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GKY & Associates, Inc.

Cumberland County Regional Water Supply Study

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Water Needs Assessment and

Water Conservation Plan

Final Report

Cumberland County Regional Water Supply Study

Water Needs Assessment and

Water Conservation Plan

March, 2009

Table of Contents

Water Needs Assessment

Water Conservation Plan

List of Tables

Water Needs Assessment

Water Conservation Plan

List of Figures

Water Needs Assessment

Water Conservation Plan

Addenda

Three previous documents written by GKY provide added reference with regard to methods and full results for the Water Needs Assessment and Water Conservation Plan.

1. *Land use assumptions for Phase II of the Cumberland County Regional Water Supply Study*. Memorandum. December 13, 2006. by Karsten Sedmera and Stuart Stein, GKY & Associates, Inc.

2. *Water Needs Assessment for the Cumberland County Regional Water Supply Study*. Memorandum. March 14, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

3. *Water Conservation Plan for the Cumberland County Regional Water Supply Study*. Memorandum. June 28, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

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Water Needs Assessment

1. Introduction

The Cumberland County Regional Water Supply Study was established by an agreement between the U.S. Army Corps of Engineers (Nashville District) and the City of Crossville, Tennessee. The Cumberland County Regional Water Supply Study has the goal of identifying a long term solution to Cumberland County's water supply needs, and carrying forward an Environmental Impact Statement investigating potential alternatives for the long term supply solution. As part of the Water Supply Study, GKY & Associates has been contracted to perform a Water Needs Assessment to estimate future demand at 10 year increments for the next 50 years.

This Water Needs Assessment builds, in sequence, a land use development analysis, population growth scenarios, and modeling of future water demands. This study represents the first in-depth analysis taking into account the rapid growth in the early 2000s.

Indeed, Cumberland County, located on the Cumberland Plateau of East Central Tennessee, faces a growing problem in meeting the ever increasing water demand in a rapidly growing county. Cumberland County has been experiencing rapid growth in part due to its considerable success in attracting retirees to live in the county. In severe droughts, this growth is already straining water supplies. As growth continues, it is likely a new water source may need to be developed. This Water Needs Assessment investigates the future demand for water under a range of growth scenarios to project how much water will be needed in the future.

The first step in determining the future water needs is to analyze the land use patterns in Cumberland County.

2. Land Use Development

One of the important steps in predicting future water demand in the next 50 years is the difficult task of predicting future population growth and land use patterns in Cumberland County, TN. Land use patterns assist in predicting population growth by making it possible to assess how much land is available for growth, and they assist in demand estimation by generating a relative breakdown of the types of water consumers in the study area. Cumberland County, however, does not have any formal land use plan (i.e., zoning) in place to control (or predict) local patterns of growth. While there are a few studies that predict population growth for the County as a whole, none of them appear to focus on local growth rates or detailed land use patterns. Figure 1 displays the land use in Cumberland County according to the 2006 tax assessor's database. The land use patterns and the state of development of parcels of various types can provide clues to future development.

Cumberland County was one of ten counties recently selected by the Tennessee Department of Economic and Community Development to participate in a pilot study called "Retire Tennessee" that is designed to promote Tennessee as a great place for retirees to call home. Two of the predominantly residential areas, Lake Tansi and Fairfield Glade represent two established communities (not official cities) that attract retirees by offering small lots, convenient maintenance agreements, and various community club amenities. The three cities in the area – Crossville (the County seat), Pleasant Hill, and Crab Orchard – have similar attractions but more diverse development patterns. Crossville, however, has more dense residential communities than either Pleasant Hill or Crab Orchard. The remainder of the County is fairly rural with scattered residential development along major roads. Two related communities called Cumberland Cove and Cumberland Lakes (henceforth called Cumberland

Cove), which boast large lots and rustic "dream" homes, form a new development area where rural land is rapidly shifting into denser residential development.

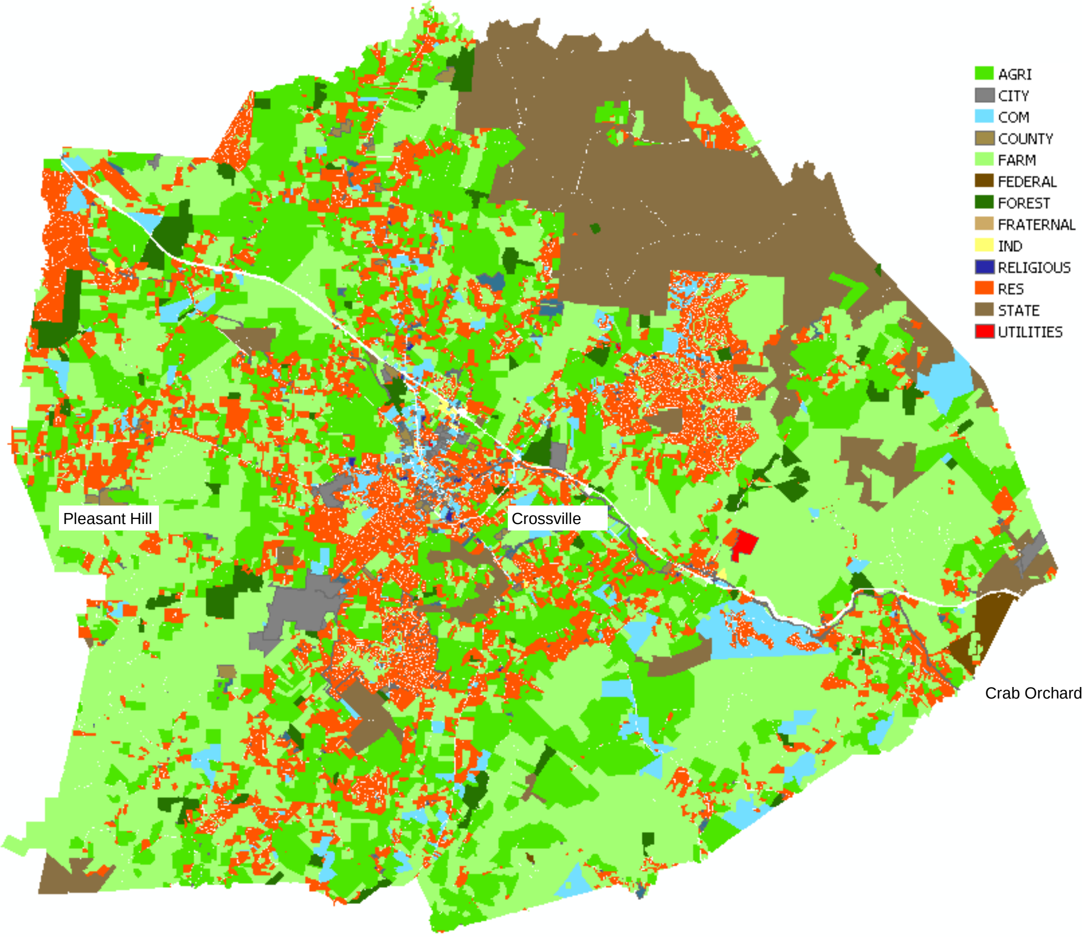

Figure 1 – Land Uses of Cumberland County according to 2006 Tax Assessor's Parcel Data

The tax assessor's database classifies each parcel into one of 12 land use categories (indicated on the map legend in Figure 1). A few clear patterns emerge from examining Figure 1. The majority of the county's land area is dominated by agricultural and farm land. The majority of residential development appears in four or five clusters. The center of the map shows the advanced development around the City of Crossville, including a dense core of commercial and residential development. There is also a large, state-owned wildlife preserve in the northeast corner of the County, which has almost no development in or immediately surrounding it. The land use pattern elsewhere in the county, however, is remarkably similar.

The database also lists the assessed land value and improvement value for each parcel. Thus any parcel with an improvement value greater than zero has been developed. For the purpose of estimating population density, only developed parcels that are classified as residential, farm, agricultural, or forest are likely to have homes on them. A few of the developed parcels classified as farm have improvement values reflecting recreational (e.g., golf resorts) or farm buildings, but most of them are residential lots with over 15 acres. Agricultural or forest parcels are "farms" that qualify for tax breaks under the TN Greenbelt program.

In order to evaluate the development potential in Cumberland County, the characteristics of the parcels (e.g. development, land value, lot size, and improvement value) were analyzed.

Figure 2 highlights the distribution of developed and undeveloped parcels of primarily privately owned residential and commercial parcels.

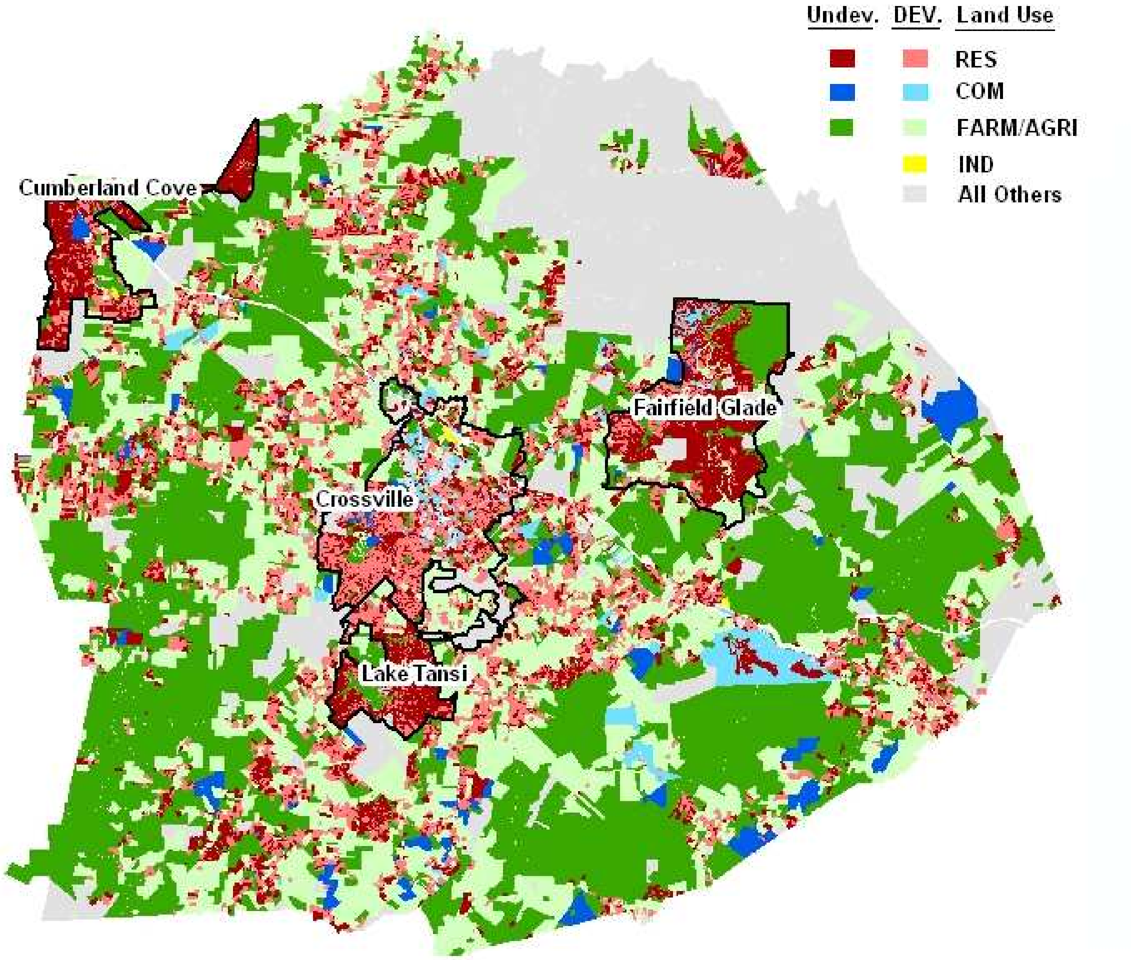

Figure 2 - Development Map of Cumberland County Showing Developed and Undeveloped Residential (RES), Commercial (COM), Industrial (IND), and Agricultural and Farm (FARM/AGRI) Parcels

Figure 2 indicates the undeveloped residential parcels (dark red) show an even clearer pattern than in Figure 1. It is evident that the dense residential communities generally cluster around Crossville, Fairfield Glade, Lake Tansi, and the Cumberland Cove area (which includes Cumberland Lakes). Furthermore, of these four regions, the latter three contain 69% of the undeveloped residential parcels in Cumberland County. Interestingly, the undeveloped commercial parcels are well distributed throughout the county.

Based on the land use analysis five study regions are selected for population and water use projections. Their geographic extents are shown in Figure 3. It should be noted that the boundaries reflect development patterns more than established political boundaries.

- City of Crossville
- Cumberland Cove (including Cumberland Lakes)
- Fairfield Glade
- Lake Tansi
- Remainder of the County

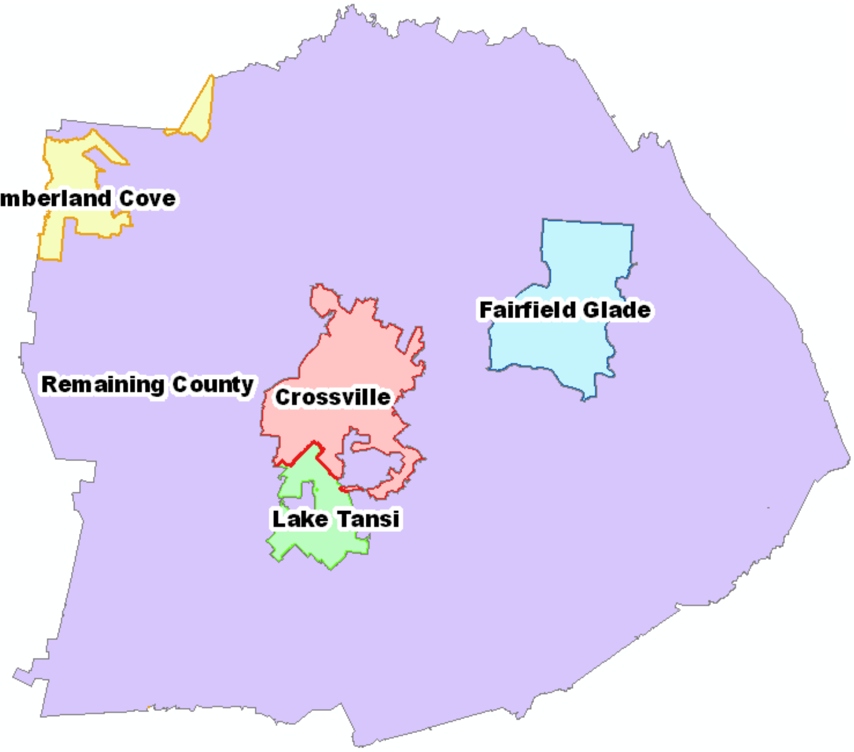

Figure 3 – Study Areas in Cumberland County

Further analysis of the parcels yielded some other general information about land use in Cumberland County that are useful for making population and water use projections. A few of the more interesting results are as follows:

- 90% of parcels in the County are residential
- 6% are farm/agricultural/forest,
- 37% of the residential parcels are developed,
- 57% of the farm/agricultural/forest parcels are developed, and
- 83.7% of the land area is residential/farm/agricultural/forest.
- The undeveloped residential parcels are, on average, half as large as the developed ones (0.92 vs 1.93 acres)

3. Growth Scenarios

The land use analysis establishes the general bounds on growth, and identifies the ultimate growth potential of the five study areas named in Section 2. Following the land use analysis, projections of the expected population growth in Cumberland County must be made in order to forecast water needs. Population forecasting is inherently uncertain, and becomes more so the further the time horizon of the forecast extends. In order to treat some of this uncertainty in a more concrete fashion, three distinct growth scenarios are carried through the remaining forecasting and modeling. They include the Slow, Expected, and Aggressive growth scenarios. The forecasts include population projections every 10 years starting in 2006 and ending in 2056. The Land Use Memo (full title: *Land use assumptions for Phase II of the*

Cumberland County Regional Water Supply Study), included in the addenda, details the methods by which the projections were made.

The growth scenarios all utilize the same starting values, and differ primarily in the specified growth rates for each ten year period. The growth rates also vary by study area. The percentage rate of growth reflects historical data, expert judgment from relevant stakeholders in the County, and other important factors (such as lack of sewer connection). Figure 4 displays the countywide population projections under the three population scenarios, as well as projections from two other studies. Note that the countywide projections are a sum of predictions for the individual study areas, each of which has independent growth projections and saturation points.

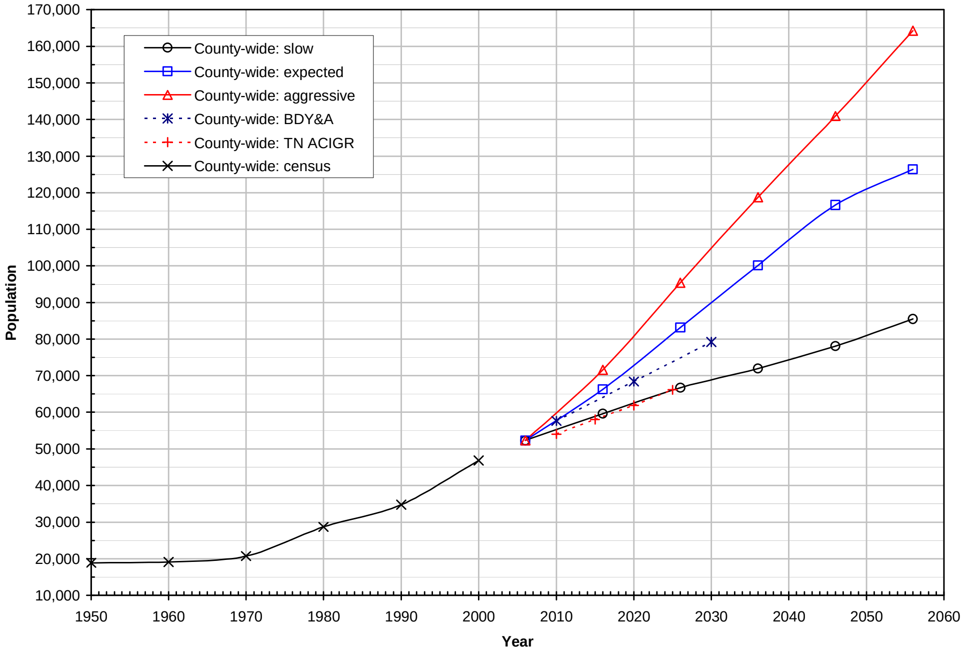

Figure 4- Population projections for Cumberland County. The three growth scenarios are displayed, as well as projections from two other studies (BDY & A 2002[i]; TN ACIGR[ii])

The population projections in fact show a wide range of variation among the growth scenarios. The range of population projections easily encompass the variability in the previous population projections, with the Slow growth scenario comparing favorably with the Tennessee Advisory Commission on Intergovernmental Relations' (TN ACIGR) forecast, and the Expected scenario a little higher than the Breedlove, Dennis, Young and Associates (BDY&A) forecast. The Aggressive scenario allows for substantial growth, but we note that even after 50 years, the projection does not begin an increasingly rapid growth phase as is often the case with simple exponential growth models.

Once the population is forecasted, it can be used to calculate projections of other relevant variables for estimating water usage. Namely, for each study area, the number of households and the number of employees must be forecast. By using historical data and stakeholder judgment, the future population per household ratio and the population per employee ratio were estimated for each forecast year. Dividing the projected populations by these factors yields the estimates of households and employees in Table 1.

Table 1 – Countywide Projections of Population, Households, and Employment for Cumberland County

Forecast Variable	Scenario	2006	2016	2026	2036	2046	2056
Population	*Slow*	*52,306*	*59,620*	*66,732*	*71,949*	*78,103*	*85,509*
	Expected	*52,306*	*66,288*	*83,157*	*100,163*	*116,643*	*126,373*
	Aggressive	*52,306*	*71,598*	*95,366*	*118,783*	*140,958*	*164,223*
Households	*Slow*	*23,345*	*27,622*	*31,990*	*35,323*	*39,294*	*44,144*
	Expected	*23,345*	*30,588*	*39,724*	*49,404*	*58,980*	*63,664*
	Aggressive	*23,345*	*33,106*	*45,772*	*59,252*	*69,006*	*79,369*
Employees	*Slow*	*25,000*	*29,083*	*33,200*	*36,522*	*40,259*	*44,305*
	Expected	*25,000*	*32,336*	*41,371*	*50,844*	*60,125*	*65,478*
	Aggressive	*25,000*	*34,926*	*47,446*	*60,296*	*72,659*	*85,090*

4. Water Needs Assessment Methods

Planning and Management Consultants, Ltd.'s IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as state-of-the-art, industry standard water demand forecasting software packages. IWR-MAIN was used as a tool to compute projected water use based on assumptions about the county's growth and water use factors. The IWR-MAIN user's manual[iii] explains in detail the structure of the model and the precise definitions of the terminology used. Where possible, we strive to use the correct IWR-MAIN terminology in describing the construction of the Cumberland water demand projection.

At the heart of the IWR-MAIN model is the usage model in Equation 1.

$$\boxed{\begin{matrix}\text{Demand}\\ Q\end{matrix}} = \boxed{\begin{matrix}\text{Counting Unit}\\ N\end{matrix}} \times \boxed{\begin{matrix}\text{Use Factor}\\ q\end{matrix}}$$

Equation 1.

In short, the demand is determined by multiplying some counting unit by a water use factor. This model determines the demand in a given time period, in a given subsector, in a given study area. A *subsector* is the base organizational unit for which water demand is projected (e.g., the residential or commercial subsector). Each subsector has its own associated *counting unit*, which is a measure of subsector size that has a strong influence on water usage (population, households, or employees, for instance). The *use factor* is simply the volumetric demand for water per counting unit (gallons of water per capita per day, per house per day, etc) in a given time period. Thus, a water demand forecast requires projecting (at a minimum) how the counting units and use factors change over time.

The total county water use in a given time period is simply a sum of the consumption for each subsector plus any leakage or other non-consumptive use. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different regions of the study universe have distinct characteristics, the study can be broken down into *study areas*, each with their own group of subsectors and usage models. In this case, the study universe encompasses all of Cumberland County.

With respect to Cumberland County, the study areas have already been identified in Section 2. For each study area, two sectors were assumed: residential and non-residential (encompassing commercial, industrial, and institutional uses). Residential water use forecasts are computed using the forecasted number of housing units as the counting unit. The non-residential sector utilizes number of employees as the counting unit. The City of Crossville study area has an

additional subsector to model the water usage of Cumberland Medical Center, whose associated counting unit is the total population of Cumberland County.

Water Use Factors

Forecasting the future values of the counting units accounts for half of the necessary inputs in (1). The other half of the inputs comprises the water usage rates. IWR-MAIN's Forecast Manager and Conservation Manager offer a range of forecasting models to estimate future water use factors. Many of the methods are econometric methods that allow using explanatory variables to build a predictive model for the use factors. Among the explanatory variables that are commonly found to be associated with water use are income, housing density, persons per household, marginal price, average daily maximum temperature, precipitation, and cooling degree days. An extensive analysis of the water usage records and available data on potential explanatory variables determined that the predictive models were not appropriate for this study. It should be noted that future needs assessments should reconsider this decision because a few more years of high-quality water usage data (including sector breakdowns) may make these more complex models viable.

Without these models, IWR-MAIN provides two primary options for calculating use factors. The first, contained within IWR-MAIN Forecast Manager, is to simply use constant use factors calculated based on the number of counting units and the base year use. The second, which requires using IWR-MAIN Conservation Manager, is to develop end use models for each subsector. Each end use has its own use factor, and the sum of the use factors for each subsector is the overall use factor for this sector. This approach is more flexible than the constant use model, though it can be made equivalent through correct application of parameters in the model.

The chosen model is the end use model, mainly due to the fact that Conservation Manager will be used to evaluate the effectiveness of conservation measures in the water conservation plan. The added benefit to using the end use model in Conservation Manager is that it is possible to define end uses on three levels of water use efficiency and shifts between them over time. This feature allows incorporating natural, market based changes in water use efficiency that result from greater average efficiency of water using fixtures and appliances over time.

When employing the end use model, it is important to have an accurate base-year water usage estimate. This water demand projection uses two seasons, so monthly estimates of base year use are necessary. The summer season includes June, July, August, and September, and the Winter season includes the rest of the year. Water use is assumed to be constant for all months within a given season.

Residential water usage factors are based on monthly residential water consumption data from the South Cumberland and Crab Orchard Utility Districts. Both user districts had acceptable monthly records of residential water consumption and the associated number of customers (households). Since the counting unit for the residential sector is the household, the water use factor is expressed in terms of gallons per day per household (gpd/hhld). The S. Cumberland and Crab Orchard data yielded annual averages of 119.7 and 118.9 gpd/hhld, respectively. Lake Tansi is almost completely encompassed in the S. Cumberland district, and Fairfield Glade is contained within the Crab Orchard district, but the rest of the study areas still need water use factors. For the sake of simplicity, and to provide a conservative estimate of demand, the rest of the study areas are simply assigned the higher S. Cumberland water use factors.

Estimating nonresidential demand is somewhat more complicated than estimating residential demand, especially in terms of disaggregating countywide demand among the study areas. As mentioned before, future employment projections are based on each study area's population

and a countywide population to employee ratio. Since Crossville's commercial development is not distributed exactly the same as residential development, it is inevitable there will be some error in the geographic distribution of commercial water demand. Without zoning though, it seems at least reasonable that future commercial development will occur near growing areas with concentrated residential development. Thus, it is likely much of the commercial development will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

The methods for generating the water use rates for the commercial sector are described in much more detail in the Needs Assessment Memo in the addenda. In a general sense, the use rates for the commercial sector were determined from actual usage records from the utility districts and then spatially disaggregated. The disaggregation was performed in GIS by determining the location of commercial and industrial parcels in the parcels database with respect to the boundaries of the study areas and the utility districts.

Passive Conservation

One major source of error in many forecasts of future water use is the failure to consider the effect of more water efficient technology. Since the Federal Energy Policy Act of 1992, U.S. manufacturers have been required to meet minimum water efficiency standards for plumbing fixtures and toilets. Since that time, manufacturers have gone well beyond the minimum standards as a way to stay competitive. The mode of change effected by the availability of more efficient technology is called passive conservation, whereby consumers conserve just by replacing their older fixtures with more efficient ones when they need to be replaced. New construction also takes advantage of the more efficient technology by default.

The average potential savings associated with more efficient appliances were determined from the AWWA's 1999 *Residential end uses of water* [iv]report. The average replacement rate was determined from the National Association of Home Builders/ Bank of America *Study of the Life Expectancy of Home Components*[v]. Though the consumption-weighted average replacement rate for all water using home components is approximately 6.5%, a more conservative rate of 5% was assumed. This is equivalent to a 20 year lifetime for many of these components. The forecasts take these shifts into account using the passive conservation tool in IWR-MAIN Conservation Manager.

The effect of this savings is a very slight decrease in the per unit water use rate over time. Though counterintuitive for a growing county, this makes sense in Cumberland County for several reasons. Firstly, as explained previously, no credible predictive models can be developed with available data. Secondly, the land use analysis demonstrated that the average area of the undeveloped residential and commercial parcels in the county is significantly smaller than the developed parcels meaning that outdoor water use will rise slower than the population growth rate. Thirdly, as more retirees move to the county, the number of people per household will continue to fall, meaning that per household indoor use rate should not increase. Finally, technological advances in manufacturing of toilets, dishwashers, and other water using appliances will tend to lower water usage as older units are replaced with more efficient ones. This conservation savings due to technology, while slight was considered necessary for inclusion in the model because of the long study period.

Unaccounted for Water

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental water main breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each of the study areas, the Unmetered/Unaccounted tool sets the year-by-year UAW percentage. (IWR-MAIN restricts the percentage to a constant value for each year, and only whole percentages are permitted.)

Previous water demand studies of Cumberland County have used a wide range of methods to model UAW. Breedlove, Dennis, Young & Associates' (BDY) 2002 *Cumberland County Water Supply Needs Assessment* selects a target loss percentage of 10% as a worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[vi] prepared by the Corps and Ogden Environmental and Energy Services, Inc. also estimated 10% UAW on the basis of non-specified estimates by the Cumberland Utility Districts.

In this study, UAW estimates for the five study areas are based on actual data from the UDs. Perhaps in response to the previous studies, the UDs have begun collecting more detailed statistics on UAW. It is with these statistics and advice from interviews with the UDs that we estimate UAW. Table 2 shows the average UAW percentages by utility district in recent years. The final row displays the number of years of data upon which the percentages are based.

Table 2– Unaccounted-for-Water data by Utility District (% of total production)

	Crab Orchard	Crossville	South Cumb.	West Cumb.	**Consumption Weighted Average**
Annual UAW%	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 2 appear incredibly high, but when we consider the short record length, it is clear that at least in some cases, some outlier values may be skewing the results. While there appears to be some potentially significant seasonal variation in the loss percentage, at least in Crab Orchard and Crossville, there are not enough data to make a strong case for modeling this variation. Additionally, IWR-MAIN does not allow seasonal variation in the Unmetered/Unaccounted percentage.

Except in Crossville, the record lengths are too short to make a valid estimation of the UAW by utility district. So we calculate the county average as weighted by consumption in the UDs. The yearly average UAW percentage is calculated as 22.4%, which is conservatively rounded upward to 23%. All of study areas except for Crossville are assumed to have this 23% average. If metering errors, line flushing, and known losses are assumed to be 5%, this means that an average of 18% of total produced water is actual loss. These figures compare favorably with the 20% rate indicated in interviews with the Crab Orchard Utility District, and 14-15% loss rate reported by West Cumberland. With the Crossville records being a bit longer, we feel comfortable setting Crossville's UAW percentage at 19%, which is slightly more conservative than the 15% unaccounted for and the 10-12% loss estimated by the Crossville UD in a May 2006 interview.

For the purposes of a baseline forecast, the UAW percentages are assumed to remain constant in time, which is a dubious assumption based on the large variances in month to month losses alone. Almost certainly, losses will either increase as the system ages, or decrease as the result of system improvements and maintenance. We are hesitant, however, to forecast changes to the UAW percentage in a baseline forecast, or impose 'desirable goals' as some past studies have done. Additionally, the conservation measures evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

Model Validation

Based on the assumptions made, it is possible to compare the projections to observed water usage. Figure 5 displays the estimated total county water consumption as compared to

observed consumption based on data from the UDs. These figures exclude UAW. On average, the estimated values are about 4% above the observed values, and therefore slightly conservative.

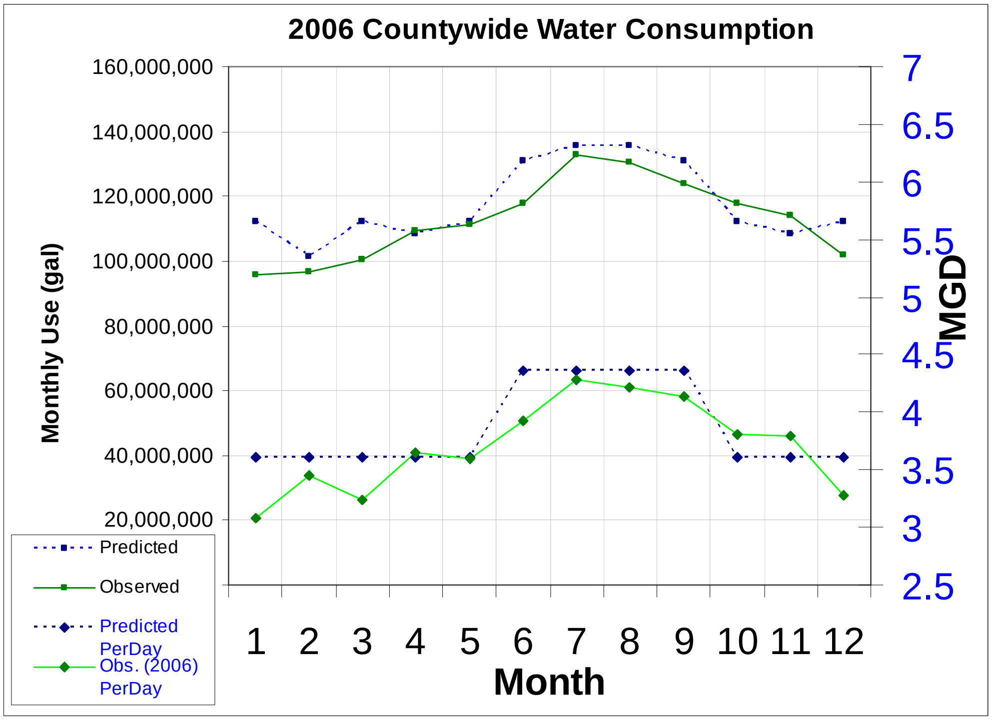

Figure 5 - Predicted versus Observed Countywide Water Consumption (excl. UAW)

The agreement shown between the observed and estimated values in water use is certainly not perfect, but it indicates the assumptions are at least reasonable, and slightly conservative. We note that there is excellent agreement at the peak water use month of July.

When the total usage includes UAW, the agreement between the observed 2006 values and predicted values is slightly worse. Data from the utility districts indicate that unaccounted for water makes up 27% of total produced water in 2006. This is higher even than the already fairly conservative assumption of 23% (19% for Crossville) used in the modeling. Figure 6 displays the estimated and observed values, which indicate the model predictions are about 7% *below* observed values. This is certainly a source of potential error, but is more likely due to above average losses in 2006. For the purposes of forecasting, the recent historical averages for UAW are a more reasonable basis for estimating future UAW than the 2006 values alone. Thus, no further calibration is necessary to match the observed and predicted 2006 demand.

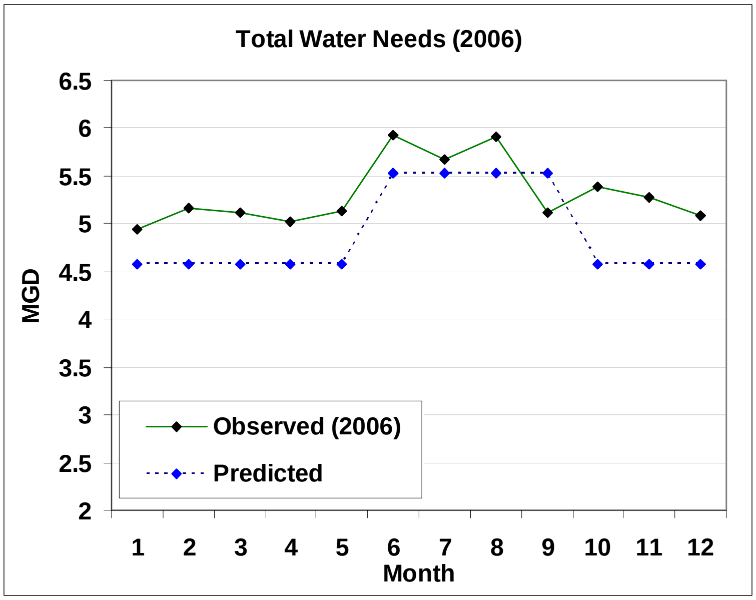

Figure 6– Model Predicted and Observed Cumberland County Water Use in 2006

5. Summary Results

The results of the baseline water supply needs assessment are presented in this section. All results are presented in terms of average daily usage in millions of gallons per day (MGD) except when otherwise noted. Summary results are presented here, but full results are available in the addenda.

It should also be noted that this is a planning level document, so the results are presented as annual or seasonal average. These figures should be sufficient for estimating water storage needs. Calculating peak usage, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak usage estimates were not called for in the scope of services, but are presented for completeness. BDY&A's 2002 *Cumberland County Water Supply Needs Assessment* cites factors in a range of 1.25 to 1.35 of daily consumption for Cumberland. The Corps' *Cumberland County Regional Water Supply Preliminary Engineering Report* appears to use 1.35 as well. Thus, a factor of 1.35 is applied to the results of this section. Note that peak factors are applied only to the consumption, and subsequently, the unadjusted UAW is added.

Countywide Results

The countywide results present the broadest picture of the water needs projections. Figure 7 presents the demand totaled for all study areas and all subsectors (including UAW). The demand for all three growth scenarios is indicated separately, however. The results indicate that demand will not quite triple in 50 years under the Aggressive scenario, less than double under the slow scenario, and roughly double under the expected scenario.

Under any growth scenario the projected demand increases significantly over the 2006 baseline. As noted previously, there is a great deal of uncertainty, particularly in the estimation of future trends in UAW. Figure 8 reports the county totals for consumption, which excludes the UAW. While there is bound to be some UAW in the future, the consumption projections are marginally more certain. The water conservation plan will more directly assess the effects of reducing UAW.

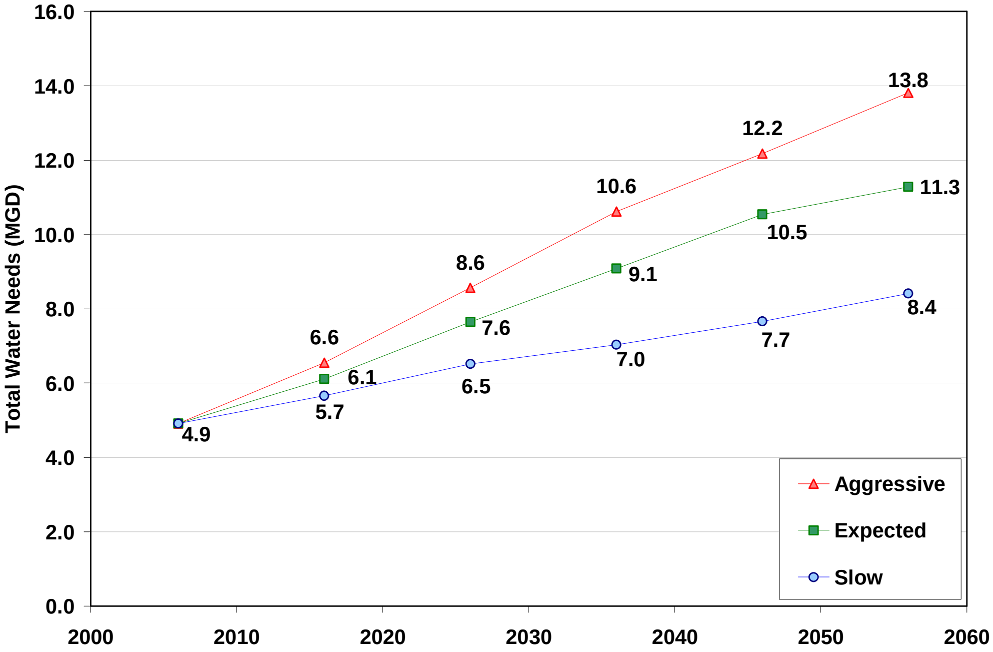

Figure 7. **Countywide Daily Average Total Water Needs for the Slow, Expected, and Aggressive Growth Scenarios.**

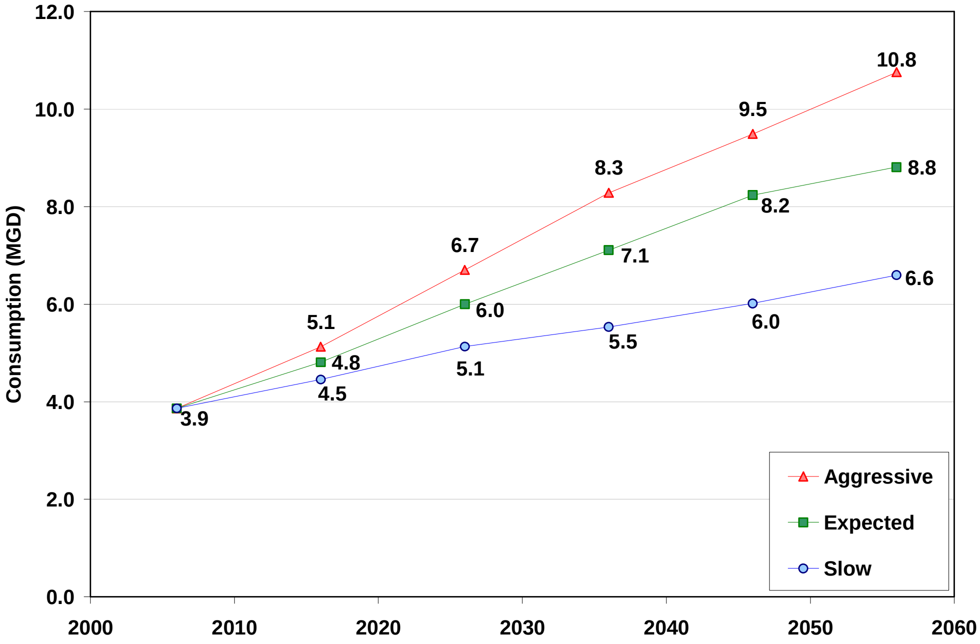

Figure 8 – Countywide Daily Average Projected Water Consumption (excludes UAW) for the Slow, Expected, and Aggressive Growth Scenarios

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, the usage varies by season. The Summer months include June-September, while the Winter includes the remaining months. The results are presented here by scenario and season. Countywide, the summer usage remains a fairly consistent 12-13% above the annual average, and winter usage is always

roughly 6-7% below. This is a result of the cumulative effects of the different winter and summer use factors for the subsectors (see the Water Needs Assessment in the addenda for full description and usage rates). Table 3 displays the countywide daily demand by season.

Table 3– Seasonal Variations and Peak Projected Total Water Needs (MGD)

Scenario	Season/Peak	2006	2016	2026	2036	2046	2056
Aggressive	Annual	4.91	6.55	8.56	10.61	12.18	13.81
	Summer	5.55	7.41	9.71	12.09	13.84	15.67
	Winter	4.59	6.12	7.99	9.87	11.34	12.87
	PEAK	*6.26*	*8.35*	*10.91*	*13.51*	*15.50*	*17.57*
Expected	Annual	4.91	6.11	7.64	9.08	10.54	11.28
	Summer	5.55	6.90	8.63	10.27	11.94	12.77
	Winter	4.59	5.71	7.14	8.48	9.84	10.54
	PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
Slow	Annual	4.91	5.66	6.52	7.03	7.66	8.41
	Summer	5.55	6.40	7.38	7.98	8.71	9.58
	Winter	4.59	5.28	6.08	6.56	7.14	7.83
	PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*

Table 3 also displays the projected peak demands, which reflect a 1.35 peakage factor applied only to the annual average consumption. As mentioned before, this factor is based on peak factors cited in previous studies and is not based on usage data. The unadjusted annual total UAW is then added on to this peak consumption to arrive at total water needs.

Water Needs Analysis By Subsector

Table 4 indicates the annual average daily demand by subsector for the entire county. In terms of total demand growth, it is clear that most of the growth occurs in the residential sector. The other sectors exhibit slightly lower percentage growth, but still increase significantly over their base year values. The NonRES results indicate that commercial growth will be of a low water intensity variety, which is consistent with a primarily service oriented commercial sector. The introduction of only a few large (industrial) water users, however, could add significantly to commercial demand, making the NonRES sector the most likely to be a low estimate of actual future demand.

Also notable is that the UAW subsector, while remaining a constant percentage of total water use, grows to become a more significant water ‘use’ than the nonresidential sector under the aggressive scenario. While the UAW percentage is based on the best available current loss estimates, this sector is most likely to reflect an overly conservative estimate of actual future UAW. The actual processes of leakage are more complex than a simple percentage loss, so growth in consumption does not necessarily mean a proportional rise in leakage. Additionally, leakage will most likely be addressed by future loss reduction measures. The impact of loss reduction measures is treated in the Water Conservation Plan.

Table 4 - Projected Total County Water Needs (MGD) by Scenario and Subsector

Scenario	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
	NonRES	1.49	1.87	2.11	2.32	2.52	2.71
	CMC	0.07	0.10	0.13	0.17	0.20	0.23
	UAW	1.04	1.42	1.86	2.33	2.69	3.05
Aggressive Total		**4.91**	**6.55**	**8.56**	**10.61**	**12.18**	**13.81**
Expected	RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
	NonRES	1.49	1.78	2.04	2.18	2.34	2.42
	CMC	0.07	0.09	0.12	0.14	0.16	0.18
	UAW	1.04	1.30	1.64	1.97	2.31	2.48
Expected Total		**4.91**	**6.11**	**7.64**	**9.08**	**10.54**	**11.28**
Slow	RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
	NonRES	1.49	1.68	1.91	1.96	2.02	2.08
	CMC	0.07	0.08	0.09	0.10	0.11	0.12
	UAW	1.04	1.20	1.38	1.50	1.65	1.82
Slow Total		**4.91**	**5.66**	**6.52**	**7.03**	**7.66**	**8.41**

* RES_PS – Residential, Public Supply; NonRES – Nonresidential; CMC – Cumberland Medical Center; UAW – Unaccounted for Water

Comparison to Previous Estimates

A comparison of GKY's water needs forecasts with previous estimates of Cumberland County's water needs clearly demonstrates the effect of prediction method chosen. Figure 9 compares the estimates in this study to those by Breedlove, Dennis, Young and Associates (BDY&A, 2002), the Army Corps of Engineers (USACE, 1998)[vii], and Lamar Dunn & Associates (LD&A, 2001). LD&A used a simple percentage growth model to estimate future demand. While this model may be appropriate in the short term, it is evident that the simplistic exponential model rapidly leads to unstable and incredibly high demand estimates at more distant time scales. It is clear that this model is insufficient for modeling long term water needs because it is overly simplistic and does not take into account any realistic limitations on growth.

Also interesting is that the BDY&A study presents a very high estimate of demand. This is likely a result of the method used for forecasting the future use factors. The study uses a gross total per capita consumption use factor to estimate the water use. BDY&A chose to express this factor as total public supply water use divided by total population (instead of population served). As a result, the numerator does not reflect the many self-supplied water users in the county (whose use would not be counted in public supply water), while the denominator does count them. This partially explains the artificially low historical use factors (54 and 77 gpd per capita in 1984 and 2000, respectively). The rapid increase in water usage factors is likely more a result of new development being added on public supply (versus self-supply) in a much higher proportion than the existing residences than it is a response to economic trends or fundamentally different water usage patterns of new residents. Furthermore, to bring the use factors to present day average values from this low starting point requires astounding gains in the per capita use factor. Projecting the future water use factors from historical values can lead to extremely high use forecasts, especially when rapid population growth continues.

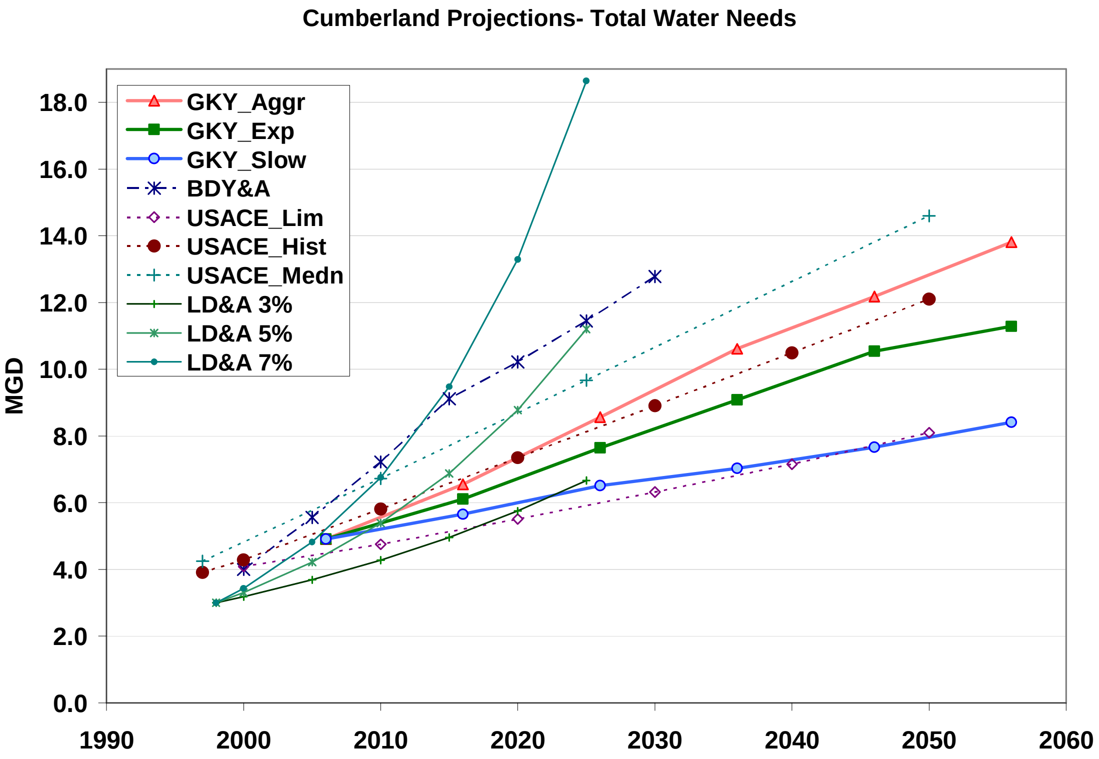

Figure 9 - A comparison of water needs forecasts for Cumberland County

The USACE projections rely upon a variety of different methods, including a model developed in IWR-MAIN (i.e. Medn → Median projection). These projections seem most closely in line with GKY's projections. The historical and limited methods actually incorporate limitations on growth, though in a more simplistic way than the GKY study.

The GKY study likely presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[viii] of the Pacific Institute note, "With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches." GKY's baseline projections present a new approach to countywide water demand forecasting, as anticipated improvements in water efficiency are taken into account. These anticipated improvements are in a sense inevitable as national laws and standards, as well as simple market availability have affected a shift to more conserving technology. For example, the Energy Policy Act of 1992 has made virtually all new toilets on the market compliant with a 1.6 gallon per flush efficiency standard.

It is important to note the efficiency assumptions are nearly completely independent of any decisions and policies made by public officials and citizens in Cumberland County. Other water use reductions may result from programs already in progress (notably, infrastructure improvements to reduce leakage). To establish a conservative baseline projection, however, we limit the conservation measures to 'natural' efficiency upgrades due to more advanced technology gaining a greater market share over time. Other conservation actions are analyzed much more thoroughly and explicitly in the Water Conservation Plan.

6. Uncertainty

The act of forecasting into the future is an inherently difficult task. It is important to recognize (1) that uncertainty is present in any projection, (2) uncertainty in baseline assumptions influences uncertainty in projections, and (3) errors compound over time, making distant projections less reliable than near-term projections.

The forecast model is designed to explicitly take into account uncertainty where possible, and otherwise, avoid introducing unknown uncertainty. (We use 'uncertainty' instead of error because error can't be calculated until the future when there are actual water demand values in the forecast years.)

The largest source of uncertainty in this forecast is likely contained in the population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth scenarios (instead of only an expected growth scenario), we introduce reasonable bounds on the uncertainty of this projection. (That is not to say that Slow and Aggressive scenario projections present the absolute lower and upper bounds on the prediction.) This understanding of uncertainty in the population projections is useful since the housing forecasts are calculated in tandem with them, and the employment projections depend directly on population as well. In these projections, the assumed growth rates, people per house statistic, and population per employee estimates all are potential sources of error. As an illustration of the potential consequences of error in initial projection, Table 5 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. (A constant percentage growth model is assumed.) Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 5 - Consequences of 0.5% error in growth rates (forecasted Units per 1000 base Units*)*

	10 years		**25 years**		**50 years**	
Initial rate projection	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*
1%	53	-56	150	-169	361	-461
2%	58	-61	190	-213	586	-746
5%	76	-79	381	-427	2435	-3075
10%	116	-120	1166	-1301	23914	-29879

Table 5 indicates just how serious minor errors in the prediction parameters can be, particularly in fast growing regions. The land use limitations on growth assumed in this study help put a limit on how large the error can be. In practice, growth can be limited (or spurred) by many factors other than land use consideration, but some limits are advisable as a constant percentage growth, exponential model is rarely a realistic assumption for a very long study period.

The other major potential source of model uncertainty is in the water use factors. While IWR-MAIN has several advanced methods of estimating future demand built into the software, additional parameter estimates and explanatory variables would be necessary (each bringing additional uncertainty). Any more complex model (such as a linear or multiplicative regression) would introduce more uncertainty through parameter estimates in addition to any uncertainty in forecasting future explanatory variable values. The water usage data provided by the UDs is just enough to come up with baseline water use factors. The small sample sizes of the water use data mean there is quite a bit of uncertainty in the water use factors (especially in the monthly values). By averaging the months within two seasons, the sample size is effectively increased, reducing the uncertainty introduced by outliers.

In a similar manner, the UAW percentages are averaged over the county to increase the effective sample size of estimate, and reduce the effect of outliers. Section 4 (Water Needs Assessments Methods) demonstrated that selection of parameters led to good agreement with real water use patterns in the base year.

The importance of the proper treatment of uncertainty in model prediction cannot be overstated. Underestimating future water needs can lead to a dangerous situation in the form of a water shortage or even running out of water. Overestimation of water needs can lead to unnecessary projects or oversized projects at a much higher cost than necessary. Without a realistic view of the uncertainty present in the forecasts, decision making on future supplies may not be truly addressing the water needs. Fully cognizant of the uncertainties present in this forecast, GKY has made every effort to document the uncertainty and present a reasonable range of potential future water needs representative of the effects of the known uncertainty.

Comparisons with previous studies have shown that this study's predictions of water needs tend to be somewhat lower than previous estimates made with simpler models. A careful consideration of the methods used in earlier studies generally leads to the conclusion that the forecasted water needs may be overestimated. This study attempts to provide as accurate a forecast of water needs as possible, with full description of methods, thus allowing the decision maker to assess the validity of the study. Assuming the study is deemed valid, the range of forecasts allows for the decision maker to lend more credence to one scenario versus the others based on their judgment and level of risk-aversion.

7. Conclusions

This Water Needs Assessment has analyzed the current and future water needs of Cumberland County using the best available data and expert opinions. Cumberland County has experienced rapid growth in the past several decades, and that growth may continue so long as the water demands can be met.

The population projections reflect demographic trends, opinions of local experts, and real limits on growth based on land use. The development of the appropriate water use factors was based directly on actual water use data from the utility districts. It must be recognized that a 50 year projection is subject to a great deal of uncertainty. The Aggressive, Expected, and Slow growth scenarios help to capture some of that uncertainty.

The projections in this report indicate that Cumberland County's water needs will very likely exceed the current supply in the next 50 years, but not quite as soon as previously projected. As the average demand becomes closer and closer to the firm yield of the existing sources, the potential for failure in a particularly severe drought year increases considerably. Therefore, Cumberland County is well advised to continue to examine and develop opportunities for conservation and securing an increase in available supplies.

8. References

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[v] NAHB/Bank of America Home Equity Study of Life Expectancy of Home Components, Feb. 2007

[vi] United States Army Corps of Engineers and Ogden Environmental and Energy Services, Inc. *Cumberland County Regional Water Supply Preliminary Engineering Report.* Dec. 1998.

[vii] Lamar Dunn & Associates, Inc. (LD&A). *Preliminary Engineering Report: Investigating the feasibility of constructing raw water impoundments downstream of Meadow Park Lake for City of Crossville.* December 2001.

[viii] Gleick, P., Haas, D., Henges-Jack, C., Srinivasan, V., Wolff, G., Cushing, K.K., and Mann, A. (2003) *Waste Not, Want Not: The Potential for Urban Water Conservation in California.* Pacific Institute for Studies in Development, Environment, and Security. Oakland, CA. November, 2003.

Water Conservation Plan

1. Introduction

Cumberland County's attention has been increasingly drawn to water resources over the past decade. Growth projections by several firms[ix,x,xi] have estimated that the water needs of Cumberland County will exceed firm yield in less than 10 years. Excluding the undesirable outcome of running out of water, Cumberland County has two options: increase water supply or reduce demand.

The Water Needs Assessment established forecasts for Cumberland County's water demands under three different growth scenarios. Before evaluating additional water supply alternatives, it is prudent to determine if conservation can effectively reduce demand. This study investigates the extent to which demand can be reduced below the baseline forecast values in the Water Needs Assessment.

Cumberland County has no significant history of water conservation programs, but a range of viable options could lead to significant water savings. This Water Conservation Plan report identifies six potential water conservation measures local government or the utility districts could reasonably enact. The effectiveness of the proposed conservation measures is modeled using the IWR-MAIN Conservation Manager© software program. IWR-MAIN is recognized as a state of the art program for modeling water demand and conservation programs.

A detailed account of the modeling methods is presented in the Water Conservation Plan Memo (full title: *Water Conservation Plan for the Cumberland County Regional Water Supply Study*) in the addenda. This document presents results of modeling the six conservation measures, and based on these results a final water conservation plan is presented.

2. Conservation in Cumberland County

Until the past few decades, Cumberland County has always had an abundant and easily accessed water supply. As a result, there has been limited impetus to encourage conservation in the county. This limited conservation experience presents a substantial opportunity for future efforts to harvest the 'low-hanging fruit' of water conservation benefits at a relatively low cost.

Cumberland County's opportunities to conserve are typical for communities of similar size and age. Cumberland County has two primary avenues for improving water efficiency. One major opportunity for conservation is for the water utility districts to reduce water loss and other unaccounted for uses. Total unaccounted for water use averages near 20% of total produced water, with losses approaching 30 or 40% for some districts in some months. This is not unusual for utility districts of a similar size and age. Cumberland County's utility districts face additional challenges resulting from the very hilly and rocky terrain of the county. High water pressure can stress pipes, and the rocky soil can both puncture pipes and create a situation where leaks have adequate drainage to avoid detection. While Cumberland County's distribution system loss rates are not atypical, reducing losses presents a major avenue for conservation. With appropriate, proactive leak detection efforts and other loss reduction measures, Cumberland County may be able to reduce its losses to ten percent or less.

While the losses in the distribution system are primarily attributable to water suppliers, the water consumers in Cumberland County are another major source of water inefficiency. Interviews with the utility district managers indicated that the majority of residences in Cumberland County use less efficient toilets and plumbing fixtures than current industry standards. This will largely be corrected over time as residents replace older fixtures with

newer, more efficient fixtures. Accelerating this transition, however, is a major opportunity for conservation.

Between reducing inefficient water use on the part of the utility districts and water consumers, there is significant potential for conservation in Cumberland County. The following sections detail several conservation measures to take advantage of this potential.

3. Conservation Measures

Six conservation measures have been identified for analysis in developing the Cumberland County Water Conservation Plan. Each conservation measure is described in brief below. More detailed policy descriptions and modeling methods for each conservation measure are included in the Water Conservation Plan memo included in the addenda. Additionally, the six conservation measures were chosen from a larger set of possible measures based on their relevance and implementability in Cumberland County. The final water conservation plan reflects a combination of some of these measures.

3.A. Unaccounted for Water Reduction (non-leakage)

While leakage is the most commonly identified contributor to Unaccounted for Water, there are other contributing factors to UAW in Cumberland County. Foremost among these are metering errors, flushing usage, and fire fighting usage. Reducing fire fighting usage is not generally within the control of water utilities. Mains flushing is an important part of system maintenance to prevent blockages and corrosion and preserve water quality. Flushing is also necessary before new connections are opened. In large new developments, flushing loss can be tremendous, especially when the opening of new connections is staggered (requiring multiple flushing events). Finally, metering errors are likely a result of older meters. Cumberland County does not have a significant number of unmetered connections.

By addressing excessive flushing and metering errors, Cumberland County may reduce its UAW percentage. All of the utility districts have either recently replaced their meters or are in the process of doing so, but replacement programs should be repeated every 10 -15 years to ensure reductions in UAW are preserved. Reductions in flushing volumes may be achieved through a review of flushing policies, and system upgrades to convert branched distribution pipe networks to looped networks where practicable.

3.B. Leak Detection and Reduction

Leak detection is another method of reducing UAW. Cumberland County faces a range of challenges in getting leakage under control. The age of the pipes, rocky soil, and large elevation differences (and resulting high pressure) have been cited by county utility managers as major causes of leakage. Leaks occur on both mains and service lines. Current leak detection efforts in the county are primarily focused on repairing leaks when they come to the surface or when there are service complaints.

A comprehensive leak detection program in Cumberland County could include several leak detection strategies. Hiring a leak detection contractor to investigate the majority of the county’s mains and service line connections would be a good start. Listening surveys use geophones and other listening devices to find leaks and digital correlators to pinpoint leak positions. In the long term, permanently installed listening devices may be the most effective method of detecting leaks. With training, utility district staff could conduct listening surveys and use a digital correlator.

3.C. Education

Educating water consumers on the value of water and the benefits of conservation, while a valuable end in itself, can also lead to real reductions in water usage. Reductions are achieved in two primary ways: convincing water users to change their water usage habits, and affecting purchasing decisions on fixture and appliance types (and whether to replace them sooner). The water utilities in Cumberland County do not currently have any dedicated customer education programs, but they do communicate with customers through billing inserts and other methods. In 2007, the City of Crossville, Cumberland County, and the utility districts used several communication methods to publicize the drought restrictions and appropriate short-term water saving tips. A true education strategy is geared more toward long-term shifts in behavior and more permanent savings.

Several types of education programs exist, and the water utilities could develop new programs, specially tailored for Cumberland County users. In general, using a variety of education strategies (each with a defined message and goal) in combination can achieve the most robust results. Table 1 indicates three general types of educational programs, the target audience, and a description.

Table 1 - Education programs

Policy	Intended audience	Description
General advertisement	All water users	Water saving tips and information.
Targeted Messages	Commercial users, homeowners with irrigation systems, homeowners with older homes, etc.	Communicate well developed messages perhaps once a year to encourage a specific conservation action, e.g: highlight cost savings from replacing toilets, promote xeriscaping, .
Education programs	School age children and families	e.g.: Programs every 2 years for 4th and 5th graders, 9th and 10th graders
	Retirees, community associations	Short (0.5 day) programs in retirement communities, civic centers.

3.D. Pricing

While water prices are generally set to reflect the costs of production, price changes do affect water demand. The price elasticity of demand indicates the amount of change in demand due to a unit change in price. See Equation (1). An elasticity of positive one indicates that a 1% increase in price will lead to a 1% increase in demand. Price elasticity of demand for water is nearly always negative (price increases reduce demand), and is generally considered to be inelastic (in between 1 and -1, or in this case, 0 and -1). In fact, when considering water demand, it is rare to see elasticities even go beyond -0.5.

$$e = \frac{\Delta q}{\Delta p}$$

Equation 1

Where:
e is the price elasticity of water demand
Δq is the percentage change in water demand by a water user (or set of users)
Δp is the percentage change in water price

There is a wide range of economics literature examining the price elasticity of demand for various water users. Focusing on residential customers, Arbués et al. (2003)[xii] and Worthington and Hoffman (2006)[xiii] provide good reviews of a large range of economic

studies investigating price elasticity of water demand under a wide range of pricing policies. In general, the majority of the estimates of residential long term elasticity fall into the -0.05 to -0.5 range. The IWR-MAIN manual cites residential elasticity as between -0.05 and -0.35.

Several UD managers expressed the view that the water demand of Cumberland County residents is somewhat to considerably more sensitive to price changes than the average U.S. citizen. Supporting this assertion is that many of Cumberland County's residents are on fixed incomes. Residents' response to price signals is also influenced by having a monthly billing cycle in all the Cumberland County UDs. As a result, elasticities in Cumberland County are assumed to be toward the upper end of the ranges presented in the manual.

Currently, all the Cumberland County utility districts have a fixed fee for consumption up to a certain initial limit (1000 or 2000 gallons), and a fixed block rate for additional consumption above the limit. A wide range of pricing strategies are available for water utilities to meet goals as wide ranging as maintaining adequate revenues to encouraging conservation. A full discussion of the pricing options considered for the modeling of this conservation measure is contained in the Water Conservation Plan memo. Due to complexity of modeling some of the pricing methods and the limitations of IWR-MAIN, a simple pricing policy is selected. The policy is simply to enact a 30% increase in marginal water price over the base price (set equal to 1) after the base year. Since the price is measured in constant 2006 dollars, the underlying assumption is that after the initial increase, price increases at a rate exactly equal to the inflation rate (or more accurately, water consumers' own discount rate).

3.E. Water Efficiency Codes and Ordinances

One of the most effective methods to generate long term water savings over baseline estimates is to influence the water efficiency of new development. Ensuring that developers are installing efficient fixtures and appliances means that new users will have a lower water use intensity than existing users. Additionally, it is significantly easier to create standards for efficiency before new units are built than to retrofit later.

Currently, Cumberland County lacks building codes in all areas except inside the Crossville city limits. Reportedly, even within Crossville, the efficiency of fixtures is rarely examined by inspectors.

A comprehensive water efficiency code and ordinance will mandate the inspection of water fixtures, toilets, and appliances to check for their efficiency. Additional ordinances may govern the outdoor use of water at commercial and institutional properties by requiring rain sensor shut-off for irrigation systems, for example. Benefits, such as reducing the connection fee, may also be considered for developers who install ultraefficient appliances and fixtures in new properties.

3.F. Retrofit, Rebate, and Replacement Programs

Retrofit, replacement, and rebate programs are other methods to reduce the average water use factors for existing users by replacing (or providing incentives to replace) existing fixtures and appliances with more water efficient models. The key is that the transition happens at a much faster rate than it would under natural replacement.

The programs can take several forms. One approach is to simply provide inexpensive fixtures and devices such as faucet aerators, shower heads and toilet dams free of charge to users. The drawback is that the consumers do not always install them. As the Massachusetts Water Resources Authority's Steven Estes Smargiassi noted[xiv], "We discovered if you gave away devices, most of them were 'installed' in kitchen drawers – not on the bathroom or kitchen fixtures." One way to mitigate this problem is to provide free installation as well. Rebate programs provide monetary incentives for the replacement of larger water using devices,

notably toilets and clothes washers. While often expensive, rebates for toilets and clothes washers can provide greater water savings than small devices, and the transition to more efficient water uses can be more easily verified.

Cumberland County's utility districts do not currently offer any retrofit, replacement, or rebate programs. These programs may be well suited to Cumberland County, as the majority of fixtures and appliances are believed to be older models. Additionally, interviews with utility district managers and other stakeholders indicated that county residents replace these fixtures and appliances at a slightly lower rate than the nation as a whole.

4. Methods

The water savings of the six conservation measures are modeled using IWR-MAIN Conservation Manager. The Water Conservation Plan Memo discusses the modeling methods, assumptions, data collection, parameter estimates, and scenario development in much greater detail. Table 2 displays the tools used in IWR-MAIN Conservation Manager to model the effects of each of the conservation measures.

Table 2- Modeling Methods of the Six Conservation Measures

Conservation Measure	IWR-MAIN Modeling Method
A. Non-Leakage UAW Reduction	Tools→ Unmetered Fraction
B. Leakage Reduction	Tools → Unmetered Fraction
C. Education	Intensity → Enter/Build, Passive Conservation
D. Pricing	Intensity → Enter/Build (Multiplicative Model)
E. Codes and Ordinances	Tools → Passive Conservation
F. Retrofit, Rebate, Replacement	Tools → Active Conservation

5. Results

The six conservation measures cover a broad range of strategies for reducing water usage. Accordingly, the modeling results indicate important differences between the conservation measures in terms of magnitude and trends of water savings. The growth scenario also affects the relative performance of the conservation measures. While the modeling methods for each conservation measure are identical between growth scenarios, certain measures perform comparatively better or worse depending on the rate of growth. Table 3 compares the total water needs projections for the baseline and six conservation measures under the 3 growth scenarios. For each year in each growth scenario, the conservation measure with the lowest total water needs is displayed in bold type.

The results indicate some clear trends in the projected water needs under the baseline and conservation scenarios. Most notably, leakage reduction appears to lead to the most substantial reductions over the entire study period. Education programs and Codes and Ordinances follow a similar pattern of starting off with very modest savings over the baseline and substantially increasing savings over time. The retrofit programs show an opposite trend, with the most substantial savings earlier in the study period. This is potentially significant as the uncertainty in the estimates is substantially lower at shorter time horizons. Interestingly, the results of non-leakage UAW reduction programs and conservation pricing programs are quite similar even though their modes of influencing water savings are very different.

Table 3- Total Water Needs for the six Conservation Measures under the three growth scenarios

Aggressive Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.52	6.34	6.14	6.30	6.23	6.43	**6.08**
2026	8.55	8.19	**7.80**	8.04	8.16	8.20	8.15
2036	10.60	10.14	**9.59**	9.90	10.10	9.90	10.27
2046	12.17	11.64	**10.97**	11.26	11.59	11.10	11.88
2056	13.81	13.22	**12.29**	12.55	13.14	12.36	13.55

Expected Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.11	5.95	5.76	5.90	5.84	6.04	**5.67**
2026	7.64	7.32	**6.98**	7.17	7.29	7.35	7.23
2036	9.08	8.69	**8.22**	8.45	8.66	8.49	8.73
2046	10.54	10.08	**9.53**	9.73	10.04	9.63	10.23
2056	11.28	10.79	**10.07**	10.20	10.75	**10.07**	11.00

Slow Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	5.66	5.50	5.33	5.43	5.41	5.59	**5.18**
2026	6.52	6.24	**5.96**	6.05	6.23	6.26	6.06
2036	7.03	6.74	**6.39**	6.46	6.72	6.55	6.63
2046	7.66	7.33	6.96	6.96	7.31	**6.95**	7.29
2056	8.41	8.04	7.54	7.50	8.02	**7.46**	8.05

It can also be instructive to look at overall cumulative water savings over the entire study period. Figure 1 through 3 display the forecasted cumulative water savings for the three growth scenarios. The magnitude of expected savings over 50 years is rather remarkable, on the order of 5 to 15 billion gallons. Comparing the different conservation measures reveals some interesting insights on their long term behavior. Even though their overall savings are quite different, Non-Leakage UAW reduction and Leak reduction demonstrate similar shapes due to their common modeling method. The conservation pricing policy, because only one major price change occurs, displays a linear trend after 2016. The effectiveness of the retrofits is very evident at first, but over time the slope of the cumulative savings line actually decreases. Finally, the Codes and Ordinances and Education programs clearly increase their cumulative savings as growth increases in the more distant future.

