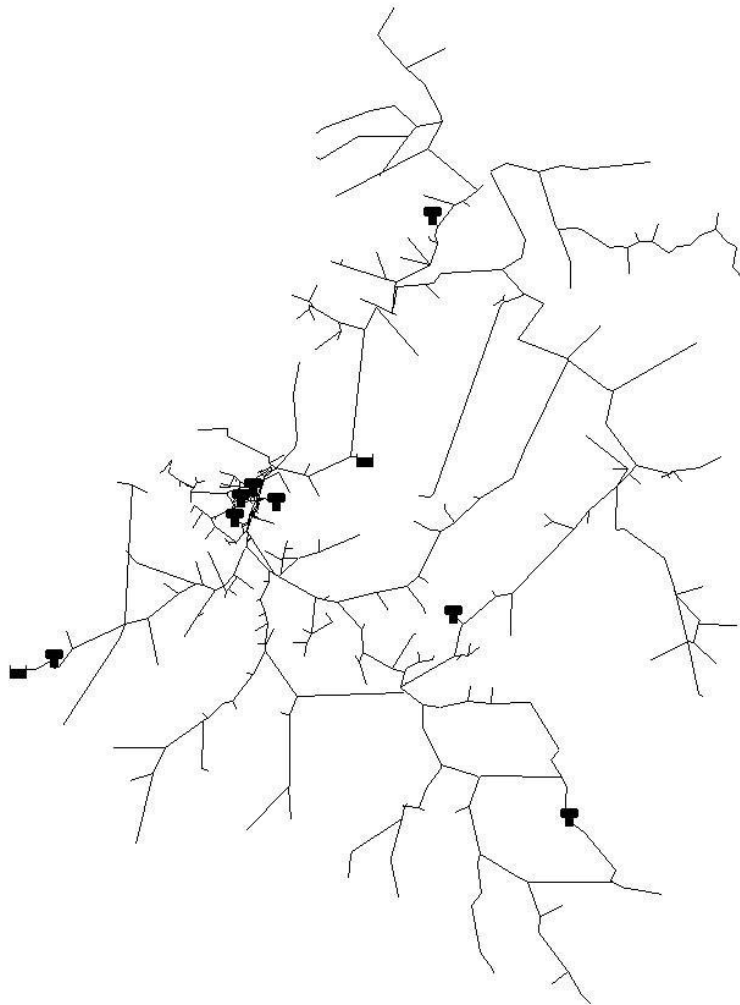


SYSTEM ID: KY 15

NARRATIVE DESCRIPTION

The KY 15 system is based on a real-world water distribution system in Kentucky. It serves 4,270 customers and sells water for \$2.85 to \$5.28 per 1,000 gallons. The system has an average demand of 1.50 MGD. The network was used by Schal et al. (2014) as part of a classification study. A general schematic of the system is shown below. The system has two reservoirs, thirteen pumps, eight elevated storage tanks, and 300 miles of pipe. Water loss within the system is estimated to be 44%.

NETWORK SCHEMATIC:



HISTORY OF THE NETWORK FILE

The KY 15 system was originally created by Stacey Schal in 2014 as part of an article “A Graphical Procedure for Sensor Network Placement Guidance for Small Utilities” which was published in 2016 in the *American Water Works Association Journal*.

ORIGINAL REFERENCE:

Schal, S., Bryson, L.S. and Ormsbee, L., 2014. A graphical procedure for sensor-placement guidance for small utilities. *Journal-American Water Works Association*, 106(10), pp.E459-E469. <https://doi.org/10.5942/JAWWA.2014.106.0093>

ABSTRACT: Efforts to improve water security have led to the development of contamination warning systems aimed at providing early indication of accidental or intentional contamination in drinking water distribution systems. Sensors that detect changes in water quality are a critical component of a contamination warning system. Because the extent of any monitoring system is constrained by a limited budget, focus is placed on optimizing the placement of sensors to maximize contamination detection and protect human health. Robust models and algorithms have been developed to recommend sensor deployment, but many require hydraulic or water quality models. Small utilities typically do not possess the resources to develop these models; therefore, researchers for this study developed the Water Quality Sensor Placement Tool to recommend placement of one water quality sensor without a model or complicated algorithm. This simple graphical procedure allows utility managers to use basic information about the geometry of their network to determine near-optimal sensor placement in limited time without complicated software.

