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Memo

To: Walter Green and Parvathi Gaddipatti, Nashville District Army Corps of Engineers

From: Stuart Stein and Lars Hanson, GKY & Associates

Date: March 14, 2008 (revised, September 23, 2008)

Re: Water Needs Assessment for the Cumberland County Regional Water Supply Study

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1. Purpose and Background

This report addresses the 50 year water demand projections for Cumberland County, TN as contracted in the *Phase II Needs Assessment and Water Conservation Plan for Cumberland County Regional Water Supply Study*.(July 11, 2006) That document states:

> "The A/E shall develop assumptions for growth rate in growing from existing to ultimate land use. The densities and land use categories will be multiplied by assumed water use factors to determine total water use on 10 year increments for a 50 year period. These projections will only be required for Cumberland County."

As indicated in the Phase II needs assessment instructions, the projections have been completed using the IWR-MAIN Forecast Manager© and IWR-MAIN Conservation Manager© software developed by Planning and Management Consultants, Ltd. (PMCL).

This report builds on the *Land-use assumptions for Phase II of the Cumberland County Regional Water Supply Study* memorandum (hereafter referred to as the "Land Use Memo") in order to develop the 50 year water demand projection. All necessary and relevant analysis used to create the projection is presented, followed by the baseline projections. The impact of conservation measures will be presented in future reports.

2. Revisions to the Land Use Memo

The Land Use Memo presented projections for population, housing units, and employment by study area and countywide for Cumberland, TN. These figures have currently been agreed upon by the relevant stakeholders.

Upon further review, however, GKY & Associates have decided to slightly revise the projections for the employment projections. We base this decision on a more careful examination of historical employment metrics upon which the projections are based.

The alteration comes from a decision to change the data source upon which the projections were based. Page 8 of the Land Use Memo indicated that a constant population/employee ratio of 2.41 was assumed based on employment data provided by the Cumberland County Chamber of Commerce for the years 1990 – 2006.

Further research indicated that the employment data given agreed quite well with the "employed persons" number of the Bureau of Labor Statistics (BLS) Civilian Labor Force estimates. The BLS data reflects the number of persons *living* in the county who are employed. To better estimate commercial water demand, it is more important to recognize the number of employees working at establishments operating in the county. The Economic Census, first under the Standard Industrial Classification (SIC) and then the North American Industrial Classification System (NAICS), keeps this particular statistic. (Data can be most easily accessed for Cumberland County using the Census Bureau's USACounties™ database: http://censtats.census.gov/usa/usa.shtml).

Figure 1 below illustrates the difference in the yearly population/employee statistics when calculated using the aforementioned data sources. All three cases used the same baseline population data from the census.