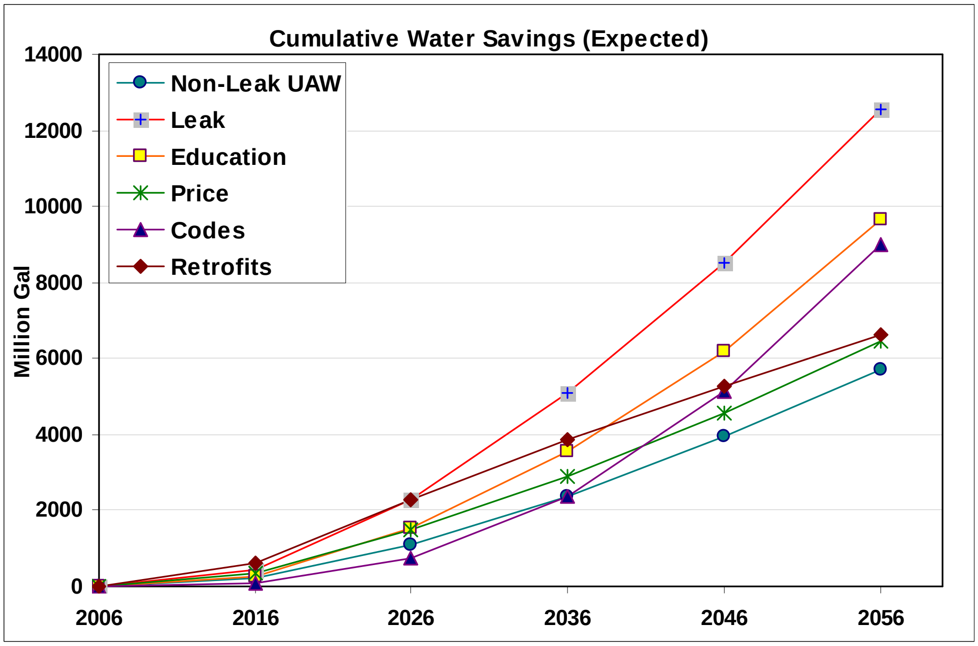

Figure 1 - Cumulative Water Savings for the Six Conservation Measures under the Expected Growth Scenario

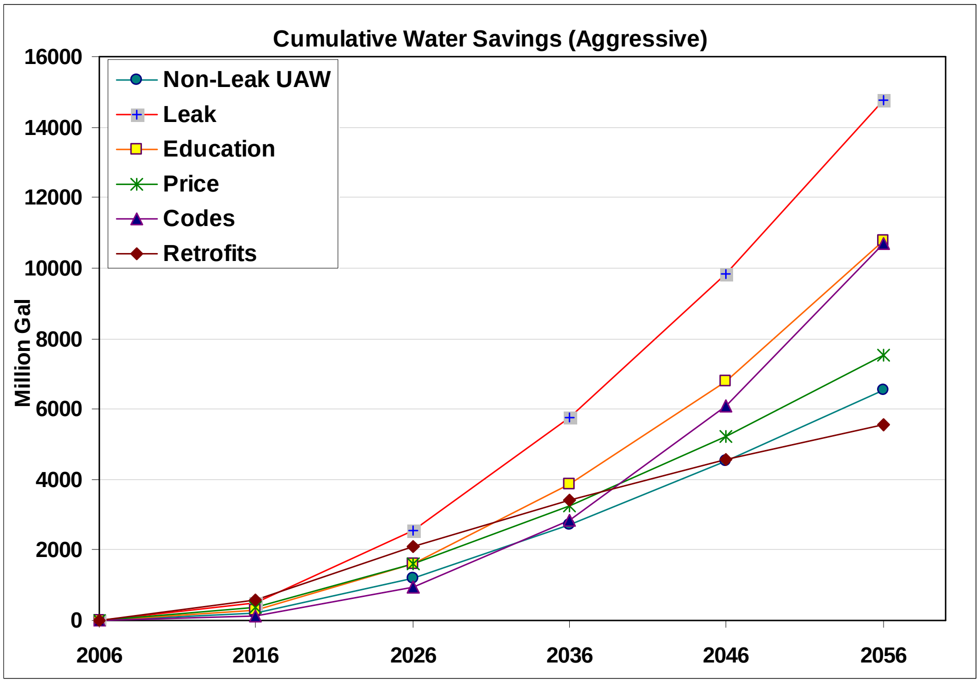

Figure 2 - Cumulative Water Savings for the Six Conservation Measures under the Aggressive Growth Scenario

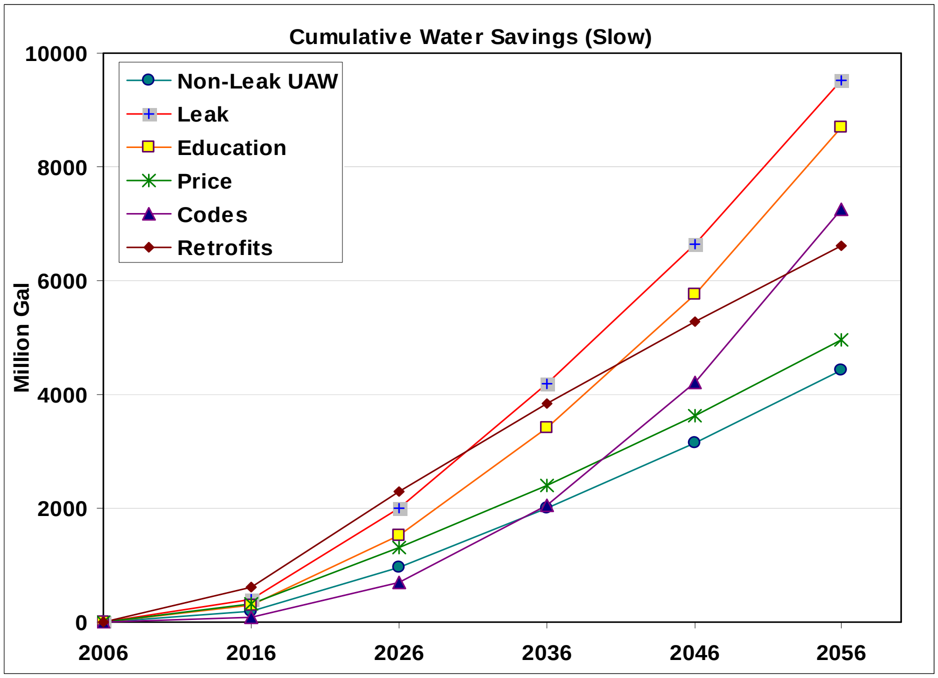

Figure 3 - Cumulative Water Savings for the Six Conservation Measures under the Slow Growth Scenario

6. Pros, Cons and Economic Benefits

The previous section investigated the comparative water savings resulting from each of the conservation measures. While the water savings are perhaps the most important consideration, several other considerations necessarily influence whether the measure should be implemented. These considerations include implementability, public acceptance, cost, uncertainty in the projections, compounding and corollary effects, and finally, economic benefits.

Each of the conservation measures has its own merits and drawbacks, and any comprehensive water conservation plan will likely have to include several conservation measures. The conservation measures which target unaccounted for water, non-leakage UAW reduction and leak detection, have a strong benefit in that they save water that was not producing revenue. Therefore, any water savings generated by these measures lead to direct economic savings. These two measures are also less complicated to implement because they can be put into place solely based on the choice of the utility districts. The drawback of both measures is their upfront cost, which can be significant, especially when pipes must be excavated for repair and replacement. The savings resulting from stopping leaks and other non-revenue producing water, however, often lead to very short payback periods.

Rapid adjustments in price carry their own pros and cons. While periodic, small water rate increases are necessary for maintaining capital investments and keeping pace with inflation, larger rate increases can be a much stronger impetus to conserve. Since water is an inelastic good, rate increases nearly always lead to smaller proportional reductions in consumption than the increase in price. As a result, water savings may be marginal, though the utilities benefit from greater total revenues. The obvious drawback to increasing rates is that rate increases are unpopular and may meet significant resistance from ratepayers. Effective conservation pricing and tiered pricing may be an alternative solution that could provide

benefits with less opposition. Analyzing more complex pricing schemes is beyond the scope of this study, but could be researched further.

Education programs have a great number of benefits, but suffer from a great deal of uncertainty about their actual effectiveness. Educating consumers about methods, benefits, and importance of water conservation can lead to changes in behavior that may save water in the short and long term. Short term changes may be achieved by behavioral changes, while long term shifts in water use may result from consumers making more informed choices when replacing toilets, washing machines, etc. Educational programs are generally not very expensive to implement, but can be ineffective without dedication to the message and sustained commitment to program implementation. Traditionally, education programs have been viewed as effective in reducing water use, but quantifying their actual water savings and economic benefits relative to investment remains difficult.

Strict water conservation provisions in building codes and public ordinances can lead to a gradual but significant reduction in potential future water use. The primary benefit of the codes is the significant long term savings, but the related drawback is that they do virtually nothing to reduce existing consumption except in the case of major renovations. Passing sufficiently comprehensive codes requires a great deal of political cooperation to implement. With the exceptions of builders and plumbers, there are generally few costs to existing stakeholders. Managing an effective inspection and enforcement program requires adding several inspectors and support staff to the local government payroll (or hiring contractors to fulfill the roles), which can be a significant long term cost.

7. Water Conservation Plan

It appears from the analysis of alternative conservation measures that Cumberland County has significant opportunities for reducing water consumption, especially in the long run. A combination of four of the identified conservation measures may provide very significant conservation savings over the baseline projections. GKY recommends the following Water Conservation Plan as best suited to meeting Cumberland County's long term water management goals. In combination, institute the following conservation measures, described previously in this report:

A. Non-Leakage UAW Reduction
B. Leakage Reduction
C. Education Programs
E. Codes and Ordinances

Modeling the Water Conservation Plan

Modeling the potential savings due to the water conservation plan is a fairly straightforward combination of the 4 identified conservation measures. The modeling methods have limited overlap. Measures A and B are both modeled by setting the UAW percentage with the unmetered/unaccounted tool. The appropriate UAW percentage is simply determined by the summing the reduction percentages under the two programs.

Codes and Ordinances are modeled in exactly the same manner as before. The Education conservation program is modeled in IWR-MAIN using the exact same intensity reductions as described in the Draft Water Conservation Plan memo. However, the passive conservation portion of the education programs is slightly affected. The rate of efficiency class shift is set by whichever rate is higher between the education and codes and ordinances conservation measures instead of adding the efficiency class shift percentages. So if 5% of units per year shift efficiency classes under the codes and ordinances conservation measure, and 3% of units per year shift with education, the total water conservation plan rate is 5% and not 8%.

Results

The results of modeling clearly demonstrate that impressive water savings are possible if an ambitious water savings plan is put into place. Figure 4 shows the baseline forecasts for the three growth scenarios (solid line), and the corresponding forecasts if the Water Conservation Plan is fully implemented (dashed lines).

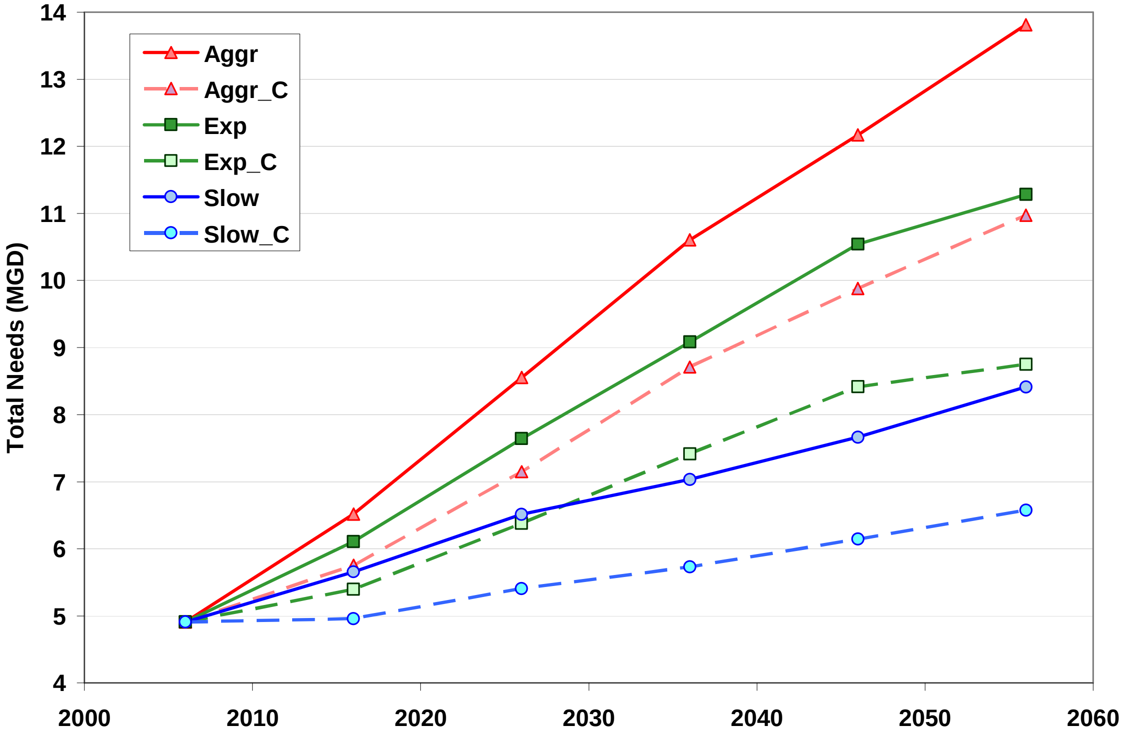

Figure 4 - Forecasted Water Needs for three growth scenarios, with and without the conservation plan

The results of the forecasts show the potentially profound effect of conservation. In general, the conservation plan can save as much as 30% over the baseline scenario. About half of this reduction comes from reduction of Unaccounted for Water alone. Over the long term, the reductions are as significant as dropping one growth scenario. That is, water use for the aggressive scenario with conservation is roughly equal to water use for the expected scenario without it. Even with conservation, water use in the county stands to increase significantly. However, under the slow growth scenario, water use remains virtually flat for the first 10 years when the conservation plan is put into place.

There is one caveat in interpreting the results of the water conservation plan. In analyzing all of the conservation measures individually, there was never a situation in which both the actual consumption and UAW rates were changed simultaneously. The water conservation plan does change both at once. Since the UAW is expressed (and modeled) as a percentage of overall demand, reducing consumption reduces UAW by default. However, the actual physical processes that cause leakage are not necessarily dependent on demand. Therefore, especially in situations where both the consumption and UAW are reduced simultaneously, the water savings may be overestimated. The modeling limitations of IWR-MAIN make it difficult to easily ameliorate this problem.

The effect of this limitation can be discerned when one looks at the results by subsector (including UAW as a subsector). Table 4 displays the results by subsector, comparing the baseline projection and water conservation plan for the three growth scenarios. It is quite

evident that a large portion of the savings comes from reductions in UAW. Under the Water Conservation Plan, UAW can be cut to as much two-thirds below the baseline forecasts. For example, under the aggressive scenario, the baseline UAW estimate in 2050 is 3.05 MGD, but with the water conservation plan, it falls to 0.99. Other subsectors see only about a 5 - 10% reduction over the baseline.

Table 4 – Total Water Needs by Subsector under the Baseline and Water Conservation Plan Forecasts(MGD)

Scenario	Forecast	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	CMC	0.07	0.10	0.13	0.17	0.20	0.23
		NonRES	1.49	1.87	2.11	2.32	2.52	2.71
		RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
		UAW	*1.04*	*1.39*	*1.85*	*2.32*	*2.68*	*3.05*
	Water Conservation Plan	CMC	0.07	0.10	0.13	0.16	0.19	0.22
		NonRES	1.49	1.84	2.06	2.25	2.41	2.56
		RES_PS	2.31	2.99	4.20	5.43	6.29	7.20
		UAW	*1.04*	*0.82*	*0.76*	*0.87*	*0.99*	*0.99*
Expected	Baseline	CMC	0.07	0.09	0.12	0.14	0.16	0.18
		NonRES	1.49	1.78	2.04	2.18	2.34	2.42
		RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
		UAW	*1.04*	*1.30*	*1.64*	*1.97*	*2.31*	*2.48*
	Water Conservation Plan	CMC	0.07	0.09	0.11	0.14	0.16	0.17
		NonRES	1.49	1.74	1.98	2.10	2.21	2.26
		RES_PS	2.31	2.79	3.61	4.44	5.20	5.53
		UAW	*1.04*	*0.77*	*0.68*	*0.74*	*0.84*	*0.79*
Slow	Baseline	CMC	0.07	0.08	0.09	0.10	0.11	0.12
		NonRES	1.49	1.68	1.91	1.96	2.02	2.08
		RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
		UAW	*1.04*	*1.20*	*1.38*	*1.50*	*1.65*	*1.82*
	Water Conservation Plan	CMC	0.07	0.08	0.09	0.10	0.10	0.11
		NonRES	1.49	1.64	1.85	1.88	1.91	1.94
		RES_PS	2.31	2.53	2.89	3.18	3.52	3.93
		UAW	*1.04*	*0.71*	*0.57*	*0.57*	*0.61*	*0.59*

While the average water needs are important in the evaluation of long term water supply planning, the peak day demand is important for the design of certain system components. As in the Water Needs Assessment, a peak factor of 1.35 is assumed. This is applied only to the consumption values, and UAW is added afterwards. Table 5 displays the peak day water needs for the baseline forecast and water conservation plan.

Table 5 – Peak Demand Values for the Baseline Forecast and Water Conservation Plan

Scenario	Program	Data	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	Consumption	3.87	5.13	6.70	8.28	9.49	10.76
		UAW	1.04	1.39	1.85	2.32	2.68	3.05
		PEAK	*6.26*	*8.31*	*10.90*	*13.50*	*15.49*	*17.57*
	Water Conservation Plan	Consumption	3.87	4.93	6.39	7.84	8.89	9.98
		UAW	1.04	0.82	0.76	0.87	0.99	0.99
		PEAK	*6.26*	*7.48*	*9.39*	*11.46*	*12.99*	*14.47*
Expected	Baseline	Consumption	3.87	4.81	6.00	7.11	8.24	8.81
		UAW	1.04	1.30	1.64	1.97	2.31	2.48
		PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
	Water Conservation Plan	Consumption	3.87	4.62	5.70	6.67	7.57	7.96
		UAW	1.04	0.77	0.68	0.74	0.84	0.79
		PEAK	*6.26*	*7.02*	*8.37*	*9.75*	*11.06*	*11.54*
Slow	Baseline	Consumption	3.87	4.45	5.13	5.53	6.02	6.59
		UAW	1.04	1.20	1.38	1.50	1.65	1.82
		PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*
	Water Conservation Plan	Consumption	3.87	4.25	4.84	5.16	5.53	5.98
		UAW	1.04	0.71	0.57	0.57	0.61	0.59
		PEAK	*6.26*	*6.45*	*7.10*	*7.54*	*8.08*	*8.67*

Analysis of the Water Conservation Plan

These four measures are the most beneficial actions Cumberland County can take for several reasons. First, the combination of measures strikes a balance between short term and long term water savings. Measures A and B (Non-leak UAW reduction and Leakage Reduction), especially when implemented in combination, provide immediate reductions in water usage. Measures C and E (Education and Codes and Ordinances) lead to much more significant savings in the long term than the short term.

These four conservation measures are also very feasible to implement. In fact, most of the measures are currently in the process of planning or implementation, though not quite to the extent described in this report. All of the utility districts have recently replaced or are replacing meters throughout their service areas. All of the utility districts claim to be reducing system leakage wherever they can, and one has even contracted leak detection services. The City of Crossville already has plumbing codes in place, and Cumberland County appears to be actively considering implementing them. None of the utility districts currently has dedicated education programs, but there are many resources available through the American Waterworks Association, the Environmental Protection Agency, various state environmental departments, private companies, and other sources.

Especially if the utility districts and county officials cooperate, the conservation measures presented here are very cost effective. Education programs are relatively low in cost. Implementing codes and ordinances has few upfront costs, but some long term enforcement and administrative costs. Measures A and B can be costly, but are generally worthwhile investments as the water savings directly reduce costs without reducing revenues. Furthermore, if leak detection services are contracted for the entire county, and leak detection

equipment is shared, costs can be reduced. Finally, leak detection costs are dropping as technology improves.

The other benefit of this plan is that it should be widely accepted by the majority of the stakeholders. Reducing unaccounted for water, and more broadly, establishing water accountability through better system information, better metering, and leak detection is a crucial step toward public acceptance of other conservation actions. Establishing building codes (and water efficiency standards) is generally acceptable as it has many positive impacts on quality of life in the county. Educational programs, as long as they are well managed, are generally accepted. Price increases for the purpose of conservation, however, are usually unpopular. Additionally, certain stakeholders have already expressed a mild opposition to retrofit and rebate programs as an unfair use of ratepayer or tax dollars.

Finally, implementing the proposed conservation measures leaves open the possibility for future conservation measures not described here. In the event that the proposed plan does not meet conservation targets, or growth occurs at a faster than projected rate, other conservation measures can be implemented. Measures A and B will lead to a much better understanding of the water balance throughout the distribution system and identify opportunities for further conservation. Establishing a framework for education programs leads to better communication between utilities, ratepayers, and other stakeholders, which could make future actions more effective. Strict efficiency codes help to create a local market for more efficient fixtures and appliances. Additionally, once codes are adopted, a legal framework is established for future amendments and ordinances.

While the conservation measures set forth are fairly common and feasible to implement, realizing the projected water conservation savings requires full engagement by the stakeholders and a sustained commitment to the conservation programs. Cumberland County has significant potential for conservation in the short and medium term as utilities reduce their water loss and customers increase their water use efficiency. In the long term, however, real shifts in behavior and in efficiency standards will need to be firmly established to see continued progress in reducing water use. It should be noted that even with significant conservation, Cumberland County's water use will almost certainly rise over the next 50 years. The rate of growth in water needs, however, can be slowed by the adoption of an ambitious conservation plan.

8. Conclusion

Cumberland County faces a challenge in meeting future water needs as the county grows. Continued rapid growth and the chance of future droughts like the one in 2007 highlight the importance of a long term solution to meeting water needs. Numerous proposals exist for increasing water supplies, but this study instead examines the potential for reducing demand.

Six feasible conservation measures have been presented as methods to effectively reduce water demand, inefficient water use, and water loss. Cumberland County has excellent potential for increasing water efficiency, both in the distribution system and on the part of water users. A comprehensive water plan can take advantage of the potential water savings, and almost certainly postpone the need for new water sources.

This Water Conservation Plan outlines a series of measures which can significantly slow the growth of Cumberland's water needs while allowing the county to grow. While the conservation targets are certainly achievable, it will take commitment and cooperation on the parts of numerous stakeholders.

9. References

[ix] United States Army Corps of Engineers and Ogden Environmental and Energy Services, Inc. *Cumberland County Regional Water Supply Preliminary Engineering Report.* Dec. 1998.

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[xiii] Worthington, A.C. and M. Hoffman. (2006). A state of the art review of residential water demand modelling, University of Wollongong, School of Accounting and Finance Working Paper Series No. 06/27, 2006. <http://ro.uow.edu.au/commpapers/301>

[xiv] Brzozowski, Carol. (2008). “The Secrets of Their Success.” *Water Efficiency*. January-February 2008. pgs 10- 12.

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Cumberland County Regional Water Supply Study

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Water Needs Assessment and

Water Conservation Plan

Final Report

Cumberland County Regional Water Supply Study

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Water Conservation Plan

March, 2009

Table of Contents

Water Needs Assessment

Water Conservation Plan

List of Tables

Water Needs Assessment

Water Conservation Plan

List of Figures

Water Needs Assessment

Water Conservation Plan

Addenda

Three previous documents written by GKY provide added reference with regard to methods and full results for the Water Needs Assessment and Water Conservation Plan.

1. *Land use assumptions for Phase II of the Cumberland County Regional Water Supply Study*. Memorandum. December 13, 2006. by Karsten Sedmera and Stuart Stein, GKY & Associates, Inc.

2. *Water Needs Assessment for the Cumberland County Regional Water Supply Study*. Memorandum. March 14, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

3. *Water Conservation Plan for the Cumberland County Regional Water Supply Study*. Memorandum. June 28, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

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Water Needs Assessment

1. Introduction

The Cumberland County Regional Water Supply Study was established by an agreement between the U.S. Army Corps of Engineers (Nashville District) and the City of Crossville, Tennessee. The Cumberland County Regional Water Supply Study has the goal of identifying a long term solution to Cumberland County's water supply needs, and carrying forward an Environmental Impact Statement investigating potential alternatives for the long term supply solution. As part of the Water Supply Study, GKY & Associates has been contracted to perform a Water Needs Assessment to estimate future demand at 10 year increments for the next 50 years.

This Water Needs Assessment builds, in sequence, a land use development analysis, population growth scenarios, and modeling of future water demands. This study represents the first in-depth analysis taking into account the rapid growth in the early 2000s.

Indeed, Cumberland County, located on the Cumberland Plateau of East Central Tennessee, faces a growing problem in meeting the ever increasing water demand in a rapidly growing county. Cumberland County has been experiencing rapid growth in part due to its considerable success in attracting retirees to live in the county. In severe droughts, this growth is already straining water supplies. As growth continues, it is likely a new water source may need to be developed. This Water Needs Assessment investigates the future demand for water under a range of growth scenarios to project how much water will be needed in the future.

The first step in determining the future water needs is to analyze the land use patterns in Cumberland County.

2. Land Use Development

One of the important steps in predicting future water demand in the next 50 years is the difficult task of predicting future population growth and land use patterns in Cumberland County, TN. Land use patterns assist in predicting population growth by making it possible to assess how much land is available for growth, and they assist in demand estimation by generating a relative breakdown of the types of water consumers in the study area. Cumberland County, however, does not have any formal land use plan (i.e., zoning) in place to control (or predict) local patterns of growth. While there are a few studies that predict population growth for the County as a whole, none of them appear to focus on local growth rates or detailed land use patterns. Figure 1 displays the land use in Cumberland County according to the 2006 tax assessor's database. The land use patterns and the state of development of parcels of various types can provide clues to future development.

Cumberland County was one of ten counties recently selected by the Tennessee Department of Economic and Community Development to participate in a pilot study called "Retire Tennessee" that is designed to promote Tennessee as a great place for retirees to call home. Two of the predominantly residential areas, Lake Tansi and Fairfield Glade represent two established communities (not official cities) that attract retirees by offering small lots, convenient maintenance agreements, and various community club amenities. The three cities in the area – Crossville (the County seat), Pleasant Hill, and Crab Orchard – have similar attractions but more diverse development patterns. Crossville, however, has more dense residential communities than either Pleasant Hill or Crab Orchard. The remainder of the County is fairly rural with scattered residential development along major roads. Two related communities called Cumberland Cove and Cumberland Lakes (henceforth called Cumberland

Cove), which boast large lots and rustic "dream" homes, form a new development area where rural land is rapidly shifting into denser residential development.

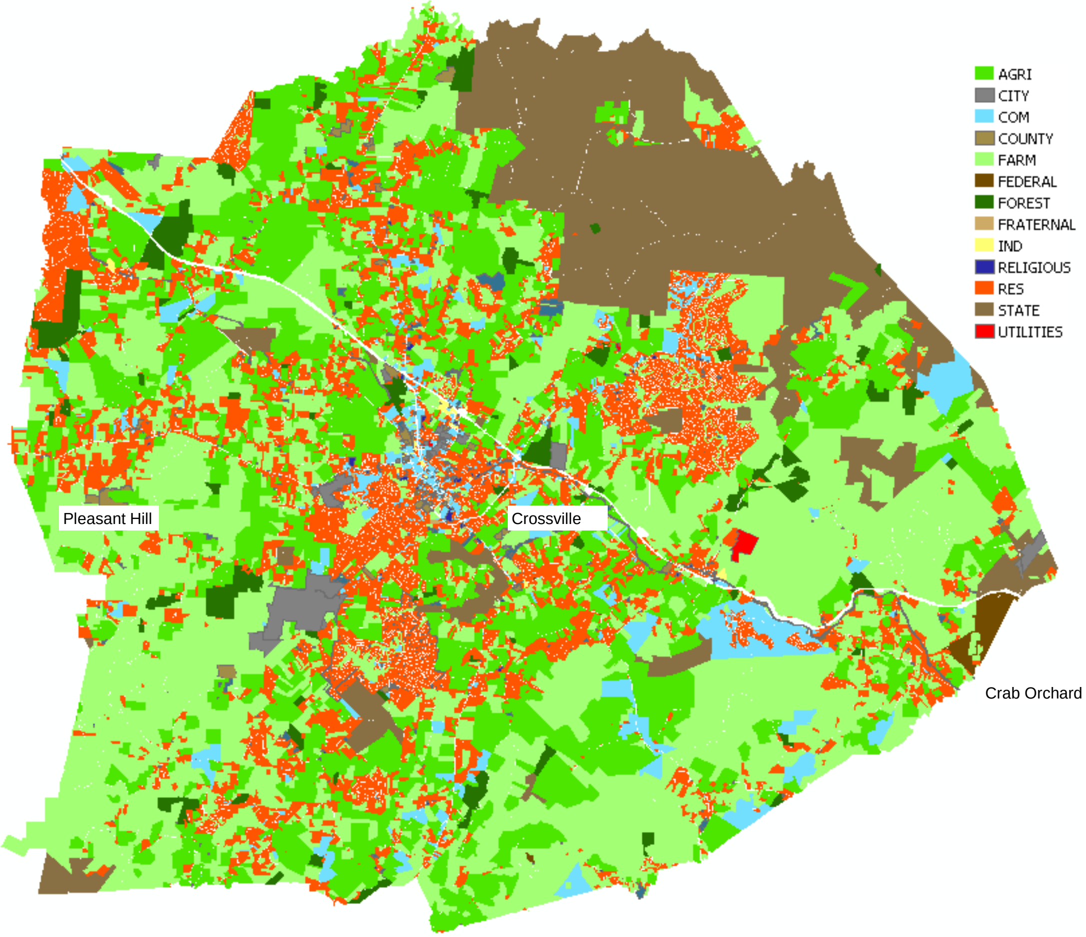

Figure 1 – Land Uses of Cumberland County according to 2006 Tax Assessor's Parcel Data

The tax assessor's database classifies each parcel into one of 12 land use categories (indicated on the map legend in Figure 1). A few clear patterns emerge from examining Figure 1. The majority of the county's land area is dominated by agricultural and farm land. The majority of residential development appears in four or five clusters. The center of the map shows the advanced development around the City of Crossville, including a dense core of commercial and residential development. There is also a large, state-owned wildlife preserve in the northeast corner of the County, which has almost no development in or immediately surrounding it. The land use pattern elsewhere in the county, however, is remarkably similar.

The database also lists the assessed land value and improvement value for each parcel. Thus any parcel with an improvement value greater than zero has been developed. For the purpose of estimating population density, only developed parcels that are classified as residential, farm, agricultural, or forest are likely to have homes on them. A few of the developed parcels classified as farm have improvement values reflecting recreational (e.g., golf resorts) or farm buildings, but most of them are residential lots with over 15 acres. Agricultural or forest parcels are "farms" that qualify for tax breaks under the TN Greenbelt program.

In order to evaluate the development potential in Cumberland County, the characteristics of the parcels (e.g. development, land value, lot size, and improvement value) were analyzed.

Figure 2 highlights the distribution of developed and undeveloped parcels of primarily privately owned residential and commercial parcels.

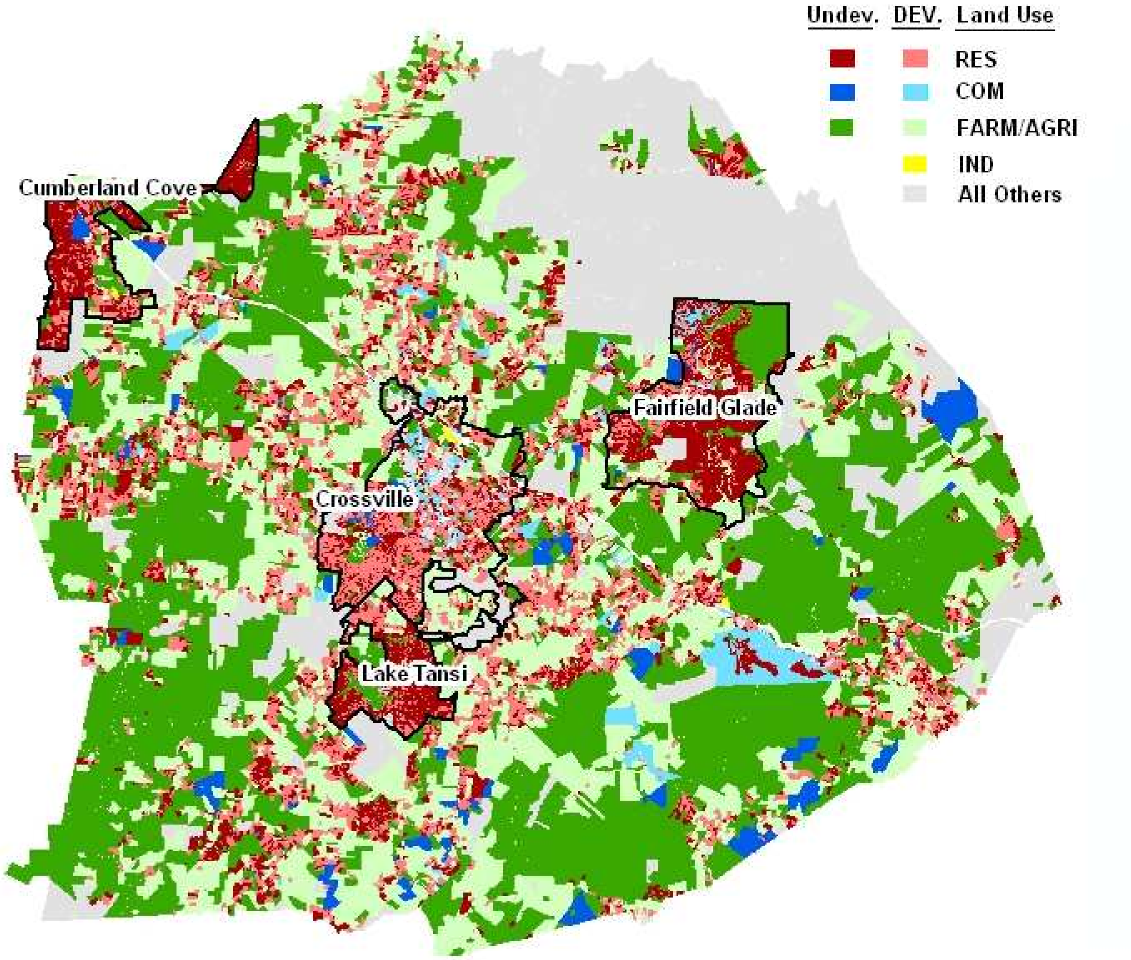

Figure 2 - Development Map of Cumberland County Showing Developed and Undeveloped Residential (RES), Commercial (COM), Industrial (IND), and Agricultural and Farm (FARM/AGRI) Parcels

Figure 2 indicates the undeveloped residential parcels (dark red) show an even clearer pattern than in Figure 1. It is evident that the dense residential communities generally cluster around Crossville, Fairfield Glade, Lake Tansi, and the Cumberland Cove area (which includes Cumberland Lakes). Furthermore, of these four regions, the latter three contain 69% of the undeveloped residential parcels in Cumberland County. Interestingly, the undeveloped commercial parcels are well distributed throughout the county.

Based on the land use analysis five study regions are selected for population and water use projections. Their geographic extents are shown in Figure 3. It should be noted that the boundaries reflect development patterns more than established political boundaries.

- City of Crossville
- Cumberland Cove (including Cumberland Lakes)
- Fairfield Glade
- Lake Tansi
- Remainder of the County

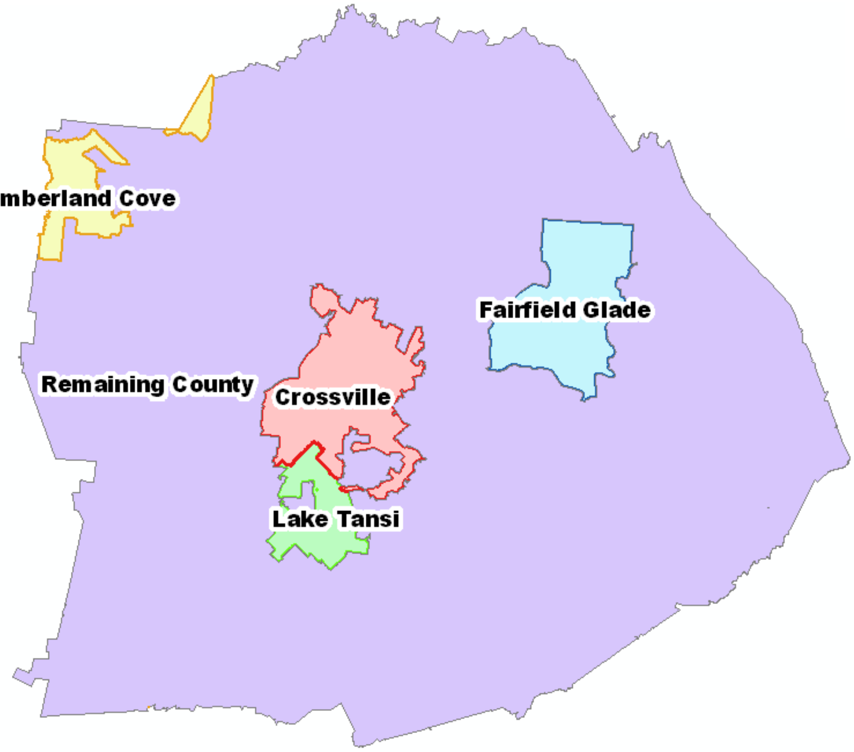

Figure 3 – Study Areas in Cumberland County

Further analysis of the parcels yielded some other general information about land use in Cumberland County that are useful for making population and water use projections. A few of the more interesting results are as follows:

- 90% of parcels in the County are residential
- 6% are farm/agricultural/forest,
- 37% of the residential parcels are developed,
- 57% of the farm/agricultural/forest parcels are developed, and
- 83.7% of the land area is residential/farm/agricultural/forest.
- The undeveloped residential parcels are, on average, half as large as the developed ones (0.92 vs 1.93 acres)

3. Growth Scenarios

The land use analysis establishes the general bounds on growth, and identifies the ultimate growth potential of the five study areas named in Section 2. Following the land use analysis, projections of the expected population growth in Cumberland County must be made in order to forecast water needs. Population forecasting is inherently uncertain, and becomes more so the further the time horizon of the forecast extends. In order to treat some of this uncertainty in a more concrete fashion, three distinct growth scenarios are carried through the remaining forecasting and modeling. They include the Slow, Expected, and Aggressive growth scenarios. The forecasts include population projections every 10 years starting in 2006 and ending in 2056. The Land Use Memo (full title: *Land use assumptions for Phase II of the*

Cumberland County Regional Water Supply Study), included in the addenda, details the methods by which the projections were made.

The growth scenarios all utilize the same starting values, and differ primarily in the specified growth rates for each ten year period. The growth rates also vary by study area. The percentage rate of growth reflects historical data, expert judgment from relevant stakeholders in the County, and other important factors (such as lack of sewer connection). Figure 4 displays the countywide population projections under the three population scenarios, as well as projections from two other studies. Note that the countywide projections are a sum of predictions for the individual study areas, each of which has independent growth projections and saturation points.

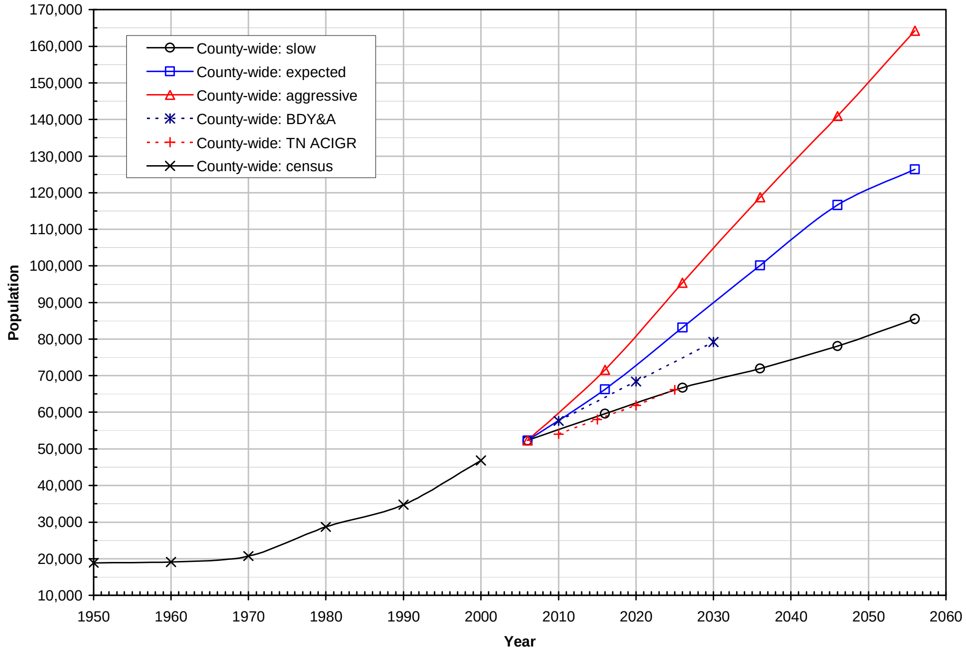

Figure 4- Population projections for Cumberland County. The three growth scenarios are displayed, as well as projections from two other studies (BDY & A 2002[i]; TN ACIGR[ii])

The population projections in fact show a wide range of variation among the growth scenarios. The range of population projections easily encompass the variability in the previous population projections, with the Slow growth scenario comparing favorably with the Tennessee Advisory Commission on Intergovernmental Relations' (TN ACIGR) forecast, and the Expected scenario a little higher than the Breedlove, Dennis, Young and Associates (BDY&A) forecast. The Aggressive scenario allows for substantial growth, but we note that even after 50 years, the projection does not begin an increasingly rapid growth phase as is often the case with simple exponential growth models.

Once the population is forecasted, it can be used to calculate projections of other relevant variables for estimating water usage. Namely, for each study area, the number of households and the number of employees must be forecast. By using historical data and stakeholder judgment, the future population per household ratio and the population per employee ratio were estimated for each forecast year. Dividing the projected populations by these factors yields the estimates of households and employees in Table 1.

Table 1 – Countywide Projections of Population, Households, and Employment for Cumberland County

Forecast Variable	Scenario	2006	2016	2026	2036	2046	2056
Population	*Slow*	*52,306*	*59,620*	*66,732*	*71,949*	*78,103*	*85,509*
	Expected	*52,306*	*66,288*	*83,157*	*100,163*	*116,643*	*126,373*
	Aggressive	*52,306*	*71,598*	*95,366*	*118,783*	*140,958*	*164,223*
Households	*Slow*	*23,345*	*27,622*	*31,990*	*35,323*	*39,294*	*44,144*
	Expected	*23,345*	*30,588*	*39,724*	*49,404*	*58,980*	*63,664*
	Aggressive	*23,345*	*33,106*	*45,772*	*59,252*	*69,006*	*79,369*
Employees	*Slow*	*25,000*	*29,083*	*33,200*	*36,522*	*40,259*	*44,305*
	Expected	*25,000*	*32,336*	*41,371*	*50,844*	*60,125*	*65,478*
	Aggressive	*25,000*	*34,926*	*47,446*	*60,296*	*72,659*	*85,090*

4. Water Needs Assessment Methods

Planning and Management Consultants, Ltd.'s IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as state-of-the-art, industry standard water demand forecasting software packages. IWR-MAIN was used as a tool to compute projected water use based on assumptions about the county's growth and water use factors. The IWR-MAIN user's manual[iii] explains in detail the structure of the model and the precise definitions of the terminology used. Where possible, we strive to use the correct IWR-MAIN terminology in describing the construction of the Cumberland water demand projection.

At the heart of the IWR-MAIN model is the usage model in Equation 1.

$$\boxed{\begin{array}{c}\text{Demand}\\ Q\end{array}} = \boxed{\begin{array}{c}\text{Counting Unit}\\ N\end{array}} \times \boxed{\begin{array}{c}\text{Use Factor}\\ q\end{array}}$$

Equation 1.

In short, the demand is determined by multiplying some counting unit by a water use factor. This model determines the demand in a given time period, in a given subsector, in a given study area. A *subsector* is the base organizational unit for which water demand is projected (e.g., the residential or commercial subsector). Each subsector has its own associated *counting unit*, which is a measure of subsector size that has a strong influence on water usage (population, households, or employees, for instance). The *use factor* is simply the volumetric demand for water per counting unit (gallons of water per capita per day, per house per day, etc) in a given time period. Thus, a water demand forecast requires projecting (at a minimum) how the counting units and use factors change over time.

The total county water use in a given time period is simply a sum of the consumption for each subsector plus any leakage or other non-consumptive use. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different regions of the study universe have distinct characteristics, the study can be broken down into *study areas*, each with their own group of subsectors and usage models. In this case, the study universe encompasses all of Cumberland County.

With respect to Cumberland County, the study areas have already been identified in Section 2. For each study area, two sectors were assumed: residential and non-residential (encompassing commercial, industrial, and institutional uses). Residential water use forecasts are computed using the forecasted number of housing units as the counting unit. The non-residential sector utilizes number of employees as the counting unit. The City of Crossville study area has an

additional subsector to model the water usage of Cumberland Medical Center, whose associated counting unit is the total population of Cumberland County.

Water Use Factors

Forecasting the future values of the counting units accounts for half of the necessary inputs in (1). The other half of the inputs comprises the water usage rates. IWR-MAIN's Forecast Manager and Conservation Manager offer a range of forecasting models to estimate future water use factors. Many of the methods are econometric methods that allow using explanatory variables to build a predictive model for the use factors. Among the explanatory variables that are commonly found to be associated with water use are income, housing density, persons per household, marginal price, average daily maximum temperature, precipitation, and cooling degree days. An extensive analysis of the water usage records and available data on potential explanatory variables determined that the predictive models were not appropriate for this study. It should be noted that future needs assessments should reconsider this decision because a few more years of high-quality water usage data (including sector breakdowns) may make these more complex models viable.

Without these models, IWR-MAIN provides two primary options for calculating use factors. The first, contained within IWR-MAIN Forecast Manager, is to simply use constant use factors calculated based on the number of counting units and the base year use. The second, which requires using IWR-MAIN Conservation Manager, is to develop end use models for each subsector. Each end use has its own use factor, and the sum of the use factors for each subsector is the overall use factor for this sector. This approach is more flexible than the constant use model, though it can be made equivalent through correct application of parameters in the model.

The chosen model is the end use model, mainly due to the fact that Conservation Manager will be used to evaluate the effectiveness of conservation measures in the water conservation plan. The added benefit to using the end use model in Conservation Manager is that it is possible to define end uses on three levels of water use efficiency and shifts between them over time. This feature allows incorporating natural, market based changes in water use efficiency that result from greater average efficiency of water using fixtures and appliances over time.

When employing the end use model, it is important to have an accurate base-year water usage estimate. This water demand projection uses two seasons, so monthly estimates of base year use are necessary. The summer season includes June, July, August, and September, and the Winter season includes the rest of the year. Water use is assumed to be constant for all months within a given season.

Residential water usage factors are based on monthly residential water consumption data from the South Cumberland and Crab Orchard Utility Districts. Both user districts had acceptable monthly records of residential water consumption and the associated number of customers (households). Since the counting unit for the residential sector is the household, the water use factor is expressed in terms of gallons per day per household (gpd/hhld). The S. Cumberland and Crab Orchard data yielded annual averages of 119.7 and 118.9 gpd/hhld, respectively. Lake Tansi is almost completely encompassed in the S. Cumberland district, and Fairfield Glade is contained within the Crab Orchard district, but the rest of the study areas still need water use factors. For the sake of simplicity, and to provide a conservative estimate of demand, the rest of the study areas are simply assigned the higher S. Cumberland water use factors.

Estimating nonresidential demand is somewhat more complicated than estimating residential demand, especially in terms of disaggregating countywide demand among the study areas. As mentioned before, future employment projections are based on each study area's population

and a countywide population to employee ratio. Since Crossville's commercial development is not distributed exactly the same as residential development, it is inevitable there will be some error in the geographic distribution of commercial water demand. Without zoning though, it seems at least reasonable that future commercial development will occur near growing areas with concentrated residential development. Thus, it is likely much of the commercial development will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

The methods for generating the water use rates for the commercial sector are described in much more detail in the Needs Assessment Memo in the addenda. In a general sense, the use rates for the commercial sector were determined from actual usage records from the utility districts and then spatially disaggregated. The disaggregation was performed in GIS by determining the location of commercial and industrial parcels in the parcels database with respect to the boundaries of the study areas and the utility districts.

Passive Conservation

One major source of error in many forecasts of future water use is the failure to consider the effect of more water efficient technology. Since the Federal Energy Policy Act of 1992, U.S. manufacturers have been required to meet minimum water efficiency standards for plumbing fixtures and toilets. Since that time, manufacturers have gone well beyond the minimum standards as a way to stay competitive. The mode of change effected by the availability of more efficient technology is called passive conservation, whereby consumers conserve just by replacing their older fixtures with more efficient ones when they need to be replaced. New construction also takes advantage of the more efficient technology by default.

The average potential savings associated with more efficient appliances were determined from the AWWA's 1999 *Residential end uses of water* [iv]report. The average replacement rate was determined from the National Association of Home Builders/ Bank of America *Study of the Life Expectancy of Home Components*[v]. Though the consumption-weighted average replacement rate for all water using home components is approximately 6.5%, a more conservative rate of 5% was assumed. This is equivalent to a 20 year lifetime for many of these components. The forecasts take these shifts into account using the passive conservation tool in IWR-MAIN Conservation Manager.

The effect of this savings is a very slight decrease in the per unit water use rate over time. Though counterintuitive for a growing county, this makes sense in Cumberland County for several reasons. Firstly, as explained previously, no credible predictive models can be developed with available data. Secondly, the land use analysis demonstrated that the average area of the undeveloped residential and commercial parcels in the county is significantly smaller than the developed parcels meaning that outdoor water use will rise slower than the population growth rate. Thirdly, as more retirees move to the county, the number of people per household will continue to fall, meaning that per household indoor use rate should not increase. Finally, technological advances in manufacturing of toilets, dishwashers, and other water using appliances will tend to lower water usage as older units are replaced with more efficient ones. This conservation savings due to technology, while slight was considered necessary for inclusion in the model because of the long study period.

Unaccounted for Water

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental water main breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each of the study areas, the Unmetered/Unaccounted tool sets the year-by-year UAW percentage. (IWR-MAIN restricts the percentage to a constant value for each year, and only whole percentages are permitted.)

Previous water demand studies of Cumberland County have used a wide range of methods to model UAW. Breedlove, Dennis, Young & Associates' (BDY) 2002 *Cumberland County Water Supply Needs Assessment* selects a target loss percentage of 10% as a worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[vi] prepared by the Corps and Ogden Environmental and Energy Services, Inc. also estimated 10% UAW on the basis of non-specified estimates by the Cumberland Utility Districts.

In this study, UAW estimates for the five study areas are based on actual data from the UDs. Perhaps in response to the previous studies, the UDs have begun collecting more detailed statistics on UAW. It is with these statistics and advice from interviews with the UDs that we estimate UAW. Table 2 shows the average UAW percentages by utility district in recent years. The final row displays the number of years of data upon which the percentages are based.

Table 2– Unaccounted-for-Water data by Utility District (% of total production)

	Crab Orchard	Crossville	South Cumb.	West Cumb.	**Consumption Weighted Average**
Annual UAW%	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 2 appear incredibly high, but when we consider the short record length, it is clear that at least in some cases, some outlier values may be skewing the results. While there appears to be some potentially significant seasonal variation in the loss percentage, at least in Crab Orchard and Crossville, there are not enough data to make a strong case for modeling this variation. Additionally, IWR-MAIN does not allow seasonal variation in the Unmetered/Unaccounted percentage.

Except in Crossville, the record lengths are too short to make a valid estimation of the UAW by utility district. So we calculate the county average as weighted by consumption in the UDs. The yearly average UAW percentage is calculated as 22.4%, which is conservatively rounded upward to 23%. All of study areas except for Crossville are assumed to have this 23% average. If metering errors, line flushing, and known losses are assumed to be 5%, this means that an average of 18% of total produced water is actual loss. These figures compare favorably with the 20% rate indicated in interviews with the Crab Orchard Utility District, and 14-15% loss rate reported by West Cumberland. With the Crossville records being a bit longer, we feel comfortable setting Crossville's UAW percentage at 19%, which is slightly more conservative than the 15% unaccounted for and the 10-12% loss estimated by the Crossville UD in a May 2006 interview.

For the purposes of a baseline forecast, the UAW percentages are assumed to remain constant in time, which is a dubious assumption based on the large variances in month to month losses alone. Almost certainly, losses will either increase as the system ages, or decrease as the result of system improvements and maintenance. We are hesitant, however, to forecast changes to the UAW percentage in a baseline forecast, or impose 'desirable goals' as some past studies have done. Additionally, the conservation measures evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

Model Validation

Based on the assumptions made, it is possible to compare the projections to observed water usage. Figure 5 displays the estimated total county water consumption as compared to

observed consumption based on data from the UDs. These figures exclude UAW. On average, the estimated values are about 4% above the observed values, and therefore slightly conservative.

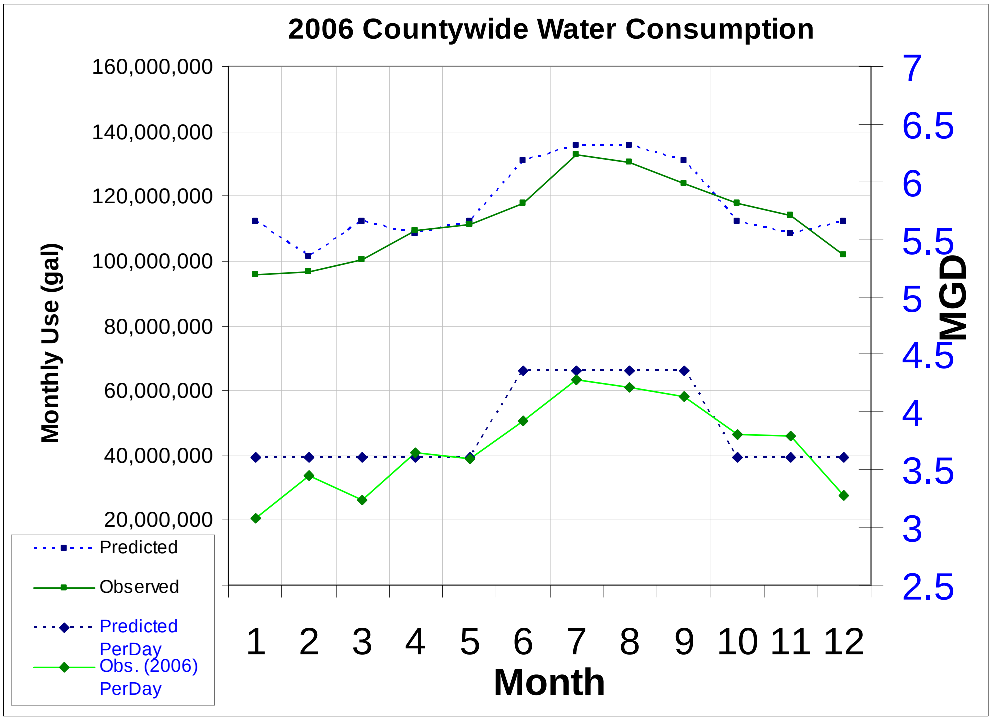

Figure 5 - Predicted versus Observed Countywide Water Consumption (excl. UAW)

The agreement shown between the observed and estimated values in water use is certainly not perfect, but it indicates the assumptions are at least reasonable, and slightly conservative. We note that there is excellent agreement at the peak water use month of July.

When the total usage includes UAW, the agreement between the observed 2006 values and predicted values is slightly worse. Data from the utility districts indicate that unaccounted for water makes up 27% of total produced water in 2006. This is higher even than the already fairly conservative assumption of 23% (19% for Crossville) used in the modeling. Figure 6 displays the estimated and observed values, which indicate the model predictions are about 7% *below* observed values. This is certainly a source of potential error, but is more likely due to above average losses in 2006. For the purposes of forecasting, the recent historical averages for UAW are a more reasonable basis for estimating future UAW than the 2006 values alone. Thus, no further calibration is necessary to match the observed and predicted 2006 demand.

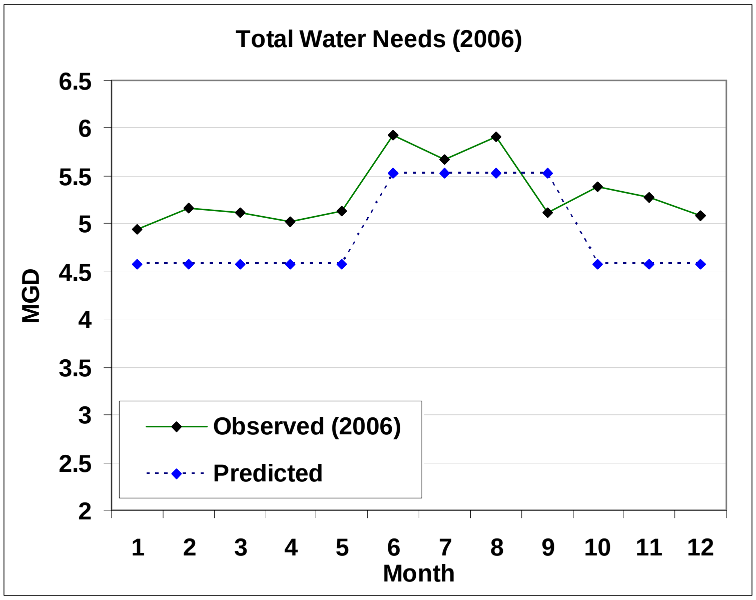

Figure 6– Model Predicted and Observed Cumberland County Water Use in 2006

5. Summary Results

The results of the baseline water supply needs assessment are presented in this section. All results are presented in terms of average daily usage in millions of gallons per day (MGD) except when otherwise noted. Summary results are presented here, but full results are available in the addenda.

It should also be noted that this is a planning level document, so the results are presented as annual or seasonal average. These figures should be sufficient for estimating water storage needs. Calculating peak usage, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak usage estimates were not called for in the scope of services, but are presented for completeness. BDY&A's 2002 *Cumberland County Water Supply Needs Assessment* cites factors in a range of 1.25 to 1.35 of daily consumption for Cumberland. The Corps' *Cumberland County Regional Water Supply Preliminary Engineering Report* appears to use 1.35 as well. Thus, a factor of 1.35 is applied to the results of this section. Note that peak factors are applied only to the consumption, and subsequently, the unadjusted UAW is added.

Countywide Results

The countywide results present the broadest picture of the water needs projections. Figure 7 presents the demand totaled for all study areas and all subsectors (including UAW). The demand for all three growth scenarios is indicated separately, however. The results indicate that demand will not quite triple in 50 years under the Aggressive scenario, less than double under the slow scenario, and roughly double under the expected scenario.

Under any growth scenario the projected demand increases significantly over the 2006 baseline. As noted previously, there is a great deal of uncertainty, particularly in the estimation of future trends in UAW. Figure 8 reports the county totals for consumption, which excludes the UAW. While there is bound to be some UAW in the future, the consumption projections are marginally more certain. The water conservation plan will more directly assess the effects of reducing UAW.

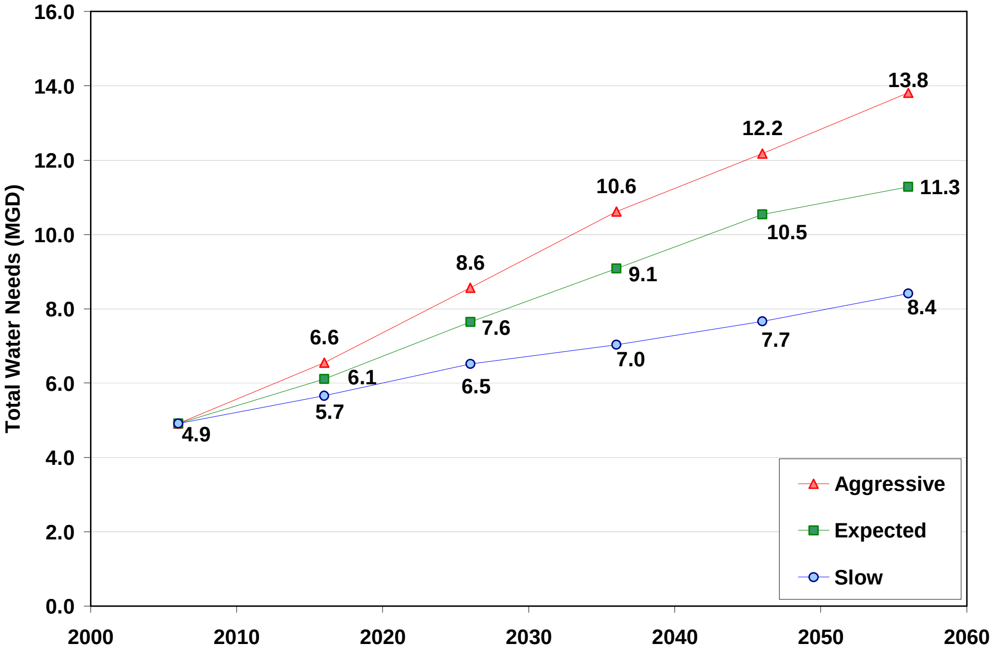

Figure 7. **Countywide Daily Average Total Water Needs for the Slow, Expected, and Aggressive Growth Scenarios.**

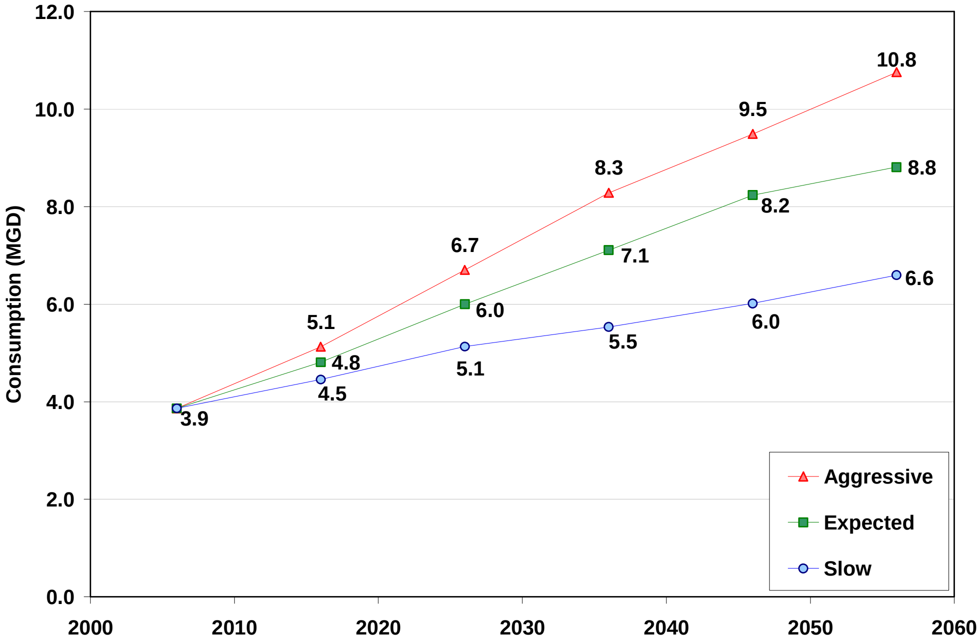

Figure 8 – Countywide Daily Average Projected Water Consumption (excludes UAW) for the Slow, Expected, and Aggressive Growth Scenarios

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, the usage varies by season. The Summer months include June-September, while the Winter includes the remaining months. The results are presented here by scenario and season. Countywide, the summer usage remains a fairly consistent 12-13% above the annual average, and winter usage is always

roughly 6-7% below. This is a result of the cumulative effects of the different winter and summer use factors for the subsectors (see the Water Needs Assessment in the addenda for full description and usage rates). Table 3 displays the countywide daily demand by season.

Table 3– Seasonal Variations and Peak Projected Total Water Needs (MGD)

Scenario	Season/Peak	2006	2016	2026	2036	2046	2056
Aggressive	Annual	4.91	6.55	8.56	10.61	12.18	13.81
	Summer	5.55	7.41	9.71	12.09	13.84	15.67
	Winter	4.59	6.12	7.99	9.87	11.34	12.87
	PEAK	*6.26*	*8.35*	*10.91*	*13.51*	*15.50*	*17.57*
Expected	Annual	4.91	6.11	7.64	9.08	10.54	11.28
	Summer	5.55	6.90	8.63	10.27	11.94	12.77
	Winter	4.59	5.71	7.14	8.48	9.84	10.54
	PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
Slow	Annual	4.91	5.66	6.52	7.03	7.66	8.41
	Summer	5.55	6.40	7.38	7.98	8.71	9.58
	Winter	4.59	5.28	6.08	6.56	7.14	7.83
	PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*

Table 3 also displays the projected peak demands, which reflect a 1.35 peakage factor applied only to the annual average consumption. As mentioned before, this factor is based on peak factors cited in previous studies and is not based on usage data. The unadjusted annual total UAW is then added on to this peak consumption to arrive at total water needs.

Water Needs Analysis By Subsector

Table 4 indicates the annual average daily demand by subsector for the entire county. In terms of total demand growth, it is clear that most of the growth occurs in the residential sector. The other sectors exhibit slightly lower percentage growth, but still increase significantly over their base year values. The NonRES results indicate that commercial growth will be of a low water intensity variety, which is consistent with a primarily service oriented commercial sector. The introduction of only a few large (industrial) water users, however, could add significantly to commercial demand, making the NonRES sector the most likely to be a low estimate of actual future demand.

Also notable is that the UAW subsector, while remaining a constant percentage of total water use, grows to become a more significant water ‘use’ than the nonresidential sector under the aggressive scenario. While the UAW percentage is based on the best available current loss estimates, this sector is most likely to reflect an overly conservative estimate of actual future UAW. The actual processes of leakage are more complex than a simple percentage loss, so growth in consumption does not necessarily mean a proportional rise in leakage. Additionally, leakage will most likely be addressed by future loss reduction measures. The impact of loss reduction measures is treated in the Water Conservation Plan.

Table 4 - Projected Total County Water Needs (MGD) by Scenario and Subsector

Scenario	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
	NonRES	1.49	1.87	2.11	2.32	2.52	2.71
	CMC	0.07	0.10	0.13	0.17	0.20	0.23
	UAW	1.04	1.42	1.86	2.33	2.69	3.05
Aggressive Total		**4.91**	**6.55**	**8.56**	**10.61**	**12.18**	**13.81**
Expected	RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
	NonRES	1.49	1.78	2.04	2.18	2.34	2.42
	CMC	0.07	0.09	0.12	0.14	0.16	0.18
	UAW	1.04	1.30	1.64	1.97	2.31	2.48
Expected Total		**4.91**	**6.11**	**7.64**	**9.08**	**10.54**	**11.28**
Slow	RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
	NonRES	1.49	1.68	1.91	1.96	2.02	2.08
	CMC	0.07	0.08	0.09	0.10	0.11	0.12
	UAW	1.04	1.20	1.38	1.50	1.65	1.82
Slow Total		**4.91**	**5.66**	**6.52**	**7.03**	**7.66**	**8.41**

* RES_PS – Residential, Public Supply; NonRES – Nonresidential; CMC – Cumberland Medical Center; UAW – Unaccounted for Water

Comparison to Previous Estimates

A comparison of GKY's water needs forecasts with previous estimates of Cumberland County's water needs clearly demonstrates the effect of prediction method chosen. Figure 9 compares the estimates in this study to those by Breedlove, Dennis, Young and Associates (BDY&A, 2002), the Army Corps of Engineers (USACE, 1998)[vii], and Lamar Dunn & Associates (LD&A, 2001). LD&A used a simple percentage growth model to estimate future demand. While this model may be appropriate in the short term, it is evident that the simplistic exponential model rapidly leads to unstable and incredibly high demand estimates at more distant time scales. It is clear that this model is insufficient for modeling long term water needs because it is overly simplistic and does not take into account any realistic limitations on growth.

