Section 7

Hydraulic Model Development and Evaluation Criteria

The hydraulic evaluation conducted to develop this master plan was performed using a computer model of the reclaimed water distribution system. This section provides a discussion of the evaluation criteria, computer model development, and calibration. Hydraulic modeling results for the existing system are also presented.

7.1 General Evaluation Criteria

The evaluation approach discussed in this section focuses on meeting key criteria under projected conditions such as maximum day demands and peak hour demands. The key criteria for evaluation of the adequacy of the reclaimed water system include system pressures, velocity, headloss, and storage requirements. Criteria for modeling of new proposed pipelines are also discussed.

7.1.1 System Pressures

The adequacy of a reclaimed water distribution system is evaluated based on its ability to provide the volume of water required to satisfy the demands of the customers in the service area at adequate system pressures. The Town adopted a minimum pressure policy (Policy Statement 129), which establishes a minimum water supply pressure to be provided through the potable and reclaimed water distribution systems of 40 psi during average and maximum day conditions, and 30 psi during peak hour conditions.

However, it is recognized that modeled node pressures may not reflect the actual pressure that a customer will experience at the point of use due to losses through service connection piping, meters, backflow prevention devices, and internal piping on the customer side. To allow for some losses between the water main and customer point of use, a minimum node pressure of 50 psi during peak hour flow is used to evaluate the reclaimed water system for this master plan. The location of peak hour system pressures less than 50 psi will be identified.

In addition, the Town would like to provide reclaimed water system pressure similar to pressure in the potable system to maintain the level of service for existing potable customers converting to reclaimed water. Predicted pressures were checked against this criterion. In particular, pressures in areas where the reclaimed water system crosses potable water system pressure zone boundaries were considered.

7.1.2 Velocity and Headloss

There are no specific standards for velocity and headloss in reclaimed water distribution systems. Therefore, the guidelines for potable water distribution systems were used in this analysis. For transmission mains, AWWA recommends a maximum design velocity of 10 feet per second (fps), with velocities less than 5 fps as the desirable range. AWWA recommends limiting headloss in transmission mains to 10 ft/1,000 ft with headlosses limited to 3 ft/1,000 ft for pipe sizes greater than 16 inches in diameter. Cesario (1995) recommends limiting headloss to 2 to 5 ft/1,000 ft for pipe

sizes less than 24 inches in diameter and 1 to 2 ft/1,000 ft for pipe sizes greater than 24 inches in diameter. These criteria were considered in the evaluation based on the role of the transmission main and its effectiveness in improving the hydraulics of the system. This analysis was based on a maximum design velocity of 10 fps, with velocities less than 5 fps as the desirable range. The analysis was also based on a maximum headloss of 10 ft/1,000 ft with headloss less than 5 ft/1,000 ft as the desirable range.

7.1.3 Storage Volume Requirements

Storage requirements for the reclaimed water system can be classified as follows:

- **Short-Term (Operating) Storage** – provided to balance hourly variations in supply and demand that occur on a daily basis. Operating storage can also include emergency/reserve storage if the reclaimed water system has uses that can tolerate only brief outages (cooling towers, toilets, industrial customers, etc.). Operating storage is usually provided by steel or concrete tanks (elevated or ground) similar to those used for potable water storage.
- **Long-Term (Seasonal) Storage** – provided to balance variations between seasonal summer and winter demands, with water produced during periods of low demand stored for an extended period of time (months) for subsequent withdrawal during periods of high demand. Long-term storage is usually provided in reservoirs, lakes, quarries, or surface impoundments.

The minimum supply/demand equalization storage volume requirement was determined by comparing the 24-hour diurnal reclaimed water supply pattern on the minimum wastewater flow day with the 24-hour diurnal demand pattern on the maximum reclaimed water demand day, specific to each service area under each demand scenario. For those hours where the demand exceeds the supply, storage is used to meet the deficit. An example comparison for Scenario 1, year 2060 demands in the Northwest Service Area is given in **Figure 7-1**.

The reliability required in the Town's reclaimed water system is not as great as that required in the potable water system since the potable system may serve as a back-up to customers which need an uninterrupted supply. However, the Town would like to maintain some operating reserve storage within the reclaimed water system. For this master plan, a reserve storage volume equal to 2 hours of max month demand was assumed. The volume of reserve storage and diurnal storage was added to determine the total operating storage requirement.