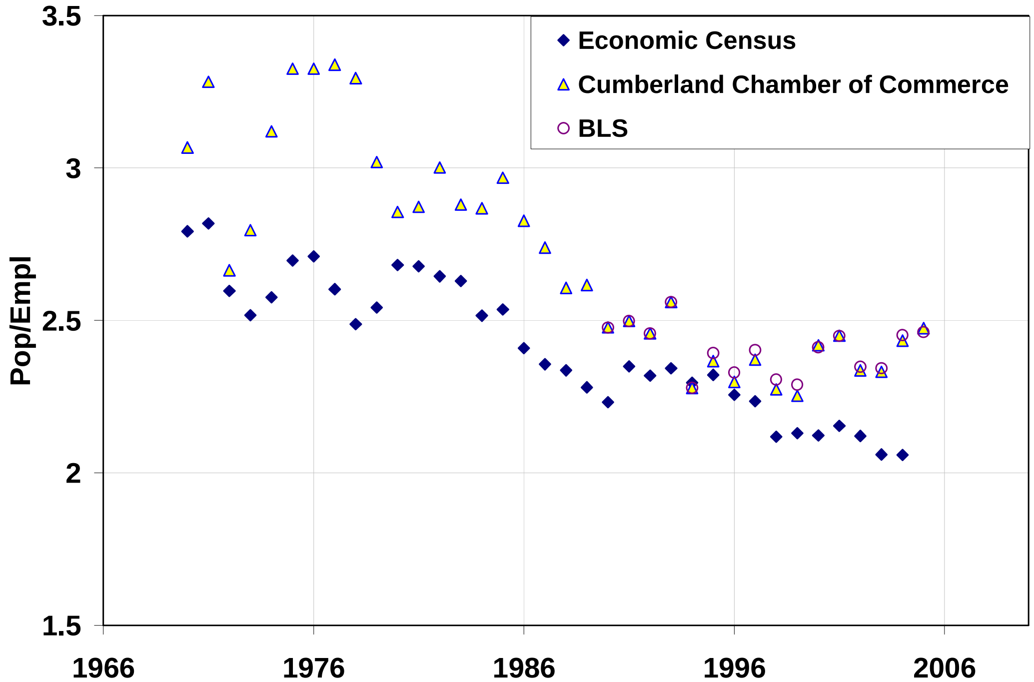

Figure 1 - Population per Employee in Cumberland County, TN calculated using 3 different data sources.

The data in Figure 1 show similar trends among the three sources until the early 1990s when Cumberland began its current growth phase. The demographic nature of new residents in the county (mostly retirees) supports concluding that there is a stabilization and perhaps a slight increase in the population to employee ratio according to Chamber of Commerce and BLS estimates. The Economic Census data show a continued decrease which may indicate that the population growth is in fact spurring economic development and driving employment growth. The additional employment for the Economic Census data can be explained by employees from nearby counties commuting to work in Cumberland, more residents working multiple jobs, and establishments with multiple shifts.

We believe that the Economic Census data lead to a more conservative (higher) water use projection. By basing the employment projection on the trends seen in the economic census data, the projections will include a greater potential for future economic development. The Economic Census data in Figure 1 indicate a continued downward trend in the population per employee statistic, though the rate of decrease has slowed.

As in the Land Use Memo, employment projections for each study area are based on a countywide population per employee value. For the revision, however, the Economic Census data are used for the baseline calculation, and the trend continues downward according to Table 1.

Table 1 - Population per Employee Statistic used for Employment Projections

Year	**2006**	**2016**	**2026**	**2036**	**2046**	**2056**
Pop/Empl *Countywide*	2.09	2.05	2.01	1.97	1.94	1.93

Table 1 indicates a change in the population per employee of -0.04 per decade until 2036, and even lower thereafter. This is significantly slower than the historical average of -0.19 per decade for the 1970 – 2004 period, which reflects in part the aging population of Cumberland, and in part, the higher (and still increasing) population and employment base, which dampens the rate of change. Still, this projection allows for economic expansion as the county grows, unlike the previous assumption of a constant population/employee ratio.

The following section shows the updated employment projections, summarized along with the population and housing projections.

3. Summary Growth Projections

The justifications and methods for the population, housing and employment projections were presented in the Land Use Memo and accompanying responses to stakeholder comments. Tables 2 – 4 show the projections for population, housing and employment, respectively.

Table 2 – Population projections for Cumberland County

Study Area	Scenario	2006	2016	2026	2036	2046	2056
Crossville	Slow	10,433	12,718	15,002	15,002	15,002	15,002
	Expected	10,433	13,355	15,002	15,002	15,002	15,002
	Aggressive	10,433	14,021	15,002	15,002	15,002	15,002
Cumberland Cove	Slow	1,235	1,506	1,836	2,238	2,728	3,325
	Expected	1,235	1,743	2,458	3,304	4,440	4,637
	Aggressive	1,235	1,919	2,980	4,410	4,637	4,637
Fairfield Glade	Slow	6,400	9,474	12,732	15,520	18,919	23,062
	Expected	6,400	9,939	15,435	22,848	30,125	30,125
	Aggressive	6,400	10,932	18,674	30,125	30,125	30,125
Lake Tansi	Slow	5,000	6,095	6,733	8,207	10,004	12,195
	Expected	5,000	8,954	14,586	19,602	23,544	23,544
	Aggressive	5,000	10,795	19,332	23,544	23,544	23,544
Remaining County	Slow	29,238	29,828	30,430	30,982	31,450	31,925
	Expected	29,238	32,297	35,676	39,408	43,531	53,065
	Aggressive	29,238	33,932	39,379	45,701	67,649	90,915
Countywide	*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*

