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The Northern California Pipe User's Group
19th Annual Sharing Technologies Seminar

Berkeley, CA
February 17, 2011

RISK-BASED PRIORITIZATION FOR SEWER MAINTENANCE AND CAPITAL IMPROVEMENTS

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ABSTRACT: The West Valley Sanitation District operates and maintains 426 miles of sewers. Based on a previous dry weather monitoring study and subsequent CCTV inspection activities, the District established an extensive list of needed rehabilitation projects spread throughout the service area, yet did not have an objective methodology for prioritization of these projects. The District decided to develop and implement a risk-based prioritization process based on guidelines recommended by the National Association of Clean Water Agencies (NACWA) in the publication "Implementing Asset Management: A Practical Guide". The analysis focused on quantifying and assessing the risks posed by the failure or inability of the District's sewers to provide service to customers at a level that is acceptable to the District. Using this approach, consequence of failure and likelihood of failure are quantified to calculate risk of failure for individual sewer assets. The risk scores were then used to prioritize sewer rehabilitation or replacement projects. The District has also found the risk scores to be useful in prioritizing system-wide CCTV inspection for the sewer system. This presentation will review the methodology, approach, and results of the risk-based prioritization model.

1 INTRODUCTION

The West Valley Sanitation District provides wastewater collection services for the cities of Campbell, Monte Sereno, Los Gatos, the majority of Saratoga and some unincorporated areas of Santa Clara County. The District's service area is approximately 29 square miles. The sewer collection system maintained and operated by the District consists of approximately 426 miles of main and trunk sewers and 206 miles of sewer laterals. Table 1 shows the distribution of sewer sizes in the District's collection system.

Table 1. Length of Sewer Pipe By Diameter Class in WVSD System

Diameter Ranges	Total Length (miles)	Percent of System
Less than 6”	298	70%
8”	72	17%
10” to 14”	30	7%
Greater than 15”	26	6%
All	***426***	***100%***

Based on the previous dry weather monitoring study known as the Basin Rehabilitation Strategic Plan, completed in 2000, and subsequent CCTV inspection activities, the District has established an extensive list of needed rehabilitation projects. Using the results of this effort, the District wanted to develop a process to prioritize sewer rehabilitation projects. The prioritization process developed for the District is designed for use with sewer mains and is not designed to be used for prioritizing lateral projects.

2 DEVELOPMENT OF PROJECT PRIORITIZATION PROCESS

The project prioritization methodology developed in this analysis is based on guidelines recommended by the National Association of Clean Water Agencies (NACWA), Association of Metropolitan Water Agencies (AMWA), and Water Environment Federation (WEF) in the publication “Implementing Asset Management: A Practical Guide” (NACWA/AMWA/WEF, 2007). The analysis focused on quantifying and assessing the risks posed by the failure or inability of the District’s sewers to provide service to customers at a level that is acceptable to the District. Using this approach, risk scores can be calculated for each sewer pipe individually. Individual pipe scores can be then be analyzed for groups of pipes to prioritize sewer rehabilitation or replacement projects.

2.1 PRIORITIZATION CRITERIA

The risk of asset failure can be used as a means to prioritize sewer rehabilitation and renewal and is calculated by quantifying the consequence of failure and likelihood of failure of assets. The consequence of failure is defined as the impact on level of service resulting from asset failure. The likelihood of failure is the possibility of asset failure and is synonymous with the “probability” of failure. The risk equation is defined as follows:

Risk = [(Consequence) x (Likelihood)]

2.1.1 CONSEQUENCE OF FAILURE CATEGORIES

Five consequence categories were developed for this project and include:

Environmental Responsibility – Potential for Large Sanitary Sewer Overflow (SSO): Larger sewer spills will have larger impacts on the community, environment, and cost to respond. The size of the sewer was chosen as the means to quantify the potential for large spills.

Environmental Responsibility - Distance to Surface Waters: Sewer overflows can enter into surface waters and have environmental impacts.

Disruption to Commuters: Sewer failures can have significant impacts to commuters due since many sewer manholes and main alignments are located within traffic lanes requiring traffic lane closures to access and perform work on sewer infrastructure.

Impacts to Community: Sewer failures can impact service provided to the community. This factor addresses sewer overflows in areas with a potential for public contact or with potential for interfering with the communities access to commercial areas, emergency facilities, or public facilities.

