Durango Integrates SCADA and GIS into a Water Distribution System Model and Utility Management System

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Background

The City of Durango has recently adopted an enterprise approach to its utility-based GIS system. An important component of this endeavor currently in development is the integration of a SCADA (Supervisory Control & Data Acquisition) system with GIS to model citywide water distribution across the hydraulic network at various water pressure zones. This modeling program was initiated to coincide with a two year joint effort between the Durango Fire and Rescue Authority (DFRA) and Durango Public Works Department to flow test the majority of the City's 880 fire hydrants servicing the water distribution system (WDS). Upon conclusion of the second year of hydrant testing in the fall of 2009, the DFRA recorded data will be evaluated against the model to quantify the distribution capacity of the city's water supply, refine the boundaries of the City's water pressure zones and to calibrate the SCADA/GIS water distribution model. The City GIS will then use this model to refine its water utility management system including development of detailed geometric network for subsequent spatial and network analysis.

Water Distribution System

Durango currently deploys 10 water storage tanks, 6 pump booster stations, 3 pressure relief valve stations or vaults and over 130 miles of pipeline, controllers and fittings to distribute community water across an approximate 10 square mile supply area. Each of these water distribution elements has a critical influence on hydraulic transmission and the establishment of individual pressure zones within the city's WDS, but the storage tanks and pressure relief valves are most critical to the SCADA/GIS integration and will receive the primary focus in this paper.

There are two types of influences that determine the definition of a pressure zone. The first is where the measurable static water pressure at a junction node anywhere along the length of a pipeline is primarily influenced by the water level in a storage tank. Because a buried pipe node cannot be tested directly, a surrogate static pressure measurement can be taken at a fire hydrant and attributed to the junction node along the distribution main from which a respective hydrant lateral originates. Hence any change to the hydraulic grade level (HGL) resulting from normal inflow/outflow flux within the water tank will result in a changing static pressure value at a hydrant within a tank-influenced hydrant basin.

Static Pressure:

P (psi) = 0.4333 psi/ft x (HGL (ft) – Hydrant Elevation (ft)).

Storage tank heights vary in the range of 15 to 64 feet within the City of Durango. To better illustrate the impacts of a dynamic HGL to an influenced node one needs to consider that a 60 foot tall tank will cause a pressure change of 0.4333 x 60 = 26 psi between empty and full.

The second type of zonal influence is where the static pressure at a node is controlled by an upstream pressure reducing valve (PRV) rendering head loss at the storage tank negligible. A pressure reducing valve should hold a steady pressure at its location. Hence the steady-state pressure at a PRV location acts like a tank that never changes its HGL.

Static Pressure under PRV control:

P (psi) = PRV Pressure (psi) + 0.4333 x (PRV Elevation (ft) – Hydrant Elevation (ft).

The City of Durango's pilot program to integrate dynamic SCADA readings with GIS was initiated in a predefined pressure zone under PRV influence. The Bodo Industrial District in south Durango was an ideal location for the initiation of the SCADA/GIS water distribution model. The boundary of the hydrant basin is well established falling between the Bear Trap PRV station and downpipe Gun Club PRV vault. The newly installed twin pressure relief valves at Bear Trap are SCADA enabled and actively collecting data. Inline SCADA receivers were installed as fixed nodes at various locations within the Bodo grid to serve as control points. And most importantly, water delivery comes directly from the City's primary storage tank, the 7 MG Terminal Reservoir Tank and not multiple tanks like within other parts of the city. Bodo is also one of the predefined hydrant basins DFRA flow tested in south Durango in 2008 (Fig. 1).

