Executive Summary

The Town of Cary's Engineering Department initiated the Water Distribution System Master Plan and Model project to develop a calibrated dynamic hydraulic and water quality model of its distribution system to use as a decision analysis tool for the planning, scheduling, budgeting, and design of water system projects in the Town's utility service area. The Town of Cary contracted CH2M HILL to develop the new system hydraulic model and prepare the new Master Plan.

The primary goals of the project were to:

- Evaluate the Town's existing water distribution system, water storage tanks, pump stations, and system operations and make recommendations to improve the reliability and operation of the water system
- Construct a new water distribution system model using Wallingford Software's InfoWorks WS software platform, including the Town of Morrisville's distribution system
- Create a comprehensive, accurate, calibrated hydraulic and water quality model that reflects existing system conditions and identifies system needs to address future projected water demands
- Prepare the model for the Town to use internally to evaluate day-to-day operations and future infrastructure projects
- Recommend a phased capital improvement program (CIP) of water system improvements to correct existing deficiencies and meet future needs in the most cost-efficient manner

This Master Plan presents a description of the analyses conducted during this project, project findings, and a discussion of the phasing and timing of recommended capital improvement projects that were determined to be beneficial for system operations. This Plan will facilitate the Town's preparation for future capital improvements to meet redundancy, capacity, and replacement challenges in the most cost-efficient manner.

E.1 Background

The Cary/Apex Water Treatment Plant began operations in 1993 and supplies water to the Town of Cary and the Town of Apex water distribution systems. The Town of Cary's system provides water service to the Town of Cary, the Town of Morrisville, the Wake County portion of Research Triangle Park, and the Raleigh-Durham International Airport. In 2006, the Town of Morrisville merged its system with the Town of Cary's system.

The Town of Cary's previous water system master plan was developed in 2000. Since that time, growth within Cary, Morrisville, and Apex has continued at a rapid pace. The Town of Cary recognized the need for a new master plan and associated computerized model of the distribution system to evaluate current conditions and operations, and to predict the impact

of providing water service to its service area for the planning periods of 2010, 2015, 2025, and build-out.

E.2 Water Demands

Water demands were developed for existing and future conditions based on parcel-level land use information and water meter billing data. CH2M HILL worked extensively with Town of Cary staff to develop the base parcel information and a demand projection methodology which can easily be replicated in the future. The demands are the basis for the system hydraulic modeling which is used to evaluate the capacity of the Town's distribution system to meet existing and future demands within its urban service area.

The Town's service area ranges in elevation from approximately 251 feet above mean sea level in the western portion of the system to approximately 520 feet above mean sea level in the central portion of the system. Based on the range of elevations, the water system has been divided into three pressure zones: the Western Pressure Zone, the Central Pressure Zone and the Southern Pressure Zone. The water demands were developed for each of the individual pressure zones.

The total future water system demand is comprised of the existing demand, projected future demand, and future non-revenue water and bulk water sales. Section 2 of this Master Plan presents detailed information about the demand projection development methodology and projections for the future planning periods.

E.2.1 Annual Average Day Demand

The annual average day demands by pressure zone are summarized in Table E-1.

TABLE E-1
Town of Cary 2007 and Projected Annual Average Day Water Demand by Pressure Zone (units in mgd)

Pressure Zone	2007	2010	2015	2025	Build-out
Central	8.7	10.1	11.3	12.0	14.7
Southern	1.9	2.2	2.5	2.8	4.0
Western	2.9	5.2	7.4	8.3	10.2
Non-Revenue Water (9%)	1.2	1.6	1.9	2.1	2.6
Total Demand	**14.7**	**19.1**	**23.1**	**25.1**	**31.5**

Note: Numbers may not add exactly due to rounding.

E.2.2 Maximum Day Demand

A peaking factor of 1.64 was selected by Town of Cary staff for use in this Master Plan to calculate the maximum day demand as a function of annual average day demand, based on a review of historical water production data. The maximum day demands by pressure zone

are summarized in Table E-2. The 2007 maximum day demand shown in this table was calculated using the peaking factor and is not a measured value.

TABLE E-2
Town of Cary Estimated 2007 and Projected Maximum Day Water Demand by Pressure Zone (units in mgd)

Pressure Zone	2007	2010	2015	2025	Build-out
Central	14.2	16.6	18.5	19.7	24.1
Southern	3.1	3.7	4.2	4.5	6.5
Western	4.7	8.5	12.1	13.5	16.8
Non-Revenue Water (9%)	2.0	2.6	3.1	3.4	4.3
Total Demand	**24.0**	**31.4**	**37.9**	**41.2**	**51.6**

Note: Numbers may not add exactly due to rounding.

