**Geometric Network**
**Issues on a Complex Water Delivery System**

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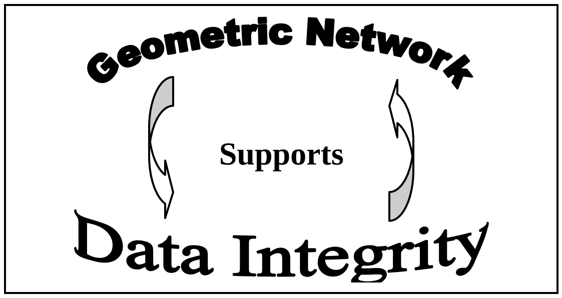


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## HISTORICAL PERSPECTIVE

This paper addresses the practical methods utilized by the Las Vegas Valley Water District to apply network theory to existing data sets and achieve the desired network functionality.

LVVWD first implemented a geometric network in 2004. Our initial goal was to utilize the network to maintain connectivity between facilities, which generally reduces the amount of work required in an editing session, and also helps ensure that features that should be connected stay connected. Additionally, we could utilize the edge-count properties of network nodes to derive and display 3 and 4 way junctions, as well as identify potential network errors. So it was feature connectivity that really began our current efforts as it uncovered data quality problems along with challenges of modeling physical reality and the logical network.

Moving beyond the benefits of maintaining connectivity in an edit session, we have been making the investment in data integrity at a detailed level to support solutions to the next generation of business problems which can be addressed using the geometric network.

## INITIAL BENEFIT

The most dramatic initial impact of building a network appears the first time an edit session is started. Without a network, when a feature, such as a pipeline, is moved, it moves independently of anything it touches. But when a network is present, any feature that is connected to that line at its end points or vertices will move accordingly and connected will be maintained. This has two primary benefits: (1) maintains data integrity, and (2) generally reduces the amount of work required from a data editor.

## GEOMETRIC NETWORK AND THE REAL ISSUE: DATA INTEGRITY

Algorithms and methodologies for operating a geometric network can be coded and put in place, like a machine ready and waiting to manufacture a product. But the inputs to the process, the actual data, must be prepared like quality ingredients if a quality output is desired. Data preparation is where the real work begins.

Mass Updates to Increase Spatial Coincidence

The initial data issues most utilities encounter when building a geometric network are typical and they tend to be a ubiquitous plague in the initial phase of development. Examples are: endpoints of arcs that should connect but which are not spatially coincident; point features (like valves or hydrants) that are not spatially coincident with the arcs on which they function; invalid geometries, such as a line that intersects itself. While these issues will impact the proper function of a network, they are generally just minor annoyances which can be fixed through mass update methods, such as automated snapping and other tools. Keep in mind that large data sets equate to large efforts. Relying on automated processes such as snapping and human processes introduce errors of their own. We have tried to rely on a mix of both as compliments to one another. For example, we set tolerances and compare attributes before making automated adjustments – such as snapping all meters to endpoints of lines that are within 18" and coded as Service Laterals.

Attribute coding is another area where mass updates can be applied. For example, abandoned/removed facilities are automatically coded as "disabled" and are disconnected from the geometric network. Additionally, features can be verified against each other – a valve's diameter should match the diameter of the pipeline on which it sits. A hydrant should have a related valve to control the flow of water in its lateral.