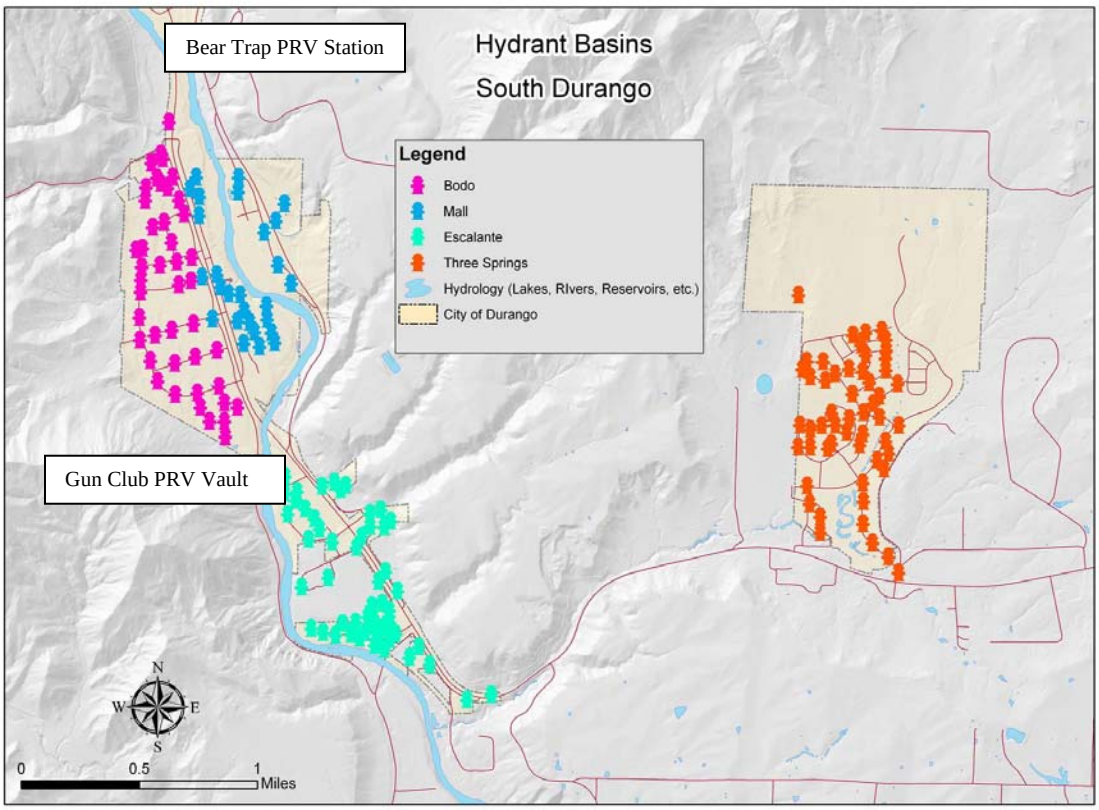

Fig. 1) Hydraulic pressure zones in south Durango serving as fire hydrant basins for the CITY/DFRA 2 year flow testing program. Map courtesy of Jim Metz, Durango Fire and Rescue

SCADA/GIS Integration

Durango utilizes a Control Microsystems SCADA system to supervise, manage and optimize the performance of its WDS. Figure 2 captures a real-time SCADA monitor interface of controlled water distribution to South Durango and the Bodo pilot area. In addition to automatic metering of the Terminal Tank and two PRV stations bookending the pressure zone, 5 automatic meter reading devices (AMR's) are installed to actively monitor inline pressure at the La Plata County Jail (3), Rocky Mountain Chocolate Factory and DFRA Fire Station #1. (Note: At the time of release of this paper, four of the 5 metering devices in Bodo were still misreading or inactive thus registering .0 psi or null values in the SCADA database model).