ADDITIONAL CITATIONS:

The original publication of Schal et. al. (2014) and by inference the KY 15 system have been cited by 3 additional authors. These may be accessed by moving your cursor over the following link while simultaneously depressing the CTRL key on your keyboard: [3 Citations](#)

AVAILABLE INFORMATION

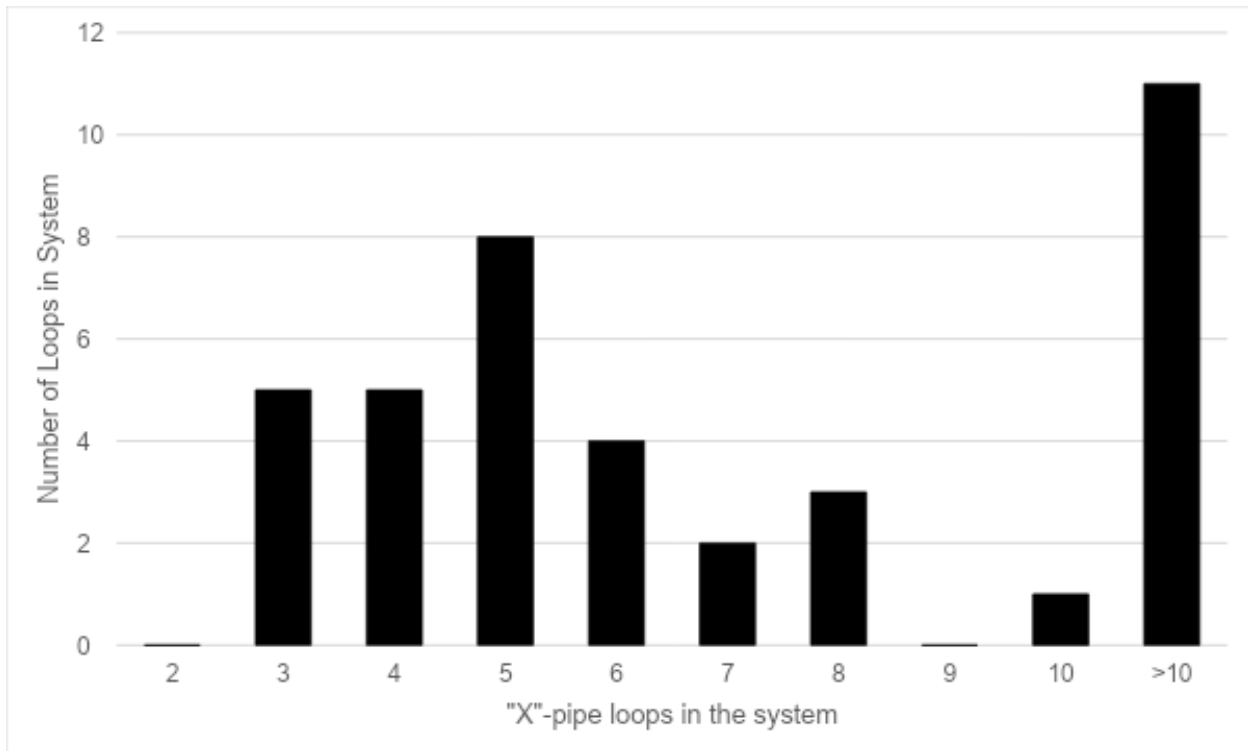
Physical attributes	Yes
Schematic diagram	Yes
Network geometry data	Yes
GIS data file	Yes
Background map	Yes
Elevation data	Yes
Pipe data	Yes
<i>Pipe material</i>	Yes
<i>Pipe age</i>	Yes
<i>Pipe pressure class</i>	No
<i>Nominal or actual diameters</i>	Nominal
Pump data	Yes
<i>Useful horsepower</i>	Yes
<i>Pump operating curves</i>	No
Tank data	Yes
<i>Elevation data</i>	Yes
<i>Stage storage curves</i>	No
<i>Water quality information</i>	No
Valve data	Yes
<i>PRV/FCV data</i>	Yes
<i>Isolation valve data</i>	Yes
<i>Hydrant data</i>	No
Demand data	Yes
<i>Total system demand</i>	Yes
<i>Nodal demand data</i>	Yes
<i>Temporal data demands</i>	Yes
<i>System leakage</i>	No
Hydraulic data	No
<i>Hydraulically calibrated model</i>	
<i>Field hydraulic calibration data</i>	
Water quality data	No
<i>Disinfection method</i>	
<i>Chlorine residual data</i>	
<i>Booster station data</i>	
<i>Fluoride/Chloride field data</i>	
<i>Water quality calibrated model</i>	
Operational data	Yes
SCADA datasets	No
Operational rules	Yes