Seasonal storage was not considered for the scenarios evaluated in this master plan. However, if the Town decides to consider seasonal storage in the future, the triangle quarry located near the NCWRF may provide an option for long-term storage of reclaimed water produced at the NCWRF.

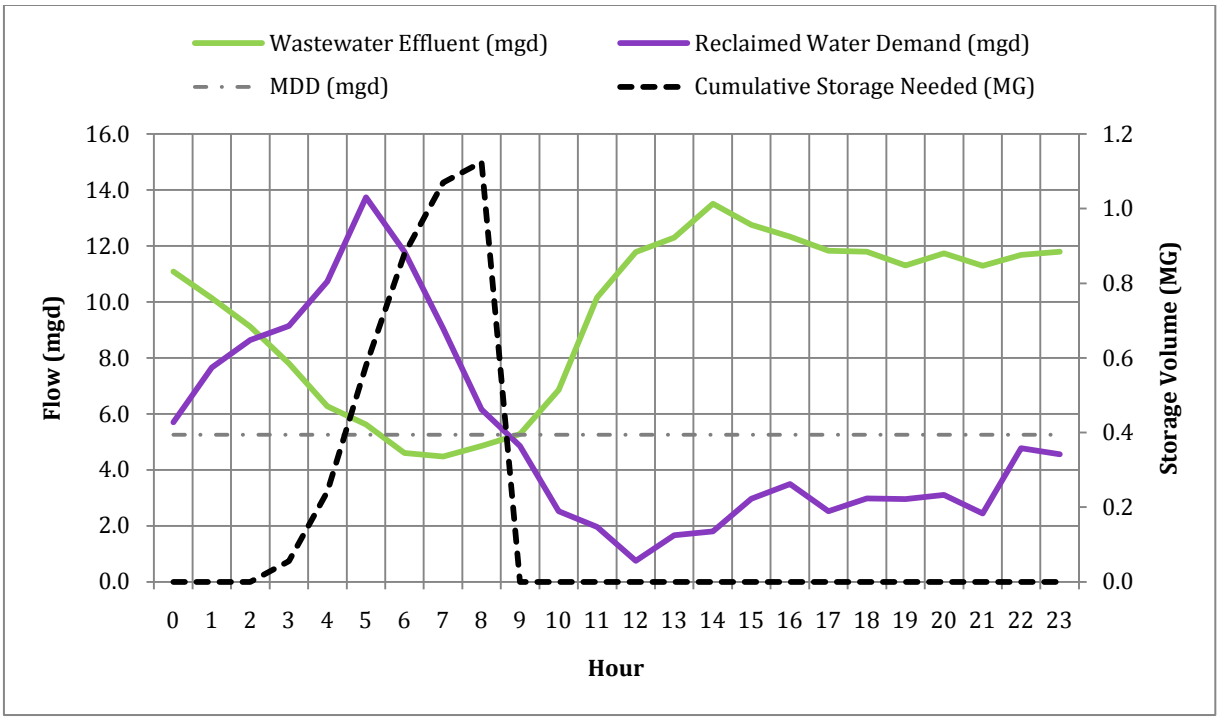


Figure 7-1
Storage Requirement for Supply and Demand Equalization;
NCWRF Scenario 1 - 2060 Maximum Day Demand

7.1.4 Storage Evaluation Approach

The adequacy of storage facilities to meet the system needs is dependent on several factors: volume, geographic location with respect to demand distribution, and hydraulic effectiveness. The minimum required storage volume is based on the volume for equalizing supply and demand and for emergency storage, as previously discussed. The storage volume must be located in an appropriate location with respect to the demand distribution. The effectiveness and reliability of storage facilities are also highly affected by the hydraulics of the system. A storage facility with the required volume and at an appropriate location in relation to the demand distribution may not be hydraulically effective because its overflow elevation is below the hydraulic grade line elevation required to provide adequate water service.