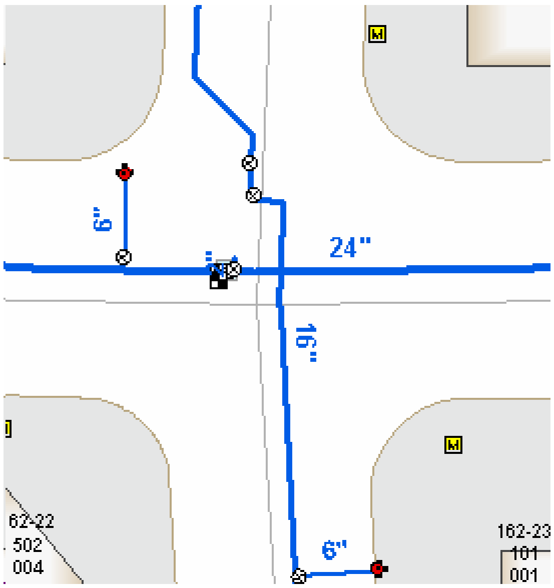
The tools of a geometric network (show connected features, identify disconnected features, trace upstream, etc.) do not really become useful to identify network errors until this type of system-wide data clean-up is nearing completion.

Once mass updates are completed, a benefit of the geometric network is that it can be used to uncover problems in our data that may have persisted. For example, attributes that do not agree between connected features. Another thing to consider besides incorrect data is data completeness. Throughout this process we identified entire elements of data we would need to create to support our goals. For example, prior to this effort we had not captured residential meters or the accompanying lateral connected to the main. So for us to perform a network shutdown and impact analysis we needed to complete those data elements. To support this desired functionality, we have just completed a nearly two-year effort of mapping over 270,000 residential meters and laterals.

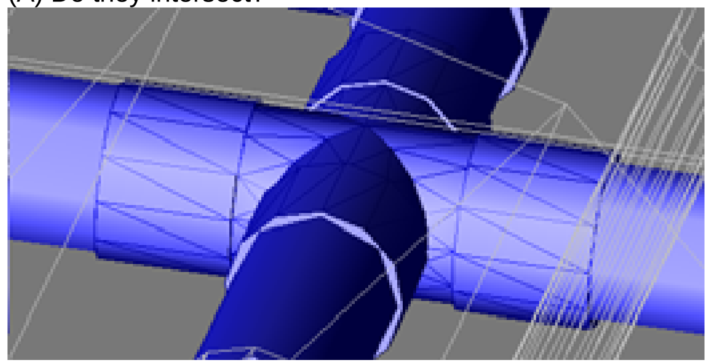
## Connectivity

Whether or not features are connected is a critical issue in a geometric network. Consider the following example of crossing pipes versus intersecting pipes.

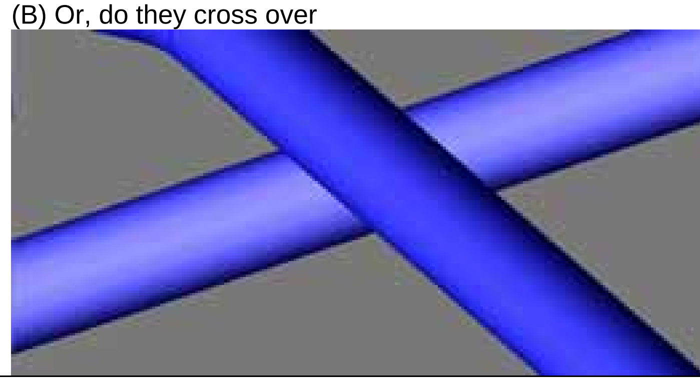
Pipelines in an intersection




(A) Do they intersect?



(B) Or, do they cross over



In many cases, we found lines in the database which were supposed to cross over each other, as in (B), but they had been intersected with each other, which then implied connectivity in the geometric network and caused them to be seen as in (A). A determination was made that the best way to ensure that lines connect in the database only when they do in the field was to begin maintaining a layer of 4-way cross fittings. If an intersection of pipelines has a 4-way cross and its pipes connect, then the pipes connect in the field. See the table below for the four possible cases.

| | **Cross exists** | **Cross does not exist** |
|---|---|---|
| **Arcs connect** | **Data valid**<br>**Pipelines intersect** | **Data invalid**<br>**Research/Correct** |
| **Arcs do not connect** | **Data invalid**<br>**Research/Correct** | **Data valid**<br>**Pipelines intersect** |

