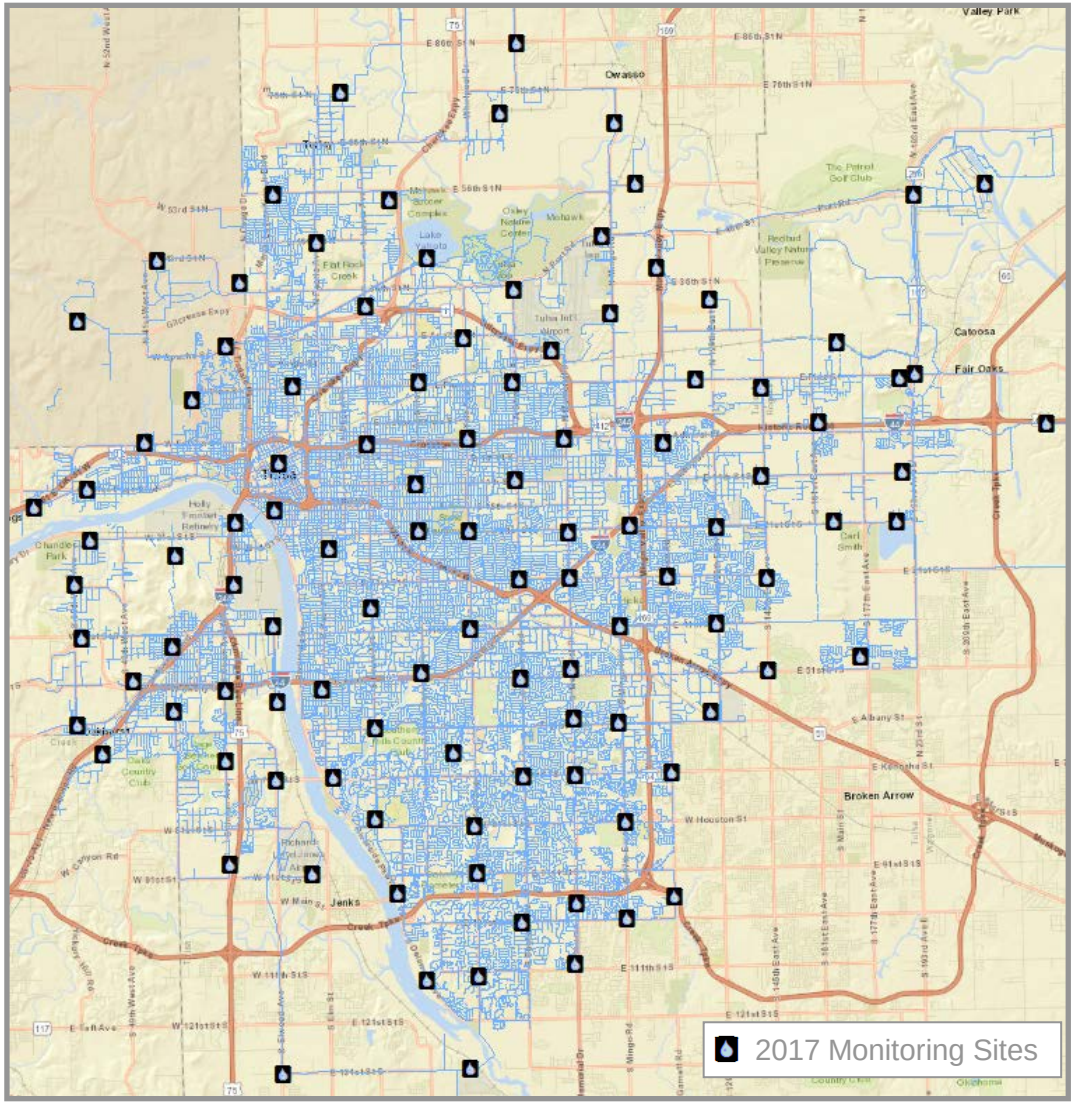
What is nitrification?

- Chloramines are formed by adding ammonia that binds to the free chlorine.
- Nitrification occurs when microbes present in the biofilm lining the distribution pipes consume the available ammonia then sequentially oxidize it to form nitrites and nitrates, which are regulated contaminants.





2017 Monitoring sites



Compliance Monitoring

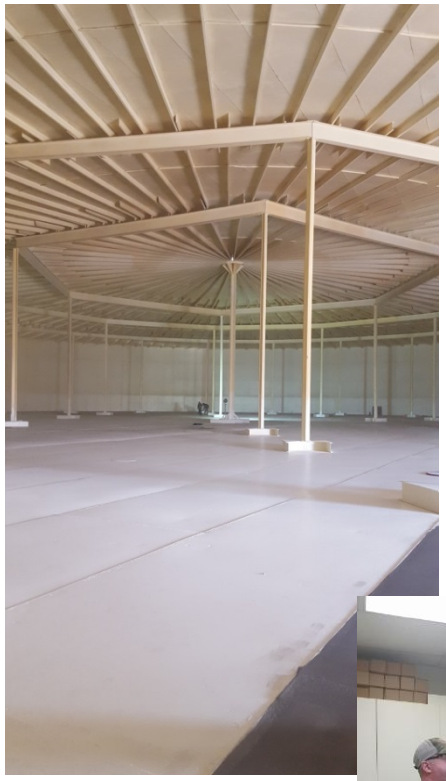
- 111 sites approved by ODEQ
- Monitored twice monthly
- Minimum of 2,664 annual tests

Nitrite Monitoring

- Goes above and beyond compliance
- Early detection/mitigation of potential nitrification conditions

Nitrification Monitoring and Response

- Storage tanks are located throughout the City to equalize daily demands and to ensure adequate pressures throughout the water supply system.
- Tanks provide critical storage needed for firefighting purposes.
- Of the City's total storage capacity of roughly 104.5 million gallons, the four tanks located at 61st and Sheridan account for just over half of that capacity.



Project charter

CITY OF Tulsa A New Kind of Energy.	WATER & SEWER DEPARTMENT	Revision No.:	
		Date Created:	8/24/2017
		Date Revised:	
	Six Sigma Info Gathering	Approved by:	
		Number:	Control #
		Section:	Division/Section

W&S Project Info Gathering Checklist

Team Members	Project Name	Nitrification Control in the Distribution System to Reduce Resource Requirements
	Date Project Initiated	August 24, 2017
	Executive Sponsor:	Clayton Edwards, W&S Director
	Project Champion:	Jo Brown, WQA Manager
	Black Belt Advisors:	Walter Miller, Eschelon LLC; Robyn Unideme, OPSI Project Manager
	Team Members:	Stefanie Hunter, Eric Lee, Eric Parker, Melissa Gray
Process	Process being evaluated:	Reducing nitrification exceedances in Tulsa's water distribution system
	Process Owner(s) - Individual(s) responsible for the business process being evaluated.	Roy Foster, Water Supply Systems; Jo Brown, Water Quality Assurance; Eric Parker, Water Distribution Systems
	What is the output from the process? (e.g. work product? Report? Inspection? Permit?)	Improved drinking water quality to utility customers, less time expended on remedial sampling, less water consumed due to unnecessary flushing, improved compliance with Federal Regulations
	Process Stakeholders (Who will be affected by the potential outcome)	Water Quality Assurance Field Staff, Water Distribution Maintenance Crews, Water Supply, Engineering Inspectors, Contractors, Utility Customers, TMUA, elected officials

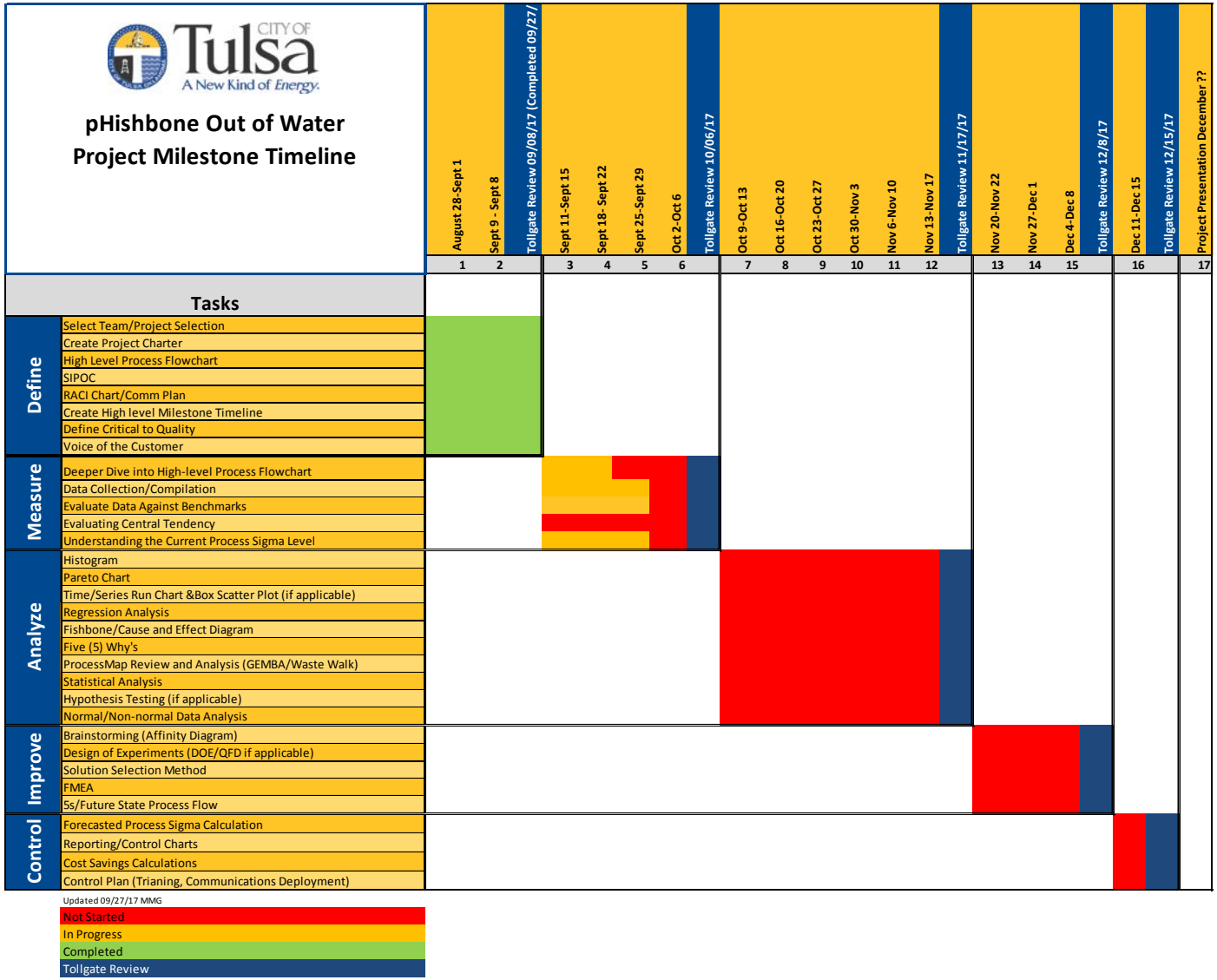
Project charter – roles

Sponsors	Name	Title
Executive Sponsor	Clayton Edwards	Water & Sewer Director
Project Champion	Jo Brown	Water Quality Assurance Manager
Project Owners	Roy Foster	Water Supply Manager
	Eric Parker	Water Distribution Systems Manager
	Jo Brown	Water Quality Assurance Manager
Master Black Belt	Walter Miller	Instructor
Black Belt	Penny Macias	Project Manager OPSI