Table 3 – Housing projections for Cumberland County

Study Area	Scenario	2006	2016	2026	2036	2046	2056
Crossville	Slow	4,774	5,943	7,144	7,265	7,372	7,501
	Expected	4,774	6,241	7,144	7,265	7,372	7,501
	Aggressive	4,774	6,552	7,144	7,265	7,372	7,501
Cumberland Cove	Slow	477	591	731	902	1,113	1,380
	Expected	477	683	979	1,332	1,812	1,924
	Aggressive	477	752	1,187	1,778	1,893	1,924
Fairfield Glade	Slow	4,137	6,316	8,720	10,778	13,323	16,473
	Expected	4,137	6,626	10,572	15,866	21,215	21,518
	Aggressive	4,137	7,288	12,790	20,920	21,215	21,518
Lake Tansi	Slow	2,196	2,697	2,999	3,680	4,517	5,543
	Expected	2,196	3,962	6,497	8,790	10,630	10,702
	Aggressive	2,196	4,776	8,611	10,558	10,630	10,702
Remaining County	Slow	11,761	12,076	12,395	12,698	12,969	13,247
	Expected	11,761	13,076	14,532	16,151	17,951	22,018
	Aggressive	11,761	13,738	16,040	18,730	27,897	37,724
Countywide	*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*

Table 4 – Revised employment projections for Cumberland County

Study Area	Scenario	2006	2016	2026	2036	2046	2056
Crossville	Slow	4,986	6,204	7,464	7,615	7,733	7,773
	Expected	4,986	6,515	7,464	7,615	7,733	7,773
	Aggressive	4,986	6,840	7,464	7,615	7,733	7,773
Cumberland Cove	Slow	590	735	913	1,136	1,406	1,723
	Expected	590	850	1,223	1,677	2,289	2,403
	Aggressive	590	936	1,482	2,239	2,390	2,403
Fairfield Glade	Slow	3,059	4,621	6,334	7,878	9,752	11,949
	Expected	3,059	4,848	7,679	11,598	15,528	15,609
	Aggressive	3,059	5,333	9,290	15,292	15,528	15,609
Lake Tansi	Slow	2,390	2,973	3,350	4,166	5,157	6,319
	Expected	2,390	4,368	7,256	9,950	12,136	12,199
	Aggressive	2,390	5,266	9,618	11,951	12,136	12,199
Remaining County	Slow	13,974	14,550	15,139	15,727	16,211	16,541
	Expected	13,974	15,755	17,749	20,004	22,439	27,495
	Aggressive	13,974	16,552	19,592	23,199	34,871	47,106
Countywide	*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*

Tables 2-4 provide important inputs for the water demand forecast model. The employment projections are revised slightly upward from the projections presented in the Land Use Memo, but all the other projections remain the same.

The housing projections in Table 3 reflect the total housing in each study area, but unfortunately, these figures are based on total developed parcel data, and include both households on public supplied water, and houses with wells. Data from the parcel database and customer data from the utility districts indicated that the Cumberland Cove and Remaining County study areas had a significant portion of households on well water. In the other three study areas, a negligible portion (<1%) got their water from wells. Since the water demand projections are to inform public supply water planning, it is important to separate out the users on wells or self-supply. (Less than 1% of commercial establishments, excluding farms and golf courses, are self supplied, so only the residential sector is considered when differentiating between public supply and self supply.)