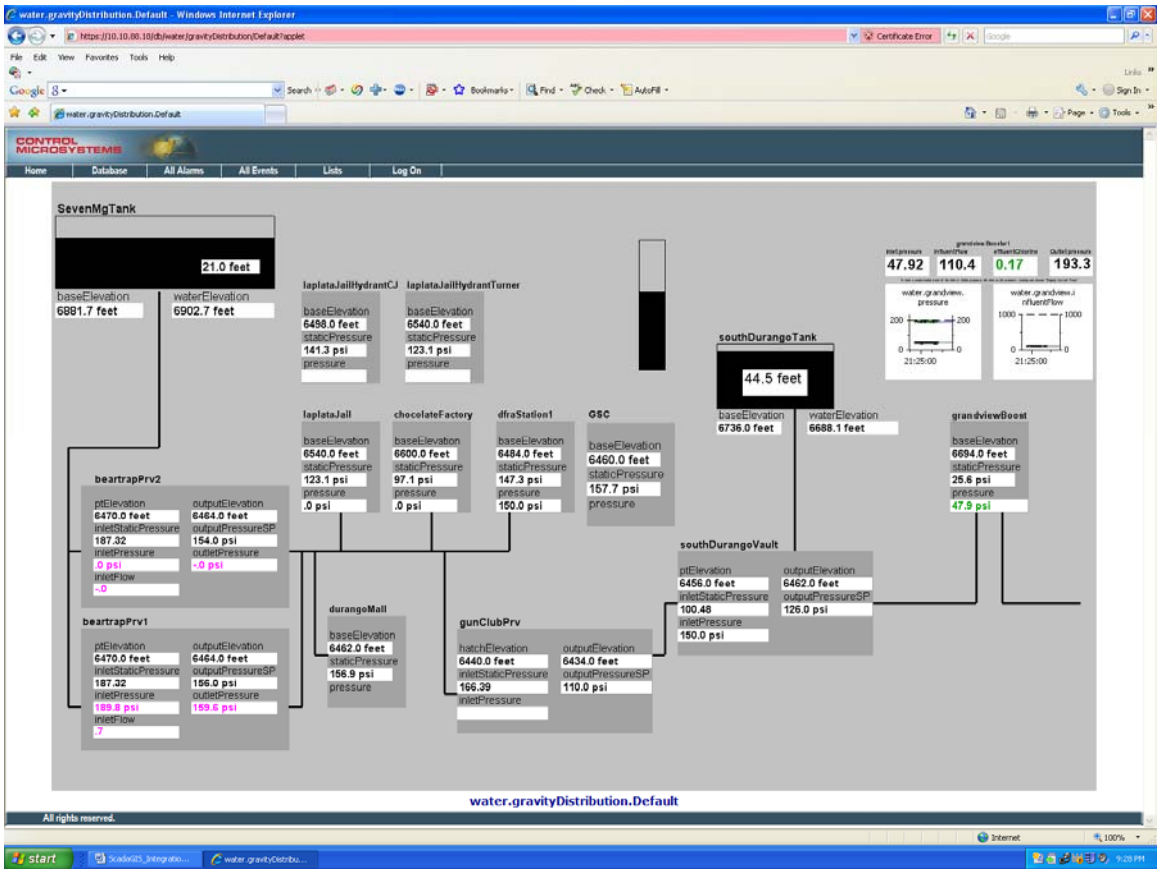

Fig. 2) Browser-based, real time basis SCADA graphic interface for the monitoring of the south Durango WDS.

Fire Hydrant Testing Program and Integration w/ the Utility Management System

Forty four fire hydrants are currently active in the Bodo pilot area. Forty were flow tested or identified for repair by DFRA in 2008, three that were not tested serve as SCADA inline control points, and one new hydrant was just brought into service in 2009. All city hydrants appear as a feature class in Durango's GIS. Spot elevation (Z) values were interpolated for each using spatial analyst and the City's 1:7200 terrain model. Knowing the twin Bear Trap PRV elevations are each 6464 feet, static pressures across the Bodo Basin were modeled from the differences in relative elevation between the hydrants and the PRV output with the independent variable in the equation being the instantaneous pressure value at the active Bear Trap PRV1 output. Live linkage of the GIS fire hydrant layer to real time SCADA measurements therefore resulted in a predictive static pressure model that is dependent on time signature fluctuations in the metered PRV output pressures. A map of the distribution of predicted static pressures in the Bodo Basin derived from the SCADA time basis output pressure of 159.6 psi at Bear Trap PRV1 is shown in Fig. 3. The map also illustrates the 40 hydrants that were flow tested or tagged for repair in 2008. The Bodo fire hydrant basin required four separate testing dates to complete. Correlating the field data with SCADA provided mixed results. Because PRV output pressures were lower on the flow dates then currently, direct comparison of the predicted value in the SCADA/GIS model to the test results could not be made without data adjustment. Assuming the output PRV values remained in the range of 140-150 psi during testing, the static pressure values at the time of the flow testing do trend somewhat accordingly to these lower PRV values (see Figure 4). However several flow testing irregularities were noted by the fire crews. Assessment of these results is ongoing, but it already seems conclusive that SCADA/GIS integration will greatly expand the ability of the City to evaluate water capacity and pressure zoning in subsequent hydrant testing programs. The model could then be expanded to enhance the City of Durango WDS and hydraulic geometric network.