Problem statement

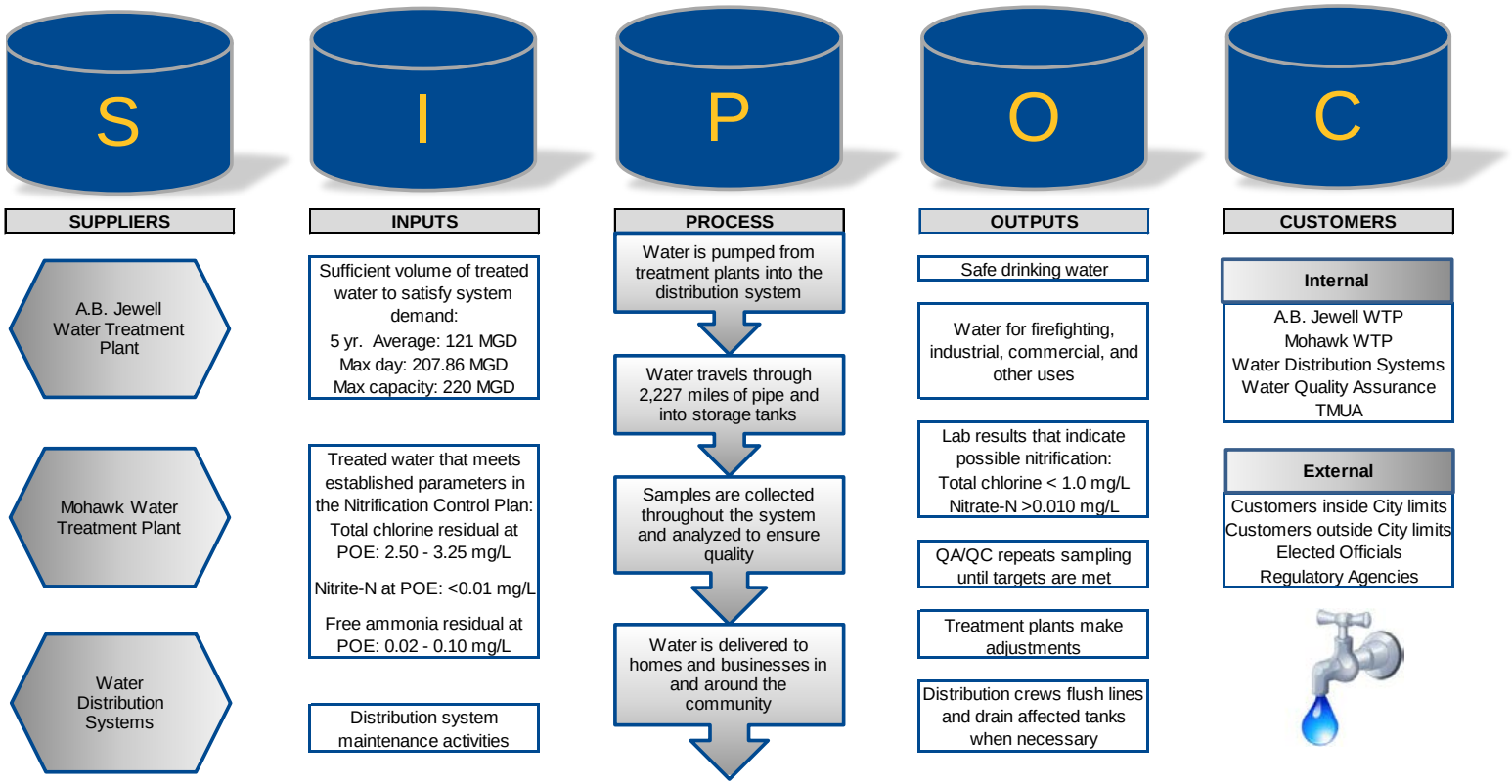
- Nitrification related water quality events in the distribution system can result in reduced disinfection levels (<1.0 mg/L total Cl2) and increased nitrite (>0.010 mg/L) levels. During the period of January 2013 – August 2017, there were 149 nitrification related events that required additional resources including multiple site visits, repeated sampling, and/or large amounts of treated water required to flush distribution lines and fill the multi-million gallon storage tanks that were drained.

Define phase – Project timeline



Define phase - SIPOC

Controlling Nitrification in the Distribution System



Define phase – RACI Chart

RACI Chart

R	Responsible	Person responsible for the task completion.
A	Accountable	Person accountable for task being completed.
C	Consulted	Stakeholders or subject matter experts.
I	Informed	Person receiving information from task.

Project:

Nitrification Control in the Distribution System to Reduce Resource Requirements

	Project Team										Stakeholders											
	Executive Sponsor - Clayton Edwards	Project Champion - Jo Brown	Master Black belt - Walter Miller	Black belt - Penny Macias	Project Manager - Melissa Gray	Stefanie Hunter	Eric Parker	Eric Lee	Benita Becton	Jhoanna Murray	Water & Sewer Department - Director	Water Supply - Water Treatment - A.B. Jewell WTP	Water Supply - Water Treatment - Mohawk WTP	Water Distribution - Mainline	Water Distribution - Operations	Water Quality Assurance	Engineering Services	Inside City Customers - Finished Water	Outside City Customers - Finished Water	Elected Officials	TMUA	ODEQ
Define and understand the Issue																						
Project Charter	C	C	C	C	R	A	A	A	I	I	I	I	I	I	I	I	I	-	-	-	I	-
High level Process Flowchart	C	C	C	C	A	A	R	A	I	I	I	I	I	I	I	I	-	-	-	-	-	-
SIPOC	C	C	C	C	A	R	A	A	I	I	I	I	I	I	I	I	-	-	-	-	-	-
RACI Chart/Communication Plan	C	C	C	C	A	A	A	R	I	I	I	I	I	I	I	I	-	-	-	-	-	-
DMAIC draft development	C	C	C	C	R	R	A	A	I	I	I	I	I	I	I	I	-	-	-	-	-	-
Define Critical to Quality	C	C	C	C	R	A	A	A	I	I	I	I	I	I	I	I	-	-	-	-	-	-
Capture Voice of Customer	C	C	C	C	R	R	R	R	I	I	I	I	I	I	I	I	I	-	-	-	-	-
Discuss issue with Water Quality Assurance	C	C	C	C	R	A	A	A	I	I	I	I	I	I	I	C	I	-	-	-	-	-
Discuss issue with Water Supply	C	C	C	C	A	A	R	A	I	I	I	C	C	I	I	I	I	-	-	-	-	-
Discuss issue with Water Distribution	C	C	C	C	A	A	R	A	I	I	I	I	I	C	C	I	C	-	-	-	-	-
Discuss issue with Elected Officials	C	C	C	C	A	A	A	R	I	I	I	I	I	I	I	I	I	-	-	C	-	-
Survey External Customers	C	C	C	C	A	A	A	R	I	I	I	I	I	I	I	I	I	-	-	C	-	-
Define Phase Tollgate Review	C	C	C	C	R	R	R	R	A	A	-	-	-	-	-	-	-	-	-	-	-	-

Define phase – Voice of the Customer and Critical to Quality

Critical to Quality

Voice of the Customer

CUSTOMER NEED

Treated water that is free from harmful substances, such as nitrites.

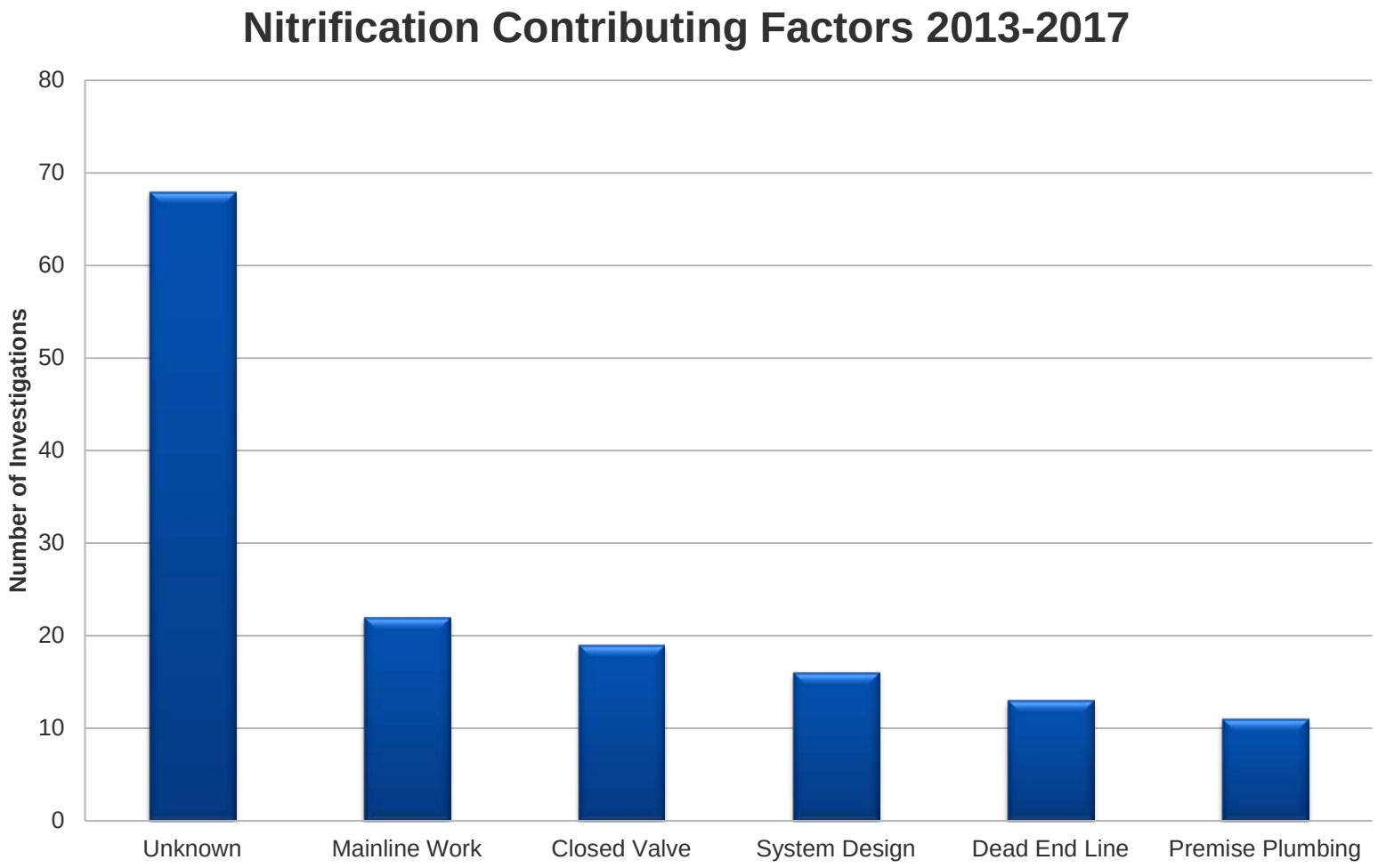
KEY PROCESS OUTPUT VARIABLES	KEY PROCESS INPUT VARIABLES
Control total chlorine residual as water enters distribution system	Total chlorine between 2.50 - 3.25 mg/L Regulatory Requirement: ≥ 2.0 mg/L at POE; ≥ 1.0 mg/L at furthest point in system
Balance effective monochloramine formation while minimizing free ammonia residual at treatment plants	Total chlorine and monochloramine residuals within 10% of each other Free ammonia between 0.02 - 0.10 mg/L
Monitor and control nitrite levels as water enters distribution system	Target goal: < 0.01 mg/L Regulatory Requirement: < 1.0 mg/L
Perform routine monitoring of total chlorine and nitrites throughout the distribution system	210 samples taken at 111 designated sites throughout system each month Monthly samples taken from primary storage tanks when water temperature is ≥ 25°C.
Exercise storage tanks to reduce water age and minimize chloramine decay	Sheridan tanks: Minimum level = 8'; Maximum = 32'; Mechanical mixers installed in tanks to reduce stratification
Perform routine maintenance on storage tanks and areas of distribution system with high potential for nitrification	Each tank inspected and cleaned every 2 years Quarterly dead-end line flushing maintenance (DELM) program
Use technology to assist with early detection of nitrification in system	Online analyzers installed in 9 locations throughout system report water quality parameters via SCADA connections
Ensure proper operation and maintenance of distribution system components	Effective disinfection of lines and tanks after maintenance is performed to reduce biofilm Awareness of large valve status (open/closed)

