PIPE BREAK ANALYSIS – WATER

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Executive Summary

In an aging Water Distribution system such as that run by the City of Austin, necessary (and often immediate) repairs begin to rise. As such a system constantly suffers new growth, aging pipes often get ignored until their situations become chronic, or they cause a great deal of other damage. Planning for system improvement projects must rise to meet the challenges offered by the aging system, as well as the expected new growth. Currently, the Austin Water Utility does this through the CIP planning process and various long range planning projects. A variety of techniques are utilized to identify where the focus must be to maintain and grow our system, including water modeling, demographic analysis, and the use of GIS and Hansen data. However, an analysis of the way in which the pipes break has only been marginally possible, so the conditions that cause system failure cannot adequately be anticipated in any of the planning efforts.

Through previous efforts by the Utility to analyze pipe breaks, various process improvements in the installation and repair of the system's pipes have been initiated. However, more can be done to anticipate system repairs, improve the processes, and monitor how effective the previous process improvements have been. So it will be necessary, periodically, to analyze how the system's pipes break and what appears to be the cause of the breakage. To enable these future analyses, data collection will need to improve.

Current data indicates that the water system is aging and may be becoming somewhat fragile. These older pipes may be very subject to the characteristics and movement of their surrounding soil. High pumpage and seasonal temperature/climate variations may also unduly stress the older pipes. Consequently, more failure in the older pipes can be expected. However, the rate of pipe breaks overall could remain much less than the height, as long as the repair continue to make permanent repairs to the pipes (using sleeves) rather than temporary repairs (using Smith and Blare temporary sleeves).

Cast iron pipe breaks most. A little over a third of the Austin water system consists of cast iron, but the material is no longer being installed. However, its replacement material, ductile iron, is beginning to suffer pipe breaks as well. The percentage of the ductile iron in the water system that is breaking is still fairly low, but it may bear watching in the future. A surprising amount of galvanized pipe (½ mile) suffers breaks, even though there is only 7 miles of it in the Austin water system. At this time, our data would tend to indicate that ductile iron and PVC are good materials for water pipes.

Overall, the Austin water system resides in some form of clay (which happens to have corrosive characteristics to steel). The worst of the soil types involved with the pipe breaks studied was Houston black clay, a fat clay that accounted for 29% of the breaks but only houses 11% of the water system. Urban lands and Austin soils accounted for 19% of the breaks, and urban lands and Austin-Brackett soils accounted for 14% of the pipe breaks. However, they only house 14% and 11% of the water system, respectively.

The soil in which the fewest breaks were found is Tarrant-Speck soils and urban lands (a clay in urban areas). Only 3% of the repeat pipe breaks occurred in this soil, but it houses 16% of the water system.

Most of the soils in Austin drain well and are not corrosive to concrete. Drainage and corrosivity to concrete do not appear to be problems for the Austin water distribution system.

Data Under Analysis

CMMS data

The Computerized Maintenance Management System (CMMS), which is used to record and manage work done on the Austin water system, stores a tremendous amount of data regarding the maintenance done to the water system. This is where the information on pipe breaks can be found. However, the CMMS does not provide an analysis of its pipe break information completely.

GIS data

The GIS data used in this analysis is from July 1997 to October 2002 and October 2010 to September 2015. For analysis of the water system at the time of the pipe breaks, it was desirous to pull GIS data that was from the same general time period.

The GIS data is very good, though it still has a couple of problems. The most injurious problem to this analysis was the lack of installation year information in the attribute records for the older pipes. This situation can only be improved by laborious research, so assumptions had to be made. The pipe records without values in the installation year field were assumed to have been installed at least by 1975, and probably before 1970. Those charts which display the pipe records by their decade of installation will show a column for “unknown” which covers this assumption, as well as columns for “1950s”, “1960s”, and “1970s”. Technically, given the situation with the information, all four of these columns qualify as the assumption of older pipes, and can be lumped together in judging the age of the pipes in the system and the pipes that were involved with the pipe breaks. The decades “1950s”, “1960s”, and “1970s” were broken out because a fair amount of data could be found for those decades which would be helpful in extrapolating the approximate decades that exist in the "unknown" column. However, very few of the records for the pipes installed prior to 1950 have a value in the installation year field, so all records prior to 1950 were lumped in with the "unknowns".

Soil data

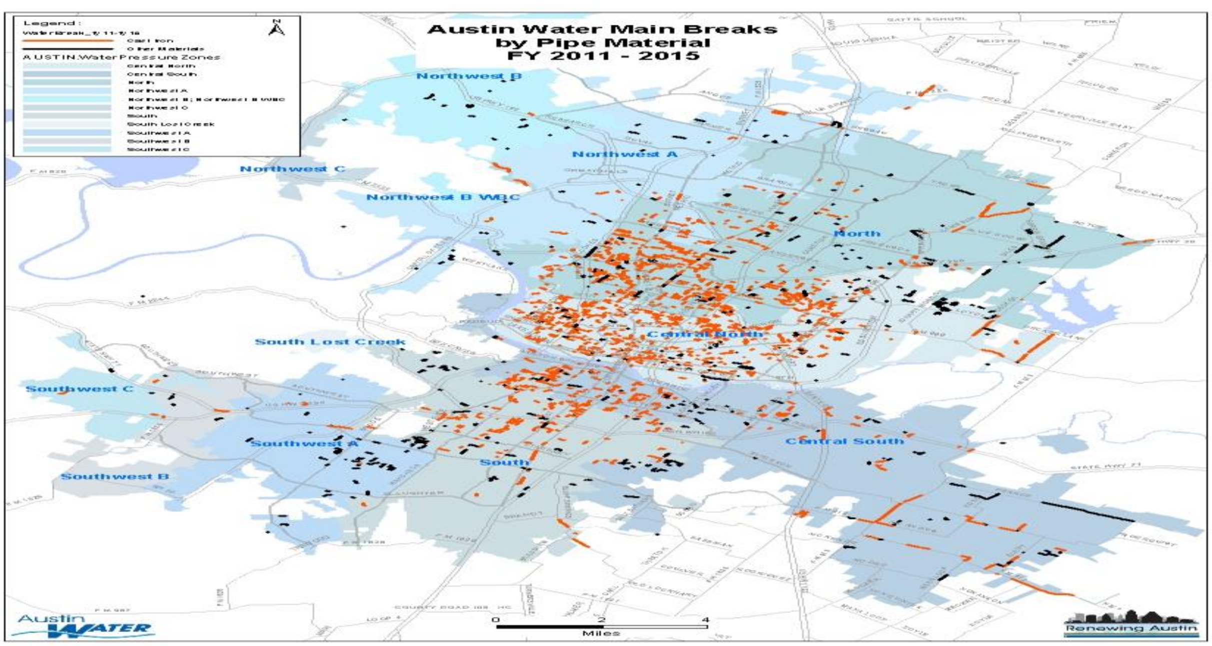
The soil data used in this analysis was obtained from the United States Department of Agriculture (USDA) website at http://www.usda.gov/. It has two components: spatial data (a one-to-one relationship) and data tables (a many-to-one relationship). The data tables contain information on each soil type which may vary according to depth. Consequently, from these tables and the spatial data, a soil data set had to be developed that might be representative of the depths at which our pipes may be buried. This data could now be displayed and analyzed spatially. This very important step allowed the study to identify the soils and soil characteristics that were prevalent in the areas where the pipe breaks occurred.