While emergency/reserve storage should be located within the reclaimed water distribution system, the supply/demand equalization portion of the storage can be located at the WRF prior to the high service pumps or in the distribution system. Storage in the distribution system will reduce the peak pumping requirements, but may require additional in-system pumping. In general, in the potable water system, equalization storage to meet peak hourly demand in excess of the maximum day demand is provided in the distribution system. However, since demands on the reclaimed water system fluctuate significantly over the seasons, too much distribution system storage can create long residence times during periods of lower demand that can result in water quality deterioration.

Storage requirements for the Town's reclaimed water system were evaluated based on all these factors. Providing additional storage within the distribution system to reduce peak pumping requirements was also considered. Storage requirements and recommendations specific to each scenario are presented in **Section 8**.

7.2 Model Development

CDM Smith developed a hydraulic model of the reclaimed water distribution system using Innovyze InfoWorks WS computer modeling software. Two distinct model networks were developed – one for the Northwest Cary service area and one for the South Cary service area.

7.2.1 Physical Model

The existing system physical model was constructed based on the Town's GIS data. All reclaimed water pipes 3 inches in diameter and greater in the GIS database were modeled, with each pipe characterized in the model by length, diameter, and a Hazen-Williams roughness coefficient (C value). C values were initially assigned based on the diameter and material of construction of the pipe, and were refined, as necessary, during calibration.

For future reclaimed water system scenarios, new pipelines were added into the hydraulic model to simulate system extensions and improvements. In general, pipes were located along existing or proposed transportation thoroughfares as identified in the *2009 Morrisville Transportation Plan* or *2008 Town of Cary Comprehensive Transportation Plan Update*. Pipes less than 18 inches in diameter are assumed to be polyvinyl chloride pipe (PVC) and are assigned a C value of 140. Pipes 18 inches in diameter and greater are assumed to be ductile iron pipe (DIP) and are assigned a C value of 130. Where possible, pipes were connected to create loops to increase efficiency of the system and provide redundancy.

For hydraulic modeling purposes, nodes are used to represent locations where pipes are connected and locations at which water is withdrawn from the system. The ground elevations were assigned at each node based on Town of Cary topographic contour data (2-foot interval).

Reclaimed water high service pumps at the NCWRF and SCWRF were modeled using site-specific pump curves. Pumps were set to deliver a target pressure at the entry to the distribution system. Target discharge pressures were set based on existing operational practices (approximately 120 psi at both NCWRF and SCWRF). As demands on the reclaimed water system increase, it is expected that use of the hydropneumatic tanks at the NCWRF and SCWRF will be phased out since the pumps will be in constant use and additional storage in the distribution system implemented. Therefore, the hydropneumatic tanks were not included in the hydraulic model.

7.2.2 Demand Allocation

Current and future average day demands were developed on an individual meter or parcel basis as part of the LRWRP project. These demands were assigned to the nearest pipe in the model, and then allocated to the appropriate node at the pipe end. Peaking factors specific to the reclaimed water end use (as discussed in Section 5) were used in the model to adjust the average day water usage to maximum day demand conditions. An additional 5 percent miscellaneous water (discussed in Section 5.4) was assigned proportionally to all nodes in the system.

Diurnal curves representing the hourly variation in demand over a day were input into the model to account for peak hour and minimum hour demand conditions. The diurnal curves for each end use are given in **Figure 7-2** and are based on the demand analysis presented in Section 4. Irrigation demand curves are assumed to be similar to the generalized customer curves presented in Section 4 for each service area since most existing reclaimed water use is for irrigation. Cooling/heating demand curves are assumed to be similar to the Town's existing cooling tower user data. Toilet flushing demand curves are assumed to be constant from 8 a.m. to 8 p.m. since toilet flushing use of reclaimed water is applicable only to commercial/industrial customers. Where existing customer-specific diurnal curves were determined through meter monitoring, those were input into the model for the appropriate customers.

On-site use of reclaimed water at the WRFs was assumed to be constant since information on the hourly variability of these uses is not available. It is assumed that non-potable use at the WRFs can be managed such that the peak on-site use does not correspond with the early morning peak irrigation demand period.