Goals, objectives, and indicators to quantify consequence were developed for each category and documented in the Consequence Matrix included as Table 2. The Consequence Matrix shows the consequence category, goal, objective, indicator, and scoring criteria utilized to determine consequence scores for each consequence category. Each category was also given a weighting based on the relative importance of the category.

2.1.2 LIKELIHOOD OF FAILURE CATEGORIES

Five indicators of likelihood of failure were developed for this project and include:

Physical Condition: Physical condition was calculated using the structural defect scores based on CCTV data included in the GBA Masterseries CMMS database or using age if no CCTV inspection data was available. Physical condition is a strong indicator of likelihood of failure and is heavily weighted.

Stoppage/SSO Likelihood: The past history of stoppages and sewer overflows on an asset are an indicator that the asset is likely to fail again in the future.

Cleaning Failure Likelihood: The amount of sewer cleaning and quantity of material found during sewer cleaning is an indicator of the likelihood of asset failure. Three years of sewer maintenance data were analyzed to develop a Normalized Cleaning Score. Each instance of light, medium, or severe findings of roots, grease, and other maintenance findings was given a score. Light, medium, and severe findings were given a score of 1, 2, and 4 respectively. The scores of all findings was summed for each pipe and divided by the number of cleanings to generate a score indicating the average severity of cleaning findings. A score of 4 indicates that each time the pipe is cleaned the sewer cleaning crews find a severe maintenance issue. The cleaning likelihood of failure factor was given a low weighting since preventive maintenance sewer cleaning is primarily performed to address recurring maintenance issues versus structural issues.

Failure Density: Assets located in areas prone to sewer failure should be given priority. This factor was generated by calculating the density of main and manhole SSOs and stoppages per square miles for the entire District. This factor is different from Stoppage/SSO Likelihood. Only pipes with an SSO or stoppage in history will have a value for Stoppage/SSO Likelihood as opposed to Failure Density in which pipes without a stoppage or SSO in history can have a Failure Density value if located within an area with stoppages and SSOs. A map of the stoppage and SSO failure density is included in Appendix A. To calculate the failure density score each stoppage was given a value of 1 and each SSO was given a value of 3. All stoppage and SSO values were summed over a three year period from Fiscal Year 2007 thorugh Fiscal Year 2009. The total stoppage and SSO scores for each pipe were then analyzed using GIS to calculate density maps indicating the score per square mile for the entire service area. Since this factor is not based on actual condition of an asset it is given a lower weighting.

Capacity: This likelihood of failure factor is calculated from capacity modeling results and is a strong indicator of likelihood of failure. As such, this factor is given a weighting equal to physical condition.
The scoring criteria and weighting for each of these likelihood of failure categories is documented in the Likelihood Matrix in Table 3.

Table 2. Consequence Matrix

Consequence Category	Goal	Consequence Objective	Indicator	Weight (not used)	Consequence Score			
					Negligible = 1	Low = 4	Moderate = 7	Severe = 10
Environmental Responsiblity – Potential for Large SSO	Protect public from pathogens and toxins Protect water quality	Minimize the potential for large spills	Size of sewer	30%	Size Class I (≤ 6")	Size Class II (8")	Size Class III (10" to 14")	Size Class IV (≥ 15")
Environmental Responsibility – Distance to Surface Water	Meet environmental regulations; Protect the public from pathogens and toxins Protect water quality	Minimize spill volume to surface waters	Spill travel distance to surface water	40%	>1,000 feet	>500 to 1,000 feet	>100 to 500 feet	<=100 feet
Disruption to Commuters	Minimize nuisance impacts	Minimize impacts to commuters	Impacts to commuters based on type of road	10%	No impact or residential street only	Impact to collector road	Impact to minor arterial	Impact to emergency transportation route, highway, highway approaches, or principal arterials
Impacts to Community	Minimize impacts to customers	Minimize impacts to areas serving key customers or large number of people or providing critical services.	Impacts to land use areas.	20%	Open Space, Park	Residential, Golf Course, Administrative	Professional Commercial, Civic Center, Low to Moderate Density Commercial, Industrial, Post Office	Hospital, Library, School, High Density Commercial