Also interesting is that the BDY&A study presents a very high estimate of demand. This is likely a result of the method used for forecasting the future use factors. The study uses a gross total per capita consumption use factor to estimate the water use. BDY&A chose to express this factor as total public supply water use divided by total population (instead of population served). As a result, the numerator does not reflect the many self-supplied water users in the county (whose use would not be counted in public supply water), while the denominator does count them. This partially explains the artificially low historical use factors (54 and 77 gpd per capita in 1984 and 2000, respectively). The rapid increase in water usage factors is likely more a result of new development being added on public supply (versus self-supply) in a much higher proportion than the existing residences than it is a response to economic trends or fundamentally different water usage patterns of new residents. Furthermore, to bring the use factors to present day average values from this low starting point requires astounding gains in the per capita use factor. Projecting the future water use factors from historical values can lead to extremely high use forecasts, especially when rapid population growth continues.

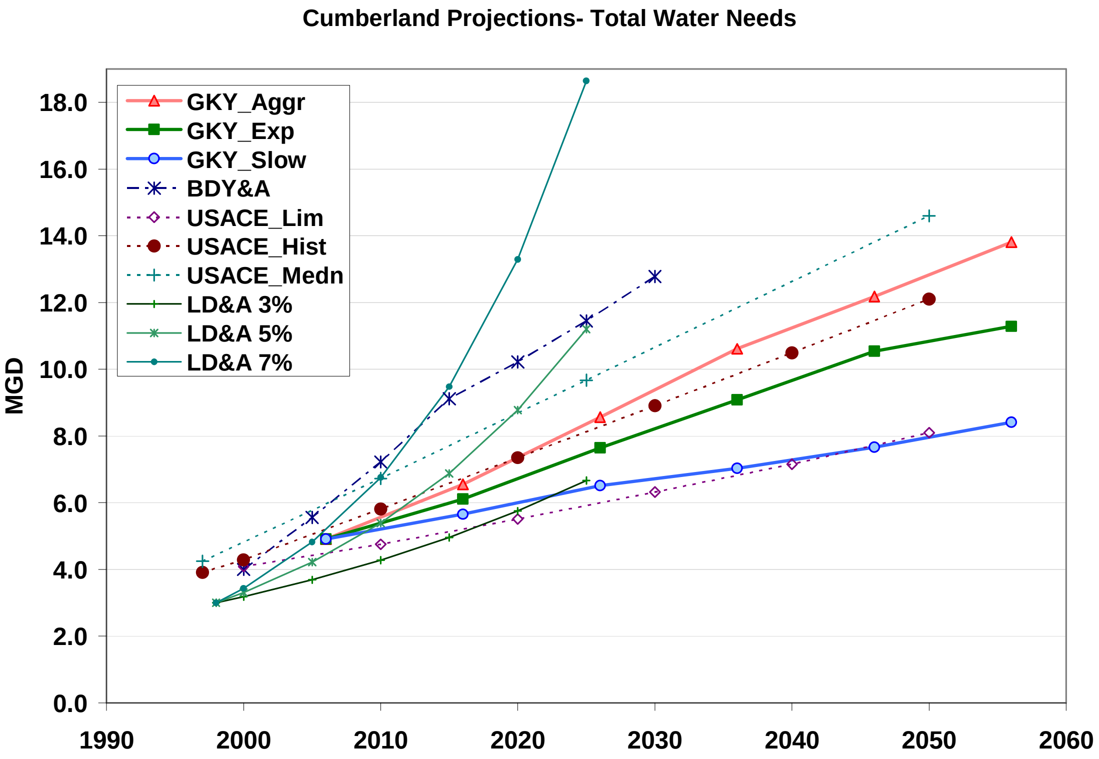

Figure 9 - A comparison of water needs forecasts for Cumberland County

The USACE projections rely upon a variety of different methods, including a model developed in IWR-MAIN (i.e. Medn → Median projection). These projections seem most closely in line with GKY's projections. The historical and limited methods actually incorporate limitations on growth, though in a more simplistic way than the GKY study.

The GKY study likely presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[viii] of the Pacific Institute note, "With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches." GKY's baseline projections present a new approach to countywide water demand forecasting, as anticipated improvements in water efficiency are taken into account. These anticipated improvements are in a sense inevitable as national laws and standards, as well as simple market availability have affected a shift to more conserving technology. For example, the Energy Policy Act of 1992 has made virtually all new toilets on the market compliant with a 1.6 gallon per flush efficiency standard.

It is important to note the efficiency assumptions are nearly completely independent of any decisions and policies made by public officials and citizens in Cumberland County. Other water use reductions may result from programs already in progress (notably, infrastructure improvements to reduce leakage). To establish a conservative baseline projection, however, we limit the conservation measures to 'natural' efficiency upgrades due to more advanced technology gaining a greater market share over time. Other conservation actions are analyzed much more thoroughly and explicitly in the Water Conservation Plan.

6. Uncertainty

The act of forecasting into the future is an inherently difficult task. It is important to recognize (1) that uncertainty is present in any projection, (2) uncertainty in baseline assumptions influences uncertainty in projections, and (3) errors compound over time, making distant projections less reliable than near-term projections.

The forecast model is designed to explicitly take into account uncertainty where possible, and otherwise, avoid introducing unknown uncertainty. (We use 'uncertainty' instead of error because error can't be calculated until the future when there are actual water demand values in the forecast years.)

The largest source of uncertainty in this forecast is likely contained in the population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth scenarios (instead of only an expected growth scenario), we introduce reasonable bounds on the uncertainty of this projection. (That is not to say that Slow and Aggressive scenario projections present the absolute lower and upper bounds on the prediction.) This understanding of uncertainty in the population projections is useful since the housing forecasts are calculated in tandem with them, and the employment projections depend directly on population as well. In these projections, the assumed growth rates, people per house statistic, and population per employee estimates all are potential sources of error. As an illustration of the potential consequences of error in initial projection, Table 5 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. (A constant percentage growth model is assumed.) Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 5 - Consequences of 0.5% error in growth rates (forecasted Units per 1000 base Units*)*

	10 years		**25 years**		**50 years**	
Initial rate projection	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*
1%	53	-56	150	-169	361	-461
2%	58	-61	190	-213	586	-746
5%	76	-79	381	-427	2435	-3075
10%	116	-120	1166	-1301	23914	-29879

Table 5 indicates just how serious minor errors in the prediction parameters can be, particularly in fast growing regions. The land use limitations on growth assumed in this study help put a limit on how large the error can be. In practice, growth can be limited (or spurred) by many factors other than land use consideration, but some limits are advisable as a constant percentage growth, exponential model is rarely a realistic assumption for a very long study period.

The other major potential source of model uncertainty is in the water use factors. While IWR-MAIN has several advanced methods of estimating future demand built into the software, additional parameter estimates and explanatory variables would be necessary (each bringing additional uncertainty). Any more complex model (such as a linear or multiplicative regression) would introduce more uncertainty through parameter estimates in addition to any uncertainty in forecasting future explanatory variable values. The water usage data provided by the UDs is just enough to come up with baseline water use factors. The small sample sizes of the water use data mean there is quite a bit of uncertainty in the water use factors (especially in the monthly values). By averaging the months within two seasons, the sample size is effectively increased, reducing the uncertainty introduced by outliers.

In a similar manner, the UAW percentages are averaged over the county to increase the effective sample size of estimate, and reduce the effect of outliers. Section 4 (Water Needs Assessments Methods) demonstrated that selection of parameters led to good agreement with real water use patterns in the base year.

The importance of the proper treatment of uncertainty in model prediction cannot be overstated. Underestimating future water needs can lead to a dangerous situation in the form of a water shortage or even running out of water. Overestimation of water needs can lead to unnecessary projects or oversized projects at a much higher cost than necessary. Without a realistic view of the uncertainty present in the forecasts, decision making on future supplies may not be truly addressing the water needs. Fully cognizant of the uncertainties present in this forecast, GKY has made every effort to document the uncertainty and present a reasonable range of potential future water needs representative of the effects of the known uncertainty.

Comparisons with previous studies have shown that this study's predictions of water needs tend to be somewhat lower than previous estimates made with simpler models. A careful consideration of the methods used in earlier studies generally leads to the conclusion that the forecasted water needs may be overestimated. This study attempts to provide as accurate a forecast of water needs as possible, with full description of methods, thus allowing the decision maker to assess the validity of the study. Assuming the study is deemed valid, the range of forecasts allows for the decision maker to lend more credence to one scenario versus the others based on their judgment and level of risk-aversion.

7. Conclusions

This Water Needs Assessment has analyzed the current and future water needs of Cumberland County using the best available data and expert opinions. Cumberland County has experienced rapid growth in the past several decades, and that growth may continue so long as the water demands can be met.

The population projections reflect demographic trends, opinions of local experts, and real limits on growth based on land use. The development of the appropriate water use factors was based directly on actual water use data from the utility districts. It must be recognized that a 50 year projection is subject to a great deal of uncertainty. The Aggressive, Expected, and Slow growth scenarios help to capture some of that uncertainty.

The projections in this report indicate that Cumberland County's water needs will very likely exceed the current supply in the next 50 years, but not quite as soon as previously projected. As the average demand becomes closer and closer to the firm yield of the existing sources, the potential for failure in a particularly severe drought year increases considerably. Therefore, Cumberland County is well advised to continue to examine and develop opportunities for conservation and securing an increase in available supplies.

8. References

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Water Conservation Plan

1. Introduction

Cumberland County's attention has been increasingly drawn to water resources over the past decade. Growth projections by several firms[ix,x,xi] have estimated that the water needs of Cumberland County will exceed firm yield in less than 10 years. Excluding the undesirable outcome of running out of water, Cumberland County has two options: increase water supply or reduce demand.

The Water Needs Assessment established forecasts for Cumberland County's water demands under three different growth scenarios. Before evaluating additional water supply alternatives, it is prudent to determine if conservation can effectively reduce demand. This study investigates the extent to which demand can be reduced below the baseline forecast values in the Water Needs Assessment.

Cumberland County has no significant history of water conservation programs, but a range of viable options could lead to significant water savings. This Water Conservation Plan report identifies six potential water conservation measures local government or the utility districts could reasonably enact. The effectiveness of the proposed conservation measures is modeled using the IWR-MAIN Conservation Manager© software program. IWR-MAIN is recognized as a state of the art program for modeling water demand and conservation programs.

A detailed account of the modeling methods is presented in the Water Conservation Plan Memo (full title: *Water Conservation Plan for the Cumberland County Regional Water Supply Study*) in the addenda. This document presents results of modeling the six conservation measures, and based on these results a final water conservation plan is presented.

2. Conservation in Cumberland County

Until the past few decades, Cumberland County has always had an abundant and easily accessed water supply. As a result, there has been limited impetus to encourage conservation in the county. This limited conservation experience presents a substantial opportunity for future efforts to harvest the 'low-hanging fruit' of water conservation benefits at a relatively low cost.

Cumberland County's opportunities to conserve are typical for communities of similar size and age. Cumberland County has two primary avenues for improving water efficiency. One major opportunity for conservation is for the water utility districts to reduce water loss and other unaccounted for uses. Total unaccounted for water use averages near 20% of total produced water, with losses approaching 30 or 40% for some districts in some months. This is not unusual for utility districts of a similar size and age. Cumberland County's utility districts face additional challenges resulting from the very hilly and rocky terrain of the county. High water pressure can stress pipes, and the rocky soil can both puncture pipes and create a situation where leaks have adequate drainage to avoid detection. While Cumberland County's distribution system loss rates are not atypical, reducing losses presents a major avenue for conservation. With appropriate, proactive leak detection efforts and other loss reduction measures, Cumberland County may be able to reduce its losses to ten percent or less.

While the losses in the distribution system are primarily attributable to water suppliers, the water consumers in Cumberland County are another major source of water inefficiency. Interviews with the utility district managers indicated that the majority of residences in Cumberland County use less efficient toilets and plumbing fixtures than current industry standards. This will largely be corrected over time as residents replace older fixtures with

newer, more efficient fixtures. Accelerating this transition, however, is a major opportunity for conservation.

Between reducing inefficient water use on the part of the utility districts and water consumers, there is significant potential for conservation in Cumberland County. The following sections detail several conservation measures to take advantage of this potential.

3. Conservation Measures

Six conservation measures have been identified for analysis in developing the Cumberland County Water Conservation Plan. Each conservation measure is described in brief below. More detailed policy descriptions and modeling methods for each conservation measure are included in the Water Conservation Plan memo included in the addenda. Additionally, the six conservation measures were chosen from a larger set of possible measures based on their relevance and implementability in Cumberland County. The final water conservation plan reflects a combination of some of these measures.

3.A. Unaccounted for Water Reduction (non-leakage)

While leakage is the most commonly identified contributor to Unaccounted for Water, there are other contributing factors to UAW in Cumberland County. Foremost among these are metering errors, flushing usage, and fire fighting usage. Reducing fire fighting usage is not generally within the control of water utilities. Mains flushing is an important part of system maintenance to prevent blockages and corrosion and preserve water quality. Flushing is also necessary before new connections are opened. In large new developments, flushing loss can be tremendous, especially when the opening of new connections is staggered (requiring multiple flushing events). Finally, metering errors are likely a result of older meters. Cumberland County does not have a significant number of unmetered connections.

By addressing excessive flushing and metering errors, Cumberland County may reduce its UAW percentage. All of the utility districts have either recently replaced their meters or are in the process of doing so, but replacement programs should be repeated every 10 -15 years to ensure reductions in UAW are preserved. Reductions in flushing volumes may be achieved through a review of flushing policies, and system upgrades to convert branched distribution pipe networks to looped networks where practicable.

3.B. Leak Detection and Reduction

Leak detection is another method of reducing UAW. Cumberland County faces a range of challenges in getting leakage under control. The age of the pipes, rocky soil, and large elevation differences (and resulting high pressure) have been cited by county utility managers as major causes of leakage. Leaks occur on both mains and service lines. Current leak detection efforts in the county are primarily focused on repairing leaks when they come to the surface or when there are service complaints.

A comprehensive leak detection program in Cumberland County could include several leak detection strategies. Hiring a leak detection contractor to investigate the majority of the county’s mains and service line connections would be a good start. Listening surveys use geophones and other listening devices to find leaks and digital correlators to pinpoint leak positions. In the long term, permanently installed listening devices may be the most effective method of detecting leaks. With training, utility district staff could conduct listening surveys and use a digital correlator.

3.C. Education

Educating water consumers on the value of water and the benefits of conservation, while a valuable end in itself, can also lead to real reductions in water usage. Reductions are achieved in two primary ways: convincing water users to change their water usage habits, and affecting purchasing decisions on fixture and appliance types (and whether to replace them sooner). The water utilities in Cumberland County do not currently have any dedicated customer education programs, but they do communicate with customers through billing inserts and other methods. In 2007, the City of Crossville, Cumberland County, and the utility districts used several communication methods to publicize the drought restrictions and appropriate short-term water saving tips. A true education strategy is geared more toward long-term shifts in behavior and more permanent savings.

Several types of education programs exist, and the water utilities could develop new programs, specially tailored for Cumberland County users. In general, using a variety of education strategies (each with a defined message and goal) in combination can achieve the most robust results. Table 1 indicates three general types of educational programs, the target audience, and a description.

Table 1 - Education programs

Policy	Intended audience	Description
General advertisement	All water users	Water saving tips and information.
Targeted Messages	Commercial users, homeowners with irrigation systems, homeowners with older homes, etc.	Communicate well developed messages perhaps once a year to encourage a specific conservation action, e.g: highlight cost savings from replacing toilets, promote xeriscaping, .
Education programs	School age children and families	e.g.: Programs every 2 years for 4th and 5th graders, 9th and 10th graders
	Retirees, community associations	Short (0.5 day) programs in retirement communities, civic centers.

3.D. Pricing

While water prices are generally set to reflect the costs of production, price changes do affect water demand. The price elasticity of demand indicates the amount of change in demand due to a unit change in price. See Equation (1). An elasticity of positive one indicates that a 1% increase in price will lead to a 1% increase in demand. Price elasticity of demand for water is nearly always negative (price increases reduce demand), and is generally considered to be inelastic (in between 1 and -1, or in this case, 0 and -1). In fact, when considering water demand, it is rare to see elasticities even go beyond -0.5.

$$e = \frac{\Delta q}{\Delta p} \qquad \textbf{Equation 1}$$

Where:

e is the price elasticity of water demand
Δq is the percentage change in water demand by a water user (or set of users)
Δp is the percentage change in water price

There is a wide range of economics literature examining the price elasticity of demand for various water users. Focusing on residential customers, Arbués et al. (2003)[xii] and Worthington and Hoffman (2006)[xiii] provide good reviews of a large range of economic

studies investigating price elasticity of water demand under a wide range of pricing policies. In general, the majority of the estimates of residential long term elasticity fall into the -0.05 to -0.5 range. The IWR-MAIN manual cites residential elasticity as between -0.05 and -0.35.

Several UD managers expressed the view that the water demand of Cumberland County residents is somewhat to considerably more sensitive to price changes than the average U.S. citizen. Supporting this assertion is that many of Cumberland County's residents are on fixed incomes. Residents' response to price signals is also influenced by having a monthly billing cycle in all the Cumberland County UDs. As a result, elasticities in Cumberland County are assumed to be toward the upper end of the ranges presented in the manual.

Currently, all the Cumberland County utility districts have a fixed fee for consumption up to a certain initial limit (1000 or 2000 gallons), and a fixed block rate for additional consumption above the limit. A wide range of pricing strategies are available for water utilities to meet goals as wide ranging as maintaining adequate revenues to encouraging conservation. A full discussion of the pricing options considered for the modeling of this conservation measure is contained in the Water Conservation Plan memo. Due to complexity of modeling some of the pricing methods and the limitations of IWR-MAIN, a simple pricing policy is selected. The policy is simply to enact a 30% increase in marginal water price over the base price (set equal to 1) after the base year. Since the price is measured in constant 2006 dollars, the underlying assumption is that after the initial increase, price increases at a rate exactly equal to the inflation rate (or more accurately, water consumers' own discount rate).

3.E. Water Efficiency Codes and Ordinances

One of the most effective methods to generate long term water savings over baseline estimates is to influence the water efficiency of new development. Ensuring that developers are installing efficient fixtures and appliances means that new users will have a lower water use intensity than existing users. Additionally, it is significantly easier to create standards for efficiency before new units are built than to retrofit later.

Currently, Cumberland County lacks building codes in all areas except inside the Crossville city limits. Reportedly, even within Crossville, the efficiency of fixtures is rarely examined by inspectors.

A comprehensive water efficiency code and ordinance will mandate the inspection of water fixtures, toilets, and appliances to check for their efficiency. Additional ordinances may govern the outdoor use of water at commercial and institutional properties by requiring rain sensor shut-off for irrigation systems, for example. Benefits, such as reducing the connection fee, may also be considered for developers who install ultraefficient appliances and fixtures in new properties.

3.F. Retrofit, Rebate, and Replacement Programs

Retrofit, replacement, and rebate programs are other methods to reduce the average water use factors for existing users by replacing (or providing incentives to replace) existing fixtures and appliances with more water efficient models. The key is that the transition happens at a much faster rate than it would under natural replacement.

The programs can take several forms. One approach is to simply provide inexpensive fixtures and devices such as faucet aerators, shower heads and toilet dams free of charge to users. The drawback is that the consumers do not always install them. As the Massachusetts Water Resources Authority's Steven Estes Smargiassi noted[xiv], "We discovered if you gave away devices, most of them were 'installed' in kitchen drawers – not on the bathroom or kitchen fixtures." One way to mitigate this problem is to provide free installation as well. Rebate programs provide monetary incentives for the replacement of larger water using devices,

notably toilets and clothes washers. While often expensive, rebates for toilets and clothes washers can provide greater water savings than small devices, and the transition to more efficient water uses can be more easily verified.

Cumberland County's utility districts do not currently offer any retrofit, replacement, or rebate programs. These programs may be well suited to Cumberland County, as the majority of fixtures and appliances are believed to be older models. Additionally, interviews with utility district managers and other stakeholders indicated that county residents replace these fixtures and appliances at a slightly lower rate than the nation as a whole.

4. Methods

The water savings of the six conservation measures are modeled using IWR-MAIN Conservation Manager. The Water Conservation Plan Memo discusses the modeling methods, assumptions, data collection, parameter estimates, and scenario development in much greater detail. Table 2 displays the tools used in IWR-MAIN Conservation Manager to model the effects of each of the conservation measures.

Table 2- Modeling Methods of the Six Conservation Measures

Conservation Measure	IWR-MAIN Modeling Method
A. Non-Leakage UAW Reduction	Tools→ Unmetered Fraction
B. Leakage Reduction	Tools → Unmetered Fraction
C. Education	Intensity → Enter/Build, Passive Conservation
D. Pricing	Intensity → Enter/Build (Multiplicative Model)
E. Codes and Ordinances	Tools → Passive Conservation
F. Retrofit, Rebate, Replacement	Tools → Active Conservation

5. Results

The six conservation measures cover a broad range of strategies for reducing water usage. Accordingly, the modeling results indicate important differences between the conservation measures in terms of magnitude and trends of water savings. The growth scenario also affects the relative performance of the conservation measures. While the modeling methods for each conservation measure are identical between growth scenarios, certain measures perform comparatively better or worse depending on the rate of growth. Table 3 compares the total water needs projections for the baseline and six conservation measures under the 3 growth scenarios. For each year in each growth scenario, the conservation measure with the lowest total water needs is displayed in bold type.

The results indicate some clear trends in the projected water needs under the baseline and conservation scenarios. Most notably, leakage reduction appears to lead to the most substantial reductions over the entire study period. Education programs and Codes and Ordinances follow a similar pattern of starting off with very modest savings over the baseline and substantially increasing savings over time. The retrofit programs show an opposite trend, with the most substantial savings earlier in the study period. This is potentially significant as the uncertainty in the estimates is substantially lower at shorter time horizons. Interestingly, the results of non-leakage UAW reduction programs and conservation pricing programs are quite similar even though their modes of influencing water savings are very different.

Table 3- Total Water Needs for the six Conservation Measures under the three growth scenarios

Aggressive Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.52	6.34	6.14	6.30	6.23	6.43	**6.08**
2026	8.55	8.19	**7.80**	8.04	8.16	8.20	8.15
2036	10.60	10.14	**9.59**	9.90	10.10	9.90	10.27
2046	12.17	11.64	**10.97**	11.26	11.59	11.10	11.88
2056	13.81	13.22	**12.29**	12.55	13.14	12.36	13.55

Expected Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.11	5.95	5.76	5.90	5.84	6.04	**5.67**
2026	7.64	7.32	**6.98**	7.17	7.29	7.35	7.23
2036	9.08	8.69	**8.22**	8.45	8.66	8.49	8.73
2046	10.54	10.08	**9.53**	9.73	10.04	9.63	10.23
2056	11.28	10.79	**10.07**	10.20	10.75	**10.07**	11.00

Slow Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	5.66	5.50	5.33	5.43	5.41	5.59	**5.18**
2026	6.52	6.24	**5.96**	6.05	6.23	6.26	6.06
2036	7.03	6.74	**6.39**	6.46	6.72	6.55	6.63
2046	7.66	7.33	6.96	6.96	7.31	**6.95**	7.29
2056	8.41	8.04	7.54	7.50	8.02	**7.46**	8.05

It can also be instructive to look at overall cumulative water savings over the entire study period. Figure 1 through 3 display the forecasted cumulative water savings for the three growth scenarios. The magnitude of expected savings over 50 years is rather remarkable, on the order of 5 to 15 billion gallons. Comparing the different conservation measures reveals some interesting insights on their long term behavior. Even though their overall savings are quite different, Non-Leakage UAW reduction and Leak reduction demonstrate similar shapes due to their common modeling method. The conservation pricing policy, because only one major price change occurs, displays a linear trend after 2016. The effectiveness of the retrofits is very evident at first, but over time the slope of the cumulative savings line actually decreases. Finally, the Codes and Ordinances and Education programs clearly increase their cumulative savings as growth increases in the more distant future.

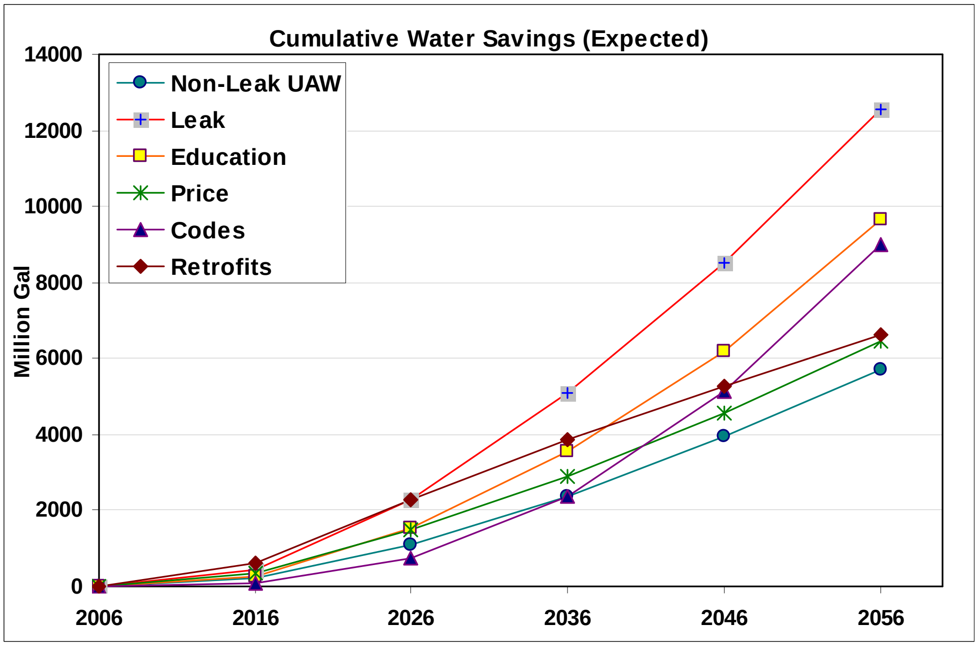

Figure 1 - Cumulative Water Savings for the Six Conservation Measures under the Expected Growth Scenario

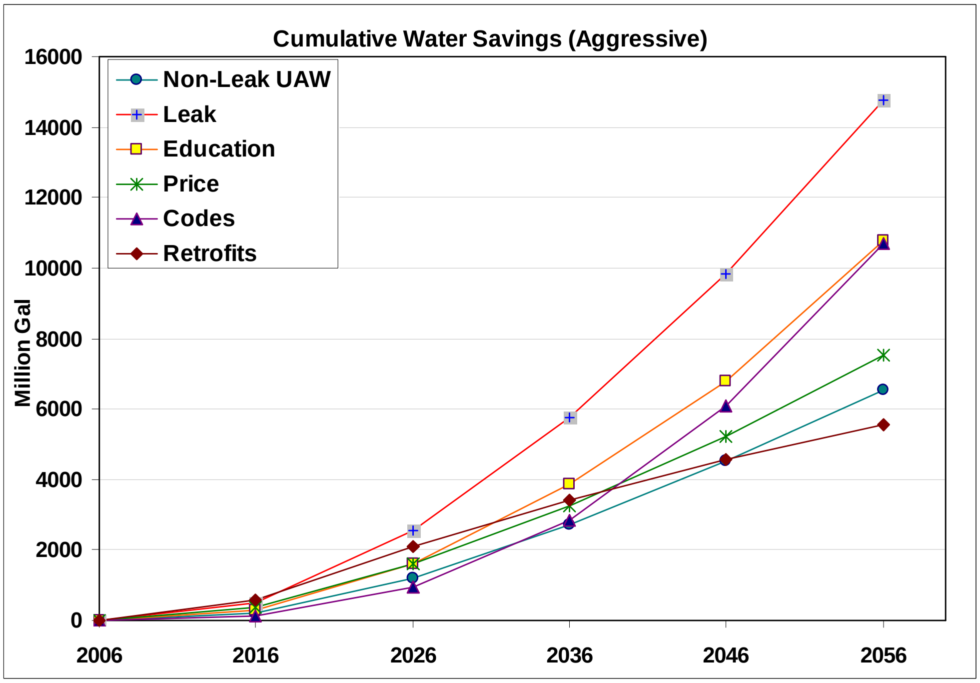

Figure 2 - Cumulative Water Savings for the Six Conservation Measures under the Aggressive Growth Scenario

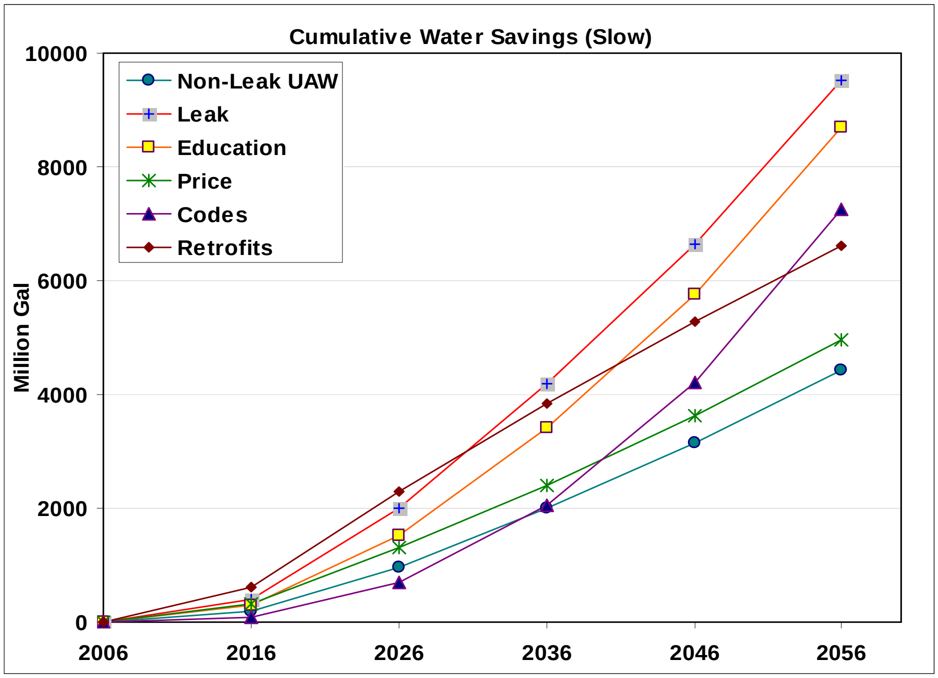

Figure 3 - Cumulative Water Savings for the Six Conservation Measures under the Slow Growth Scenario

6. Pros, Cons and Economic Benefits

The previous section investigated the comparative water savings resulting from each of the conservation measures. While the water savings are perhaps the most important consideration, several other considerations necessarily influence whether the measure should be implemented. These considerations include implementability, public acceptance, cost, uncertainty in the projections, compounding and corollary effects, and finally, economic benefits.

Each of the conservation measures has its own merits and drawbacks, and any comprehensive water conservation plan will likely have to include several conservation measures. The conservation measures which target unaccounted for water, non-leakage UAW reduction and leak detection, have a strong benefit in that they save water that was not producing revenue. Therefore, any water savings generated by these measures lead to direct economic savings. These two measures are also less complicated to implement because they can be put into place solely based on the choice of the utility districts. The drawback of both measures is their upfront cost, which can be significant, especially when pipes must be excavated for repair and replacement. The savings resulting from stopping leaks and other non-revenue producing water, however, often lead to very short payback periods.

Rapid adjustments in price carry their own pros and cons. While periodic, small water rate increases are necessary for maintaining capital investments and keeping pace with inflation, larger rate increases can be a much stronger impetus to conserve. Since water is an inelastic good, rate increases nearly always lead to smaller proportional reductions in consumption than the increase in price. As a result, water savings may be marginal, though the utilities benefit from greater total revenues. The obvious drawback to increasing rates is that rate increases are unpopular and may meet significant resistance from ratepayers. Effective conservation pricing and tiered pricing may be an alternative solution that could provide

benefits with less opposition. Analyzing more complex pricing schemes is beyond the scope of this study, but could be researched further.

Education programs have a great number of benefits, but suffer from a great deal of uncertainty about their actual effectiveness. Educating consumers about methods, benefits, and importance of water conservation can lead to changes in behavior that may save water in the short and long term. Short term changes may be achieved by behavioral changes, while long term shifts in water use may result from consumers making more informed choices when replacing toilets, washing machines, etc. Educational programs are generally not very expensive to implement, but can be ineffective without dedication to the message and sustained commitment to program implementation. Traditionally, education programs have been viewed as effective in reducing water use, but quantifying their actual water savings and economic benefits relative to investment remains difficult.

Strict water conservation provisions in building codes and public ordinances can lead to a gradual but significant reduction in potential future water use. The primary benefit of the codes is the significant long term savings, but the related drawback is that they do virtually nothing to reduce existing consumption except in the case of major renovations. Passing sufficiently comprehensive codes requires a great deal of political cooperation to implement. With the exceptions of builders and plumbers, there are generally few costs to existing stakeholders. Managing an effective inspection and enforcement program requires adding several inspectors and support staff to the local government payroll (or hiring contractors to fulfill the roles), which can be a significant long term cost.

7. Water Conservation Plan

It appears from the analysis of alternative conservation measures that Cumberland County has significant opportunities for reducing water consumption, especially in the long run. A combination of four of the identified conservation measures may provide very significant conservation savings over the baseline projections. GKY recommends the following Water Conservation Plan as best suited to meeting Cumberland County’s long term water management goals. In combination, institute the following conservation measures, described previously in this report:

A. Non-Leakage UAW Reduction
B. Leakage Reduction
C. Education Programs
E. Codes and Ordinances

Modeling the Water Conservation Plan

Modeling the potential savings due to the water conservation plan is a fairly straightforward combination of the 4 identified conservation measures. The modeling methods have limited overlap. Measures A and B are both modeled by setting the UAW percentage with the unmetered/unaccounted tool. The appropriate UAW percentage is simply determined by the summing the reduction percentages under the two programs.

Codes and Ordinances are modeled in exactly the same manner as before. The Education conservation program is modeled in IWR-MAIN using the exact same intensity reductions as described in the Draft Water Conservation Plan memo. However, the passive conservation portion of the education programs is slightly affected. The rate of efficiency class shift is set by whichever rate is higher between the education and codes and ordinances conservation measures instead of adding the efficiency class shift percentages. So if 5% of units per year shift efficiency classes under the codes and ordinances conservation measure, and 3% of units per year shift with education, the total water conservation plan rate is 5% and not 8%.

Results

The results of modeling clearly demonstrate that impressive water savings are possible if an ambitious water savings plan is put into place. Figure 4 shows the baseline forecasts for the three growth scenarios (solid line), and the corresponding forecasts if the Water Conservation Plan is fully implemented (dashed lines).

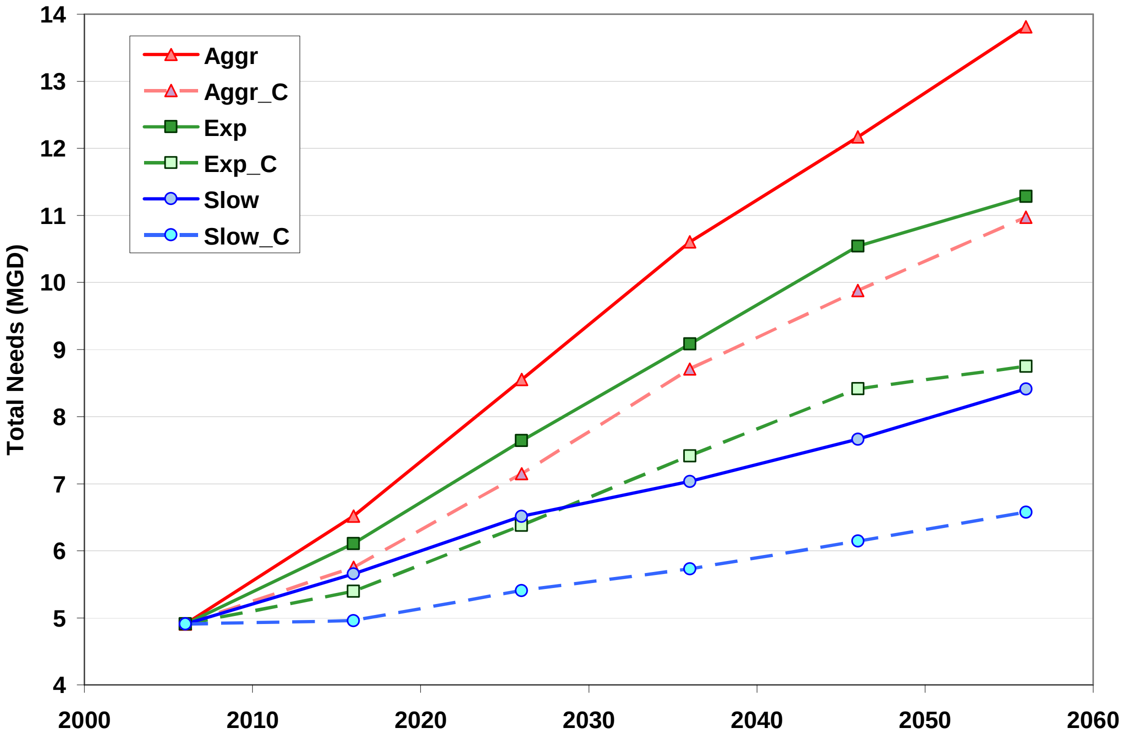

Figure 4 - Forecasted Water Needs for three growth scenarios, with and without the conservation plan

The results of the forecasts show the potentially profound effect of conservation. In general, the conservation plan can save as much as 30% over the baseline scenario. About half of this reduction comes from reduction of Unaccounted for Water alone. Over the long term, the reductions are as significant as dropping one growth scenario. That is, water use for the aggressive scenario with conservation is roughly equal to water use for the expected scenario without it. Even with conservation, water use in the county stands to increase significantly. However, under the slow growth scenario, water use remains virtually flat for the first 10 years when the conservation plan is put into place.

There is one caveat in interpreting the results of the water conservation plan. In analyzing all of the conservation measures individually, there was never a situation in which both the actual consumption and UAW rates were changed simultaneously. The water conservation plan does change both at once. Since the UAW is expressed (and modeled) as a percentage of overall demand, reducing consumption reduces UAW by default. However, the actual physical processes that cause leakage are not necessarily dependent on demand. Therefore, especially in situations where both the consumption and UAW are reduced simultaneously, the water savings may be overestimated. The modeling limitations of IWR-MAIN make it difficult to easily ameliorate this problem.

The effect of this limitation can be discerned when one looks at the results by subsector (including UAW as a subsector). Table 4 displays the results by subsector, comparing the baseline projection and water conservation plan for the three growth scenarios. It is quite

evident that a large portion of the savings comes from reductions in UAW. Under the Water Conservation Plan, UAW can be cut to as much two-thirds below the baseline forecasts. For example, under the aggressive scenario, the baseline UAW estimate in 2050 is 3.05 MGD, but with the water conservation plan, it falls to 0.99. Other subsectors see only about a 5 - 10% reduction over the baseline.

Table 4 – Total Water Needs by Subsector under the Baseline and Water Conservation Plan Forecasts(MGD)

Scenario	Forecast	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	CMC	0.07	0.10	0.13	0.17	0.20	0.23
		NonRES	1.49	1.87	2.11	2.32	2.52	2.71
		RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
		UAW	*1.04*	*1.39*	*1.85*	*2.32*	*2.68*	*3.05*
	Water Conservation Plan	CMC	0.07	0.10	0.13	0.16	0.19	0.22
		NonRES	1.49	1.84	2.06	2.25	2.41	2.56
		RES_PS	2.31	2.99	4.20	5.43	6.29	7.20
		UAW	*1.04*	*0.82*	*0.76*	*0.87*	*0.99*	*0.99*
Expected	Baseline	CMC	0.07	0.09	0.12	0.14	0.16	0.18
		NonRES	1.49	1.78	2.04	2.18	2.34	2.42
		RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
		UAW	*1.04*	*1.30*	*1.64*	*1.97*	*2.31*	*2.48*
	Water Conservation Plan	CMC	0.07	0.09	0.11	0.14	0.16	0.17
		NonRES	1.49	1.74	1.98	2.10	2.21	2.26
		RES_PS	2.31	2.79	3.61	4.44	5.20	5.53
		UAW	*1.04*	*0.77*	*0.68*	*0.74*	*0.84*	*0.79*
Slow	Baseline	CMC	0.07	0.08	0.09	0.10	0.11	0.12
		NonRES	1.49	1.68	1.91	1.96	2.02	2.08
		RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
		UAW	*1.04*	*1.20*	*1.38*	*1.50*	*1.65*	*1.82*
	Water Conservation Plan	CMC	0.07	0.08	0.09	0.10	0.10	0.11
		NonRES	1.49	1.64	1.85	1.88	1.91	1.94
		RES_PS	2.31	2.53	2.89	3.18	3.52	3.93
		UAW	*1.04*	*0.71*	*0.57*	*0.57*	*0.61*	*0.59*

While the average water needs are important in the evaluation of long term water supply planning, the peak day demand is important for the design of certain system components. As in the Water Needs Assessment, a peak factor of 1.35 is assumed. This is applied only to the consumption values, and UAW is added afterwards. Table 5 displays the peak day water needs for the baseline forecast and water conservation plan.

Table 5 – Peak Demand Values for the Baseline Forecast and Water Conservation Plan

Scenario	Program	Data	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	Consumption	3.87	5.13	6.70	8.28	9.49	10.76
		UAW	1.04	1.39	1.85	2.32	2.68	3.05
		PEAK	*6.26*	*8.31*	*10.90*	*13.50*	*15.49*	*17.57*
	Water Conservation Plan	Consumption	3.87	4.93	6.39	7.84	8.89	9.98
		UAW	1.04	0.82	0.76	0.87	0.99	0.99
		PEAK	*6.26*	*7.48*	*9.39*	*11.46*	*12.99*	*14.47*
Expected	Baseline	Consumption	3.87	4.81	6.00	7.11	8.24	8.81
		UAW	1.04	1.30	1.64	1.97	2.31	2.48
		PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
	Water Conservation Plan	Consumption	3.87	4.62	5.70	6.67	7.57	7.96
		UAW	1.04	0.77	0.68	0.74	0.84	0.79
		PEAK	*6.26*	*7.02*	*8.37*	*9.75*	*11.06*	*11.54*
Slow	Baseline	Consumption	3.87	4.45	5.13	5.53	6.02	6.59
		UAW	1.04	1.20	1.38	1.50	1.65	1.82
		PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*
	Water Conservation Plan	Consumption	3.87	4.25	4.84	5.16	5.53	5.98
		UAW	1.04	0.71	0.57	0.57	0.61	0.59
		PEAK	*6.26*	*6.45*	*7.10*	*7.54*	*8.08*	*8.67*

Analysis of the Water Conservation Plan

These four measures are the most beneficial actions Cumberland County can take for several reasons. First, the combination of measures strikes a balance between short term and long term water savings. Measures A and B (Non-leak UAW reduction and Leakage Reduction), especially when implemented in combination, provide immediate reductions in water usage. Measures C and E (Education and Codes and Ordinances) lead to much more significant savings in the long term than the short term.

These four conservation measures are also very feasible to implement. In fact, most of the measures are currently in the process of planning or implementation, though not quite to the extent described in this report. All of the utility districts have recently replaced or are replacing meters throughout their service areas. All of the utility districts claim to be reducing system leakage wherever they can, and one has even contracted leak detection services. The City of Crossville already has plumbing codes in place, and Cumberland County appears to be actively considering implementing them. None of the utility districts currently has dedicated education programs, but there are many resources available through the American Waterworks Association, the Environmental Protection Agency, various state environmental departments, private companies, and other sources.

Especially if the utility districts and county officials cooperate, the conservation measures presented here are very cost effective. Education programs are relatively low in cost. Implementing codes and ordinances has few upfront costs, but some long term enforcement and administrative costs. Measures A and B can be costly, but are generally worthwhile investments as the water savings directly reduce costs without reducing revenues. Furthermore, if leak detection services are contracted for the entire county, and leak detection

equipment is shared, costs can be reduced. Finally, leak detection costs are dropping as technology improves.

The other benefit of this plan is that it should be widely accepted by the majority of the stakeholders. Reducing unaccounted for water, and more broadly, establishing water accountability through better system information, better metering, and leak detection is a crucial step toward public acceptance of other conservation actions. Establishing building codes (and water efficiency standards) is generally acceptable as it has many positive impacts on quality of life in the county. Educational programs, as long as they are well managed, are generally accepted. Price increases for the purpose of conservation, however, are usually unpopular. Additionally, certain stakeholders have already expressed a mild opposition to retrofit and rebate programs as an unfair use of ratepayer or tax dollars.

Finally, implementing the proposed conservation measures leaves open the possibility for future conservation measures not described here. In the event that the proposed plan does not meet conservation targets, or growth occurs at a faster than projected rate, other conservation measures can be implemented. Measures A and B will lead to a much better understanding of the water balance throughout the distribution system and identify opportunities for further conservation. Establishing a framework for education programs leads to better communication between utilities, ratepayers, and other stakeholders, which could make future actions more effective. Strict efficiency codes help to create a local market for more efficient fixtures and appliances. Additionally, once codes are adopted, a legal framework is established for future amendments and ordinances.

While the conservation measures set forth are fairly common and feasible to implement, realizing the projected water conservation savings requires full engagement by the stakeholders and a sustained commitment to the conservation programs. Cumberland County has significant potential for conservation in the short and medium term as utilities reduce their water loss and customers increase their water use efficiency. In the long term, however, real shifts in behavior and in efficiency standards will need to be firmly established to see continued progress in reducing water use. It should be noted that even with significant conservation, Cumberland County's water use will almost certainly rise over the next 50 years. The rate of growth in water needs, however, can be slowed by the adoption of an ambitious conservation plan.

8. Conclusion

Cumberland County faces a challenge in meeting future water needs as the county grows. Continued rapid growth and the chance of future droughts like the one in 2007 highlight the importance of a long term solution to meeting water needs. Numerous proposals exist for increasing water supplies, but this study instead examines the potential for reducing demand.

Six feasible conservation measures have been presented as methods to effectively reduce water demand, inefficient water use, and water loss. Cumberland County has excellent potential for increasing water efficiency, both in the distribution system and on the part of water users. A comprehensive water plan can take advantage of the potential water savings, and almost certainly postpone the need for new water sources.

This Water Conservation Plan outlines a series of measures which can significantly slow the growth of Cumberland's water needs while allowing the county to grow. While the conservation targets are certainly achievable, it will take commitment and cooperation on the parts of numerous stakeholders.

9. References

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GKY & Associates, Inc.

Cumberland County Regional Water Supply Study

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Water Needs Assessment and

Water Conservation Plan

Final Report

Cumberland County Regional Water Supply Study

Water Needs Assessment and

Water Conservation Plan

March, 2009

Table of Contents

Water Needs Assessment

Water Conservation Plan

List of Tables

Water Needs Assessment

Water Conservation Plan

List of Figures

Water Needs Assessment

Water Conservation Plan

Addenda

Three previous documents written by GKY provide added reference with regard to methods and full results for the Water Needs Assessment and Water Conservation Plan.

1. *Land use assumptions for Phase II of the Cumberland County Regional Water Supply Study*. Memorandum. December 13, 2006. by Karsten Sedmera and Stuart Stein, GKY & Associates, Inc.

2. *Water Needs Assessment for the Cumberland County Regional Water Supply Study*. Memorandum. March 14, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

3. *Water Conservation Plan for the Cumberland County Regional Water Supply Study*. Memorandum. June 28, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

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Water Needs Assessment

1. Introduction

The Cumberland County Regional Water Supply Study was established by an agreement between the U.S. Army Corps of Engineers (Nashville District) and the City of Crossville, Tennessee. The Cumberland County Regional Water Supply Study has the goal of identifying a long term solution to Cumberland County's water supply needs, and carrying forward an Environmental Impact Statement investigating potential alternatives for the long term supply solution. As part of the Water Supply Study, GKY & Associates has been contracted to perform a Water Needs Assessment to estimate future demand at 10 year increments for the next 50 years.

This Water Needs Assessment builds, in sequence, a land use development analysis, population growth scenarios, and modeling of future water demands. This study represents the first in-depth analysis taking into account the rapid growth in the early 2000s.

Indeed, Cumberland County, located on the Cumberland Plateau of East Central Tennessee, faces a growing problem in meeting the ever increasing water demand in a rapidly growing county. Cumberland County has been experiencing rapid growth in part due to its considerable success in attracting retirees to live in the county. In severe droughts, this growth is already straining water supplies. As growth continues, it is likely a new water source may need to be developed. This Water Needs Assessment investigates the future demand for water under a range of growth scenarios to project how much water will be needed in the future.

The first step in determining the future water needs is to analyze the land use patterns in Cumberland County.

2. Land Use Development

One of the important steps in predicting future water demand in the next 50 years is the difficult task of predicting future population growth and land use patterns in Cumberland County, TN. Land use patterns assist in predicting population growth by making it possible to assess how much land is available for growth, and they assist in demand estimation by generating a relative breakdown of the types of water consumers in the study area. Cumberland County, however, does not have any formal land use plan (i.e., zoning) in place to control (or predict) local patterns of growth. While there are a few studies that predict population growth for the County as a whole, none of them appear to focus on local growth rates or detailed land use patterns. Figure 1 displays the land use in Cumberland County according to the 2006 tax assessor's database. The land use patterns and the state of development of parcels of various types can provide clues to future development.

Cumberland County was one of ten counties recently selected by the Tennessee Department of Economic and Community Development to participate in a pilot study called "Retire Tennessee" that is designed to promote Tennessee as a great place for retirees to call home. Two of the predominantly residential areas, Lake Tansi and Fairfield Glade represent two established communities (not official cities) that attract retirees by offering small lots, convenient maintenance agreements, and various community club amenities. The three cities in the area – Crossville (the County seat), Pleasant Hill, and Crab Orchard – have similar attractions but more diverse development patterns. Crossville, however, has more dense residential communities than either Pleasant Hill or Crab Orchard. The remainder of the County is fairly rural with scattered residential development along major roads. Two related communities called Cumberland Cove and Cumberland Lakes (henceforth called Cumberland

Cove), which boast large lots and rustic "dream" homes, form a new development area where rural land is rapidly shifting into denser residential development.

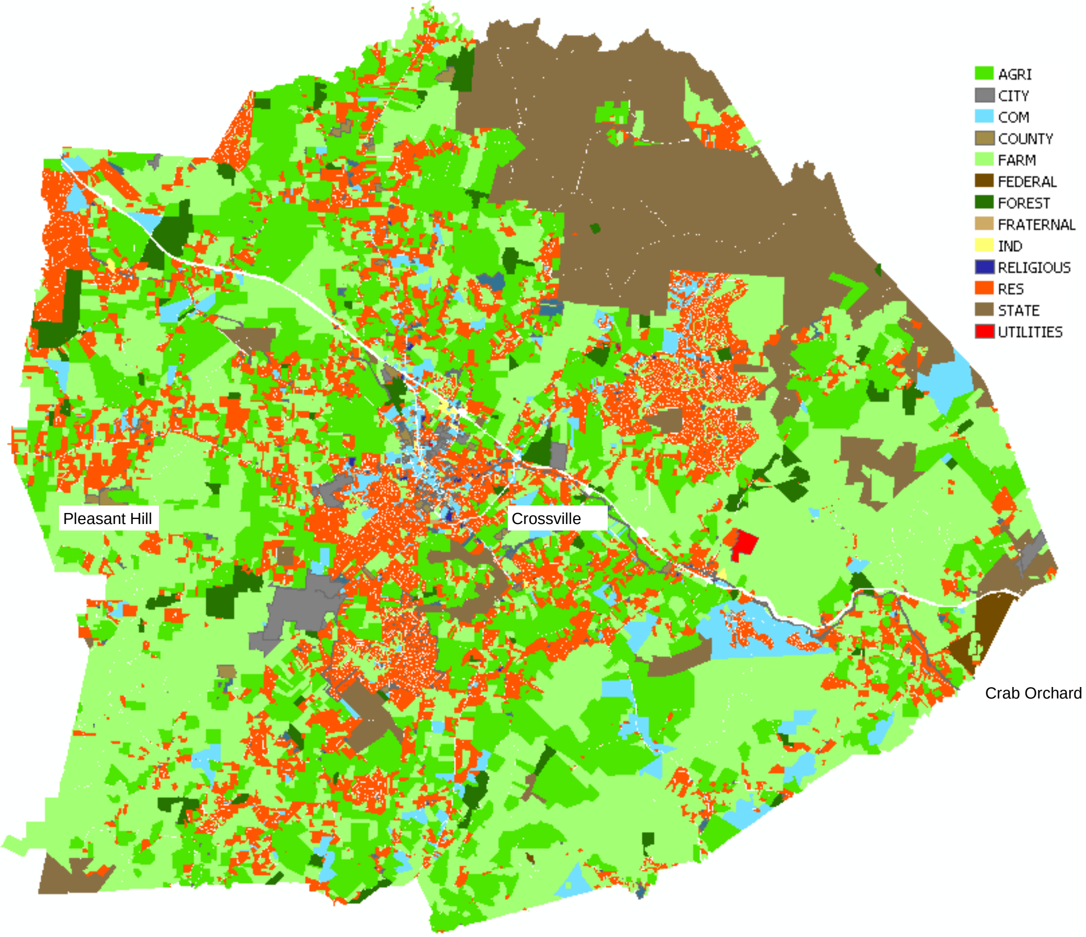

Figure 1 – Land Uses of Cumberland County according to 2006 Tax Assessor's Parcel Data

The tax assessor's database classifies each parcel into one of 12 land use categories (indicated on the map legend in Figure 1). A few clear patterns emerge from examining Figure 1. The majority of the county's land area is dominated by agricultural and farm land. The majority of residential development appears in four or five clusters. The center of the map shows the advanced development around the City of Crossville, including a dense core of commercial and residential development. There is also a large, state-owned wildlife preserve in the northeast corner of the County, which has almost no development in or immediately surrounding it. The land use pattern elsewhere in the county, however, is remarkably similar.

The database also lists the assessed land value and improvement value for each parcel. Thus any parcel with an improvement value greater than zero has been developed. For the purpose of estimating population density, only developed parcels that are classified as residential, farm, agricultural, or forest are likely to have homes on them. A few of the developed parcels classified as farm have improvement values reflecting recreational (e.g., golf resorts) or farm buildings, but most of them are residential lots with over 15 acres. Agricultural or forest parcels are "farms" that qualify for tax breaks under the TN Greenbelt program.

In order to evaluate the development potential in Cumberland County, the characteristics of the parcels (e.g. development, land value, lot size, and improvement value) were analyzed.

Figure 2 highlights the distribution of developed and undeveloped parcels of primarily privately owned residential and commercial parcels.

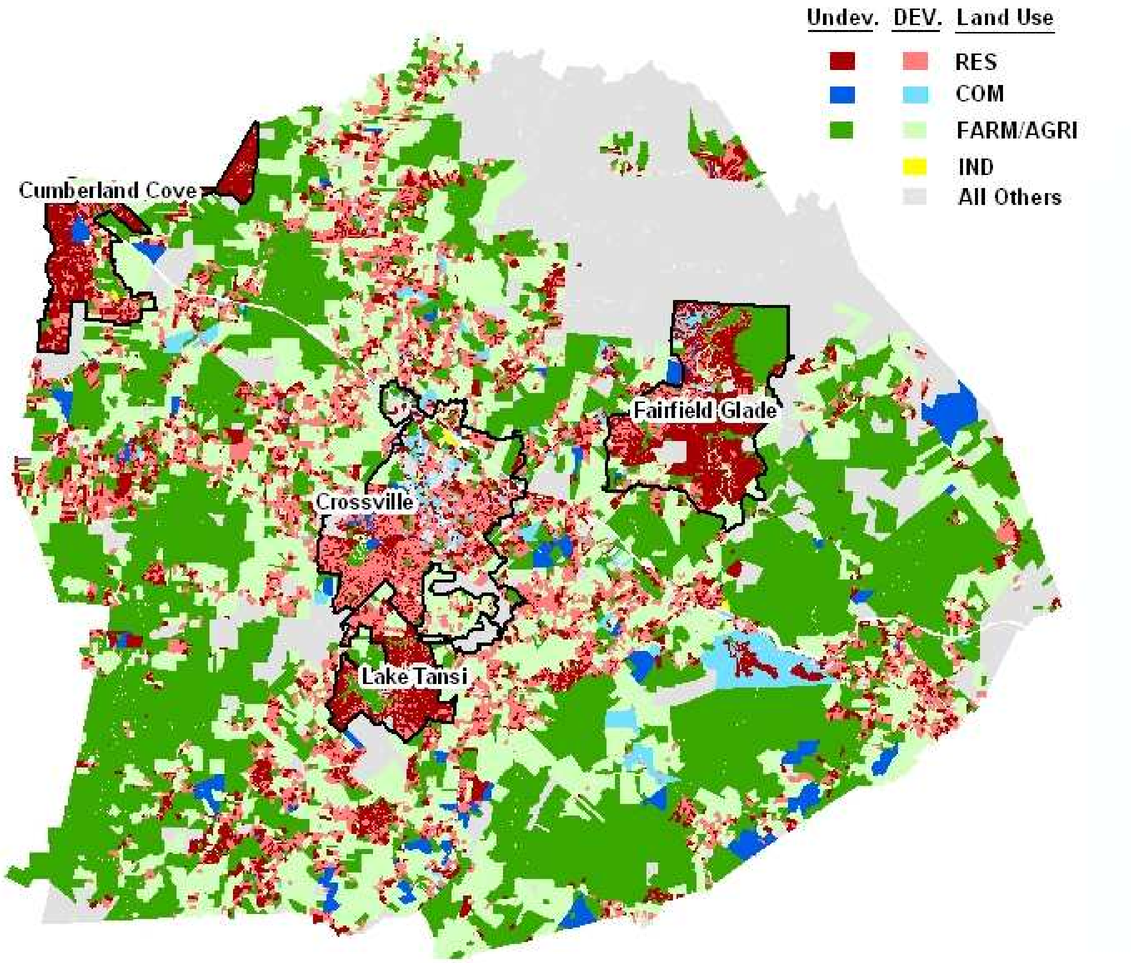

Figure 2 - Development Map of Cumberland County Showing Developed and Undeveloped Residential (RES), Commercial (COM), Industrial (IND), and Agricultural and Farm (FARM/AGRI) Parcels

Figure 2 indicates the undeveloped residential parcels (dark red) show an even clearer pattern than in Figure 1. It is evident that the dense residential communities generally cluster around Crossville, Fairfield Glade, Lake Tansi, and the Cumberland Cove area (which includes Cumberland Lakes). Furthermore, of these four regions, the latter three contain 69% of the undeveloped residential parcels in Cumberland County. Interestingly, the undeveloped commercial parcels are well distributed throughout the county.

Based on the land use analysis five study regions are selected for population and water use projections. Their geographic extents are shown in Figure 3. It should be noted that the boundaries reflect development patterns more than established political boundaries.

- City of Crossville
- Cumberland Cove (including Cumberland Lakes)
- Fairfield Glade
- Lake Tansi
- Remainder of the County

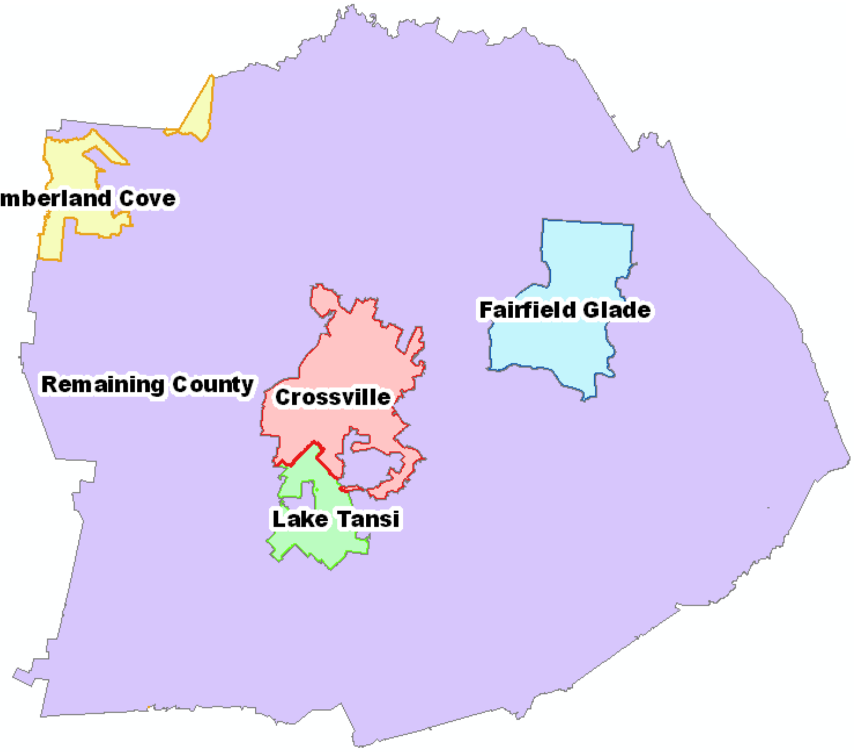

Figure 3 – Study Areas in Cumberland County

Further analysis of the parcels yielded some other general information about land use in Cumberland County that are useful for making population and water use projections. A few of the more interesting results are as follows:

- 90% of parcels in the County are residential
- 6% are farm/agricultural/forest,
- 37% of the residential parcels are developed,
- 57% of the farm/agricultural/forest parcels are developed, and
- 83.7% of the land area is residential/farm/agricultural/forest.
- The undeveloped residential parcels are, on average, half as large as the developed ones (0.92 vs 1.93 acres)

3. Growth Scenarios

The land use analysis establishes the general bounds on growth, and identifies the ultimate growth potential of the five study areas named in Section 2. Following the land use analysis, projections of the expected population growth in Cumberland County must be made in order to forecast water needs. Population forecasting is inherently uncertain, and becomes more so the further the time horizon of the forecast extends. In order to treat some of this uncertainty in a more concrete fashion, three distinct growth scenarios are carried through the remaining forecasting and modeling. They include the Slow, Expected, and Aggressive growth scenarios. The forecasts include population projections every 10 years starting in 2006 and ending in 2056. The Land Use Memo (full title: *Land use assumptions for Phase II of the*

Cumberland County Regional Water Supply Study), included in the addenda, details the methods by which the projections were made.

The growth scenarios all utilize the same starting values, and differ primarily in the specified growth rates for each ten year period. The growth rates also vary by study area. The percentage rate of growth reflects historical data, expert judgment from relevant stakeholders in the County, and other important factors (such as lack of sewer connection). Figure 4 displays the countywide population projections under the three population scenarios, as well as projections from two other studies. Note that the countywide projections are a sum of predictions for the individual study areas, each of which has independent growth projections and saturation points.

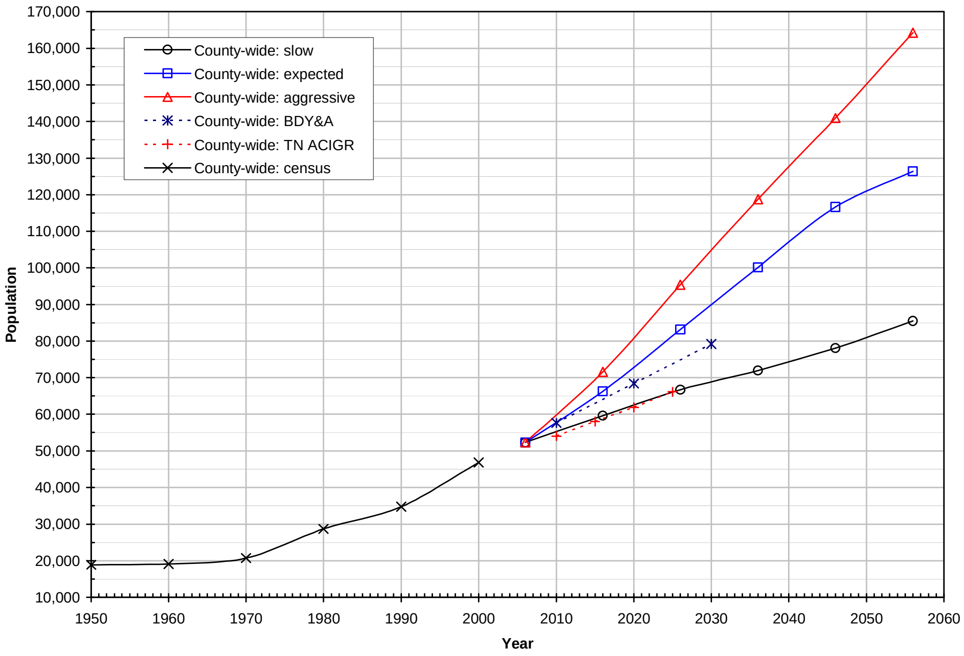

Figure 4- Population projections for Cumberland County. The three growth scenarios are displayed, as well as projections from two other studies (BDY & A 2002[i]; TN ACIGR[ii])

The population projections in fact show a wide range of variation among the growth scenarios. The range of population projections easily encompass the variability in the previous population projections, with the Slow growth scenario comparing favorably with the Tennessee Advisory Commission on Intergovernmental Relations' (TN ACIGR) forecast, and the Expected scenario a little higher than the Breedlove, Dennis, Young and Associates (BDY&A) forecast. The Aggressive scenario allows for substantial growth, but we note that even after 50 years, the projection does not begin an increasingly rapid growth phase as is often the case with simple exponential growth models.

Once the population is forecasted, it can be used to calculate projections of other relevant variables for estimating water usage. Namely, for each study area, the number of households and the number of employees must be forecast. By using historical data and stakeholder judgment, the future population per household ratio and the population per employee ratio were estimated for each forecast year. Dividing the projected populations by these factors yields the estimates of households and employees in Table 1.

Table 1 – Countywide Projections of Population, Households, and Employment for Cumberland County

Forecast Variable	Scenario	2006	2016	2026	2036	2046	2056
Population	*Slow*	*52,306*	*59,620*	*66,732*	*71,949*	*78,103*	*85,509*
	Expected	*52,306*	*66,288*	*83,157*	*100,163*	*116,643*	*126,373*
	Aggressive	*52,306*	*71,598*	*95,366*	*118,783*	*140,958*	*164,223*
Households	*Slow*	*23,345*	*27,622*	*31,990*	*35,323*	*39,294*	*44,144*
	Expected	*23,345*	*30,588*	*39,724*	*49,404*	*58,980*	*63,664*
	Aggressive	*23,345*	*33,106*	*45,772*	*59,252*	*69,006*	*79,369*
Employees	*Slow*	*25,000*	*29,083*	*33,200*	*36,522*	*40,259*	*44,305*
	Expected	*25,000*	*32,336*	*41,371*	*50,844*	*60,125*	*65,478*
	Aggressive	*25,000*	*34,926*	*47,446*	*60,296*	*72,659*	*85,090*

4. Water Needs Assessment Methods

Planning and Management Consultants, Ltd.'s IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as state-of-the-art, industry standard water demand forecasting software packages. IWR-MAIN was used as a tool to compute projected water use based on assumptions about the county's growth and water use factors. The IWR-MAIN user's manual[iii] explains in detail the structure of the model and the precise definitions of the terminology used. Where possible, we strive to use the correct IWR-MAIN terminology in describing the construction of the Cumberland water demand projection.

At the heart of the IWR-MAIN model is the usage model in Equation 1.

$$\boxed{\begin{array}{c}\text{Demand}\\ Q\end{array}} = \boxed{\begin{array}{c}\text{Counting Unit}\\ N\end{array}} \times \boxed{\begin{array}{c}\text{Use Factor}\\ q\end{array}}$$

Equation 1.

In short, the demand is determined by multiplying some counting unit by a water use factor. This model determines the demand in a given time period, in a given subsector, in a given study area. A *subsector* is the base organizational unit for which water demand is projected (e.g., the residential or commercial subsector). Each subsector has its own associated *counting unit*, which is a measure of subsector size that has a strong influence on water usage (population, households, or employees, for instance). The *use factor* is simply the volumetric demand for water per counting unit (gallons of water per capita per day, per house per day, etc) in a given time period. Thus, a water demand forecast requires projecting (at a minimum) how the counting units and use factors change over time.

The total county water use in a given time period is simply a sum of the consumption for each subsector plus any leakage or other non-consumptive use. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different regions of the study universe have distinct characteristics, the study can be broken down into *study areas*, each with their own group of subsectors and usage models. In this case, the study universe encompasses all of Cumberland County.

With respect to Cumberland County, the study areas have already been identified in Section 2. For each study area, two sectors were assumed: residential and non-residential (encompassing commercial, industrial, and institutional uses). Residential water use forecasts are computed using the forecasted number of housing units as the counting unit. The non-residential sector utilizes number of employees as the counting unit. The City of Crossville study area has an

additional subsector to model the water usage of Cumberland Medical Center, whose associated counting unit is the total population of Cumberland County.

Water Use Factors

Forecasting the future values of the counting units accounts for half of the necessary inputs in (1). The other half of the inputs comprises the water usage rates. IWR-MAIN's Forecast Manager and Conservation Manager offer a range of forecasting models to estimate future water use factors. Many of the methods are econometric methods that allow using explanatory variables to build a predictive model for the use factors. Among the explanatory variables that are commonly found to be associated with water use are income, housing density, persons per household, marginal price, average daily maximum temperature, precipitation, and cooling degree days. An extensive analysis of the water usage records and available data on potential explanatory variables determined that the predictive models were not appropriate for this study. It should be noted that future needs assessments should reconsider this decision because a few more years of high-quality water usage data (including sector breakdowns) may make these more complex models viable.