E.2.3 Town of Apex Demand

The demand projections developed by CH2M HILL for the Town of Apex 2007 Local Water Supply Plan were used in this Master Plan. The Town of Apex was treated as a single user in this study.

E.3 Existing Water System Operations

Section 3 of this Master Plan documents the current operation of the Town of Cary water distribution system and current infrastructure components.

Jordan Lake supplies raw water to the Cary/Apex Water Treatment Plant, which has a total capacity of 40 million gallons per day (mgd); plans to expand the plant to at least 56 mgd are underway. The Cary/Apex Water Treatment Plant and high service pump station supplies the Western Pressure Zone through a 30-inch diameter main and the Central and Southern Pressure Zones through a parallel 42-inch diameter main. The Town of Apex is supplied by the 42-inch transmission main through two active master meter control valves.

Pumping facilities include the high service pump station at the Cary/Apex Water Treatment Plant and four booster pump stations. System storage is provided by six elevated storage tanks and one ground storage tank. There are also two 3-million gallon clearwells and one 2-million gallon clearwell located at the Cary/Apex Water Treatment Plant. The total system storage is 17.25 million gallons but the "usable" volume is approximately 12 million gallons as described in Section 3.4 of this Master Plan. There are six active control valves and 13 master flow meters in the Town of Cary's system.

During field visits conducted as part of this Master Plan, CH2M HILL prepared detailed facility worksheets to organize and document information about these key system components. This information was gathered to ensure accurate infrastructure

representation in the hydraulic model and served as the basis for the subsequent system analysis. The facility worksheets are included on a CD in Appendix A.

E.4 Model Development

Prior to this Master Plan, the Town of Cary selected Wallingford Software's InfoWorks WS modeling software as the platform to be used for this analysis. For this Master Plan, CH2M HILL created a completely new "full-pipe" model using the Wallingford InfoWorks WS v9.5 software that includes all pipes 6-inches in diameter and greater.

The model was constructed based on the Town's water distribution system GIS layers, record drawings, site visits and CH2M HILL's detailed facility worksheets. The model includes Morrisville's distribution system since it merged with the Town of Cary's system. The model construction process was completed by adding the necessary elevations, demands, and controls to the model. Demand allocation is an automated process of spatially assigning existing and future water demands to the model and consisted of geo-coded customer billing data, non-revenue generated water, and future demand projections.

E.4.1 Field Testing and Steady State Model Calibration

Extensive field testing was performed prior to the model calibration to ensure that the model would be calibrated and could accurately simulate the water distribution system under a wide range of flow and pressure conditions. This information was used to calibrate the steady state model and the extended period simulation model. A field test plan was prepared that suited the age, configuration, size, and condition of the Town of Cary system. Two types of tests were conducted to perform the steady state calibration: four system hydraulic grade line tests and twenty-nine (29) hydrant fire flow profile tests.

The system hydraulic grade line tests were used to evaluate the trunk main system (pipes greater than 12-inch diameter) and were conducted across an entire pressure zone. The fire flow profile tests were used to evaluate the grid system (pipes less than 12-inch diameter) and were conducted in smaller areas of a pressure zone. These two types of tests are robust and powerful tools for calibrating hydraulic models. Four "level of confidence" criteria developed by CH2M HILL for both static and residual pressures were adopted for this study as shown in Table E-3. Of the 29 fire flow profile tests, 15 were rated with confidence levels of very high, 6 as high, 3 as medium, and only 5 as low. For the 5 tests that resulted in a low level of confidence, the potential causes of the error were:

- Suspected closed or partially closed valve
- Potential inaccuracies in diurnal demands

After simulating suspected closed valves or adjusting the local diurnal demands in the model, some of the tests resulted in a high level of confidence rating.

TABLE E-3
Level of Confidence Criteria: Field Testing and Steady State Model Calibration

Level of Confidence	Field vs. Model Pressure Errors (Static & Residual)
Very High	Less than 7 feet
High	7 to 12 feet
Medium	12 to 25 feet
Low	More than 25 feet

E.4.2 Extended Period Simulation Model Calibration

Following calibration for steady state conditions, the extended period simulation (EPS) aspect of the model was calibrated. Unlike steady state calibration which matches field data taken from a snapshot in time, EPS calibration verifies that the model accurately simulates the distribution system over a period of 24 hours or more. The EPS calibration ensures that the operational controls and diurnal demands are accurately incorporated into the hydraulic model.

Diurnal demand patterns were developed for the Western, Central and Southern Pressure Zones using Town of Cary's SCADA historical trend data and performing a flow balance. Some localized areas in the Western Pressure Zone (Research Triangle Park area) and the Central Pressure Zone (Morrisville and RDU Airport) required adjustments in order to achieve EPS calibration.