Table 3. Likelihood Matrix

Likelihood Category	Source	Weight	Likelihood Score				
			Negligible = 1	**Unlikely = 2**	**Possible = 4**	**Likely = 7**	**Very Likely = 10**
Physical Condition	CCTV Inspection Data (for pipes with inspection data)	50%	Sum of Structural Points < 5	Sum of Structural Defect Points >=5 and <10.	Sum of Structural Defect Points >=10 and <50.	Sum of Structural Defect Points >=50 and <130.	Sum of Structural Defect Points >130.
	Pipe Age (for pipes with no inspection data)		Installed after 1981	Installed between 1971 and 1980	Installed between 1960 and 1970	Installed between 1951 and 1960	Installed before 1951
Stoppage/SSO Failure Likelihood	SSO/ Stoppage History	10%	No history of SSOs or stoppages	1 stoppage	>=2 stoppages	1 SSO	>=2 SSOs
Cleaning Failure Likelihood	Sewer Cleaning Maintenance History	10%	No sewer cleaning findings.	Normalized Cleaning Score <=1	Normalized Cleaning Score <=2	Normalized Cleaning Score <=4	Normalized Cleaning Score >4
Capacity	Capacity Model	30%	Model shows no surcharge or pipe not in model (small diameter).	Model shows that these pipes are likely to have surcharge only under future conditions (both DWF and WWF) when the loads become higher due to intensified land use or population increase.	Model shows that these pipes are likely to have surcharge, but there is more than 5' of freeboard available	Model shows that these pipes are likely to have noticeable surcharge of over 1' and less than 5' of freeboard. Relief or replacement sewer required.	Model shows that these pipes are likely to have SSOs under a 10-year storm

Note:
Freeboard = Difference between ground level and water level.

2.2 PRIORITIZATION DATA ANALYSIS

A geodatabase was created incorporating key GIS data, including the District's sewer network, roads, surface waters such as creeks and reservoirs, property boundaries and land uses. Sewer maintenance, repair and cleaning data provided by the District were analyzed according to the consequence and likelihood categories listed in Tables 2 and 3. The analyzed data tables were added into the geodatabase, and linked to the sewer network GIS by pipe ID. Consequence and likelihood scores were assigned to each pipe for each category, and an overall weighted and maximum consequence score and a weighted likelihood score were calculated for each pipe.

2.3 PRIORITIZATION RESULTS

Maps showing the distribution of consequence and likelihood scores for the District's system in each category were developed. Consequence scores for each factor can be either 1, 4, 7, or 10. For purposes of calculating the risk score, the maximum consequence score was selected for each pipe. The maximum consequence score was selected to calculate asset risk instead of the weighted score because the weighted consequence score was highly skewed to the lower consequence scores (ranging from 1 to 4) and was resulting in scores for all pipes being clustered in the lower risk score range. The overall likelihood score was calculated by summing the weighted likelihood scores from each of the categories to obtain a total likelihood score ranging from 1 to 10.

The risk scores for each sewer pipe in the District's system are presented in two figures. Figure 1 presents the risk scores for pipes with CCTV inspection data. Figure 2 presents the risk scores for pipes with no CCTV inspection data. The risk score was calculated by multiplying the overall consequence score by the overall likelihood score. The risk scores for the District range from 1 to 78. The risk scores were then grouped into the risk categories listed in Table 4.

Table 4. Percentage of WVSD Sewer Pipes By Risk Category

Risk Category	Risk Score Range	Percentage of WVSD Pipes
High	45 to100	1%
Medium	26 to 44	2%
Low	13 to 25	11%
Very Low	1 to 12	86%

Using this approach, a risk score was calculated for every individual sewer pipe. The next step for WVSD is to use this score to prioritize future repair, rehabilitation, or replacement projects. Using the individual risk scores for sewer pipes, the risk scores for projects can be calculated using a variety of methods that include:

1. Using the score of the highest risk pipe included on a project as the project score.
2. Using the average of the pipe risk scores as the project risk score.
3. Multiplying the risk score for each pipe segment by the segment length to generate a risk-feet score for each pipes, adding all risk-feet scores for pipes on a project, and then dividing the total project risk-feet score by the total project length.

All of these methods will yield slightly different outcomes yet will accomplish the goal of creating a project score that can be used to rank projects versus one another.