SCADA data

The SCADA system compiles a great deal of information on the water distribution system at certain specified points and times. However, the water pressure data it keeps was not used for this analysis.

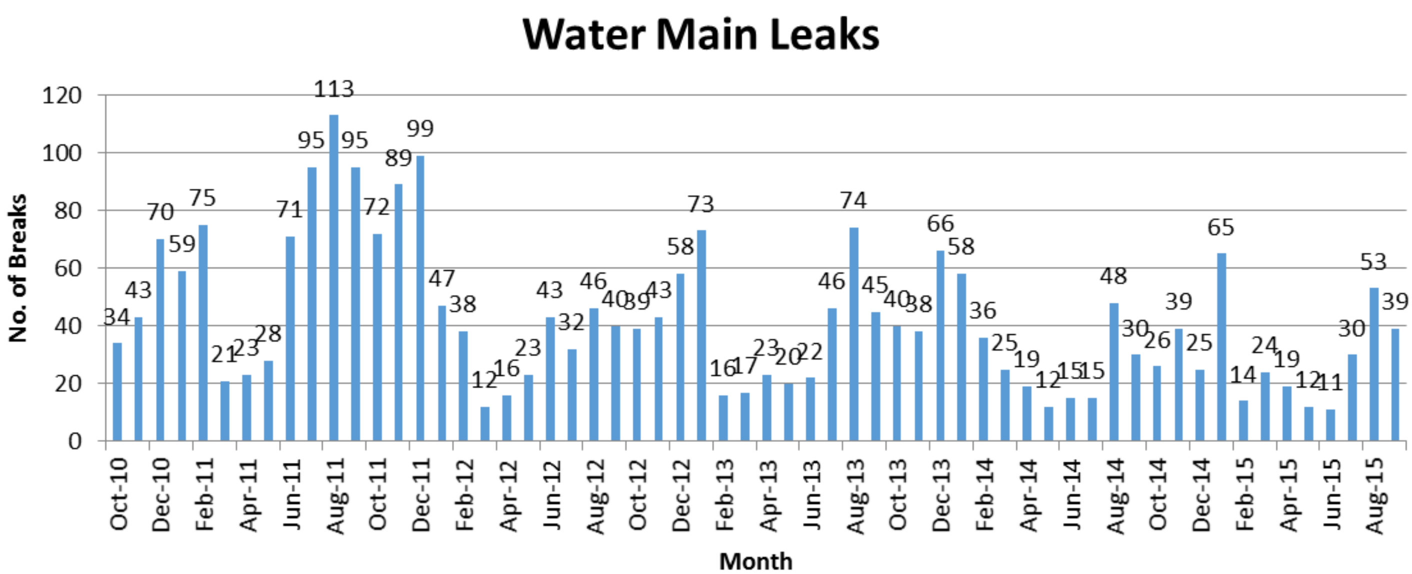
Analysis

Austin Water Hansen data break history was utilized to analyze the breaks on the Austin water mains.



Pipe Breaks over Time

An initial breakdown of the data revealed that repeat pipe breaks rose sharply in August and again, almost as sharply, in December. A contributing factor to the tendency to break pipe in the months with higher temperatures might be seasonal increases in water usage. During such months when the temperature rises and the precipitation decreases or ceases entirely, water usage and pumpage increases. Besides the soil condition, pipe breaks appear to rise similarly to the pumpage increases, which might suggest that the added water being sent through the already stressed pipes may stress them further



Pipe Composition

A look at the pipe material most often involved with the repeated pipe breaks reveals cast iron (CI) to be a material of considerable interest. Nearly 78% of the pipe breaks occurred in cast iron pipe while only 30.40 % of the entire water system is cast iron. Approximately 99% of the cast iron pipe where the breaks occurred was installed prior to 1980. Most of it was installed before 1971, when Austin Water began to bed the trenches rather than bury the pipe directly in the ground. Consequently, most of the CI pipe where the breaks occurred is at least 30 years old and is buried directly in the ground – unprotected from soil elements and ground movement.

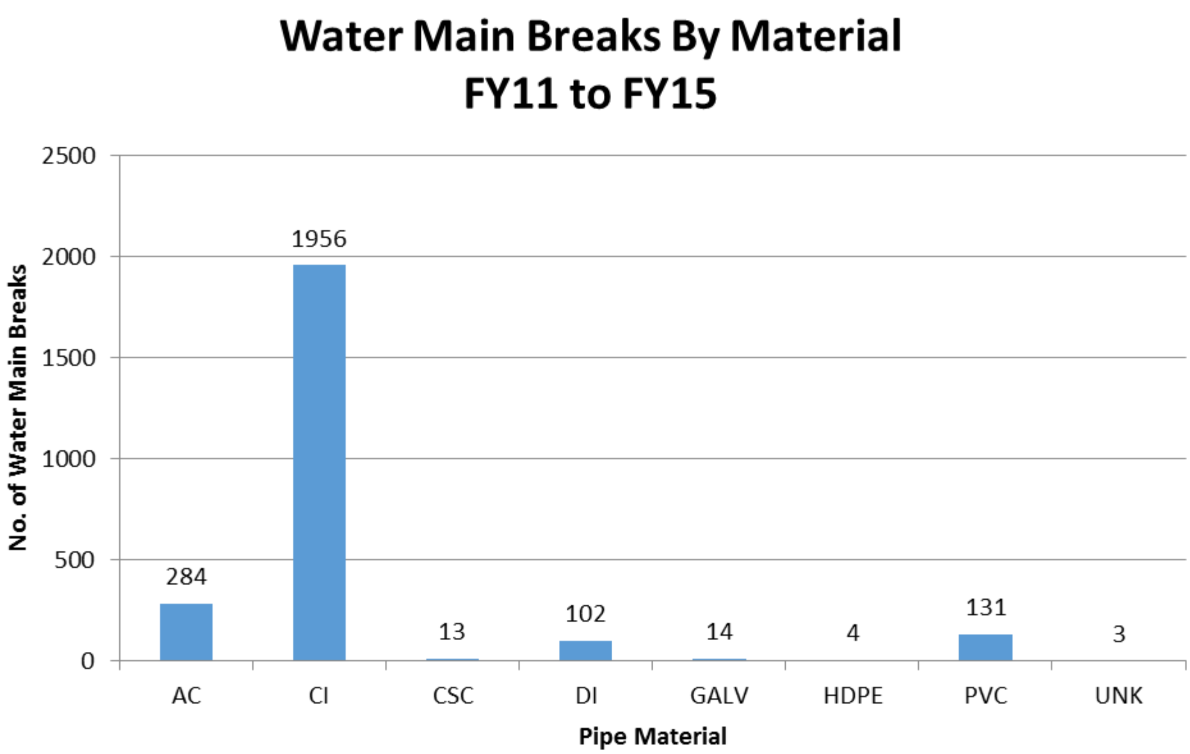
Approximately 11.34 % of the AC pipes in the water system suffered breaks during the FY11-FY15. PVC pipe was involved with 5.23% and DI pipe with 4.07% of the pipe breaks studied.