While production facilities are typically sized to satisfy maximum day demand requirements, storage tanks are sized to supply the volume of water in excess of the maximum day demand. This volume is called the equalization component of storage. Equalization is calculated by evaluating the diurnal demand pattern for a particular pressure zone or district. Calculating equalization factors is described in Section 4.4.1.2 of this Master Plan. For most water systems, equalization factors range from 10% to 15%. For this study, the equalization percentages derived for each pressure zone are recommended for sizing future storage tanks. The following equalization factors were determined for the Town of Cary system:

- Western Pressure Zone: 16%
- Central Pressure Zone: 12%
- Southern Pressure Zone: 24%

Four factors were used to evaluate the accuracy of the EPS calibration: elevated tank levels, high service pump station flows, high service pump station pressures, and control valve flows. In most cases, the model corresponded well with the provided SCADA data after minor refinements to the model.

Both the steady state and extended period simulation calibration results were in very good agreement with field measurements. The model reflected existing system conditions and achieved the appropriate level of accuracy to be used for master planning purposes, the

identification of system needs to address future projected water demands, and to prepare capital improvement program recommendations.

E.5 Design Criteria & Preliminary Analysis

E.5.1 System Hydraulic Evaluation Criteria

The water distribution system hydraulic evaluation criteria adopted for this Master Plan are detailed in Table E-4 and include:

- Water Supply
- System Pressure
- Fire Flow Demand
- Water Storage
- Piping Hydraulics
- Emergency Conditions

The criteria were used to size the recommended water system network components including pump stations, storage tanks, control valves, and pipe diameters. The following minimum system pressures were used in the analyses:

- Minimum during average day demand and maximum day demand: 40 psi
- Minimum during peak hour demand: 30 psi
- Minimum during maximum day demand plus fire flow demand: 20 psi

TABLE E-4
Water Distribution System Hydraulic Evaluation Criteria

System Parameter	Evaluation Criterion	Value	Design Standard/Guideline
Water Supply	Firm Pumping Capacity[a]	MDD[b]	Industry Standard Practice
	Firm Pumping Capacity + Elevated Storage Tank Supply	PHD[c]	Industry Standard Practice
	Firm Pumping Capacity + Elevated Storage Tank Supply	MDD + FF	Industry Standard Practice
	System Emergency Capacity[d]	ADD[e]	Developed for this Master Plan
System Pressure	Minimum, during ADD or MDD	40 psi	Town of Cary Policy Statement 129
	Minimum, during PHD	30 psi	Town of Cary Policy Statement 129 and NCAC T15A:18C.0405(b)
	Minimum, during MDD + Fire Flow	20 psi	Town of Cary Policy Statement 129 and NCAC T15A:18C.0405(b)
	Recommended Maximum Pressure	125 psi	Developed for this Master Plan
Water Storage	Minimum Combined Elevated and Ground Storage Capacity	½ ADD	NCAC T15A:18C.0805
	Equalization Volume	12-24% of ADD[f]	Developed for this Master Plan
	Fire Flow Volume	3,500 gpm x 3 hrs	Town of Cary Master Plan (2000)
	Emergency Volume	25% of ADD	Town of Cary Master Plan (2000)
Fire Flow Demand	Maximum Fire Flow[g]	3,500 gpm	Town of Cary Master Plan (2000)
	Minimum Residential Fire Flow	1,000 gpm	Town of Cary Standard Spec. Sect. 6
	Minimum Non-Residential Fire Flow[h]	1,500 gpm	Town of Cary Standard Spec. Sect. 6
Piping Hydraulics	Maximum Velocity during MDD	5 ft/sec	AWWA M32 (p. 68)
	Maximum Velocity during PHD or MDD+FF	10 ft/sec	AWWA M32 (p. 69)
	Maximum Head Loss (D<16-inch)	6 ft per 1000 ft[i]	AWWA M32 (p. 68)
	Maximum Head Loss (D>16-inch)	2 ft per 1000 ft[i]	AWWA M32 (p. 68)

[a] Firm Pumping Capacity: Capacity of pumping facility with largest pump out of service.

[b] MDD: Peaking factor of 1.64 was selected for use in this Master Plan to calculate the maximum day demand as a function of average day demand.

[c] PHD: Peak hour demand was simulated based on diurnal demand curve; defined as the maximum volume (or flow rate) of water delivered to the system during any single hour of the MDD.

[d] System Emergency Capacity: Total capacity of all pumping facilities minus largest facility (i.e. Cary/Apex WTP High Service Pump Station CPZ pumps or 42-inch transmission main out of service) plus total emergency storage volume of storage tanks.

[e] ADD: Average day demand, defined as the average volume (or flow rate) of water delivered to the system or pressure zone during a single day.

[f] Equalization factors by pressure zone: 12% (CPZ), 16% (WPZ), and 24% (SPZ). Tanks not allowed to drop below 20-ft during modeling analysis.