SYSTEM CLASSIFICATION:

PIPE/LOOP HISTOGRAM:

Hoagland et al. (2015) designed a network classification algorithm for use in classifying water distribution systems as either “branched,” “looped,” or “gridded” based on the observed frequency of network loops with different numbers of distinct pipe segments. The frequency distribution for the KY 14 system is provided below. Using this information, Hoagland et al., classified this system as being a BRANCHED system.

# Total Pipes:	671
# Branch Pipes:	418
Ratio (Branch Pipes / Total Pipes):	0.623



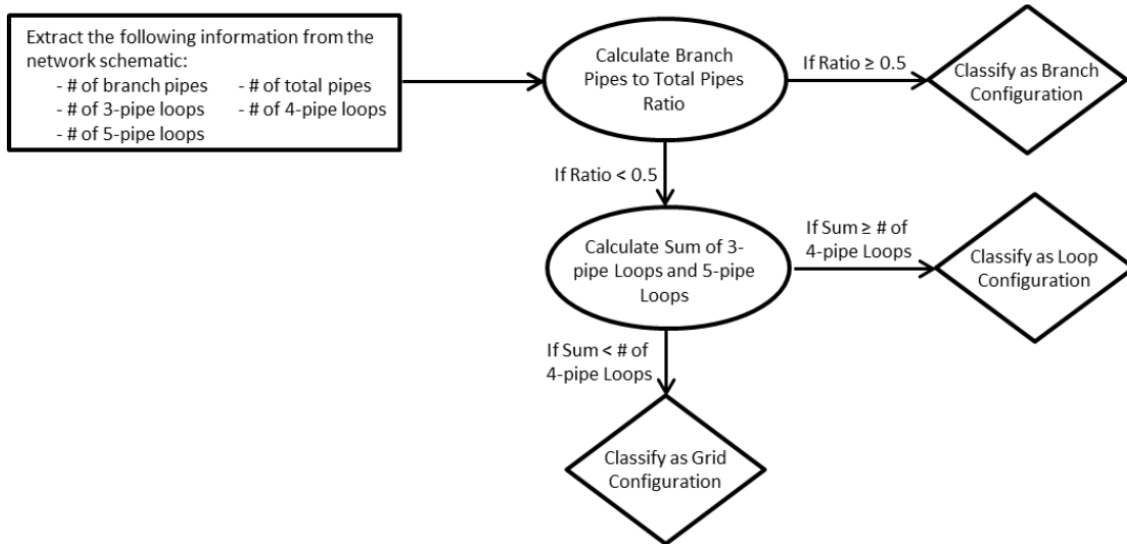


Figure 3.4. Classification Algorithm (Hoagland et al., 2015)

Hoagland, Steven & Schal, Stacey & Ormsbee, Lindell & Bryson, Lindsey. (2015). Classification of Water Distribution Systems for Research Applications. 696-702. 10.1061/9780784479162.064.

NETWORK STRUCTURE METRICS:

Building on the work of Hoagland et al., (2015), Hwang & Lansey (2017) created an expanded classification system that allows for further classification of a system as being either a transmission or distribution branched, looped, gridded, or hybrid system. Their algorithm streamlines the classification system by removing unnecessary nodes that do not contribute to the structure of the system while still retaining their use as intermediate points for demand data entry. A full description of the algorithm can be found in the cited reference.