Asbestos concrete (AC) pipe accounted for 17.89% of Austin Water Distribution System. However, this material is no longer used due to the asbestos health risk.

Ductile iron (DI) pipe, the current alternative to cast iron pipe, is 25.89% of the distribution system. PVC pipe is 17.92% of the distribution system.

Pipe Type	**Total Number of Mains by Pipe Type**	**Total Miles of Mains by Pipe Type**	**% Of Water System by Length**
Ductile Iron (DI)	45,111	900	25.89%
Cast Iron (CI)	31,525	1,057	30.40%
Polyvinyl Chloride (PVC)	23,700	623	17.92%
Asbestos Cement (AC)	16,918	622	17.89%
Concrete Steel Cylinder (CSC)	3,441	261	7.50%
Galvanized (GALV)	231	8	0.22%
High Density Polyethylene	111	3	0.09%
Steel	10	3	0.08%
Totals	**121,047**	**3,477**	**100.0%**

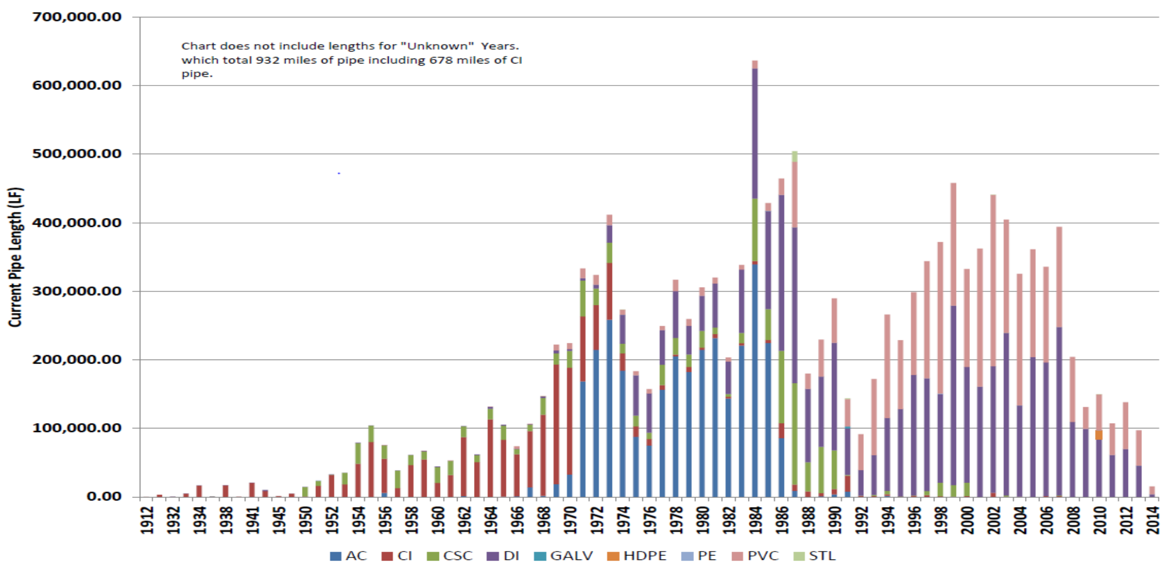
Source: 2010 AMP report



Pipe Age

Approximately 90% of the pipe where breaks occurred is 30 years old or older. In fact, 41.5% of the entire water system is at least 30 years old, and another 14.9% was installed in the 1970's, making it very nearly 30 years old itself. All told, 56.4% of the system is aging and may eventually need maintenance or replacement.

Figure 1 - Pipe Material and Length by Year Installed



Soils

The soil in which a pipe is buried can have a variety of deleterious effects on it. The longer the pipe stays buried there, the greater the deterioration it may suffer. It is possible that many incidents of breakage are a result of the effects and movement of the soil in combination with the pipe age and material.

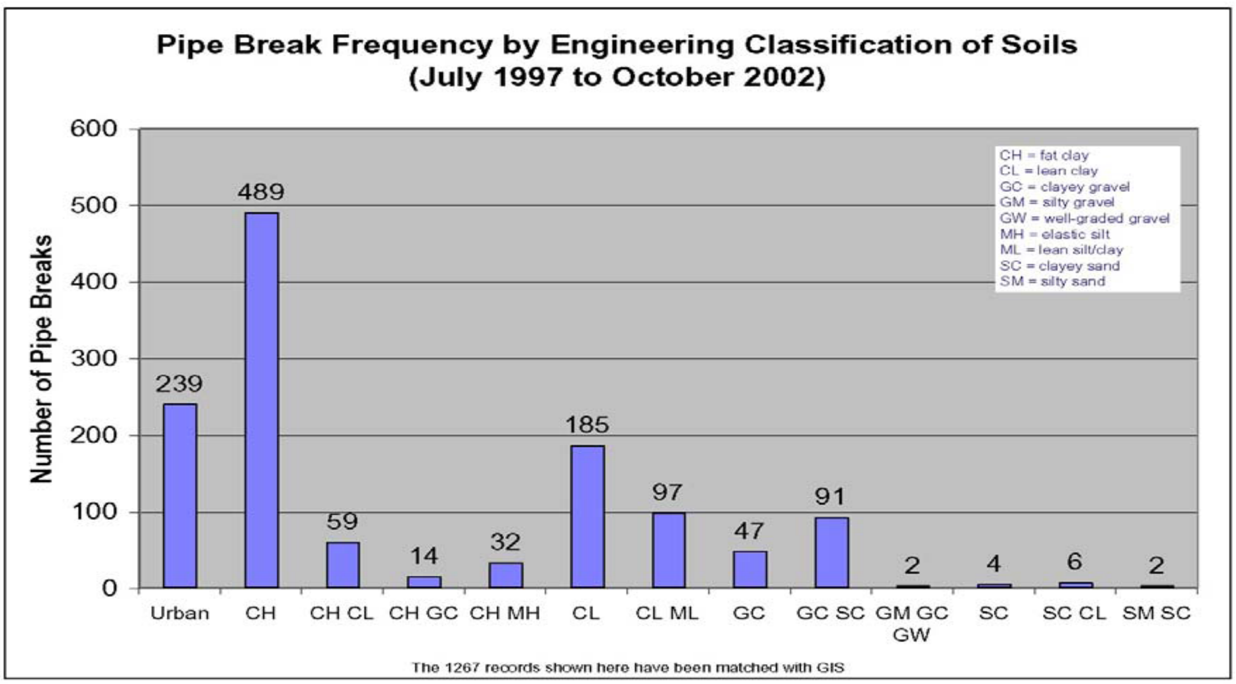
The greatest number of repeat pipe breaks occurred in clays (primarily fat clays) and urban areas. The Austin area soils are largely clay, many of them fat clays, so this is not a surprise. However, Houston black clay figures prominently in the numbers of the repeat pipe breaks. Per 2002 study, from July 1997 to October 2002, 1267 repeat pipe breaks happened with 29% of the repeat pipe breaks in Houston black clay and urban areas on Houston black clay (fig. 14), even though only 11% of the water system is laid in Houston black clay. So 369 of the 1267 repeat pipe breaks happened in only 222 miles of the water system. However, it should be noted that 94% of these pipes were installed before 1978 and are aging. (Houston black clay is a fat clay with an AASHTO (American Association of State Highway and Transportation Officials) soil classification of A-7. Soil classifications of A-6, A-7, or a combination of these two are silty clayey soils.)