Define phase – Communications plan

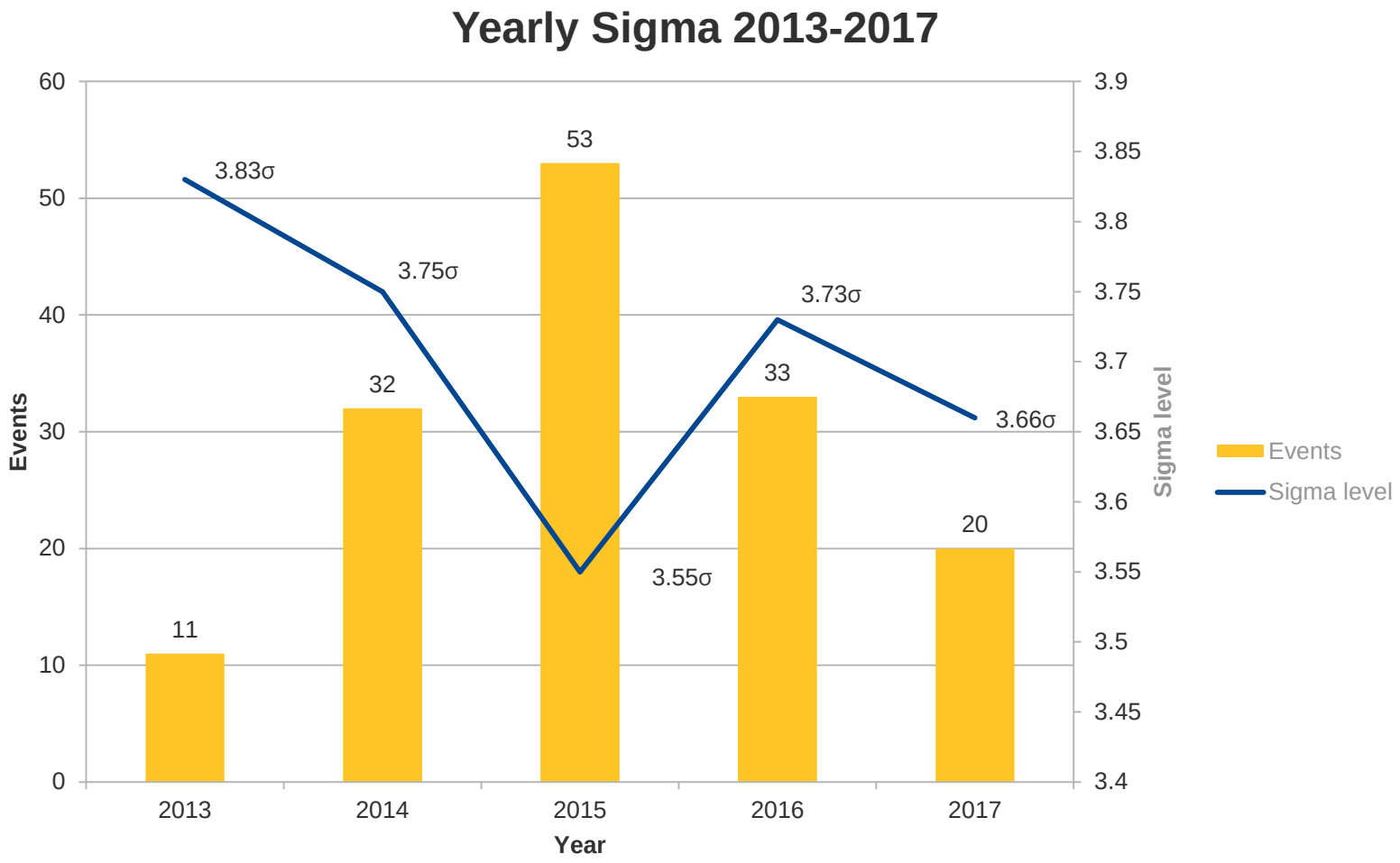
Communications Plan							
Stakeholder	**Objective**	**Message**	**Delivery**	**Frequency**	**Timing**	**Responsibility**	**Feedback**
Executive Sponsor - Clayton Edwards	Provide support to BB team and key stakeholders	Status update	Written report at end of each phase	End of each phase	Within one week of completion	BB Team	1. In person 2. Email 3. At meetings
Project Chamption - Jo Brown	Provide support to BB team and key stakeholders	Status update	Written report at end of each phase	End of each phase	Within one week of completion	BB Team	1. In person 2. Email 3. At meetings
Master Blackbelt - Walter Miller	Provide support to BB team	Status update	Email	1. As needed 2. At beginning and end of each phase	Within one week of completion	BB Team	Email
Blackbelt - Penny Macias	Provide support to BB team	Status update	1. In person 2. Email	Bi-weekly	Within one week of completion	BB Team	1. In person 2. Email 3. At meetings
Project Manager - Melissa Gray	Manage BB project	Teamwork	1. In person 2. Email	Weekly	At each meeting	BB Team	1. In person 2. Email 3. At meetings
Stefanie Hunter	Contribute to BB project	Teamwork	1. In person 2. Email	Weekly	At each meeting	BB Team	1. In person 2. Email 3. At meetings
Eric Parker	Contribute to BB project	Teamwork	1. In person 2. Email	Weekly	At each meeting	BB Team	1. In person 2. Email 3. At meetings
Eric Lee	Contribute to BB project	Teamwork	1. In person 2. Email	Weekly	At each meeting	BB Team	1. In person 2. Email 3. At meetings
Benita Becton	Contribute to BB project	Teamwork	1. In person 2. Email	Weekly	At each meeting	BB Team	1. In person 2. Email 3. At meetings
Jhoanna Murray	Contribute to BB project	Teamwork	1. In person 2. Email	Weekly	At each meeting	BB Team	1. In person 2. Email 3. At meetings