While the households on self and public supply must be calculated, the overall number of households remains as presented in Table 3. As mentioned before, the only study areas affected are Cumberland Cove and Remaining County. Based on the 2006 parcel data in the Tennessee Comptroller's Computer Assisted Appraisal System (CAAS), the portion of residential households not on public supply water is 46.0% in Cumberland Cove, and 32.4% in the Remaining County study areas. These figures are used to calculate the baseline division between public supply and self-supply households.

We assume that no new self-supplied housed will be added to the study. The Land Use Memo clearly indicates that the growth rates do not include subdivision of farm parcels in the Remaining County area in part because “many of these succeed due to sufficient well and septic conditions.” Therefore, we can exclude the possibility of growth in self-supplied households. It is more likely that there will be a decrease over time in the number of the self-supplied households due to expansions of the water system and the natural “death” rate of housing.

The death rate (or demolition rate) of housing was calculated by comparing the number of houses (by year built) in the 1990 and 2000 census. The yearly average demolition rate was weighted by the number of houses in each age category in the 1990 census. The final weighted average demolition rate is 0.88% per year. Rounding this up to 1% (to include houses being connected to public supply), we compute the yearly number of self-supply houses for each study year. No variation in demolition rate is assumed by scenario. The number of houses on public supply is calculated by subtracting the number of self-supplied houses from the total housing projection in Table 3. Table 5 shows the forecasted counts of residential households on public supply (“PS”) and self-supply (“SS”).

From this point forward, the water usage of the self-supplied households will not be included in the overall water demand projections. A separate section of the results, however, will present water use projections for these households.

Table 5 – Self supply and Public Supply households in Cumberland Cove and Remaining County

Study Area	PS/SS	Scenario	2006	2016	2026	2036	2046	2056
Cumberland Cove	SS	any	219	162	119	88	65	48
	PS	Slow	258	429	612	814	1048	1332
	PS	Expected	258	521	860	1244	1747	1876
	PS	Aggressive	258	590	1068	1690	1828	1876
Remaining County	SS	any	3811	2810	2072	1528	1127	831
	PS	Slow	7950	9266	10323	11170	11842	12416
	PS	Expected	7950	10266	12460	14623	16824	21187
	PS	Aggressive	7950	10928	13968	17202	26770	36893

4. Modeling Approach

The IWR-MAIN Forecast Manager© and Conservation Manager© are recognized as a state-of-the-art, industry standard water forecasting software. We utilize IWR-MAIN 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[i] explains in the detail the structure of 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 following usage model:

$$\boxed{\begin{array}{c}\text{Demand}\\ Q\end{array}} = \boxed{\begin{array}{c}\text{Counting Unit}\\ N\end{array}} \times \boxed{\begin{array}{c}\text{Use Factor}\\ q\end{array}} \qquad (1)$$

In short, the demand is determined multiplying some counting unit by a *per counting unit* 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. 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 (per capita, per house, etc) in a given time period. Thus, a water demand forecast requires projecting (at 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 demand for each subsector. (Subsectors can be grouped into sectors, but this has no effect on the overall projection.) If different parts of the study universe have different 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. Sections 4.1 – 4.5 describe the model structure particular to Cumberland County. Finally, as contracted, this study is a 50 year forecast with 2006 as a base year, and projections in 10 year increments.

4.1 Study Areas

The Land Use Memo and other previous consultations with the stakeholders have identified five study areas for the water demand projections. The Cumberland Cove, Fairfield Glade, and Lake Tansi areas have been identified as the primary growth areas in the county. The City of Crossville is the county's urban and commercial center, and the Remaining County area contains the rest of the county. Figure 2 shows the geographic extents of the five study areas.