Without these models, IWR-MAIN provides two primary options for calculating use factors. The first, contained within IWR-MAIN Forecast Manager, is to simply use constant use factors calculated based on the number of counting units and the base year use. The second, which requires using IWR-MAIN Conservation Manager, is to develop end use models for each subsector. Each end use has its own use factor, and the sum of the use factors for each subsector is the overall use factor for this sector. This approach is more flexible than the constant use model, though it can be made equivalent through correct application of parameters in the model.

The chosen model is the end use model, mainly due to the fact that Conservation Manager will be used to evaluate the effectiveness of conservation measures in the water conservation plan. The added benefit to using the end use model in Conservation Manager is that it is possible to define end uses on three levels of water use efficiency and shifts between them over time. This feature allows incorporating natural, market based changes in water use efficiency that result from greater average efficiency of water using fixtures and appliances over time.

When employing the end use model, it is important to have an accurate base-year water usage estimate. This water demand projection uses two seasons, so monthly estimates of base year use are necessary. The summer season includes June, July, August, and September, and the Winter season includes the rest of the year. Water use is assumed to be constant for all months within a given season.

Residential water usage factors are based on monthly residential water consumption data from the South Cumberland and Crab Orchard Utility Districts. Both user districts had acceptable monthly records of residential water consumption and the associated number of customers (households). Since the counting unit for the residential sector is the household, the water use factor is expressed in terms of gallons per day per household (gpd/hhld). The S. Cumberland and Crab Orchard data yielded annual averages of 119.7 and 118.9 gpd/hhld, respectively. Lake Tansi is almost completely encompassed in the S. Cumberland district, and Fairfield Glade is contained within the Crab Orchard district, but the rest of the study areas still need water use factors. For the sake of simplicity, and to provide a conservative estimate of demand, the rest of the study areas are simply assigned the higher S. Cumberland water use factors.

Estimating nonresidential demand is somewhat more complicated than estimating residential demand, especially in terms of disaggregating countywide demand among the study areas. As mentioned before, future employment projections are based on each study area's population

and a countywide population to employee ratio. Since Crossville's commercial development is not distributed exactly the same as residential development, it is inevitable there will be some error in the geographic distribution of commercial water demand. Without zoning though, it seems at least reasonable that future commercial development will occur near growing areas with concentrated residential development. Thus, it is likely much of the commercial development will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

The methods for generating the water use rates for the commercial sector are described in much more detail in the Needs Assessment Memo in the addenda. In a general sense, the use rates for the commercial sector were determined from actual usage records from the utility districts and then spatially disaggregated. The disaggregation was performed in GIS by determining the location of commercial and industrial parcels in the parcels database with respect to the boundaries of the study areas and the utility districts.

Passive Conservation

One major source of error in many forecasts of future water use is the failure to consider the effect of more water efficient technology. Since the Federal Energy Policy Act of 1992, U.S. manufacturers have been required to meet minimum water efficiency standards for plumbing fixtures and toilets. Since that time, manufacturers have gone well beyond the minimum standards as a way to stay competitive. The mode of change effected by the availability of more efficient technology is called passive conservation, whereby consumers conserve just by replacing their older fixtures with more efficient ones when they need to be replaced. New construction also takes advantage of the more efficient technology by default.

The average potential savings associated with more efficient appliances were determined from the AWWA's 1999 *Residential end uses of water* [iv]report. The average replacement rate was determined from the National Association of Home Builders/ Bank of America *Study of the Life Expectancy of Home Components*[v]. Though the consumption-weighted average replacement rate for all water using home components is approximately 6.5%, a more conservative rate of 5% was assumed. This is equivalent to a 20 year lifetime for many of these components. The forecasts take these shifts into account using the passive conservation tool in IWR-MAIN Conservation Manager.

The effect of this savings is a very slight decrease in the per unit water use rate over time. Though counterintuitive for a growing county, this makes sense in Cumberland County for several reasons. Firstly, as explained previously, no credible predictive models can be developed with available data. Secondly, the land use analysis demonstrated that the average area of the undeveloped residential and commercial parcels in the county is significantly smaller than the developed parcels meaning that outdoor water use will rise slower than the population growth rate. Thirdly, as more retirees move to the county, the number of people per household will continue to fall, meaning that per household indoor use rate should not increase. Finally, technological advances in manufacturing of toilets, dishwashers, and other water using appliances will tend to lower water usage as older units are replaced with more efficient ones. This conservation savings due to technology, while slight was considered necessary for inclusion in the model because of the long study period.

Unaccounted for Water

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental water main breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each of the study areas, the Unmetered/Unaccounted tool sets the year-by-year UAW percentage. (IWR-MAIN restricts the percentage to a constant value for each year, and only whole percentages are permitted.)

Previous water demand studies of Cumberland County have used a wide range of methods to model UAW. Breedlove, Dennis, Young & Associates' (BDY) 2002 *Cumberland County Water Supply Needs Assessment* selects a target loss percentage of 10% as a worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[vi] prepared by the Corps and Ogden Environmental and Energy Services, Inc. also estimated 10% UAW on the basis of non-specified estimates by the Cumberland Utility Districts.

In this study, UAW estimates for the five study areas are based on actual data from the UDs. Perhaps in response to the previous studies, the UDs have begun collecting more detailed statistics on UAW. It is with these statistics and advice from interviews with the UDs that we estimate UAW. Table 2 shows the average UAW percentages by utility district in recent years. The final row displays the number of years of data upon which the percentages are based.

Table 2– Unaccounted-for-Water data by Utility District (% of total production)

	Crab Orchard	Crossville	South Cumb.	West Cumb.	**Consumption Weighted Average**
Annual UAW%	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 2 appear incredibly high, but when we consider the short record length, it is clear that at least in some cases, some outlier values may be skewing the results. While there appears to be some potentially significant seasonal variation in the loss percentage, at least in Crab Orchard and Crossville, there are not enough data to make a strong case for modeling this variation. Additionally, IWR-MAIN does not allow seasonal variation in the Unmetered/Unaccounted percentage.

Except in Crossville, the record lengths are too short to make a valid estimation of the UAW by utility district. So we calculate the county average as weighted by consumption in the UDs. The yearly average UAW percentage is calculated as 22.4%, which is conservatively rounded upward to 23%. All of study areas except for Crossville are assumed to have this 23% average. If metering errors, line flushing, and known losses are assumed to be 5%, this means that an average of 18% of total produced water is actual loss. These figures compare favorably with the 20% rate indicated in interviews with the Crab Orchard Utility District, and 14-15% loss rate reported by West Cumberland. With the Crossville records being a bit longer, we feel comfortable setting Crossville's UAW percentage at 19%, which is slightly more conservative than the 15% unaccounted for and the 10-12% loss estimated by the Crossville UD in a May 2006 interview.

For the purposes of a baseline forecast, the UAW percentages are assumed to remain constant in time, which is a dubious assumption based on the large variances in month to month losses alone. Almost certainly, losses will either increase as the system ages, or decrease as the result of system improvements and maintenance. We are hesitant, however, to forecast changes to the UAW percentage in a baseline forecast, or impose 'desirable goals' as some past studies have done. Additionally, the conservation measures evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

Model Validation

Based on the assumptions made, it is possible to compare the projections to observed water usage. Figure 5 displays the estimated total county water consumption as compared to

observed consumption based on data from the UDs. These figures exclude UAW. On average, the estimated values are about 4% above the observed values, and therefore slightly conservative.

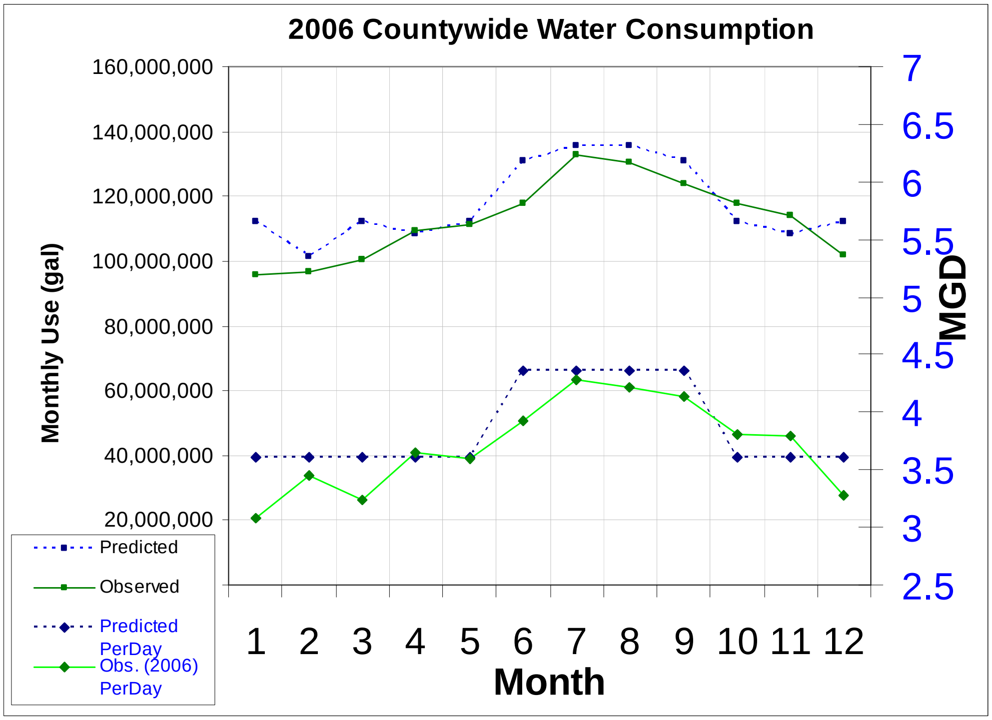

Figure 5 - Predicted versus Observed Countywide Water Consumption (excl. UAW)

The agreement shown between the observed and estimated values in water use is certainly not perfect, but it indicates the assumptions are at least reasonable, and slightly conservative. We note that there is excellent agreement at the peak water use month of July.

When the total usage includes UAW, the agreement between the observed 2006 values and predicted values is slightly worse. Data from the utility districts indicate that unaccounted for water makes up 27% of total produced water in 2006. This is higher even than the already fairly conservative assumption of 23% (19% for Crossville) used in the modeling. Figure 6 displays the estimated and observed values, which indicate the model predictions are about 7% *below* observed values. This is certainly a source of potential error, but is more likely due to above average losses in 2006. For the purposes of forecasting, the recent historical averages for UAW are a more reasonable basis for estimating future UAW than the 2006 values alone. Thus, no further calibration is necessary to match the observed and predicted 2006 demand.

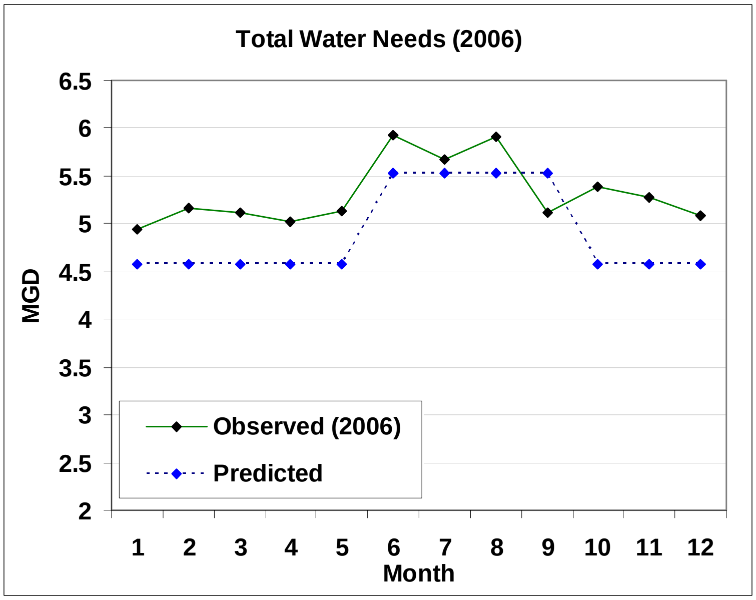

Figure 6– Model Predicted and Observed Cumberland County Water Use in 2006

5. Summary Results

The results of the baseline water supply needs assessment are presented in this section. All results are presented in terms of average daily usage in millions of gallons per day (MGD) except when otherwise noted. Summary results are presented here, but full results are available in the addenda.

It should also be noted that this is a planning level document, so the results are presented as annual or seasonal average. These figures should be sufficient for estimating water storage needs. Calculating peak usage, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak usage estimates were not called for in the scope of services, but are presented for completeness. BDY&A's 2002 *Cumberland County Water Supply Needs Assessment* cites factors in a range of 1.25 to 1.35 of daily consumption for Cumberland. The Corps' *Cumberland County Regional Water Supply Preliminary Engineering Report* appears to use 1.35 as well. Thus, a factor of 1.35 is applied to the results of this section. Note that peak factors are applied only to the consumption, and subsequently, the unadjusted UAW is added.

Countywide Results

The countywide results present the broadest picture of the water needs projections. Figure 7 presents the demand totaled for all study areas and all subsectors (including UAW). The demand for all three growth scenarios is indicated separately, however. The results indicate that demand will not quite triple in 50 years under the Aggressive scenario, less than double under the slow scenario, and roughly double under the expected scenario.

Under any growth scenario the projected demand increases significantly over the 2006 baseline. As noted previously, there is a great deal of uncertainty, particularly in the estimation of future trends in UAW. Figure 8 reports the county totals for consumption, which excludes the UAW. While there is bound to be some UAW in the future, the consumption projections are marginally more certain. The water conservation plan will more directly assess the effects of reducing UAW.

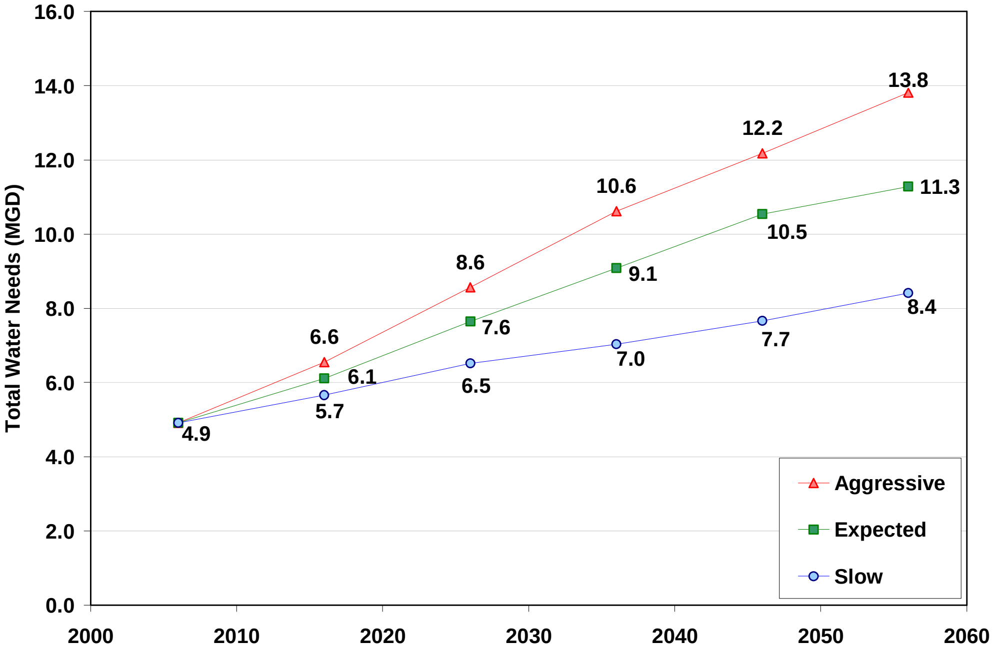

Figure 7. **Countywide Daily Average Total Water Needs for the Slow, Expected, and Aggressive Growth Scenarios.**

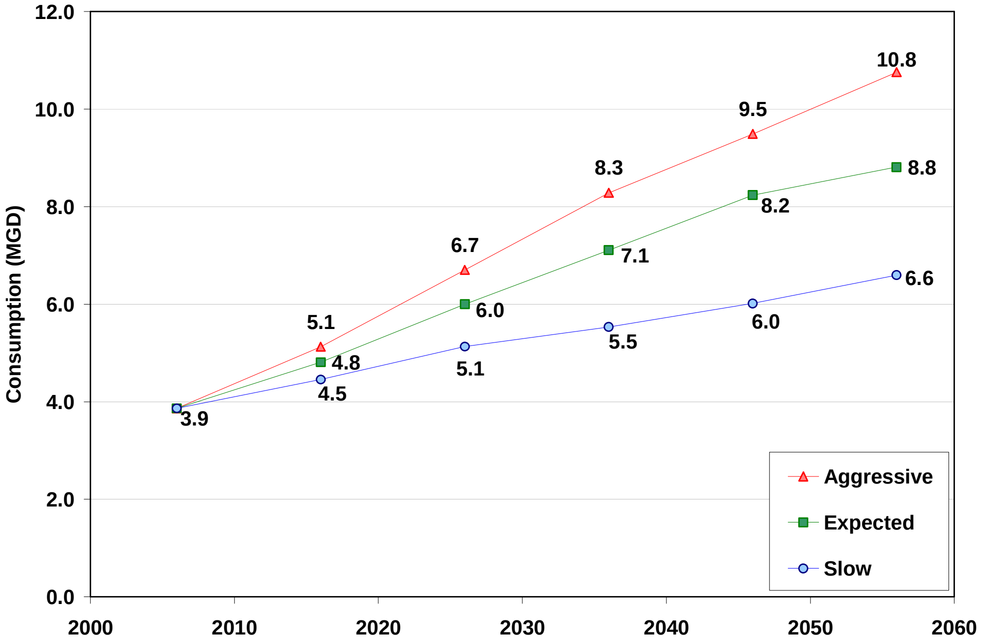

Figure 8 – Countywide Daily Average Projected Water Consumption (excludes UAW) for the Slow, Expected, and Aggressive Growth Scenarios

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, the usage varies by season. The Summer months include June-September, while the Winter includes the remaining months. The results are presented here by scenario and season. Countywide, the summer usage remains a fairly consistent 12-13% above the annual average, and winter usage is always

roughly 6-7% below. This is a result of the cumulative effects of the different winter and summer use factors for the subsectors (see the Water Needs Assessment in the addenda for full description and usage rates). Table 3 displays the countywide daily demand by season.

Table 3– Seasonal Variations and Peak Projected Total Water Needs (MGD)

Scenario	Season/Peak	2006	2016	2026	2036	2046	2056
Aggressive	Annual	4.91	6.55	8.56	10.61	12.18	13.81
	Summer	5.55	7.41	9.71	12.09	13.84	15.67
	Winter	4.59	6.12	7.99	9.87	11.34	12.87
	PEAK	*6.26*	*8.35*	*10.91*	*13.51*	*15.50*	*17.57*
Expected	Annual	4.91	6.11	7.64	9.08	10.54	11.28
	Summer	5.55	6.90	8.63	10.27	11.94	12.77
	Winter	4.59	5.71	7.14	8.48	9.84	10.54
	PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
Slow	Annual	4.91	5.66	6.52	7.03	7.66	8.41
	Summer	5.55	6.40	7.38	7.98	8.71	9.58
	Winter	4.59	5.28	6.08	6.56	7.14	7.83
	PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*

Table 3 also displays the projected peak demands, which reflect a 1.35 peakage factor applied only to the annual average consumption. As mentioned before, this factor is based on peak factors cited in previous studies and is not based on usage data. The unadjusted annual total UAW is then added on to this peak consumption to arrive at total water needs.

Water Needs Analysis By Subsector

Table 4 indicates the annual average daily demand by subsector for the entire county. In terms of total demand growth, it is clear that most of the growth occurs in the residential sector. The other sectors exhibit slightly lower percentage growth, but still increase significantly over their base year values. The NonRES results indicate that commercial growth will be of a low water intensity variety, which is consistent with a primarily service oriented commercial sector. The introduction of only a few large (industrial) water users, however, could add significantly to commercial demand, making the NonRES sector the most likely to be a low estimate of actual future demand.

Also notable is that the UAW subsector, while remaining a constant percentage of total water use, grows to become a more significant water ‘use’ than the nonresidential sector under the aggressive scenario. While the UAW percentage is based on the best available current loss estimates, this sector is most likely to reflect an overly conservative estimate of actual future UAW. The actual processes of leakage are more complex than a simple percentage loss, so growth in consumption does not necessarily mean a proportional rise in leakage. Additionally, leakage will most likely be addressed by future loss reduction measures. The impact of loss reduction measures is treated in the Water Conservation Plan.

Table 4 - Projected Total County Water Needs (MGD) by Scenario and Subsector

Scenario	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
	NonRES	1.49	1.87	2.11	2.32	2.52	2.71
	CMC	0.07	0.10	0.13	0.17	0.20	0.23
	UAW	1.04	1.42	1.86	2.33	2.69	3.05
Aggressive Total		**4.91**	**6.55**	**8.56**	**10.61**	**12.18**	**13.81**
Expected	RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
	NonRES	1.49	1.78	2.04	2.18	2.34	2.42
	CMC	0.07	0.09	0.12	0.14	0.16	0.18
	UAW	1.04	1.30	1.64	1.97	2.31	2.48
Expected Total		**4.91**	**6.11**	**7.64**	**9.08**	**10.54**	**11.28**
Slow	RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
	NonRES	1.49	1.68	1.91	1.96	2.02	2.08
	CMC	0.07	0.08	0.09	0.10	0.11	0.12
	UAW	1.04	1.20	1.38	1.50	1.65	1.82
Slow Total		**4.91**	**5.66**	**6.52**	**7.03**	**7.66**	**8.41**

* RES_PS – Residential, Public Supply; NonRES – Nonresidential; CMC – Cumberland Medical Center; UAW – Unaccounted for Water

Comparison to Previous Estimates

A comparison of GKY's water needs forecasts with previous estimates of Cumberland County's water needs clearly demonstrates the effect of prediction method chosen. Figure 9 compares the estimates in this study to those by Breedlove, Dennis, Young and Associates (BDY&A, 2002), the Army Corps of Engineers (USACE, 1998)[vii], and Lamar Dunn & Associates (LD&A, 2001). LD&A used a simple percentage growth model to estimate future demand. While this model may be appropriate in the short term, it is evident that the simplistic exponential model rapidly leads to unstable and incredibly high demand estimates at more distant time scales. It is clear that this model is insufficient for modeling long term water needs because it is overly simplistic and does not take into account any realistic limitations on growth.

Also interesting is that the BDY&A study presents a very high estimate of demand. This is likely a result of the method used for forecasting the future use factors. The study uses a gross total per capita consumption use factor to estimate the water use. BDY&A chose to express this factor as total public supply water use divided by total population (instead of population served). As a result, the numerator does not reflect the many self-supplied water users in the county (whose use would not be counted in public supply water), while the denominator does count them. This partially explains the artificially low historical use factors (54 and 77 gpd per capita in 1984 and 2000, respectively). The rapid increase in water usage factors is likely more a result of new development being added on public supply (versus self-supply) in a much higher proportion than the existing residences than it is a response to economic trends or fundamentally different water usage patterns of new residents. Furthermore, to bring the use factors to present day average values from this low starting point requires astounding gains in the per capita use factor. Projecting the future water use factors from historical values can lead to extremely high use forecasts, especially when rapid population growth continues.

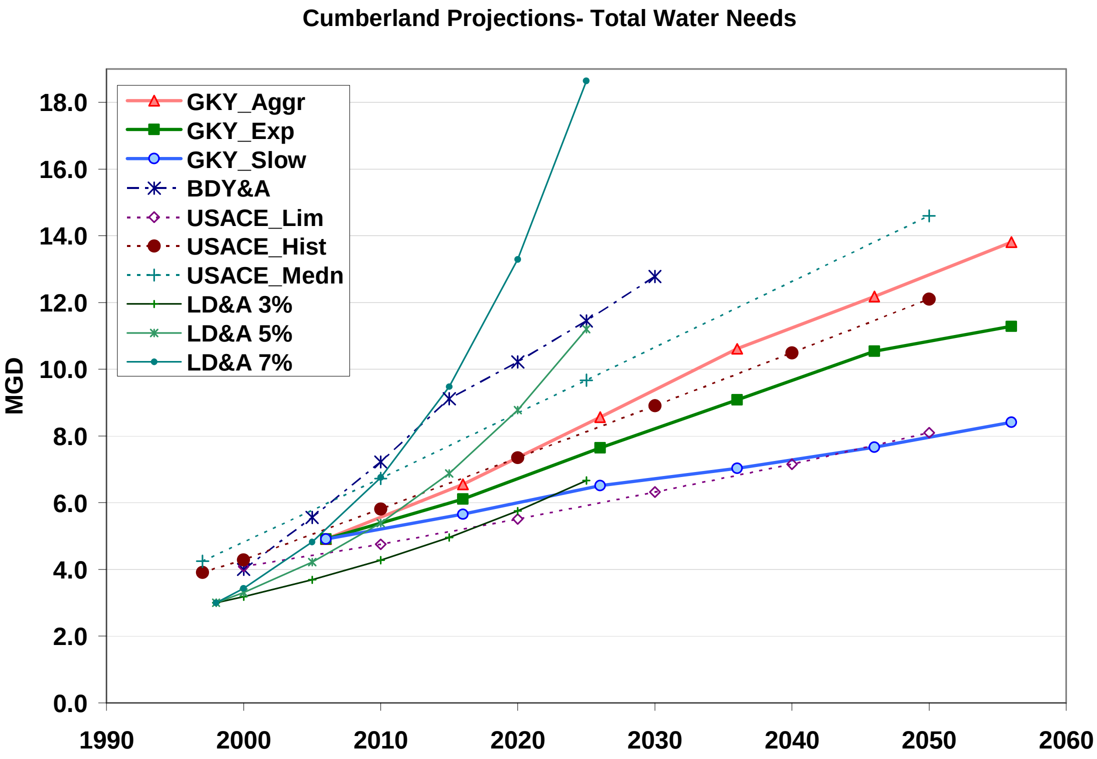

Figure 9 - A comparison of water needs forecasts for Cumberland County

The USACE projections rely upon a variety of different methods, including a model developed in IWR-MAIN (i.e. Medn → Median projection). These projections seem most closely in line with GKY's projections. The historical and limited methods actually incorporate limitations on growth, though in a more simplistic way than the GKY study.

The GKY study likely presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[viii] of the Pacific Institute note, "With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches." GKY's baseline projections present a new approach to countywide water demand forecasting, as anticipated improvements in water efficiency are taken into account. These anticipated improvements are in a sense inevitable as national laws and standards, as well as simple market availability have affected a shift to more conserving technology. For example, the Energy Policy Act of 1992 has made virtually all new toilets on the market compliant with a 1.6 gallon per flush efficiency standard.

It is important to note the efficiency assumptions are nearly completely independent of any decisions and policies made by public officials and citizens in Cumberland County. Other water use reductions may result from programs already in progress (notably, infrastructure improvements to reduce leakage). To establish a conservative baseline projection, however, we limit the conservation measures to 'natural' efficiency upgrades due to more advanced technology gaining a greater market share over time. Other conservation actions are analyzed much more thoroughly and explicitly in the Water Conservation Plan.

6. Uncertainty

The act of forecasting into the future is an inherently difficult task. It is important to recognize (1) that uncertainty is present in any projection, (2) uncertainty in baseline assumptions influences uncertainty in projections, and (3) errors compound over time, making distant projections less reliable than near-term projections.

The forecast model is designed to explicitly take into account uncertainty where possible, and otherwise, avoid introducing unknown uncertainty. (We use 'uncertainty' instead of error because error can't be calculated until the future when there are actual water demand values in the forecast years.)

The largest source of uncertainty in this forecast is likely contained in the population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth scenarios (instead of only an expected growth scenario), we introduce reasonable bounds on the uncertainty of this projection. (That is not to say that Slow and Aggressive scenario projections present the absolute lower and upper bounds on the prediction.) This understanding of uncertainty in the population projections is useful since the housing forecasts are calculated in tandem with them, and the employment projections depend directly on population as well. In these projections, the assumed growth rates, people per house statistic, and population per employee estimates all are potential sources of error. As an illustration of the potential consequences of error in initial projection, Table 5 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. (A constant percentage growth model is assumed.) Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 5 - Consequences of 0.5% error in growth rates (forecasted Units per 1000 base Units*)*

	10 years		**25 years**		**50 years**	
Initial rate projection	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*
1%	53	-56	150	-169	361	-461
2%	58	-61	190	-213	586	-746
5%	76	-79	381	-427	2435	-3075
10%	116	-120	1166	-1301	23914	-29879

Table 5 indicates just how serious minor errors in the prediction parameters can be, particularly in fast growing regions. The land use limitations on growth assumed in this study help put a limit on how large the error can be. In practice, growth can be limited (or spurred) by many factors other than land use consideration, but some limits are advisable as a constant percentage growth, exponential model is rarely a realistic assumption for a very long study period.

The other major potential source of model uncertainty is in the water use factors. While IWR-MAIN has several advanced methods of estimating future demand built into the software, additional parameter estimates and explanatory variables would be necessary (each bringing additional uncertainty). Any more complex model (such as a linear or multiplicative regression) would introduce more uncertainty through parameter estimates in addition to any uncertainty in forecasting future explanatory variable values. The water usage data provided by the UDs is just enough to come up with baseline water use factors. The small sample sizes of the water use data mean there is quite a bit of uncertainty in the water use factors (especially in the monthly values). By averaging the months within two seasons, the sample size is effectively increased, reducing the uncertainty introduced by outliers.

In a similar manner, the UAW percentages are averaged over the county to increase the effective sample size of estimate, and reduce the effect of outliers. Section 4 (Water Needs Assessments Methods) demonstrated that selection of parameters led to good agreement with real water use patterns in the base year.

The importance of the proper treatment of uncertainty in model prediction cannot be overstated. Underestimating future water needs can lead to a dangerous situation in the form of a water shortage or even running out of water. Overestimation of water needs can lead to unnecessary projects or oversized projects at a much higher cost than necessary. Without a realistic view of the uncertainty present in the forecasts, decision making on future supplies may not be truly addressing the water needs. Fully cognizant of the uncertainties present in this forecast, GKY has made every effort to document the uncertainty and present a reasonable range of potential future water needs representative of the effects of the known uncertainty.

Comparisons with previous studies have shown that this study's predictions of water needs tend to be somewhat lower than previous estimates made with simpler models. A careful consideration of the methods used in earlier studies generally leads to the conclusion that the forecasted water needs may be overestimated. This study attempts to provide as accurate a forecast of water needs as possible, with full description of methods, thus allowing the decision maker to assess the validity of the study. Assuming the study is deemed valid, the range of forecasts allows for the decision maker to lend more credence to one scenario versus the others based on their judgment and level of risk-aversion.

7. Conclusions

This Water Needs Assessment has analyzed the current and future water needs of Cumberland County using the best available data and expert opinions. Cumberland County has experienced rapid growth in the past several decades, and that growth may continue so long as the water demands can be met.

The population projections reflect demographic trends, opinions of local experts, and real limits on growth based on land use. The development of the appropriate water use factors was based directly on actual water use data from the utility districts. It must be recognized that a 50 year projection is subject to a great deal of uncertainty. The Aggressive, Expected, and Slow growth scenarios help to capture some of that uncertainty.

The projections in this report indicate that Cumberland County's water needs will very likely exceed the current supply in the next 50 years, but not quite as soon as previously projected. As the average demand becomes closer and closer to the firm yield of the existing sources, the potential for failure in a particularly severe drought year increases considerably. Therefore, Cumberland County is well advised to continue to examine and develop opportunities for conservation and securing an increase in available supplies.

8. References

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[i] Breedlove, Dennis, Young & Associates, Inc. (BDY&A). *Cumberland County Water Supply Needs Assessment*. May 2002.

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[v] NAHB/Bank of America Home Equity Study of Life Expectancy of Home Components, Feb. 2007

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[viii] Gleick, P., Haas, D., Henges-Jack, C., Srinivasan, V., Wolff, G., Cushing, K.K., and Mann, A. (2003) *Waste Not, Want Not: The Potential for Urban Water Conservation in California.* Pacific Institute for Studies in Development, Environment, and Security. Oakland, CA. November, 2003.

Water Conservation Plan

1. Introduction

Cumberland County's attention has been increasingly drawn to water resources over the past decade. Growth projections by several firms[ix,x,xi] have estimated that the water needs of Cumberland County will exceed firm yield in less than 10 years. Excluding the undesirable outcome of running out of water, Cumberland County has two options: increase water supply or reduce demand.

The Water Needs Assessment established forecasts for Cumberland County's water demands under three different growth scenarios. Before evaluating additional water supply alternatives, it is prudent to determine if conservation can effectively reduce demand. This study investigates the extent to which demand can be reduced below the baseline forecast values in the Water Needs Assessment.

Cumberland County has no significant history of water conservation programs, but a range of viable options could lead to significant water savings. This Water Conservation Plan report identifies six potential water conservation measures local government or the utility districts could reasonably enact. The effectiveness of the proposed conservation measures is modeled using the IWR-MAIN Conservation Manager© software program. IWR-MAIN is recognized as a state of the art program for modeling water demand and conservation programs.

A detailed account of the modeling methods is presented in the Water Conservation Plan Memo (full title: *Water Conservation Plan for the Cumberland County Regional Water Supply Study*) in the addenda. This document presents results of modeling the six conservation measures, and based on these results a final water conservation plan is presented.

2. Conservation in Cumberland County

Until the past few decades, Cumberland County has always had an abundant and easily accessed water supply. As a result, there has been limited impetus to encourage conservation in the county. This limited conservation experience presents a substantial opportunity for future efforts to harvest the 'low-hanging fruit' of water conservation benefits at a relatively low cost.

Cumberland County's opportunities to conserve are typical for communities of similar size and age. Cumberland County has two primary avenues for improving water efficiency. One major opportunity for conservation is for the water utility districts to reduce water loss and other unaccounted for uses. Total unaccounted for water use averages near 20% of total produced water, with losses approaching 30 or 40% for some districts in some months. This is not unusual for utility districts of a similar size and age. Cumberland County's utility districts face additional challenges resulting from the very hilly and rocky terrain of the county. High water pressure can stress pipes, and the rocky soil can both puncture pipes and create a situation where leaks have adequate drainage to avoid detection. While Cumberland County's distribution system loss rates are not atypical, reducing losses presents a major avenue for conservation. With appropriate, proactive leak detection efforts and other loss reduction measures, Cumberland County may be able to reduce its losses to ten percent or less.

While the losses in the distribution system are primarily attributable to water suppliers, the water consumers in Cumberland County are another major source of water inefficiency. Interviews with the utility district managers indicated that the majority of residences in Cumberland County use less efficient toilets and plumbing fixtures than current industry standards. This will largely be corrected over time as residents replace older fixtures with

newer, more efficient fixtures. Accelerating this transition, however, is a major opportunity for conservation.

Between reducing inefficient water use on the part of the utility districts and water consumers, there is significant potential for conservation in Cumberland County. The following sections detail several conservation measures to take advantage of this potential.

3. Conservation Measures

Six conservation measures have been identified for analysis in developing the Cumberland County Water Conservation Plan. Each conservation measure is described in brief below. More detailed policy descriptions and modeling methods for each conservation measure are included in the Water Conservation Plan memo included in the addenda. Additionally, the six conservation measures were chosen from a larger set of possible measures based on their relevance and implementability in Cumberland County. The final water conservation plan reflects a combination of some of these measures.

3.A. Unaccounted for Water Reduction (non-leakage)

While leakage is the most commonly identified contributor to Unaccounted for Water, there are other contributing factors to UAW in Cumberland County. Foremost among these are metering errors, flushing usage, and fire fighting usage. Reducing fire fighting usage is not generally within the control of water utilities. Mains flushing is an important part of system maintenance to prevent blockages and corrosion and preserve water quality. Flushing is also necessary before new connections are opened. In large new developments, flushing loss can be tremendous, especially when the opening of new connections is staggered (requiring multiple flushing events). Finally, metering errors are likely a result of older meters. Cumberland County does not have a significant number of unmetered connections.

By addressing excessive flushing and metering errors, Cumberland County may reduce its UAW percentage. All of the utility districts have either recently replaced their meters or are in the process of doing so, but replacement programs should be repeated every 10 -15 years to ensure reductions in UAW are preserved. Reductions in flushing volumes may be achieved through a review of flushing policies, and system upgrades to convert branched distribution pipe networks to looped networks where practicable.

3.B. Leak Detection and Reduction

Leak detection is another method of reducing UAW. Cumberland County faces a range of challenges in getting leakage under control. The age of the pipes, rocky soil, and large elevation differences (and resulting high pressure) have been cited by county utility managers as major causes of leakage. Leaks occur on both mains and service lines. Current leak detection efforts in the county are primarily focused on repairing leaks when they come to the surface or when there are service complaints.

A comprehensive leak detection program in Cumberland County could include several leak detection strategies. Hiring a leak detection contractor to investigate the majority of the county’s mains and service line connections would be a good start. Listening surveys use geophones and other listening devices to find leaks and digital correlators to pinpoint leak positions. In the long term, permanently installed listening devices may be the most effective method of detecting leaks. With training, utility district staff could conduct listening surveys and use a digital correlator.

3.C. Education

Educating water consumers on the value of water and the benefits of conservation, while a valuable end in itself, can also lead to real reductions in water usage. Reductions are achieved in two primary ways: convincing water users to change their water usage habits, and affecting purchasing decisions on fixture and appliance types (and whether to replace them sooner). The water utilities in Cumberland County do not currently have any dedicated customer education programs, but they do communicate with customers through billing inserts and other methods. In 2007, the City of Crossville, Cumberland County, and the utility districts used several communication methods to publicize the drought restrictions and appropriate short-term water saving tips. A true education strategy is geared more toward long-term shifts in behavior and more permanent savings.

Several types of education programs exist, and the water utilities could develop new programs, specially tailored for Cumberland County users. In general, using a variety of education strategies (each with a defined message and goal) in combination can achieve the most robust results. Table 1 indicates three general types of educational programs, the target audience, and a description.

Table 1 - Education programs

Policy	Intended audience	Description
General advertisement	All water users	Water saving tips and information.
Targeted Messages	Commercial users, homeowners with irrigation systems, homeowners with older homes, etc.	Communicate well developed messages perhaps once a year to encourage a specific conservation action, e.g: highlight cost savings from replacing toilets, promote xeriscaping, .
Education programs	School age children and families	e.g.: Programs every 2 years for 4th and 5th graders, 9th and 10th graders
	Retirees, community associations	Short (0.5 day) programs in retirement communities, civic centers.

3.D. Pricing

While water prices are generally set to reflect the costs of production, price changes do affect water demand. The price elasticity of demand indicates the amount of change in demand due to a unit change in price. See Equation (1). An elasticity of positive one indicates that a 1% increase in price will lead to a 1% increase in demand. Price elasticity of demand for water is nearly always negative (price increases reduce demand), and is generally considered to be inelastic (in between 1 and -1, or in this case, 0 and -1). In fact, when considering water demand, it is rare to see elasticities even go beyond -0.5.

$$e = \frac{\Delta q}{\Delta p}$$ **Equation 1**

Where:

e is the price elasticity of water demand
Δq is the percentage change in water demand by a water user (or set of users)
Δp is the percentage change in water price

There is a wide range of economics literature examining the price elasticity of demand for various water users. Focusing on residential customers, Arbués et al. (2003)[xii] and Worthington and Hoffman (2006)[xiii] provide good reviews of a large range of economic

studies investigating price elasticity of water demand under a wide range of pricing policies. In general, the majority of the estimates of residential long term elasticity fall into the -0.05 to -0.5 range. The IWR-MAIN manual cites residential elasticity as between -0.05 and -0.35.

Several UD managers expressed the view that the water demand of Cumberland County residents is somewhat to considerably more sensitive to price changes than the average U.S. citizen. Supporting this assertion is that many of Cumberland County's residents are on fixed incomes. Residents' response to price signals is also influenced by having a monthly billing cycle in all the Cumberland County UDs. As a result, elasticities in Cumberland County are assumed to be toward the upper end of the ranges presented in the manual.

Currently, all the Cumberland County utility districts have a fixed fee for consumption up to a certain initial limit (1000 or 2000 gallons), and a fixed block rate for additional consumption above the limit. A wide range of pricing strategies are available for water utilities to meet goals as wide ranging as maintaining adequate revenues to encouraging conservation. A full discussion of the pricing options considered for the modeling of this conservation measure is contained in the Water Conservation Plan memo. Due to complexity of modeling some of the pricing methods and the limitations of IWR-MAIN, a simple pricing policy is selected. The policy is simply to enact a 30% increase in marginal water price over the base price (set equal to 1) after the base year. Since the price is measured in constant 2006 dollars, the underlying assumption is that after the initial increase, price increases at a rate exactly equal to the inflation rate (or more accurately, water consumers' own discount rate).

3.E. Water Efficiency Codes and Ordinances

One of the most effective methods to generate long term water savings over baseline estimates is to influence the water efficiency of new development. Ensuring that developers are installing efficient fixtures and appliances means that new users will have a lower water use intensity than existing users. Additionally, it is significantly easier to create standards for efficiency before new units are built than to retrofit later.

Currently, Cumberland County lacks building codes in all areas except inside the Crossville city limits. Reportedly, even within Crossville, the efficiency of fixtures is rarely examined by inspectors.

A comprehensive water efficiency code and ordinance will mandate the inspection of water fixtures, toilets, and appliances to check for their efficiency. Additional ordinances may govern the outdoor use of water at commercial and institutional properties by requiring rain sensor shut-off for irrigation systems, for example. Benefits, such as reducing the connection fee, may also be considered for developers who install ultraefficient appliances and fixtures in new properties.

3.F. Retrofit, Rebate, and Replacement Programs

Retrofit, replacement, and rebate programs are other methods to reduce the average water use factors for existing users by replacing (or providing incentives to replace) existing fixtures and appliances with more water efficient models. The key is that the transition happens at a much faster rate than it would under natural replacement.

The programs can take several forms. One approach is to simply provide inexpensive fixtures and devices such as faucet aerators, shower heads and toilet dams free of charge to users. The drawback is that the consumers do not always install them. As the Massachusetts Water Resources Authority's Steven Estes Smargiassi noted[xiv], "We discovered if you gave away devices, most of them were 'installed' in kitchen drawers – not on the bathroom or kitchen fixtures." One way to mitigate this problem is to provide free installation as well. Rebate programs provide monetary incentives for the replacement of larger water using devices,

notably toilets and clothes washers. While often expensive, rebates for toilets and clothes washers can provide greater water savings than small devices, and the transition to more efficient water uses can be more easily verified.

Cumberland County's utility districts do not currently offer any retrofit, replacement, or rebate programs. These programs may be well suited to Cumberland County, as the majority of fixtures and appliances are believed to be older models. Additionally, interviews with utility district managers and other stakeholders indicated that county residents replace these fixtures and appliances at a slightly lower rate than the nation as a whole.

4. Methods

The water savings of the six conservation measures are modeled using IWR-MAIN Conservation Manager. The Water Conservation Plan Memo discusses the modeling methods, assumptions, data collection, parameter estimates, and scenario development in much greater detail. Table 2 displays the tools used in IWR-MAIN Conservation Manager to model the effects of each of the conservation measures.

Table 2- Modeling Methods of the Six Conservation Measures

Conservation Measure	IWR-MAIN Modeling Method
A. Non-Leakage UAW Reduction	Tools→ Unmetered Fraction
B. Leakage Reduction	Tools → Unmetered Fraction
C. Education	Intensity → Enter/Build, Passive Conservation
D. Pricing	Intensity → Enter/Build (Multiplicative Model)
E. Codes and Ordinances	Tools → Passive Conservation
F. Retrofit, Rebate, Replacement	Tools → Active Conservation

5. Results

The six conservation measures cover a broad range of strategies for reducing water usage. Accordingly, the modeling results indicate important differences between the conservation measures in terms of magnitude and trends of water savings. The growth scenario also affects the relative performance of the conservation measures. While the modeling methods for each conservation measure are identical between growth scenarios, certain measures perform comparatively better or worse depending on the rate of growth. Table 3 compares the total water needs projections for the baseline and six conservation measures under the 3 growth scenarios. For each year in each growth scenario, the conservation measure with the lowest total water needs is displayed in bold type.

The results indicate some clear trends in the projected water needs under the baseline and conservation scenarios. Most notably, leakage reduction appears to lead to the most substantial reductions over the entire study period. Education programs and Codes and Ordinances follow a similar pattern of starting off with very modest savings over the baseline and substantially increasing savings over time. The retrofit programs show an opposite trend, with the most substantial savings earlier in the study period. This is potentially significant as the uncertainty in the estimates is substantially lower at shorter time horizons. Interestingly, the results of non-leakage UAW reduction programs and conservation pricing programs are quite similar even though their modes of influencing water savings are very different.

Table 3- Total Water Needs for the six Conservation Measures under the three growth scenarios

Aggressive Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.52	6.34	6.14	6.30	6.23	6.43	**6.08**
2026	8.55	8.19	**7.80**	8.04	8.16	8.20	8.15
2036	10.60	10.14	**9.59**	9.90	10.10	9.90	10.27
2046	12.17	11.64	**10.97**	11.26	11.59	11.10	11.88
2056	13.81	13.22	**12.29**	12.55	13.14	12.36	13.55

Expected Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.11	5.95	5.76	5.90	5.84	6.04	**5.67**
2026	7.64	7.32	**6.98**	7.17	7.29	7.35	7.23
2036	9.08	8.69	**8.22**	8.45	8.66	8.49	8.73
2046	10.54	10.08	**9.53**	9.73	10.04	9.63	10.23
2056	11.28	10.79	**10.07**	10.20	10.75	**10.07**	11.00

Slow Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	5.66	5.50	5.33	5.43	5.41	5.59	**5.18**
2026	6.52	6.24	**5.96**	6.05	6.23	6.26	6.06
2036	7.03	6.74	**6.39**	6.46	6.72	6.55	6.63
2046	7.66	7.33	6.96	6.96	7.31	**6.95**	7.29
2056	8.41	8.04	7.54	7.50	8.02	**7.46**	8.05

It can also be instructive to look at overall cumulative water savings over the entire study period. Figure 1 through 3 display the forecasted cumulative water savings for the three growth scenarios. The magnitude of expected savings over 50 years is rather remarkable, on the order of 5 to 15 billion gallons. Comparing the different conservation measures reveals some interesting insights on their long term behavior. Even though their overall savings are quite different, Non-Leakage UAW reduction and Leak reduction demonstrate similar shapes due to their common modeling method. The conservation pricing policy, because only one major price change occurs, displays a linear trend after 2016. The effectiveness of the retrofits is very evident at first, but over time the slope of the cumulative savings line actually decreases. Finally, the Codes and Ordinances and Education programs clearly increase their cumulative savings as growth increases in the more distant future.

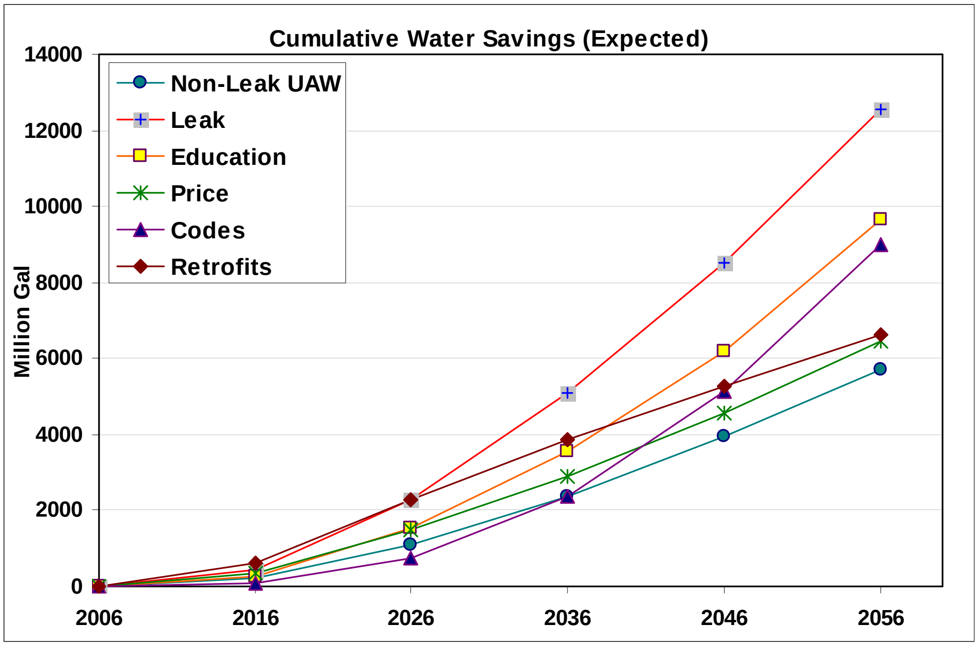

Figure 1 - Cumulative Water Savings for the Six Conservation Measures under the Expected Growth Scenario

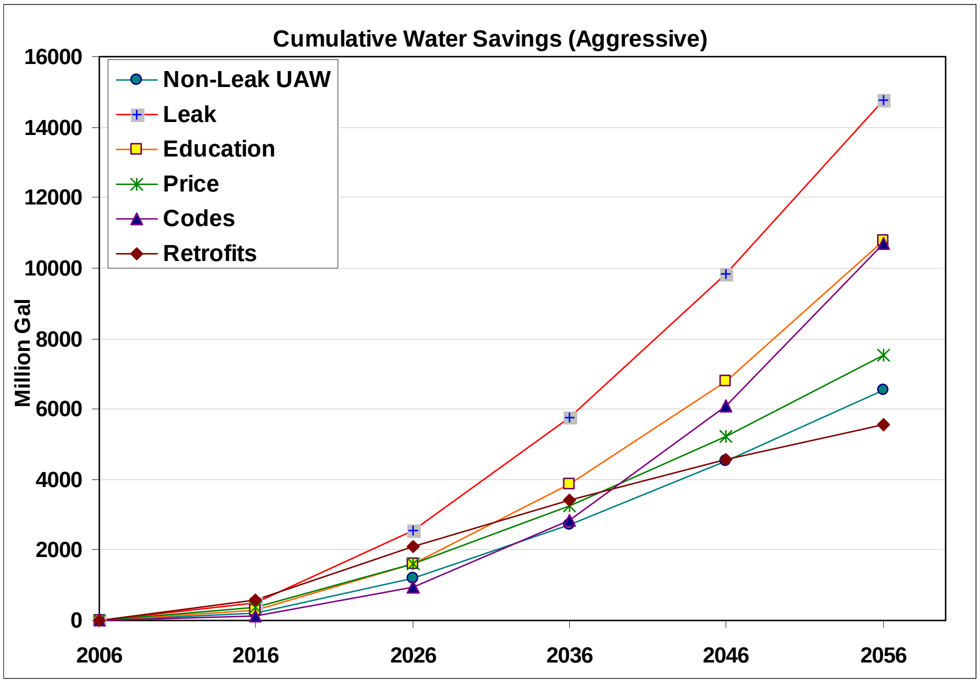

Figure 2 - Cumulative Water Savings for the Six Conservation Measures under the Aggressive Growth Scenario

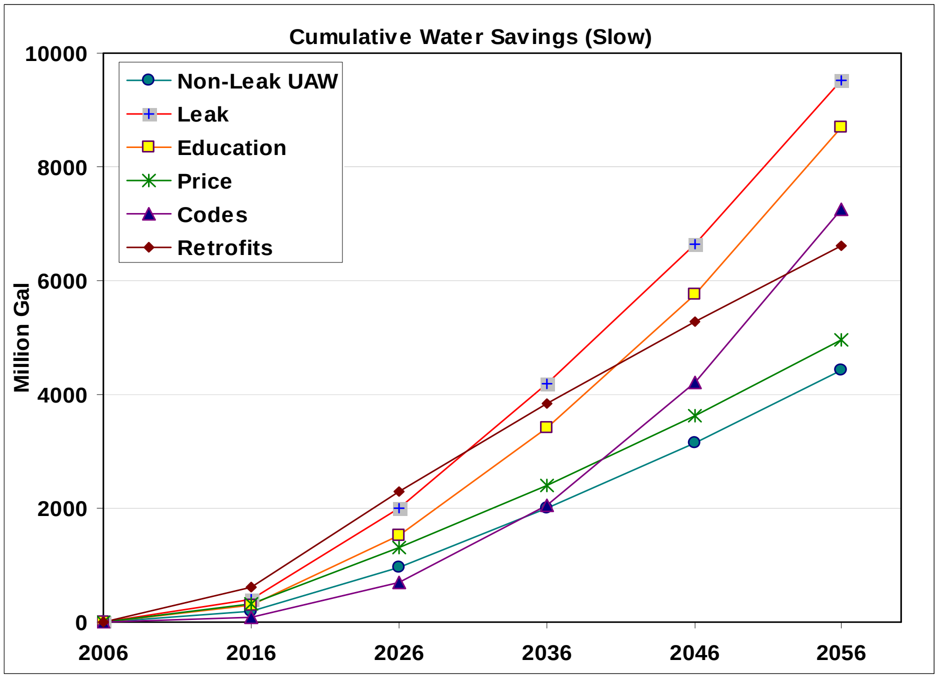

Figure 3 - Cumulative Water Savings for the Six Conservation Measures under the Slow Growth Scenario

6. Pros, Cons and Economic Benefits

The previous section investigated the comparative water savings resulting from each of the conservation measures. While the water savings are perhaps the most important consideration, several other considerations necessarily influence whether the measure should be implemented. These considerations include implementability, public acceptance, cost, uncertainty in the projections, compounding and corollary effects, and finally, economic benefits.

Each of the conservation measures has its own merits and drawbacks, and any comprehensive water conservation plan will likely have to include several conservation measures. The conservation measures which target unaccounted for water, non-leakage UAW reduction and leak detection, have a strong benefit in that they save water that was not producing revenue. Therefore, any water savings generated by these measures lead to direct economic savings. These two measures are also less complicated to implement because they can be put into place solely based on the choice of the utility districts. The drawback of both measures is their upfront cost, which can be significant, especially when pipes must be excavated for repair and replacement. The savings resulting from stopping leaks and other non-revenue producing water, however, often lead to very short payback periods.

Rapid adjustments in price carry their own pros and cons. While periodic, small water rate increases are necessary for maintaining capital investments and keeping pace with inflation, larger rate increases can be a much stronger impetus to conserve. Since water is an inelastic good, rate increases nearly always lead to smaller proportional reductions in consumption than the increase in price. As a result, water savings may be marginal, though the utilities benefit from greater total revenues. The obvious drawback to increasing rates is that rate increases are unpopular and may meet significant resistance from ratepayers. Effective conservation pricing and tiered pricing may be an alternative solution that could provide

benefits with less opposition. Analyzing more complex pricing schemes is beyond the scope of this study, but could be researched further.

Education programs have a great number of benefits, but suffer from a great deal of uncertainty about their actual effectiveness. Educating consumers about methods, benefits, and importance of water conservation can lead to changes in behavior that may save water in the short and long term. Short term changes may be achieved by behavioral changes, while long term shifts in water use may result from consumers making more informed choices when replacing toilets, washing machines, etc. Educational programs are generally not very expensive to implement, but can be ineffective without dedication to the message and sustained commitment to program implementation. Traditionally, education programs have been viewed as effective in reducing water use, but quantifying their actual water savings and economic benefits relative to investment remains difficult.

Strict water conservation provisions in building codes and public ordinances can lead to a gradual but significant reduction in potential future water use. The primary benefit of the codes is the significant long term savings, but the related drawback is that they do virtually nothing to reduce existing consumption except in the case of major renovations. Passing sufficiently comprehensive codes requires a great deal of political cooperation to implement. With the exceptions of builders and plumbers, there are generally few costs to existing stakeholders. Managing an effective inspection and enforcement program requires adding several inspectors and support staff to the local government payroll (or hiring contractors to fulfill the roles), which can be a significant long term cost.

7. Water Conservation Plan

It appears from the analysis of alternative conservation measures that Cumberland County has significant opportunities for reducing water consumption, especially in the long run. A combination of four of the identified conservation measures may provide very significant conservation savings over the baseline projections. GKY recommends the following Water Conservation Plan as best suited to meeting Cumberland County's long term water management goals. In combination, institute the following conservation measures, described previously in this report:

A. Non-Leakage UAW Reduction
B. Leakage Reduction
C. Education Programs
E. Codes and Ordinances

Modeling the Water Conservation Plan

Modeling the potential savings due to the water conservation plan is a fairly straightforward combination of the 4 identified conservation measures. The modeling methods have limited overlap. Measures A and B are both modeled by setting the UAW percentage with the unmetered/unaccounted tool. The appropriate UAW percentage is simply determined by the summing the reduction percentages under the two programs.

Codes and Ordinances are modeled in exactly the same manner as before. The Education conservation program is modeled in IWR-MAIN using the exact same intensity reductions as described in the Draft Water Conservation Plan memo. However, the passive conservation portion of the education programs is slightly affected. The rate of efficiency class shift is set by whichever rate is higher between the education and codes and ordinances conservation measures instead of adding the efficiency class shift percentages. So if 5% of units per year shift efficiency classes under the codes and ordinances conservation measure, and 3% of units per year shift with education, the total water conservation plan rate is 5% and not 8%.

Results

The results of modeling clearly demonstrate that impressive water savings are possible if an ambitious water savings plan is put into place. Figure 4 shows the baseline forecasts for the three growth scenarios (solid line), and the corresponding forecasts if the Water Conservation Plan is fully implemented (dashed lines).

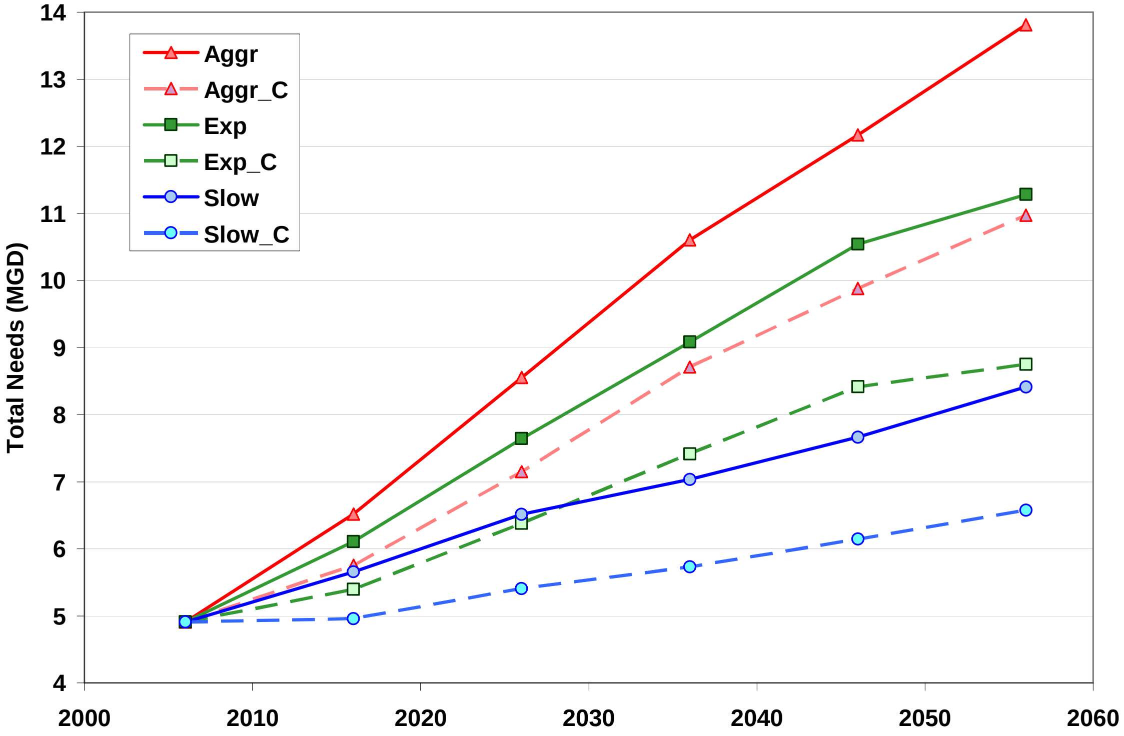

Figure 4 - Forecasted Water Needs for three growth scenarios, with and without the conservation plan

The results of the forecasts show the potentially profound effect of conservation. In general, the conservation plan can save as much as 30% over the baseline scenario. About half of this reduction comes from reduction of Unaccounted for Water alone. Over the long term, the reductions are as significant as dropping one growth scenario. That is, water use for the aggressive scenario with conservation is roughly equal to water use for the expected scenario without it. Even with conservation, water use in the county stands to increase significantly. However, under the slow growth scenario, water use remains virtually flat for the first 10 years when the conservation plan is put into place.

There is one caveat in interpreting the results of the water conservation plan. In analyzing all of the conservation measures individually, there was never a situation in which both the actual consumption and UAW rates were changed simultaneously. The water conservation plan does change both at once. Since the UAW is expressed (and modeled) as a percentage of overall demand, reducing consumption reduces UAW by default. However, the actual physical processes that cause leakage are not necessarily dependent on demand. Therefore, especially in situations where both the consumption and UAW are reduced simultaneously, the water savings may be overestimated. The modeling limitations of IWR-MAIN make it difficult to easily ameliorate this problem.

The effect of this limitation can be discerned when one looks at the results by subsector (including UAW as a subsector). Table 4 displays the results by subsector, comparing the baseline projection and water conservation plan for the three growth scenarios. It is quite

evident that a large portion of the savings comes from reductions in UAW. Under the Water Conservation Plan, UAW can be cut to as much two-thirds below the baseline forecasts. For example, under the aggressive scenario, the baseline UAW estimate in 2050 is 3.05 MGD, but with the water conservation plan, it falls to 0.99. Other subsectors see only about a 5 - 10% reduction over the baseline.

Table 4 – Total Water Needs by Subsector under the Baseline and Water Conservation Plan Forecasts(MGD)

Scenario	Forecast	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	CMC	0.07	0.10	0.13	0.17	0.20	0.23
		NonRES	1.49	1.87	2.11	2.32	2.52	2.71
		RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
		UAW	*1.04*	*1.39*	*1.85*	*2.32*	*2.68*	*3.05*
	Water Conservation Plan	CMC	0.07	0.10	0.13	0.16	0.19	0.22
		NonRES	1.49	1.84	2.06	2.25	2.41	2.56
		RES_PS	2.31	2.99	4.20	5.43	6.29	7.20
		UAW	*1.04*	*0.82*	*0.76*	*0.87*	*0.99*	*0.99*
Expected	Baseline	CMC	0.07	0.09	0.12	0.14	0.16	0.18
		NonRES	1.49	1.78	2.04	2.18	2.34	2.42
		RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
		UAW	*1.04*	*1.30*	*1.64*	*1.97*	*2.31*	*2.48*
	Water Conservation Plan	CMC	0.07	0.09	0.11	0.14	0.16	0.17
		NonRES	1.49	1.74	1.98	2.10	2.21	2.26
		RES_PS	2.31	2.79	3.61	4.44	5.20	5.53
		UAW	*1.04*	*0.77*	*0.68*	*0.74*	*0.84*	*0.79*
Slow	Baseline	CMC	0.07	0.08	0.09	0.10	0.11	0.12
		NonRES	1.49	1.68	1.91	1.96	2.02	2.08
		RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
		UAW	*1.04*	*1.20*	*1.38*	*1.50*	*1.65*	*1.82*
	Water Conservation Plan	CMC	0.07	0.08	0.09	0.10	0.10	0.11
		NonRES	1.49	1.64	1.85	1.88	1.91	1.94
		RES_PS	2.31	2.53	2.89	3.18	3.52	3.93
		UAW	*1.04*	*0.71*	*0.57*	*0.57*	*0.61*	*0.59*

While the average water needs are important in the evaluation of long term water supply planning, the peak day demand is important for the design of certain system components. As in the Water Needs Assessment, a peak factor of 1.35 is assumed. This is applied only to the consumption values, and UAW is added afterwards. Table 5 displays the peak day water needs for the baseline forecast and water conservation plan.

Table 5 – Peak Demand Values for the Baseline Forecast and Water Conservation Plan

Scenario	Program	Data	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	Consumption	3.87	5.13	6.70	8.28	9.49	10.76
		UAW	1.04	1.39	1.85	2.32	2.68	3.05
		PEAK	*6.26*	*8.31*	*10.90*	*13.50*	*15.49*	*17.57*
	Water Conservation Plan	Consumption	3.87	4.93	6.39	7.84	8.89	9.98
		UAW	1.04	0.82	0.76	0.87	0.99	0.99
		PEAK	*6.26*	*7.48*	*9.39*	*11.46*	*12.99*	*14.47*
Expected	Baseline	Consumption	3.87	4.81	6.00	7.11	8.24	8.81
		UAW	1.04	1.30	1.64	1.97	2.31	2.48
		PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
	Water Conservation Plan	Consumption	3.87	4.62	5.70	6.67	7.57	7.96
		UAW	1.04	0.77	0.68	0.74	0.84	0.79
		PEAK	*6.26*	*7.02*	*8.37*	*9.75*	*11.06*	*11.54*
Slow	Baseline	Consumption	3.87	4.45	5.13	5.53	6.02	6.59
		UAW	1.04	1.20	1.38	1.50	1.65	1.82
		PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*
	Water Conservation Plan	Consumption	3.87	4.25	4.84	5.16	5.53	5.98
		UAW	1.04	0.71	0.57	0.57	0.61	0.59
		PEAK	*6.26*	*6.45*	*7.10*	*7.54*	*8.08*	*8.67*

Analysis of the Water Conservation Plan

These four measures are the most beneficial actions Cumberland County can take for several reasons. First, the combination of measures strikes a balance between short term and long term water savings. Measures A and B (Non-leak UAW reduction and Leakage Reduction), especially when implemented in combination, provide immediate reductions in water usage. Measures C and E (Education and Codes and Ordinances) lead to much more significant savings in the long term than the short term.

These four conservation measures are also very feasible to implement. In fact, most of the measures are currently in the process of planning or implementation, though not quite to the extent described in this report. All of the utility districts have recently replaced or are replacing meters throughout their service areas. All of the utility districts claim to be reducing system leakage wherever they can, and one has even contracted leak detection services. The City of Crossville already has plumbing codes in place, and Cumberland County appears to be actively considering implementing them. None of the utility districts currently has dedicated education programs, but there are many resources available through the American Waterworks Association, the Environmental Protection Agency, various state environmental departments, private companies, and other sources.

Especially if the utility districts and county officials cooperate, the conservation measures presented here are very cost effective. Education programs are relatively low in cost. Implementing codes and ordinances has few upfront costs, but some long term enforcement and administrative costs. Measures A and B can be costly, but are generally worthwhile investments as the water savings directly reduce costs without reducing revenues. Furthermore, if leak detection services are contracted for the entire county, and leak detection

equipment is shared, costs can be reduced. Finally, leak detection costs are dropping as technology improves.

The other benefit of this plan is that it should be widely accepted by the majority of the stakeholders. Reducing unaccounted for water, and more broadly, establishing water accountability through better system information, better metering, and leak detection is a crucial step toward public acceptance of other conservation actions. Establishing building codes (and water efficiency standards) is generally acceptable as it has many positive impacts on quality of life in the county. Educational programs, as long as they are well managed, are generally accepted. Price increases for the purpose of conservation, however, are usually unpopular. Additionally, certain stakeholders have already expressed a mild opposition to retrofit and rebate programs as an unfair use of ratepayer or tax dollars.

Finally, implementing the proposed conservation measures leaves open the possibility for future conservation measures not described here. In the event that the proposed plan does not meet conservation targets, or growth occurs at a faster than projected rate, other conservation measures can be implemented. Measures A and B will lead to a much better understanding of the water balance throughout the distribution system and identify opportunities for further conservation. Establishing a framework for education programs leads to better communication between utilities, ratepayers, and other stakeholders, which could make future actions more effective. Strict efficiency codes help to create a local market for more efficient fixtures and appliances. Additionally, once codes are adopted, a legal framework is established for future amendments and ordinances.

While the conservation measures set forth are fairly common and feasible to implement, realizing the projected water conservation savings requires full engagement by the stakeholders and a sustained commitment to the conservation programs. Cumberland County has significant potential for conservation in the short and medium term as utilities reduce their water loss and customers increase their water use efficiency. In the long term, however, real shifts in behavior and in efficiency standards will need to be firmly established to see continued progress in reducing water use. It should be noted that even with significant conservation, Cumberland County's water use will almost certainly rise over the next 50 years. The rate of growth in water needs, however, can be slowed by the adoption of an ambitious conservation plan.

8. Conclusion

Cumberland County faces a challenge in meeting future water needs as the county grows. Continued rapid growth and the chance of future droughts like the one in 2007 highlight the importance of a long term solution to meeting water needs. Numerous proposals exist for increasing water supplies, but this study instead examines the potential for reducing demand.

Six feasible conservation measures have been presented as methods to effectively reduce water demand, inefficient water use, and water loss. Cumberland County has excellent potential for increasing water efficiency, both in the distribution system and on the part of water users. A comprehensive water plan can take advantage of the potential water savings, and almost certainly postpone the need for new water sources.