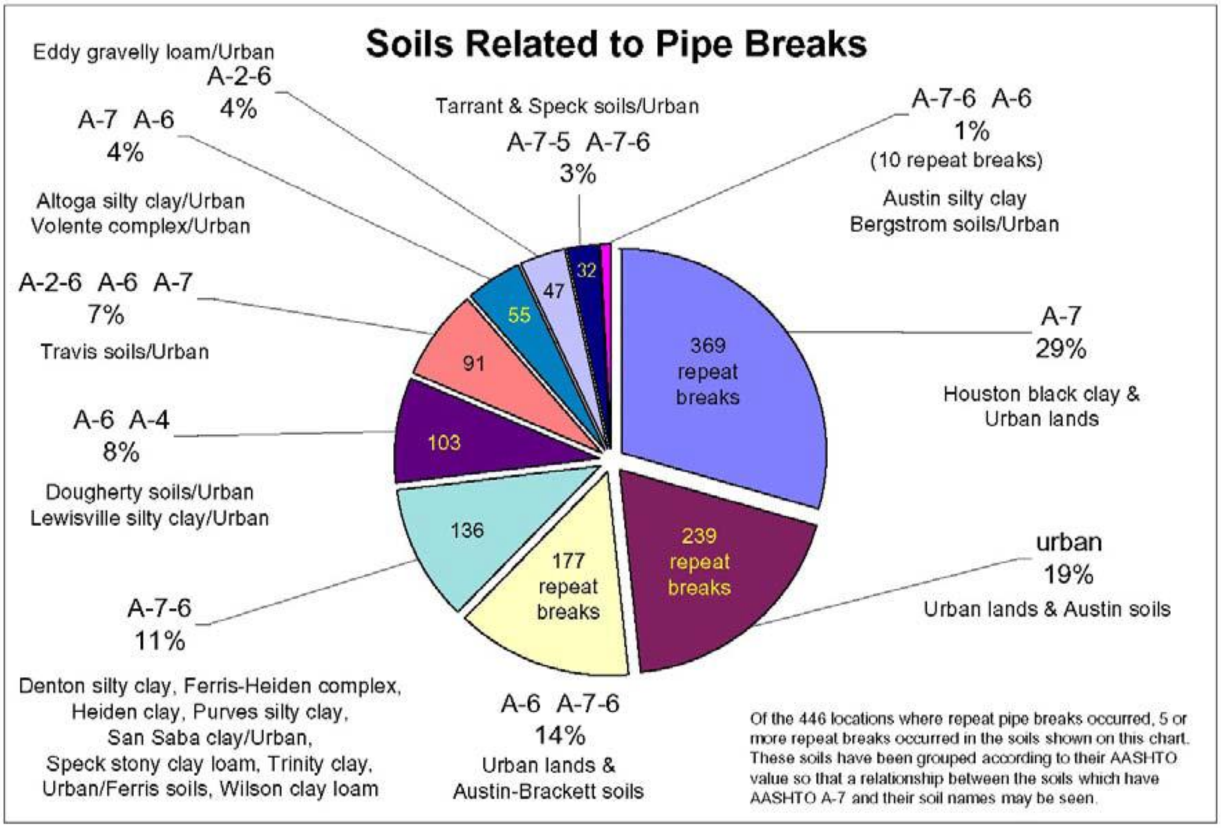
According to the study 19% of the pipe breaks occurred in urban lands and Austin (silty clay) soils. Approximately 14% of the water system is laid in these soils. The soil data does not provide a great deal of information for these soils other than the fact that they are urban. It is possible that the soil is typically so disturbed as to be actually too varied for a true soil classification to be given. Approximately 96% of the pipes in these soils were installed before 1973.

Only 11% of the water system is laid in these soils (roughly the same amount of the system which is laid in Houston black clay). Approximately 97% of the pipes in these soils were installed before 1974. From this comparison, while the pipe break numbers are still high for this soil, it becomes apparent that Houston black clay is somehow hard on our water system. (This soil has an AASHTO classification of A-6 A-7-6.)