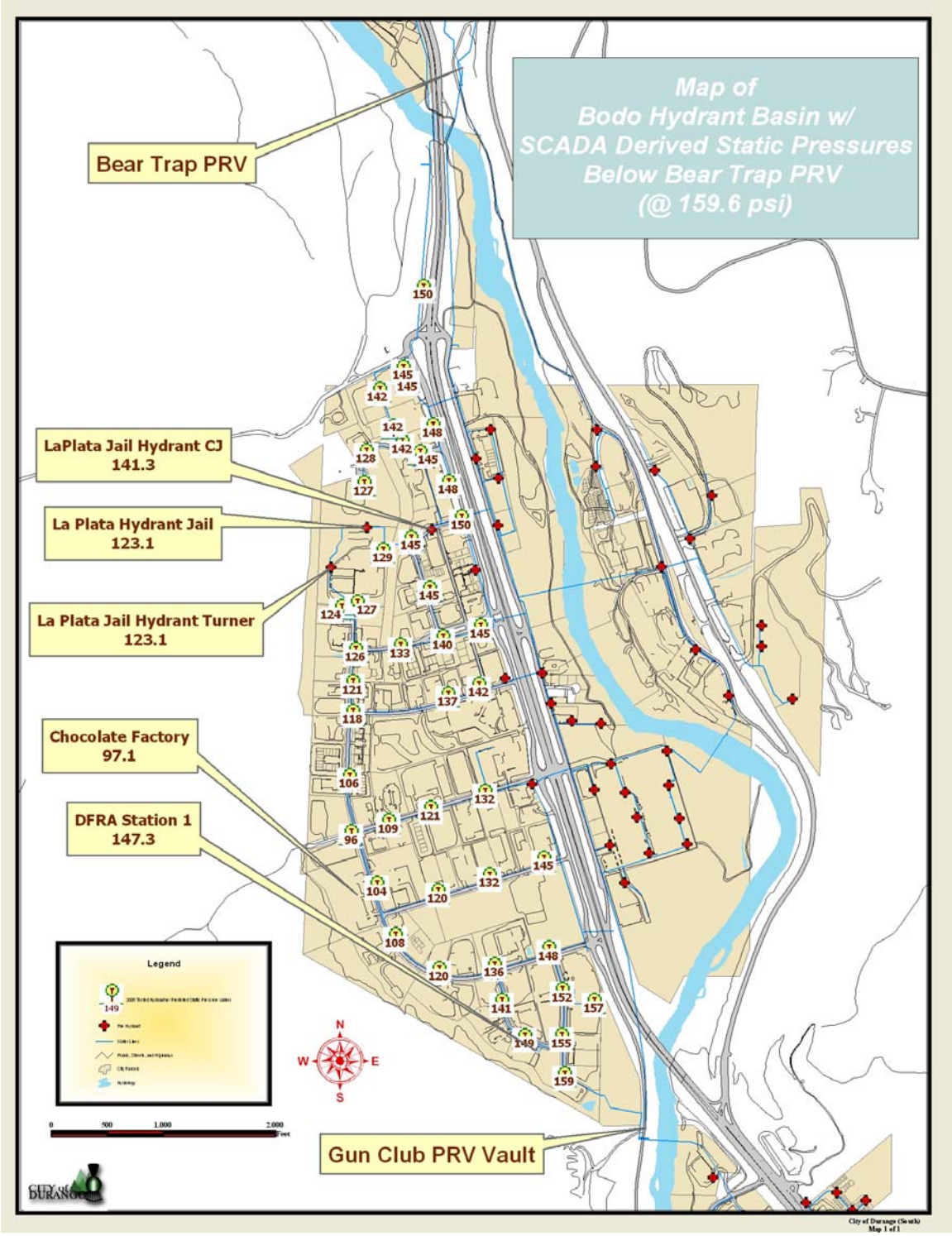

Fig. 3) Grid of derived static pressures (psi) at fire hydrant nodes and SCADA metered control points under Bear Trap PRV1 control (output pressure = 159.6 psi). Hydrant distribution is across Bodo Pressure Zone.