This Water Conservation Plan outlines a series of measures which can significantly slow the growth of Cumberland's water needs while allowing the county to grow. While the conservation targets are certainly achievable, it will take commitment and cooperation on the parts of numerous stakeholders.

9. References

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Cumberland County Regional Water Supply Study

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Water Needs Assessment and

Water Conservation Plan

Final Report

Cumberland County Regional Water Supply Study

Water Needs Assessment and

Water Conservation Plan

March, 2009

Table of Contents

Water Needs Assessment

Water Conservation Plan

List of Tables

Water Needs Assessment

Water Conservation Plan

List of Figures

Water Needs Assessment

Water Conservation Plan

Addenda

Three previous documents written by GKY provide added reference with regard to methods and full results for the Water Needs Assessment and Water Conservation Plan.

1. *Land use assumptions for Phase II of the Cumberland County Regional Water Supply Study*. Memorandum. December 13, 2006. by Karsten Sedmera and Stuart Stein, GKY & Associates, Inc.

2. *Water Needs Assessment for the Cumberland County Regional Water Supply Study*. Memorandum. March 14, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

3. *Water Conservation Plan for the Cumberland County Regional Water Supply Study*. Memorandum. June 28, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

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Water Needs Assessment

1. Introduction

The Cumberland County Regional Water Supply Study was established by an agreement between the U.S. Army Corps of Engineers (Nashville District) and the City of Crossville, Tennessee. The Cumberland County Regional Water Supply Study has the goal of identifying a long term solution to Cumberland County's water supply needs, and carrying forward an Environmental Impact Statement investigating potential alternatives for the long term supply solution. As part of the Water Supply Study, GKY & Associates has been contracted to perform a Water Needs Assessment to estimate future demand at 10 year increments for the next 50 years.

This Water Needs Assessment builds, in sequence, a land use development analysis, population growth scenarios, and modeling of future water demands. This study represents the first in-depth analysis taking into account the rapid growth in the early 2000s.

Indeed, Cumberland County, located on the Cumberland Plateau of East Central Tennessee, faces a growing problem in meeting the ever increasing water demand in a rapidly growing county. Cumberland County has been experiencing rapid growth in part due to its considerable success in attracting retirees to live in the county. In severe droughts, this growth is already straining water supplies. As growth continues, it is likely a new water source may need to be developed. This Water Needs Assessment investigates the future demand for water under a range of growth scenarios to project how much water will be needed in the future.

The first step in determining the future water needs is to analyze the land use patterns in Cumberland County.

2. Land Use Development

One of the important steps in predicting future water demand in the next 50 years is the difficult task of predicting future population growth and land use patterns in Cumberland County, TN. Land use patterns assist in predicting population growth by making it possible to assess how much land is available for growth, and they assist in demand estimation by generating a relative breakdown of the types of water consumers in the study area. Cumberland County, however, does not have any formal land use plan (i.e., zoning) in place to control (or predict) local patterns of growth. While there are a few studies that predict population growth for the County as a whole, none of them appear to focus on local growth rates or detailed land use patterns. Figure 1 displays the land use in Cumberland County according to the 2006 tax assessor's database. The land use patterns and the state of development of parcels of various types can provide clues to future development.

Cumberland County was one of ten counties recently selected by the Tennessee Department of Economic and Community Development to participate in a pilot study called "Retire Tennessee" that is designed to promote Tennessee as a great place for retirees to call home. Two of the predominantly residential areas, Lake Tansi and Fairfield Glade represent two established communities (not official cities) that attract retirees by offering small lots, convenient maintenance agreements, and various community club amenities. The three cities in the area – Crossville (the County seat), Pleasant Hill, and Crab Orchard – have similar attractions but more diverse development patterns. Crossville, however, has more dense residential communities than either Pleasant Hill or Crab Orchard. The remainder of the County is fairly rural with scattered residential development along major roads. Two related communities called Cumberland Cove and Cumberland Lakes (henceforth called Cumberland

Cove), which boast large lots and rustic "dream" homes, form a new development area where rural land is rapidly shifting into denser residential development.

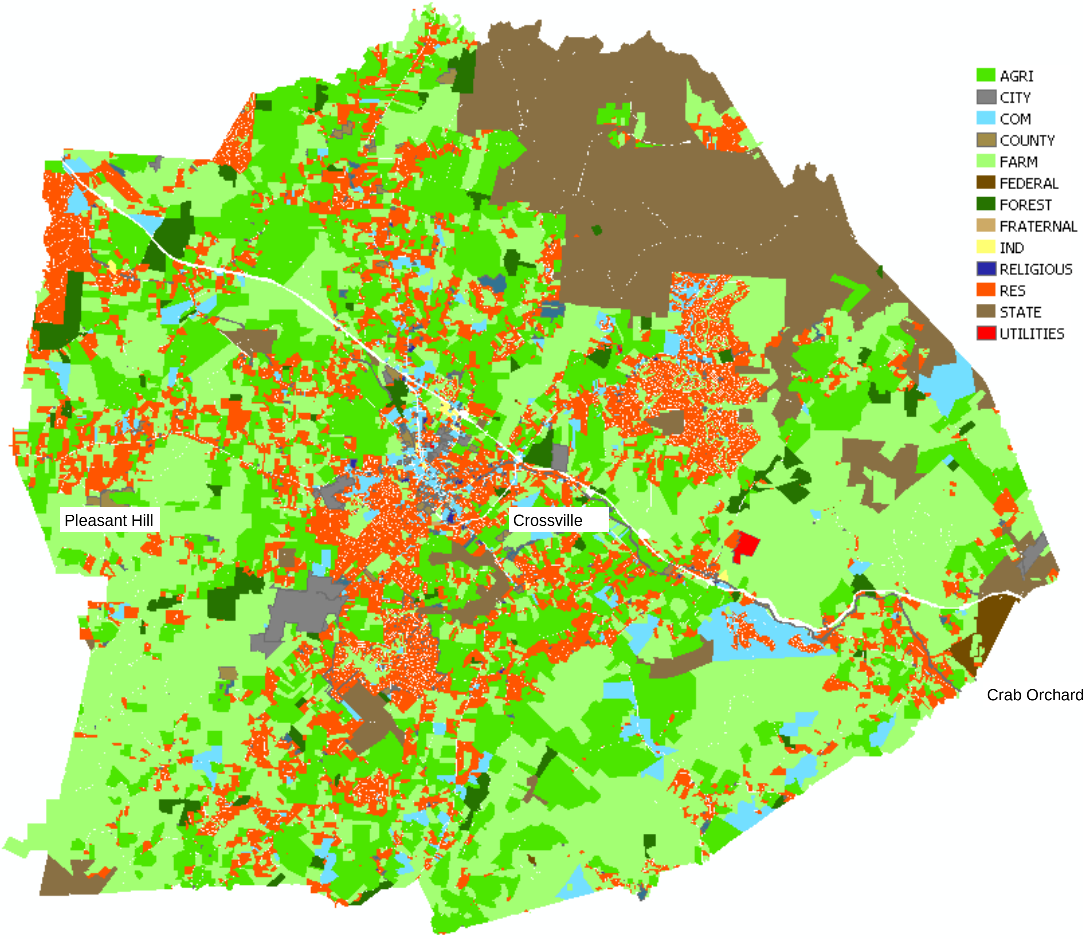

Figure 1 – Land Uses of Cumberland County according to 2006 Tax Assessor's Parcel Data

The tax assessor's database classifies each parcel into one of 12 land use categories (indicated on the map legend in Figure 1). A few clear patterns emerge from examining Figure 1. The majority of the county's land area is dominated by agricultural and farm land. The majority of residential development appears in four or five clusters. The center of the map shows the advanced development around the City of Crossville, including a dense core of commercial and residential development. There is also a large, state-owned wildlife preserve in the northeast corner of the County, which has almost no development in or immediately surrounding it. The land use pattern elsewhere in the county, however, is remarkably similar.

The database also lists the assessed land value and improvement value for each parcel. Thus any parcel with an improvement value greater than zero has been developed. For the purpose of estimating population density, only developed parcels that are classified as residential, farm, agricultural, or forest are likely to have homes on them. A few of the developed parcels classified as farm have improvement values reflecting recreational (e.g., golf resorts) or farm buildings, but most of them are residential lots with over 15 acres. Agricultural or forest parcels are "farms" that qualify for tax breaks under the TN Greenbelt program.

In order to evaluate the development potential in Cumberland County, the characteristics of the parcels (e.g. development, land value, lot size, and improvement value) were analyzed.

Figure 2 highlights the distribution of developed and undeveloped parcels of primarily privately owned residential and commercial parcels.

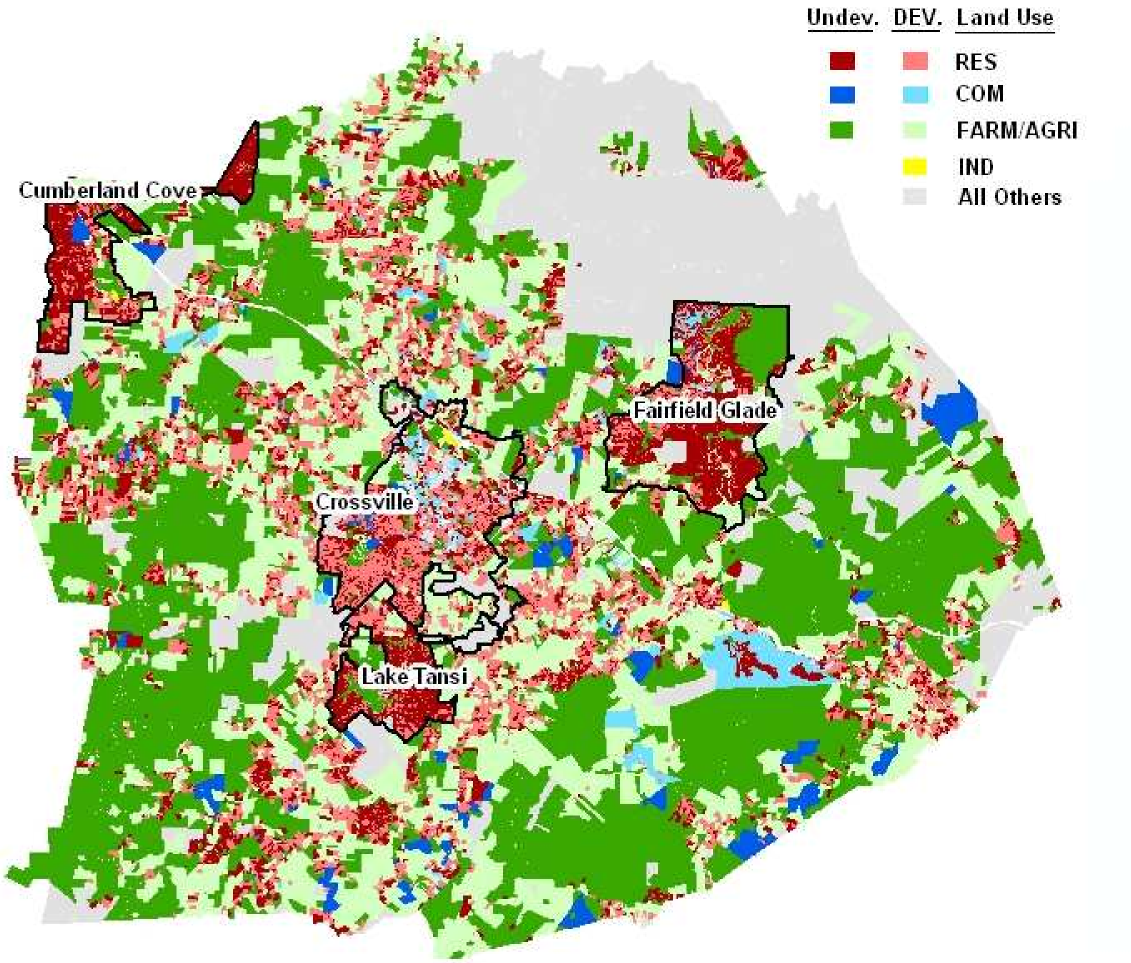

Figure 2 - Development Map of Cumberland County Showing Developed and Undeveloped Residential (RES), Commercial (COM), Industrial (IND), and Agricultural and Farm (FARM/AGRI) Parcels

Figure 2 indicates the undeveloped residential parcels (dark red) show an even clearer pattern than in Figure 1. It is evident that the dense residential communities generally cluster around Crossville, Fairfield Glade, Lake Tansi, and the Cumberland Cove area (which includes Cumberland Lakes). Furthermore, of these four regions, the latter three contain 69% of the undeveloped residential parcels in Cumberland County. Interestingly, the undeveloped commercial parcels are well distributed throughout the county.

Based on the land use analysis five study regions are selected for population and water use projections. Their geographic extents are shown in Figure 3. It should be noted that the boundaries reflect development patterns more than established political boundaries.

- City of Crossville
- Cumberland Cove (including Cumberland Lakes)
- Fairfield Glade
- Lake Tansi
- Remainder of the County

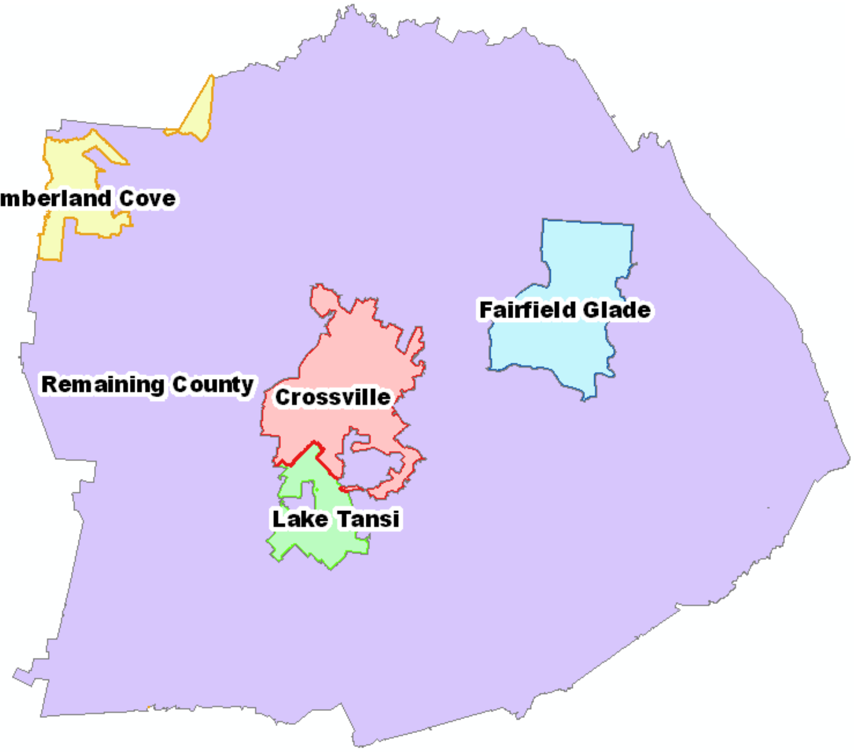

Figure 3 – Study Areas in Cumberland County

Further analysis of the parcels yielded some other general information about land use in Cumberland County that are useful for making population and water use projections. A few of the more interesting results are as follows:

- 90% of parcels in the County are residential
- 6% are farm/agricultural/forest,
- 37% of the residential parcels are developed,
- 57% of the farm/agricultural/forest parcels are developed, and
- 83.7% of the land area is residential/farm/agricultural/forest.
- The undeveloped residential parcels are, on average, half as large as the developed ones (0.92 vs 1.93 acres)

3. Growth Scenarios

The land use analysis establishes the general bounds on growth, and identifies the ultimate growth potential of the five study areas named in Section 2. Following the land use analysis, projections of the expected population growth in Cumberland County must be made in order to forecast water needs. Population forecasting is inherently uncertain, and becomes more so the further the time horizon of the forecast extends. In order to treat some of this uncertainty in a more concrete fashion, three distinct growth scenarios are carried through the remaining forecasting and modeling. They include the Slow, Expected, and Aggressive growth scenarios. The forecasts include population projections every 10 years starting in 2006 and ending in 2056. The Land Use Memo (full title: *Land use assumptions for Phase II of the*

Cumberland County Regional Water Supply Study), included in the addenda, details the methods by which the projections were made.

The growth scenarios all utilize the same starting values, and differ primarily in the specified growth rates for each ten year period. The growth rates also vary by study area. The percentage rate of growth reflects historical data, expert judgment from relevant stakeholders in the County, and other important factors (such as lack of sewer connection). Figure 4 displays the countywide population projections under the three population scenarios, as well as projections from two other studies. Note that the countywide projections are a sum of predictions for the individual study areas, each of which has independent growth projections and saturation points.

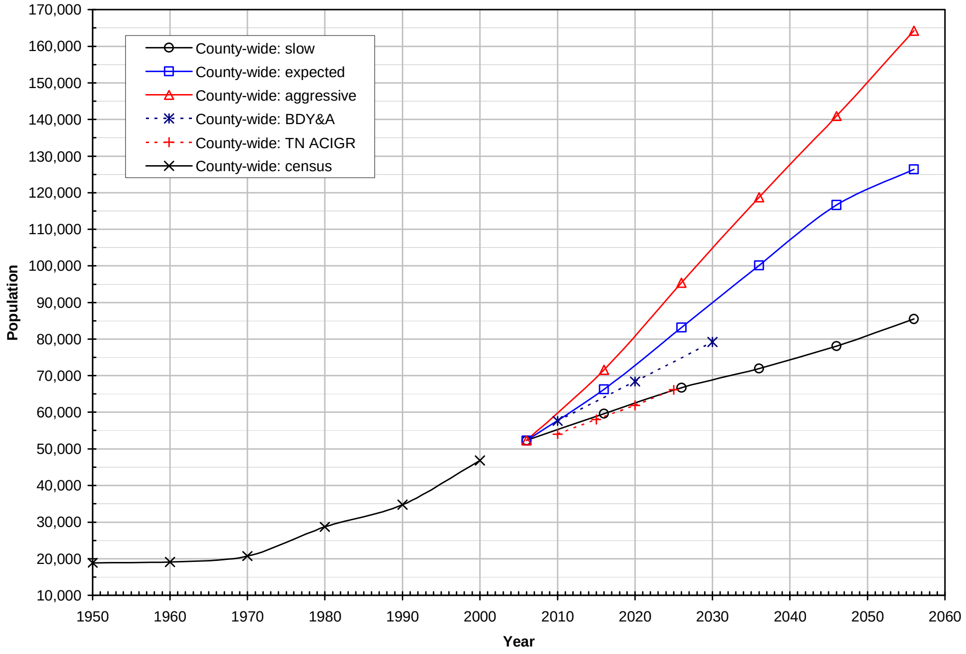

Figure 4- Population projections for Cumberland County. The three growth scenarios are displayed, as well as projections from two other studies (BDY & A 2002[i]; TN ACIGR[ii])

The population projections in fact show a wide range of variation among the growth scenarios. The range of population projections easily encompass the variability in the previous population projections, with the Slow growth scenario comparing favorably with the Tennessee Advisory Commission on Intergovernmental Relations' (TN ACIGR) forecast, and the Expected scenario a little higher than the Breedlove, Dennis, Young and Associates (BDY&A) forecast. The Aggressive scenario allows for substantial growth, but we note that even after 50 years, the projection does not begin an increasingly rapid growth phase as is often the case with simple exponential growth models.

Once the population is forecasted, it can be used to calculate projections of other relevant variables for estimating water usage. Namely, for each study area, the number of households and the number of employees must be forecast. By using historical data and stakeholder judgment, the future population per household ratio and the population per employee ratio were estimated for each forecast year. Dividing the projected populations by these factors yields the estimates of households and employees in Table 1.

Table 1 – Countywide Projections of Population, Households, and Employment for Cumberland County

Forecast Variable	Scenario	2006	2016	2026	2036	2046	2056
Population	*Slow*	*52,306*	*59,620*	*66,732*	*71,949*	*78,103*	*85,509*
	Expected	*52,306*	*66,288*	*83,157*	*100,163*	*116,643*	*126,373*
	Aggressive	*52,306*	*71,598*	*95,366*	*118,783*	*140,958*	*164,223*
Households	*Slow*	*23,345*	*27,622*	*31,990*	*35,323*	*39,294*	*44,144*
	Expected	*23,345*	*30,588*	*39,724*	*49,404*	*58,980*	*63,664*
	Aggressive	*23,345*	*33,106*	*45,772*	*59,252*	*69,006*	*79,369*
Employees	*Slow*	*25,000*	*29,083*	*33,200*	*36,522*	*40,259*	*44,305*
	Expected	*25,000*	*32,336*	*41,371*	*50,844*	*60,125*	*65,478*
	Aggressive	*25,000*	*34,926*	*47,446*	*60,296*	*72,659*	*85,090*

4. Water Needs Assessment Methods

Planning and Management Consultants, Ltd.'s IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as state-of-the-art, industry standard water demand forecasting software packages. IWR-MAIN was used as a tool to compute projected water use based on assumptions about the county's growth and water use factors. The IWR-MAIN user's manual[iii] explains in detail the structure of the model and the precise definitions of the terminology used. Where possible, we strive to use the correct IWR-MAIN terminology in describing the construction of the Cumberland water demand projection.

At the heart of the IWR-MAIN model is the usage model in Equation 1.

$$\boxed{\begin{matrix}\text{Demand}\\ Q\end{matrix}} = \boxed{\begin{matrix}\text{Counting Unit}\\ N\end{matrix}} \times \boxed{\begin{matrix}\text{Use Factor}\\ q\end{matrix}}$$

Equation 1.

In short, the demand is determined by multiplying some counting unit by a water use factor. This model determines the demand in a given time period, in a given subsector, in a given study area. A *subsector* is the base organizational unit for which water demand is projected (e.g., the residential or commercial subsector). Each subsector has its own associated *counting unit*, which is a measure of subsector size that has a strong influence on water usage (population, households, or employees, for instance). The *use factor* is simply the volumetric demand for water per counting unit (gallons of water per capita per day, per house per day, etc) in a given time period. Thus, a water demand forecast requires projecting (at a minimum) how the counting units and use factors change over time.

The total county water use in a given time period is simply a sum of the consumption for each subsector plus any leakage or other non-consumptive use. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different regions of the study universe have distinct characteristics, the study can be broken down into *study areas*, each with their own group of subsectors and usage models. In this case, the study universe encompasses all of Cumberland County.

With respect to Cumberland County, the study areas have already been identified in Section 2. For each study area, two sectors were assumed: residential and non-residential (encompassing commercial, industrial, and institutional uses). Residential water use forecasts are computed using the forecasted number of housing units as the counting unit. The non-residential sector utilizes number of employees as the counting unit. The City of Crossville study area has an

additional subsector to model the water usage of Cumberland Medical Center, whose associated counting unit is the total population of Cumberland County.

Water Use Factors

Forecasting the future values of the counting units accounts for half of the necessary inputs in (1). The other half of the inputs comprises the water usage rates. IWR-MAIN's Forecast Manager and Conservation Manager offer a range of forecasting models to estimate future water use factors. Many of the methods are econometric methods that allow using explanatory variables to build a predictive model for the use factors. Among the explanatory variables that are commonly found to be associated with water use are income, housing density, persons per household, marginal price, average daily maximum temperature, precipitation, and cooling degree days. An extensive analysis of the water usage records and available data on potential explanatory variables determined that the predictive models were not appropriate for this study. It should be noted that future needs assessments should reconsider this decision because a few more years of high-quality water usage data (including sector breakdowns) may make these more complex models viable.

Without these models, IWR-MAIN provides two primary options for calculating use factors. The first, contained within IWR-MAIN Forecast Manager, is to simply use constant use factors calculated based on the number of counting units and the base year use. The second, which requires using IWR-MAIN Conservation Manager, is to develop end use models for each subsector. Each end use has its own use factor, and the sum of the use factors for each subsector is the overall use factor for this sector. This approach is more flexible than the constant use model, though it can be made equivalent through correct application of parameters in the model.

The chosen model is the end use model, mainly due to the fact that Conservation Manager will be used to evaluate the effectiveness of conservation measures in the water conservation plan. The added benefit to using the end use model in Conservation Manager is that it is possible to define end uses on three levels of water use efficiency and shifts between them over time. This feature allows incorporating natural, market based changes in water use efficiency that result from greater average efficiency of water using fixtures and appliances over time.

When employing the end use model, it is important to have an accurate base-year water usage estimate. This water demand projection uses two seasons, so monthly estimates of base year use are necessary. The summer season includes June, July, August, and September, and the Winter season includes the rest of the year. Water use is assumed to be constant for all months within a given season.

Residential water usage factors are based on monthly residential water consumption data from the South Cumberland and Crab Orchard Utility Districts. Both user districts had acceptable monthly records of residential water consumption and the associated number of customers (households). Since the counting unit for the residential sector is the household, the water use factor is expressed in terms of gallons per day per household (gpd/hhld). The S. Cumberland and Crab Orchard data yielded annual averages of 119.7 and 118.9 gpd/hhld, respectively. Lake Tansi is almost completely encompassed in the S. Cumberland district, and Fairfield Glade is contained within the Crab Orchard district, but the rest of the study areas still need water use factors. For the sake of simplicity, and to provide a conservative estimate of demand, the rest of the study areas are simply assigned the higher S. Cumberland water use factors.

Estimating nonresidential demand is somewhat more complicated than estimating residential demand, especially in terms of disaggregating countywide demand among the study areas. As mentioned before, future employment projections are based on each study area's population

and a countywide population to employee ratio. Since Crossville's commercial development is not distributed exactly the same as residential development, it is inevitable there will be some error in the geographic distribution of commercial water demand. Without zoning though, it seems at least reasonable that future commercial development will occur near growing areas with concentrated residential development. Thus, it is likely much of the commercial development will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

The methods for generating the water use rates for the commercial sector are described in much more detail in the Needs Assessment Memo in the addenda. In a general sense, the use rates for the commercial sector were determined from actual usage records from the utility districts and then spatially disaggregated. The disaggregation was performed in GIS by determining the location of commercial and industrial parcels in the parcels database with respect to the boundaries of the study areas and the utility districts.

Passive Conservation

One major source of error in many forecasts of future water use is the failure to consider the effect of more water efficient technology. Since the Federal Energy Policy Act of 1992, U.S. manufacturers have been required to meet minimum water efficiency standards for plumbing fixtures and toilets. Since that time, manufacturers have gone well beyond the minimum standards as a way to stay competitive. The mode of change effected by the availability of more efficient technology is called passive conservation, whereby consumers conserve just by replacing their older fixtures with more efficient ones when they need to be replaced. New construction also takes advantage of the more efficient technology by default.

The average potential savings associated with more efficient appliances were determined from the AWWA's 1999 *Residential end uses of water* [iv]report. The average replacement rate was determined from the National Association of Home Builders/ Bank of America *Study of the Life Expectancy of Home Components*[v]. Though the consumption-weighted average replacement rate for all water using home components is approximately 6.5%, a more conservative rate of 5% was assumed. This is equivalent to a 20 year lifetime for many of these components. The forecasts take these shifts into account using the passive conservation tool in IWR-MAIN Conservation Manager.

The effect of this savings is a very slight decrease in the per unit water use rate over time. Though counterintuitive for a growing county, this makes sense in Cumberland County for several reasons. Firstly, as explained previously, no credible predictive models can be developed with available data. Secondly, the land use analysis demonstrated that the average area of the undeveloped residential and commercial parcels in the county is significantly smaller than the developed parcels meaning that outdoor water use will rise slower than the population growth rate. Thirdly, as more retirees move to the county, the number of people per household will continue to fall, meaning that per household indoor use rate should not increase. Finally, technological advances in manufacturing of toilets, dishwashers, and other water using appliances will tend to lower water usage as older units are replaced with more efficient ones. This conservation savings due to technology, while slight was considered necessary for inclusion in the model because of the long study period.

Unaccounted for Water

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental water main breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each of the study areas, the Unmetered/Unaccounted tool sets the year-by-year UAW percentage. (IWR-MAIN restricts the percentage to a constant value for each year, and only whole percentages are permitted.)

Previous water demand studies of Cumberland County have used a wide range of methods to model UAW. Breedlove, Dennis, Young & Associates' (BDY) 2002 *Cumberland County Water Supply Needs Assessment* selects a target loss percentage of 10% as a worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[vi] prepared by the Corps and Ogden Environmental and Energy Services, Inc. also estimated 10% UAW on the basis of non-specified estimates by the Cumberland Utility Districts.

In this study, UAW estimates for the five study areas are based on actual data from the UDs. Perhaps in response to the previous studies, the UDs have begun collecting more detailed statistics on UAW. It is with these statistics and advice from interviews with the UDs that we estimate UAW. Table 2 shows the average UAW percentages by utility district in recent years. The final row displays the number of years of data upon which the percentages are based.

Table 2– Unaccounted-for-Water data by Utility District (% of total production)

	Crab Orchard	Crossville	South Cumb.	West Cumb.	**Consumption Weighted Average**
Annual UAW%	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 2 appear incredibly high, but when we consider the short record length, it is clear that at least in some cases, some outlier values may be skewing the results. While there appears to be some potentially significant seasonal variation in the loss percentage, at least in Crab Orchard and Crossville, there are not enough data to make a strong case for modeling this variation. Additionally, IWR-MAIN does not allow seasonal variation in the Unmetered/Unaccounted percentage.

Except in Crossville, the record lengths are too short to make a valid estimation of the UAW by utility district. So we calculate the county average as weighted by consumption in the UDs. The yearly average UAW percentage is calculated as 22.4%, which is conservatively rounded upward to 23%. All of study areas except for Crossville are assumed to have this 23% average. If metering errors, line flushing, and known losses are assumed to be 5%, this means that an average of 18% of total produced water is actual loss. These figures compare favorably with the 20% rate indicated in interviews with the Crab Orchard Utility District, and 14-15% loss rate reported by West Cumberland. With the Crossville records being a bit longer, we feel comfortable setting Crossville's UAW percentage at 19%, which is slightly more conservative than the 15% unaccounted for and the 10-12% loss estimated by the Crossville UD in a May 2006 interview.

For the purposes of a baseline forecast, the UAW percentages are assumed to remain constant in time, which is a dubious assumption based on the large variances in month to month losses alone. Almost certainly, losses will either increase as the system ages, or decrease as the result of system improvements and maintenance. We are hesitant, however, to forecast changes to the UAW percentage in a baseline forecast, or impose 'desirable goals' as some past studies have done. Additionally, the conservation measures evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

Model Validation

Based on the assumptions made, it is possible to compare the projections to observed water usage. Figure 5 displays the estimated total county water consumption as compared to

observed consumption based on data from the UDs. These figures exclude UAW. On average, the estimated values are about 4% above the observed values, and therefore slightly conservative.

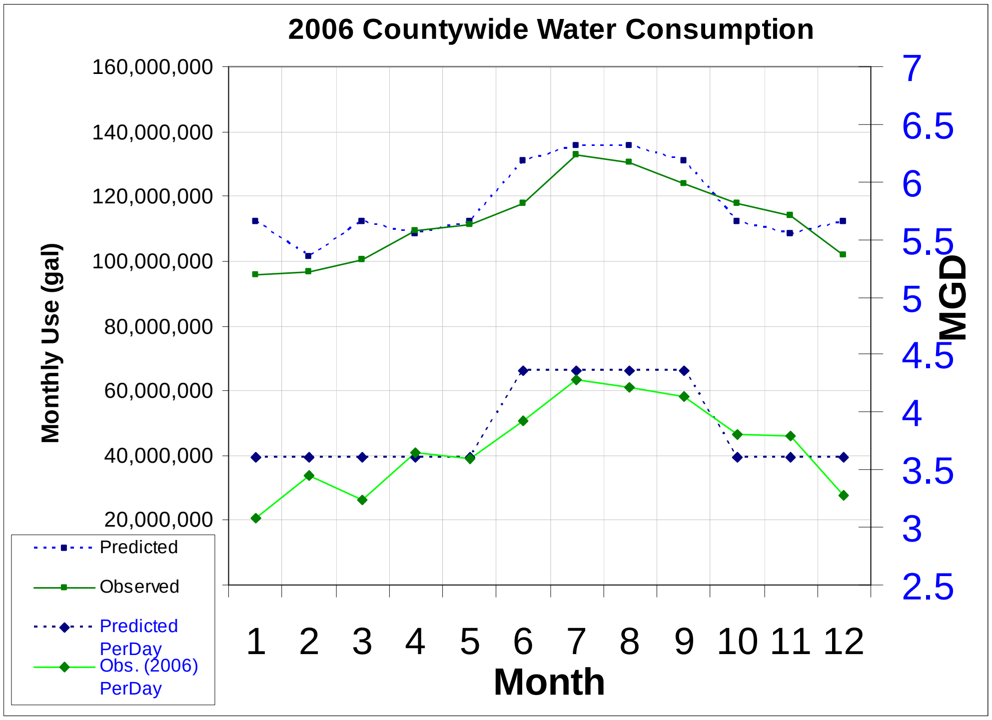

Figure 5 - Predicted versus Observed Countywide Water Consumption (excl. UAW)

The agreement shown between the observed and estimated values in water use is certainly not perfect, but it indicates the assumptions are at least reasonable, and slightly conservative. We note that there is excellent agreement at the peak water use month of July.

When the total usage includes UAW, the agreement between the observed 2006 values and predicted values is slightly worse. Data from the utility districts indicate that unaccounted for water makes up 27% of total produced water in 2006. This is higher even than the already fairly conservative assumption of 23% (19% for Crossville) used in the modeling. Figure 6 displays the estimated and observed values, which indicate the model predictions are about 7% *below* observed values. This is certainly a source of potential error, but is more likely due to above average losses in 2006. For the purposes of forecasting, the recent historical averages for UAW are a more reasonable basis for estimating future UAW than the 2006 values alone. Thus, no further calibration is necessary to match the observed and predicted 2006 demand.

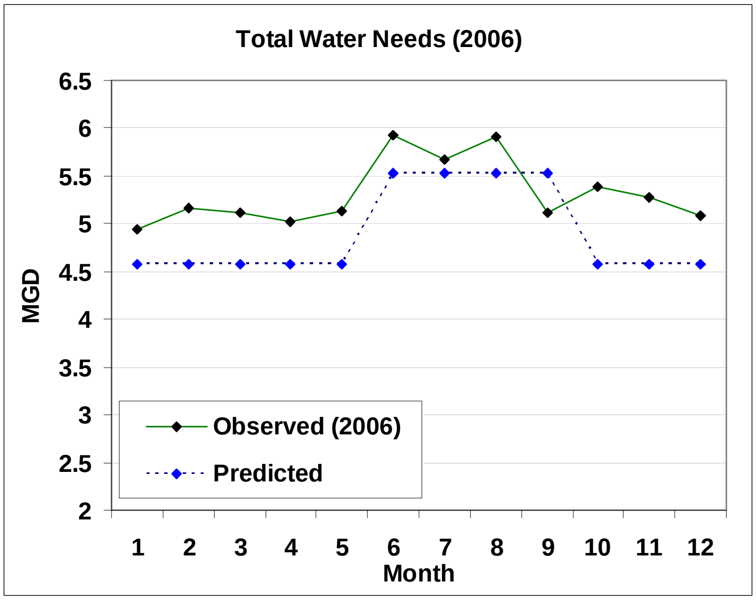

Figure 6– Model Predicted and Observed Cumberland County Water Use in 2006

5. Summary Results

The results of the baseline water supply needs assessment are presented in this section. All results are presented in terms of average daily usage in millions of gallons per day (MGD) except when otherwise noted. Summary results are presented here, but full results are available in the addenda.

It should also be noted that this is a planning level document, so the results are presented as annual or seasonal average. These figures should be sufficient for estimating water storage needs. Calculating peak usage, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak usage estimates were not called for in the scope of services, but are presented for completeness. BDY&A's 2002 *Cumberland County Water Supply Needs Assessment* cites factors in a range of 1.25 to 1.35 of daily consumption for Cumberland. The Corps' *Cumberland County Regional Water Supply Preliminary Engineering Report* appears to use 1.35 as well. Thus, a factor of 1.35 is applied to the results of this section. Note that peak factors are applied only to the consumption, and subsequently, the unadjusted UAW is added.

Countywide Results

The countywide results present the broadest picture of the water needs projections. Figure 7 presents the demand totaled for all study areas and all subsectors (including UAW). The demand for all three growth scenarios is indicated separately, however. The results indicate that demand will not quite triple in 50 years under the Aggressive scenario, less than double under the slow scenario, and roughly double under the expected scenario.

Under any growth scenario the projected demand increases significantly over the 2006 baseline. As noted previously, there is a great deal of uncertainty, particularly in the estimation of future trends in UAW. Figure 8 reports the county totals for consumption, which excludes the UAW. While there is bound to be some UAW in the future, the consumption projections are marginally more certain. The water conservation plan will more directly assess the effects of reducing UAW.

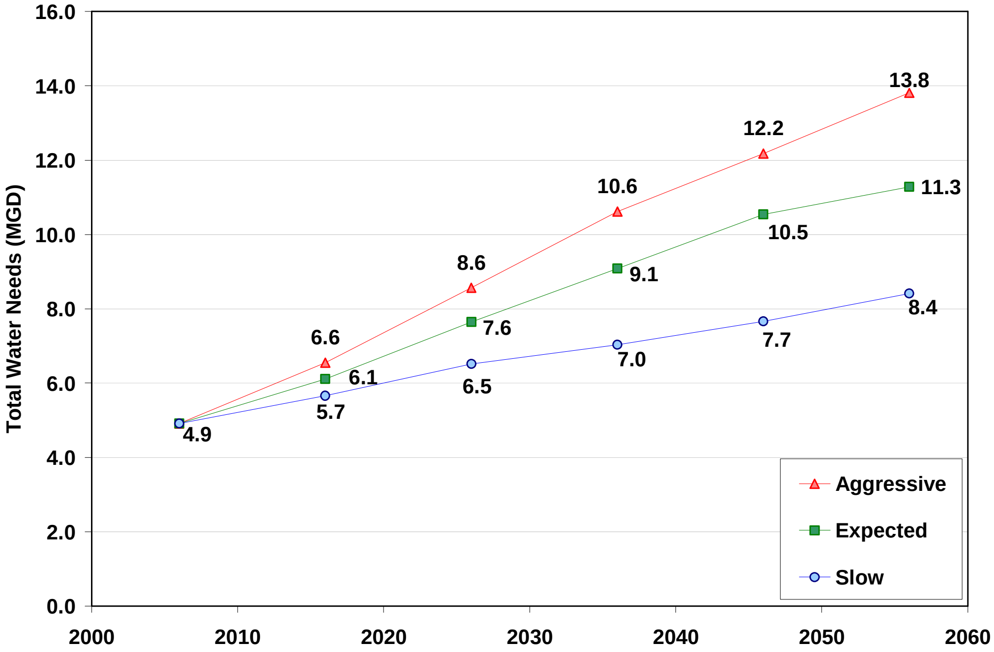

Figure 7. **Countywide Daily Average Total Water Needs for the Slow, Expected, and Aggressive Growth Scenarios.**

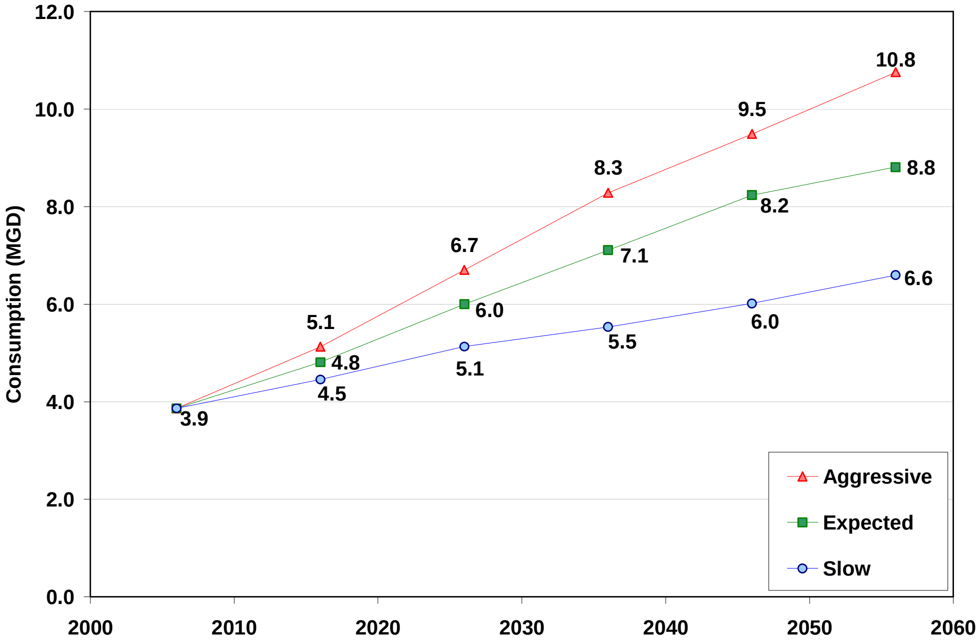

Figure 8 – Countywide Daily Average Projected Water Consumption (excludes UAW) for the Slow, Expected, and Aggressive Growth Scenarios

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, the usage varies by season. The Summer months include June-September, while the Winter includes the remaining months. The results are presented here by scenario and season. Countywide, the summer usage remains a fairly consistent 12-13% above the annual average, and winter usage is always

roughly 6-7% below. This is a result of the cumulative effects of the different winter and summer use factors for the subsectors (see the Water Needs Assessment in the addenda for full description and usage rates). Table 3 displays the countywide daily demand by season.

Table 3– Seasonal Variations and Peak Projected Total Water Needs (MGD)

Scenario	Season/Peak	2006	2016	2026	2036	2046	2056
Aggressive	Annual	4.91	6.55	8.56	10.61	12.18	13.81
	Summer	5.55	7.41	9.71	12.09	13.84	15.67
	Winter	4.59	6.12	7.99	9.87	11.34	12.87
	PEAK	*6.26*	*8.35*	*10.91*	*13.51*	*15.50*	*17.57*
Expected	Annual	4.91	6.11	7.64	9.08	10.54	11.28
	Summer	5.55	6.90	8.63	10.27	11.94	12.77
	Winter	4.59	5.71	7.14	8.48	9.84	10.54
	PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
Slow	Annual	4.91	5.66	6.52	7.03	7.66	8.41
	Summer	5.55	6.40	7.38	7.98	8.71	9.58
	Winter	4.59	5.28	6.08	6.56	7.14	7.83
	PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*

Table 3 also displays the projected peak demands, which reflect a 1.35 peakage factor applied only to the annual average consumption. As mentioned before, this factor is based on peak factors cited in previous studies and is not based on usage data. The unadjusted annual total UAW is then added on to this peak consumption to arrive at total water needs.

Water Needs Analysis By Subsector

Table 4 indicates the annual average daily demand by subsector for the entire county. In terms of total demand growth, it is clear that most of the growth occurs in the residential sector. The other sectors exhibit slightly lower percentage growth, but still increase significantly over their base year values. The NonRES results indicate that commercial growth will be of a low water intensity variety, which is consistent with a primarily service oriented commercial sector. The introduction of only a few large (industrial) water users, however, could add significantly to commercial demand, making the NonRES sector the most likely to be a low estimate of actual future demand.

Also notable is that the UAW subsector, while remaining a constant percentage of total water use, grows to become a more significant water ‘use’ than the nonresidential sector under the aggressive scenario. While the UAW percentage is based on the best available current loss estimates, this sector is most likely to reflect an overly conservative estimate of actual future UAW. The actual processes of leakage are more complex than a simple percentage loss, so growth in consumption does not necessarily mean a proportional rise in leakage. Additionally, leakage will most likely be addressed by future loss reduction measures. The impact of loss reduction measures is treated in the Water Conservation Plan.

Table 4 - Projected Total County Water Needs (MGD) by Scenario and Subsector

Scenario	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
	NonRES	1.49	1.87	2.11	2.32	2.52	2.71
	CMC	0.07	0.10	0.13	0.17	0.20	0.23
	UAW	1.04	1.42	1.86	2.33	2.69	3.05
Aggressive Total		**4.91**	**6.55**	**8.56**	**10.61**	**12.18**	**13.81**
Expected	RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
	NonRES	1.49	1.78	2.04	2.18	2.34	2.42
	CMC	0.07	0.09	0.12	0.14	0.16	0.18
	UAW	1.04	1.30	1.64	1.97	2.31	2.48
Expected Total		**4.91**	**6.11**	**7.64**	**9.08**	**10.54**	**11.28**
Slow	RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
	NonRES	1.49	1.68	1.91	1.96	2.02	2.08
	CMC	0.07	0.08	0.09	0.10	0.11	0.12
	UAW	1.04	1.20	1.38	1.50	1.65	1.82
Slow Total		**4.91**	**5.66**	**6.52**	**7.03**	**7.66**	**8.41**

* RES_PS – Residential, Public Supply; NonRES – Nonresidential; CMC – Cumberland Medical Center; UAW – Unaccounted for Water

Comparison to Previous Estimates

A comparison of GKY's water needs forecasts with previous estimates of Cumberland County's water needs clearly demonstrates the effect of prediction method chosen. Figure 9 compares the estimates in this study to those by Breedlove, Dennis, Young and Associates (BDY&A, 2002), the Army Corps of Engineers (USACE, 1998)[vii], and Lamar Dunn & Associates (LD&A, 2001). LD&A used a simple percentage growth model to estimate future demand. While this model may be appropriate in the short term, it is evident that the simplistic exponential model rapidly leads to unstable and incredibly high demand estimates at more distant time scales. It is clear that this model is insufficient for modeling long term water needs because it is overly simplistic and does not take into account any realistic limitations on growth.

Also interesting is that the BDY&A study presents a very high estimate of demand. This is likely a result of the method used for forecasting the future use factors. The study uses a gross total per capita consumption use factor to estimate the water use. BDY&A chose to express this factor as total public supply water use divided by total population (instead of population served). As a result, the numerator does not reflect the many self-supplied water users in the county (whose use would not be counted in public supply water), while the denominator does count them. This partially explains the artificially low historical use factors (54 and 77 gpd per capita in 1984 and 2000, respectively). The rapid increase in water usage factors is likely more a result of new development being added on public supply (versus self-supply) in a much higher proportion than the existing residences than it is a response to economic trends or fundamentally different water usage patterns of new residents. Furthermore, to bring the use factors to present day average values from this low starting point requires astounding gains in the per capita use factor. Projecting the future water use factors from historical values can lead to extremely high use forecasts, especially when rapid population growth continues.

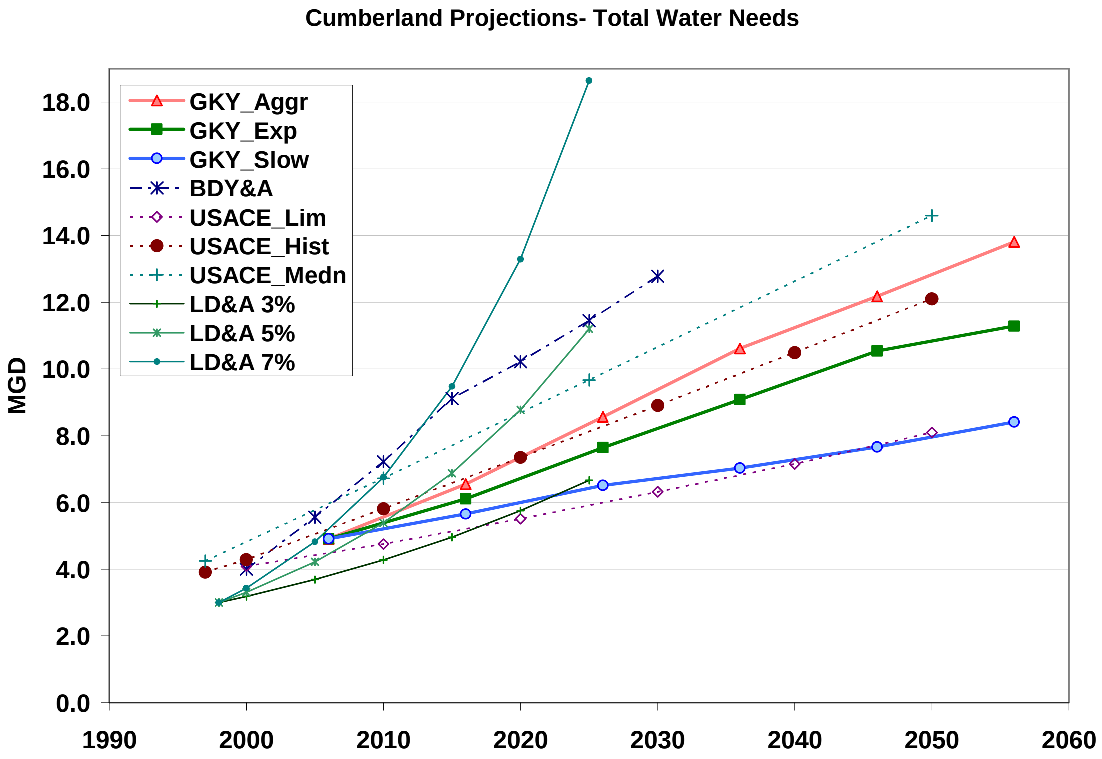

Figure 9 - A comparison of water needs forecasts for Cumberland County

The USACE projections rely upon a variety of different methods, including a model developed in IWR-MAIN (i.e. Medn → Median projection). These projections seem most closely in line with GKY's projections. The historical and limited methods actually incorporate limitations on growth, though in a more simplistic way than the GKY study.

The GKY study likely presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[viii] of the Pacific Institute note, "With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches." GKY's baseline projections present a new approach to countywide water demand forecasting, as anticipated improvements in water efficiency are taken into account. These anticipated improvements are in a sense inevitable as national laws and standards, as well as simple market availability have affected a shift to more conserving technology. For example, the Energy Policy Act of 1992 has made virtually all new toilets on the market compliant with a 1.6 gallon per flush efficiency standard.

It is important to note the efficiency assumptions are nearly completely independent of any decisions and policies made by public officials and citizens in Cumberland County. Other water use reductions may result from programs already in progress (notably, infrastructure improvements to reduce leakage). To establish a conservative baseline projection, however, we limit the conservation measures to 'natural' efficiency upgrades due to more advanced technology gaining a greater market share over time. Other conservation actions are analyzed much more thoroughly and explicitly in the Water Conservation Plan.

6. Uncertainty

The act of forecasting into the future is an inherently difficult task. It is important to recognize (1) that uncertainty is present in any projection, (2) uncertainty in baseline assumptions influences uncertainty in projections, and (3) errors compound over time, making distant projections less reliable than near-term projections.

The forecast model is designed to explicitly take into account uncertainty where possible, and otherwise, avoid introducing unknown uncertainty. (We use 'uncertainty' instead of error because error can't be calculated until the future when there are actual water demand values in the forecast years.)

The largest source of uncertainty in this forecast is likely contained in the population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth scenarios (instead of only an expected growth scenario), we introduce reasonable bounds on the uncertainty of this projection. (That is not to say that Slow and Aggressive scenario projections present the absolute lower and upper bounds on the prediction.) This understanding of uncertainty in the population projections is useful since the housing forecasts are calculated in tandem with them, and the employment projections depend directly on population as well. In these projections, the assumed growth rates, people per house statistic, and population per employee estimates all are potential sources of error. As an illustration of the potential consequences of error in initial projection, Table 5 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. (A constant percentage growth model is assumed.) Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 5 - Consequences of 0.5% error in growth rates (forecasted Units per 1000 base Units*)*

	10 years		**25 years**		**50 years**	
Initial rate projection	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*
1%	53	-56	150	-169	361	-461
2%	58	-61	190	-213	586	-746
5%	76	-79	381	-427	2435	-3075
10%	116	-120	1166	-1301	23914	-29879

Table 5 indicates just how serious minor errors in the prediction parameters can be, particularly in fast growing regions. The land use limitations on growth assumed in this study help put a limit on how large the error can be. In practice, growth can be limited (or spurred) by many factors other than land use consideration, but some limits are advisable as a constant percentage growth, exponential model is rarely a realistic assumption for a very long study period.

The other major potential source of model uncertainty is in the water use factors. While IWR-MAIN has several advanced methods of estimating future demand built into the software, additional parameter estimates and explanatory variables would be necessary (each bringing additional uncertainty). Any more complex model (such as a linear or multiplicative regression) would introduce more uncertainty through parameter estimates in addition to any uncertainty in forecasting future explanatory variable values. The water usage data provided by the UDs is just enough to come up with baseline water use factors. The small sample sizes of the water use data mean there is quite a bit of uncertainty in the water use factors (especially in the monthly values). By averaging the months within two seasons, the sample size is effectively increased, reducing the uncertainty introduced by outliers.

In a similar manner, the UAW percentages are averaged over the county to increase the effective sample size of estimate, and reduce the effect of outliers. Section 4 (Water Needs Assessments Methods) demonstrated that selection of parameters led to good agreement with real water use patterns in the base year.

The importance of the proper treatment of uncertainty in model prediction cannot be overstated. Underestimating future water needs can lead to a dangerous situation in the form of a water shortage or even running out of water. Overestimation of water needs can lead to unnecessary projects or oversized projects at a much higher cost than necessary. Without a realistic view of the uncertainty present in the forecasts, decision making on future supplies may not be truly addressing the water needs. Fully cognizant of the uncertainties present in this forecast, GKY has made every effort to document the uncertainty and present a reasonable range of potential future water needs representative of the effects of the known uncertainty.

Comparisons with previous studies have shown that this study's predictions of water needs tend to be somewhat lower than previous estimates made with simpler models. A careful consideration of the methods used in earlier studies generally leads to the conclusion that the forecasted water needs may be overestimated. This study attempts to provide as accurate a forecast of water needs as possible, with full description of methods, thus allowing the decision maker to assess the validity of the study. Assuming the study is deemed valid, the range of forecasts allows for the decision maker to lend more credence to one scenario versus the others based on their judgment and level of risk-aversion.

7. Conclusions

This Water Needs Assessment has analyzed the current and future water needs of Cumberland County using the best available data and expert opinions. Cumberland County has experienced rapid growth in the past several decades, and that growth may continue so long as the water demands can be met.

The population projections reflect demographic trends, opinions of local experts, and real limits on growth based on land use. The development of the appropriate water use factors was based directly on actual water use data from the utility districts. It must be recognized that a 50 year projection is subject to a great deal of uncertainty. The Aggressive, Expected, and Slow growth scenarios help to capture some of that uncertainty.

The projections in this report indicate that Cumberland County's water needs will very likely exceed the current supply in the next 50 years, but not quite as soon as previously projected. As the average demand becomes closer and closer to the firm yield of the existing sources, the potential for failure in a particularly severe drought year increases considerably. Therefore, Cumberland County is well advised to continue to examine and develop opportunities for conservation and securing an increase in available supplies.

8. References

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Water Conservation Plan

1. Introduction

Cumberland County's attention has been increasingly drawn to water resources over the past decade. Growth projections by several firms[ix,x,xi] have estimated that the water needs of Cumberland County will exceed firm yield in less than 10 years. Excluding the undesirable outcome of running out of water, Cumberland County has two options: increase water supply or reduce demand.

The Water Needs Assessment established forecasts for Cumberland County's water demands under three different growth scenarios. Before evaluating additional water supply alternatives, it is prudent to determine if conservation can effectively reduce demand. This study investigates the extent to which demand can be reduced below the baseline forecast values in the Water Needs Assessment.

Cumberland County has no significant history of water conservation programs, but a range of viable options could lead to significant water savings. This Water Conservation Plan report identifies six potential water conservation measures local government or the utility districts could reasonably enact. The effectiveness of the proposed conservation measures is modeled using the IWR-MAIN Conservation Manager© software program. IWR-MAIN is recognized as a state of the art program for modeling water demand and conservation programs.

A detailed account of the modeling methods is presented in the Water Conservation Plan Memo (full title: *Water Conservation Plan for the Cumberland County Regional Water Supply Study*) in the addenda. This document presents results of modeling the six conservation measures, and based on these results a final water conservation plan is presented.

2. Conservation in Cumberland County

Until the past few decades, Cumberland County has always had an abundant and easily accessed water supply. As a result, there has been limited impetus to encourage conservation in the county. This limited conservation experience presents a substantial opportunity for future efforts to harvest the 'low-hanging fruit' of water conservation benefits at a relatively low cost.

Cumberland County's opportunities to conserve are typical for communities of similar size and age. Cumberland County has two primary avenues for improving water efficiency. One major opportunity for conservation is for the water utility districts to reduce water loss and other unaccounted for uses. Total unaccounted for water use averages near 20% of total produced water, with losses approaching 30 or 40% for some districts in some months. This is not unusual for utility districts of a similar size and age. Cumberland County's utility districts face additional challenges resulting from the very hilly and rocky terrain of the county. High water pressure can stress pipes, and the rocky soil can both puncture pipes and create a situation where leaks have adequate drainage to avoid detection. While Cumberland County's distribution system loss rates are not atypical, reducing losses presents a major avenue for conservation. With appropriate, proactive leak detection efforts and other loss reduction measures, Cumberland County may be able to reduce its losses to ten percent or less.

While the losses in the distribution system are primarily attributable to water suppliers, the water consumers in Cumberland County are another major source of water inefficiency. Interviews with the utility district managers indicated that the majority of residences in Cumberland County use less efficient toilets and plumbing fixtures than current industry standards. This will largely be corrected over time as residents replace older fixtures with

newer, more efficient fixtures. Accelerating this transition, however, is a major opportunity for conservation.

Between reducing inefficient water use on the part of the utility districts and water consumers, there is significant potential for conservation in Cumberland County. The following sections detail several conservation measures to take advantage of this potential.

3. Conservation Measures

Six conservation measures have been identified for analysis in developing the Cumberland County Water Conservation Plan. Each conservation measure is described in brief below. More detailed policy descriptions and modeling methods for each conservation measure are included in the Water Conservation Plan memo included in the addenda. Additionally, the six conservation measures were chosen from a larger set of possible measures based on their relevance and implementability in Cumberland County. The final water conservation plan reflects a combination of some of these measures.

3.A. Unaccounted for Water Reduction (non-leakage)

While leakage is the most commonly identified contributor to Unaccounted for Water, there are other contributing factors to UAW in Cumberland County. Foremost among these are metering errors, flushing usage, and fire fighting usage. Reducing fire fighting usage is not generally within the control of water utilities. Mains flushing is an important part of system maintenance to prevent blockages and corrosion and preserve water quality. Flushing is also necessary before new connections are opened. In large new developments, flushing loss can be tremendous, especially when the opening of new connections is staggered (requiring multiple flushing events). Finally, metering errors are likely a result of older meters. Cumberland County does not have a significant number of unmetered connections.

By addressing excessive flushing and metering errors, Cumberland County may reduce its UAW percentage. All of the utility districts have either recently replaced their meters or are in the process of doing so, but replacement programs should be repeated every 10 -15 years to ensure reductions in UAW are preserved. Reductions in flushing volumes may be achieved through a review of flushing policies, and system upgrades to convert branched distribution pipe networks to looped networks where practicable.

3.B. Leak Detection and Reduction

Leak detection is another method of reducing UAW. Cumberland County faces a range of challenges in getting leakage under control. The age of the pipes, rocky soil, and large elevation differences (and resulting high pressure) have been cited by county utility managers as major causes of leakage. Leaks occur on both mains and service lines. Current leak detection efforts in the county are primarily focused on repairing leaks when they come to the surface or when there are service complaints.

A comprehensive leak detection program in Cumberland County could include several leak detection strategies. Hiring a leak detection contractor to investigate the majority of the county’s mains and service line connections would be a good start. Listening surveys use geophones and other listening devices to find leaks and digital correlators to pinpoint leak positions. In the long term, permanently installed listening devices may be the most effective method of detecting leaks. With training, utility district staff could conduct listening surveys and use a digital correlator.

3.C. Education

Educating water consumers on the value of water and the benefits of conservation, while a valuable end in itself, can also lead to real reductions in water usage. Reductions are achieved in two primary ways: convincing water users to change their water usage habits, and affecting purchasing decisions on fixture and appliance types (and whether to replace them sooner). The water utilities in Cumberland County do not currently have any dedicated customer education programs, but they do communicate with customers through billing inserts and other methods. In 2007, the City of Crossville, Cumberland County, and the utility districts used several communication methods to publicize the drought restrictions and appropriate short-term water saving tips. A true education strategy is geared more toward long-term shifts in behavior and more permanent savings.

Several types of education programs exist, and the water utilities could develop new programs, specially tailored for Cumberland County users. In general, using a variety of education strategies (each with a defined message and goal) in combination can achieve the most robust results. Table 1 indicates three general types of educational programs, the target audience, and a description.

Table 1 - Education programs

Policy	Intended audience	Description
General advertisement	All water users	Water saving tips and information.
Targeted Messages	Commercial users, homeowners with irrigation systems, homeowners with older homes, etc.	Communicate well developed messages perhaps once a year to encourage a specific conservation action, e.g: highlight cost savings from replacing toilets, promote xeriscaping, .
Education programs	School age children and families	e.g.: Programs every 2 years for 4th and 5th graders, 9th and 10th graders
	Retirees, community associations	Short (0.5 day) programs in retirement communities, civic centers.

3.D. Pricing

While water prices are generally set to reflect the costs of production, price changes do affect water demand. The price elasticity of demand indicates the amount of change in demand due to a unit change in price. See Equation (1). An elasticity of positive one indicates that a 1% increase in price will lead to a 1% increase in demand. Price elasticity of demand for water is nearly always negative (price increases reduce demand), and is generally considered to be inelastic (in between 1 and -1, or in this case, 0 and -1). In fact, when considering water demand, it is rare to see elasticities even go beyond -0.5.

$$e = \frac{\Delta q}{\Delta p}$$ **Equation 1**

Where:

e is the price elasticity of water demand
Δq is the percentage change in water demand by a water user (or set of users)
Δp is the percentage change in water price

There is a wide range of economics literature examining the price elasticity of demand for various water users. Focusing on residential customers, Arbués et al. (2003)[xii] and Worthington and Hoffman (2006)[xiii] provide good reviews of a large range of economic

studies investigating price elasticity of water demand under a wide range of pricing policies. In general, the majority of the estimates of residential long term elasticity fall into the -0.05 to -0.5 range. The IWR-MAIN manual cites residential elasticity as between -0.05 and -0.35.

Several UD managers expressed the view that the water demand of Cumberland County residents is somewhat to considerably more sensitive to price changes than the average U.S. citizen. Supporting this assertion is that many of Cumberland County's residents are on fixed incomes. Residents' response to price signals is also influenced by having a monthly billing cycle in all the Cumberland County UDs. As a result, elasticities in Cumberland County are assumed to be toward the upper end of the ranges presented in the manual.

Currently, all the Cumberland County utility districts have a fixed fee for consumption up to a certain initial limit (1000 or 2000 gallons), and a fixed block rate for additional consumption above the limit. A wide range of pricing strategies are available for water utilities to meet goals as wide ranging as maintaining adequate revenues to encouraging conservation. A full discussion of the pricing options considered for the modeling of this conservation measure is contained in the Water Conservation Plan memo. Due to complexity of modeling some of the pricing methods and the limitations of IWR-MAIN, a simple pricing policy is selected. The policy is simply to enact a 30% increase in marginal water price over the base price (set equal to 1) after the base year. Since the price is measured in constant 2006 dollars, the underlying assumption is that after the initial increase, price increases at a rate exactly equal to the inflation rate (or more accurately, water consumers' own discount rate).

3.E. Water Efficiency Codes and Ordinances

One of the most effective methods to generate long term water savings over baseline estimates is to influence the water efficiency of new development. Ensuring that developers are installing efficient fixtures and appliances means that new users will have a lower water use intensity than existing users. Additionally, it is significantly easier to create standards for efficiency before new units are built than to retrofit later.

Currently, Cumberland County lacks building codes in all areas except inside the Crossville city limits. Reportedly, even within Crossville, the efficiency of fixtures is rarely examined by inspectors.

A comprehensive water efficiency code and ordinance will mandate the inspection of water fixtures, toilets, and appliances to check for their efficiency. Additional ordinances may govern the outdoor use of water at commercial and institutional properties by requiring rain sensor shut-off for irrigation systems, for example. Benefits, such as reducing the connection fee, may also be considered for developers who install ultraefficient appliances and fixtures in new properties.

3.F. Retrofit, Rebate, and Replacement Programs

Retrofit, replacement, and rebate programs are other methods to reduce the average water use factors for existing users by replacing (or providing incentives to replace) existing fixtures and appliances with more water efficient models. The key is that the transition happens at a much faster rate than it would under natural replacement.

The programs can take several forms. One approach is to simply provide inexpensive fixtures and devices such as faucet aerators, shower heads and toilet dams free of charge to users. The drawback is that the consumers do not always install them. As the Massachusetts Water Resources Authority's Steven Estes Smargiassi noted[xiv], "We discovered if you gave away devices, most of them were 'installed' in kitchen drawers – not on the bathroom or kitchen fixtures." One way to mitigate this problem is to provide free installation as well. Rebate programs provide monetary incentives for the replacement of larger water using devices,

notably toilets and clothes washers. While often expensive, rebates for toilets and clothes washers can provide greater water savings than small devices, and the transition to more efficient water uses can be more easily verified.

Cumberland County's utility districts do not currently offer any retrofit, replacement, or rebate programs. These programs may be well suited to Cumberland County, as the majority of fixtures and appliances are believed to be older models. Additionally, interviews with utility district managers and other stakeholders indicated that county residents replace these fixtures and appliances at a slightly lower rate than the nation as a whole.

4. Methods

The water savings of the six conservation measures are modeled using IWR-MAIN Conservation Manager. The Water Conservation Plan Memo discusses the modeling methods, assumptions, data collection, parameter estimates, and scenario development in much greater detail. Table 2 displays the tools used in IWR-MAIN Conservation Manager to model the effects of each of the conservation measures.

Table 2- Modeling Methods of the Six Conservation Measures

Conservation Measure	IWR-MAIN Modeling Method
A. Non-Leakage UAW Reduction	Tools→ Unmetered Fraction
B. Leakage Reduction	Tools → Unmetered Fraction
C. Education	Intensity → Enter/Build, Passive Conservation
D. Pricing	Intensity → Enter/Build (Multiplicative Model)
E. Codes and Ordinances	Tools → Passive Conservation
F. Retrofit, Rebate, Replacement	Tools → Active Conservation

5. Results

The six conservation measures cover a broad range of strategies for reducing water usage. Accordingly, the modeling results indicate important differences between the conservation measures in terms of magnitude and trends of water savings. The growth scenario also affects the relative performance of the conservation measures. While the modeling methods for each conservation measure are identical between growth scenarios, certain measures perform comparatively better or worse depending on the rate of growth. Table 3 compares the total water needs projections for the baseline and six conservation measures under the 3 growth scenarios. For each year in each growth scenario, the conservation measure with the lowest total water needs is displayed in bold type.

The results indicate some clear trends in the projected water needs under the baseline and conservation scenarios. Most notably, leakage reduction appears to lead to the most substantial reductions over the entire study period. Education programs and Codes and Ordinances follow a similar pattern of starting off with very modest savings over the baseline and substantially increasing savings over time. The retrofit programs show an opposite trend, with the most substantial savings earlier in the study period. This is potentially significant as the uncertainty in the estimates is substantially lower at shorter time horizons. Interestingly, the results of non-leakage UAW reduction programs and conservation pricing programs are quite similar even though their modes of influencing water savings are very different.

Table 3- Total Water Needs for the six Conservation Measures under the three growth scenarios

Aggressive Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.52	6.34	6.14	6.30	6.23	6.43	**6.08**
2026	8.55	8.19	**7.80**	8.04	8.16	8.20	8.15
2036	10.60	10.14	**9.59**	9.90	10.10	9.90	10.27
2046	12.17	11.64	**10.97**	11.26	11.59	11.10	11.88
2056	13.81	13.22	**12.29**	12.55	13.14	12.36	13.55

Expected Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.11	5.95	5.76	5.90	5.84	6.04	**5.67**
2026	7.64	7.32	**6.98**	7.17	7.29	7.35	7.23
2036	9.08	8.69	**8.22**	8.45	8.66	8.49	8.73
2046	10.54	10.08	**9.53**	9.73	10.04	9.63	10.23
2056	11.28	10.79	**10.07**	10.20	10.75	**10.07**	11.00

Slow Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	5.66	5.50	5.33	5.43	5.41	5.59	**5.18**
2026	6.52	6.24	**5.96**	6.05	6.23	6.26	6.06
2036	7.03	6.74	**6.39**	6.46	6.72	6.55	6.63
2046	7.66	7.33	6.96	6.96	7.31	**6.95**	7.29
2056	8.41	8.04	7.54	7.50	8.02	**7.46**	8.05

It can also be instructive to look at overall cumulative water savings over the entire study period. Figure 1 through 3 display the forecasted cumulative water savings for the three growth scenarios. The magnitude of expected savings over 50 years is rather remarkable, on the order of 5 to 15 billion gallons. Comparing the different conservation measures reveals some interesting insights on their long term behavior. Even though their overall savings are quite different, Non-Leakage UAW reduction and Leak reduction demonstrate similar shapes due to their common modeling method. The conservation pricing policy, because only one major price change occurs, displays a linear trend after 2016. The effectiveness of the retrofits is very evident at first, but over time the slope of the cumulative savings line actually decreases. Finally, the Codes and Ordinances and Education programs clearly increase their cumulative savings as growth increases in the more distant future.