[g] Maximum Fire Flow: Fire flow requirement at commercial, industrial, and institutional customers when ISO "needed fire flow" information is not available.

[h] Minimum Non-Residential Fire Flow: Minimum fire flow when ISO "needed fire flow" is less than 1,500 gpm.

[i] Value shown is recommended for the design of new facilities. Existing facilities may have a higher value.

E.5.2 Preliminary Analysis

E.5.2.1 System Pressure

The North Carolina Administrative Code (NCAC T15A:18c.0405b) states that elevated storage tanks should be designed to provide at least 20 psi during fire flow conditions and 30 psi during peak flow conditions. The Town of Cary applies its Policy Statement 129 which is similar to the NCAC criteria. Policy Statement 129 states that minimum pressure for water distribution systems, including pumping facilities and storage tanks or reservoirs, should be designed so that water pressures of at least 40 psi at ground level will be maintained at all points in the system, including the highest ground elevations in the service area. A minimum pressure of 30 psi is allowed given that peak flow requirements can be satisfied. During fire flow events the water pressure should not fall below 20 psi at any hydrants in the system. The maximum pressure goal in the system is not to exceed 125 psi, but despite that requirement, static pressures above 125 psi are tolerable. High pressure areas are primarily located in the Morrisville area.

Pressure requirements in a water distribution system are typically defined spatially as the pressure required "at the curb" or at the customer meter demarcation point. However, planning departments typically evaluate the entire land area or parcel to ensure that high elevation areas are identified and addressed with appropriate pipe configuration and sizing.

In recent years, the Town has received pressure complaints primarily at high elevation areas where pressures "at the curb" were approaching the limits of Policy Statement 129. In order to verify that the above policy was appropriate for the Town of Cary water system, considering the typical pressure losses from the street, through the customer meter, and to the point of use, the Town of Cary requested an analysis of appropriate procedures and policies for the selection of residential water service line and meter sizes. Section 5.2.1 of this Master Plan includes an evaluation of Town of Cary residential service lines and Section 5.2.2 includes an evaluation of specific areas of low pressure in the system.

A review of the low pressure (high elevation) areas in the Town and the existing pressure zone boundaries indicated that only small areas in each pressure zone are at high elevations that result in pressures that are just slightly above the minimum design criteria shown in Table E-4 and which may experience peak hour pressure fluctuations. However, many of these high elevation areas have planned pipeline capital projects which will strengthen the piping network and reduce the potential for peak hour pressure fluctuations.

As shown in Figure 6-1A in Section 6 of this Master Plan, the portion of the Western Pressure Zone east of NC-55 experiences pressures below the peak hour criteria when the Davis Drive pressure reducing valve is off-line causing all the flow to be conveyed through the single 16-inch main along Morrisville-Carpenter Road. However, operation of the Davis Drive pressure reducing valve during peak hour demand could alleviate this condition as shown in Figure 6-1B.

Based on the conclusions and recommendations from the residential service line evaluation and the evaluation of low pressure (high elevation) areas, CH2M HILL recommends that Policy Statement 129 not be modified at this time. After collecting and reviewing a representative sample of hourly consumption data and after completing several near-term

pipeline projects, the Town may wish to re-evaluate Policy Statement 129 at that time. In conjunction with this recommendation, Section 5.2.3 of this Master Plan describes an option to create low pressure (high elevation) "special service area" districts which could require new development to increase the lateral service line size beyond the adopted standards to further minimize pressure loss. This approach would strategically focus on the low pressure areas while not imposing additional constraints on areas with adequate pressure.

E.5.2.2 Water Storage

The North Carolina Administrative Code (NCAC T15A:18C.0805) requires that the total combined ground and elevated storage volume should be equal to half of the average day demand. Based on the NCAC criteria, the existing available storage of 12 million gallons is greater than half of the projected 2010 average day demand of 9.5 mgd.

In order to meet the NCAC storage requirements at build-out, two new elevated tanks are recommended. The proposed 2 million gallon I-540 Elevated Tank, the proposed 1 million gallon Holly Springs Elevated Tank, and an increase in the "usable" volume of the Old Apex Ground Storage Tank will provide the necessary storage volume to ensure that the build-out available storage of 16 million gallons will be greater than half of the projected build-out average day demand of 15.25 mgd.

Assuming that the infrastructure improvement recommendations provided in this Master Plan are implemented, the Town of Cary should be in compliance with the NCAC storage requirements.