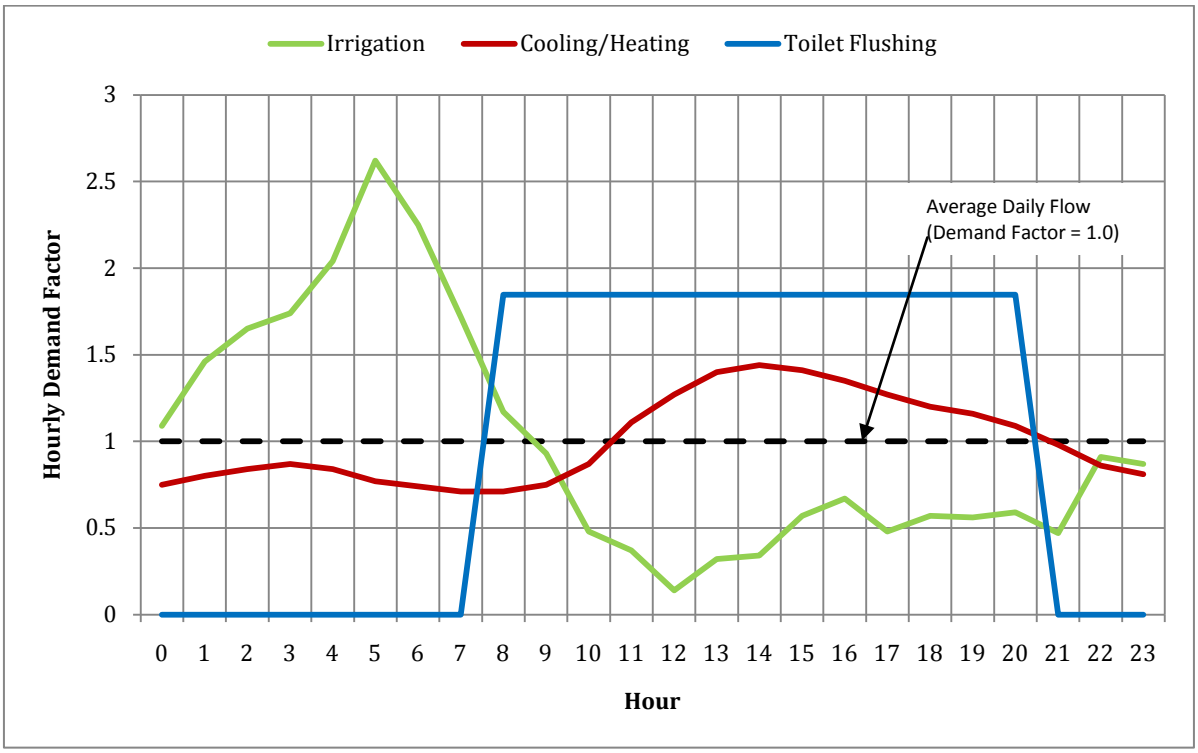


Figure 7-2
Unit Diurnal Reclaimed Water Use Patterns

7.3 Model Calibration

The accuracy of a computer model is highly dependent on its degree of calibration. To determine if a computer model is calibrated, actual field conditions are simulated using the model. System operating parameters (e.g. system pressures, etc.) generated by the model are compared with the parameters measured in the field.