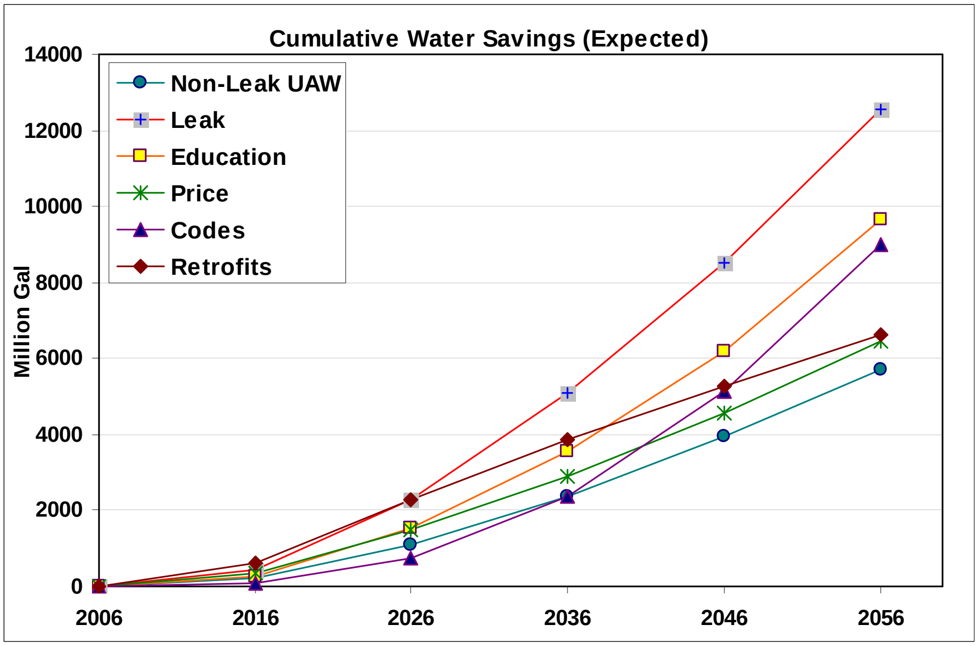

Figure 1 - Cumulative Water Savings for the Six Conservation Measures under the Expected Growth Scenario

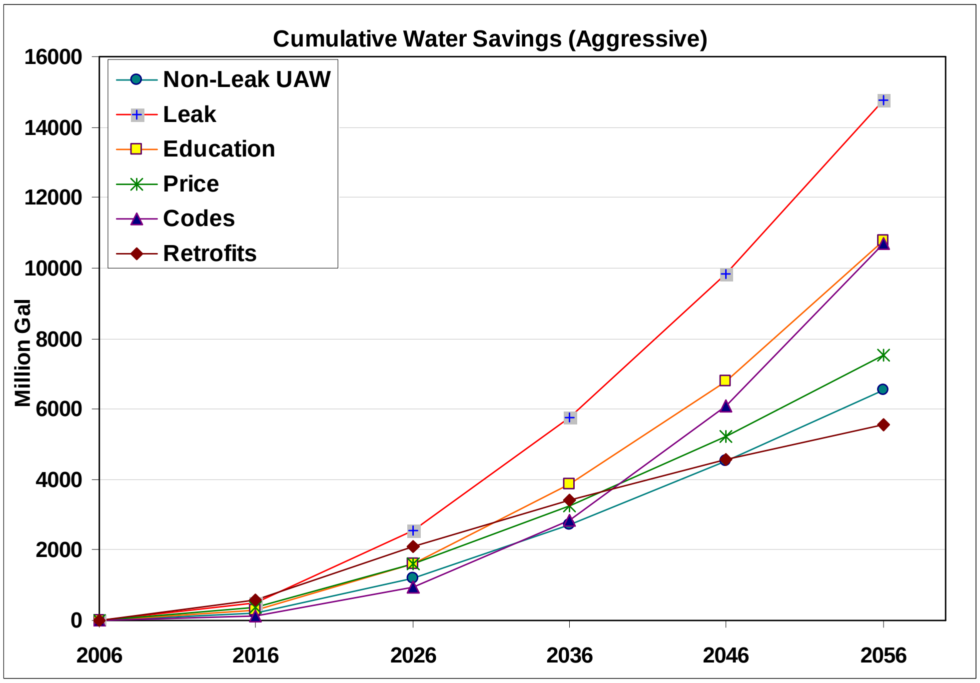

Figure 2 - Cumulative Water Savings for the Six Conservation Measures under the Aggressive Growth Scenario

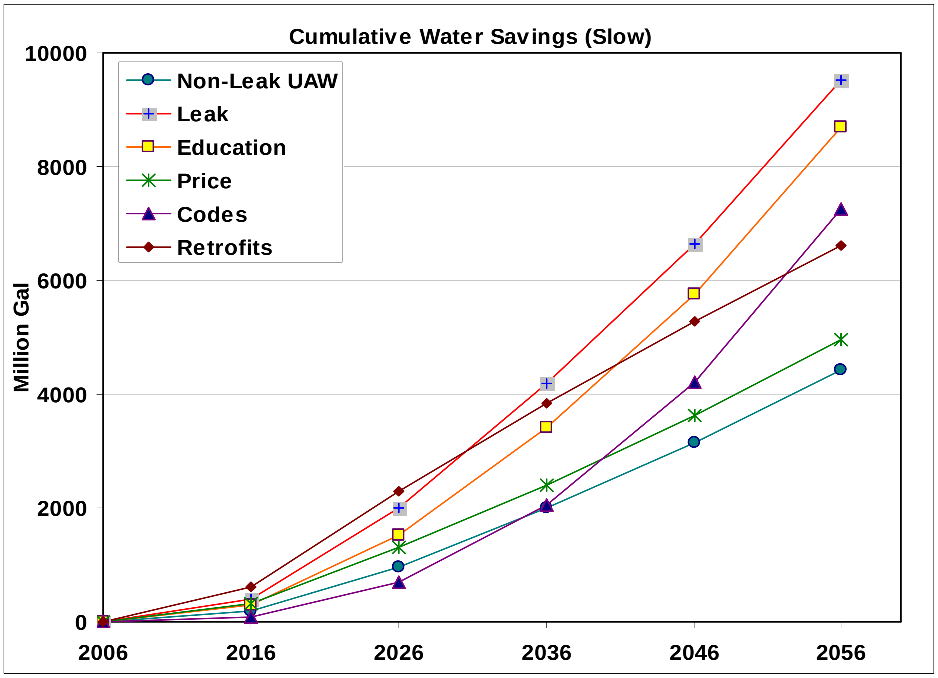

Figure 3 - Cumulative Water Savings for the Six Conservation Measures under the Slow Growth Scenario

6. Pros, Cons and Economic Benefits

The previous section investigated the comparative water savings resulting from each of the conservation measures. While the water savings are perhaps the most important consideration, several other considerations necessarily influence whether the measure should be implemented. These considerations include implementability, public acceptance, cost, uncertainty in the projections, compounding and corollary effects, and finally, economic benefits.

Each of the conservation measures has its own merits and drawbacks, and any comprehensive water conservation plan will likely have to include several conservation measures. The conservation measures which target unaccounted for water, non-leakage UAW reduction and leak detection, have a strong benefit in that they save water that was not producing revenue. Therefore, any water savings generated by these measures lead to direct economic savings. These two measures are also less complicated to implement because they can be put into place solely based on the choice of the utility districts. The drawback of both measures is their upfront cost, which can be significant, especially when pipes must be excavated for repair and replacement. The savings resulting from stopping leaks and other non-revenue producing water, however, often lead to very short payback periods.

Rapid adjustments in price carry their own pros and cons. While periodic, small water rate increases are necessary for maintaining capital investments and keeping pace with inflation, larger rate increases can be a much stronger impetus to conserve. Since water is an inelastic good, rate increases nearly always lead to smaller proportional reductions in consumption than the increase in price. As a result, water savings may be marginal, though the utilities benefit from greater total revenues. The obvious drawback to increasing rates is that rate increases are unpopular and may meet significant resistance from ratepayers. Effective conservation pricing and tiered pricing may be an alternative solution that could provide

benefits with less opposition. Analyzing more complex pricing schemes is beyond the scope of this study, but could be researched further.

Education programs have a great number of benefits, but suffer from a great deal of uncertainty about their actual effectiveness. Educating consumers about methods, benefits, and importance of water conservation can lead to changes in behavior that may save water in the short and long term. Short term changes may be achieved by behavioral changes, while long term shifts in water use may result from consumers making more informed choices when replacing toilets, washing machines, etc. Educational programs are generally not very expensive to implement, but can be ineffective without dedication to the message and sustained commitment to program implementation. Traditionally, education programs have been viewed as effective in reducing water use, but quantifying their actual water savings and economic benefits relative to investment remains difficult.

Strict water conservation provisions in building codes and public ordinances can lead to a gradual but significant reduction in potential future water use. The primary benefit of the codes is the significant long term savings, but the related drawback is that they do virtually nothing to reduce existing consumption except in the case of major renovations. Passing sufficiently comprehensive codes requires a great deal of political cooperation to implement. With the exceptions of builders and plumbers, there are generally few costs to existing stakeholders. Managing an effective inspection and enforcement program requires adding several inspectors and support staff to the local government payroll (or hiring contractors to fulfill the roles), which can be a significant long term cost.

7. Water Conservation Plan

It appears from the analysis of alternative conservation measures that Cumberland County has significant opportunities for reducing water consumption, especially in the long run. A combination of four of the identified conservation measures may provide very significant conservation savings over the baseline projections. GKY recommends the following Water Conservation Plan as best suited to meeting Cumberland County’s long term water management goals. In combination, institute the following conservation measures, described previously in this report:

A. Non-Leakage UAW Reduction
B. Leakage Reduction
C. Education Programs
E. Codes and Ordinances

Modeling the Water Conservation Plan

Modeling the potential savings due to the water conservation plan is a fairly straightforward combination of the 4 identified conservation measures. The modeling methods have limited overlap. Measures A and B are both modeled by setting the UAW percentage with the unmetered/unaccounted tool. The appropriate UAW percentage is simply determined by the summing the reduction percentages under the two programs.

Codes and Ordinances are modeled in exactly the same manner as before. The Education conservation program is modeled in IWR-MAIN using the exact same intensity reductions as described in the Draft Water Conservation Plan memo. However, the passive conservation portion of the education programs is slightly affected. The rate of efficiency class shift is set by whichever rate is higher between the education and codes and ordinances conservation measures instead of adding the efficiency class shift percentages. So if 5% of units per year shift efficiency classes under the codes and ordinances conservation measure, and 3% of units per year shift with education, the total water conservation plan rate is 5% and not 8%.

Results

The results of modeling clearly demonstrate that impressive water savings are possible if an ambitious water savings plan is put into place. Figure 4 shows the baseline forecasts for the three growth scenarios (solid line), and the corresponding forecasts if the Water Conservation Plan is fully implemented (dashed lines).

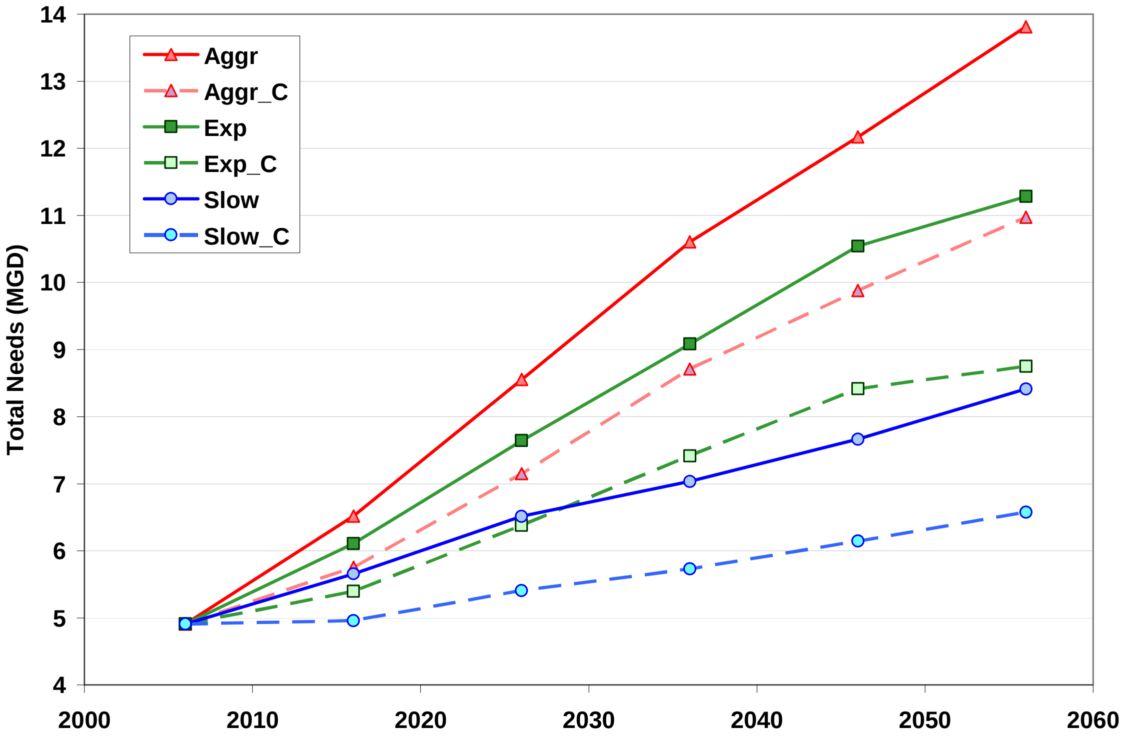

Figure 4 - Forecasted Water Needs for three growth scenarios, with and without the conservation plan

The results of the forecasts show the potentially profound effect of conservation. In general, the conservation plan can save as much as 30% over the baseline scenario. About half of this reduction comes from reduction of Unaccounted for Water alone. Over the long term, the reductions are as significant as dropping one growth scenario. That is, water use for the aggressive scenario with conservation is roughly equal to water use for the expected scenario without it. Even with conservation, water use in the county stands to increase significantly. However, under the slow growth scenario, water use remains virtually flat for the first 10 years when the conservation plan is put into place.

There is one caveat in interpreting the results of the water conservation plan. In analyzing all of the conservation measures individually, there was never a situation in which both the actual consumption and UAW rates were changed simultaneously. The water conservation plan does change both at once. Since the UAW is expressed (and modeled) as a percentage of overall demand, reducing consumption reduces UAW by default. However, the actual physical processes that cause leakage are not necessarily dependent on demand. Therefore, especially in situations where both the consumption and UAW are reduced simultaneously, the water savings may be overestimated. The modeling limitations of IWR-MAIN make it difficult to easily ameliorate this problem.

The effect of this limitation can be discerned when one looks at the results by subsector (including UAW as a subsector). Table 4 displays the results by subsector, comparing the baseline projection and water conservation plan for the three growth scenarios. It is quite

evident that a large portion of the savings comes from reductions in UAW. Under the Water Conservation Plan, UAW can be cut to as much two-thirds below the baseline forecasts. For example, under the aggressive scenario, the baseline UAW estimate in 2050 is 3.05 MGD, but with the water conservation plan, it falls to 0.99. Other subsectors see only about a 5 - 10% reduction over the baseline.

Table 4 – Total Water Needs by Subsector under the Baseline and Water Conservation Plan Forecasts(MGD)

Scenario	Forecast	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	CMC	0.07	0.10	0.13	0.17	0.20	0.23
		NonRES	1.49	1.87	2.11	2.32	2.52	2.71
		RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
		UAW	*1.04*	*1.39*	*1.85*	*2.32*	*2.68*	*3.05*
	Water Conservation Plan	CMC	0.07	0.10	0.13	0.16	0.19	0.22
		NonRES	1.49	1.84	2.06	2.25	2.41	2.56
		RES_PS	2.31	2.99	4.20	5.43	6.29	7.20
		UAW	*1.04*	*0.82*	*0.76*	*0.87*	*0.99*	*0.99*
Expected	Baseline	CMC	0.07	0.09	0.12	0.14	0.16	0.18
		NonRES	1.49	1.78	2.04	2.18	2.34	2.42
		RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
		UAW	*1.04*	*1.30*	*1.64*	*1.97*	*2.31*	*2.48*
	Water Conservation Plan	CMC	0.07	0.09	0.11	0.14	0.16	0.17
		NonRES	1.49	1.74	1.98	2.10	2.21	2.26
		RES_PS	2.31	2.79	3.61	4.44	5.20	5.53
		UAW	*1.04*	*0.77*	*0.68*	*0.74*	*0.84*	*0.79*
Slow	Baseline	CMC	0.07	0.08	0.09	0.10	0.11	0.12
		NonRES	1.49	1.68	1.91	1.96	2.02	2.08
		RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
		UAW	*1.04*	*1.20*	*1.38*	*1.50*	*1.65*	*1.82*
	Water Conservation Plan	CMC	0.07	0.08	0.09	0.10	0.10	0.11
		NonRES	1.49	1.64	1.85	1.88	1.91	1.94
		RES_PS	2.31	2.53	2.89	3.18	3.52	3.93
		UAW	*1.04*	*0.71*	*0.57*	*0.57*	*0.61*	*0.59*

While the average water needs are important in the evaluation of long term water supply planning, the peak day demand is important for the design of certain system components. As in the Water Needs Assessment, a peak factor of 1.35 is assumed. This is applied only to the consumption values, and UAW is added afterwards. Table 5 displays the peak day water needs for the baseline forecast and water conservation plan.

Table 5 – Peak Demand Values for the Baseline Forecast and Water Conservation Plan

Scenario	Program	Data	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	Consumption	3.87	5.13	6.70	8.28	9.49	10.76
		UAW	1.04	1.39	1.85	2.32	2.68	3.05
		PEAK	*6.26*	*8.31*	*10.90*	*13.50*	*15.49*	*17.57*
	Water Conservation Plan	Consumption	3.87	4.93	6.39	7.84	8.89	9.98
		UAW	1.04	0.82	0.76	0.87	0.99	0.99
		PEAK	*6.26*	*7.48*	*9.39*	*11.46*	*12.99*	*14.47*
Expected	Baseline	Consumption	3.87	4.81	6.00	7.11	8.24	8.81
		UAW	1.04	1.30	1.64	1.97	2.31	2.48
		PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
	Water Conservation Plan	Consumption	3.87	4.62	5.70	6.67	7.57	7.96
		UAW	1.04	0.77	0.68	0.74	0.84	0.79
		PEAK	*6.26*	*7.02*	*8.37*	*9.75*	*11.06*	*11.54*
Slow	Baseline	Consumption	3.87	4.45	5.13	5.53	6.02	6.59
		UAW	1.04	1.20	1.38	1.50	1.65	1.82
		PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*
	Water Conservation Plan	Consumption	3.87	4.25	4.84	5.16	5.53	5.98
		UAW	1.04	0.71	0.57	0.57	0.61	0.59
		PEAK	*6.26*	*6.45*	*7.10*	*7.54*	*8.08*	*8.67*

Analysis of the Water Conservation Plan

These four measures are the most beneficial actions Cumberland County can take for several reasons. First, the combination of measures strikes a balance between short term and long term water savings. Measures A and B (Non-leak UAW reduction and Leakage Reduction), especially when implemented in combination, provide immediate reductions in water usage. Measures C and E (Education and Codes and Ordinances) lead to much more significant savings in the long term than the short term.

These four conservation measures are also very feasible to implement. In fact, most of the measures are currently in the process of planning or implementation, though not quite to the extent described in this report. All of the utility districts have recently replaced or are replacing meters throughout their service areas. All of the utility districts claim to be reducing system leakage wherever they can, and one has even contracted leak detection services. The City of Crossville already has plumbing codes in place, and Cumberland County appears to be actively considering implementing them. None of the utility districts currently has dedicated education programs, but there are many resources available through the American Waterworks Association, the Environmental Protection Agency, various state environmental departments, private companies, and other sources.

Especially if the utility districts and county officials cooperate, the conservation measures presented here are very cost effective. Education programs are relatively low in cost. Implementing codes and ordinances has few upfront costs, but some long term enforcement and administrative costs. Measures A and B can be costly, but are generally worthwhile investments as the water savings directly reduce costs without reducing revenues. Furthermore, if leak detection services are contracted for the entire county, and leak detection

equipment is shared, costs can be reduced. Finally, leak detection costs are dropping as technology improves.

The other benefit of this plan is that it should be widely accepted by the majority of the stakeholders. Reducing unaccounted for water, and more broadly, establishing water accountability through better system information, better metering, and leak detection is a crucial step toward public acceptance of other conservation actions. Establishing building codes (and water efficiency standards) is generally acceptable as it has many positive impacts on quality of life in the county. Educational programs, as long as they are well managed, are generally accepted. Price increases for the purpose of conservation, however, are usually unpopular. Additionally, certain stakeholders have already expressed a mild opposition to retrofit and rebate programs as an unfair use of ratepayer or tax dollars.

Finally, implementing the proposed conservation measures leaves open the possibility for future conservation measures not described here. In the event that the proposed plan does not meet conservation targets, or growth occurs at a faster than projected rate, other conservation measures can be implemented. Measures A and B will lead to a much better understanding of the water balance throughout the distribution system and identify opportunities for further conservation. Establishing a framework for education programs leads to better communication between utilities, ratepayers, and other stakeholders, which could make future actions more effective. Strict efficiency codes help to create a local market for more efficient fixtures and appliances. Additionally, once codes are adopted, a legal framework is established for future amendments and ordinances.

While the conservation measures set forth are fairly common and feasible to implement, realizing the projected water conservation savings requires full engagement by the stakeholders and a sustained commitment to the conservation programs. Cumberland County has significant potential for conservation in the short and medium term as utilities reduce their water loss and customers increase their water use efficiency. In the long term, however, real shifts in behavior and in efficiency standards will need to be firmly established to see continued progress in reducing water use. It should be noted that even with significant conservation, Cumberland County's water use will almost certainly rise over the next 50 years. The rate of growth in water needs, however, can be slowed by the adoption of an ambitious conservation plan.

8. Conclusion

Cumberland County faces a challenge in meeting future water needs as the county grows. Continued rapid growth and the chance of future droughts like the one in 2007 highlight the importance of a long term solution to meeting water needs. Numerous proposals exist for increasing water supplies, but this study instead examines the potential for reducing demand.

Six feasible conservation measures have been presented as methods to effectively reduce water demand, inefficient water use, and water loss. Cumberland County has excellent potential for increasing water efficiency, both in the distribution system and on the part of water users. A comprehensive water plan can take advantage of the potential water savings, and almost certainly postpone the need for new water sources.

This Water Conservation Plan outlines a series of measures which can significantly slow the growth of Cumberland's water needs while allowing the county to grow. While the conservation targets are certainly achievable, it will take commitment and cooperation on the parts of numerous stakeholders.

9. References

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Cumberland County Regional Water Supply Study

* * *

Water Needs Assessment and *Water Conservation Plan*

Final Report

Cumberland County Regional Water Supply Study

Water Needs Assessment and

Water Conservation Plan

March, 2009

Table of Contents

Water Needs Assessment

Water Conservation Plan

List of Tables

Water Needs Assessment

Water Conservation Plan

List of Figures

Water Needs Assessment

Water Conservation Plan

Addenda

Three previous documents written by GKY provide added reference with regard to methods and full results for the Water Needs Assessment and Water Conservation Plan.

1. *Land use assumptions for Phase II of the Cumberland County Regional Water Supply Study*. Memorandum. December 13, 2006. by Karsten Sedmera and Stuart Stein, GKY & Associates, Inc.

2. *Water Needs Assessment for the Cumberland County Regional Water Supply Study*. Memorandum. March 14, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

3. *Water Conservation Plan for the Cumberland County Regional Water Supply Study*. Memorandum. June 28, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

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Water Needs Assessment

1. Introduction

The Cumberland County Regional Water Supply Study was established by an agreement between the U.S. Army Corps of Engineers (Nashville District) and the City of Crossville, Tennessee. The Cumberland County Regional Water Supply Study has the goal of identifying a long term solution to Cumberland County's water supply needs, and carrying forward an Environmental Impact Statement investigating potential alternatives for the long term supply solution. As part of the Water Supply Study, GKY & Associates has been contracted to perform a Water Needs Assessment to estimate future demand at 10 year increments for the next 50 years.

This Water Needs Assessment builds, in sequence, a land use development analysis, population growth scenarios, and modeling of future water demands. This study represents the first in-depth analysis taking into account the rapid growth in the early 2000s.

Indeed, Cumberland County, located on the Cumberland Plateau of East Central Tennessee, faces a growing problem in meeting the ever increasing water demand in a rapidly growing county. Cumberland County has been experiencing rapid growth in part due to its considerable success in attracting retirees to live in the county. In severe droughts, this growth is already straining water supplies. As growth continues, it is likely a new water source may need to be developed. This Water Needs Assessment investigates the future demand for water under a range of growth scenarios to project how much water will be needed in the future.

The first step in determining the future water needs is to analyze the land use patterns in Cumberland County.

2. Land Use Development

One of the important steps in predicting future water demand in the next 50 years is the difficult task of predicting future population growth and land use patterns in Cumberland County, TN. Land use patterns assist in predicting population growth by making it possible to assess how much land is available for growth, and they assist in demand estimation by generating a relative breakdown of the types of water consumers in the study area. Cumberland County, however, does not have any formal land use plan (i.e., zoning) in place to control (or predict) local patterns of growth. While there are a few studies that predict population growth for the County as a whole, none of them appear to focus on local growth rates or detailed land use patterns. Figure 1 displays the land use in Cumberland County according to the 2006 tax assessor's database. The land use patterns and the state of development of parcels of various types can provide clues to future development.

Cumberland County was one of ten counties recently selected by the Tennessee Department of Economic and Community Development to participate in a pilot study called "Retire Tennessee" that is designed to promote Tennessee as a great place for retirees to call home. Two of the predominantly residential areas, Lake Tansi and Fairfield Glade represent two established communities (not official cities) that attract retirees by offering small lots, convenient maintenance agreements, and various community club amenities. The three cities in the area – Crossville (the County seat), Pleasant Hill, and Crab Orchard – have similar attractions but more diverse development patterns. Crossville, however, has more dense residential communities than either Pleasant Hill or Crab Orchard. The remainder of the County is fairly rural with scattered residential development along major roads. Two related communities called Cumberland Cove and Cumberland Lakes (henceforth called Cumberland

Cove), which boast large lots and rustic "dream" homes, form a new development area where rural land is rapidly shifting into denser residential development.

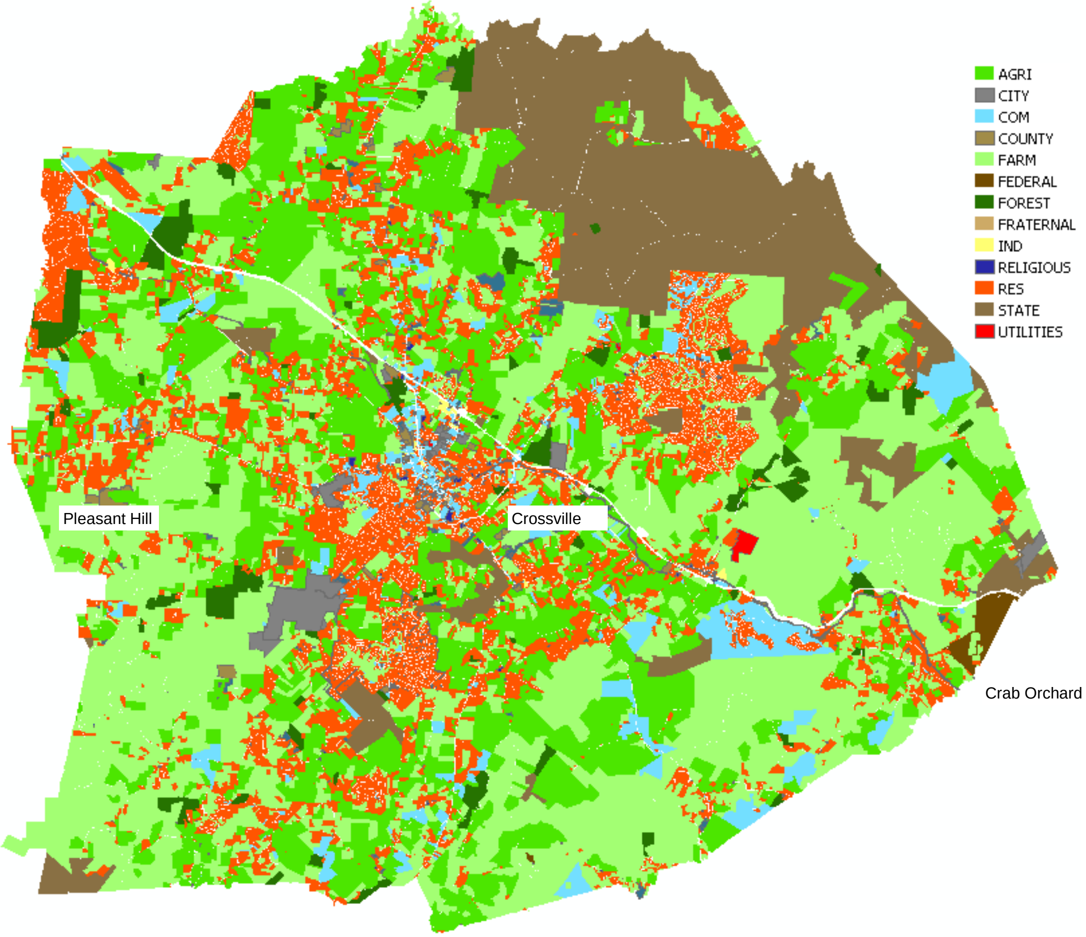

Figure 1 – Land Uses of Cumberland County according to 2006 Tax Assessor's Parcel Data

The tax assessor's database classifies each parcel into one of 12 land use categories (indicated on the map legend in Figure 1). A few clear patterns emerge from examining Figure 1. The majority of the county's land area is dominated by agricultural and farm land. The majority of residential development appears in four or five clusters. The center of the map shows the advanced development around the City of Crossville, including a dense core of commercial and residential development. There is also a large, state-owned wildlife preserve in the northeast corner of the County, which has almost no development in or immediately surrounding it. The land use pattern elsewhere in the county, however, is remarkably similar.

The database also lists the assessed land value and improvement value for each parcel. Thus any parcel with an improvement value greater than zero has been developed. For the purpose of estimating population density, only developed parcels that are classified as residential, farm, agricultural, or forest are likely to have homes on them. A few of the developed parcels classified as farm have improvement values reflecting recreational (e.g., golf resorts) or farm buildings, but most of them are residential lots with over 15 acres. Agricultural or forest parcels are "farms" that qualify for tax breaks under the TN Greenbelt program.

In order to evaluate the development potential in Cumberland County, the characteristics of the parcels (e.g. development, land value, lot size, and improvement value) were analyzed.

Figure 2 highlights the distribution of developed and undeveloped parcels of primarily privately owned residential and commercial parcels.

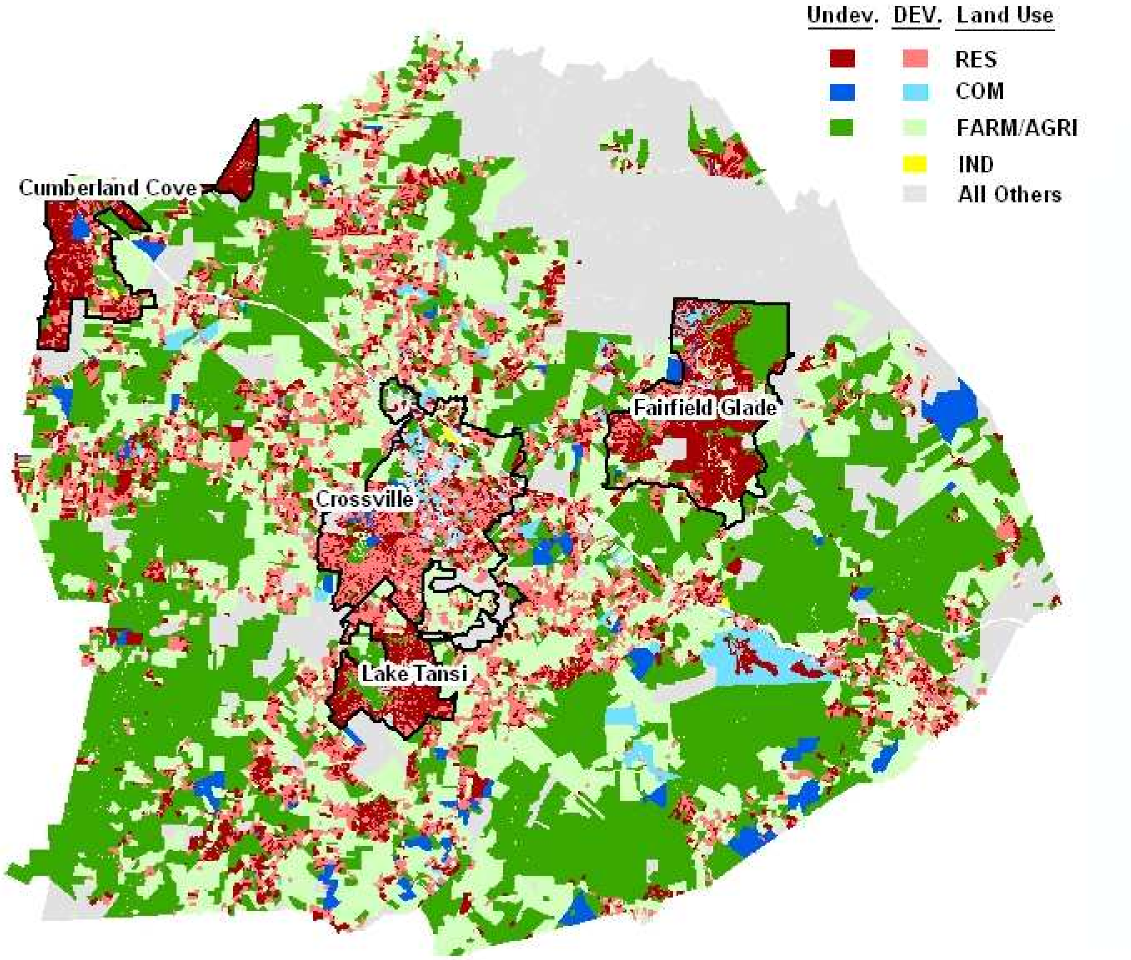

Figure 2 - Development Map of Cumberland County Showing Developed and Undeveloped Residential (RES), Commercial (COM), Industrial (IND), and Agricultural and Farm (FARM/AGRI) Parcels

Figure 2 indicates the undeveloped residential parcels (dark red) show an even clearer pattern than in Figure 1. It is evident that the dense residential communities generally cluster around Crossville, Fairfield Glade, Lake Tansi, and the Cumberland Cove area (which includes Cumberland Lakes). Furthermore, of these four regions, the latter three contain 69% of the undeveloped residential parcels in Cumberland County. Interestingly, the undeveloped commercial parcels are well distributed throughout the county.

Based on the land use analysis five study regions are selected for population and water use projections. Their geographic extents are shown in Figure 3. It should be noted that the boundaries reflect development patterns more than established political boundaries.

- City of Crossville
- Cumberland Cove (including Cumberland Lakes)
- Fairfield Glade
- Lake Tansi
- Remainder of the County

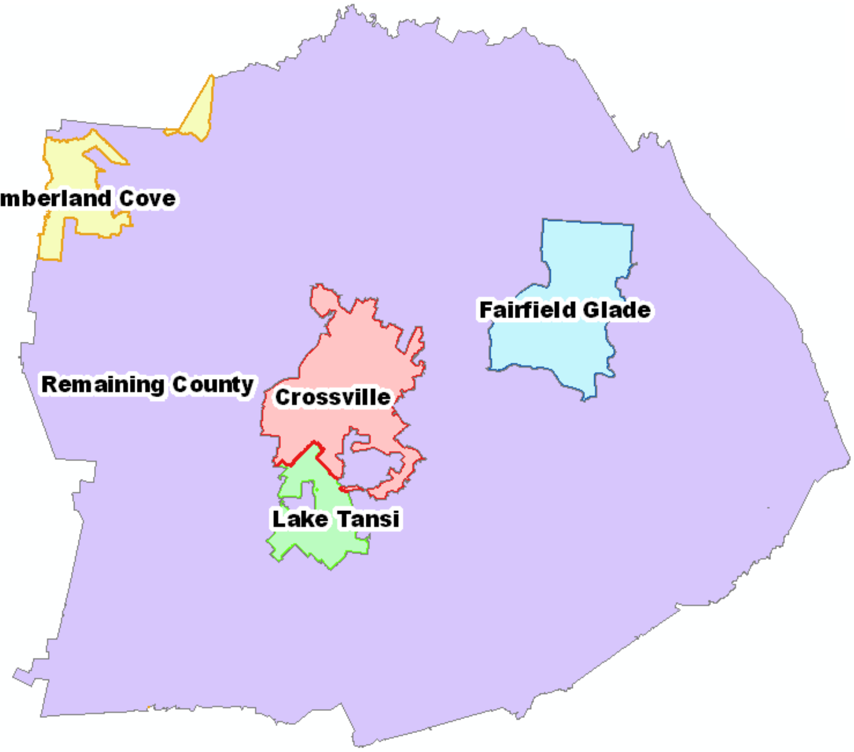

Figure 3 – Study Areas in Cumberland County

Further analysis of the parcels yielded some other general information about land use in Cumberland County that are useful for making population and water use projections. A few of the more interesting results are as follows:

- 90% of parcels in the County are residential
- 6% are farm/agricultural/forest,
- 37% of the residential parcels are developed,
- 57% of the farm/agricultural/forest parcels are developed, and
- 83.7% of the land area is residential/farm/agricultural/forest.
- The undeveloped residential parcels are, on average, half as large as the developed ones (0.92 vs 1.93 acres)

3. Growth Scenarios

The land use analysis establishes the general bounds on growth, and identifies the ultimate growth potential of the five study areas named in Section 2. Following the land use analysis, projections of the expected population growth in Cumberland County must be made in order to forecast water needs. Population forecasting is inherently uncertain, and becomes more so the further the time horizon of the forecast extends. In order to treat some of this uncertainty in a more concrete fashion, three distinct growth scenarios are carried through the remaining forecasting and modeling. They include the Slow, Expected, and Aggressive growth scenarios. The forecasts include population projections every 10 years starting in 2006 and ending in 2056. The Land Use Memo (full title: *Land use assumptions for Phase II of the*

Cumberland County Regional Water Supply Study), included in the addenda, details the methods by which the projections were made.

The growth scenarios all utilize the same starting values, and differ primarily in the specified growth rates for each ten year period. The growth rates also vary by study area. The percentage rate of growth reflects historical data, expert judgment from relevant stakeholders in the County, and other important factors (such as lack of sewer connection). Figure 4 displays the countywide population projections under the three population scenarios, as well as projections from two other studies. Note that the countywide projections are a sum of predictions for the individual study areas, each of which has independent growth projections and saturation points.

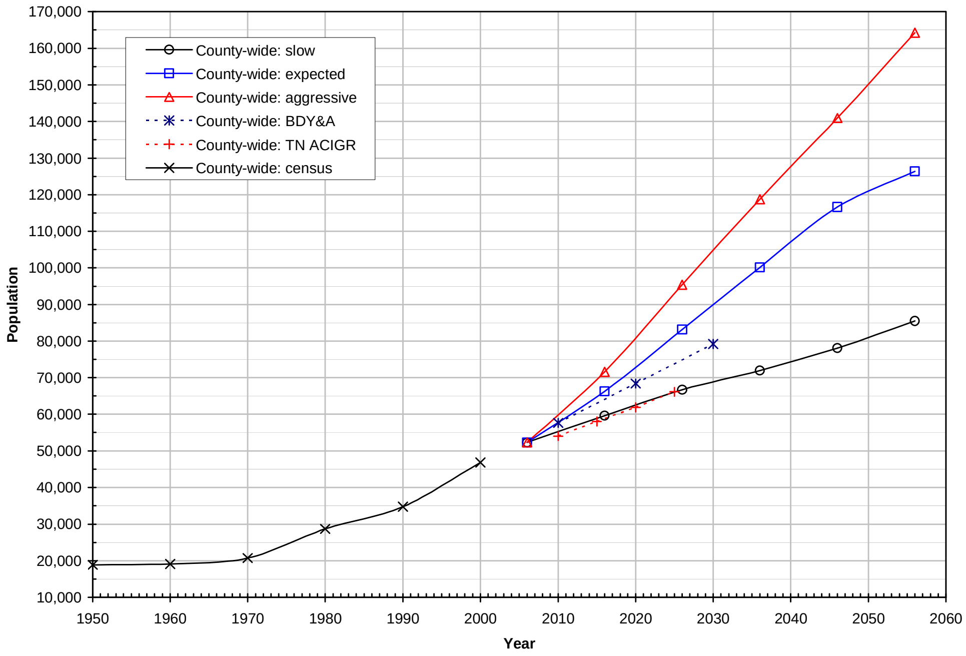

Figure 4- Population projections for Cumberland County. The three growth scenarios are displayed, as well as projections from two other studies (BDY & A 2002[i]; TN ACIGR[ii])

The population projections in fact show a wide range of variation among the growth scenarios. The range of population projections easily encompass the variability in the previous population projections, with the Slow growth scenario comparing favorably with the Tennessee Advisory Commission on Intergovernmental Relations' (TN ACIGR) forecast, and the Expected scenario a little higher than the Breedlove, Dennis, Young and Associates (BDY&A) forecast. The Aggressive scenario allows for substantial growth, but we note that even after 50 years, the projection does not begin an increasingly rapid growth phase as is often the case with simple exponential growth models.

Once the population is forecasted, it can be used to calculate projections of other relevant variables for estimating water usage. Namely, for each study area, the number of households and the number of employees must be forecast. By using historical data and stakeholder judgment, the future population per household ratio and the population per employee ratio were estimated for each forecast year. Dividing the projected populations by these factors yields the estimates of households and employees in Table 1.

Table 1 – Countywide Projections of Population, Households, and Employment for Cumberland County

Forecast Variable	Scenario	2006	2016	2026	2036	2046	2056
Population	*Slow*	*52,306*	*59,620*	*66,732*	*71,949*	*78,103*	*85,509*
	Expected	*52,306*	*66,288*	*83,157*	*100,163*	*116,643*	*126,373*
	Aggressive	*52,306*	*71,598*	*95,366*	*118,783*	*140,958*	*164,223*
Households	*Slow*	*23,345*	*27,622*	*31,990*	*35,323*	*39,294*	*44,144*
	Expected	*23,345*	*30,588*	*39,724*	*49,404*	*58,980*	*63,664*
	Aggressive	*23,345*	*33,106*	*45,772*	*59,252*	*69,006*	*79,369*
Employees	*Slow*	*25,000*	*29,083*	*33,200*	*36,522*	*40,259*	*44,305*
	Expected	*25,000*	*32,336*	*41,371*	*50,844*	*60,125*	*65,478*
	Aggressive	*25,000*	*34,926*	*47,446*	*60,296*	*72,659*	*85,090*

4. Water Needs Assessment Methods

Planning and Management Consultants, Ltd.'s IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as state-of-the-art, industry standard water demand forecasting software packages. IWR-MAIN was used as a tool to compute projected water use based on assumptions about the county's growth and water use factors. The IWR-MAIN user's manual[iii] explains in detail the structure of the model and the precise definitions of the terminology used. Where possible, we strive to use the correct IWR-MAIN terminology in describing the construction of the Cumberland water demand projection.

At the heart of the IWR-MAIN model is the usage model in Equation 1.

$$\boxed{\begin{array}{c}\text{Demand}\\ Q\end{array}} = \boxed{\begin{array}{c}\text{Counting Unit}\\ N\end{array}} \times \boxed{\begin{array}{c}\text{Use Factor}\\ q\end{array}}$$

Equation 1.

In short, the demand is determined by multiplying some counting unit by a water use factor. This model determines the demand in a given time period, in a given subsector, in a given study area. A *subsector* is the base organizational unit for which water demand is projected (e.g., the residential or commercial subsector). Each subsector has its own associated *counting unit*, which is a measure of subsector size that has a strong influence on water usage (population, households, or employees, for instance). The *use factor* is simply the volumetric demand for water per counting unit (gallons of water per capita per day, per house per day, etc) in a given time period. Thus, a water demand forecast requires projecting (at a minimum) how the counting units and use factors change over time.

The total county water use in a given time period is simply a sum of the consumption for each subsector plus any leakage or other non-consumptive use. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different regions of the study universe have distinct characteristics, the study can be broken down into *study areas*, each with their own group of subsectors and usage models. In this case, the study universe encompasses all of Cumberland County.

With respect to Cumberland County, the study areas have already been identified in Section 2. For each study area, two sectors were assumed: residential and non-residential (encompassing commercial, industrial, and institutional uses). Residential water use forecasts are computed using the forecasted number of housing units as the counting unit. The non-residential sector utilizes number of employees as the counting unit. The City of Crossville study area has an

additional subsector to model the water usage of Cumberland Medical Center, whose associated counting unit is the total population of Cumberland County.

Water Use Factors

Forecasting the future values of the counting units accounts for half of the necessary inputs in (1). The other half of the inputs comprises the water usage rates. IWR-MAIN's Forecast Manager and Conservation Manager offer a range of forecasting models to estimate future water use factors. Many of the methods are econometric methods that allow using explanatory variables to build a predictive model for the use factors. Among the explanatory variables that are commonly found to be associated with water use are income, housing density, persons per household, marginal price, average daily maximum temperature, precipitation, and cooling degree days. An extensive analysis of the water usage records and available data on potential explanatory variables determined that the predictive models were not appropriate for this study. It should be noted that future needs assessments should reconsider this decision because a few more years of high-quality water usage data (including sector breakdowns) may make these more complex models viable.

Without these models, IWR-MAIN provides two primary options for calculating use factors. The first, contained within IWR-MAIN Forecast Manager, is to simply use constant use factors calculated based on the number of counting units and the base year use. The second, which requires using IWR-MAIN Conservation Manager, is to develop end use models for each subsector. Each end use has its own use factor, and the sum of the use factors for each subsector is the overall use factor for this sector. This approach is more flexible than the constant use model, though it can be made equivalent through correct application of parameters in the model.

The chosen model is the end use model, mainly due to the fact that Conservation Manager will be used to evaluate the effectiveness of conservation measures in the water conservation plan. The added benefit to using the end use model in Conservation Manager is that it is possible to define end uses on three levels of water use efficiency and shifts between them over time. This feature allows incorporating natural, market based changes in water use efficiency that result from greater average efficiency of water using fixtures and appliances over time.

When employing the end use model, it is important to have an accurate base-year water usage estimate. This water demand projection uses two seasons, so monthly estimates of base year use are necessary. The summer season includes June, July, August, and September, and the Winter season includes the rest of the year. Water use is assumed to be constant for all months within a given season.

Residential water usage factors are based on monthly residential water consumption data from the South Cumberland and Crab Orchard Utility Districts. Both user districts had acceptable monthly records of residential water consumption and the associated number of customers (households). Since the counting unit for the residential sector is the household, the water use factor is expressed in terms of gallons per day per household (gpd/hhld). The S. Cumberland and Crab Orchard data yielded annual averages of 119.7 and 118.9 gpd/hhld, respectively. Lake Tansi is almost completely encompassed in the S. Cumberland district, and Fairfield Glade is contained within the Crab Orchard district, but the rest of the study areas still need water use factors. For the sake of simplicity, and to provide a conservative estimate of demand, the rest of the study areas are simply assigned the higher S. Cumberland water use factors.

Estimating nonresidential demand is somewhat more complicated than estimating residential demand, especially in terms of disaggregating countywide demand among the study areas. As mentioned before, future employment projections are based on each study area's population

and a countywide population to employee ratio. Since Crossville's commercial development is not distributed exactly the same as residential development, it is inevitable there will be some error in the geographic distribution of commercial water demand. Without zoning though, it seems at least reasonable that future commercial development will occur near growing areas with concentrated residential development. Thus, it is likely much of the commercial development will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

The methods for generating the water use rates for the commercial sector are described in much more detail in the Needs Assessment Memo in the addenda. In a general sense, the use rates for the commercial sector were determined from actual usage records from the utility districts and then spatially disaggregated. The disaggregation was performed in GIS by determining the location of commercial and industrial parcels in the parcels database with respect to the boundaries of the study areas and the utility districts.

Passive Conservation

One major source of error in many forecasts of future water use is the failure to consider the effect of more water efficient technology. Since the Federal Energy Policy Act of 1992, U.S. manufacturers have been required to meet minimum water efficiency standards for plumbing fixtures and toilets. Since that time, manufacturers have gone well beyond the minimum standards as a way to stay competitive. The mode of change effected by the availability of more efficient technology is called passive conservation, whereby consumers conserve just by replacing their older fixtures with more efficient ones when they need to be replaced. New construction also takes advantage of the more efficient technology by default.

The average potential savings associated with more efficient appliances were determined from the AWWA's 1999 *Residential end uses of water* [iv]report. The average replacement rate was determined from the National Association of Home Builders/ Bank of America *Study of the Life Expectancy of Home Components*[v]. Though the consumption-weighted average replacement rate for all water using home components is approximately 6.5%, a more conservative rate of 5% was assumed. This is equivalent to a 20 year lifetime for many of these components. The forecasts take these shifts into account using the passive conservation tool in IWR-MAIN Conservation Manager.

The effect of this savings is a very slight decrease in the per unit water use rate over time. Though counterintuitive for a growing county, this makes sense in Cumberland County for several reasons. Firstly, as explained previously, no credible predictive models can be developed with available data. Secondly, the land use analysis demonstrated that the average area of the undeveloped residential and commercial parcels in the county is significantly smaller than the developed parcels meaning that outdoor water use will rise slower than the population growth rate. Thirdly, as more retirees move to the county, the number of people per household will continue to fall, meaning that per household indoor use rate should not increase. Finally, technological advances in manufacturing of toilets, dishwashers, and other water using appliances will tend to lower water usage as older units are replaced with more efficient ones. This conservation savings due to technology, while slight was considered necessary for inclusion in the model because of the long study period.

Unaccounted for Water

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental water main breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each of the study areas, the Unmetered/Unaccounted tool sets the year-by-year UAW percentage. (IWR-MAIN restricts the percentage to a constant value for each year, and only whole percentages are permitted.)

Previous water demand studies of Cumberland County have used a wide range of methods to model UAW. Breedlove, Dennis, Young & Associates' (BDY) 2002 *Cumberland County Water Supply Needs Assessment* selects a target loss percentage of 10% as a worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[vi] prepared by the Corps and Ogden Environmental and Energy Services, Inc. also estimated 10% UAW on the basis of non-specified estimates by the Cumberland Utility Districts.

In this study, UAW estimates for the five study areas are based on actual data from the UDs. Perhaps in response to the previous studies, the UDs have begun collecting more detailed statistics on UAW. It is with these statistics and advice from interviews with the UDs that we estimate UAW. Table 2 shows the average UAW percentages by utility district in recent years. The final row displays the number of years of data upon which the percentages are based.

Table 2– Unaccounted-for-Water data by Utility District (% of total production)

	Crab Orchard	Crossville	South Cumb.	West Cumb.	**Consumption Weighted Average**
Annual UAW%	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 2 appear incredibly high, but when we consider the short record length, it is clear that at least in some cases, some outlier values may be skewing the results. While there appears to be some potentially significant seasonal variation in the loss percentage, at least in Crab Orchard and Crossville, there are not enough data to make a strong case for modeling this variation. Additionally, IWR-MAIN does not allow seasonal variation in the Unmetered/Unaccounted percentage.

Except in Crossville, the record lengths are too short to make a valid estimation of the UAW by utility district. So we calculate the county average as weighted by consumption in the UDs. The yearly average UAW percentage is calculated as 22.4%, which is conservatively rounded upward to 23%. All of study areas except for Crossville are assumed to have this 23% average. If metering errors, line flushing, and known losses are assumed to be 5%, this means that an average of 18% of total produced water is actual loss. These figures compare favorably with the 20% rate indicated in interviews with the Crab Orchard Utility District, and 14-15% loss rate reported by West Cumberland. With the Crossville records being a bit longer, we feel comfortable setting Crossville's UAW percentage at 19%, which is slightly more conservative than the 15% unaccounted for and the 10-12% loss estimated by the Crossville UD in a May 2006 interview.

For the purposes of a baseline forecast, the UAW percentages are assumed to remain constant in time, which is a dubious assumption based on the large variances in month to month losses alone. Almost certainly, losses will either increase as the system ages, or decrease as the result of system improvements and maintenance. We are hesitant, however, to forecast changes to the UAW percentage in a baseline forecast, or impose 'desirable goals' as some past studies have done. Additionally, the conservation measures evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

Model Validation

Based on the assumptions made, it is possible to compare the projections to observed water usage. Figure 5 displays the estimated total county water consumption as compared to

observed consumption based on data from the UDs. These figures exclude UAW. On average, the estimated values are about 4% above the observed values, and therefore slightly conservative.

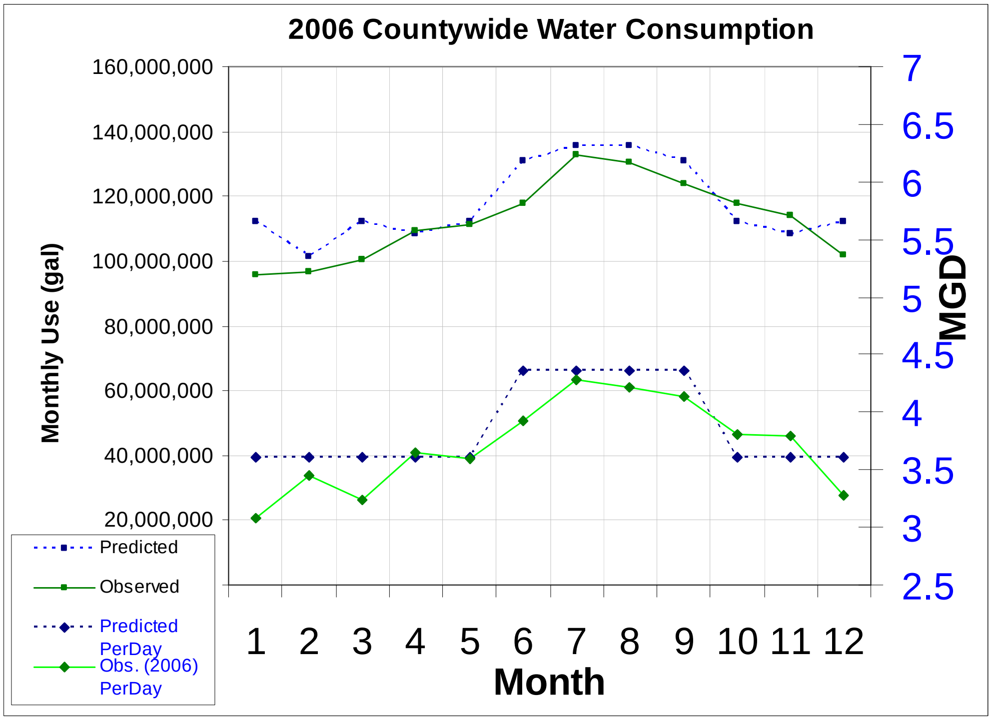

Figure 5 - Predicted versus Observed Countywide Water Consumption (excl. UAW)

The agreement shown between the observed and estimated values in water use is certainly not perfect, but it indicates the assumptions are at least reasonable, and slightly conservative. We note that there is excellent agreement at the peak water use month of July.

When the total usage includes UAW, the agreement between the observed 2006 values and predicted values is slightly worse. Data from the utility districts indicate that unaccounted for water makes up 27% of total produced water in 2006. This is higher even than the already fairly conservative assumption of 23% (19% for Crossville) used in the modeling. Figure 6 displays the estimated and observed values, which indicate the model predictions are about 7% *below* observed values. This is certainly a source of potential error, but is more likely due to above average losses in 2006. For the purposes of forecasting, the recent historical averages for UAW are a more reasonable basis for estimating future UAW than the 2006 values alone. Thus, no further calibration is necessary to match the observed and predicted 2006 demand.

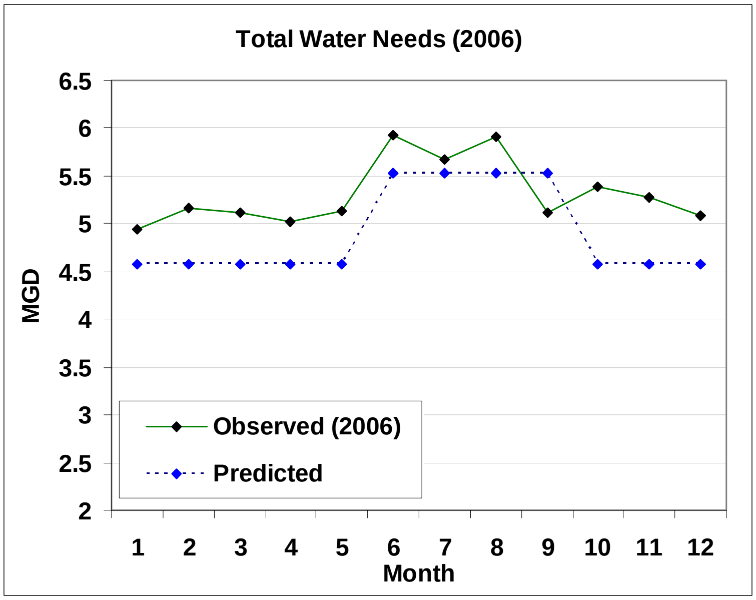

Figure 6– Model Predicted and Observed Cumberland County Water Use in 2006

5. Summary Results

The results of the baseline water supply needs assessment are presented in this section. All results are presented in terms of average daily usage in millions of gallons per day (MGD) except when otherwise noted. Summary results are presented here, but full results are available in the addenda.

It should also be noted that this is a planning level document, so the results are presented as annual or seasonal average. These figures should be sufficient for estimating water storage needs. Calculating peak usage, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak usage estimates were not called for in the scope of services, but are presented for completeness. BDY&A's 2002 *Cumberland County Water Supply Needs Assessment* cites factors in a range of 1.25 to 1.35 of daily consumption for Cumberland. The Corps' *Cumberland County Regional Water Supply Preliminary Engineering Report* appears to use 1.35 as well. Thus, a factor of 1.35 is applied to the results of this section. Note that peak factors are applied only to the consumption, and subsequently, the unadjusted UAW is added.

Countywide Results

The countywide results present the broadest picture of the water needs projections. Figure 7 presents the demand totaled for all study areas and all subsectors (including UAW). The demand for all three growth scenarios is indicated separately, however. The results indicate that demand will not quite triple in 50 years under the Aggressive scenario, less than double under the slow scenario, and roughly double under the expected scenario.

Under any growth scenario the projected demand increases significantly over the 2006 baseline. As noted previously, there is a great deal of uncertainty, particularly in the estimation of future trends in UAW. Figure 8 reports the county totals for consumption, which excludes the UAW. While there is bound to be some UAW in the future, the consumption projections are marginally more certain. The water conservation plan will more directly assess the effects of reducing UAW.

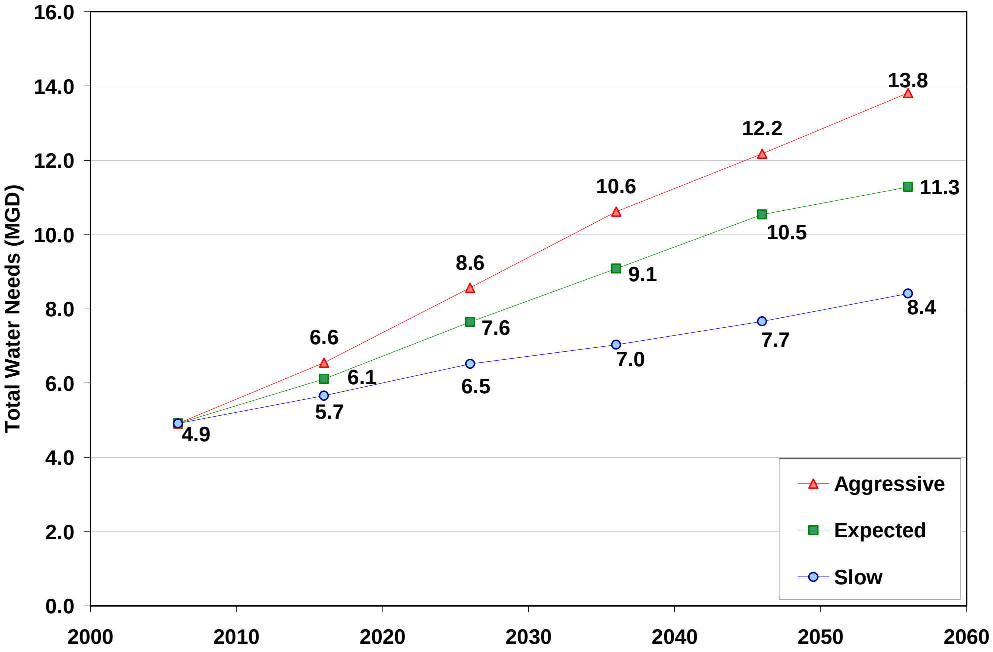

Figure 7. Countywide Daily Average Total Water Needs for the Slow, Expected, and Aggressive Growth Scenarios.

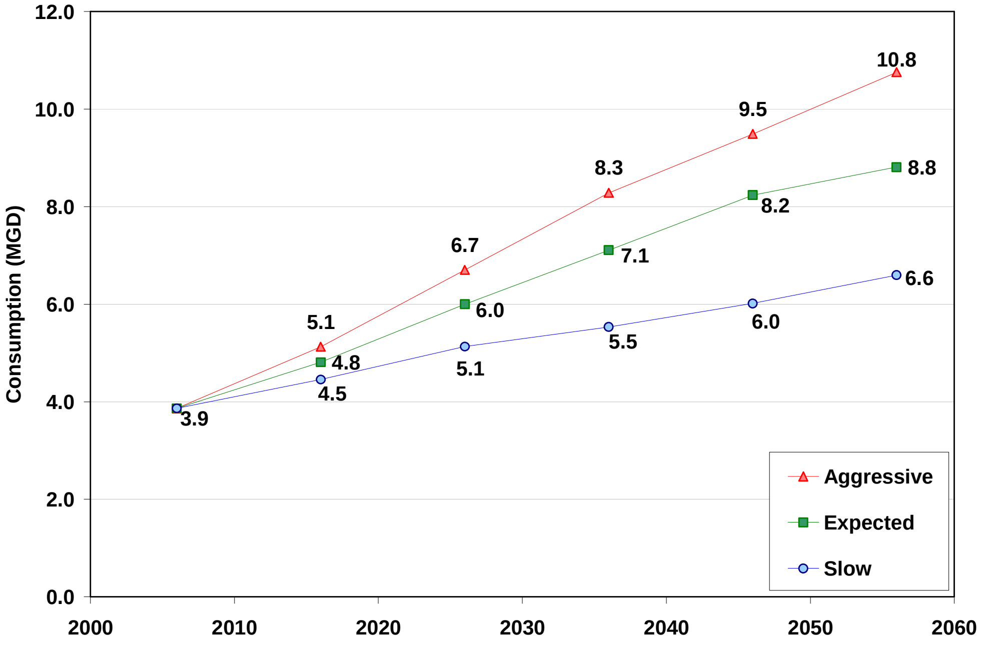

Figure 8 – Countywide Daily Average Projected Water Consumption (excludes UAW) for the Slow, Expected, and Aggressive Growth Scenarios

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, the usage varies by season. The Summer months include June-September, while the Winter includes the remaining months. The results are presented here by scenario and season. Countywide, the summer usage remains a fairly consistent 12-13% above the annual average, and winter usage is always

roughly 6-7% below. This is a result of the cumulative effects of the different winter and summer use factors for the subsectors (see the Water Needs Assessment in the addenda for full description and usage rates). Table 3 displays the countywide daily demand by season.

Table 3– Seasonal Variations and Peak Projected Total Water Needs (MGD)

Scenario	Season/Peak	2006	2016	2026	2036	2046	2056
Aggressive	Annual	4.91	6.55	8.56	10.61	12.18	13.81
	Summer	5.55	7.41	9.71	12.09	13.84	15.67
	Winter	4.59	6.12	7.99	9.87	11.34	12.87
	PEAK	*6.26*	*8.35*	*10.91*	*13.51*	*15.50*	*17.57*
Expected	Annual	4.91	6.11	7.64	9.08	10.54	11.28
	Summer	5.55	6.90	8.63	10.27	11.94	12.77
	Winter	4.59	5.71	7.14	8.48	9.84	10.54
	PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
Slow	Annual	4.91	5.66	6.52	7.03	7.66	8.41
	Summer	5.55	6.40	7.38	7.98	8.71	9.58
	Winter	4.59	5.28	6.08	6.56	7.14	7.83
	PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*

Table 3 also displays the projected peak demands, which reflect a 1.35 peakage factor applied only to the annual average consumption. As mentioned before, this factor is based on peak factors cited in previous studies and is not based on usage data. The unadjusted annual total UAW is then added on to this peak consumption to arrive at total water needs.

Water Needs Analysis By Subsector

Table 4 indicates the annual average daily demand by subsector for the entire county. In terms of total demand growth, it is clear that most of the growth occurs in the residential sector. The other sectors exhibit slightly lower percentage growth, but still increase significantly over their base year values. The NonRES results indicate that commercial growth will be of a low water intensity variety, which is consistent with a primarily service oriented commercial sector. The introduction of only a few large (industrial) water users, however, could add significantly to commercial demand, making the NonRES sector the most likely to be a low estimate of actual future demand.

Also notable is that the UAW subsector, while remaining a constant percentage of total water use, grows to become a more significant water ‘use’ than the nonresidential sector under the aggressive scenario. While the UAW percentage is based on the best available current loss estimates, this sector is most likely to reflect an overly conservative estimate of actual future UAW. The actual processes of leakage are more complex than a simple percentage loss, so growth in consumption does not necessarily mean a proportional rise in leakage. Additionally, leakage will most likely be addressed by future loss reduction measures. The impact of loss reduction measures is treated in the Water Conservation Plan.

Table 4 - Projected Total County Water Needs (MGD) by Scenario and Subsector

Scenario	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
	NonRES	1.49	1.87	2.11	2.32	2.52	2.71
	CMC	0.07	0.10	0.13	0.17	0.20	0.23
	UAW	1.04	1.42	1.86	2.33	2.69	3.05
Aggressive Total		**4.91**	**6.55**	**8.56**	**10.61**	**12.18**	**13.81**
Expected	RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
	NonRES	1.49	1.78	2.04	2.18	2.34	2.42
	CMC	0.07	0.09	0.12	0.14	0.16	0.18
	UAW	1.04	1.30	1.64	1.97	2.31	2.48
Expected Total		**4.91**	**6.11**	**7.64**	**9.08**	**10.54**	**11.28**
Slow	RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
	NonRES	1.49	1.68	1.91	1.96	2.02	2.08
	CMC	0.07	0.08	0.09	0.10	0.11	0.12
	UAW	1.04	1.20	1.38	1.50	1.65	1.82
Slow Total		**4.91**	**5.66**	**6.52**	**7.03**	**7.66**	**8.41**

* RES_PS – Residential, Public Supply; NonRES – Nonresidential; CMC – Cumberland Medical Center; UAW – Unaccounted for Water

Comparison to Previous Estimates

A comparison of GKY's water needs forecasts with previous estimates of Cumberland County's water needs clearly demonstrates the effect of prediction method chosen. Figure 9 compares the estimates in this study to those by Breedlove, Dennis, Young and Associates (BDY&A, 2002), the Army Corps of Engineers (USACE, 1998)[vii], and Lamar Dunn & Associates (LD&A, 2001). LD&A used a simple percentage growth model to estimate future demand. While this model may be appropriate in the short term, it is evident that the simplistic exponential model rapidly leads to unstable and incredibly high demand estimates at more distant time scales. It is clear that this model is insufficient for modeling long term water needs because it is overly simplistic and does not take into account any realistic limitations on growth.

Also interesting is that the BDY&A study presents a very high estimate of demand. This is likely a result of the method used for forecasting the future use factors. The study uses a gross total per capita consumption use factor to estimate the water use. BDY&A chose to express this factor as total public supply water use divided by total population (instead of population served). As a result, the numerator does not reflect the many self-supplied water users in the county (whose use would not be counted in public supply water), while the denominator does count them. This partially explains the artificially low historical use factors (54 and 77 gpd per capita in 1984 and 2000, respectively). The rapid increase in water usage factors is likely more a result of new development being added on public supply (versus self-supply) in a much higher proportion than the existing residences than it is a response to economic trends or fundamentally different water usage patterns of new residents. Furthermore, to bring the use factors to present day average values from this low starting point requires astounding gains in the per capita use factor. Projecting the future water use factors from historical values can lead to extremely high use forecasts, especially when rapid population growth continues.