3. REFERENCES

NACWA/AMWA/WEF (2007). Implementing Asset Management, A Practical Guide, pp. 19-44.

Figure 1. Risk Scores for Pipes with CCTV Data

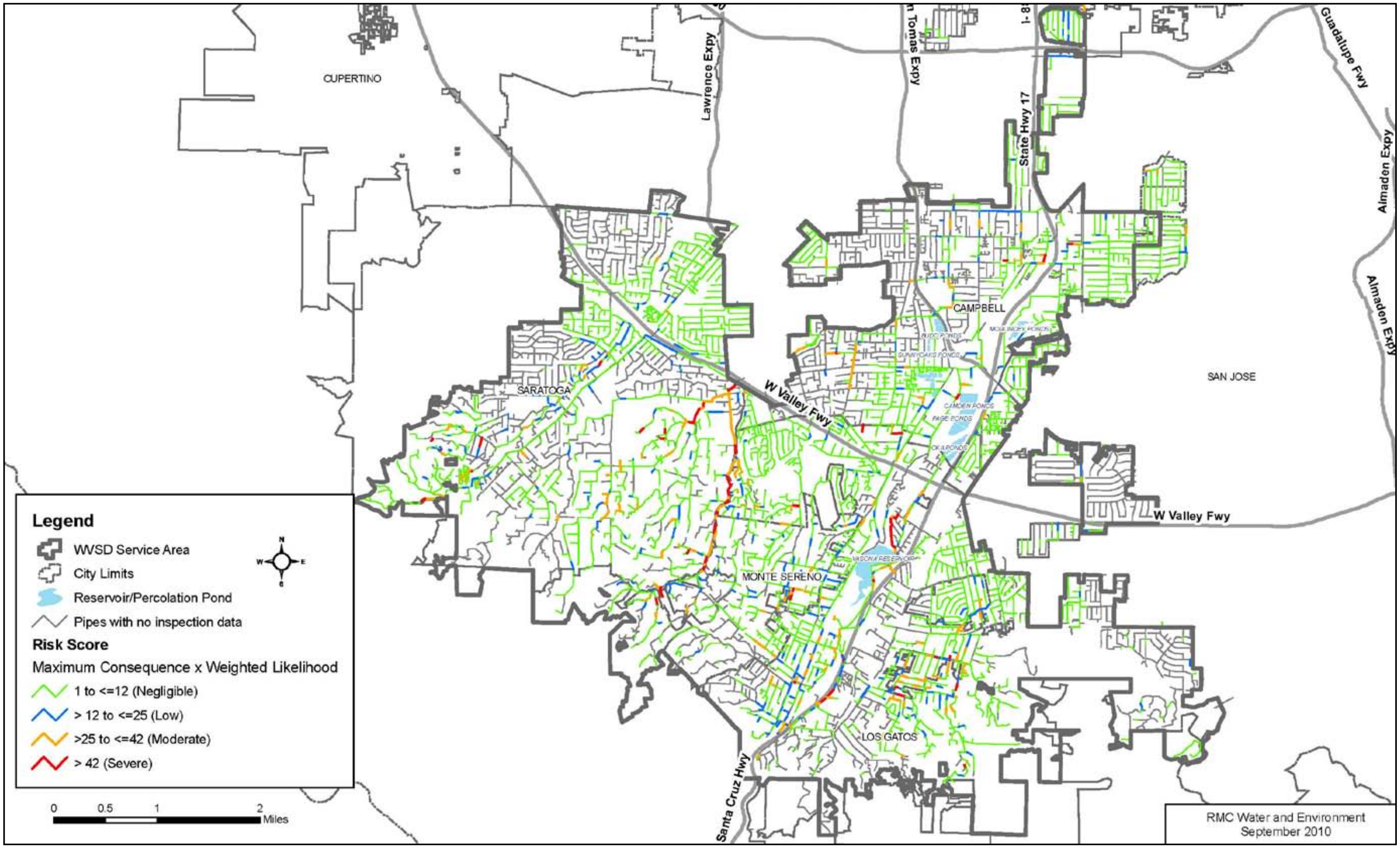

Figure 2. Risk Scores for Pipes Using Age Data (No CCTV Data)