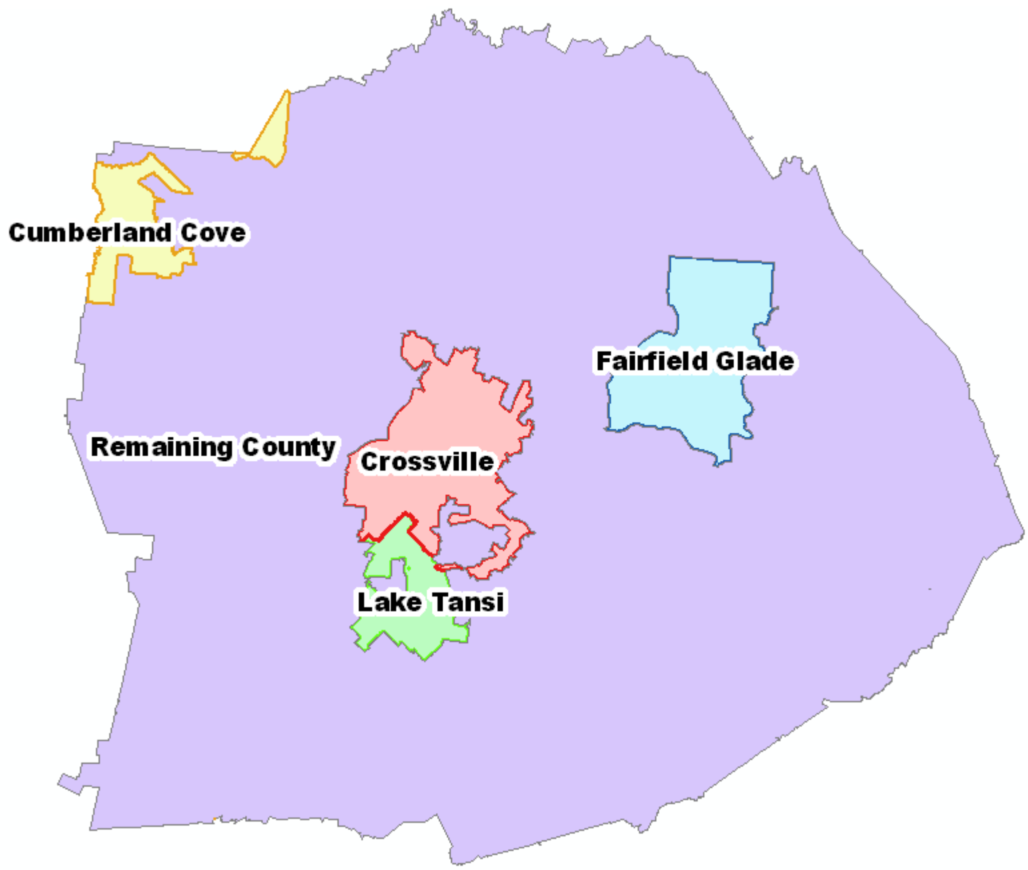

Figure 2 – The Five Cumberland County study areas

4.2 Sectors, Subsectors, and Counting Units

The study areas listed above have a similar set of sectors, subsectors, and counting units to limit the number of methods of counting unit projections. Table 6 displays the organization of the IWR-MAIN model with respect to sectors and subsectors. Additionally, the study areas that contain each of the subsector are indicated in the column at right. Tables 2 -5 contain the (previously) forecasted values of the counting units. Counting units for each subsector are identified in Table 6.

Table 6 – Sectors, subsectors, and counting units used for Cumberland County

Sector	Subsector	Counting Units	Study Areas
Residential	RES_PS	Housing Units	All
	RES_SS	Housing Units	Remaining County, CumberlandCove
NonResidential	NonRES	Employees	All
Cumberland Med. Center	CMC	Population (county)	Crossville
Other	UAW	%	All

Table 6 indicates a fairly coarse breakdown of sectors. The residential sector is broken into houses on public supply (RES-PS) and those on self-supplied water (RES-SS). Only the Cumberland Cove and Remaining County areas have significant numbers of self-supplied households (these are excluded from demand forecasts and reported separately in the results). The large majority of Cumberland County houses are single family homes, so no further breakdowns are made by type of dwelling unit. Tables 3 and 5 indicate the forecasted housing unit values for all of the subsectors.

All of the study areas include a non-residential sector. The non-residential subsector primarily includes commercial and industrial water users. The counting units are employee counts, which are projected in Table 4.