E.5.2.3 Piping Hydraulics

Piping hydraulic design criteria consist of velocity and head loss criteria used during the computer modeling analysis. The American Water Works Association (AWWA) recommends a maximum design velocity of 10 feet per second (fps) with 5 fps as a more desirable range and head loss less than 2 feet per 1000 feet for large transmission mains (>16-inch) and less than 10 feet per 1000 feet for smaller piping (<16-inch). For this analysis, transmission main velocities were limited to approximately 5 fps during maximum day and peak hour conditions which provided for a relatively flat system curve at the Cary/Apex Water Treatment Plant high service pump station. For the remainder of the Town's system, 10 fps was used as a peak hour velocity criterion but it was found that almost all of the peak hour velocities were below 5 fps after the planned improvements were incorporated into the model.

E.5.2.4 Emergency Conditions

The most critical emergency condition defined by the Town of Cary and evaluated in this Master Plan was the loss of the 42-inch transmission main from the Cary/Apex Water Treatment Plant to the Central Pressure Zone during both average day and maximum day demands for existing and future conditions. The 42-inch main serves the largest portion of the Town of Cary system.

This situation would result in the temporary shut down of the Central Pressure Zone high service pumps and reconfiguration of large valving between the Western Pressure Zone 30-inch transmission main and the portion of the 42-inch main that would still be in service.

The Central Pressure Zone pumps could then be re-started and would supply flow to the entire system through the 30-inch transmission main. For this analysis, it was assumed a maximum flow rate of 24 mgd could be conveyed through the 30-inch transmission main which is based on peak velocity criteria of 7.5 fps and 107 feet of head loss.

In addition, the Davis Drive Pump Station (City of Durham connection) and the Trinity Road Pump Station (City of Raleigh connection) would be utilized at full capacity to provide flow to the Cary System. A desktop flow balance indicated that during average day demand conditions, the Raleigh and Durham connections were not necessary until the year 2015 and that flows remained within the capacities of the Davis Drive and Trinity Road Pump Stations from 2015 until build-out. However, during future maximum day demand conditions the Durham connection would be at full capacity until 2025 and the Raleigh connection was within the range of the pump station capacity until 2015. After 2025 and 2015 respectively, the needed flows were beyond the capacity of the stations. Section 5.4 of this Master Plan provides more details.

The Town considers that a breakage of this magnitude during a future maximum day demand condition is quite conservative and the chance of this occurrence is low. To reduce the extremely large supply deficit that would occur in the future planning periods would require significant transmission main redundancy from the Cary/Apex Water Treatment Plant to the Central Pressure Zone at great capital expense. Based on the conclusions of this analysis, the Town chose to only consider the loss of the 42-inch transmission main during average day demand conditions. Future study of the hypothetical loss of the 42-inch transmission main under maximum month demand conditions is recommended.

E.6 Hydraulic Evaluation

Utilizing the steady state and extended period simulation functionality of the hydraulic model, the hydraulic evaluation of the Town of Cary system was conducted for the defined planning periods. The model identified deficiencies based on the hydraulic evaluation criteria adopted for this Master Plan. Proposed pipes, tanks, and pumps were evaluated in different combinations until an optimum design was established to eliminate simulated deficiencies. The following demand conditions were analyzed: maximum day demand, maximum day demand plus fire flow, and peak hour demand. The hydraulic evaluation of the Town's system included:

- Existing System – By Pressure Zone
- Future System – Pressure Zone Boundaries
- Future System – Transmission Mains
- Future System – High Service Pump Station
- Future System – Piping, Storage Tanks, and Control Valves

E.6.1 Existing System – By Pressure Zone

The existing system hydraulic evaluation was conducted using projected 2009 demands derived by interpolating between the 2007 production and 2010 projected demands. The

2009 demands were used for existing conditions in order to provide a model that is as accurate as possible to evaluate the Town's current system performance. For the existing system 2009 maximum day demand evaluation, it was assumed that none of the programmed 2009 capital projects would be on-line by the summer peak demand period.

A fire flow analysis was conducted on every hydrant in the Town of Cary system under existing maximum day demand conditions. Commercial areas were reviewed to determine if a trunk main within the grouping of commercial parcels met the available fire flow demand criteria. Areas not zoned as commercial were assumed to be residential. In both cases, the scope of this analysis focused on areas of fire flow adequacy and not individual parcels or facilities.

The results of the existing system evaluation were compared to the adopted system hydraulic evaluation criteria for this project as shown in Table E-4.

E.6.1.1 Western Pressure Zone

During projected 2009 maximum day demand, the majority of the Western Pressure Zone maintains pressure greater than 50 psi during peak hour conditions as long as the Davis Drive Pressure Reducing Valve is on-line. A few low elevation areas at the western part of the zone have pressures that are over 100 psi. Peak hour pipe velocities in the Western Pressure Zone are predominately below 3 fps, with a few larger mains near the Carpenter Elevated Tank, along Morrisville Carpenter Road, and downstream of the Davis Drive Pressure Reducing Valve between 3 and 5 fps, within the evaluation criteria limits.