Measure Phase

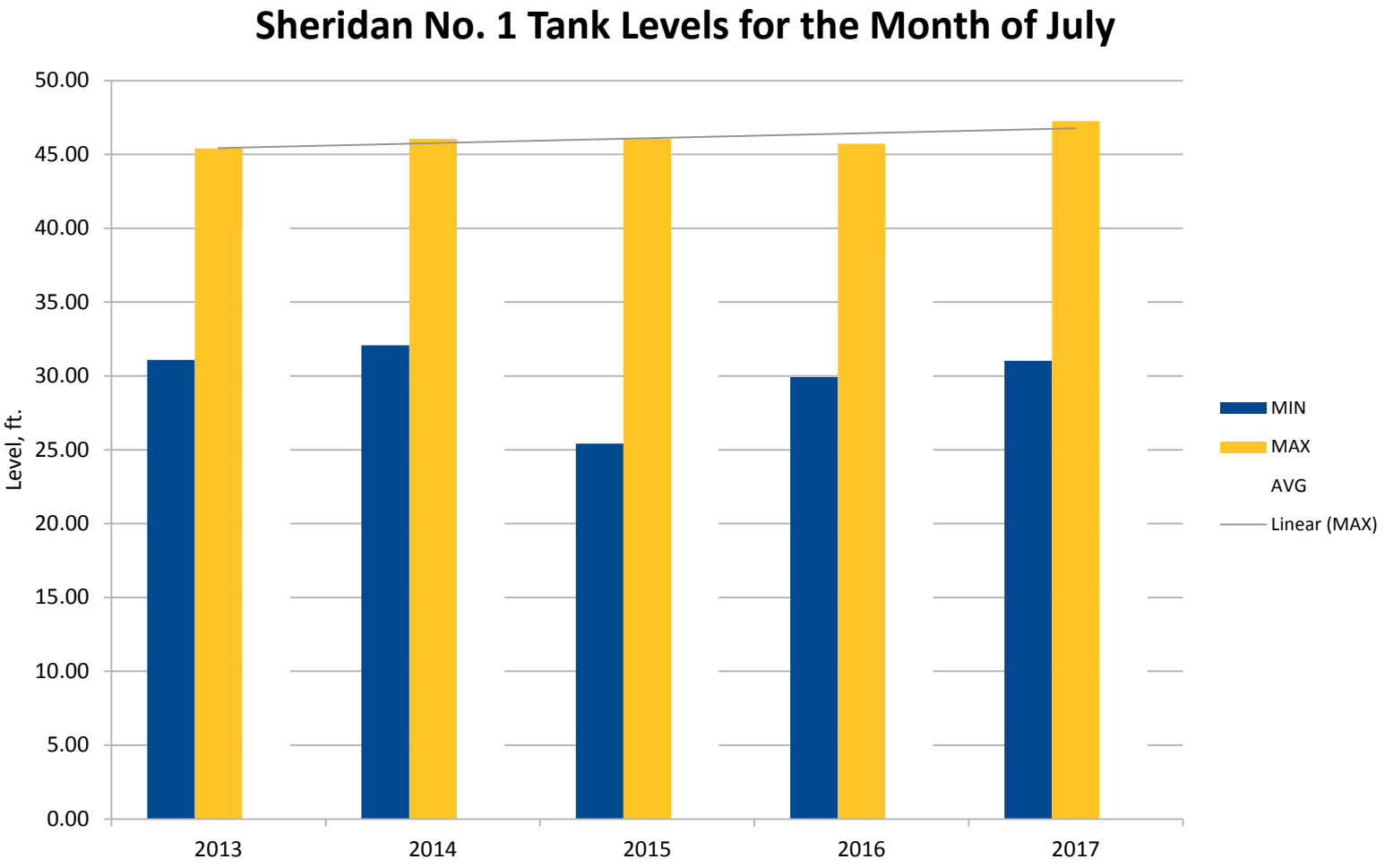
Measure phase



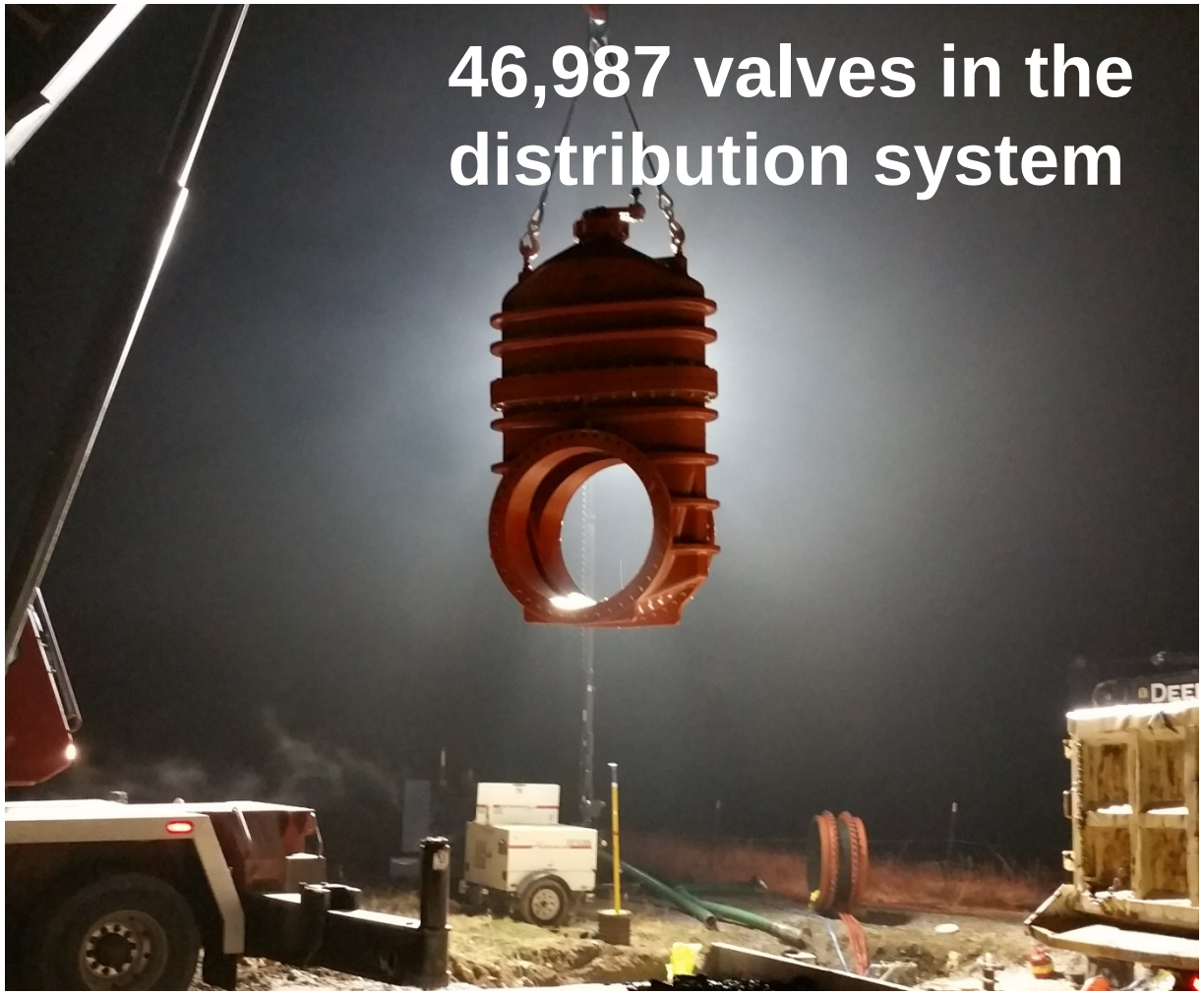
Measure phase – Sigma level



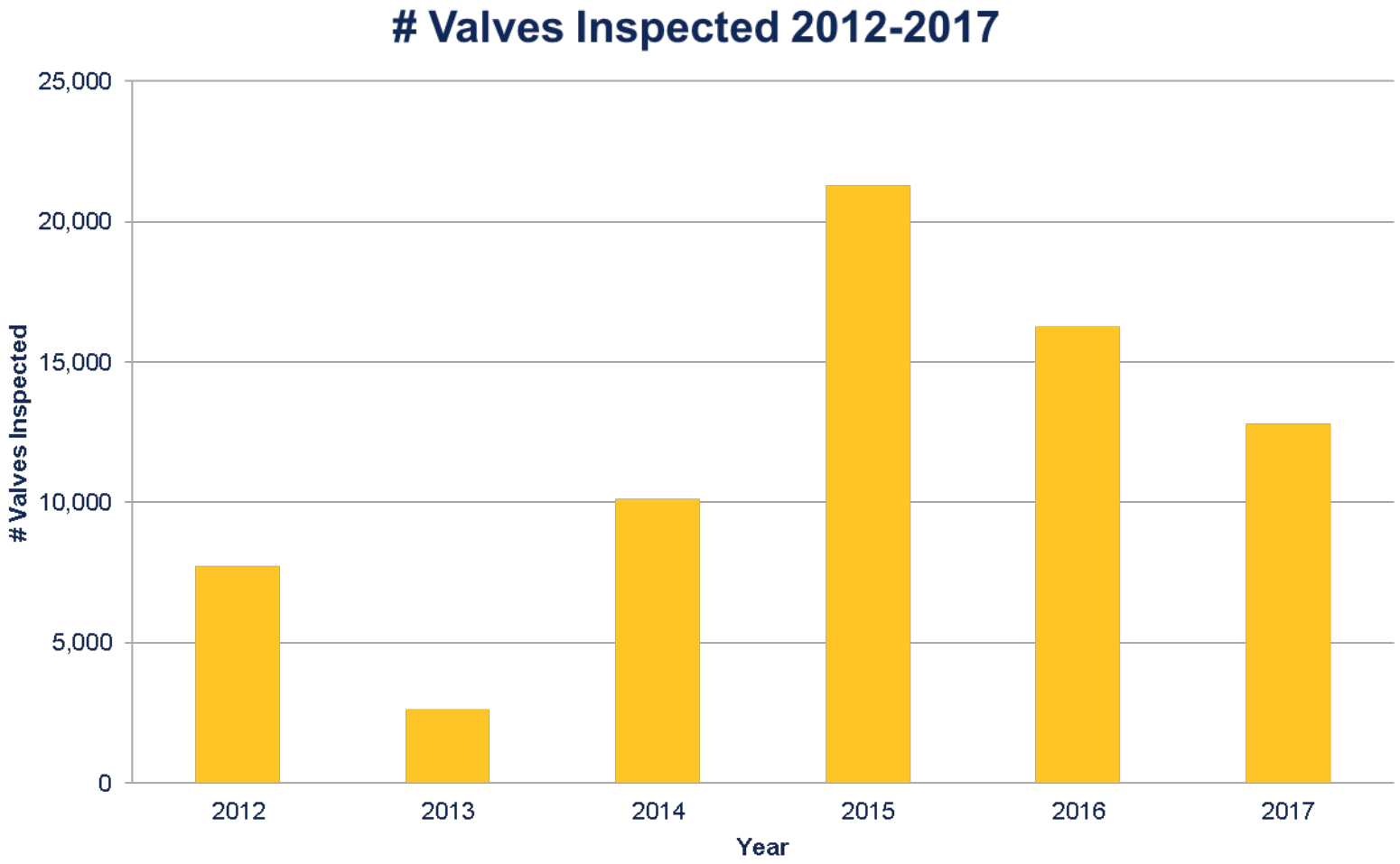
Measure phase – Water tank levels



Measure phase – Valves



Measure phase

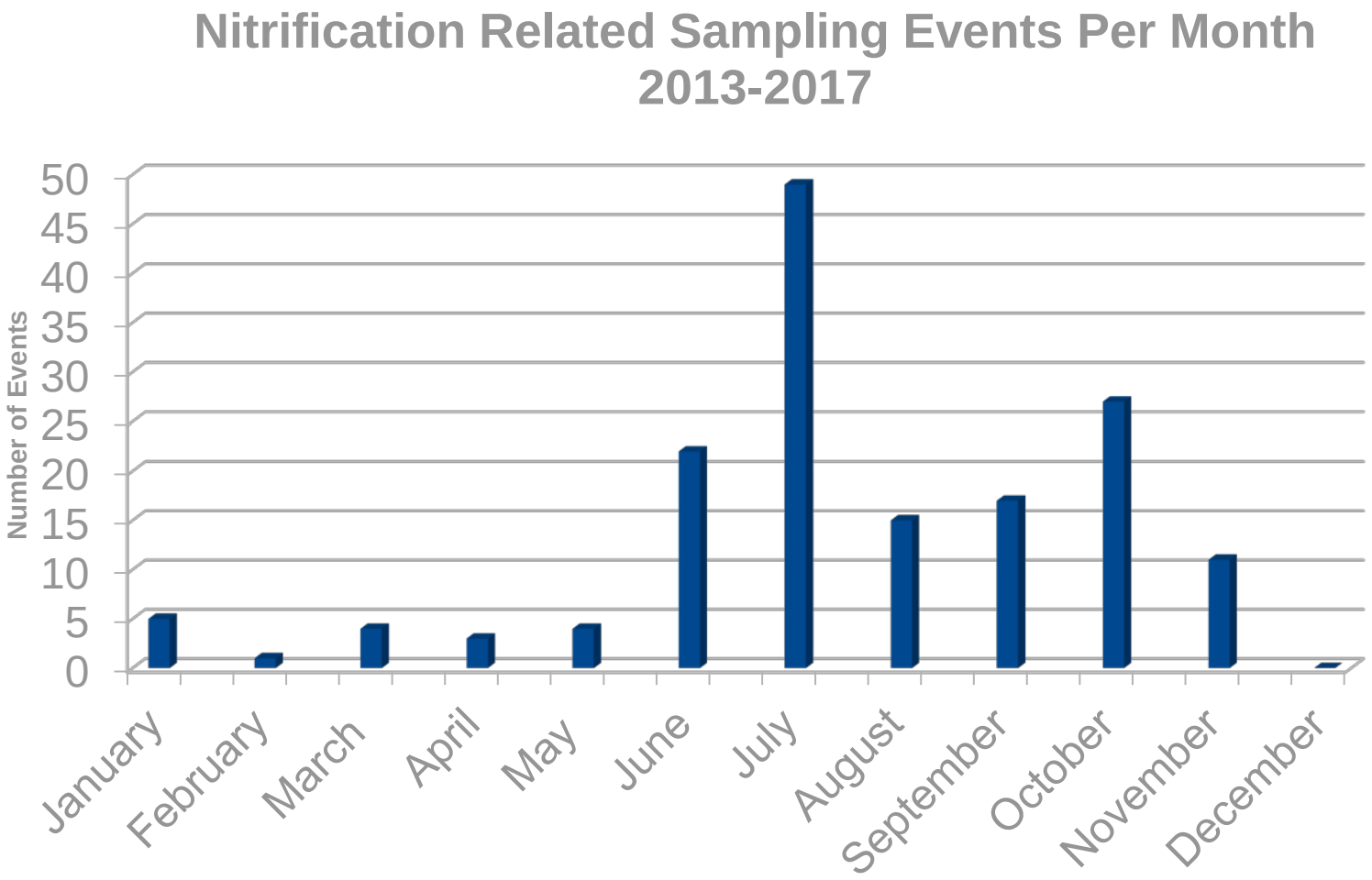


Measure phase – Flushing dead-end water lines

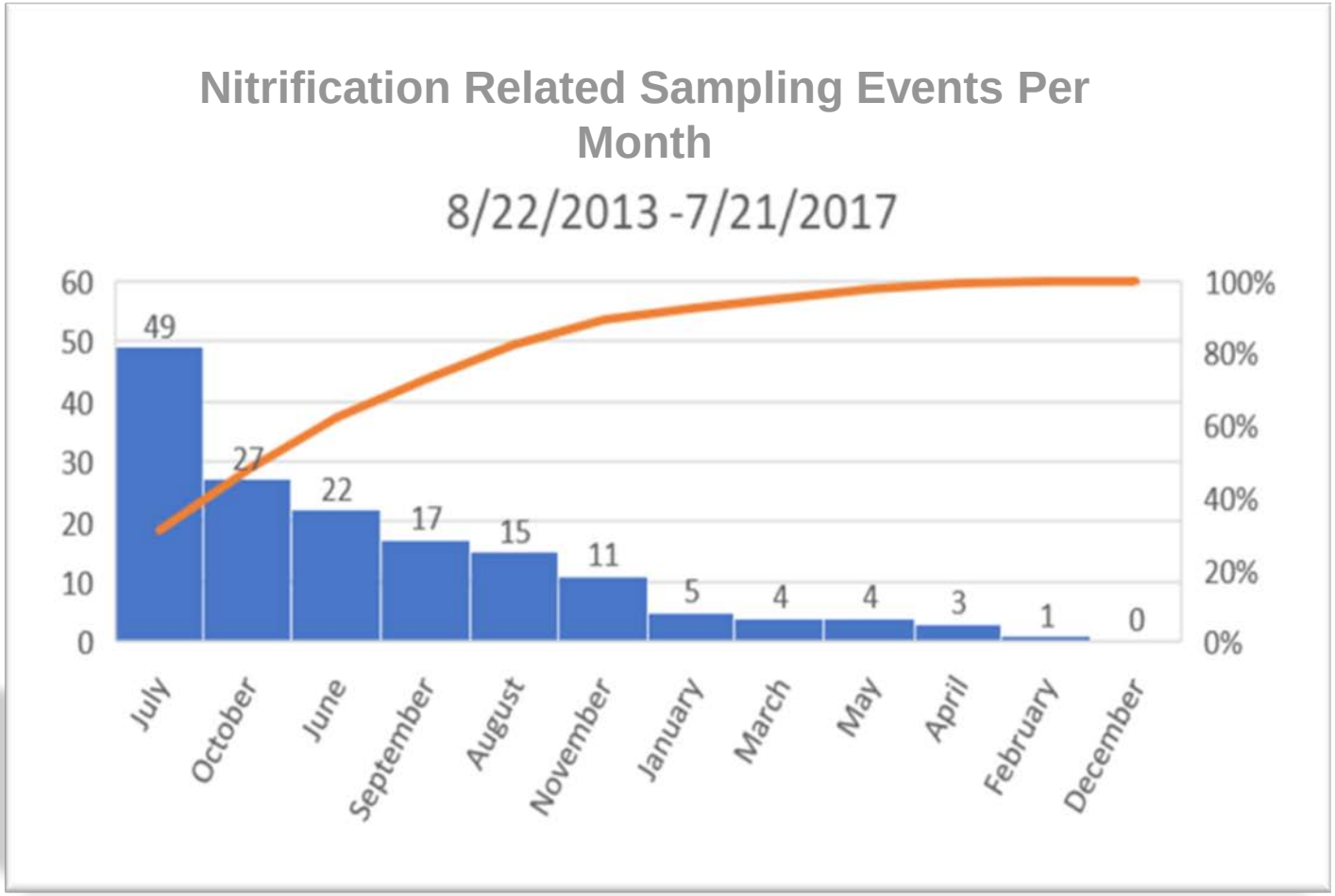
Totals for Year 2017		
Month	Dead-end lines	Other
January	222,460	638,700
February	249,397	498,000
March	69,555	540,025
April	172,190	51,000
May	417,085	143,560
June	186,377	1,045,800
July	194,425	710,818
August	586,930	1,319,800
September	325,707	709,547
October	294,025	1,106,500
November	385,735	716,000
December	569,986	810,500
TOTAL GALLONS	3,673,872	8,290,250