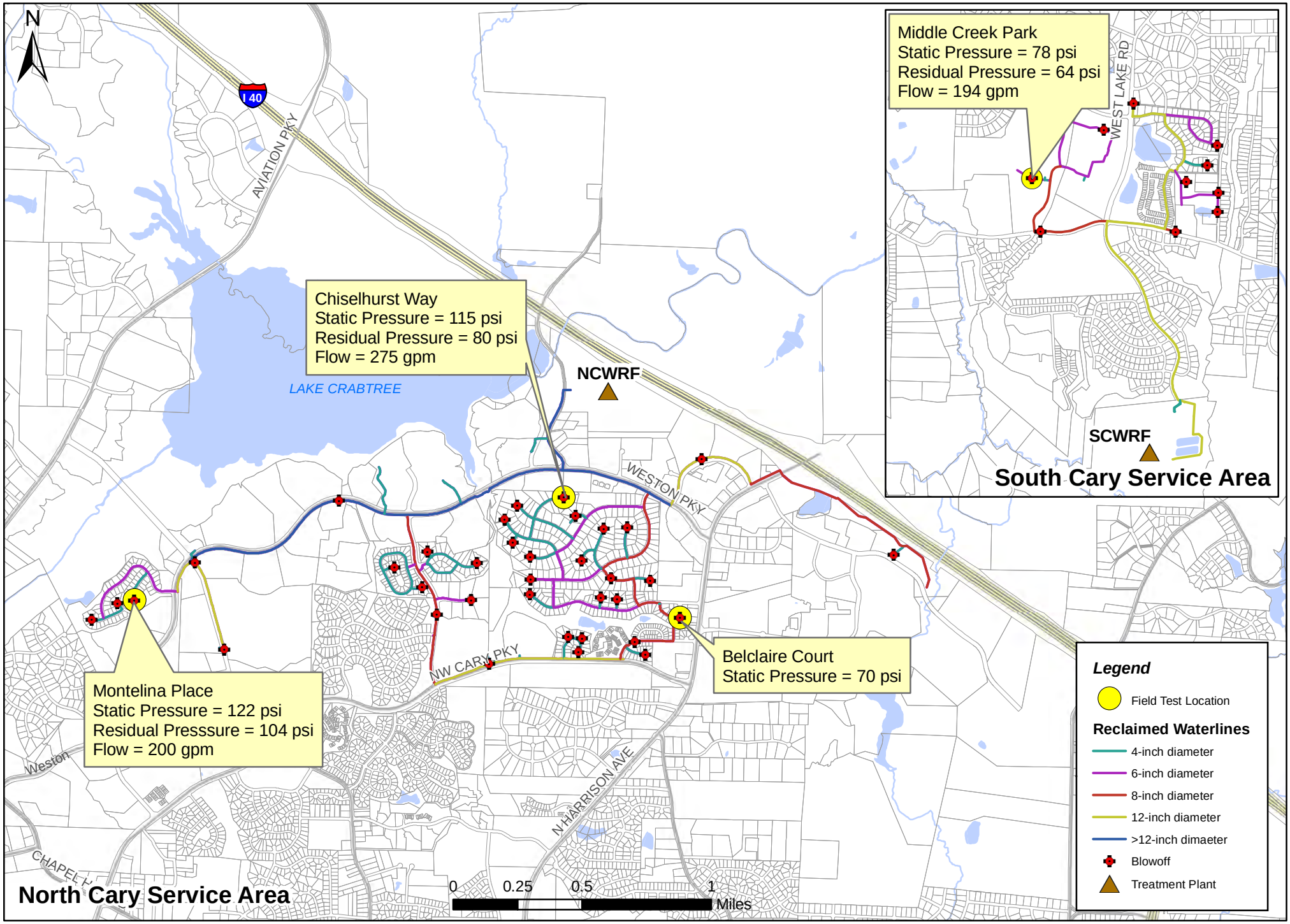
To calibrate the Town's reclaimed water model, field pressure data for static and flowing conditions were collected on August 3, 2011. Data for two flow tests and a static pressure reading near the highest system elevation was collected for the North Cary reclaimed water system. Data from one flow test was collected for the South Cary reclaimed water system. Flow tests were conducted using a procedure similar to hydrant flow tests on the potable water system, with reclaimed water blowoff valves opened to induce a large demand on the system instead of opening a hydrant. Although the blowoff flow rate could not be measured directly due to the configuration of existing blowoff piping into sanitary sewer manholes, staff was able to estimate the blowoff flow rate using SCADA data from the high service pumps at the WRFs. The system demands, operating conditions, and blowoff flow rates observed during the field tests were then simulated in the hydraulic model, and the modeled and field pressures were compared at each location.

Field test data and locations are summarized on **Figure 7-3**. For all of the field tests, the static and residual pressures simulated in the model were within 4 psi of the static and residual pressures observed in the field. Since the existing reclaimed water systems are fairly simplistic, with no distribution system pumps or storage and a single pressure zone, this data was considered adequate to consider the reclaimed water system model to be calibrated for the purposes of this master plan.