At the advice of several stakeholders, the Cumberland Medical Center (CMC) is included as a separate water user. Though there are CMC-owned buildings in several parts of the county, the majority of the demand occurs in Crossville, so the entire CMC sector is placed in Crossville. The counting unit for CMC, however, is the entire county population since residents from the entire county use it. The countywide population estimates can be found in Table 2, and further discussion of CMC can be found in Section 4.4.3.

The "Other" sector includes all water losses, or unaccounted for water (UAW). This is expressed as percentage of the total water use in a given study area. UAW is modeled by the Unmetered/Unaccounted tool in IWR-MAIN, and is calculated during the forecast, so no counting unit projection is needed. The percentage, however, must be specified for each year. Section 4.5 discusses the calculation of these percentages for the study areas.

4.3 Forecasting Model

IWR-MAIN's Forecast Manager and Conservation 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.

The effectiveness of a water use forecast depends, however, on the quality of the water usage data, the availability of historical explanatory variable data at appropriate geographic and time scales, and the ability to forecast future values of the explanatory variables. Since most of the forecast models depend on some kind of regression, it is important to have high quality historical water data. Cumberland's water use data is somewhat limited, though. For instance, of the four UDs, only Crossville has more than 4 years of monthly usage data, and only Crab Orchard reliably separates the commercial and residential sectors. Additionally, it is important to have historical data on the explanatory variables at a similar time scale, and be able to project the variables' future values. Neither of these conditions were met, and tests of regressions of various types with several combinations of explanatory variables yielded poor results. Thus, use factor models based on explanatory variables were rejected in 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. We further recommend that all utility districts begin tracking water use by sector (type of user), or at minimum by size of connection.

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. Failing to account for these efficiency changes is one reason water usage factors so often over-estimate actual future use. This point is discussed in greater detail in Section 6.5.

The end use model and calculation of associated parameters is discussed in detail in Appendix A. The following section presents the base year water use factors for each subsector. In all cases, the parameters of the end use model are constructed such that the water use factors match these reported values.

4.4 Base-year Water Usage Factors

When employing a constant 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 includes the rest of the year. Water use is assumed to be constant for all months within a given season.

The following sections describe how ‘water usage factors’ are determined for each sector.

4.4.1 Residential (RES_PS)

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).

As mentioned previously, the water demand varies by season, but not within seasons. Thus, the summer water use factor is the June – September average gpd/hhld, while the winter factor is the average of the remaining months. The South Cumberland and Crab Orchard averages are both based on roughly three years of user data.

The S. Cumberland and Crab Orchard data yielded annual averages of 119.69 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, the rest of the study areas are simply assigned the more conservative (overall) S. Cumberland water use factors. This assumption is partially supported by the people per household statistic (2006). See Table 7 for the residential water use factors and associated study areas.

Table 7 – Base-year (2006) residential water use factors

	Source Data	*S. Cumberland*	*Crab Orchard*
	Associated StudyAreas (pop/house)	*Crossville(2.19), CumberlandCove(2.59), LakeTansi(2.28), RemainingCounty(2.49)*	*Fairfield Glade (1.55)*
Demand (gpd/hhld)	Winter	114.00	108.15
	Summer	130.66	140.32
	Annual Avg.	119.69	118.90

4.4.2 NonResidential (NonRES)

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 some future commercial development will occur near growing areas with concentrated residential development. Still, it is likely much of the commercial will remain in Crossville, so the water use factors present an opportunity to partially redistribute demand more realistically.

There are four steps to estimating the commercial water demand by study area:

1. Determine portion of total developed commercial and industrial parcels in all UD-Study Area combinations

The location of the non-residential parcels in the county is one way to spatially disaggregate the non-residential water demand. We use the sum of developed commercial and industrial parcels as representative of all non-residential parcels. Then we compute the fraction of total parcels in each intersecting region of a study area and utility district. Figure 3 displays the study areas, utility district boundaries and location of the non-residential parcels.