Analyze Phase

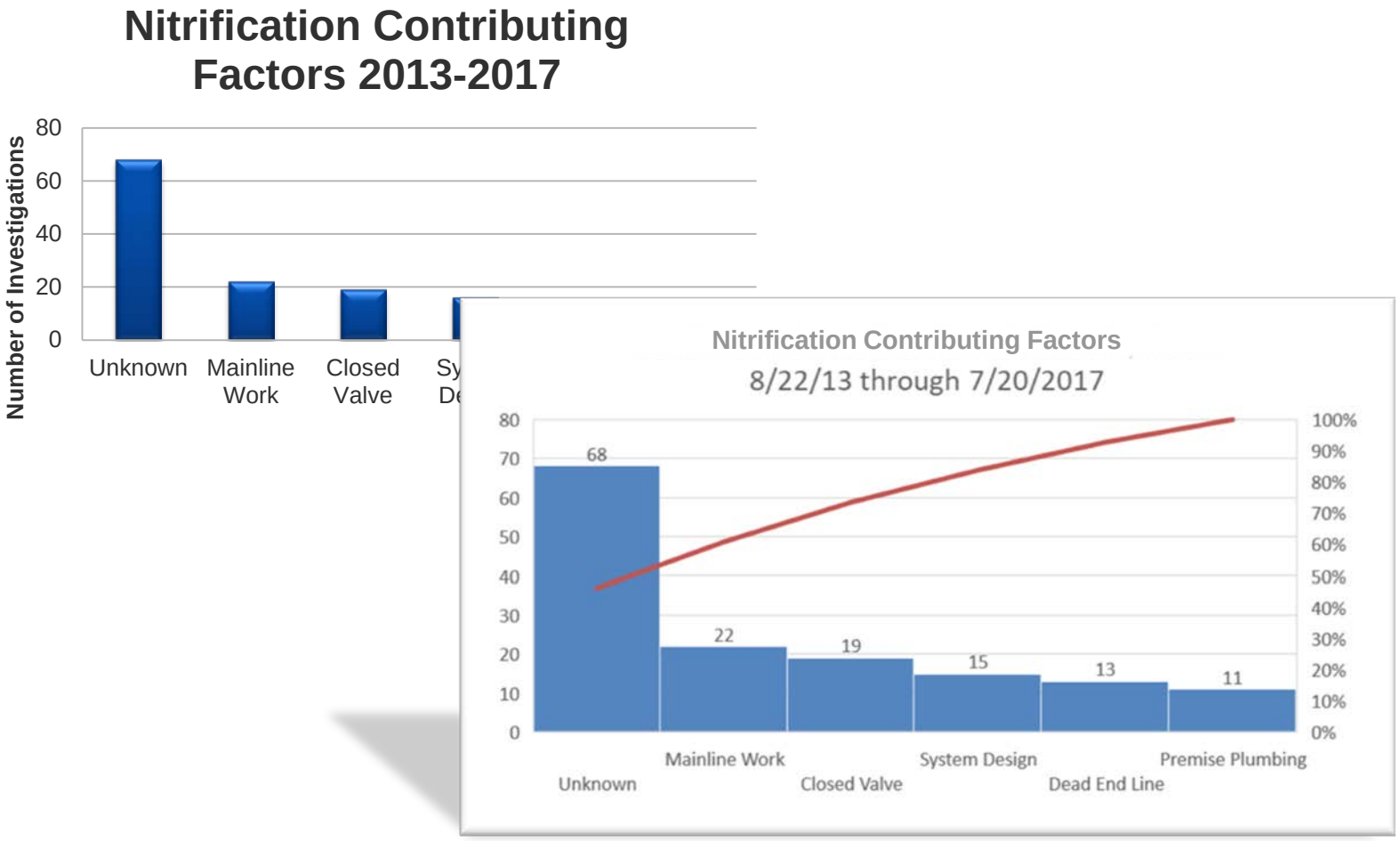
Analyze phase



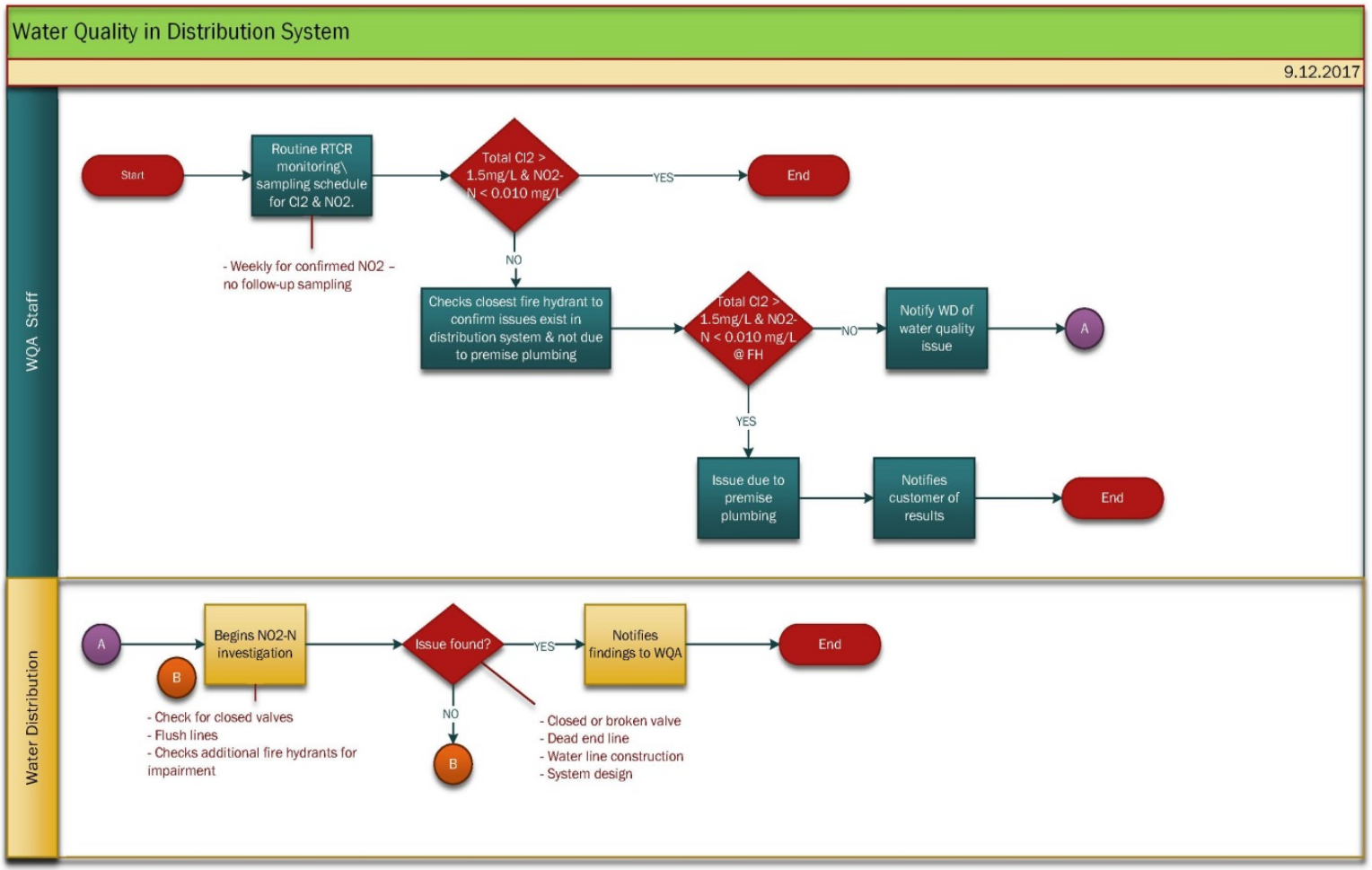
Analyze phase – Pareto chart



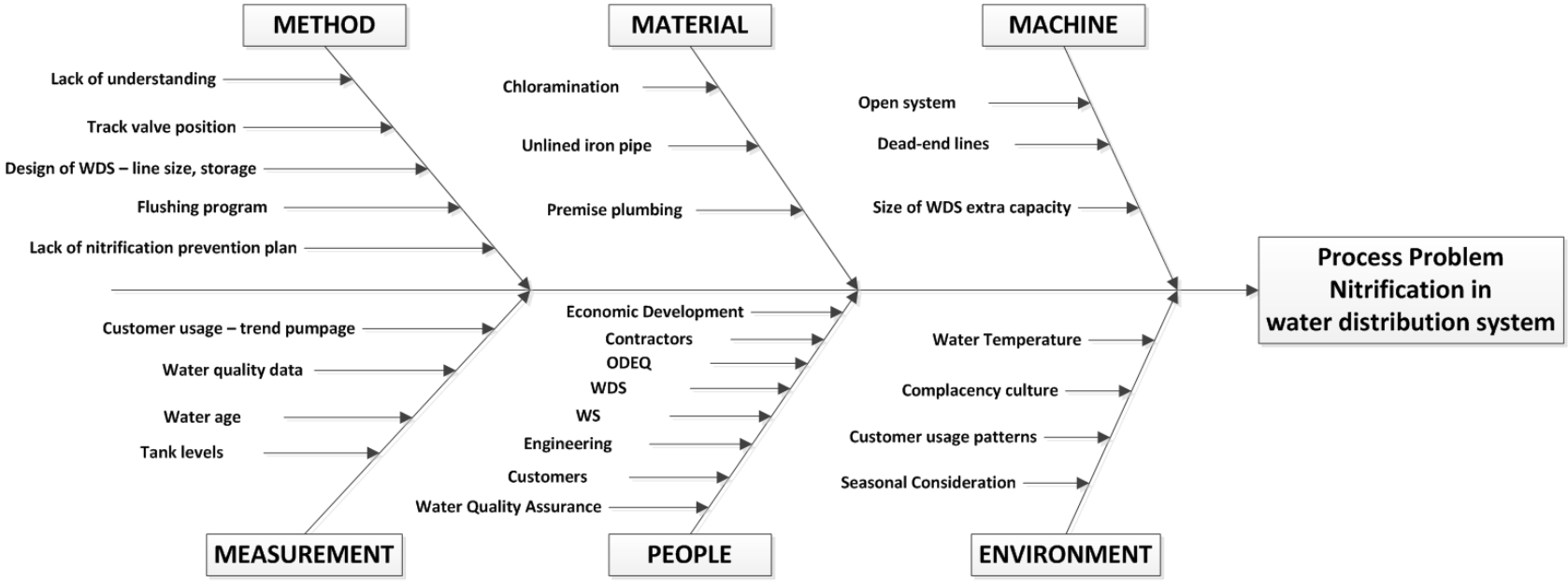
Analyze phase – Nitrification events in a Pareto chart