7.4 Existing System Evaluation

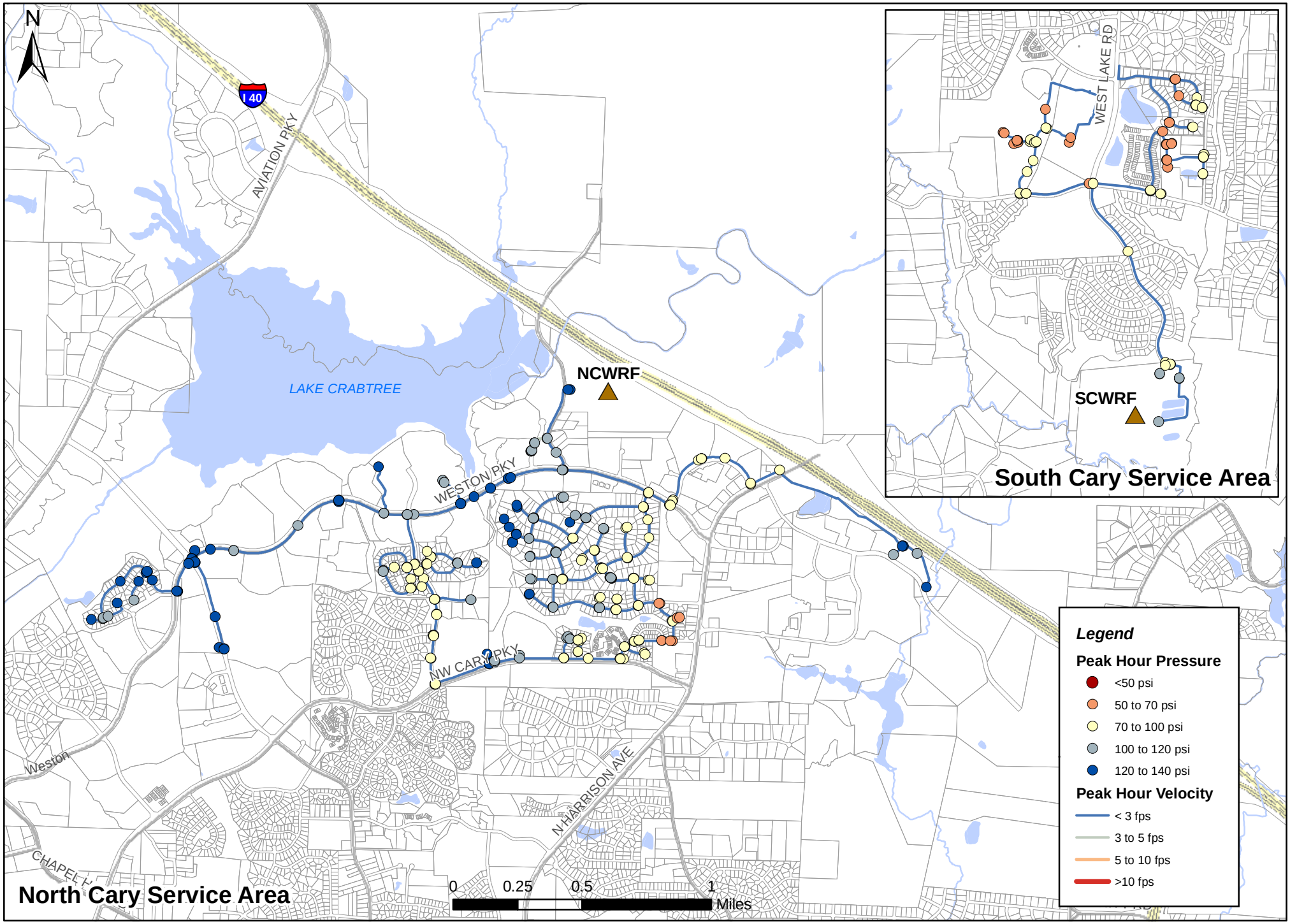
The existing reclaimed water system was evaluated under current maximum day demand conditions using the calibrated hydraulic model. An EPS simulation was performed and the resulting pressures and pipe velocities are shown on **Figure 7-4** for the North Cary and South Cary distribution systems. The existing system meets all pressure, velocity, and headloss criteria presented in Section 7.1. The West Cary distribution system was not evaluated under existing conditions since some of the pipelines are still in design/construction and not all customers are receiving reclaimed water.

Future scenario evaluation is presented in **Section 8**.



CDM Smith

Figure 7-3
Field Test Locations and Data



CDM Smith

Figure 7-4
Existing Reclaimed Water System; Peak Hour Pressure and Velocity