The available fire flow in the Research Triangle Park area was predominately between 1,000 and 2,500 gpm but the Town has already programmed a short section of 16-inch main from Green Level-to-Durham Road that will increase the fire flow to the commercial design criteria of 3,500 gpm.

The available fire flow in the residential areas was predominately above 1,000 gpm with a few exceptions in the southeast quadrant of the zone which were between 700 and 1,000 gpm. With the addition of a 12-inch water main project currently programmed along High House Road, the fire flow will also be improved at these locations.

E.6.1.2 Central and Southern Pressure Zones

While the Central and Southern Pressure Zone elevated tanks have very different overflow elevations, the two zones were analyzed together due to the operation of Kildaire Farm Road and Cary Parkway open/close valves as fully open/fully closed valves. The primary supply mains to the Southern Pressure Zone at Kildaire Farm Road and Cary Parkway are nearly reaching or potentially exceeding design capacity based on operational level requirements at the Plumtree Way Elevated Tank. This finding is based on the observed operation of the Kildaire Farm Road and Cary Parkway control valves being open for 22 out of 24 hours of the day during the summer of 2008 and based on the 2009 maximum day demand model simulation which shows potential difficulty maintaining water levels in the Plumtree Elevated Way Tank.

Peak hour pressures over much of the Central and Southern Pressure Zones are greater than 100 psi with one exception along Penny Road in the Southern Pressure Zone where peak

hour pressures are approximately 30 to 40 psi. Peak hour pipe velocities are for the most part below 3 fps with a few trunk mains below 7 fps, which are within the evaluation criteria limits.

E.6.2 Future System – Pressure Zone Boundaries

The pressure zone boundaries and tank overflow elevations are well established based on the highest elevations in each pressure zone. However, some areas within the Town of Morrisville operate at excessively high pressures reaching 150 psi which can lead to increased water loss and main breaks over time.

The primary goal of this pressure zone boundary analysis was to develop pressure zone boundary alternatives which focused on providing industry standard capacity and pressure to the Morrisville area rather than satisfying existing sprinkler system design rates. Three pressure zone boundary alternatives which represent varying scales of expansion of the Western Pressure Zone into the Morrisville and RDU Airport area, as shown in Figure 6-3 of this Master Plan, were developed as follows:

- Alternative 1 – Small expansion of Western 540 Pressure Zone into the lowest elevations of Morrisville
- Alternative 2 – Medium expansion of Western 540 Pressure Zone encompassing the entire area west of Highway 54
- Alternative 3 – Large expansion of Western 540 Pressure Zone plus new Airport 605 Pressure Zone encompassing all of the Morrisville and RDU Airport areas

The analysis is presented in Section 6.2 of this Master Plan. Based on the analysis, it is recommended that the Town consider implementing Alternatives 1 and 2 in phases. Alternative 1 could be implemented in the near-term after conducting a detailed design study and completing several small scale capital projects. After successfully completing Alternative 1, the Town could implement Alternative 2 possibly by the 2015 time frame. This schedule would provide the Town with time to conduct the detailed design studies and to complete the necessary capital projects and address potential compromised sprinkler systems in the expanded Western Pressure Zone boundary.

E.6.3 Future System – Transmission Mains

Transmission mains are defined as the key supply mains from the Cary/Apex Water Treatment Plant high service pump station to the Western and Central Pressure Zones.

Future transmission mains for the Western and Central Pressure Zones had been recommended in the previous master plan. CH2M HILL re-evaluated each previously recommended project using the updated 2010, 2015, 2025, and build-out maximum day demand projections. The following three conceptual design strategies were employed in the analysis:

- Increase supply to the southern region of the Central Pressure Zone
- Create relatively flat system curves for the Western and Central Pressure Zones in order to maximum capacity at the high service pump station
- Provide transmission main redundancy

E.6.3.1 Western Pressure Zone

Based on the hydraulic modeling analysis, the existing 30-inch transmission main that supplies the Western Pressure Zone is not adequate to supply the maximum day demand at build-out. Redundancy is required in the zone by the 2010 time frame due to the proposed I-540 highway construction project which will potentially isolate the western part of the Western Pressure Zone. Construction of a new 24-inch transmission main from the high service pump station to the western side of the zone along Wimberly Road and Green Level West Road, as shown in Figure 6-4 in Section 6 of this Master Plan, will provide redundancy in the zone to better facilitate the I-540 highway construction project and delay the need for an additional storage tank in the Western Pressure Zone.

E.6.3.2 Central and Southern Pressure Zones

Based on the hydraulic modeling analysis, the existing 42-inch transmission main that supplies the Central and Southern Pressure Zones and the Town of Apex is adequate to supply the maximum day demand at build-out. However, head loss was excessive in the existing 36-inch main along Holt Road and Jenks Carpenter Road and in the 30-inch main along Waldo Rood Road. It is recommended that a 24-inch main be constructed to the south along Holt Road, Howell Road, Farm Pond Road, and West High Street which will strategically convey more water to the southern portion of the Central and Southern Pressure Zones where capacity is limited.