Application of the Hwang and Lansey classification algorithm to the system yields the following statics and associated classification:

Parameter	Value
Edges	703
Pipes	662
Nodes	669
Average Diameter	5.3
Reduced Nodes	148
Reduced Edges	182
Branched Edges	444
Branched Index	0.7
Meshed Connectedness	0
Reduced Meshed Connectedness	0.12
Link Density	0
Average Node Degree	2.1
Hwang & Lansey Classification	Distribution Branch

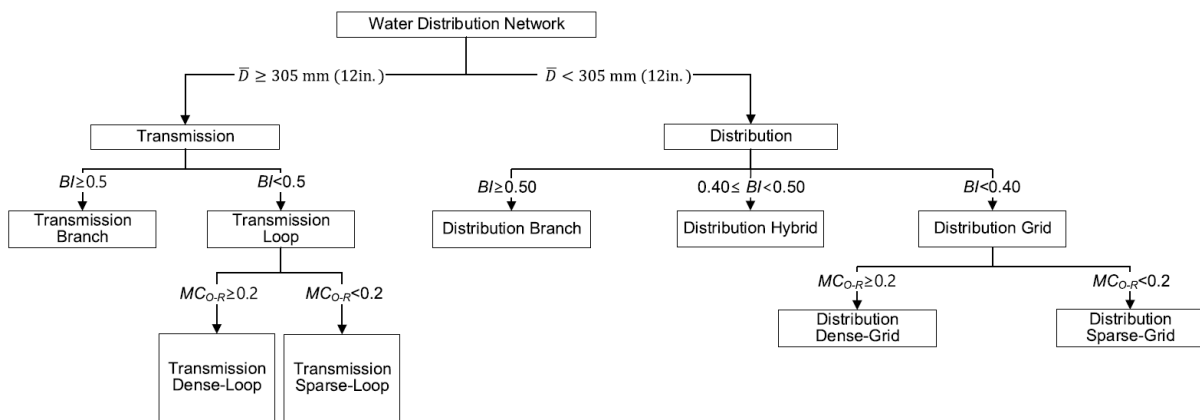


Figure 7. Water Distribution System Classification Flowchart (Hwang & Lansey, 2017)

Hwang H. & Lansey, K. (2015) "Water distribution system classification using system characteristics and graph theory metrics." *Journal of water resource planning and management* 143(12) [https://doi.org/10.1061/\(ASCE\)WR.1943-5452.0000850](https://doi.org/10.1061/(ASCE)WR.1943-5452.0000850)

DETAILED DATA SUMMARIES

PHYSICAL ASSETS:

Asset Type:	# of Assets
Master Meters	0
Tanks	8
Pumps	13
Water Sources	2

NETWORK CHARACTERISTICS:

# Total Pipes:	671
# Junctions	582
# Reservoirs	2
# Tanks	8
# Regulating Valves	28
# Isolation Values	Unknown
# Hydrants	Unknown
Elevation Data	YES

PIPE DATA:

Diameter (in)	Length (ft)
1	2356
2	44,025
3	107,224
4	475,659
6	745,714
8	190,585
12	12,995

PUMP DATA:

Pump Horsepower	YES
Pump Curves:	NO

DEMAND STATISTICS:

Demographic Type	Population	Households
Directly Serviceable:	13,253	5,730
Indirectly Serviceable:	6,636	2,274
Total Serviceable:	19,889	8,004

Production Statistics	
Total Annual Volume Produced (MG):	959.8
Total Annual Volume Purchased (MG):	13.901
Total Annual Volume Provided (MG):	973.701
Estimated Annual Water Loss:	44%

Water Costs	
Customer Type	Cost per 1000 gallons
Customers within the municipality	\$2.85
Customers outside the municipality	\$5.28

CUSTOMERS AND USAGE:

Customer Type	Customer Count	Average Demand (MG)
Wholesale:	1	182.568
Residential:	4,058	359.646
Commercial:	210	5.906
Institutional:		
Industrial:	1	
Other:	4,270	
Total Customers:		
Flushing, Maintenance & Fire Protection:		1.200
Total Water Usage:		549.320

DATA FILE ATTRIBUTES:

ATTRIBUTE		UNITS
Pipe Length & Diameter	X	Feet & inches
Pipe Age	X	Year Installed
Node Elevation	X	Feet
Node Demand	X	GPM
Valves		
Hydrants		
Tank Levels	X	Feet
Tank Volume	X	Cubic Feet
PRVs		
WTP		
WTP Capacity		
Pump Data	X	HP