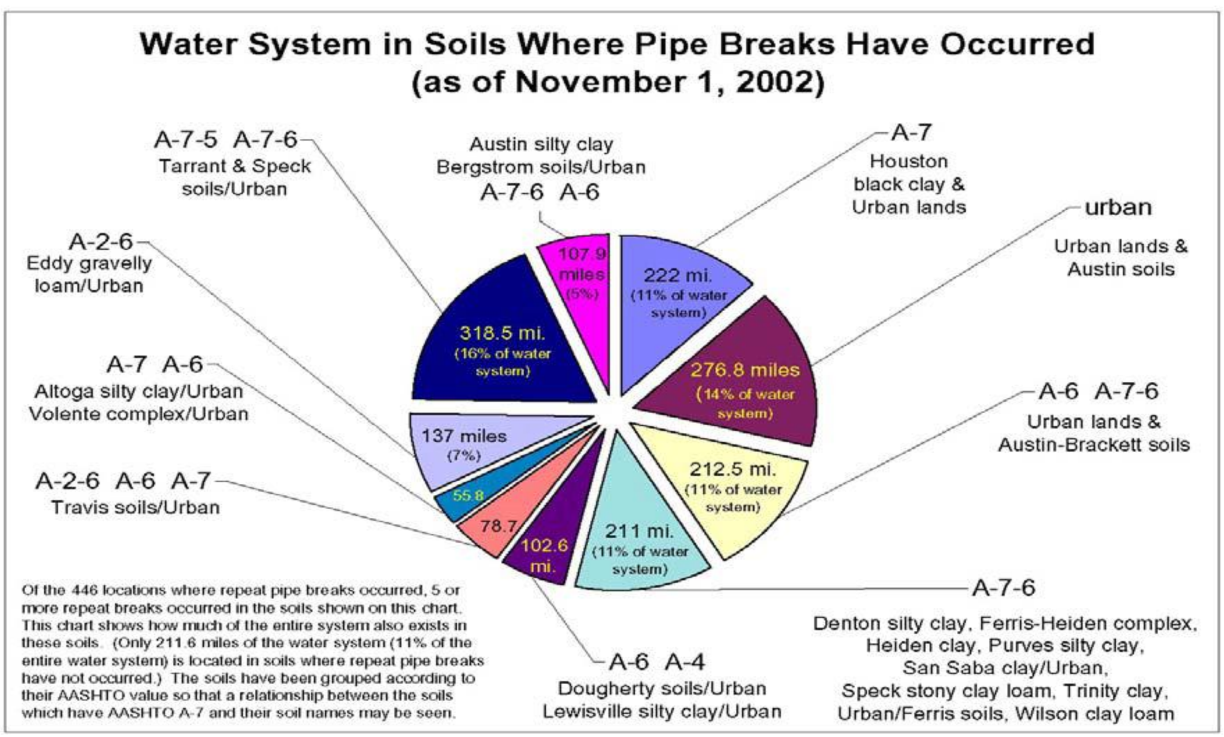
Approximately 11% of the pipe breaks occurred in a group of soils which are all similar fat clays (AASHTO A-7-6). Approximately 11% of the water system is laid in these soils. Approximately 88% of the pipes in these soils were installed before 1980.

In contrast to the high pipe break soils, only 3% of the pipe breaks occurred in Tarrant-Speck soils and Urban lands. Approximately 16% of the water system is laid in these soils. Approximately 87% of the pipes in these soils were installed before 1980.