E.6.4 Future System – High Service Pump Station

The hydraulic modeling analysis of the Cary/Apex Water Treatment Plant high service pump station was conducted in conjunction with the transmission main design. A master plan for the high service pump station was developed based on the following factors:

- Projected maximum day demand
- Hydraulic effects of the proposed transmission main improvements described above
- Capacity and head of existing pumps
- Available empty slots at the pump station

The proposed 2010 transmission main improvements will impact the operating point of existing and future pumps. Detailed design efforts conducted in the future should evaluate the adequacy of existing and future pump curve selections based on the proposed transmission main improvements.

Table E-5 presents the proposed combination of Western Pressure Zone pumps required to satisfy planning year flow projections and meet the hydraulic evaluation criteria shown in Table E-4.

Details of the high service pump station analysis are included in Section 6.4.2 of this Master Plan. Figures 6-5 and 6-6 provide the high service pump station system curves, proposed flows and station configuration.

TABLE E-5
High Service Pump Station Western Pressure Zone Pumps Required to Meet Maximum Day Demands

Planning Year / Demand	Pumps Required	Pump Design Criteria
Year 2007 Maximum Day Demand	1 existing pump	5.5 mgd at 305-ft TDH[a]
Year 2010 Maximum Day Demand	2 existing pumps	5.5 mgd at 305-ft TDH each
Year 2015, 2025, and Build-out Maximum Day Demand	2 existing pumps and 1 new pump	5.5 mgd at 305-ft TDH each

[a] TDH = Total Dynamic Head

Table E-6 presents the proposed combination of Central Pressure Zone pumps required to satisfy planning year flow projections and meet the hydraulic evaluation criteria shown in Table E-4.

TABLE E-6
High Service Pump Station Central Pressure Zone Pumps Required to Meet Maximum Day Demands

Planning Year / Demand	Pumps Required	Pump Design Criteria
Year 2007 and 2010 Maximum Day Demand	3 existing large pumps	9.0 mgd at 450-ft TDH[a]
Year 2015 Maximum Day Demand	3 existing large pumps and 1 existing small pump	9.0 mgd and 5.5 mgd respectively at 450-ft TDH
Year 2025 Maximum Day Demand	3 existing large pumps and 2 existing small pumps	9.0 mgd and 5.5 mgd respectively at 450-ft TDH
Build-out Maximum Day Demand	5 new extra-large pumps	10.0 mgd at 485-ft TDH

[a] TDH = Total Dynamic Head

E.6.5 Future System – Piping, Storage Tanks, and Control Valves

Hydraulic modeling analyses were conducted for each of the planning periods to demonstrate that the Town of Cary system can adequately satisfy projected maximum day demand, peak hour demand, and maximum day demand + fire flow water demands. This analysis focused primarily on the necessary piping, storage tanks, and control valves to meet the evaluation criteria.

The existing pressure zone boundaries were utilized for completion of all modeling analyses including the build-out simulation. However, if the pressure zone modifications described in Section 6.2 of this Master Plan are implemented, some of the recommended piping may need to be upsized or expedited based on a future detailed pressure zone study.

For the extended period simulations, the diurnal demand patterns described in Section 4 of this Master Plan were utilized for the Town of Cary system. However, a diurnal demand pattern was not applied to the Town of Apex demand points in the model and the analysis was based on the assumption that the Town of Apex storage tanks can adequately provide

equalization flows during maximum day demands. In order to evaluate the potential impacts to the Town of Cary system in detail, it is recommended that the Town of Apex's distribution system be included as part of the Town of Cary's distribution system hydraulic model. A discussion of this recommendation is included in Section 7.9.8 of this Master Plan.

Section 6.5 of this Master Plan provides detailed descriptions of the analyses and findings. Recommended projects were included in the capital improvement program.

E.7 Recommended Capital Improvement Program

One of the primary goals of this Master Plan is to recommend a phased capital improvement program (CIP) of water distribution system improvements that will enable the Town of Cary to correct existing deficiencies and meet future needs in the most cost-efficient manner.

Section 7 of this Master Plan presents the recommended CIP for each of the defined planning periods:

- Phase 1 – 2010
- Phase 2 – 2015
- Phase 3 – 2025
- Phase 4 – Build-out
- Undesignated Phase – Designated as "local service area" projects which may be required to satisfy site specific conditions but are not required to satisfy the design criteria adopted for this Master Plan

The proposed improvements for each planning period are subdivided into four major types of infrastructure:

- Storage
- Pumping
- Control valves
- Piping improvements

Table 7-1 provides a detailed list of the recommended CIP projects and each project location is shown in Figure 6-7.