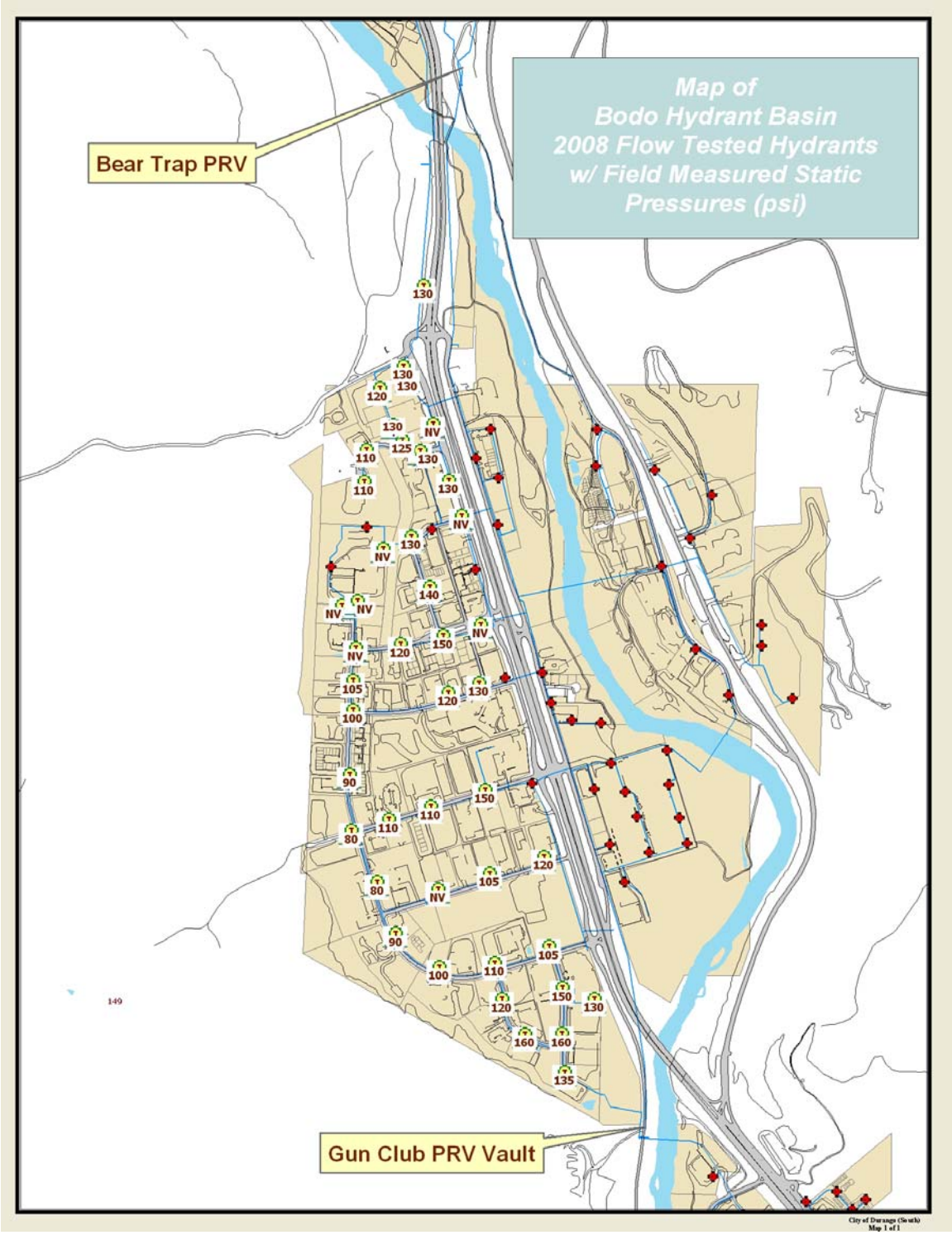

Fig. 4) Grid of measured static pressures (psi) at fire hydrants flow tested in 2008, Bodo Pressure Zone. Output PRV pressures at the Bear Trap station were in the range of 140-150 psi.

References:

Advanced Water Distribution Modeling and Management, First Edition

Haestad Methods, Thomas M. Walski, Donald V. Chase, Dragan A. Savic, Walter M. Grayman, Stephen Beckwith and Edmundo Koelle; Haestead Press, January 24, 2003

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