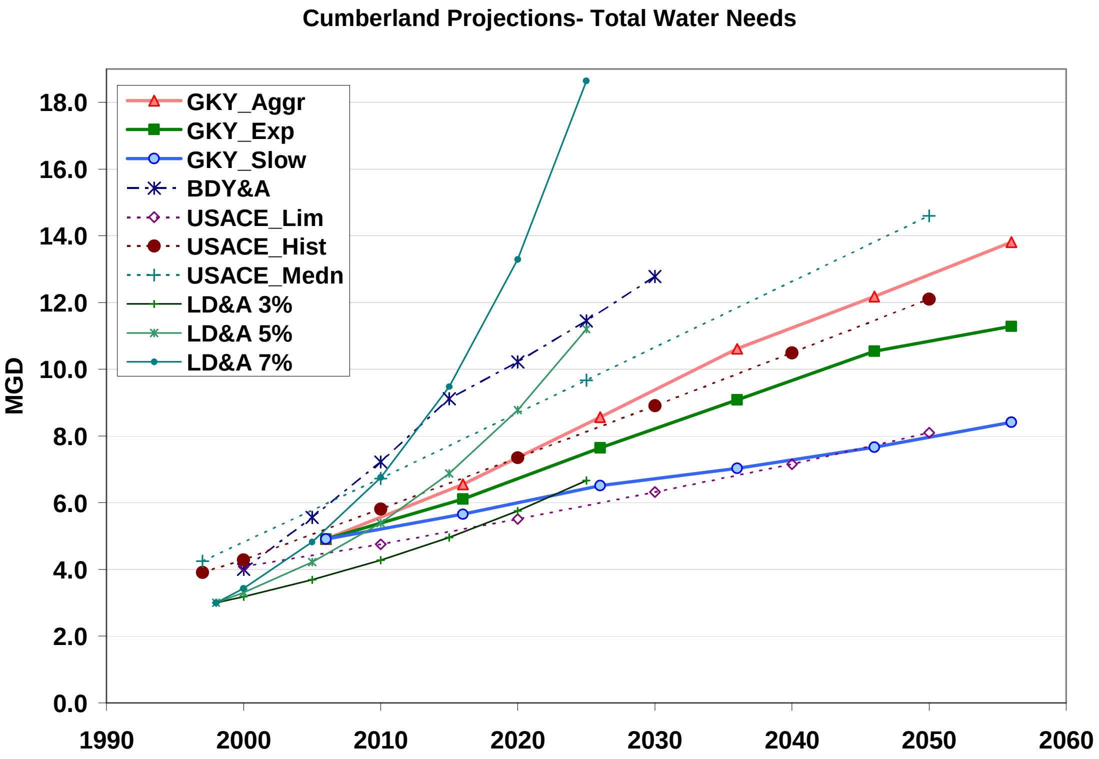

Figure 9 - A comparison of water needs forecasts for Cumberland County

The USACE projections rely upon a variety of different methods, including a model developed in IWR-MAIN (i.e. Medn → Median projection). These projections seem most closely in line with GKY's projections. The historical and limited methods actually incorporate limitations on growth, though in a more simplistic way than the GKY study.

The GKY study likely presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[viii] of the Pacific Institute note, "With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches." GKY's baseline projections present a new approach to countywide water demand forecasting, as anticipated improvements in water efficiency are taken into account. These anticipated improvements are in a sense inevitable as national laws and standards, as well as simple market availability have affected a shift to more conserving technology. For example, the Energy Policy Act of 1992 has made virtually all new toilets on the market compliant with a 1.6 gallon per flush efficiency standard.

It is important to note the efficiency assumptions are nearly completely independent of any decisions and policies made by public officials and citizens in Cumberland County. Other water use reductions may result from programs already in progress (notably, infrastructure improvements to reduce leakage). To establish a conservative baseline projection, however, we limit the conservation measures to 'natural' efficiency upgrades due to more advanced technology gaining a greater market share over time. Other conservation actions are analyzed much more thoroughly and explicitly in the Water Conservation Plan.

6. Uncertainty

The act of forecasting into the future is an inherently difficult task. It is important to recognize (1) that uncertainty is present in any projection, (2) uncertainty in baseline assumptions influences uncertainty in projections, and (3) errors compound over time, making distant projections less reliable than near-term projections.

The forecast model is designed to explicitly take into account uncertainty where possible, and otherwise, avoid introducing unknown uncertainty. (We use 'uncertainty' instead of error because error can't be calculated until the future when there are actual water demand values in the forecast years.)

The largest source of uncertainty in this forecast is likely contained in the population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth scenarios (instead of only an expected growth scenario), we introduce reasonable bounds on the uncertainty of this projection. (That is not to say that Slow and Aggressive scenario projections present the absolute lower and upper bounds on the prediction.) This understanding of uncertainty in the population projections is useful since the housing forecasts are calculated in tandem with them, and the employment projections depend directly on population as well. In these projections, the assumed growth rates, people per house statistic, and population per employee estimates all are potential sources of error. As an illustration of the potential consequences of error in initial projection, Table 5 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. (A constant percentage growth model is assumed.) Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 5 - Consequences of 0.5% error in growth rates (forecasted Units per 1000 base Units*)*

	10 years		**25 years**		**50 years**	
Initial rate projection	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*
1%	53	-56	150	-169	361	-461
2%	58	-61	190	-213	586	-746
5%	76	-79	381	-427	2435	-3075
10%	116	-120	1166	-1301	23914	-29879

Table 5 indicates just how serious minor errors in the prediction parameters can be, particularly in fast growing regions. The land use limitations on growth assumed in this study help put a limit on how large the error can be. In practice, growth can be limited (or spurred) by many factors other than land use consideration, but some limits are advisable as a constant percentage growth, exponential model is rarely a realistic assumption for a very long study period.

The other major potential source of model uncertainty is in the water use factors. While IWR-MAIN has several advanced methods of estimating future demand built into the software, additional parameter estimates and explanatory variables would be necessary (each bringing additional uncertainty). Any more complex model (such as a linear or multiplicative regression) would introduce more uncertainty through parameter estimates in addition to any uncertainty in forecasting future explanatory variable values. The water usage data provided by the UDs is just enough to come up with baseline water use factors. The small sample sizes of the water use data mean there is quite a bit of uncertainty in the water use factors (especially in the monthly values). By averaging the months within two seasons, the sample size is effectively increased, reducing the uncertainty introduced by outliers.

In a similar manner, the UAW percentages are averaged over the county to increase the effective sample size of estimate, and reduce the effect of outliers. Section 4 (Water Needs Assessments Methods) demonstrated that selection of parameters led to good agreement with real water use patterns in the base year.

The importance of the proper treatment of uncertainty in model prediction cannot be overstated. Underestimating future water needs can lead to a dangerous situation in the form of a water shortage or even running out of water. Overestimation of water needs can lead to unnecessary projects or oversized projects at a much higher cost than necessary. Without a realistic view of the uncertainty present in the forecasts, decision making on future supplies may not be truly addressing the water needs. Fully cognizant of the uncertainties present in this forecast, GKY has made every effort to document the uncertainty and present a reasonable range of potential future water needs representative of the effects of the known uncertainty.

Comparisons with previous studies have shown that this study's predictions of water needs tend to be somewhat lower than previous estimates made with simpler models. A careful consideration of the methods used in earlier studies generally leads to the conclusion that the forecasted water needs may be overestimated. This study attempts to provide as accurate a forecast of water needs as possible, with full description of methods, thus allowing the decision maker to assess the validity of the study. Assuming the study is deemed valid, the range of forecasts allows for the decision maker to lend more credence to one scenario versus the others based on their judgment and level of risk-aversion.

7. Conclusions

This Water Needs Assessment has analyzed the current and future water needs of Cumberland County using the best available data and expert opinions. Cumberland County has experienced rapid growth in the past several decades, and that growth may continue so long as the water demands can be met.

The population projections reflect demographic trends, opinions of local experts, and real limits on growth based on land use. The development of the appropriate water use factors was based directly on actual water use data from the utility districts. It must be recognized that a 50 year projection is subject to a great deal of uncertainty. The Aggressive, Expected, and Slow growth scenarios help to capture some of that uncertainty.

The projections in this report indicate that Cumberland County's water needs will very likely exceed the current supply in the next 50 years, but not quite as soon as previously projected. As the average demand becomes closer and closer to the firm yield of the existing sources, the potential for failure in a particularly severe drought year increases considerably. Therefore, Cumberland County is well advised to continue to examine and develop opportunities for conservation and securing an increase in available supplies.

8. References

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Water Conservation Plan

1. Introduction

Cumberland County's attention has been increasingly drawn to water resources over the past decade. Growth projections by several firms[ix,x,xi] have estimated that the water needs of Cumberland County will exceed firm yield in less than 10 years. Excluding the undesirable outcome of running out of water, Cumberland County has two options: increase water supply or reduce demand.

The Water Needs Assessment established forecasts for Cumberland County's water demands under three different growth scenarios. Before evaluating additional water supply alternatives, it is prudent to determine if conservation can effectively reduce demand. This study investigates the extent to which demand can be reduced below the baseline forecast values in the Water Needs Assessment.

Cumberland County has no significant history of water conservation programs, but a range of viable options could lead to significant water savings. This Water Conservation Plan report identifies six potential water conservation measures local government or the utility districts could reasonably enact. The effectiveness of the proposed conservation measures is modeled using the IWR-MAIN Conservation Manager© software program. IWR-MAIN is recognized as a state of the art program for modeling water demand and conservation programs.

A detailed account of the modeling methods is presented in the Water Conservation Plan Memo (full title: *Water Conservation Plan for the Cumberland County Regional Water Supply Study*) in the addenda. This document presents results of modeling the six conservation measures, and based on these results a final water conservation plan is presented.

2. Conservation in Cumberland County

Until the past few decades, Cumberland County has always had an abundant and easily accessed water supply. As a result, there has been limited impetus to encourage conservation in the county. This limited conservation experience presents a substantial opportunity for future efforts to harvest the 'low-hanging fruit' of water conservation benefits at a relatively low cost.

Cumberland County's opportunities to conserve are typical for communities of similar size and age. Cumberland County has two primary avenues for improving water efficiency. One major opportunity for conservation is for the water utility districts to reduce water loss and other unaccounted for uses. Total unaccounted for water use averages near 20% of total produced water, with losses approaching 30 or 40% for some districts in some months. This is not unusual for utility districts of a similar size and age. Cumberland County's utility districts face additional challenges resulting from the very hilly and rocky terrain of the county. High water pressure can stress pipes, and the rocky soil can both puncture pipes and create a situation where leaks have adequate drainage to avoid detection. While Cumberland County's distribution system loss rates are not atypical, reducing losses presents a major avenue for conservation. With appropriate, proactive leak detection efforts and other loss reduction measures, Cumberland County may be able to reduce its losses to ten percent or less.

While the losses in the distribution system are primarily attributable to water suppliers, the water consumers in Cumberland County are another major source of water inefficiency. Interviews with the utility district managers indicated that the majority of residences in Cumberland County use less efficient toilets and plumbing fixtures than current industry standards. This will largely be corrected over time as residents replace older fixtures with

newer, more efficient fixtures. Accelerating this transition, however, is a major opportunity for conservation.

Between reducing inefficient water use on the part of the utility districts and water consumers, there is significant potential for conservation in Cumberland County. The following sections detail several conservation measures to take advantage of this potential.

3. Conservation Measures

Six conservation measures have been identified for analysis in developing the Cumberland County Water Conservation Plan. Each conservation measure is described in brief below. More detailed policy descriptions and modeling methods for each conservation measure are included in the Water Conservation Plan memo included in the addenda. Additionally, the six conservation measures were chosen from a larger set of possible measures based on their relevance and implementability in Cumberland County. The final water conservation plan reflects a combination of some of these measures.

3.A. Unaccounted for Water Reduction (non-leakage)

While leakage is the most commonly identified contributor to Unaccounted for Water, there are other contributing factors to UAW in Cumberland County. Foremost among these are metering errors, flushing usage, and fire fighting usage. Reducing fire fighting usage is not generally within the control of water utilities. Mains flushing is an important part of system maintenance to prevent blockages and corrosion and preserve water quality. Flushing is also necessary before new connections are opened. In large new developments, flushing loss can be tremendous, especially when the opening of new connections is staggered (requiring multiple flushing events). Finally, metering errors are likely a result of older meters. Cumberland County does not have a significant number of unmetered connections.

By addressing excessive flushing and metering errors, Cumberland County may reduce its UAW percentage. All of the utility districts have either recently replaced their meters or are in the process of doing so, but replacement programs should be repeated every 10 -15 years to ensure reductions in UAW are preserved. Reductions in flushing volumes may be achieved through a review of flushing policies, and system upgrades to convert branched distribution pipe networks to looped networks where practicable.

3.B. Leak Detection and Reduction

Leak detection is another method of reducing UAW. Cumberland County faces a range of challenges in getting leakage under control. The age of the pipes, rocky soil, and large elevation differences (and resulting high pressure) have been cited by county utility managers as major causes of leakage. Leaks occur on both mains and service lines. Current leak detection efforts in the county are primarily focused on repairing leaks when they come to the surface or when there are service complaints.

A comprehensive leak detection program in Cumberland County could include several leak detection strategies. Hiring a leak detection contractor to investigate the majority of the county’s mains and service line connections would be a good start. Listening surveys use geophones and other listening devices to find leaks and digital correlators to pinpoint leak positions. In the long term, permanently installed listening devices may be the most effective method of detecting leaks. With training, utility district staff could conduct listening surveys and use a digital correlator.

3.C. Education

Educating water consumers on the value of water and the benefits of conservation, while a valuable end in itself, can also lead to real reductions in water usage. Reductions are achieved in two primary ways: convincing water users to change their water usage habits, and affecting purchasing decisions on fixture and appliance types (and whether to replace them sooner). The water utilities in Cumberland County do not currently have any dedicated customer education programs, but they do communicate with customers through billing inserts and other methods. In 2007, the City of Crossville, Cumberland County, and the utility districts used several communication methods to publicize the drought restrictions and appropriate short-term water saving tips. A true education strategy is geared more toward long-term shifts in behavior and more permanent savings.

Several types of education programs exist, and the water utilities could develop new programs, specially tailored for Cumberland County users. In general, using a variety of education strategies (each with a defined message and goal) in combination can achieve the most robust results. Table 1 indicates three general types of educational programs, the target audience, and a description.

Table 1 - Education programs

Policy	Intended audience	Description
General advertisement	All water users	Water saving tips and information.
Targeted Messages	Commercial users, homeowners with irrigation systems, homeowners with older homes, etc.	Communicate well developed messages perhaps once a year to encourage a specific conservation action, e.g: highlight cost savings from replacing toilets, promote xeriscaping, .
Education programs	School age children and families	e.g.: Programs every 2 years for 4th and 5th graders, 9th and 10th graders
	Retirees, community associations	Short (0.5 day) programs in retirement communities, civic centers.

3.D. Pricing

While water prices are generally set to reflect the costs of production, price changes do affect water demand. The price elasticity of demand indicates the amount of change in demand due to a unit change in price. See Equation (1). An elasticity of positive one indicates that a 1% increase in price will lead to a 1% increase in demand. Price elasticity of demand for water is nearly always negative (price increases reduce demand), and is generally considered to be inelastic (in between 1 and -1, or in this case, 0 and -1). In fact, when considering water demand, it is rare to see elasticities even go beyond -0.5.

$$e = \frac{\Delta q}{\Delta p}$$ **Equation 1**

Where:

e is the price elasticity of water demand
Δq is the percentage change in water demand by a water user (or set of users)
Δp is the percentage change in water price

There is a wide range of economics literature examining the price elasticity of demand for various water users. Focusing on residential customers, Arbués et al. (2003)[xii] and Worthington and Hoffman (2006)[xiii] provide good reviews of a large range of economic

studies investigating price elasticity of water demand under a wide range of pricing policies. In general, the majority of the estimates of residential long term elasticity fall into the -0.05 to -0.5 range. The IWR-MAIN manual cites residential elasticity as between -0.05 and -0.35.

Several UD managers expressed the view that the water demand of Cumberland County residents is somewhat to considerably more sensitive to price changes than the average U.S. citizen. Supporting this assertion is that many of Cumberland County's residents are on fixed incomes. Residents' response to price signals is also influenced by having a monthly billing cycle in all the Cumberland County UDs. As a result, elasticities in Cumberland County are assumed to be toward the upper end of the ranges presented in the manual.

Currently, all the Cumberland County utility districts have a fixed fee for consumption up to a certain initial limit (1000 or 2000 gallons), and a fixed block rate for additional consumption above the limit. A wide range of pricing strategies are available for water utilities to meet goals as wide ranging as maintaining adequate revenues to encouraging conservation. A full discussion of the pricing options considered for the modeling of this conservation measure is contained in the Water Conservation Plan memo. Due to complexity of modeling some of the pricing methods and the limitations of IWR-MAIN, a simple pricing policy is selected. The policy is simply to enact a 30% increase in marginal water price over the base price (set equal to 1) after the base year. Since the price is measured in constant 2006 dollars, the underlying assumption is that after the initial increase, price increases at a rate exactly equal to the inflation rate (or more accurately, water consumers' own discount rate).

3.E. Water Efficiency Codes and Ordinances

One of the most effective methods to generate long term water savings over baseline estimates is to influence the water efficiency of new development. Ensuring that developers are installing efficient fixtures and appliances means that new users will have a lower water use intensity than existing users. Additionally, it is significantly easier to create standards for efficiency before new units are built than to retrofit later.

Currently, Cumberland County lacks building codes in all areas except inside the Crossville city limits. Reportedly, even within Crossville, the efficiency of fixtures is rarely examined by inspectors.

A comprehensive water efficiency code and ordinance will mandate the inspection of water fixtures, toilets, and appliances to check for their efficiency. Additional ordinances may govern the outdoor use of water at commercial and institutional properties by requiring rain sensor shut-off for irrigation systems, for example. Benefits, such as reducing the connection fee, may also be considered for developers who install ultraefficient appliances and fixtures in new properties.

3.F. Retrofit, Rebate, and Replacement Programs

Retrofit, replacement, and rebate programs are other methods to reduce the average water use factors for existing users by replacing (or providing incentives to replace) existing fixtures and appliances with more water efficient models. The key is that the transition happens at a much faster rate than it would under natural replacement.

The programs can take several forms. One approach is to simply provide inexpensive fixtures and devices such as faucet aerators, shower heads and toilet dams free of charge to users. The drawback is that the consumers do not always install them. As the Massachusetts Water Resources Authority's Steven Estes Smargiassi noted[xiv], "We discovered if you gave away devices, most of them were 'installed' in kitchen drawers – not on the bathroom or kitchen fixtures." One way to mitigate this problem is to provide free installation as well. Rebate programs provide monetary incentives for the replacement of larger water using devices,

notably toilets and clothes washers. While often expensive, rebates for toilets and clothes washers can provide greater water savings than small devices, and the transition to more efficient water uses can be more easily verified.

Cumberland County's utility districts do not currently offer any retrofit, replacement, or rebate programs. These programs may be well suited to Cumberland County, as the majority of fixtures and appliances are believed to be older models. Additionally, interviews with utility district managers and other stakeholders indicated that county residents replace these fixtures and appliances at a slightly lower rate than the nation as a whole.

4. Methods

The water savings of the six conservation measures are modeled using IWR-MAIN Conservation Manager. The Water Conservation Plan Memo discusses the modeling methods, assumptions, data collection, parameter estimates, and scenario development in much greater detail. Table 2 displays the tools used in IWR-MAIN Conservation Manager to model the effects of each of the conservation measures.

Table 2- Modeling Methods of the Six Conservation Measures

Conservation Measure	IWR-MAIN Modeling Method
A. Non-Leakage UAW Reduction	Tools→ Unmetered Fraction
B. Leakage Reduction	Tools → Unmetered Fraction
C. Education	Intensity → Enter/Build, Passive Conservation
D. Pricing	Intensity → Enter/Build (Multiplicative Model)
E. Codes and Ordinances	Tools → Passive Conservation
F. Retrofit, Rebate, Replacement	Tools → Active Conservation

5. Results

The six conservation measures cover a broad range of strategies for reducing water usage. Accordingly, the modeling results indicate important differences between the conservation measures in terms of magnitude and trends of water savings. The growth scenario also affects the relative performance of the conservation measures. While the modeling methods for each conservation measure are identical between growth scenarios, certain measures perform comparatively better or worse depending on the rate of growth. Table 3 compares the total water needs projections for the baseline and six conservation measures under the 3 growth scenarios. For each year in each growth scenario, the conservation measure with the lowest total water needs is displayed in bold type.

The results indicate some clear trends in the projected water needs under the baseline and conservation scenarios. Most notably, leakage reduction appears to lead to the most substantial reductions over the entire study period. Education programs and Codes and Ordinances follow a similar pattern of starting off with very modest savings over the baseline and substantially increasing savings over time. The retrofit programs show an opposite trend, with the most substantial savings earlier in the study period. This is potentially significant as the uncertainty in the estimates is substantially lower at shorter time horizons. Interestingly, the results of non-leakage UAW reduction programs and conservation pricing programs are quite similar even though their modes of influencing water savings are very different.

Table 3- Total Water Needs for the six Conservation Measures under the three growth scenarios

Aggressive Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.52	6.34	6.14	6.30	6.23	6.43	**6.08**
2026	8.55	8.19	**7.80**	8.04	8.16	8.20	8.15
2036	10.60	10.14	**9.59**	9.90	10.10	9.90	10.27
2046	12.17	11.64	**10.97**	11.26	11.59	11.10	11.88
2056	13.81	13.22	**12.29**	12.55	13.14	12.36	13.55

Expected Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.11	5.95	5.76	5.90	5.84	6.04	**5.67**
2026	7.64	7.32	**6.98**	7.17	7.29	7.35	7.23
2036	9.08	8.69	**8.22**	8.45	8.66	8.49	8.73
2046	10.54	10.08	**9.53**	9.73	10.04	9.63	10.23
2056	11.28	10.79	**10.07**	10.20	10.75	**10.07**	11.00

Slow Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	5.66	5.50	5.33	5.43	5.41	5.59	**5.18**
2026	6.52	6.24	**5.96**	6.05	6.23	6.26	6.06
2036	7.03	6.74	**6.39**	6.46	6.72	6.55	6.63
2046	7.66	7.33	6.96	6.96	7.31	**6.95**	7.29
2056	8.41	8.04	7.54	7.50	8.02	**7.46**	8.05

It can also be instructive to look at overall cumulative water savings over the entire study period. Figure 1 through 3 display the forecasted cumulative water savings for the three growth scenarios. The magnitude of expected savings over 50 years is rather remarkable, on the order of 5 to 15 billion gallons. Comparing the different conservation measures reveals some interesting insights on their long term behavior. Even though their overall savings are quite different, Non-Leakage UAW reduction and Leak reduction demonstrate similar shapes due to their common modeling method. The conservation pricing policy, because only one major price change occurs, displays a linear trend after 2016. The effectiveness of the retrofits is very evident at first, but over time the slope of the cumulative savings line actually decreases. Finally, the Codes and Ordinances and Education programs clearly increase their cumulative savings as growth increases in the more distant future.

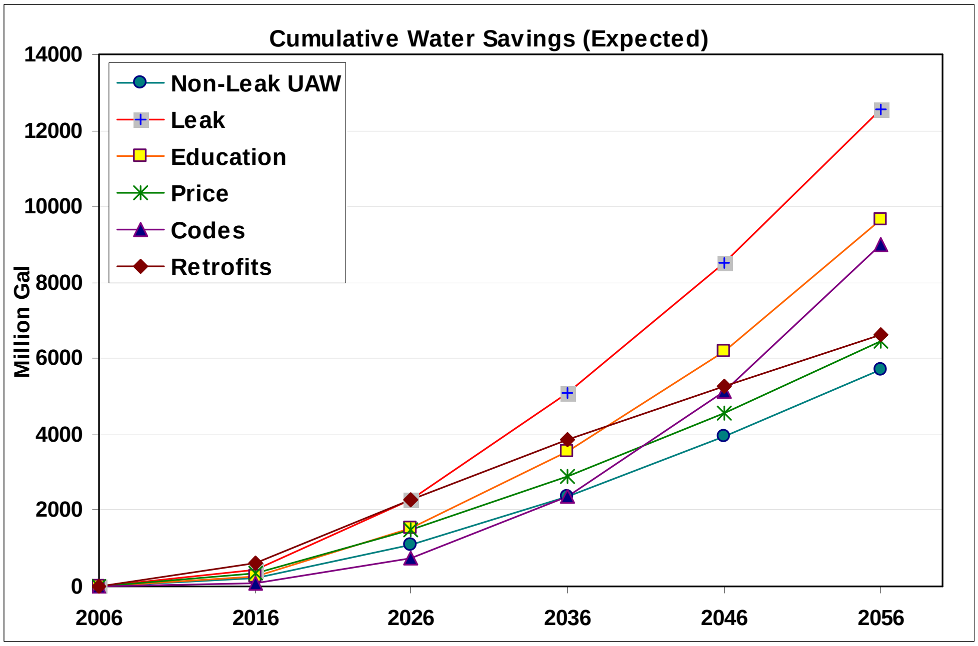

Figure 1 - Cumulative Water Savings for the Six Conservation Measures under the Expected Growth Scenario

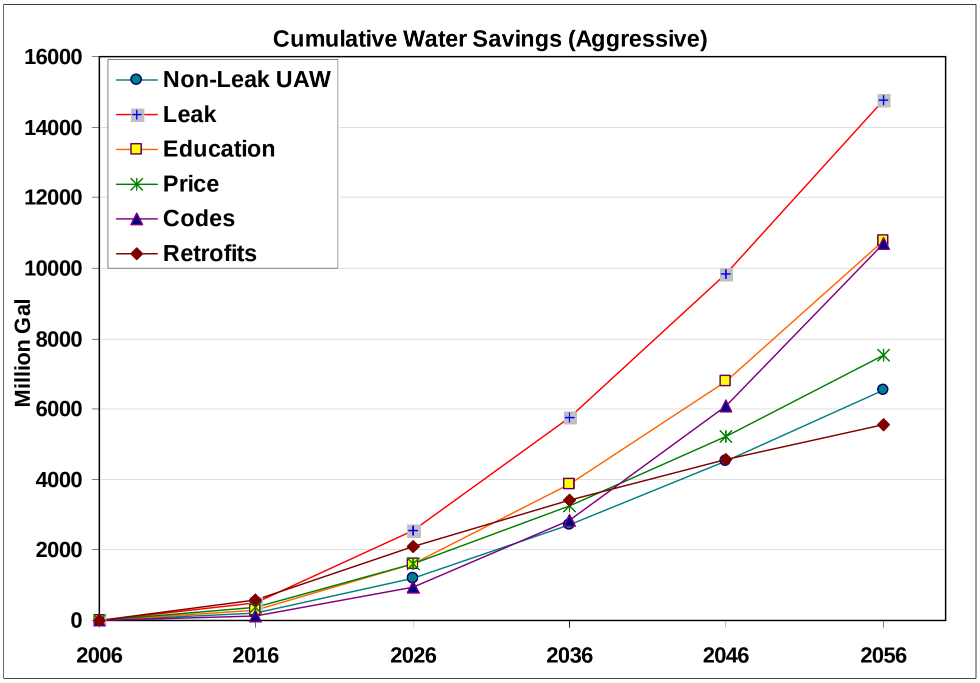

Figure 2 - Cumulative Water Savings for the Six Conservation Measures under the Aggressive Growth Scenario

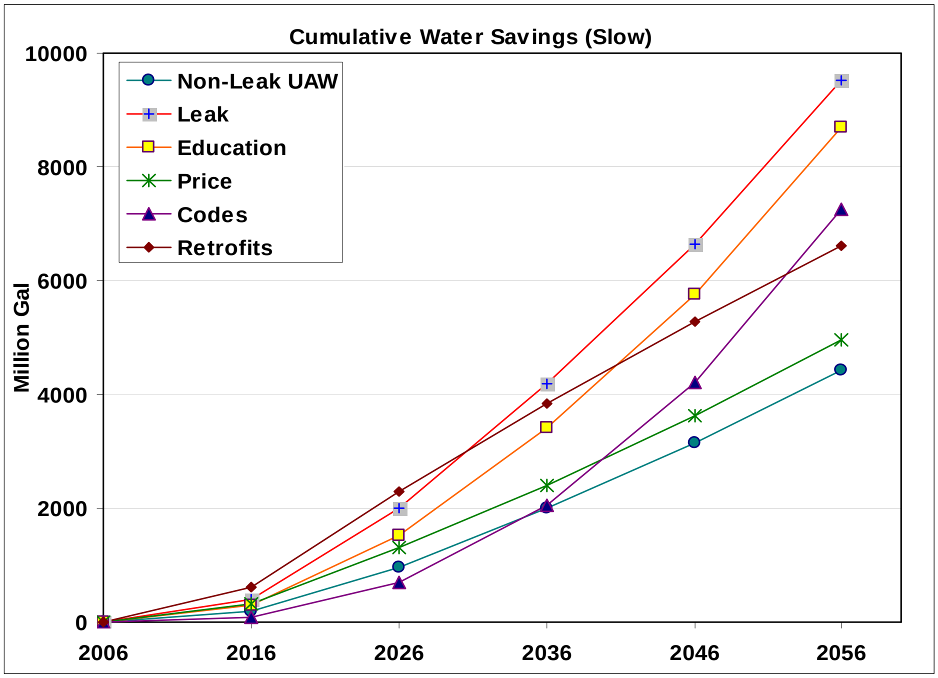

Figure 3 - Cumulative Water Savings for the Six Conservation Measures under the Slow Growth Scenario

6. Pros, Cons and Economic Benefits

The previous section investigated the comparative water savings resulting from each of the conservation measures. While the water savings are perhaps the most important consideration, several other considerations necessarily influence whether the measure should be implemented. These considerations include implementability, public acceptance, cost, uncertainty in the projections, compounding and corollary effects, and finally, economic benefits.

Each of the conservation measures has its own merits and drawbacks, and any comprehensive water conservation plan will likely have to include several conservation measures. The conservation measures which target unaccounted for water, non-leakage UAW reduction and leak detection, have a strong benefit in that they save water that was not producing revenue. Therefore, any water savings generated by these measures lead to direct economic savings. These two measures are also less complicated to implement because they can be put into place solely based on the choice of the utility districts. The drawback of both measures is their upfront cost, which can be significant, especially when pipes must be excavated for repair and replacement. The savings resulting from stopping leaks and other non-revenue producing water, however, often lead to very short payback periods.

Rapid adjustments in price carry their own pros and cons. While periodic, small water rate increases are necessary for maintaining capital investments and keeping pace with inflation, larger rate increases can be a much stronger impetus to conserve. Since water is an inelastic good, rate increases nearly always lead to smaller proportional reductions in consumption than the increase in price. As a result, water savings may be marginal, though the utilities benefit from greater total revenues. The obvious drawback to increasing rates is that rate increases are unpopular and may meet significant resistance from ratepayers. Effective conservation pricing and tiered pricing may be an alternative solution that could provide

benefits with less opposition. Analyzing more complex pricing schemes is beyond the scope of this study, but could be researched further.

Education programs have a great number of benefits, but suffer from a great deal of uncertainty about their actual effectiveness. Educating consumers about methods, benefits, and importance of water conservation can lead to changes in behavior that may save water in the short and long term. Short term changes may be achieved by behavioral changes, while long term shifts in water use may result from consumers making more informed choices when replacing toilets, washing machines, etc. Educational programs are generally not very expensive to implement, but can be ineffective without dedication to the message and sustained commitment to program implementation. Traditionally, education programs have been viewed as effective in reducing water use, but quantifying their actual water savings and economic benefits relative to investment remains difficult.

Strict water conservation provisions in building codes and public ordinances can lead to a gradual but significant reduction in potential future water use. The primary benefit of the codes is the significant long term savings, but the related drawback is that they do virtually nothing to reduce existing consumption except in the case of major renovations. Passing sufficiently comprehensive codes requires a great deal of political cooperation to implement. With the exceptions of builders and plumbers, there are generally few costs to existing stakeholders. Managing an effective inspection and enforcement program requires adding several inspectors and support staff to the local government payroll (or hiring contractors to fulfill the roles), which can be a significant long term cost.

7. Water Conservation Plan

It appears from the analysis of alternative conservation measures that Cumberland County has significant opportunities for reducing water consumption, especially in the long run. A combination of four of the identified conservation measures may provide very significant conservation savings over the baseline projections. GKY recommends the following Water Conservation Plan as best suited to meeting Cumberland County's long term water management goals. In combination, institute the following conservation measures, described previously in this report:

A. Non-Leakage UAW Reduction
B. Leakage Reduction
C. Education Programs
E. Codes and Ordinances

Modeling the Water Conservation Plan

Modeling the potential savings due to the water conservation plan is a fairly straightforward combination of the 4 identified conservation measures. The modeling methods have limited overlap. Measures A and B are both modeled by setting the UAW percentage with the unmetered/unaccounted tool. The appropriate UAW percentage is simply determined by the summing the reduction percentages under the two programs.

Codes and Ordinances are modeled in exactly the same manner as before. The Education conservation program is modeled in IWR-MAIN using the exact same intensity reductions as described in the Draft Water Conservation Plan memo. However, the passive conservation portion of the education programs is slightly affected. The rate of efficiency class shift is set by whichever rate is higher between the education and codes and ordinances conservation measures instead of adding the efficiency class shift percentages. So if 5% of units per year shift efficiency classes under the codes and ordinances conservation measure, and 3% of units per year shift with education, the total water conservation plan rate is 5% and not 8%.

Results

The results of modeling clearly demonstrate that impressive water savings are possible if an ambitious water savings plan is put into place. Figure 4 shows the baseline forecasts for the three growth scenarios (solid line), and the corresponding forecasts if the Water Conservation Plan is fully implemented (dashed lines).

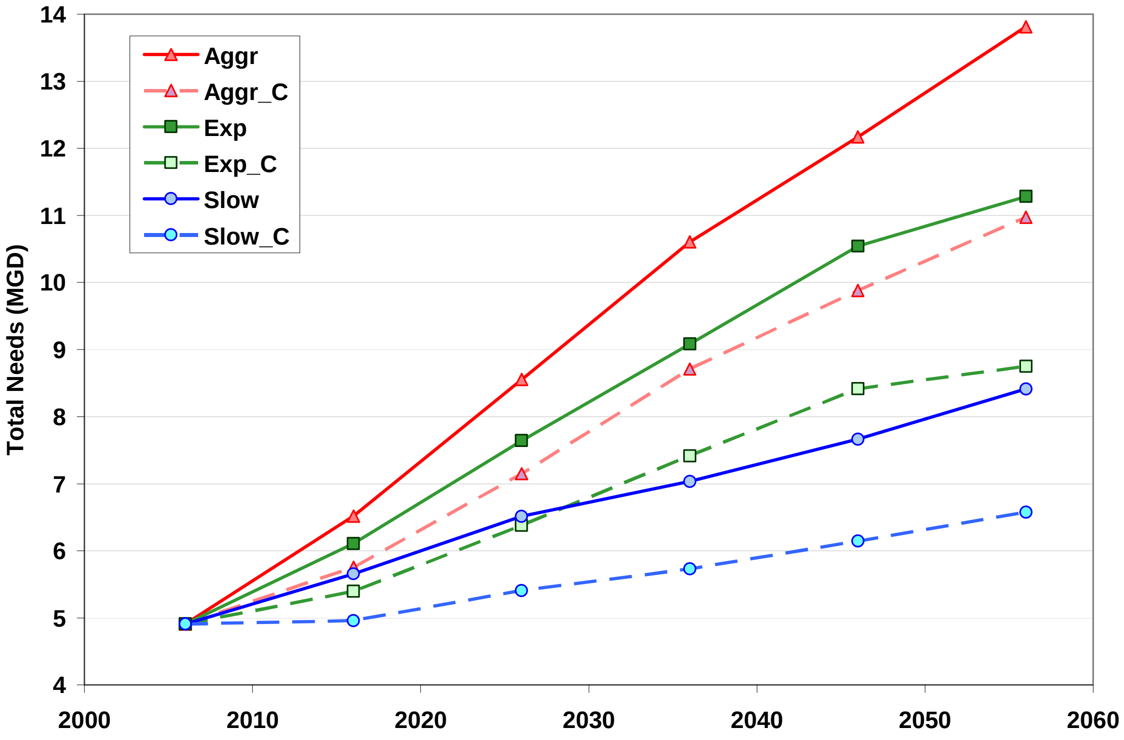

Figure 4 - Forecasted Water Needs for three growth scenarios, with and without the conservation plan

The results of the forecasts show the potentially profound effect of conservation. In general, the conservation plan can save as much as 30% over the baseline scenario. About half of this reduction comes from reduction of Unaccounted for Water alone. Over the long term, the reductions are as significant as dropping one growth scenario. That is, water use for the aggressive scenario with conservation is roughly equal to water use for the expected scenario without it. Even with conservation, water use in the county stands to increase significantly. However, under the slow growth scenario, water use remains virtually flat for the first 10 years when the conservation plan is put into place.

There is one caveat in interpreting the results of the water conservation plan. In analyzing all of the conservation measures individually, there was never a situation in which both the actual consumption and UAW rates were changed simultaneously. The water conservation plan does change both at once. Since the UAW is expressed (and modeled) as a percentage of overall demand, reducing consumption reduces UAW by default. However, the actual physical processes that cause leakage are not necessarily dependent on demand. Therefore, especially in situations where both the consumption and UAW are reduced simultaneously, the water savings may be overestimated. The modeling limitations of IWR-MAIN make it difficult to easily ameliorate this problem.

The effect of this limitation can be discerned when one looks at the results by subsector (including UAW as a subsector). Table 4 displays the results by subsector, comparing the baseline projection and water conservation plan for the three growth scenarios. It is quite

evident that a large portion of the savings comes from reductions in UAW. Under the Water Conservation Plan, UAW can be cut to as much two-thirds below the baseline forecasts. For example, under the aggressive scenario, the baseline UAW estimate in 2050 is 3.05 MGD, but with the water conservation plan, it falls to 0.99. Other subsectors see only about a 5 - 10% reduction over the baseline.

Table 4 – Total Water Needs by Subsector under the Baseline and Water Conservation Plan Forecasts(MGD)

Scenario	Forecast	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	CMC	0.07	0.10	0.13	0.17	0.20	0.23
		NonRES	1.49	1.87	2.11	2.32	2.52	2.71
		RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
		UAW	*1.04*	*1.39*	*1.85*	*2.32*	*2.68*	*3.05*
	Water Conservation Plan	CMC	0.07	0.10	0.13	0.16	0.19	0.22
		NonRES	1.49	1.84	2.06	2.25	2.41	2.56
		RES_PS	2.31	2.99	4.20	5.43	6.29	7.20
		UAW	*1.04*	*0.82*	*0.76*	*0.87*	*0.99*	*0.99*
Expected	Baseline	CMC	0.07	0.09	0.12	0.14	0.16	0.18
		NonRES	1.49	1.78	2.04	2.18	2.34	2.42
		RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
		UAW	*1.04*	*1.30*	*1.64*	*1.97*	*2.31*	*2.48*
	Water Conservation Plan	CMC	0.07	0.09	0.11	0.14	0.16	0.17
		NonRES	1.49	1.74	1.98	2.10	2.21	2.26
		RES_PS	2.31	2.79	3.61	4.44	5.20	5.53
		UAW	*1.04*	*0.77*	*0.68*	*0.74*	*0.84*	*0.79*
Slow	Baseline	CMC	0.07	0.08	0.09	0.10	0.11	0.12
		NonRES	1.49	1.68	1.91	1.96	2.02	2.08
		RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
		UAW	*1.04*	*1.20*	*1.38*	*1.50*	*1.65*	*1.82*
	Water Conservation Plan	CMC	0.07	0.08	0.09	0.10	0.10	0.11
		NonRES	1.49	1.64	1.85	1.88	1.91	1.94
		RES_PS	2.31	2.53	2.89	3.18	3.52	3.93
		UAW	*1.04*	*0.71*	*0.57*	*0.57*	*0.61*	*0.59*

While the average water needs are important in the evaluation of long term water supply planning, the peak day demand is important for the design of certain system components. As in the Water Needs Assessment, a peak factor of 1.35 is assumed. This is applied only to the consumption values, and UAW is added afterwards. Table 5 displays the peak day water needs for the baseline forecast and water conservation plan.

Table 5 – Peak Demand Values for the Baseline Forecast and Water Conservation Plan

Scenario	Program	Data	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	Consumption	3.87	5.13	6.70	8.28	9.49	10.76
		UAW	1.04	1.39	1.85	2.32	2.68	3.05
		PEAK	*6.26*	*8.31*	*10.90*	*13.50*	*15.49*	*17.57*
	Water Conservation Plan	Consumption	3.87	4.93	6.39	7.84	8.89	9.98
		UAW	1.04	0.82	0.76	0.87	0.99	0.99
		PEAK	*6.26*	*7.48*	*9.39*	*11.46*	*12.99*	*14.47*
Expected	Baseline	Consumption	3.87	4.81	6.00	7.11	8.24	8.81
		UAW	1.04	1.30	1.64	1.97	2.31	2.48
		PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
	Water Conservation Plan	Consumption	3.87	4.62	5.70	6.67	7.57	7.96
		UAW	1.04	0.77	0.68	0.74	0.84	0.79
		PEAK	*6.26*	*7.02*	*8.37*	*9.75*	*11.06*	*11.54*
Slow	Baseline	Consumption	3.87	4.45	5.13	5.53	6.02	6.59
		UAW	1.04	1.20	1.38	1.50	1.65	1.82
		PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*
	Water Conservation Plan	Consumption	3.87	4.25	4.84	5.16	5.53	5.98
		UAW	1.04	0.71	0.57	0.57	0.61	0.59
		PEAK	*6.26*	*6.45*	*7.10*	*7.54*	*8.08*	*8.67*

Analysis of the Water Conservation Plan

These four measures are the most beneficial actions Cumberland County can take for several reasons. First, the combination of measures strikes a balance between short term and long term water savings. Measures A and B (Non-leak UAW reduction and Leakage Reduction), especially when implemented in combination, provide immediate reductions in water usage. Measures C and E (Education and Codes and Ordinances) lead to much more significant savings in the long term than the short term.

These four conservation measures are also very feasible to implement. In fact, most of the measures are currently in the process of planning or implementation, though not quite to the extent described in this report. All of the utility districts have recently replaced or are replacing meters throughout their service areas. All of the utility districts claim to be reducing system leakage wherever they can, and one has even contracted leak detection services. The City of Crossville already has plumbing codes in place, and Cumberland County appears to be actively considering implementing them. None of the utility districts currently has dedicated education programs, but there are many resources available through the American Waterworks Association, the Environmental Protection Agency, various state environmental departments, private companies, and other sources.

Especially if the utility districts and county officials cooperate, the conservation measures presented here are very cost effective. Education programs are relatively low in cost. Implementing codes and ordinances has few upfront costs, but some long term enforcement and administrative costs. Measures A and B can be costly, but are generally worthwhile investments as the water savings directly reduce costs without reducing revenues. Furthermore, if leak detection services are contracted for the entire county, and leak detection

equipment is shared, costs can be reduced. Finally, leak detection costs are dropping as technology improves.

The other benefit of this plan is that it should be widely accepted by the majority of the stakeholders. Reducing unaccounted for water, and more broadly, establishing water accountability through better system information, better metering, and leak detection is a crucial step toward public acceptance of other conservation actions. Establishing building codes (and water efficiency standards) is generally acceptable as it has many positive impacts on quality of life in the county. Educational programs, as long as they are well managed, are generally accepted. Price increases for the purpose of conservation, however, are usually unpopular. Additionally, certain stakeholders have already expressed a mild opposition to retrofit and rebate programs as an unfair use of ratepayer or tax dollars.

Finally, implementing the proposed conservation measures leaves open the possibility for future conservation measures not described here. In the event that the proposed plan does not meet conservation targets, or growth occurs at a faster than projected rate, other conservation measures can be implemented. Measures A and B will lead to a much better understanding of the water balance throughout the distribution system and identify opportunities for further conservation. Establishing a framework for education programs leads to better communication between utilities, ratepayers, and other stakeholders, which could make future actions more effective. Strict efficiency codes help to create a local market for more efficient fixtures and appliances. Additionally, once codes are adopted, a legal framework is established for future amendments and ordinances.

While the conservation measures set forth are fairly common and feasible to implement, realizing the projected water conservation savings requires full engagement by the stakeholders and a sustained commitment to the conservation programs. Cumberland County has significant potential for conservation in the short and medium term as utilities reduce their water loss and customers increase their water use efficiency. In the long term, however, real shifts in behavior and in efficiency standards will need to be firmly established to see continued progress in reducing water use. It should be noted that even with significant conservation, Cumberland County’s water use will almost certainly rise over the next 50 years. The rate of growth in water needs, however, can be slowed by the adoption of an ambitious conservation plan.

8. Conclusion

Cumberland County faces a challenge in meeting future water needs as the county grows. Continued rapid growth and the chance of future droughts like the one in 2007 highlight the importance of a long term solution to meeting water needs. Numerous proposals exist for increasing water supplies, but this study instead examines the potential for reducing demand.

Six feasible conservation measures have been presented as methods to effectively reduce water demand, inefficient water use, and water loss. Cumberland County has excellent potential for increasing water efficiency, both in the distribution system and on the part of water users. A comprehensive water plan can take advantage of the potential water savings, and almost certainly postpone the need for new water sources.

This Water Conservation Plan outlines a series of measures which can significantly slow the growth of Cumberland’s water needs while allowing the county to grow. While the conservation targets are certainly achievable, it will take commitment and cooperation on the parts of numerous stakeholders.

9. References

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GKY & Associates, Inc.

Cumberland County Regional Water Supply Study

* * *

Water Needs Assessment and

Water Conservation Plan

Final Report

Cumberland County Regional Water Supply Study

Water Needs Assessment and

Water Conservation Plan

March, 2009

Table of Contents

Water Needs Assessment

Water Conservation Plan

List of Tables

Water Needs Assessment

Water Conservation Plan

List of Figures

Water Needs Assessment

Water Conservation Plan

Addenda

Three previous documents written by GKY provide added reference with regard to methods and full results for the Water Needs Assessment and Water Conservation Plan.

1. *Land use assumptions for Phase II of the Cumberland County Regional Water Supply Study*. Memorandum. December 13, 2006. by Karsten Sedmera and Stuart Stein, GKY & Associates, Inc.

2. *Water Needs Assessment for the Cumberland County Regional Water Supply Study*. Memorandum. March 14, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

3. *Water Conservation Plan for the Cumberland County Regional Water Supply Study*. Memorandum. June 28, 2008. by Lars Hanson and Stuart Stein, GKY & Associates, Inc.

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Water Needs Assessment

1. Introduction

The Cumberland County Regional Water Supply Study was established by an agreement between the U.S. Army Corps of Engineers (Nashville District) and the City of Crossville, Tennessee. The Cumberland County Regional Water Supply Study has the goal of identifying a long term solution to Cumberland County's water supply needs, and carrying forward an Environmental Impact Statement investigating potential alternatives for the long term supply solution. As part of the Water Supply Study, GKY & Associates has been contracted to perform a Water Needs Assessment to estimate future demand at 10 year increments for the next 50 years.

This Water Needs Assessment builds, in sequence, a land use development analysis, population growth scenarios, and modeling of future water demands. This study represents the first in-depth analysis taking into account the rapid growth in the early 2000s.

Indeed, Cumberland County, located on the Cumberland Plateau of East Central Tennessee, faces a growing problem in meeting the ever increasing water demand in a rapidly growing county. Cumberland County has been experiencing rapid growth in part due to its considerable success in attracting retirees to live in the county. In severe droughts, this growth is already straining water supplies. As growth continues, it is likely a new water source may need to be developed. This Water Needs Assessment investigates the future demand for water under a range of growth scenarios to project how much water will be needed in the future.

The first step in determining the future water needs is to analyze the land use patterns in Cumberland County.

2. Land Use Development

One of the important steps in predicting future water demand in the next 50 years is the difficult task of predicting future population growth and land use patterns in Cumberland County, TN. Land use patterns assist in predicting population growth by making it possible to assess how much land is available for growth, and they assist in demand estimation by generating a relative breakdown of the types of water consumers in the study area. Cumberland County, however, does not have any formal land use plan (i.e., zoning) in place to control (or predict) local patterns of growth. While there are a few studies that predict population growth for the County as a whole, none of them appear to focus on local growth rates or detailed land use patterns. Figure 1 displays the land use in Cumberland County according to the 2006 tax assessor's database. The land use patterns and the state of development of parcels of various types can provide clues to future development.

Cumberland County was one of ten counties recently selected by the Tennessee Department of Economic and Community Development to participate in a pilot study called "Retire Tennessee" that is designed to promote Tennessee as a great place for retirees to call home. Two of the predominantly residential areas, Lake Tansi and Fairfield Glade represent two established communities (not official cities) that attract retirees by offering small lots, convenient maintenance agreements, and various community club amenities. The three cities in the area – Crossville (the County seat), Pleasant Hill, and Crab Orchard – have similar attractions but more diverse development patterns. Crossville, however, has more dense residential communities than either Pleasant Hill or Crab Orchard. The remainder of the County is fairly rural with scattered residential development along major roads. Two related communities called Cumberland Cove and Cumberland Lakes (henceforth called Cumberland

Cove), which boast large lots and rustic “dream” homes, form a new development area where rural land is rapidly shifting into denser residential development.

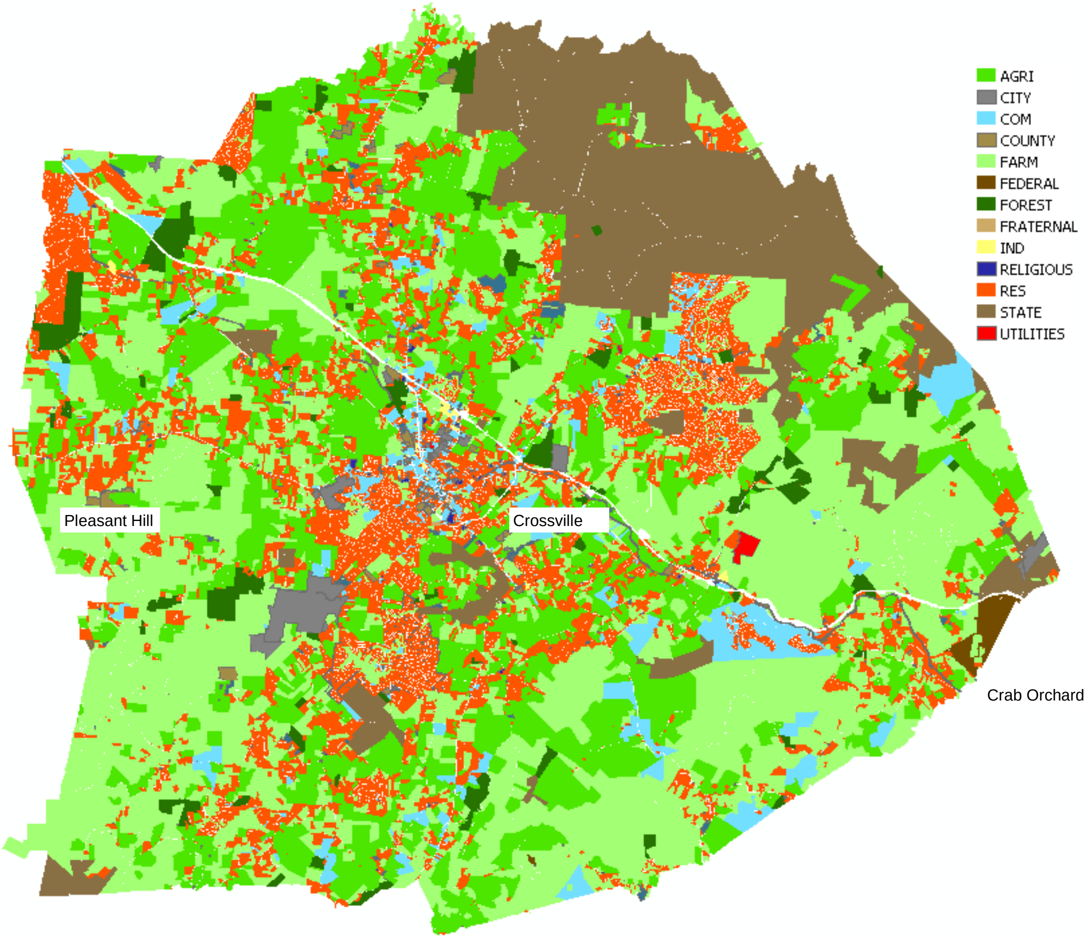

Figure 1 – Land Uses of Cumberland County according to 2006 Tax Assessor’s Parcel Data

The tax assessor’s database classifies each parcel into one of 12 land use categories (indicated on the map legend in Figure 1). A few clear patterns emerge from examining Figure 1. The majority of the county’s land area is dominated by agricultural and farm land. The majority of residential development appears in four or five clusters. The center of the map shows the advanced development around the City of Crossville, including a dense core of commercial and residential development. There is also a large, state-owned wildlife preserve in the northeast corner of the County, which has almost no development in or immediately surrounding it. The land use pattern elsewhere in the county, however, is remarkably similar.

The database also lists the assessed land value and improvement value for each parcel. Thus any parcel with an improvement value greater than zero has been developed. For the purpose of estimating population density, only developed parcels that are classified as residential, farm, agricultural, or forest are likely to have homes on them. A few of the developed parcels classified as farm have improvement values reflecting recreational (e.g., golf resorts) or farm buildings, but most of them are residential lots with over 15 acres. Agricultural or forest parcels are “farms” that qualify for tax breaks under the TN Greenbelt program.

In order to evaluate the development potential in Cumberland County, the characteristics of the parcels (e.g. development, land value, lot size, and improvement value) were analyzed.

Figure 2 highlights the distribution of developed and undeveloped parcels of primarily privately owned residential and commercial parcels.

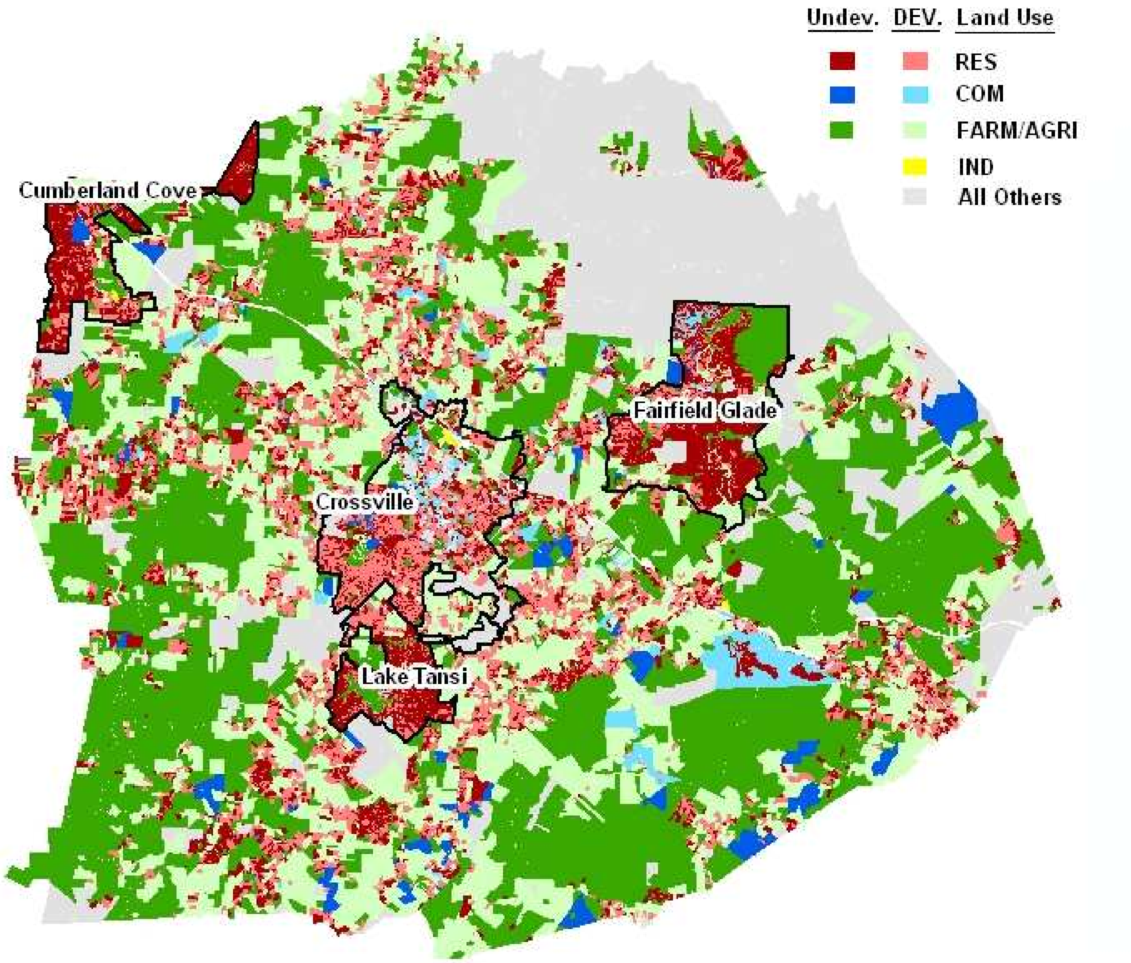

Figure 2 - Development Map of Cumberland County Showing Developed and Undeveloped Residential (RES), Commercial (COM), Industrial (IND), and Agricultural and Farm (FARM/AGRI) Parcels

Figure 2 indicates the undeveloped residential parcels (dark red) show an even clearer pattern than in Figure 1. It is evident that the dense residential communities generally cluster around Crossville, Fairfield Glade, Lake Tansi, and the Cumberland Cove area (which includes Cumberland Lakes). Furthermore, of these four regions, the latter three contain 69% of the undeveloped residential parcels in Cumberland County. Interestingly, the undeveloped commercial parcels are well distributed throughout the county.

Based on the land use analysis five study regions are selected for population and water use projections. Their geographic extents are shown in Figure 3. It should be noted that the boundaries reflect development patterns more than established political boundaries.

- City of Crossville
- Cumberland Cove (including Cumberland Lakes)
- Fairfield Glade
- Lake Tansi
- Remainder of the County

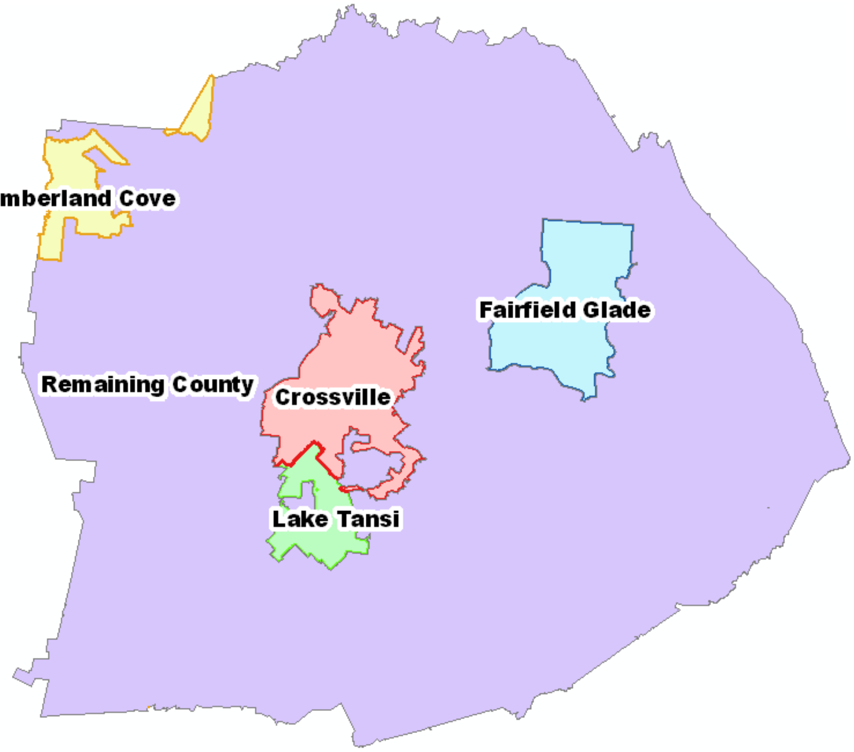

Figure 3 – Study Areas in Cumberland County

Further analysis of the parcels yielded some other general information about land use in Cumberland County that are useful for making population and water use projections. A few of the more interesting results are as follows:

- 90% of parcels in the County are residential
- 6% are farm/agricultural/forest,
- 37% of the residential parcels are developed,
- 57% of the farm/agricultural/forest parcels are developed, and
- 83.7% of the land area is residential/farm/agricultural/forest.
- The undeveloped residential parcels are, on average, half as large as the developed ones (0.92 vs 1.93 acres)

3. Growth Scenarios

The land use analysis establishes the general bounds on growth, and identifies the ultimate growth potential of the five study areas named in Section 2. Following the land use analysis, projections of the expected population growth in Cumberland County must be made in order to forecast water needs. Population forecasting is inherently uncertain, and becomes more so the further the time horizon of the forecast extends. In order to treat some of this uncertainty in a more concrete fashion, three distinct growth scenarios are carried through the remaining forecasting and modeling. They include the Slow, Expected, and Aggressive growth scenarios. The forecasts include population projections every 10 years starting in 2006 and ending in 2056. The Land Use Memo (full title: *Land use assumptions for Phase II of the*

Cumberland County Regional Water Supply Study), included in the addenda, details the methods by which the projections were made.

The growth scenarios all utilize the same starting values, and differ primarily in the specified growth rates for each ten year period. The growth rates also vary by study area. The percentage rate of growth reflects historical data, expert judgment from relevant stakeholders in the County, and other important factors (such as lack of sewer connection). Figure 4 displays the countywide population projections under the three population scenarios, as well as projections from two other studies. Note that the countywide projections are a sum of predictions for the individual study areas, each of which has independent growth projections and saturation points.

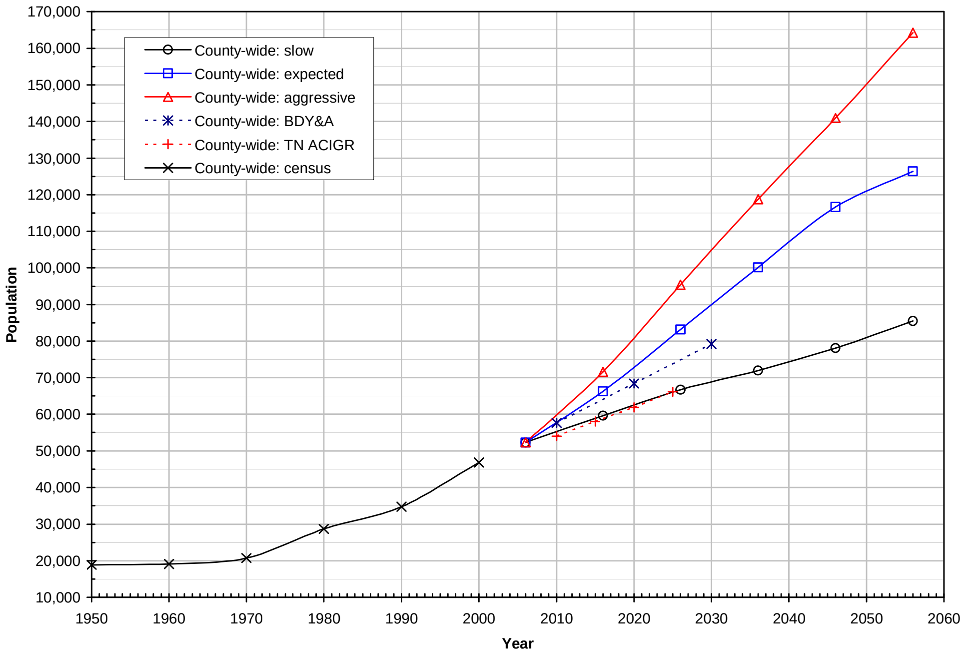

Figure 4- Population projections for Cumberland County. The three growth scenarios are displayed, as well as projections from two other studies (BDY & A 2002[i]; TN ACIGR[ii])

The population projections in fact show a wide range of variation among the growth scenarios. The range of population projections easily encompass the variability in the previous population projections, with the Slow growth scenario comparing favorably with the Tennessee Advisory Commission on Intergovernmental Relations' (TN ACIGR) forecast, and the Expected scenario a little higher than the Breedlove, Dennis, Young and Associates (BDY&A) forecast. The Aggressive scenario allows for substantial growth, but we note that even after 50 years, the projection does not begin an increasingly rapid growth phase as is often the case with simple exponential growth models.

Once the population is forecasted, it can be used to calculate projections of other relevant variables for estimating water usage. Namely, for each study area, the number of households and the number of employees must be forecast. By using historical data and stakeholder judgment, the future population per household ratio and the population per employee ratio were estimated for each forecast year. Dividing the projected populations by these factors yields the estimates of households and employees in Table 1.

Table 1 – Countywide Projections of Population, Households, and Employment for Cumberland County

Forecast Variable	Scenario	2006	2016	2026	2036	2046	2056
Population	*Slow*	*52,306*	*59,620*	*66,732*	*71,949*	*78,103*	*85,509*
	Expected	*52,306*	*66,288*	*83,157*	*100,163*	*116,643*	*126,373*
	Aggressive	*52,306*	*71,598*	*95,366*	*118,783*	*140,958*	*164,223*
Households	*Slow*	*23,345*	*27,622*	*31,990*	*35,323*	*39,294*	*44,144*
	Expected	*23,345*	*30,588*	*39,724*	*49,404*	*58,980*	*63,664*
	Aggressive	*23,345*	*33,106*	*45,772*	*59,252*	*69,006*	*79,369*
Employees	*Slow*	*25,000*	*29,083*	*33,200*	*36,522*	*40,259*	*44,305*
	Expected	*25,000*	*32,336*	*41,371*	*50,844*	*60,125*	*65,478*
	Aggressive	*25,000*	*34,926*	*47,446*	*60,296*	*72,659*	*85,090*

4. Water Needs Assessment Methods

Planning and Management Consultants, Ltd.'s IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as state-of-the-art, industry standard water demand forecasting software packages. IWR-MAIN was used as a tool to compute projected water use based on assumptions about the county's growth and water use factors. The IWR-MAIN user's manual[iii] explains in detail the structure of the model and the precise definitions of the terminology used. Where possible, we strive to use the correct IWR-MAIN terminology in describing the construction of the Cumberland water demand projection.

At the heart of the IWR-MAIN model is the usage model in Equation 1.

$$\boxed{\begin{array}{c}\text{Demand}\\ Q\end{array}} = \boxed{\begin{array}{c}\text{Counting Unit}\\ N\end{array}} \times \boxed{\begin{array}{c}\text{Use Factor}\\ q\end{array}}$$

Equation 1.

In short, the demand is determined by multiplying some counting unit by a water use factor. This model determines the demand in a given time period, in a given subsector, in a given study area. A *subsector* is the base organizational unit for which water demand is projected (e.g., the residential or commercial subsector). Each subsector has its own associated *counting unit*, which is a measure of subsector size that has a strong influence on water usage (population, households, or employees, for instance). The *use factor* is simply the volumetric demand for water per counting unit (gallons of water per capita per day, per house per day, etc) in a given time period. Thus, a water demand forecast requires projecting (at a minimum) how the counting units and use factors change over time.

The total county water use in a given time period is simply a sum of the consumption for each subsector plus any leakage or other non-consumptive use. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different regions of the study universe have distinct characteristics, the study can be broken down into *study areas*, each with their own group of subsectors and usage models. In this case, the study universe encompasses all of Cumberland County.

With respect to Cumberland County, the study areas have already been identified in Section 2. For each study area, two sectors were assumed: residential and non-residential (encompassing commercial, industrial, and institutional uses). Residential water use forecasts are computed using the forecasted number of housing units as the counting unit. The non-residential sector utilizes number of employees as the counting unit. The City of Crossville study area has an

additional subsector to model the water usage of Cumberland Medical Center, whose associated counting unit is the total population of Cumberland County.

Water Use Factors

Forecasting the future values of the counting units accounts for half of the necessary inputs in (1). The other half of the inputs comprises the water usage rates. IWR-MAIN's Forecast Manager and Conservation Manager offer a range of forecasting models to estimate future water use factors. Many of the methods are econometric methods that allow using explanatory variables to build a predictive model for the use factors. Among the explanatory variables that are commonly found to be associated with water use are income, housing density, persons per household, marginal price, average daily maximum temperature, precipitation, and cooling degree days. An extensive analysis of the water usage records and available data on potential explanatory variables determined that the predictive models were not appropriate for this study. It should be noted that future needs assessments should reconsider this decision because a few more years of high-quality water usage data (including sector breakdowns) may make these more complex models viable.

Without these models, IWR-MAIN provides two primary options for calculating use factors. The first, contained within IWR-MAIN Forecast Manager, is to simply use constant use factors calculated based on the number of counting units and the base year use. The second, which requires using IWR-MAIN Conservation Manager, is to develop end use models for each subsector. Each end use has its own use factor, and the sum of the use factors for each subsector is the overall use factor for this sector. This approach is more flexible than the constant use model, though it can be made equivalent through correct application of parameters in the model.

The chosen model is the end use model, mainly due to the fact that Conservation Manager will be used to evaluate the effectiveness of conservation measures in the water conservation plan. The added benefit to using the end use model in Conservation Manager is that it is possible to define end uses on three levels of water use efficiency and shifts between them over time. This feature allows incorporating natural, market based changes in water use efficiency that result from greater average efficiency of water using fixtures and appliances over time.