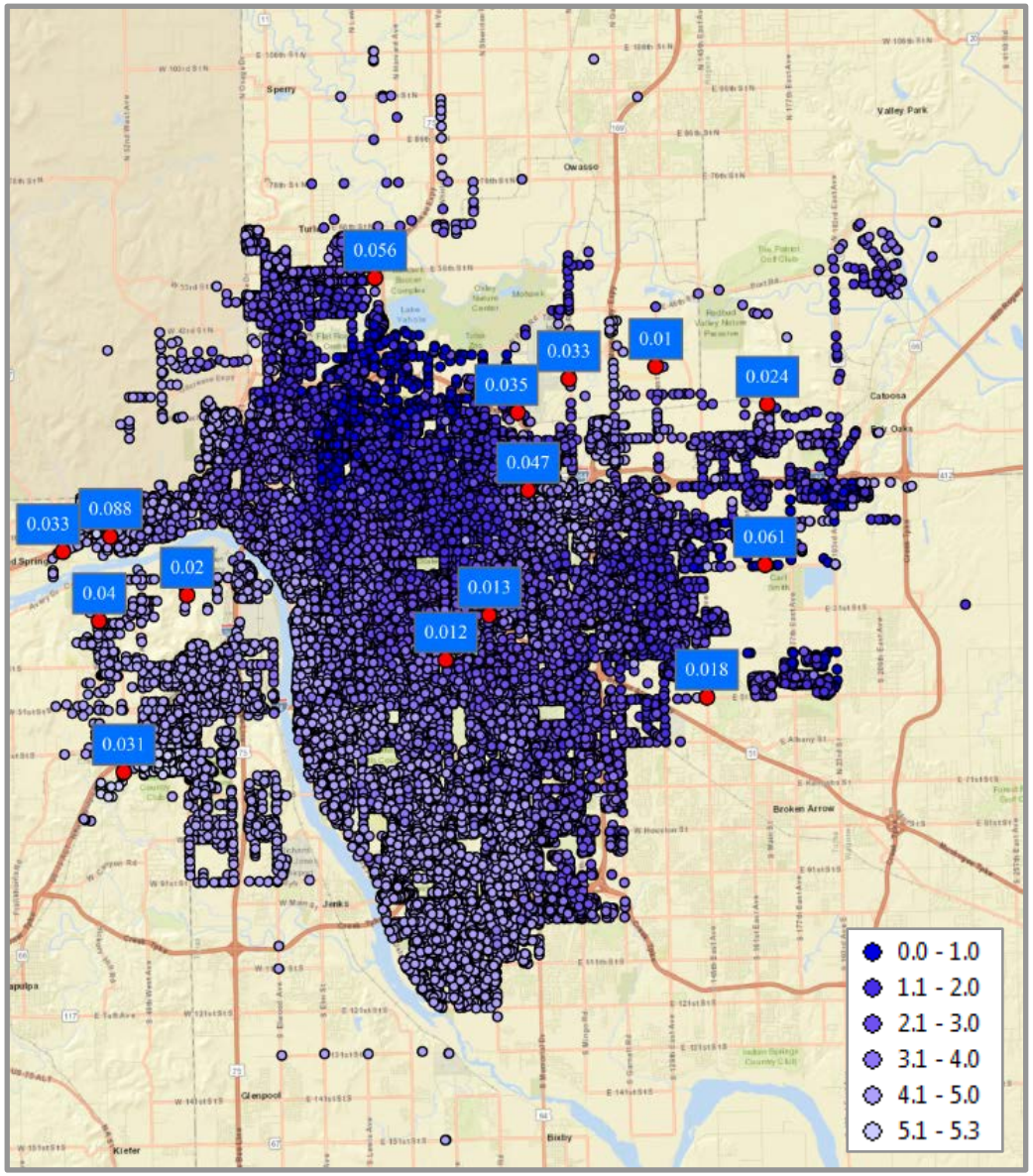
Analyze phase – Process map



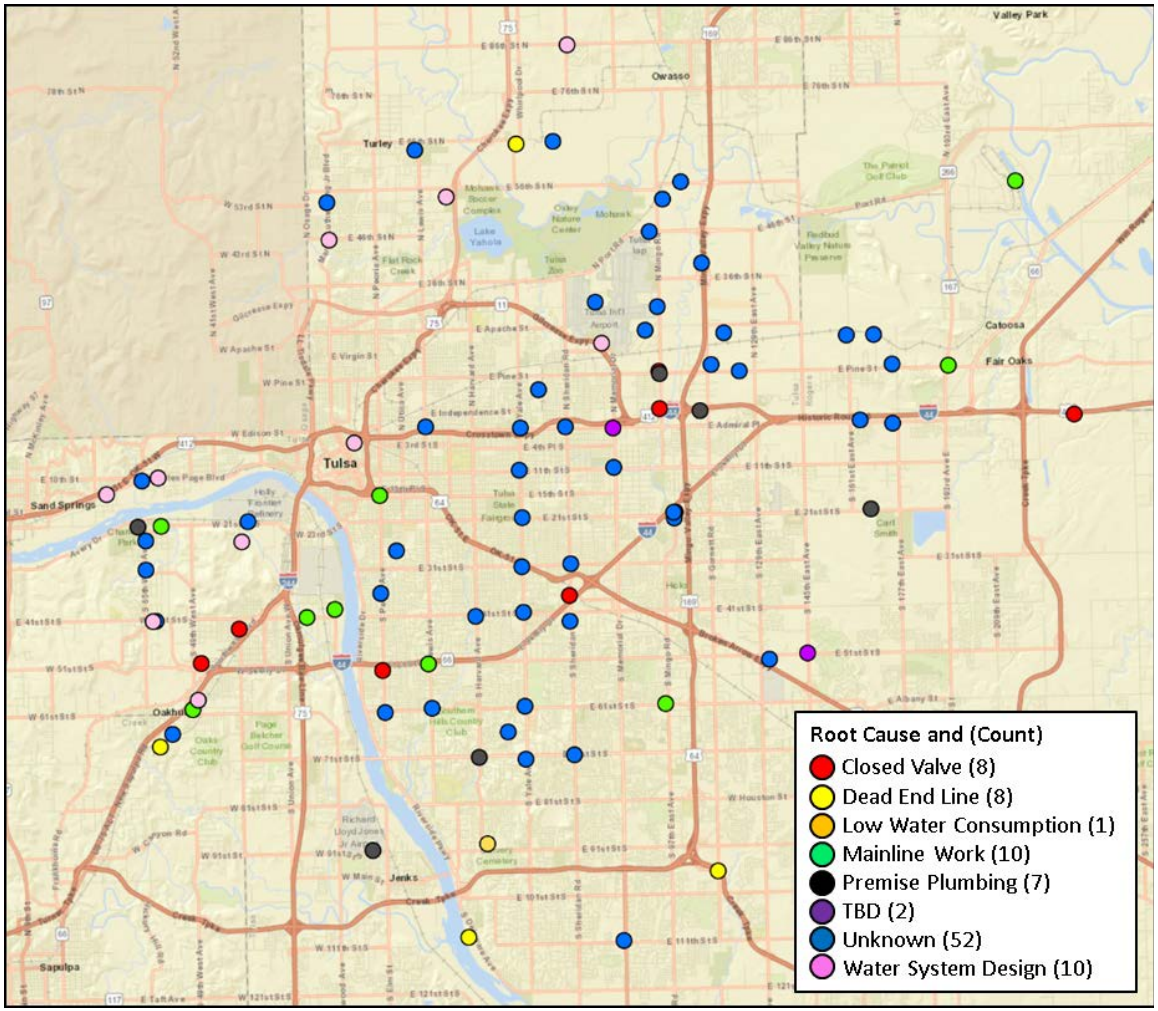
Analyze phase – Fishbone



Analyze phase – Water age and events

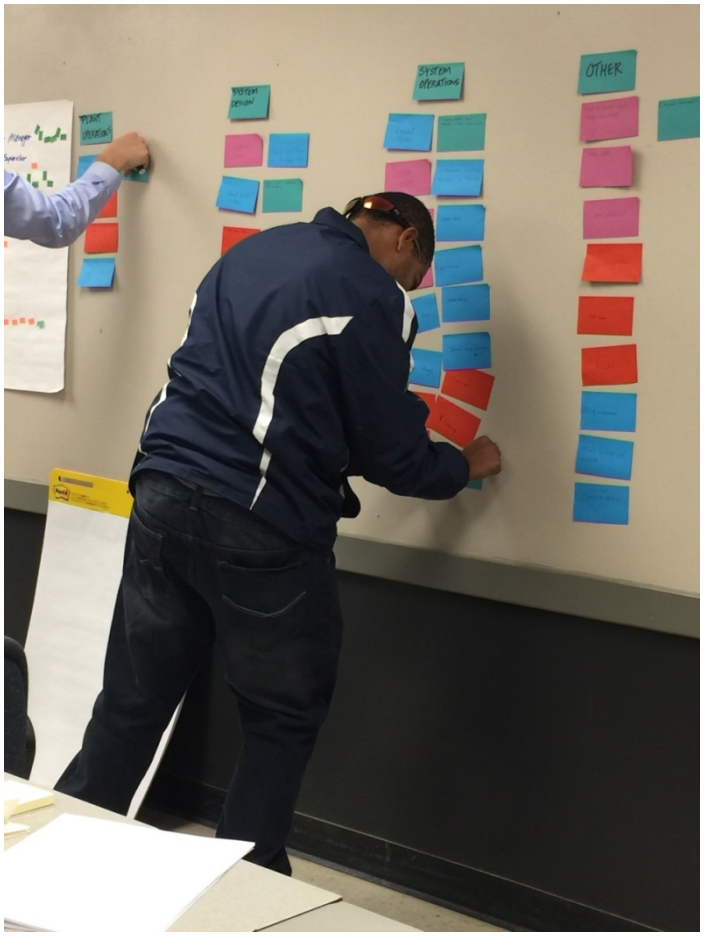


Analyze phase – Root cause

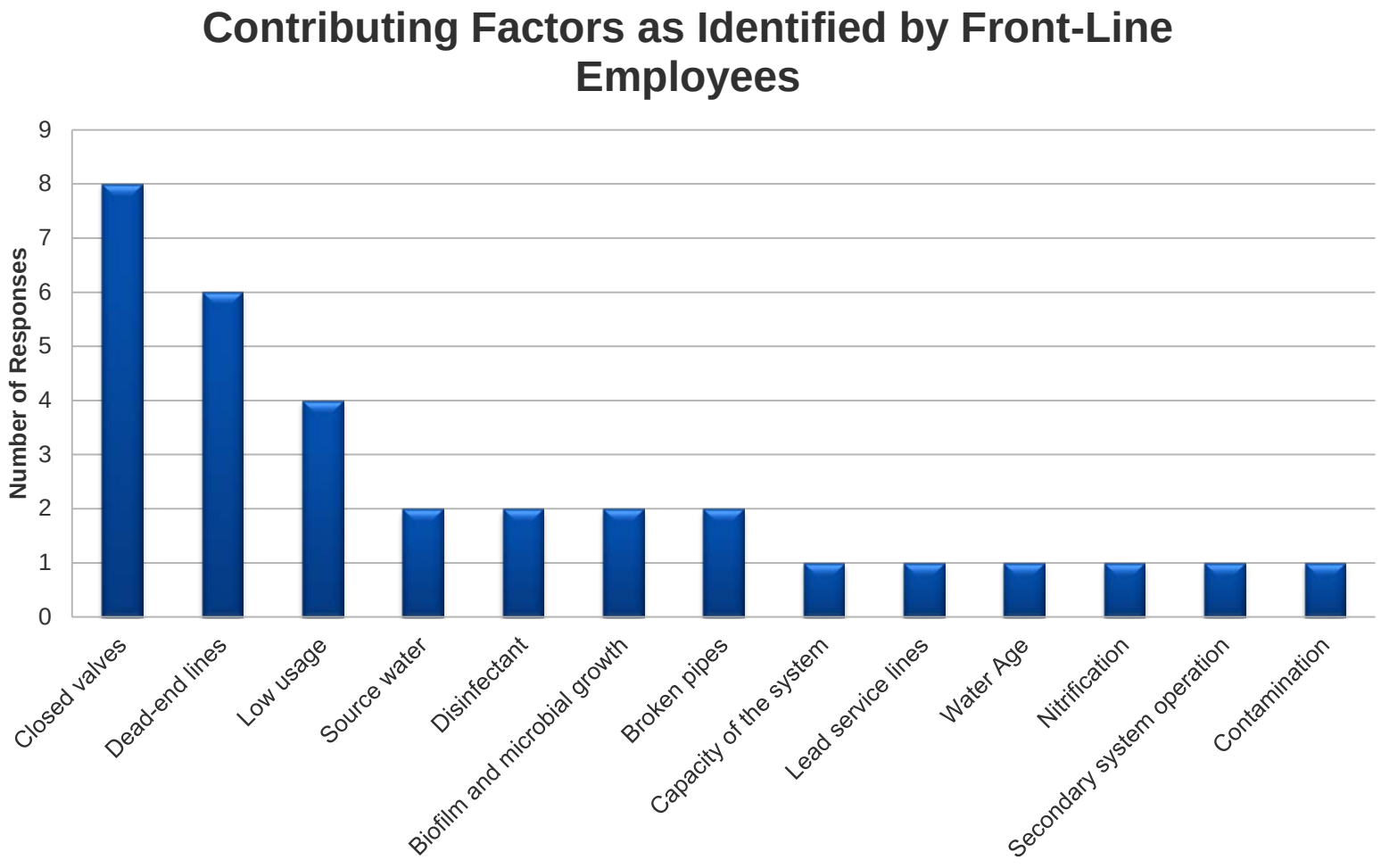


Improve Phase

Improve phase – Focus group & Affinity diagram



Improve phase – Focus group results



Improve phase – Using survey results

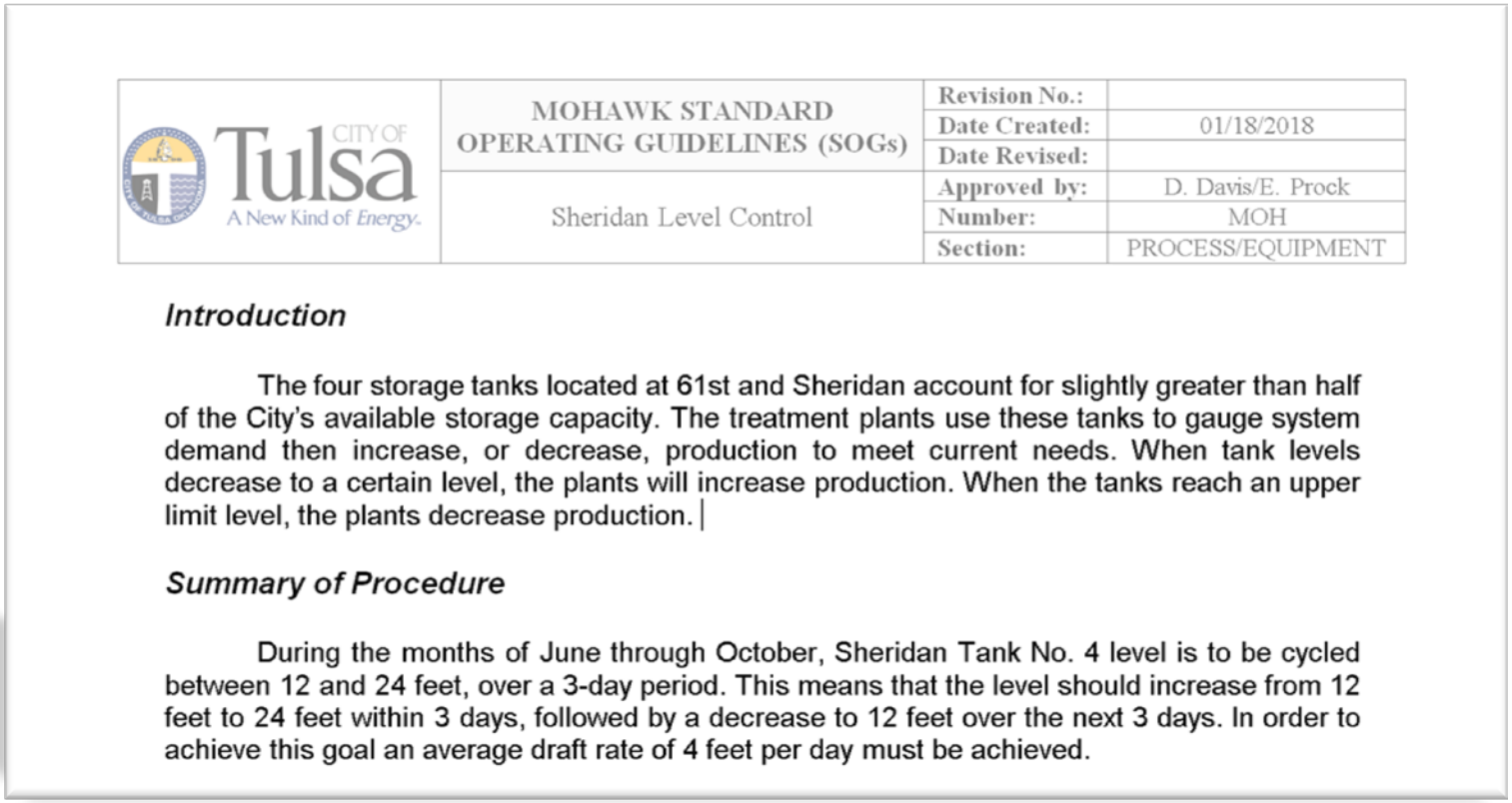
- Focus Group and survey results – Water Distribution, Water Supply, Quality Assurance, Engineering Services
  - Employees feel a high standard of water quality exists in the City of Tulsa
  - Few employees felt they directly impacted water quality in the system
  - Many employees not aware of water quality indicators or how actions performed in the distribution system can directly affect water age and quality

Improve phase – Solution selection method

- Using results of focus group, survey, fishbone diagram (Ishikawa), etc., the primary contributing factors are:
  - Water age
  - Water temperature
  - Employee (and contractor) knowledge
- The solution is:
  - Optimizing control of storage tank levels
  - Error proof (poka-yoke) valve opening and closing procedures