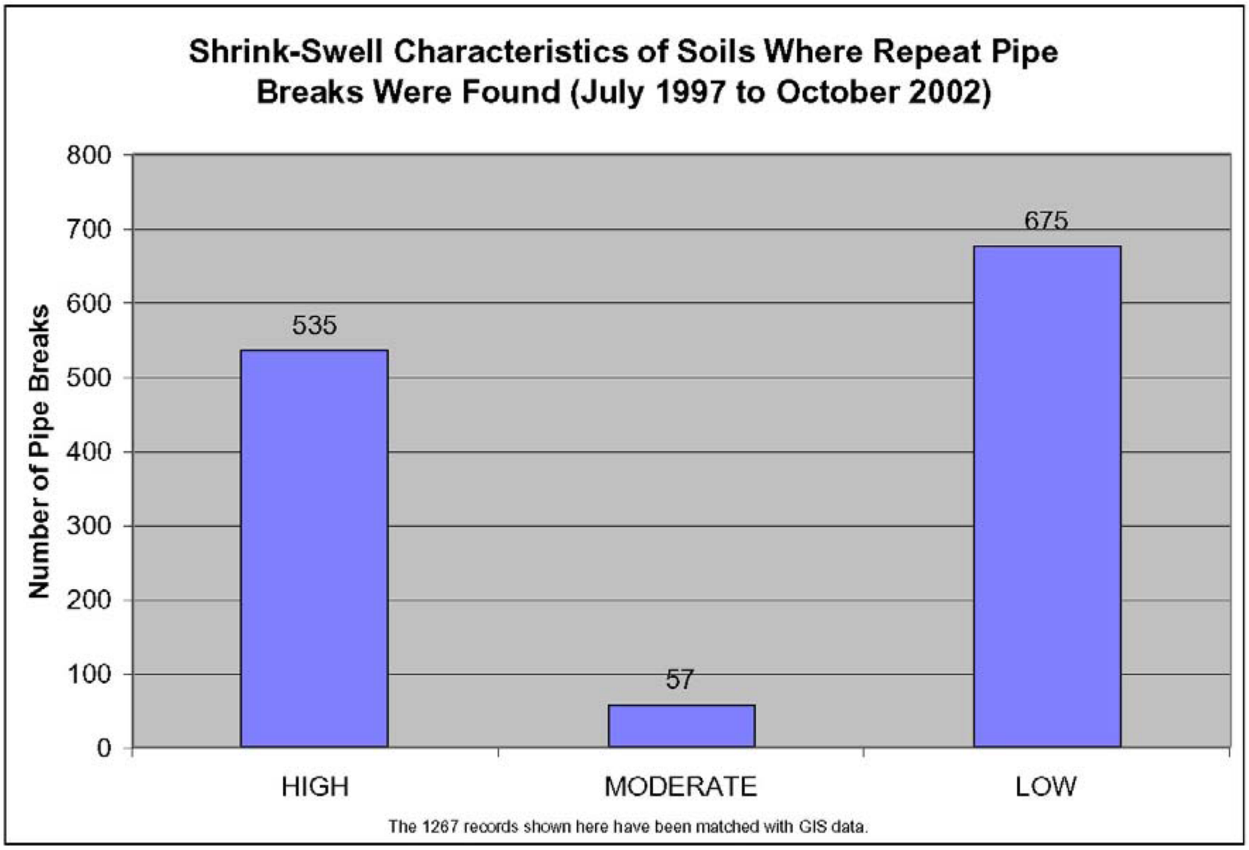


Source: AWU 2003 system planning and GIS report

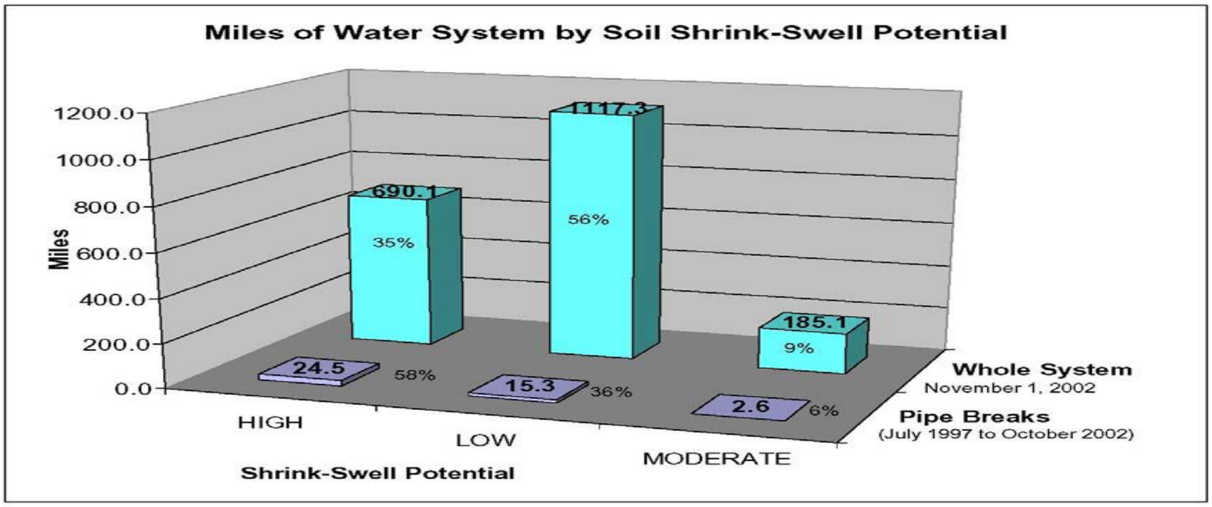


Soil Shrink-Swell Characteristics

From July 1997 to October 2002 ,53% of the repeat pipe breaks occurred in soils which do not shrink and swell a lot at the depths where Austin water system would be typically buried. Approximately 42% occurred in soils that do shrink and swell. Only 35% of the system resides in high shrink-swell soils. About 56% reside in low shrink-swell soils. While, according to these numbers, soil shrink-swell potential is not a major contributor to the frequency of pipe breaks, it does appear to be a contributor upon occasion. Lateral fractures in the pipe have been seen in the field indicating that some form of linear stress is being applied to the pipe – quite possibly from soil movement.

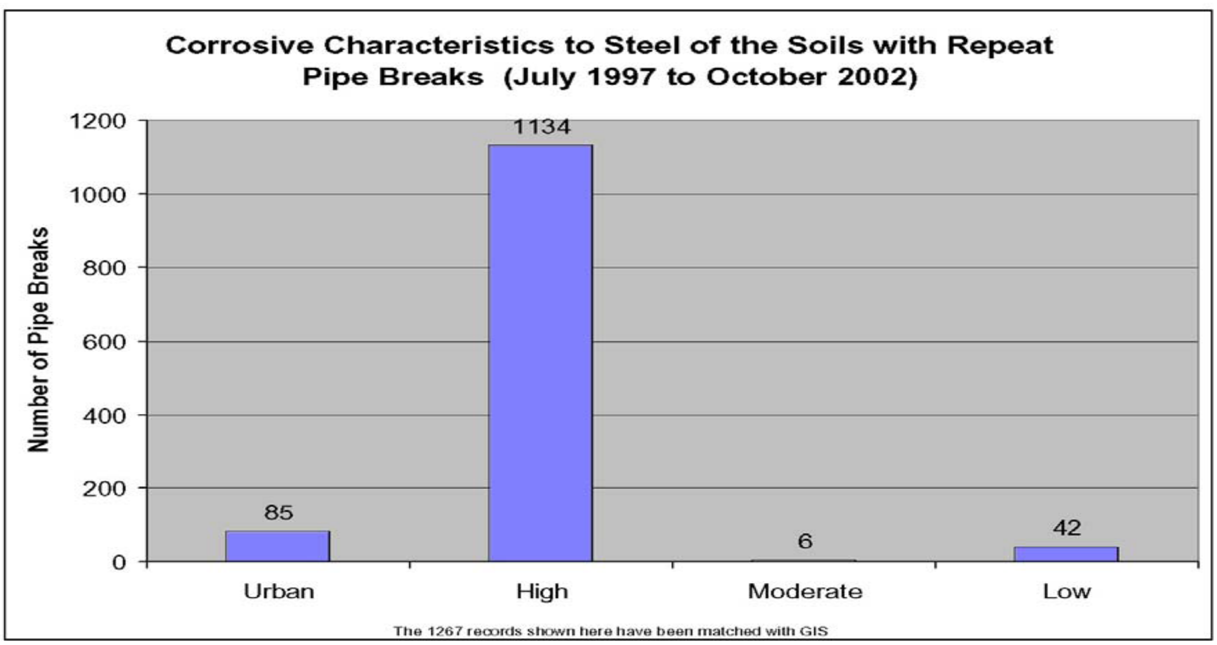


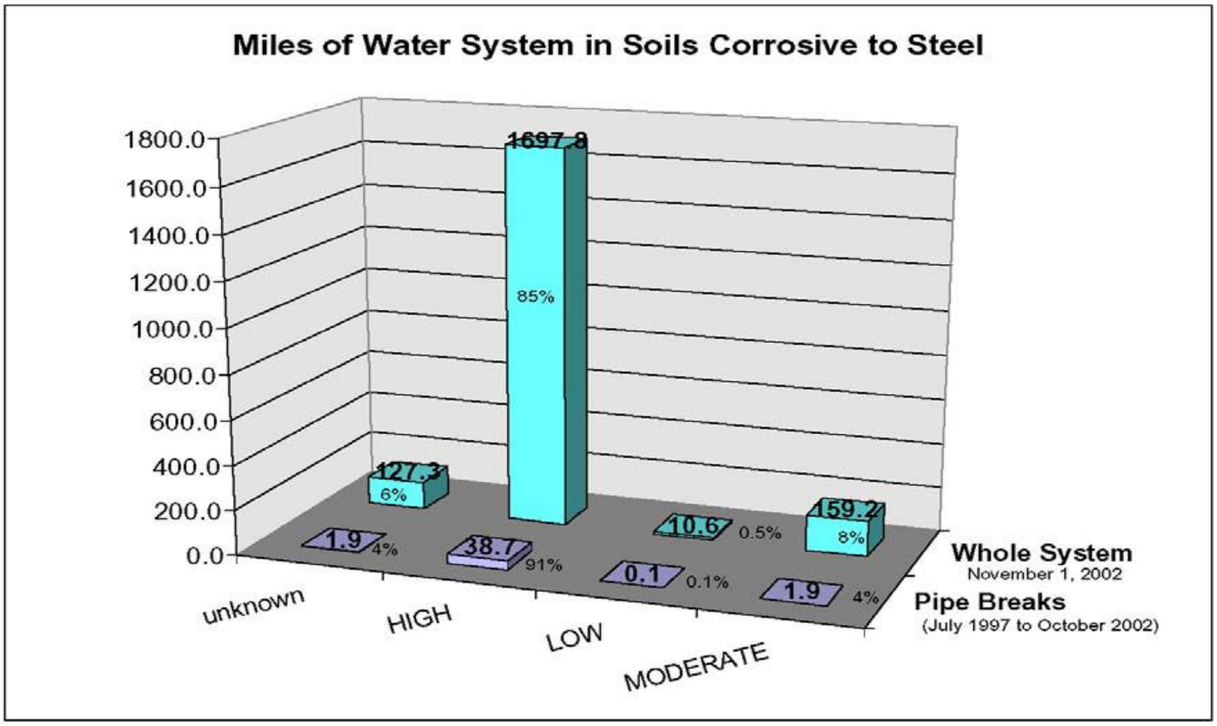
Source: AWU 2003 system planning and GIS report



