Weekly report: Sept. 3-Sept. 17, 2012

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September 18, 2014

1 Goals for the week

- Plot consumption of water versus amount of water treated by plants over time.
- Plot the estimated I&I over time.
- Understand the distribution of sensors across the city over time.
- Find all the logical pipe segments inside the city.
- Obtain specific features for all the pipe segments.
- Determine the ranking for the logical pipes segments of the city of Cambridge.

2 Activities

- Calculate total amount of water consumed by end users based on billing information, and total amount of water treated based on billing information from Region of Waterloo.
- Determine allowed I&I every year based on the growing rate of the population of Cambridge.
- Calculate the additional I&I every year based on the difference of water consumption along with the allowed I&I versus the total amount of water treated in the city.
- Determine location and dates when sensors were collecting information.
- Store additional information about the periods of times when each sensor was available in the database.
- Group sensors according to periods of time when they were collecting data together.
- Show distribution of sensors across the city over time on the map.

- Determine the directionality of water flow inside the pipes across the city.
- Analyze each group of sensors on the map in order to identify logical pipes segments.
- Determine the pipes that were "in service" around the proximities of each sensor in order to identify all the sources of incoming flow into each logical pipe segment.
- Determine what crossing pipes were actually connected to each logical pipe segment.
- Analyze the existence of additional sources of inflow to the pipes such as houses/businesses within the logical pipe segments.
- Calculate features about incoming and outgoing flow of each logical pipe segments.
- Obtain additional features about the I&I during dry weather (dates with less than 2 mm of rain).
- Calculate separate information of dry weather I&I for weekdays and weekends.
- Calculate the slope for the amount of I&I generated based on the amount of rain for each logical pipe segment.

3 What I learnt (insights)

- I&I has increased over time at a higher rate than population growth. As mentioned last meeting, there is a considerable increase in the gap between consumed and treated water in 2008. This gap is reduced again over time and seems to be stable again by 2013.
- The peak of the total amount of water treated by the plants is reached by the end of the winter, probably due to snow melting and rains happening at the beginning of spring. Also, as a confirmation of the fact that rain is the main source of I&I, it is possible to see in the plots of water consumption versus treated water that the time of the year when the gap between those to lines is smaller is summer since it is the season with lower amount of rain. However, for the case of yearly based analysis, there is not a clear trend about years with more rains that had higher I&I.
- There is a total number of 97 sensors that have been installed and relocated from 2008 to 2014. These sensors can be divided into 8 groups (variable number of sensors for each group) that have been installed for an average of 110 days each. Each sensor within the same group has a different installation date and up to two sensors were installed each day. Refer to the following table for a summary of the data about each group of sensors:

Group	Number of sensors	Initial Date	Final date
Group 1	**16**	**2009-06-12**	**2009-09-30**
Group 2	**17**	**2009-09-30**	**2010-04-05**
Group 3	**5**	**2009-11-30**	**2010-04-05**
Group 4	**4**	**2010-05-11**	**2010-07-02**
Group 5	**21**	**2010-08-27**	**2011-04-05**
Group 6	**8**	**2011-04-14**	**2011-08-15**
Group 7	**16**	**2012-06-19**	**2013-01-09**
Group 8	**10**	**2013-02-01**	**2014-03-31**

- 11 logical pipe segments were identified; this work had to be done manually since the City of Cambridge does not keep records of the logical pipe segments formed with the new sensors installed. According to James Johnstone (Cambridge) there have been 3 or 4 engineers in charge of planning the new location of sensors and each one of them have followed a different logic. After all the analysis, I found out that only 32 out of the 91 sensors were located in a way that allows to form logical pipe segments. Besides these sensors, there are some others that are located in a way that isolates specific areas/neighborhoods; they were probably installed to measure I&I in this areas considering houses/businesses as the sources for incoming flow.

- Also, according to James, the rest of sensors were possibly installed to measure the flow for specific pipes that potentially had high I&I or other kind of problems, however, he and Mike do know the logic used to estimate the I&I since these are sensors were installed independently in different areas of the city.

- There is a at least three factors that should be considered when defining a logical pipe segment. First, there is maintenance and cleaning done on pipes and this might overlap with the time that flow was being measured for a logical pipe segment. Hence, in order to determine what pipes add flow to a certain pipe segment it is required to determine all the pipes around it that were in service during the time that measurements were obtained. Second, it is necessary to determine what pipes are actually connected since not all the lines crossing in the map represent pipes joined together; generally, in most of the cases, crossing pipes are not joined together but have one pipe installed underneath the other. Finally, it is important to consider that there might be sources of incoming flows into each logical pipe segment such as houses/businesses which have to be accounted for, since they should not confused with additional I&I.

- QGIS allows to determine directionality of the flow of water inside the pipes. These properties can be generally modified inside each layer's properties but it is required to confirmed the correctness of the results since it might present errors. Some errors had to be fixed but the results obtained from the program were mostly accurate.

4 Proposed goals for next week

- Analyze the sensors that isolate independent areas of the city.
- Research ways to identify I&I without defining logical pipe segments in order to maximize the use of the data obtained with the rest of the sensors.
- Match fixes of specific pipes, that have been fixed due to I&I problems, with the identified logical pipe segments and times when sensors where installed obtaining data from those pipes.
- Determine how known data about pipes cracks and fixes can be used to model pipes with potential problems that are causing inflow. Probably apply a machine learning algorithm to detect possible patterns in the data.

5 Meeting agenda

1. Analysis of the results.
2. Definition of an plan in order to inform the engineers from Cambridge about the work that has been done with the data.
3. Definition of next steps for the current analysis.
4. Review thesis project schedule.

6 Notes

NA