When employing the end use model, it is important to have an accurate base-year water usage estimate. This water demand projection uses two seasons, so monthly estimates of base year use are necessary. The summer season includes June, July, August, and September, and the Winter season includes the rest of the year. Water use is assumed to be constant for all months within a given season.

Residential water usage factors are based on monthly residential water consumption data from the South Cumberland and Crab Orchard Utility Districts. Both user districts had acceptable monthly records of residential water consumption and the associated number of customers (households). Since the counting unit for the residential sector is the household, the water use factor is expressed in terms of gallons per day per household (gpd/hhld). The S. Cumberland and Crab Orchard data yielded annual averages of 119.7 and 118.9 gpd/hhld, respectively. Lake Tansi is almost completely encompassed in the S. Cumberland district, and Fairfield Glade is contained within the Crab Orchard district, but the rest of the study areas still need water use factors. For the sake of simplicity, and to provide a conservative estimate of demand, the rest of the study areas are simply assigned the higher S. Cumberland water use factors.

Estimating nonresidential demand is somewhat more complicated than estimating residential demand, especially in terms of disaggregating countywide demand among the study areas. As mentioned before, future employment projections are based on each study area's population

and a countywide population to employee ratio. Since Crossville's commercial development is not distributed exactly the same as residential development, it is inevitable there will be some error in the geographic distribution of commercial water demand. Without zoning though, it seems at least reasonable that future commercial development will occur near growing areas with concentrated residential development. Thus, it is likely much of the commercial development will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

The methods for generating the water use rates for the commercial sector are described in much more detail in the Needs Assessment Memo in the addenda. In a general sense, the use rates for the commercial sector were determined from actual usage records from the utility districts and then spatially disaggregated. The disaggregation was performed in GIS by determining the location of commercial and industrial parcels in the parcels database with respect to the boundaries of the study areas and the utility districts.

Passive Conservation

One major source of error in many forecasts of future water use is the failure to consider the effect of more water efficient technology. Since the Federal Energy Policy Act of 1992, U.S. manufacturers have been required to meet minimum water efficiency standards for plumbing fixtures and toilets. Since that time, manufacturers have gone well beyond the minimum standards as a way to stay competitive. The mode of change effected by the availability of more efficient technology is called passive conservation, whereby consumers conserve just by replacing their older fixtures with more efficient ones when they need to be replaced. New construction also takes advantage of the more efficient technology by default.

The average potential savings associated with more efficient appliances were determined from the AWWA's 1999 *Residential end uses of water* [iv]report. The average replacement rate was determined from the National Association of Home Builders/ Bank of America *Study of the Life Expectancy of Home Components*[v]. Though the consumption-weighted average replacement rate for all water using home components is approximately 6.5%, a more conservative rate of 5% was assumed. This is equivalent to a 20 year lifetime for many of these components. The forecasts take these shifts into account using the passive conservation tool in IWR-MAIN Conservation Manager.

The effect of this savings is a very slight decrease in the per unit water use rate over time. Though counterintuitive for a growing county, this makes sense in Cumberland County for several reasons. Firstly, as explained previously, no credible predictive models can be developed with available data. Secondly, the land use analysis demonstrated that the average area of the undeveloped residential and commercial parcels in the county is significantly smaller than the developed parcels meaning that outdoor water use will rise slower than the population growth rate. Thirdly, as more retirees move to the county, the number of people per household will continue to fall, meaning that per household indoor use rate should not increase. Finally, technological advances in manufacturing of toilets, dishwashers, and other water using appliances will tend to lower water usage as older units are replaced with more efficient ones. This conservation savings due to technology, while slight was considered necessary for inclusion in the model because of the long study period.

Unaccounted for Water

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental water main breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each of the study areas, the Unmetered/Unaccounted tool sets the year-by-year UAW percentage. (IWR-MAIN restricts the percentage to a constant value for each year, and only whole percentages are permitted.)

Previous water demand studies of Cumberland County have used a wide range of methods to model UAW. Breedlove, Dennis, Young & Associates' (BDY) 2002 *Cumberland County Water Supply Needs Assessment* selects a target loss percentage of 10% as a worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[vi] prepared by the Corps and Ogden Environmental and Energy Services, Inc. also estimated 10% UAW on the basis of non-specified estimates by the Cumberland Utility Districts.

In this study, UAW estimates for the five study areas are based on actual data from the UDs. Perhaps in response to the previous studies, the UDs have begun collecting more detailed statistics on UAW. It is with these statistics and advice from interviews with the UDs that we estimate UAW. Table 2 shows the average UAW percentages by utility district in recent years. The final row displays the number of years of data upon which the percentages are based.

Table 2– Unaccounted-for-Water data by Utility District (% of total production)

	Crab Orchard	Crossville	South Cumb.	West Cumb.	**Consumption Weighted Average**
Annual UAW%	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 2 appear incredibly high, but when we consider the short record length, it is clear that at least in some cases, some outlier values may be skewing the results. While there appears to be some potentially significant seasonal variation in the loss percentage, at least in Crab Orchard and Crossville, there are not enough data to make a strong case for modeling this variation. Additionally, IWR-MAIN does not allow seasonal variation in the Unmetered/Unaccounted percentage.

Except in Crossville, the record lengths are too short to make a valid estimation of the UAW by utility district. So we calculate the county average as weighted by consumption in the UDs. The yearly average UAW percentage is calculated as 22.4%, which is conservatively rounded upward to 23%. All of study areas except for Crossville are assumed to have this 23% average. If metering errors, line flushing, and known losses are assumed to be 5%, this means that an average of 18% of total produced water is actual loss. These figures compare favorably with the 20% rate indicated in interviews with the Crab Orchard Utility District, and 14-15% loss rate reported by West Cumberland. With the Crossville records being a bit longer, we feel comfortable setting Crossville's UAW percentage at 19%, which is slightly more conservative than the 15% unaccounted for and the 10-12% loss estimated by the Crossville UD in a May 2006 interview.

For the purposes of a baseline forecast, the UAW percentages are assumed to remain constant in time, which is a dubious assumption based on the large variances in month to month losses alone. Almost certainly, losses will either increase as the system ages, or decrease as the result of system improvements and maintenance. We are hesitant, however, to forecast changes to the UAW percentage in a baseline forecast, or impose 'desirable goals' as some past studies have done. Additionally, the conservation measures evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

Model Validation

Based on the assumptions made, it is possible to compare the projections to observed water usage. Figure 5 displays the estimated total county water consumption as compared to

observed consumption based on data from the UDs. These figures exclude UAW. On average, the estimated values are about 4% above the observed values, and therefore slightly conservative.

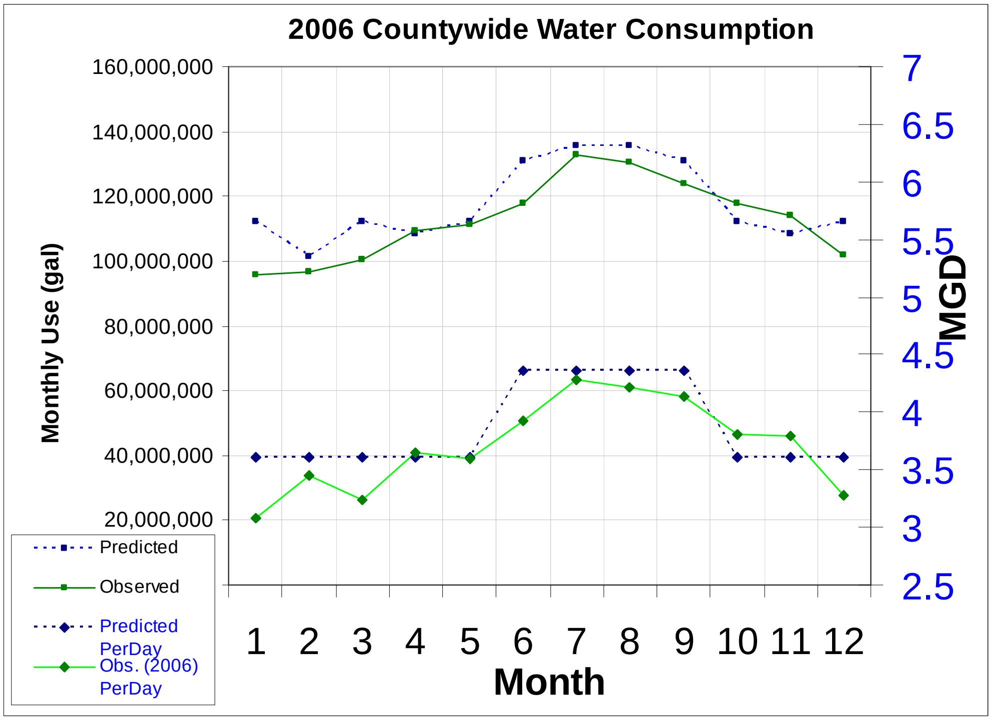

Figure 5 - Predicted versus Observed Countywide Water Consumption (excl. UAW)

The agreement shown between the observed and estimated values in water use is certainly not perfect, but it indicates the assumptions are at least reasonable, and slightly conservative. We note that there is excellent agreement at the peak water use month of July.

When the total usage includes UAW, the agreement between the observed 2006 values and predicted values is slightly worse. Data from the utility districts indicate that unaccounted for water makes up 27% of total produced water in 2006. This is higher even than the already fairly conservative assumption of 23% (19% for Crossville) used in the modeling. Figure 6 displays the estimated and observed values, which indicate the model predictions are about 7% *below* observed values. This is certainly a source of potential error, but is more likely due to above average losses in 2006. For the purposes of forecasting, the recent historical averages for UAW are a more reasonable basis for estimating future UAW than the 2006 values alone. Thus, no further calibration is necessary to match the observed and predicted 2006 demand.

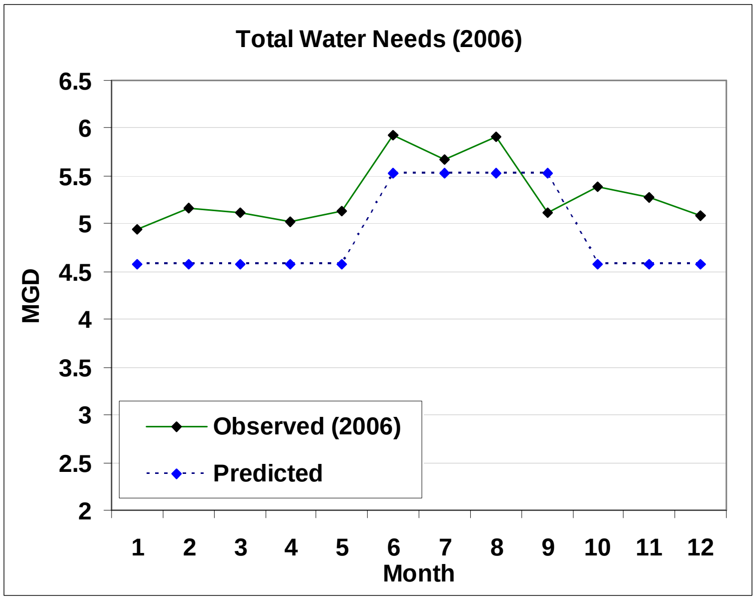

Figure 6– Model Predicted and Observed Cumberland County Water Use in 2006

5. Summary Results

The results of the baseline water supply needs assessment are presented in this section. All results are presented in terms of average daily usage in millions of gallons per day (MGD) except when otherwise noted. Summary results are presented here, but full results are available in the addenda.

It should also be noted that this is a planning level document, so the results are presented as annual or seasonal average. These figures should be sufficient for estimating water storage needs. Calculating peak usage, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak usage estimates were not called for in the scope of services, but are presented for completeness. BDY&A's 2002 *Cumberland County Water Supply Needs Assessment* cites factors in a range of 1.25 to 1.35 of daily consumption for Cumberland. The Corps' *Cumberland County Regional Water Supply Preliminary Engineering Report* appears to use 1.35 as well. Thus, a factor of 1.35 is applied to the results of this section. Note that peak factors are applied only to the consumption, and subsequently, the unadjusted UAW is added.

Countywide Results

The countywide results present the broadest picture of the water needs projections. Figure 7 presents the demand totaled for all study areas and all subsectors (including UAW). The demand for all three growth scenarios is indicated separately, however. The results indicate that demand will not quite triple in 50 years under the Aggressive scenario, less than double under the slow scenario, and roughly double under the expected scenario.

Under any growth scenario the projected demand increases significantly over the 2006 baseline. As noted previously, there is a great deal of uncertainty, particularly in the estimation of future trends in UAW. Figure 8 reports the county totals for consumption, which excludes the UAW. While there is bound to be some UAW in the future, the consumption projections are marginally more certain. The water conservation plan will more directly assess the effects of reducing UAW.

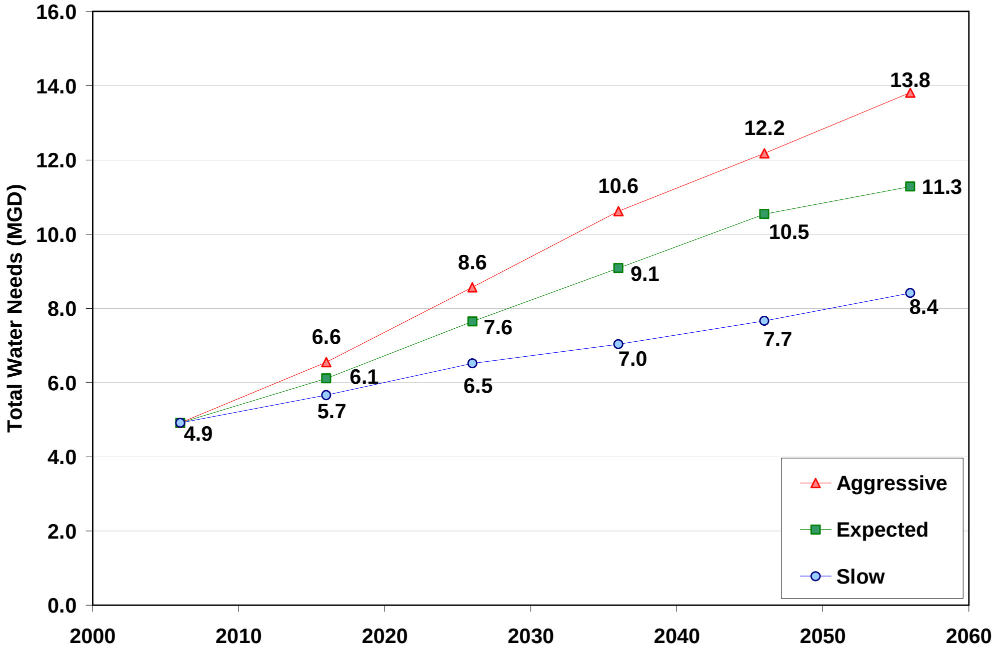

Figure 7. **Countywide Daily Average Total Water Needs for the Slow, Expected, and Aggressive Growth Scenarios.**

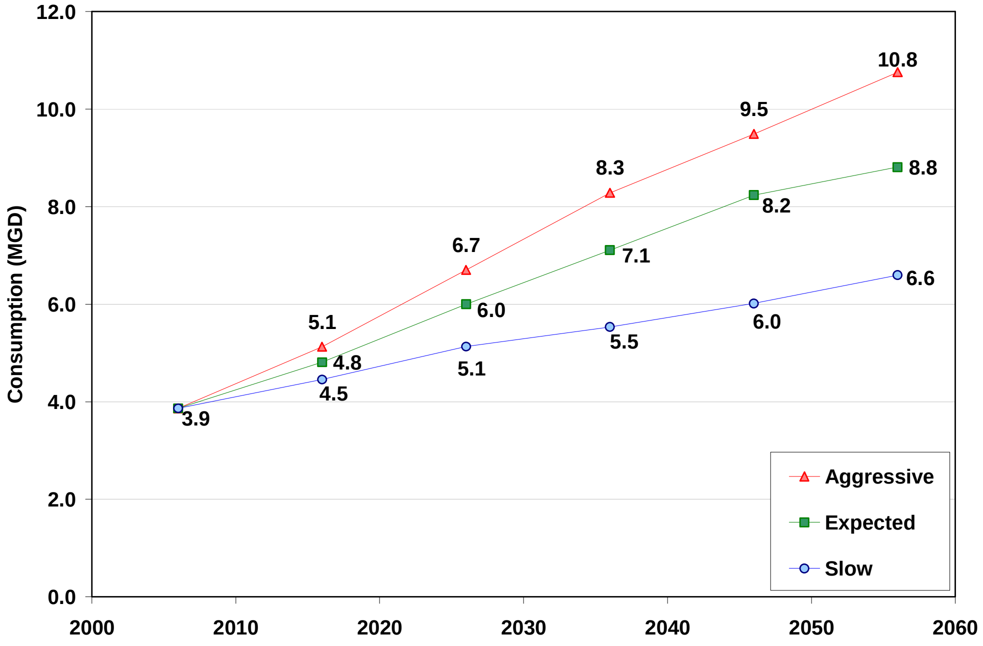

Figure 8 – Countywide Daily Average Projected Water Consumption (excludes UAW) for the Slow, Expected, and Aggressive Growth Scenarios

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, the usage varies by season. The Summer months include June-September, while the Winter includes the remaining months. The results are presented here by scenario and season. Countywide, the summer usage remains a fairly consistent 12-13% above the annual average, and winter usage is always

roughly 6-7% below. This is a result of the cumulative effects of the different winter and summer use factors for the subsectors (see the Water Needs Assessment in the addenda for full description and usage rates). Table 3 displays the countywide daily demand by season.

Table 3– Seasonal Variations and Peak Projected Total Water Needs (MGD)

Scenario	Season/Peak	2006	2016	2026	2036	2046	2056
Aggressive	Annual	4.91	6.55	8.56	10.61	12.18	13.81
	Summer	5.55	7.41	9.71	12.09	13.84	15.67
	Winter	4.59	6.12	7.99	9.87	11.34	12.87
	PEAK	*6.26*	*8.35*	*10.91*	*13.51*	*15.50*	*17.57*
Expected	Annual	4.91	6.11	7.64	9.08	10.54	11.28
	Summer	5.55	6.90	8.63	10.27	11.94	12.77
	Winter	4.59	5.71	7.14	8.48	9.84	10.54
	PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
Slow	Annual	4.91	5.66	6.52	7.03	7.66	8.41
	Summer	5.55	6.40	7.38	7.98	8.71	9.58
	Winter	4.59	5.28	6.08	6.56	7.14	7.83
	PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*

Table 3 also displays the projected peak demands, which reflect a 1.35 peakage factor applied only to the annual average consumption. As mentioned before, this factor is based on peak factors cited in previous studies and is not based on usage data. The unadjusted annual total UAW is then added on to this peak consumption to arrive at total water needs.

Water Needs Analysis By Subsector

Table 4 indicates the annual average daily demand by subsector for the entire county. In terms of total demand growth, it is clear that most of the growth occurs in the residential sector. The other sectors exhibit slightly lower percentage growth, but still increase significantly over their base year values. The NonRES results indicate that commercial growth will be of a low water intensity variety, which is consistent with a primarily service oriented commercial sector. The introduction of only a few large (industrial) water users, however, could add significantly to commercial demand, making the NonRES sector the most likely to be a low estimate of actual future demand.

Also notable is that the UAW subsector, while remaining a constant percentage of total water use, grows to become a more significant water ‘use’ than the nonresidential sector under the aggressive scenario. While the UAW percentage is based on the best available current loss estimates, this sector is most likely to reflect an overly conservative estimate of actual future UAW. The actual processes of leakage are more complex than a simple percentage loss, so growth in consumption does not necessarily mean a proportional rise in leakage. Additionally, leakage will most likely be addressed by future loss reduction measures. The impact of loss reduction measures is treated in the Water Conservation Plan.

Table 4 - Projected Total County Water Needs (MGD) by Scenario and Subsector

Scenario	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
	NonRES	1.49	1.87	2.11	2.32	2.52	2.71
	CMC	0.07	0.10	0.13	0.17	0.20	0.23
	UAW	1.04	1.42	1.86	2.33	2.69	3.05
Aggressive Total		**4.91**	**6.55**	**8.56**	**10.61**	**12.18**	**13.81**
Expected	RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
	NonRES	1.49	1.78	2.04	2.18	2.34	2.42
	CMC	0.07	0.09	0.12	0.14	0.16	0.18
	UAW	1.04	1.30	1.64	1.97	2.31	2.48
Expected Total		**4.91**	**6.11**	**7.64**	**9.08**	**10.54**	**11.28**
Slow	RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
	NonRES	1.49	1.68	1.91	1.96	2.02	2.08
	CMC	0.07	0.08	0.09	0.10	0.11	0.12
	UAW	1.04	1.20	1.38	1.50	1.65	1.82
Slow Total		**4.91**	**5.66**	**6.52**	**7.03**	**7.66**	**8.41**

* RES_PS – Residential, Public Supply; NonRES – Nonresidential; CMC – Cumberland Medical Center; UAW – Unaccounted for Water

Comparison to Previous Estimates

A comparison of GKY's water needs forecasts with previous estimates of Cumberland County's water needs clearly demonstrates the effect of prediction method chosen. Figure 9 compares the estimates in this study to those by Breedlove, Dennis, Young and Associates (BDY&A, 2002), the Army Corps of Engineers (USACE, 1998)[vii], and Lamar Dunn & Associates (LD&A, 2001). LD&A used a simple percentage growth model to estimate future demand. While this model may be appropriate in the short term, it is evident that the simplistic exponential model rapidly leads to unstable and incredibly high demand estimates at more distant time scales. It is clear that this model is insufficient for modeling long term water needs because it is overly simplistic and does not take into account any realistic limitations on growth.

Also interesting is that the BDY&A study presents a very high estimate of demand. This is likely a result of the method used for forecasting the future use factors. The study uses a gross total per capita consumption use factor to estimate the water use. BDY&A chose to express this factor as total public supply water use divided by total population (instead of population served). As a result, the numerator does not reflect the many self-supplied water users in the county (whose use would not be counted in public supply water), while the denominator does count them. This partially explains the artificially low historical use factors (54 and 77 gpd per capita in 1984 and 2000, respectively). The rapid increase in water usage factors is likely more a result of new development being added on public supply (versus self-supply) in a much higher proportion than the existing residences than it is a response to economic trends or fundamentally different water usage patterns of new residents. Furthermore, to bring the use factors to present day average values from this low starting point requires astounding gains in the per capita use factor. Projecting the future water use factors from historical values can lead to extremely high use forecasts, especially when rapid population growth continues.

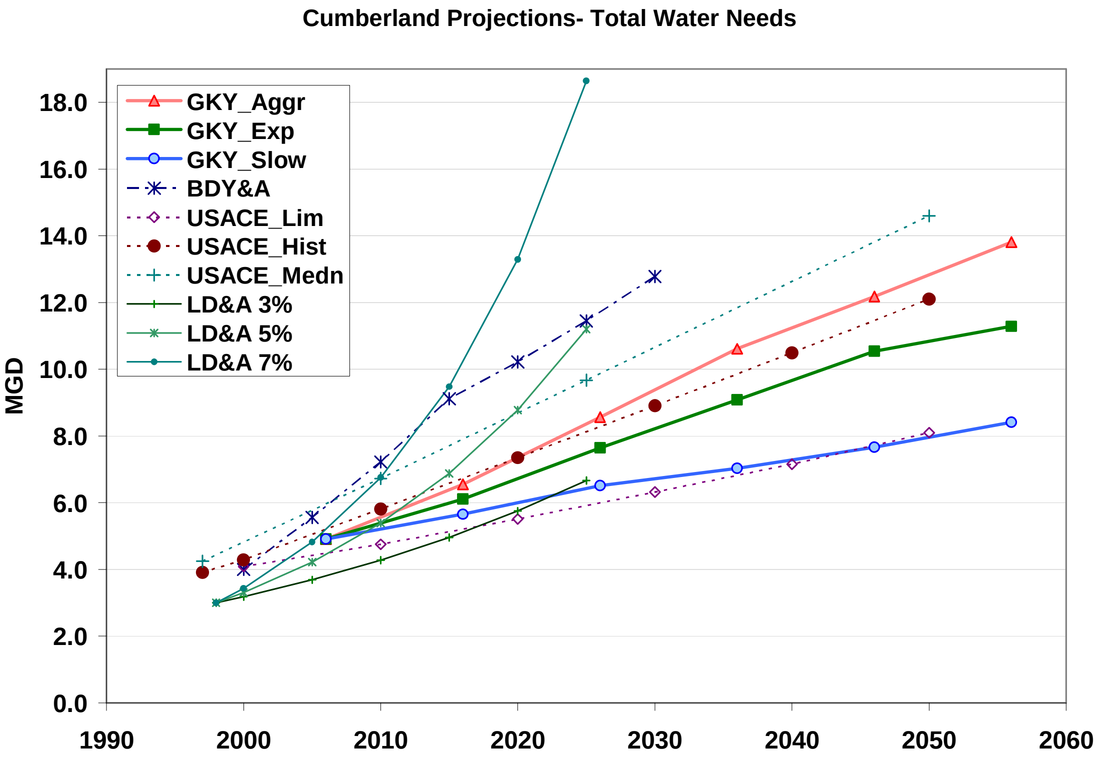

Figure 9 - A comparison of water needs forecasts for Cumberland County

The USACE projections rely upon a variety of different methods, including a model developed in IWR-MAIN (i.e. Medn → Median projection). These projections seem most closely in line with GKY's projections. The historical and limited methods actually incorporate limitations on growth, though in a more simplistic way than the GKY study.

The GKY study likely presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[viii] of the Pacific Institute note, "With very few exceptions, forecasts of future water use have greatly exceeded actual water withdrawals. Only within the past few years have new projections begun to incorporate new thinking and approaches." GKY's baseline projections present a new approach to countywide water demand forecasting, as anticipated improvements in water efficiency are taken into account. These anticipated improvements are in a sense inevitable as national laws and standards, as well as simple market availability have affected a shift to more conserving technology. For example, the Energy Policy Act of 1992 has made virtually all new toilets on the market compliant with a 1.6 gallon per flush efficiency standard.

It is important to note the efficiency assumptions are nearly completely independent of any decisions and policies made by public officials and citizens in Cumberland County. Other water use reductions may result from programs already in progress (notably, infrastructure improvements to reduce leakage). To establish a conservative baseline projection, however, we limit the conservation measures to 'natural' efficiency upgrades due to more advanced technology gaining a greater market share over time. Other conservation actions are analyzed much more thoroughly and explicitly in the Water Conservation Plan.

6. Uncertainty

The act of forecasting into the future is an inherently difficult task. It is important to recognize (1) that uncertainty is present in any projection, (2) uncertainty in baseline assumptions influences uncertainty in projections, and (3) errors compound over time, making distant projections less reliable than near-term projections.

The forecast model is designed to explicitly take into account uncertainty where possible, and otherwise, avoid introducing unknown uncertainty. (We use 'uncertainty' instead of error because error can't be calculated until the future when there are actual water demand values in the forecast years.)

The largest source of uncertainty in this forecast is likely contained in the population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth scenarios (instead of only an expected growth scenario), we introduce reasonable bounds on the uncertainty of this projection. (That is not to say that Slow and Aggressive scenario projections present the absolute lower and upper bounds on the prediction.) This understanding of uncertainty in the population projections is useful since the housing forecasts are calculated in tandem with them, and the employment projections depend directly on population as well. In these projections, the assumed growth rates, people per house statistic, and population per employee estimates all are potential sources of error. As an illustration of the potential consequences of error in initial projection, Table 5 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. (A constant percentage growth model is assumed.) Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 5 - Consequences of 0.5% error in growth rates (forecasted Units per 1000 base Units*)*

	10 years		**25 years**		**50 years**	
Initial rate projection	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*	*0.5% high*	*0.5% low*
1%	53	-56	150	-169	361	-461
2%	58	-61	190	-213	586	-746
5%	76	-79	381	-427	2435	-3075
10%	116	-120	1166	-1301	23914	-29879

Table 5 indicates just how serious minor errors in the prediction parameters can be, particularly in fast growing regions. The land use limitations on growth assumed in this study help put a limit on how large the error can be. In practice, growth can be limited (or spurred) by many factors other than land use consideration, but some limits are advisable as a constant percentage growth, exponential model is rarely a realistic assumption for a very long study period.

The other major potential source of model uncertainty is in the water use factors. While IWR-MAIN has several advanced methods of estimating future demand built into the software, additional parameter estimates and explanatory variables would be necessary (each bringing additional uncertainty). Any more complex model (such as a linear or multiplicative regression) would introduce more uncertainty through parameter estimates in addition to any uncertainty in forecasting future explanatory variable values. The water usage data provided by the UDs is just enough to come up with baseline water use factors. The small sample sizes of the water use data mean there is quite a bit of uncertainty in the water use factors (especially in the monthly values). By averaging the months within two seasons, the sample size is effectively increased, reducing the uncertainty introduced by outliers.

In a similar manner, the UAW percentages are averaged over the county to increase the effective sample size of estimate, and reduce the effect of outliers. Section 4 (Water Needs Assessments Methods) demonstrated that selection of parameters led to good agreement with real water use patterns in the base year.

The importance of the proper treatment of uncertainty in model prediction cannot be overstated. Underestimating future water needs can lead to a dangerous situation in the form of a water shortage or even running out of water. Overestimation of water needs can lead to unnecessary projects or oversized projects at a much higher cost than necessary. Without a realistic view of the uncertainty present in the forecasts, decision making on future supplies may not be truly addressing the water needs. Fully cognizant of the uncertainties present in this forecast, GKY has made every effort to document the uncertainty and present a reasonable range of potential future water needs representative of the effects of the known uncertainty.

Comparisons with previous studies have shown that this study's predictions of water needs tend to be somewhat lower than previous estimates made with simpler models. A careful consideration of the methods used in earlier studies generally leads to the conclusion that the forecasted water needs may be overestimated. This study attempts to provide as accurate a forecast of water needs as possible, with full description of methods, thus allowing the decision maker to assess the validity of the study. Assuming the study is deemed valid, the range of forecasts allows for the decision maker to lend more credence to one scenario versus the others based on their judgment and level of risk-aversion.

7. Conclusions

This Water Needs Assessment has analyzed the current and future water needs of Cumberland County using the best available data and expert opinions. Cumberland County has experienced rapid growth in the past several decades, and that growth may continue so long as the water demands can be met.

The population projections reflect demographic trends, opinions of local experts, and real limits on growth based on land use. The development of the appropriate water use factors was based directly on actual water use data from the utility districts. It must be recognized that a 50 year projection is subject to a great deal of uncertainty. The Aggressive, Expected, and Slow growth scenarios help to capture some of that uncertainty.

The projections in this report indicate that Cumberland County's water needs will very likely exceed the current supply in the next 50 years, but not quite as soon as previously projected. As the average demand becomes closer and closer to the firm yield of the existing sources, the potential for failure in a particularly severe drought year increases considerably. Therefore, Cumberland County is well advised to continue to examine and develop opportunities for conservation and securing an increase in available supplies.

8. References

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[vii] Lamar Dunn & Associates, Inc. (LD&A). *Preliminary Engineering Report: Investigating the feasibility of constructing raw water impoundments downstream of Meadow Park Lake for City of Crossville.* December 2001.

[viii] Gleick, P., Haas, D., Henges-Jack, C., Srinivasan, V., Wolff, G., Cushing, K.K., and Mann, A. (2003) *Waste Not, Want Not: The Potential for Urban Water Conservation in California.* Pacific Institute for Studies in Development, Environment, and Security. Oakland, CA. November, 2003.

Water Conservation Plan

1. Introduction

Cumberland County's attention has been increasingly drawn to water resources over the past decade. Growth projections by several firms[ix,x,xi] have estimated that the water needs of Cumberland County will exceed firm yield in less than 10 years. Excluding the undesirable outcome of running out of water, Cumberland County has two options: increase water supply or reduce demand.

The Water Needs Assessment established forecasts for Cumberland County's water demands under three different growth scenarios. Before evaluating additional water supply alternatives, it is prudent to determine if conservation can effectively reduce demand. This study investigates the extent to which demand can be reduced below the baseline forecast values in the Water Needs Assessment.

Cumberland County has no significant history of water conservation programs, but a range of viable options could lead to significant water savings. This Water Conservation Plan report identifies six potential water conservation measures local government or the utility districts could reasonably enact. The effectiveness of the proposed conservation measures is modeled using the IWR-MAIN Conservation Manager© software program. IWR-MAIN is recognized as a state of the art program for modeling water demand and conservation programs.

A detailed account of the modeling methods is presented in the Water Conservation Plan Memo (full title: *Water Conservation Plan for the Cumberland County Regional Water Supply Study*) in the addenda. This document presents results of modeling the six conservation measures, and based on these results a final water conservation plan is presented.

2. Conservation in Cumberland County

Until the past few decades, Cumberland County has always had an abundant and easily accessed water supply. As a result, there has been limited impetus to encourage conservation in the county. This limited conservation experience presents a substantial opportunity for future efforts to harvest the 'low-hanging fruit' of water conservation benefits at a relatively low cost.

Cumberland County's opportunities to conserve are typical for communities of similar size and age. Cumberland County has two primary avenues for improving water efficiency. One major opportunity for conservation is for the water utility districts to reduce water loss and other unaccounted for uses. Total unaccounted for water use averages near 20% of total produced water, with losses approaching 30 or 40% for some districts in some months. This is not unusual for utility districts of a similar size and age. Cumberland County's utility districts face additional challenges resulting from the very hilly and rocky terrain of the county. High water pressure can stress pipes, and the rocky soil can both puncture pipes and create a situation where leaks have adequate drainage to avoid detection. While Cumberland County's distribution system loss rates are not atypical, reducing losses presents a major avenue for conservation. With appropriate, proactive leak detection efforts and other loss reduction measures, Cumberland County may be able to reduce its losses to ten percent or less.

While the losses in the distribution system are primarily attributable to water suppliers, the water consumers in Cumberland County are another major source of water inefficiency. Interviews with the utility district managers indicated that the majority of residences in Cumberland County use less efficient toilets and plumbing fixtures than current industry standards. This will largely be corrected over time as residents replace older fixtures with

newer, more efficient fixtures. Accelerating this transition, however, is a major opportunity for conservation.

Between reducing inefficient water use on the part of the utility districts and water consumers, there is significant potential for conservation in Cumberland County. The following sections detail several conservation measures to take advantage of this potential.

3. Conservation Measures

Six conservation measures have been identified for analysis in developing the Cumberland County Water Conservation Plan. Each conservation measure is described in brief below. More detailed policy descriptions and modeling methods for each conservation measure are included in the Water Conservation Plan memo included in the addenda. Additionally, the six conservation measures were chosen from a larger set of possible measures based on their relevance and implementability in Cumberland County. The final water conservation plan reflects a combination of some of these measures.

3.A. Unaccounted for Water Reduction (non-leakage)

While leakage is the most commonly identified contributor to Unaccounted for Water, there are other contributing factors to UAW in Cumberland County. Foremost among these are metering errors, flushing usage, and fire fighting usage. Reducing fire fighting usage is not generally within the control of water utilities. Mains flushing is an important part of system maintenance to prevent blockages and corrosion and preserve water quality. Flushing is also necessary before new connections are opened. In large new developments, flushing loss can be tremendous, especially when the opening of new connections is staggered (requiring multiple flushing events). Finally, metering errors are likely a result of older meters. Cumberland County does not have a significant number of unmetered connections.

By addressing excessive flushing and metering errors, Cumberland County may reduce its UAW percentage. All of the utility districts have either recently replaced their meters or are in the process of doing so, but replacement programs should be repeated every 10 -15 years to ensure reductions in UAW are preserved. Reductions in flushing volumes may be achieved through a review of flushing policies, and system upgrades to convert branched distribution pipe networks to looped networks where practicable.

3.B. Leak Detection and Reduction

Leak detection is another method of reducing UAW. Cumberland County faces a range of challenges in getting leakage under control. The age of the pipes, rocky soil, and large elevation differences (and resulting high pressure) have been cited by county utility managers as major causes of leakage. Leaks occur on both mains and service lines. Current leak detection efforts in the county are primarily focused on repairing leaks when they come to the surface or when there are service complaints.

A comprehensive leak detection program in Cumberland County could include several leak detection strategies. Hiring a leak detection contractor to investigate the majority of the county’s mains and service line connections would be a good start. Listening surveys use geophones and other listening devices to find leaks and digital correlators to pinpoint leak positions. In the long term, permanently installed listening devices may be the most effective method of detecting leaks. With training, utility district staff could conduct listening surveys and use a digital correlator.

3.C. Education

Educating water consumers on the value of water and the benefits of conservation, while a valuable end in itself, can also lead to real reductions in water usage. Reductions are achieved in two primary ways: convincing water users to change their water usage habits, and affecting purchasing decisions on fixture and appliance types (and whether to replace them sooner). The water utilities in Cumberland County do not currently have any dedicated customer education programs, but they do communicate with customers through billing inserts and other methods. In 2007, the City of Crossville, Cumberland County, and the utility districts used several communication methods to publicize the drought restrictions and appropriate short-term water saving tips. A true education strategy is geared more toward long-term shifts in behavior and more permanent savings.

Several types of education programs exist, and the water utilities could develop new programs, specially tailored for Cumberland County users. In general, using a variety of education strategies (each with a defined message and goal) in combination can achieve the most robust results. Table 1 indicates three general types of educational programs, the target audience, and a description.

Table 1 - Education programs

Policy	Intended audience	Description
General advertisement	All water users	Water saving tips and information.
Targeted Messages	Commercial users, homeowners with irrigation systems, homeowners with older homes, etc.	Communicate well developed messages perhaps once a year to encourage a specific conservation action, e.g: highlight cost savings from replacing toilets, promote xeriscaping, .
Education programs	School age children and families	e.g.: Programs every 2 years for 4th and 5th graders, 9th and 10th graders
	Retirees, community associations	Short (0.5 day) programs in retirement communities, civic centers.

3.D. Pricing

While water prices are generally set to reflect the costs of production, price changes do affect water demand. The price elasticity of demand indicates the amount of change in demand due to a unit change in price. See Equation (1). An elasticity of positive one indicates that a 1% increase in price will lead to a 1% increase in demand. Price elasticity of demand for water is nearly always negative (price increases reduce demand), and is generally considered to be inelastic (in between 1 and -1, or in this case, 0 and -1). In fact, when considering water demand, it is rare to see elasticities even go beyond -0.5.

$$e = \frac{\Delta q}{\Delta p}$$ **Equation 1**

Where:

e is the price elasticity of water demand

Δq is the percentage change in water demand by a water user (or set of users)

Δp is the percentage change in water price

There is a wide range of economics literature examining the price elasticity of demand for various water users. Focusing on residential customers, Arbués et al. (2003)[xii] and Worthington and Hoffman (2006)[xiii] provide good reviews of a large range of economic

studies investigating price elasticity of water demand under a wide range of pricing policies. In general, the majority of the estimates of residential long term elasticity fall into the -0.05 to -0.5 range. The IWR-MAIN manual cites residential elasticity as between -0.05 and -0.35.

Several UD managers expressed the view that the water demand of Cumberland County residents is somewhat to considerably more sensitive to price changes than the average U.S. citizen. Supporting this assertion is that many of Cumberland County's residents are on fixed incomes. Residents' response to price signals is also influenced by having a monthly billing cycle in all the Cumberland County UDs. As a result, elasticities in Cumberland County are assumed to be toward the upper end of the ranges presented in the manual.

Currently, all the Cumberland County utility districts have a fixed fee for consumption up to a certain initial limit (1000 or 2000 gallons), and a fixed block rate for additional consumption above the limit. A wide range of pricing strategies are available for water utilities to meet goals as wide ranging as maintaining adequate revenues to encouraging conservation. A full discussion of the pricing options considered for the modeling of this conservation measure is contained in the Water Conservation Plan memo. Due to complexity of modeling some of the pricing methods and the limitations of IWR-MAIN, a simple pricing policy is selected. The policy is simply to enact a 30% increase in marginal water price over the base price (set equal to 1) after the base year. Since the price is measured in constant 2006 dollars, the underlying assumption is that after the initial increase, price increases at a rate exactly equal to the inflation rate (or more accurately, water consumers' own discount rate).

3.E. Water Efficiency Codes and Ordinances

One of the most effective methods to generate long term water savings over baseline estimates is to influence the water efficiency of new development. Ensuring that developers are installing efficient fixtures and appliances means that new users will have a lower water use intensity than existing users. Additionally, it is significantly easier to create standards for efficiency before new units are built than to retrofit later.

Currently, Cumberland County lacks building codes in all areas except inside the Crossville city limits. Reportedly, even within Crossville, the efficiency of fixtures is rarely examined by inspectors.

A comprehensive water efficiency code and ordinance will mandate the inspection of water fixtures, toilets, and appliances to check for their efficiency. Additional ordinances may govern the outdoor use of water at commercial and institutional properties by requiring rain sensor shut-off for irrigation systems, for example. Benefits, such as reducing the connection fee, may also be considered for developers who install ultraefficient appliances and fixtures in new properties.

3.F. Retrofit, Rebate, and Replacement Programs

Retrofit, replacement, and rebate programs are other methods to reduce the average water use factors for existing users by replacing (or providing incentives to replace) existing fixtures and appliances with more water efficient models. The key is that the transition happens at a much faster rate than it would under natural replacement.

The programs can take several forms. One approach is to simply provide inexpensive fixtures and devices such as faucet aerators, shower heads and toilet dams free of charge to users. The drawback is that the consumers do not always install them. As the Massachusetts Water Resources Authority's Steven Estes Smargiassi noted[xiv], "We discovered if you gave away devices, most of them were 'installed' in kitchen drawers – not on the bathroom or kitchen fixtures." One way to mitigate this problem is to provide free installation as well. Rebate programs provide monetary incentives for the replacement of larger water using devices,

notably toilets and clothes washers. While often expensive, rebates for toilets and clothes washers can provide greater water savings than small devices, and the transition to more efficient water uses can be more easily verified.

Cumberland County's utility districts do not currently offer any retrofit, replacement, or rebate programs. These programs may be well suited to Cumberland County, as the majority of fixtures and appliances are believed to be older models. Additionally, interviews with utility district managers and other stakeholders indicated that county residents replace these fixtures and appliances at a slightly lower rate than the nation as a whole.

4. Methods

The water savings of the six conservation measures are modeled using IWR-MAIN Conservation Manager. The Water Conservation Plan Memo discusses the modeling methods, assumptions, data collection, parameter estimates, and scenario development in much greater detail. Table 2 displays the tools used in IWR-MAIN Conservation Manager to model the effects of each of the conservation measures.

Table 2- Modeling Methods of the Six Conservation Measures

Conservation Measure	IWR-MAIN Modeling Method
A. Non-Leakage UAW Reduction	Tools→ Unmetered Fraction
B. Leakage Reduction	Tools → Unmetered Fraction
C. Education	Intensity → Enter/Build, Passive Conservation
D. Pricing	Intensity → Enter/Build (Multiplicative Model)
E. Codes and Ordinances	Tools → Passive Conservation
F. Retrofit, Rebate, Replacement	Tools → Active Conservation

5. Results

The six conservation measures cover a broad range of strategies for reducing water usage. Accordingly, the modeling results indicate important differences between the conservation measures in terms of magnitude and trends of water savings. The growth scenario also affects the relative performance of the conservation measures. While the modeling methods for each conservation measure are identical between growth scenarios, certain measures perform comparatively better or worse depending on the rate of growth. Table 3 compares the total water needs projections for the baseline and six conservation measures under the 3 growth scenarios. For each year in each growth scenario, the conservation measure with the lowest total water needs is displayed in bold type.

The results indicate some clear trends in the projected water needs under the baseline and conservation scenarios. Most notably, leakage reduction appears to lead to the most substantial reductions over the entire study period. Education programs and Codes and Ordinances follow a similar pattern of starting off with very modest savings over the baseline and substantially increasing savings over time. The retrofit programs show an opposite trend, with the most substantial savings earlier in the study period. This is potentially significant as the uncertainty in the estimates is substantially lower at shorter time horizons. Interestingly, the results of non-leakage UAW reduction programs and conservation pricing programs are quite similar even though their modes of influencing water savings are very different.

Table 3- Total Water Needs for the six Conservation Measures under the three growth scenarios

Aggressive Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.52	6.34	6.14	6.30	6.23	6.43	**6.08**
2026	8.55	8.19	**7.80**	8.04	8.16	8.20	8.15
2036	10.60	10.14	**9.59**	9.90	10.10	9.90	10.27
2046	12.17	11.64	**10.97**	11.26	11.59	11.10	11.88
2056	13.81	13.22	**12.29**	12.55	13.14	12.36	13.55

Expected Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	6.11	5.95	5.76	5.90	5.84	6.04	**5.67**
2026	7.64	7.32	**6.98**	7.17	7.29	7.35	7.23
2036	9.08	8.69	**8.22**	8.45	8.66	8.49	8.73
2046	10.54	10.08	**9.53**	9.73	10.04	9.63	10.23
2056	11.28	10.79	**10.07**	10.20	10.75	**10.07**	11.00

Slow Scenario

Year	Baseline	A) Non-Leakage UAW	B) Leakage Reduction	C) Education	D) Price	E) Codes and Ordinances	F) Retrofits
2006	4.91	4.91	4.91	4.91	4.91	4.91	4.91
2016	5.66	5.50	5.33	5.43	5.41	5.59	**5.18**
2026	6.52	6.24	**5.96**	6.05	6.23	6.26	6.06
2036	7.03	6.74	**6.39**	6.46	6.72	6.55	6.63
2046	7.66	7.33	6.96	6.96	7.31	**6.95**	7.29
2056	8.41	8.04	7.54	7.50	8.02	**7.46**	8.05

It can also be instructive to look at overall cumulative water savings over the entire study period. Figure 1 through 3 display the forecasted cumulative water savings for the three growth scenarios. The magnitude of expected savings over 50 years is rather remarkable, on the order of 5 to 15 billion gallons. Comparing the different conservation measures reveals some interesting insights on their long term behavior. Even though their overall savings are quite different, Non-Leakage UAW reduction and Leak reduction demonstrate similar shapes due to their common modeling method. The conservation pricing policy, because only one major price change occurs, displays a linear trend after 2016. The effectiveness of the retrofits is very evident at first, but over time the slope of the cumulative savings line actually decreases. Finally, the Codes and Ordinances and Education programs clearly increase their cumulative savings as growth increases in the more distant future.

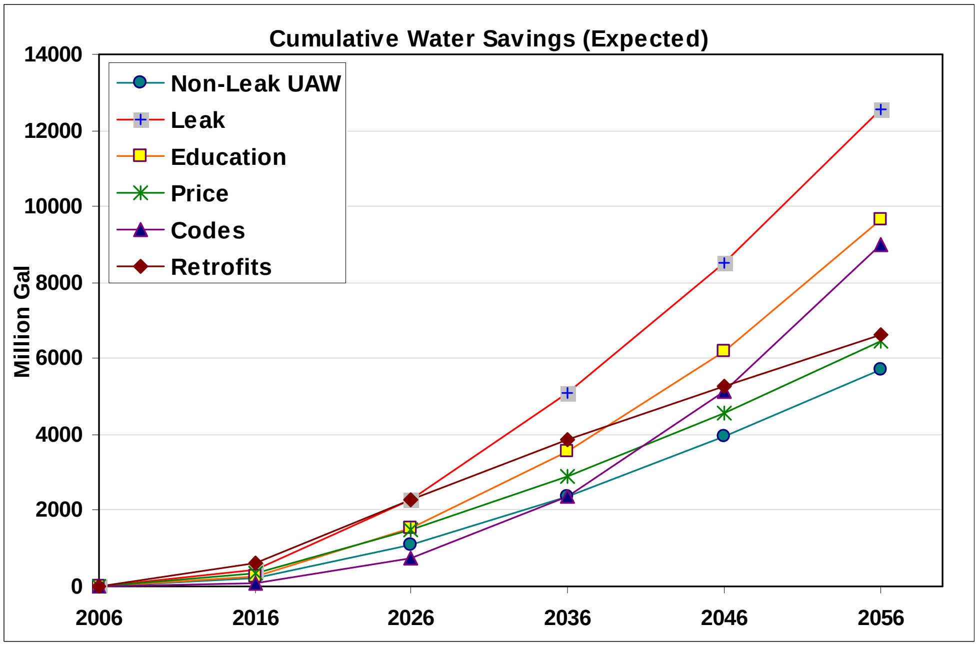

Figure 1 - Cumulative Water Savings for the Six Conservation Measures under the Expected Growth Scenario

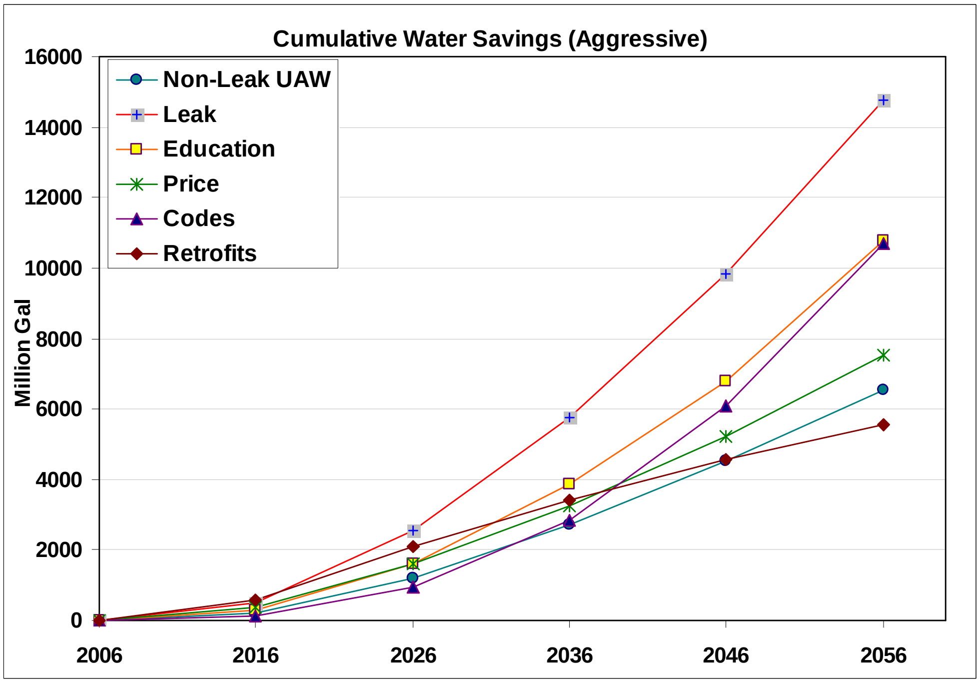

Figure 2 - Cumulative Water Savings for the Six Conservation Measures under the Aggressive Growth Scenario

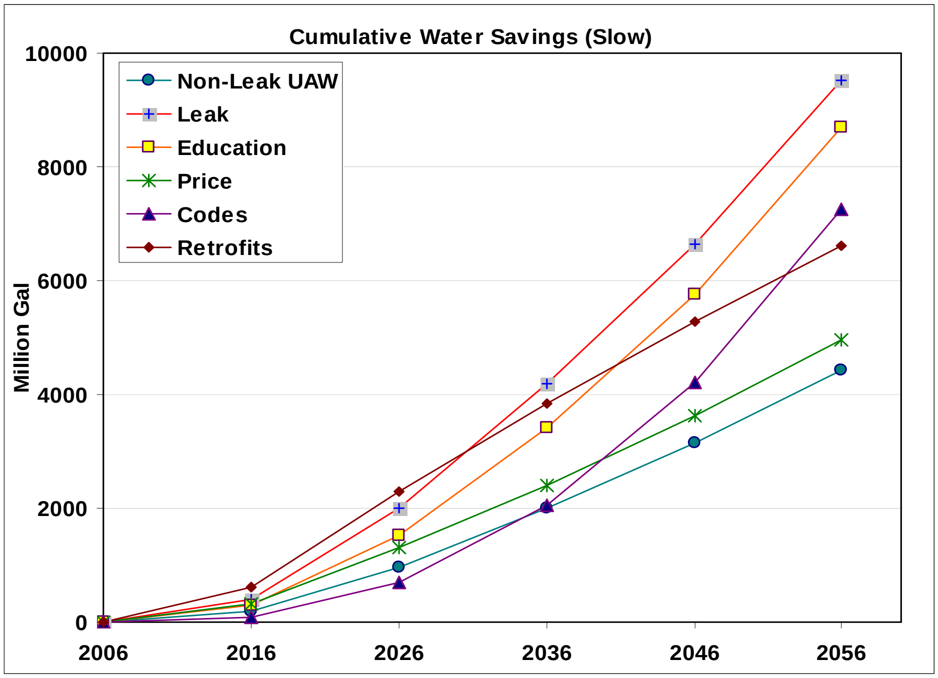

Figure 3 - Cumulative Water Savings for the Six Conservation Measures under the Slow Growth Scenario

6. Pros, Cons and Economic Benefits

The previous section investigated the comparative water savings resulting from each of the conservation measures. While the water savings are perhaps the most important consideration, several other considerations necessarily influence whether the measure should be implemented. These considerations include implementability, public acceptance, cost, uncertainty in the projections, compounding and corollary effects, and finally, economic benefits.

Each of the conservation measures has its own merits and drawbacks, and any comprehensive water conservation plan will likely have to include several conservation measures. The conservation measures which target unaccounted for water, non-leakage UAW reduction and leak detection, have a strong benefit in that they save water that was not producing revenue. Therefore, any water savings generated by these measures lead to direct economic savings. These two measures are also less complicated to implement because they can be put into place solely based on the choice of the utility districts. The drawback of both measures is their upfront cost, which can be significant, especially when pipes must be excavated for repair and replacement. The savings resulting from stopping leaks and other non-revenue producing water, however, often lead to very short payback periods.

Rapid adjustments in price carry their own pros and cons. While periodic, small water rate increases are necessary for maintaining capital investments and keeping pace with inflation, larger rate increases can be a much stronger impetus to conserve. Since water is an inelastic good, rate increases nearly always lead to smaller proportional reductions in consumption than the increase in price. As a result, water savings may be marginal, though the utilities benefit from greater total revenues. The obvious drawback to increasing rates is that rate increases are unpopular and may meet significant resistance from ratepayers. Effective conservation pricing and tiered pricing may be an alternative solution that could provide

benefits with less opposition. Analyzing more complex pricing schemes is beyond the scope of this study, but could be researched further.

Education programs have a great number of benefits, but suffer from a great deal of uncertainty about their actual effectiveness. Educating consumers about methods, benefits, and importance of water conservation can lead to changes in behavior that may save water in the short and long term. Short term changes may be achieved by behavioral changes, while long term shifts in water use may result from consumers making more informed choices when replacing toilets, washing machines, etc. Educational programs are generally not very expensive to implement, but can be ineffective without dedication to the message and sustained commitment to program implementation. Traditionally, education programs have been viewed as effective in reducing water use, but quantifying their actual water savings and economic benefits relative to investment remains difficult.

Strict water conservation provisions in building codes and public ordinances can lead to a gradual but significant reduction in potential future water use. The primary benefit of the codes is the significant long term savings, but the related drawback is that they do virtually nothing to reduce existing consumption except in the case of major renovations. Passing sufficiently comprehensive codes requires a great deal of political cooperation to implement. With the exceptions of builders and plumbers, there are generally few costs to existing stakeholders. Managing an effective inspection and enforcement program requires adding several inspectors and support staff to the local government payroll (or hiring contractors to fulfill the roles), which can be a significant long term cost.

7. Water Conservation Plan

It appears from the analysis of alternative conservation measures that Cumberland County has significant opportunities for reducing water consumption, especially in the long run. A combination of four of the identified conservation measures may provide very significant conservation savings over the baseline projections. GKY recommends the following Water Conservation Plan as best suited to meeting Cumberland County’s long term water management goals. In combination, institute the following conservation measures, described previously in this report:

A. Non-Leakage UAW Reduction
B. Leakage Reduction
C. Education Programs
E. Codes and Ordinances

Modeling the Water Conservation Plan

Modeling the potential savings due to the water conservation plan is a fairly straightforward combination of the 4 identified conservation measures. The modeling methods have limited overlap. Measures A and B are both modeled by setting the UAW percentage with the unmetered/unaccounted tool. The appropriate UAW percentage is simply determined by the summing the reduction percentages under the two programs.

Codes and Ordinances are modeled in exactly the same manner as before. The Education conservation program is modeled in IWR-MAIN using the exact same intensity reductions as described in the Draft Water Conservation Plan memo. However, the passive conservation portion of the education programs is slightly affected. The rate of efficiency class shift is set by whichever rate is higher between the education and codes and ordinances conservation measures instead of adding the efficiency class shift percentages. So if 5% of units per year shift efficiency classes under the codes and ordinances conservation measure, and 3% of units per year shift with education, the total water conservation plan rate is 5% and not 8%.

Results

The results of modeling clearly demonstrate that impressive water savings are possible if an ambitious water savings plan is put into place. Figure 4 shows the baseline forecasts for the three growth scenarios (solid line), and the corresponding forecasts if the Water Conservation Plan is fully implemented (dashed lines).

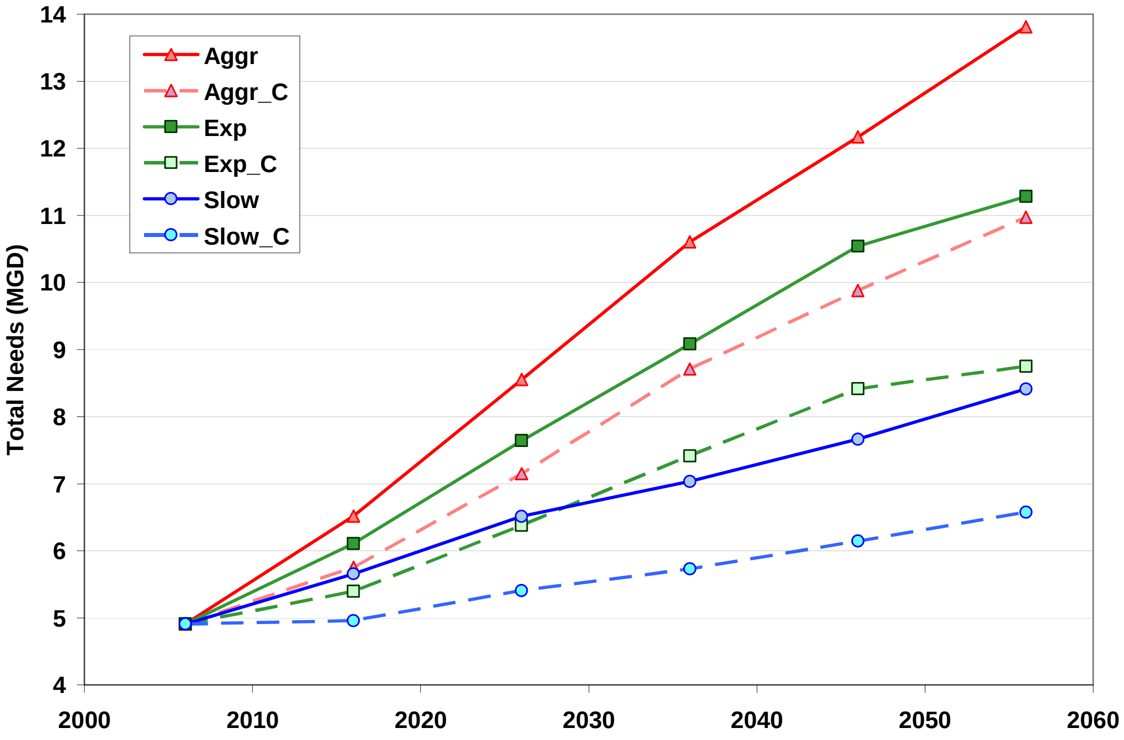

Figure 4 - Forecasted Water Needs for three growth scenarios, with and without the conservation plan

The results of the forecasts show the potentially profound effect of conservation. In general, the conservation plan can save as much as 30% over the baseline scenario. About half of this reduction comes from reduction of Unaccounted for Water alone. Over the long term, the reductions are as significant as dropping one growth scenario. That is, water use for the aggressive scenario with conservation is roughly equal to water use for the expected scenario without it. Even with conservation, water use in the county stands to increase significantly. However, under the slow growth scenario, water use remains virtually flat for the first 10 years when the conservation plan is put into place.

There is one caveat in interpreting the results of the water conservation plan. In analyzing all of the conservation measures individually, there was never a situation in which both the actual consumption and UAW rates were changed simultaneously. The water conservation plan does change both at once. Since the UAW is expressed (and modeled) as a percentage of overall demand, reducing consumption reduces UAW by default. However, the actual physical processes that cause leakage are not necessarily dependent on demand. Therefore, especially in situations where both the consumption and UAW are reduced simultaneously, the water savings may be overestimated. The modeling limitations of IWR-MAIN make it difficult to easily ameliorate this problem.

The effect of this limitation can be discerned when one looks at the results by subsector (including UAW as a subsector). Table 4 displays the results by subsector, comparing the baseline projection and water conservation plan for the three growth scenarios. It is quite

evident that a large portion of the savings comes from reductions in UAW. Under the Water Conservation Plan, UAW can be cut to as much two-thirds below the baseline forecasts. For example, under the aggressive scenario, the baseline UAW estimate in 2050 is 3.05 MGD, but with the water conservation plan, it falls to 0.99. Other subsectors see only about a 5 - 10% reduction over the baseline.

Table 4 – Total Water Needs by Subsector under the Baseline and Water Conservation Plan Forecasts(MGD)

Scenario	Forecast	Subsector	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	CMC	0.07	0.10	0.13	0.17	0.20	0.23
		NonRES	1.49	1.87	2.11	2.32	2.52	2.71
		RES_PS	2.31	3.16	4.46	5.80	6.78	7.82
		UAW	*1.04*	*1.39*	*1.85*	*2.32*	*2.68*	*3.05*
	Water Conservation Plan	CMC	0.07	0.10	0.13	0.16	0.19	0.22
		NonRES	1.49	1.84	2.06	2.25	2.41	2.56
		RES_PS	2.31	2.99	4.20	5.43	6.29	7.20
		UAW	*1.04*	*0.82*	*0.76*	*0.87*	*0.99*	*0.99*
Expected	Baseline	CMC	0.07	0.09	0.12	0.14	0.16	0.18
		NonRES	1.49	1.78	2.04	2.18	2.34	2.42
		RES_PS	2.31	2.93	3.84	4.79	5.74	6.21
		UAW	*1.04*	*1.30*	*1.64*	*1.97*	*2.31*	*2.48*
	Water Conservation Plan	CMC	0.07	0.09	0.11	0.14	0.16	0.17
		NonRES	1.49	1.74	1.98	2.10	2.21	2.26
		RES_PS	2.31	2.79	3.61	4.44	5.20	5.53
		UAW	*1.04*	*0.77*	*0.68*	*0.74*	*0.84*	*0.79*
Slow	Baseline	CMC	0.07	0.08	0.09	0.10	0.11	0.12
		NonRES	1.49	1.68	1.91	1.96	2.02	2.08
		RES_PS	2.31	2.70	3.13	3.47	3.88	4.39
		UAW	*1.04*	*1.20*	*1.38*	*1.50*	*1.65*	*1.82*
	Water Conservation Plan	CMC	0.07	0.08	0.09	0.10	0.10	0.11
		NonRES	1.49	1.64	1.85	1.88	1.91	1.94
		RES_PS	2.31	2.53	2.89	3.18	3.52	3.93
		UAW	*1.04*	*0.71*	*0.57*	*0.57*	*0.61*	*0.59*

While the average water needs are important in the evaluation of long term water supply planning, the peak day demand is important for the design of certain system components. As in the Water Needs Assessment, a peak factor of 1.35 is assumed. This is applied only to the consumption values, and UAW is added afterwards. Table 5 displays the peak day water needs for the baseline forecast and water conservation plan.

Table 5 – Peak Demand Values for the Baseline Forecast and Water Conservation Plan

Scenario	Program	Data	2006	2016	2026	2036	2046	2056
Aggressive	Baseline	Consumption	3.87	5.13	6.70	8.28	9.49	10.76
		UAW	1.04	1.39	1.85	2.32	2.68	3.05
		PEAK	*6.26*	*8.31*	*10.90*	*13.50*	*15.49*	*17.57*
	Water Conservation Plan	Consumption	3.87	4.93	6.39	7.84	8.89	9.98
		UAW	1.04	0.82	0.76	0.87	0.99	0.99
		PEAK	*6.26*	*7.48*	*9.39*	*11.46*	*12.99*	*14.47*
Expected	Baseline	Consumption	3.87	4.81	6.00	7.11	8.24	8.81
		UAW	1.04	1.30	1.64	1.97	2.31	2.48
		PEAK	*6.26*	*7.79*	*9.74*	*11.57*	*13.42*	*14.36*
	Water Conservation Plan	Consumption	3.87	4.62	5.70	6.67	7.57	7.96
		UAW	1.04	0.77	0.68	0.74	0.84	0.79
		PEAK	*6.26*	*7.02*	*8.37*	*9.75*	*11.06*	*11.54*
Slow	Baseline	Consumption	3.87	4.45	5.13	5.53	6.02	6.59
		UAW	1.04	1.20	1.38	1.50	1.65	1.82
		PEAK	*6.26*	*7.22*	*8.31*	*8.97*	*9.77*	*10.72*
	Water Conservation Plan	Consumption	3.87	4.25	4.84	5.16	5.53	5.98
		UAW	1.04	0.71	0.57	0.57	0.61	0.59
		PEAK	*6.26*	*6.45*	*7.10*	*7.54*	*8.08*	*8.67*

Analysis of the Water Conservation Plan

These four measures are the most beneficial actions Cumberland County can take for several reasons. First, the combination of measures strikes a balance between short term and long term water savings. Measures A and B (Non-leak UAW reduction and Leakage Reduction), especially when implemented in combination, provide immediate reductions in water usage. Measures C and E (Education and Codes and Ordinances) lead to much more significant savings in the long term than the short term.

These four conservation measures are also very feasible to implement. In fact, most of the measures are currently in the process of planning or implementation, though not quite to the extent described in this report. All of the utility districts have recently replaced or are replacing meters throughout their service areas. All of the utility districts claim to be reducing system leakage wherever they can, and one has even contracted leak detection services. The City of Crossville already has plumbing codes in place, and Cumberland County appears to be actively considering implementing them. None of the utility districts currently has dedicated education programs, but there are many resources available through the American Waterworks Association, the Environmental Protection Agency, various state environmental departments, private companies, and other sources.

Especially if the utility districts and county officials cooperate, the conservation measures presented here are very cost effective. Education programs are relatively low in cost. Implementing codes and ordinances has few upfront costs, but some long term enforcement and administrative costs. Measures A and B can be costly, but are generally worthwhile investments as the water savings directly reduce costs without reducing revenues. Furthermore, if leak detection services are contracted for the entire county, and leak detection

equipment is shared, costs can be reduced. Finally, leak detection costs are dropping as technology improves.

The other benefit of this plan is that it should be widely accepted by the majority of the stakeholders. Reducing unaccounted for water, and more broadly, establishing water accountability through better system information, better metering, and leak detection is a crucial step toward public acceptance of other conservation actions. Establishing building codes (and water efficiency standards) is generally acceptable as it has many positive impacts on quality of life in the county. Educational programs, as long as they are well managed, are generally accepted. Price increases for the purpose of conservation, however, are usually unpopular. Additionally, certain stakeholders have already expressed a mild opposition to retrofit and rebate programs as an unfair use of ratepayer or tax dollars.

Finally, implementing the proposed conservation measures leaves open the possibility for future conservation measures not described here. In the event that the proposed plan does not meet conservation targets, or growth occurs at a faster than projected rate, other conservation measures can be implemented. Measures A and B will lead to a much better understanding of the water balance throughout the distribution system and identify opportunities for further conservation. Establishing a framework for education programs leads to better communication between utilities, ratepayers, and other stakeholders, which could make future actions more effective. Strict efficiency codes help to create a local market for more efficient fixtures and appliances. Additionally, once codes are adopted, a legal framework is established for future amendments and ordinances.

While the conservation measures set forth are fairly common and feasible to implement, realizing the projected water conservation savings requires full engagement by the stakeholders and a sustained commitment to the conservation programs. Cumberland County has significant potential for conservation in the short and medium term as utilities reduce their water loss and customers increase their water use efficiency. In the long term, however, real shifts in behavior and in efficiency standards will need to be firmly established to see continued progress in reducing water use. It should be noted that even with significant conservation, Cumberland County's water use will almost certainly rise over the next 50 years. The rate of growth in water needs, however, can be slowed by the adoption of an ambitious conservation plan.

8. Conclusion

Cumberland County faces a challenge in meeting future water needs as the county grows. Continued rapid growth and the chance of future droughts like the one in 2007 highlight the importance of a long term solution to meeting water needs. Numerous proposals exist for increasing water supplies, but this study instead examines the potential for reducing demand.

Six feasible conservation measures have been presented as methods to effectively reduce water demand, inefficient water use, and water loss. Cumberland County has excellent potential for increasing water efficiency, both in the distribution system and on the part of water users. A comprehensive water plan can take advantage of the potential water savings, and almost certainly postpone the need for new water sources.

This Water Conservation Plan outlines a series of measures which can significantly slow the growth of Cumberland's water needs while allowing the county to grow. While the conservation targets are certainly achievable, it will take commitment and cooperation on the parts of numerous stakeholders.

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