Soil Corrosivity -- Steel

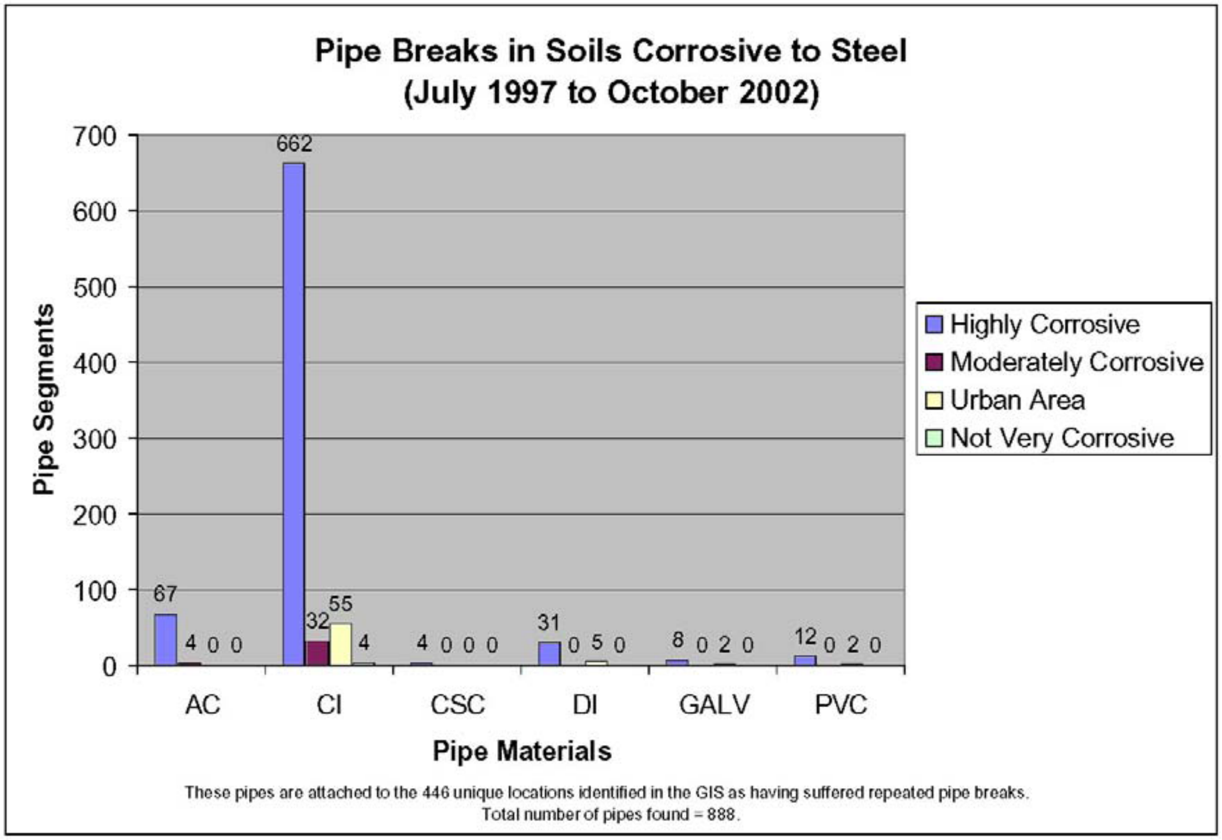
Approximately 89.5% of the repeat pipe breaks from 1997 to 2002 occurred in soils which were highly corrosive to steel (fig. 18). However, 85% of the water system resides in soils which are highly corrosive to steel, and 8% resides in soils which are moderately corrosive to steel (fig. 19). So, if a pipe were to break, it is very likely that it would reside in soil highly corrosive to steel. Corrosion is often seen on broken CI pipes, though, so soil corrosivity cannot be ignored as a contributor to the frequency of pipe breaks.





Source: AWU 2003 system planning and GIS report

Since 85% of the pipes that broke were cast iron (CI) and 89.5% of the repeat pipe breaks occurred in soils corrosive to steel, the number of cast iron pipes which broke in corrosive soil becomes interesting. Approximately 75% of the cast iron pipes which broke during the study period were located in soils corrosive to steel (fig. 20). Approximately 34.3 of the 35 miles of cast iron pipe located in corrosive soils were installed prior to 1971. These pipes were typically laid directly in the soil (without bedding or protective wraps), and they are now over 30 years old. The 0.7 miles of pipe suffering breaks which did get laid with bedding in the trench to protect it from soil and soil movements, did not receive any protective wrapping. These pipes are nearly over 30 years old themselves



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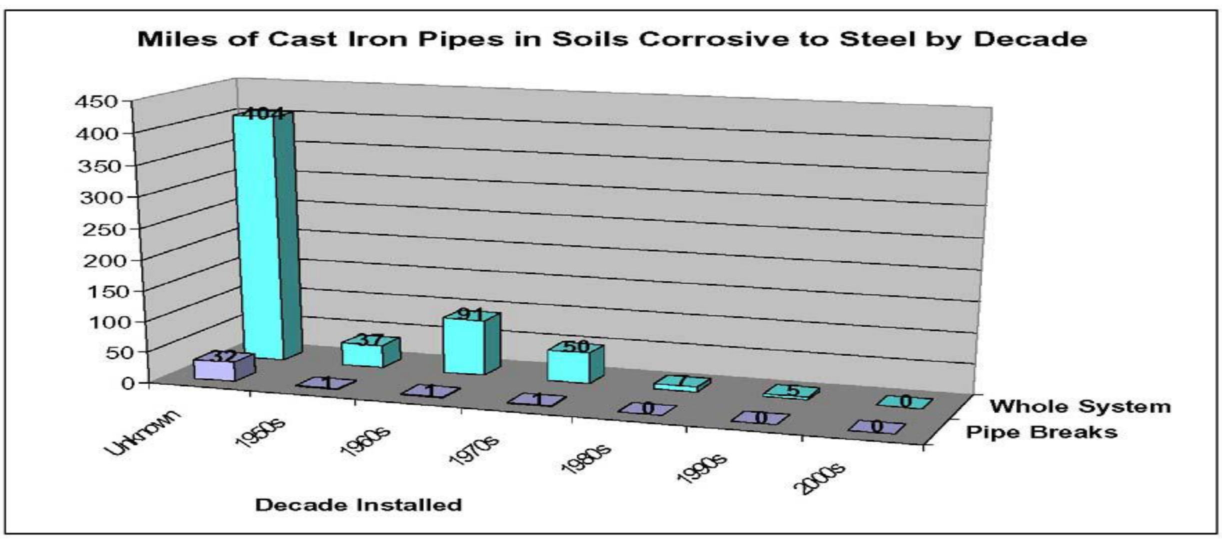