The total cost of the recommended CIP projects is $84.3 million. However the projects that comprise the recommended CIP are distributed spatially throughout the service area and also temporally by defined planning period. Tables E-7 and E-8 present a summary of the project costs for each planning period by type of recommended infrastructure and percent of total CIP costs, respectively. Table E-9 presents the project costs by pressure zone for all of the planning periods and the percent of total CIP costs.

TABLE E-7
CIP Project Costs by Planning Period and Type of Recommended Infrastructure
(Costs in 2009 Dollars with no Escalation for Year of Construction)

Type of Recommended Infrastructure	2009	2010	2015	2025	Build-out	Undesignated	Total by Infrastructure Type
Storage	$ -	$ -	$5,556,800	$ -	$8,514,500	$ -	$14,071,300
Pumping	$ -	$2,800,000	$ -	$990,000	$7,000,000	$ -	$10,790,000
Control Valve	$ -	$691,300	$ -	$ -	$702,700	$80,000	$1,474,000
Piping	$6,822,600	$27,781,700	$10,875,500	$888,900	$2,090,900	$9,519,600	$57,979,200
Total by Planning Period	$6,822,600	$31,273,000	$16,432,300	$1,878,900	$18,308,100	$9,599,600	$84,314,500

TABLE E-8
CIP Project Costs by Planning Period and Type of Recommended Infrastructure (units in percent of Total CIP cost of $84.3 million)

Type of Recommended Infrastructure	2009	2010	2015	2025	Build-out	Undesignated	Total by Infrastructure Type
Storage	0%	0%	7%	0%	10%	0%	**17%**
Pumping	0%	3%	0%	1%	8%	0%	**12%**
Control Valve	0%	1%	0%	0%	1%	0%	**2%**
Piping	8%	33%	13%	1%	2%	11%	**68%**
Percent of Total CIP by Planning Period	**8%**	**37%**	**20%**	**2%**	**21%**	**11%**	

Note: Numbers may not add exactly to 100% due to rounding.

TABLE E-9
CIP Project Costs by Pressure Zone for all Planning Periods and Percentage of Total CIP Cost of $84.3 million
(Costs in 2009 Dollars with no Escalation for Year of Construction)

Western Pressure Zone	Central Pressure Zone	Southern Pressure Zone
$33,005,000	$35,853,800	$15,455,700
39% of Total CIP Cost	43% of Total CIP Cost	18% of Total CIP Cost

E.8 Recommendations for Further Study

Section 7.9 of this Master Plan presents ten recommendations for additional analyses that would help clarify, validate, or modify future CIP items and enhance the water distribution system model developed for this Master Plan.

The three most important recommendations for further study are listed below. The first two recommendations are the most critical to refining the current hydraulic model calibration which may allow the Town of Cary to delay or eliminate certain capital projects and reduce capital expenditures. The third recommendation is for a detailed analysis of a possible expansion of the Western Pressure Zone.

Refinement of System Diurnal Demands and Peak Hour Demand Reduction

A series of district measurements is being performed as an amendment to the contract for this Master Plan to develop the chlorine residual-based water quality system model. The district measurements will help refine the system diurnal demands and these new demands will be used to further refine the hydraulic model calibration. It is recommended that the diurnal demand variations be analyzed in detail by area within the distribution system. It is recommended that an analysis of this data be conducted to evaluate water conservation measures that reduce water demand during the peak hours of the day which may impact the sizing, timing or need for recommended CIP projects and delay capital expenditures.

Town of Apex Water Distribution System Model and Analysis

Since the Town of Apex's water distribution system demands are supplied through two connections with the Town of Cary system, the Town of Cary's system pressure and flows can be impacted by fluctuations in Apex's demands. To evaluate the potential impacts in detail, it is recommended that the Town of Apex's distribution system be included as part of the Town of Cary's distribution system hydraulic model developed for this Master Plan. The resulting model would be used to evaluate the supply requirements from the Cary/Apex Water Treatment Plant and the significant capital expenditure required by the Town of Cary to increase supply to the southern portions of the Central Pressure Zone and Southern Pressure Zone. This analysis would address the Town of Apex future diurnal demands and available storage, and the Town of Cary Southern PZ capacity limitations.

Detailed Design Study for Possible Western Pressure Zone Expansion

Section 6.2 of this Master Plan describes the possibility of expanding the Western Pressure Zone to accommodate the Morrisville area and presents two alternatives for further evaluation. A phased approach incorporating these two concepts is recommended as well as a detailed design study for a possible phased expansion of the Western Pressure Zone, which would include an investigation of the low pressure zone area to establish a specific zone boundary.