As Figure 3 indicates, most of the commercial development is in Crossville, but the utility districts and study areas do not have perfect overlap. For the purposes of this demand estimation, Crossville and Catoosa remain separate, though they are currently the same utility district.

2. Estimate total county water demand based on UD estimates and fraction of parcels in UD

Estimates of total commercial water demand are known for Crab Orchard and South Cumberland UDs, and estimated for the City of Crossville (not including Catoosa) based on further assumptions from interviews with the City of Crossville UD. Using these estimates and the previously calculated portion of parcels in each UD, the expected total county non-residential water demand is projected. Total UD commercial demand divided by fraction of parcels in the UD equals the expected countywide demand. For the S. Cumberland, Crab Orchard, and City of Crossville UDs, the expected total nonresidential daily demand is roughly 1.1, 1.2 and 1.7 MGD, respectively. These figures are used to calculate the demand in the study areas in step 3. The expected total demand in the Catoosa and W. Cumberland areas is assumed to be equal to that of Crab Orchard. This assumption is based on the similar density of commercial development reflected in Figure 3.

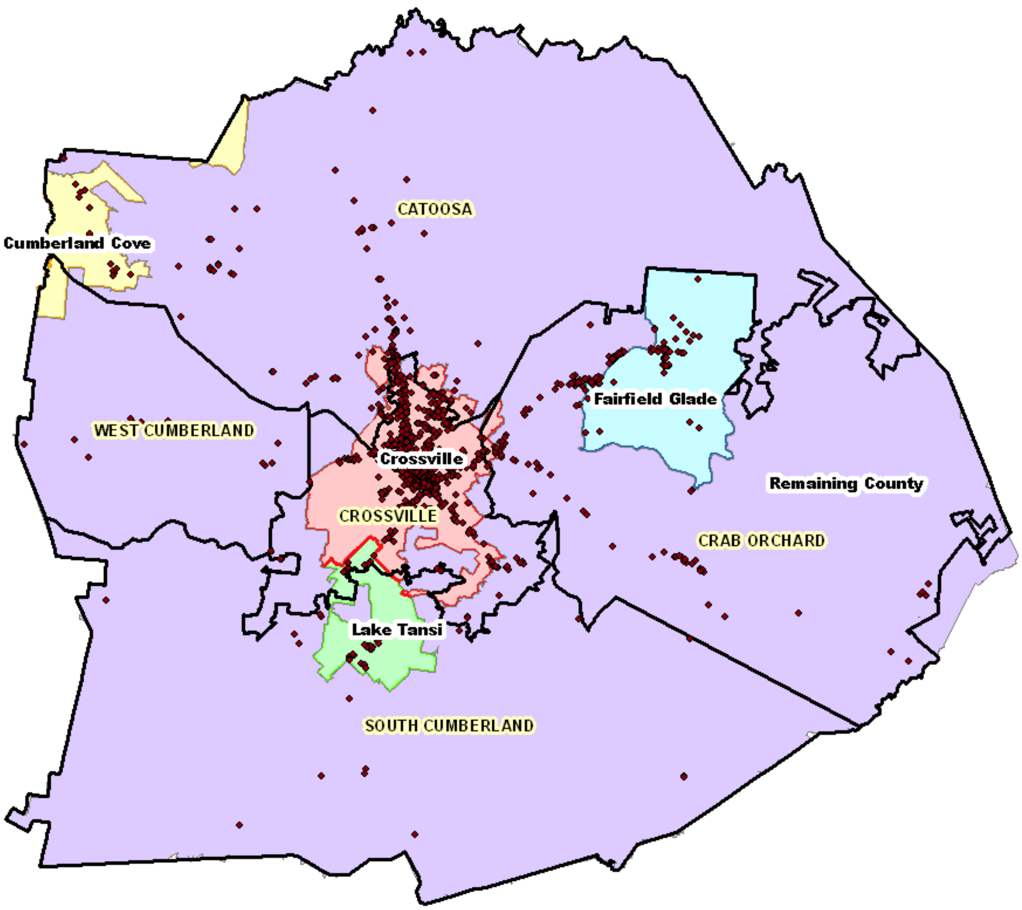

Figure 3 – Location of non-residential establishments (●) with respect to study areas and utility district boundaries.