Identification of Sources and Sinks – Some features are both

The concept of sources and sinks is simple and works well within a limited scope. However, in our method of modeling our water delivery system, the reality is that pumps and reservoirs function as both sources and sinks. This complicates things and can be at odds with the goal of storing one representation for each feature, such as a pump. Currently, all reservoirs have artificial points in the network which represent their sink and the source functions separately, since they are connected to physically different pipelines, and all pumps are coded as sources. This is still problematic, though, because a pump typically gets its water from a reservoir, which means flow direction is from a reservoir (source in this case) to a pump (sink in this case), but if the pump is coded as a source, the network will not calculate flow in the proper direction.  Our current resolution is to dynamically re-code certain features at the time of the analysis, depending on the nature of the modeling effort.  Re-coding may include identification of sources/sinks and whether or not a feature is network enabled.

End Points

In order for data validation to be conducted efficiently, all line features are required to have a connection with another network feature on both ends, whether that is another pipe, a meter, a hydrant or some other feature (not including orphan junctions).  Historically, we have not captured database features for endcaps (as in the case where a line has been cut and capped).  However, we have decided to start capturing endcap features to satisfy this requirement.  Once this effort is complete, a QC check can be run which identifies as errors any waterline with an endpoint that is not spatially coincident with another feature.

Multiple Networks within a Network

There are physical separations within our water distribution system which essentially divide our system into distinct, but interconnected, networks called pressure zones.  These physical separations are critical junctions and must be accurately identified.  The primary features that define zone separations are listed here:

- Zone Valves – Closed valves at the junction of two pipelines from different zones, and therefore the pipelines one either side are carrying water at different pressures.
- Pressure Reducing Valves – These features typically control the flow of water between two zones by reducing the pressure.
- Pumps – These features deliver water, usually to a zone at a higher elevation – they control the flow of water between two zones by increasing the pressure.

Geometric Network on a 2D Dataset

Spatially coincident lines (a main line and a bypass line)

There are cases where lines have been mapped as spatially coincident because they are vertically stacked in the field, and because we have a goal of mapping facilities with a high level of spatial accuracy (and we do so in a 2-D database).  This presents two specific problems, one of which is cartographic representation, which is typically handled on a case-by-case basis. However, when running geometric network functions, this presents a problem that cannot efficiently be handled on a case-by-case basis.  Currently, our solution is to map the less significant of the two lines with a small offset, which will allow the geometric network to see the lines with their proper connectivity.

Again, because we work in a 2D database, pipe segments which run directly vertical present a problem because their starting and ending X,Y coordinates are the same.  To compound the issue, these pipes typically have valves on them which may be normally closed, which we would code as disabled in the network.  In the 3-D world, this does not pose a problem because water still flows through the mainline pipe as it should.  However, the geometric network see a closed (disabled) valve on top of a pipeline and stops the flow of water in the simulation.  Our options:

1. Map the lines horizontally as a representation of the line and place the valve on the correct line, off of the main line.
2. Leave the valve in an Enabled state, which will cause the network to allow water to flow.
3. Discontinue mapping these pipelines and valves.

We have currently chosen option 2 as the quickest way to get the network up and running.  It only requires an attribute change, and does not require additional feature creation/editing as option 1 would require.  However, our ultimate goal is to have the ability to map and model our distribution system in a true 3-dimensional framework.

Adding Intelligence to Data

GIS features, like pipelines and valves, have a spatial component and attributes, and we have become very good at capturing that information.  What has been missing is system-level intelligence so that each feature also knows its role in a larger, interconnected system.  The questions we are working toward answering with our data are now: How does this feature impact any other feature, and how does the system function as a whole?  For the standard example: if a pipe breaks, which valves do I have to shut to isolate it, and then which customers are affected? Now zoom out to a system level: pipelines that are physically in the same trench may have less to do with each other than pipes that may be a mile or more apart - and the issue we are working toward resolving is getting the data to realize that relationship.