Over the entire system, 532 miles of cast iron (26.7% of the system) was laid directly in corrosive soils before 1970. Another 28 miles was laid in 1970 and 1971. Almost none of

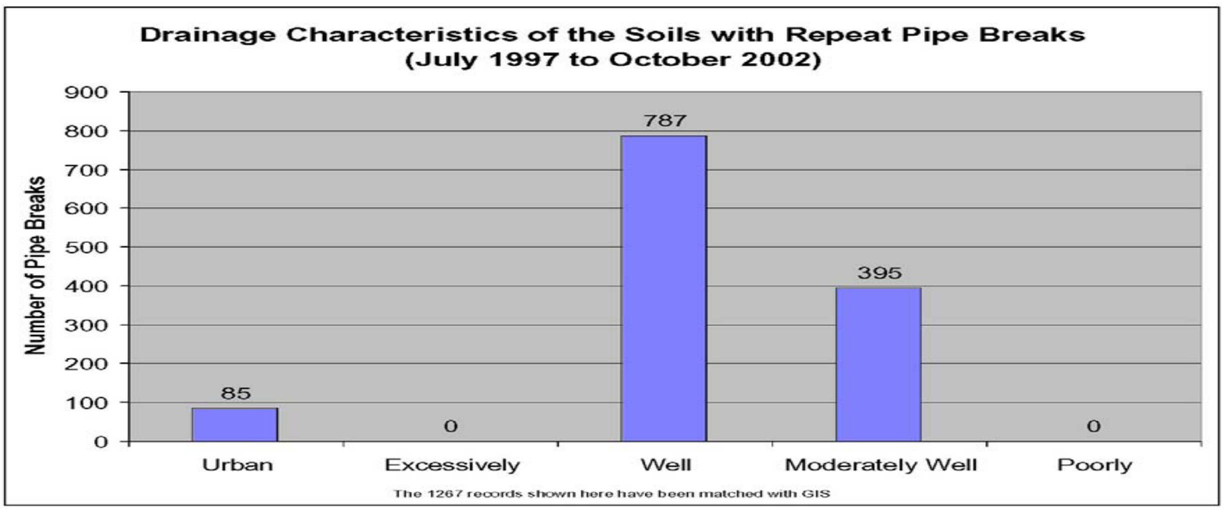
these pipes were laid with any bedding or protective wrappings, and all of them have been in the ground for over 30 years. About 27 more miles of cast iron (installed between 1971 and 1987) were laid in bedded trenches, but without protective wrappings, bringing the total of generally unprotected cast iron pipe in the system to 587 miles (29.4% of the whole system).
Austin Water is no longer installing cast iron pipe. Instead, ductile iron (DI) is being used. Of the pipe breaks in 2002 study, 4% occurred on DI pipes.

Soil Corrosivity -- Concrete

Most of the soils on which Austin sits are not terribly corrosive to concrete pipes. Only 97 of the pipe breaks that occurred between July 1997 and October 2002 (7.7%) occurred in soils that were even moderately corrosive to concrete

Drainage

Most of the soils around Austin drain well or moderately well. Approximately 395 repeat pipe breaks (31%) occurred in soils that drained only moderately well. Approximately 787 of the breaks (62%) occurred in soils that drain well. While drainage can be a factor in soil movement, especially when dealing with fat clays, it would appear that it is a very minor factor with respect to the repeat pipe breaks in this study



Recommendations

Future Analysis

The methods by which the utilities install and maintain its infrastructure have changed periodically since 1971. Future studies will be needed to determine the effectiveness of these changes and to develop guidelines that will help the utilities better plan for rehabilitation and maintenance of their water system.

Improved Data Collection and Data Sets

Improved data collection could help the utilities better analyze the failures in the water system. These analyses can help pinpoint dire problems, identify process improvements that provided good results, and help establish performance measures for the groups responsible for installing and maintaining the water distribution system infrastructure. Data collection is the first step in the analysis process.

Improved Field Data Collection (CMMS)

Utilities should make all efforts to capture and store following information on their CMMS system to be able to analyses their main failures at least every 5 years regarding the infrastructure and the nature of their failures

- Material/method used to repair break (Blare, sleeve, etc.)
- Soil conditions around pipe where break occurred (swollen clay, shrunk clay, gravel, etc.)
- Is the pipe bedded in its trench?
- Is the pipe polywrapped to protect it from the soil surrounding it?
- Is the interior pipe diameter narrowing through lime deposits and what is the current diameter? (important for older pipe) -- This information may even help the Systems Planning modelers create more accurate models for older areas of town.
- Was the break linear (along the pipe) or vertical (across the pipe)?
- Is this a repeated pipe repair? (Has this pipe broken in this area before?)
- Why is this repair needed?
    - A Blare was last used to repair the pipe.
    - Contractor broke the pipe.
    - Subsidence
    - ground movement

GIS Data Improvement

The GIS data is continually improving, though the data on the older pipes often does not have valid installation dates. This makes it difficult to accurately estimate the age of the parts of the infrastructure that are beginning to fail, or how much of the current infrastructure is approaching the age when portions should be expected to fail and will need to be scheduled for maintenance or replacement. The collection of this data will be a laborious research project involving information only available on antiquated maps and in archived files. Without the information, we can only guess at the age of the pipes that are failing, but will have no real data on which we can depend. However, over time, all of these pipes will become ancient enough that specific dates may be only interesting, since they will all eventually need to be worked on or replaced after a while. The installation date is currently entered during all new GIS data entry.

Index to data sources:

Water pipe data:

Austin Water Utility (Systems Analysis/GIS).

Water Pipe Break data or Repeated Pipe Break data:

Austin Water Utility's Facilities Maintenance System (also referred to as CMMS or Hansen)

Soil Data:

United States Department of Agriculture (www.usda.gov). The soil survey for each particular county and state must be consulted for in depth explanations as to the soil types in the data and their characteristics. Some of the soil surveys for Texas are available in pdf format online at http://www.tx.nrcs.usda.gov/soil/soil_surveys.html. However, the only current reference for Travis County Soils is the "Soil Survey of Travis County, Texas" from 1974.