  - Employee education and training

Control Phase

Control phase – Plant standard operating guideline (SOG) and plant controls



CITY OF Tulsa A New Kind of Energy.	MOHAWK STANDARD OPERATING GUIDELINES (SOGs)	Revision No.:	
		Date Created:	01/18/2018
		Date Revised:	
	Sheridan Level Control	Approved by:	D. Davis/E. Prock
		Number:	MOH
		Section:	PROCESS/EQUIPMENT

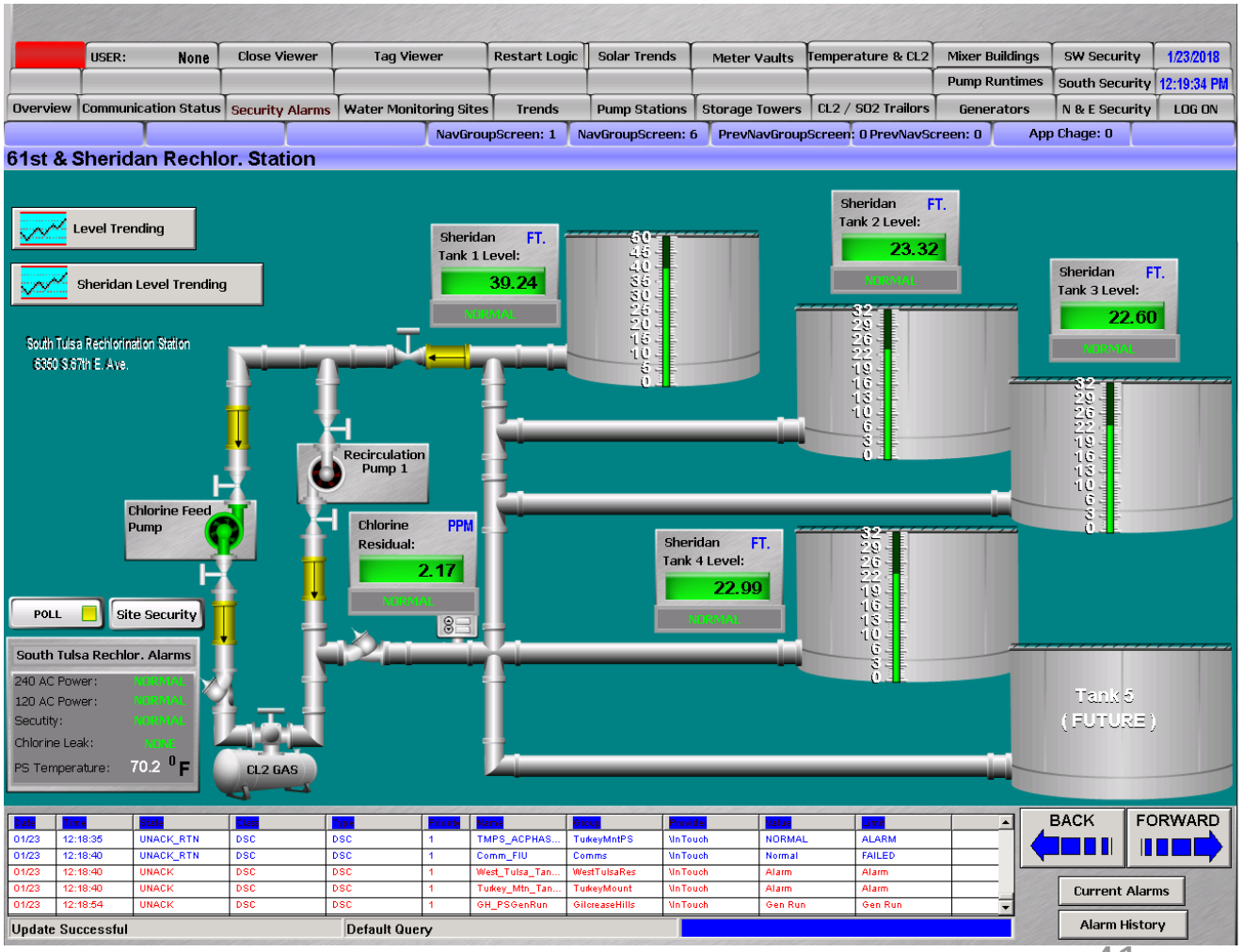
Introduction

The four storage tanks located at 61st and Sheridan account for slightly greater than half of the City's available storage capacity. The treatment plants use these tanks to gauge system demand then increase, or decrease, production to meet current needs. When tank levels decrease to a certain level, the plants will increase production. When the tanks reach an upper limit level, the plants decrease production.

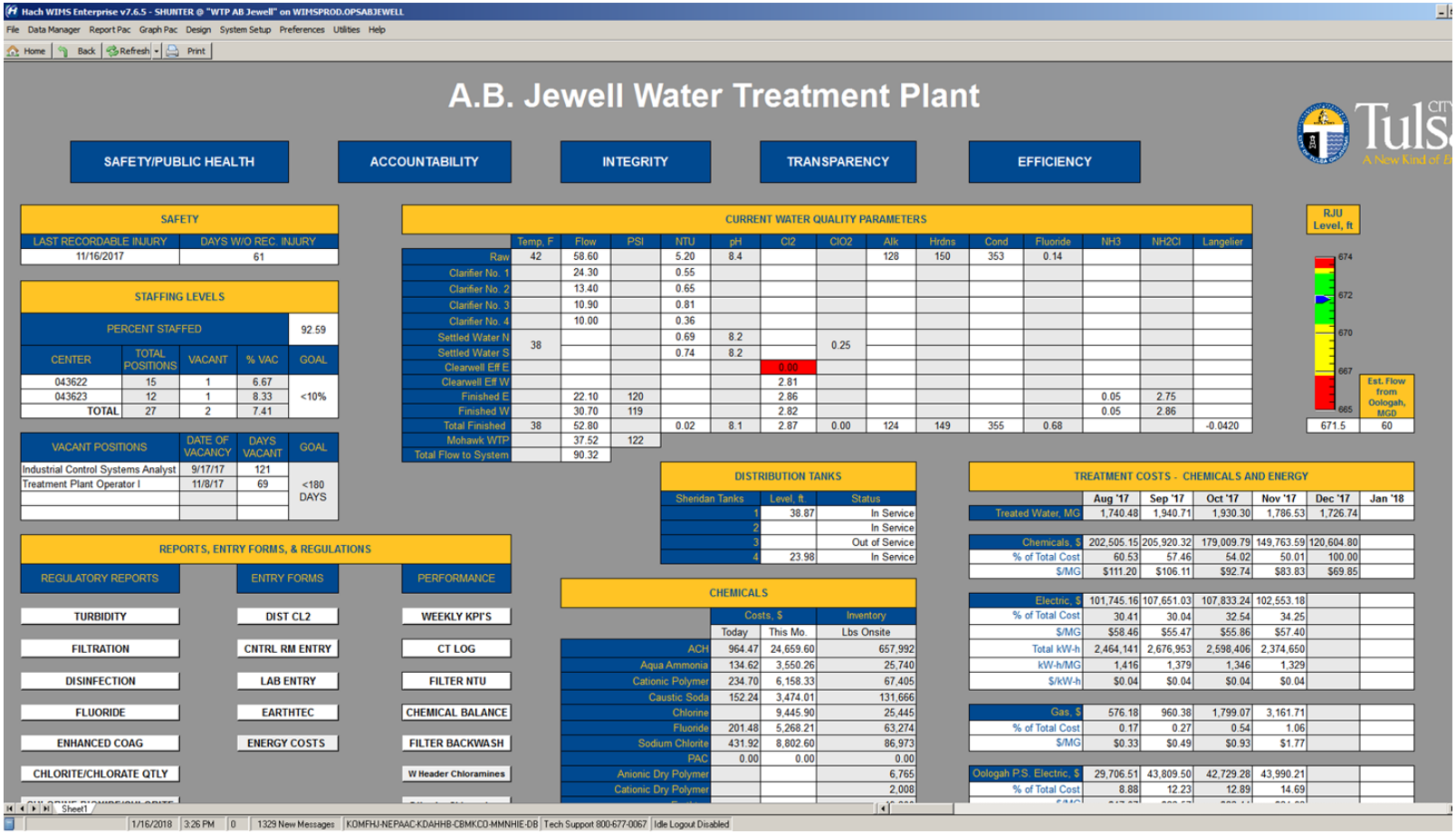
Summary of Procedure

During the months of June through October, Sheridan Tank No. 4 level is to be cycled between 12 and 24 feet, over a 3-day period. This means that the level should increase from 12 feet to 24 feet within 3 days, followed by a decrease to 12 feet over the next 3 days. In order to achieve this goal an average draft rate of 4 feet per day must be achieved.

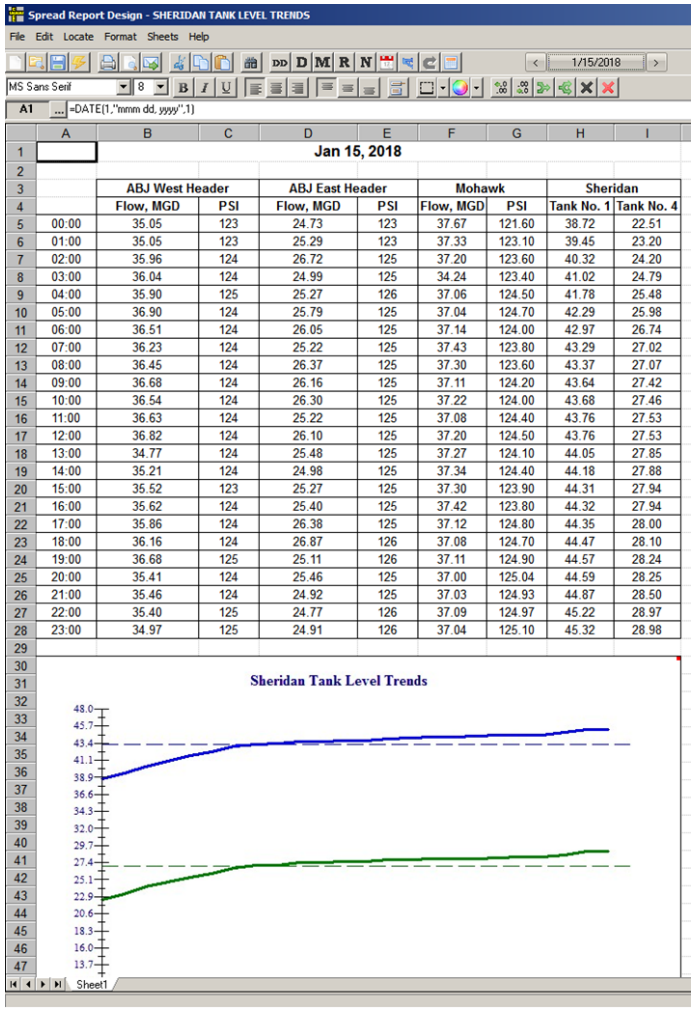
Control phase – Monitoring Sheridan tank levels



Control phase – Utilizing technology to monitor water system activity



Control phase – Monitoring flows and tank levels in Hach WIMS



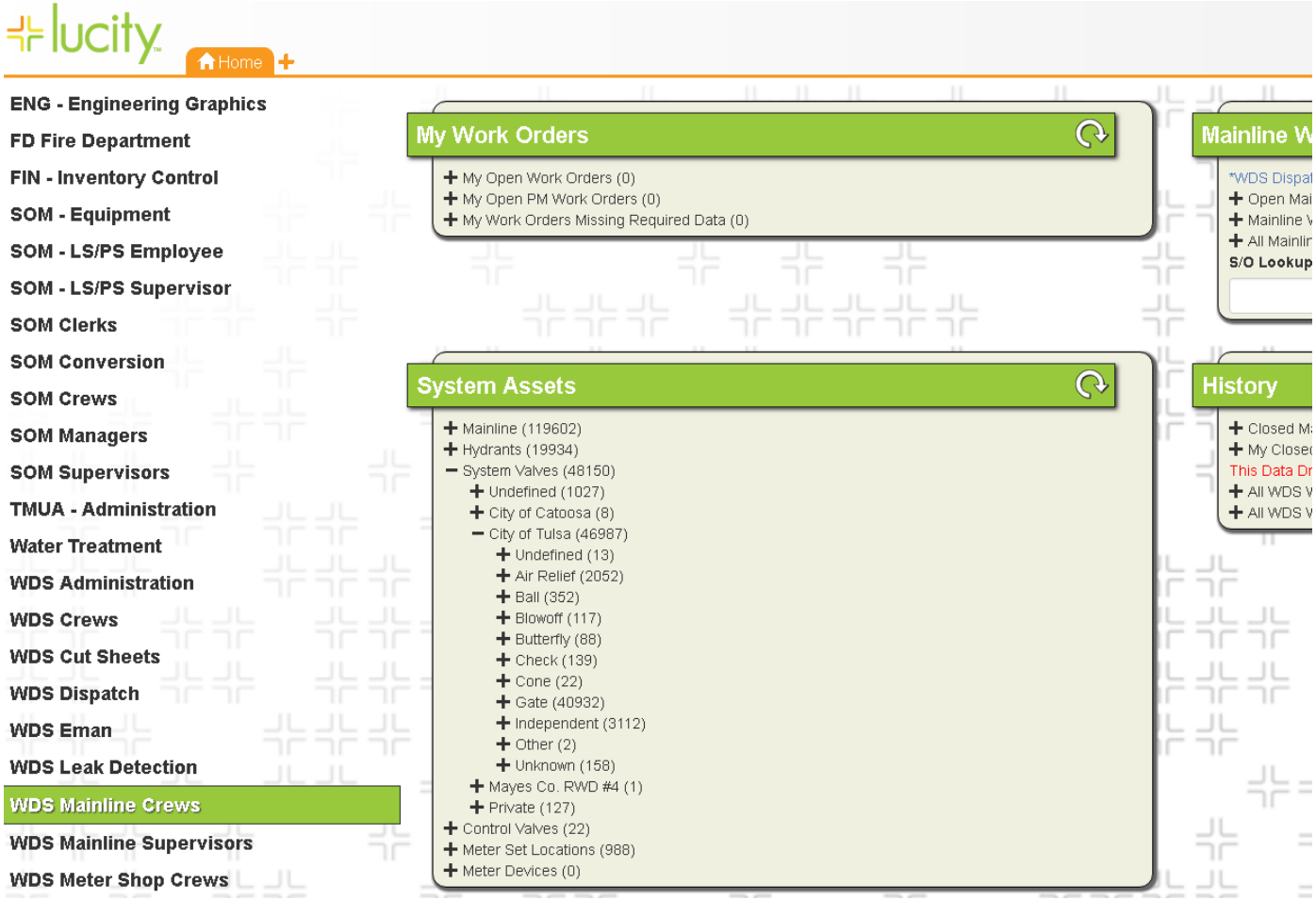
Jan 15, 2018

	ABJ West Header		ABJ East Header		Mohawk		Sheridan	
	Flow, MGD	PSI	Flow, MGD	PSI	Flow, MGD	PSI	Tank No. 1	Tank No. 4
00:00	35.05	123	24.73	123	37.67	121.60	38.72	22.51
01:00	35.05	123	25.29	123	37.33	123.10	39.45	23.20
02:00	35.96	124	26.72	125	37.20	123.60	40.32	24.20
03:00	36.04	124	24.99	125	34.24	123.40	41.02	24.79
04:00	35.90	125	25.27	126	37.06	124.50	41.78	25.48
05:00	36.90	124	25.79	125	37.04	124.70	42.29	25.98
06:00	36.51	124	26.05	125	37.14	124.00	42.97	26.74
07:00	36.23	124	25.22	125	37.43	123.80	43.29	27.02
08:00	36.45	124	26.37	125	37.30	123.60	43.37	27.07
09:00	36.68	124	26.16	125	37.11	124.20	43.64	27.42
10:00	36.54	124	26.30	125	37.22	124.00	43.68	27.46
11:00	36.63	124	25.22	125	37.08	124.40	43.76	27.53
12:00	36.82	124	26.10	125	37.20	124.50	43.76	27.53
13:00	34.77	124	25.48	125	37.27	124.10	44.05	27.85
14:00	35.21	124	24.98	125	37.34	124.40	44.18	27.88
15:00	35.52	123	25.27	125	37.30	123.90	44.31	27.94
16:00	35.62	124	25.40	125	37.42	123.80	44.32	27.94
17:00	35.86	124	26.38	125	37.12	124.80	44.35	28.00
18:00	36.16	124	26.87	126	37.08	124.70	44.47	28.10
19:00	36.68	125	25.11	126	37.11	124.90	44.57	28.24
20:00	35.41	124	25.46	125	37.00	125.04	44.59	28.25
21:00	35.46	124	24.92	125	37.03	124.93	44.87	28.50
22:00	35.40	125	24.77	126	37.09	124.97	45.22	28.97
23:00	34.97	125	24.91	126	37.04	125.10	45.32	28.98

Control phase – Valve opening and closing procedures, valve tracking

- Debris caps – pilot program – phased-in approach for Water Distribution mainline crews and contractors
  - Cost: $8,990 ($58/cap, 5 per crew, 31 crews)
  - Rollout: starting in Spring
- Pilot program to include training, communication and deployment plan
- Utilize Lucity – computerized maintenance management system – to track valve positions

Control phase – Technology to track valve positions



Control phase – Employee education and knowledge

- Training program on tank standard operating guidelines – treatment plant operators
- Training program on valve operations – Water Distribution Systems operators, Field Engineering inspectors and contractors
- Nitrification education/water quality education – chloramines
- Pocket color wheels - $80/each – tools and training for chlorine analysis (program cost is $2,480)

Control phase – Sigma level

- We are 3.68σ level – goal is to be at a 4.0σ level within 4 years
- Reduction of nitrification related sampling events of approximately 30 per year (149 total events over five years) to an average of 13 per year (62 total events over four years)
- Cost Savings included on next slide

Nitrification Control in the Distribution System Savings		
FY 17 Nitrification Related Investigations		25
FY17 Repeat Site Visits		225
FY17 Budget Investigation Costs		
Salaries & Benefits		$27,000
Materials & Supplies		$4,000
Other Services		$10,000
Capital		-
TOTAL SITE VISIT COST		**$41,000**
Water Tank Drainage Cost		
Treatment cost/million gallons of water		$170
Millions of gallons drained		14
TOTAL WATER DRAINAGE COST		**$2,000**
Water Flushing Cost		
Total hours flushed		450
Millions of gallons flushed		27
TOTAL WATER FLUSHING COST		**$5,000**
FY17 Nitrification Cost Including Overheard		
Site Visit Cost		$41,000
Water Tank Drainage		$2,000
Water Flushing Cost		$5,000
FY17 Nitrification Events Cost		$48,000
30% Overhead		$14,000
TOTAL YEARLY COST		**$62,000**
Estimated Yearly Cost Savings		
30% expenditure reduction to reach a 3.7σ level	FY19	$19,000
35% expenditure reduction to reach a 3.8σ level	FY20	$22,000
40% expenditure reduction to reach a 3.9σ level	FY21	$25,000
4.0σ level	FY22	$30,000
Total Project Cost Savings		**$96,000**
Total Project Costs		**$11,470**
TOTAL NET PROJECT COST SAVINGS		**$84,530**

Black belt project – Lessons learned

- BB Certification has allowed the application of the LSS tools – valuable experience that we will use for continual improvement
- Recruiting Green Belt members to assist strengthened the team effort
- TMUA and UEI set the framework for LSS implementation
  - Data management tools
  - Strategic planning
  - Top down support

Reference material

- City of Tulsa Nitrification Control and Response Plan rev3 February 2017
- EPA, Office of Water (4601M) Distribution System Issue Paper: Nitrification
- AWWA M56 Manual: Fundamentals and Control of Nitrification in Chloraminated Drinking Water Distribution Systems
- AWWA M68 Manual: Water Quality in Distribution Systems

Don’t want to be a farmer working in the sun
Don’t want to be an outlaw always on the run
Don’t want to be a climber reaching for the top
Don’t want to be anything where I don’t know when to stop

A dream it’s true
But I’d see it through
If I could be
Wasting my time with you

From the song “Waste” by Phish

THANK YOU!

CITY OF Tulsa
A New Kind of Energy