3. Apportion water demand among the study areas according to expected total demand and geographic distribution

Using the expected total demand for each UD, we calculate the expected demand for each study area. Table 8 shows the fraction of total parcels in each study area – utility district combination. Impossible combinations are shown in gray. The demand in each study area is calculated by multiplying each cell in Table 8 by the appropriate expected total demand (indicated in the last row of the table), and then summing across the rows.

For example, the expected total NonRES demand in Fairfield Glade equals 0.060 (see table 8) times 1.23 (the expected total nonresidential demand in Crab Orchard), which is 0.07 MGD (see Table 9). For Crossville, 0.661(1.70) + 0.012(1.23) + 0.032(1.23) = 1.18.

Using this method, it is possible to generate the expected total demand by study area. Table 9 has the total water usage for each subsector. The variations in expected total demand partially take into account the geographic differences in nonresidential usage. Still, this method assumes that all parcels within a UD have identical water use patterns.

Table 8 – Fraction of Nonresidential parcels by study area and UD

UtilDistrict: / StudyArea	CROSS-VILLE	CRAB ORCHARD	SOUTH CUMB.	CATOOSA	WEST CUMB.	Grand Total
Crossville	0.661	0.012	0.000	0.032		0.704
Cumberland Cove				0.011	0.000	0.011
Fairfield Glade		0.060				0.060
Lake Tansi	0.000		0.021			0.021
Remaining County	0.026	0.085	0.016	0.061	0.016	0.204
Grand Total	0.687	0.157	0.036	0.104	0.016	1.000
Expected Countywide Demand (MGD)	***1.70***	***1.23***	***1.12***	***1.23****	***1.23****	

*Assumed equal to Crab Orchard

4. Calculate water use per employee and make seasonal adjustments

To make these calculations ready for use in IWR-MAIN, a water use per employee factor is needed. The total water use for each study area is simply divided the number of employees in the each study area (in the base year). Table 9 reports the values. As a note, the water use factors for Crossville have been adjusted to avoid double counting Cumberland Medical Center demand.

Seasonal adjustments in the water use factors are calculated in the same manner as in the residential sector, but using the commercial usage data. The rightmost column indicates on which UD's data the seasonal variations are based.

Table 9 – Non-Residential Water Usage Factors by Study Area

Study Area	**Exp. NonRES demand (MGD)**	**Employ ees** (2006)	**Water Use Factor** (gpd/empl)	**Winter factor** (gpd/empl)	**Summer factor** (gpd/empl)	**Seasonality data source**
Crossville	1.18	4986	235.7	207.4	248.4	Crossville
Cumberland Cove	0.01	590	23.1	20.7	29.6	Crab Orchard
Fairfield Glade	0.07	3059	24.2	21.6	31.0	Crab Orchard
Lake Tansi	0.02	2390	9.7	7.9	13.0	S. Cumberland
Remaining County	0.23	13974	18.6	16.7	23.9	Crab Orchard

4.4.3 Cumberland Medical Center

Due to the expectation that Cumberland County's primary population growth will come from an influx of retirees, some stakeholders expressed interest in seeing a separate forecast of the Cumberland Medical Center (CMC) demand. Three years of data on the Cumberland Medical Center accounts were available. As shown in Figure 4, the water demand remains roughly consistent on a per population (countywide) basis. We calculate the seasonal usage factors as averages of the demand in the appropriate months. For Cumberland Medical Center, this translates to 1.3 gpd per person in the Winter, and 1.59 gpd per person in the Summer.

Since the water use factor is specified as gpd per day per person, the counting unit for this subsector is logically population. Table 2 includes the countywide population projections for all three growth scenarios that are used as the counting units for CMC in the IWR-MAIN model.

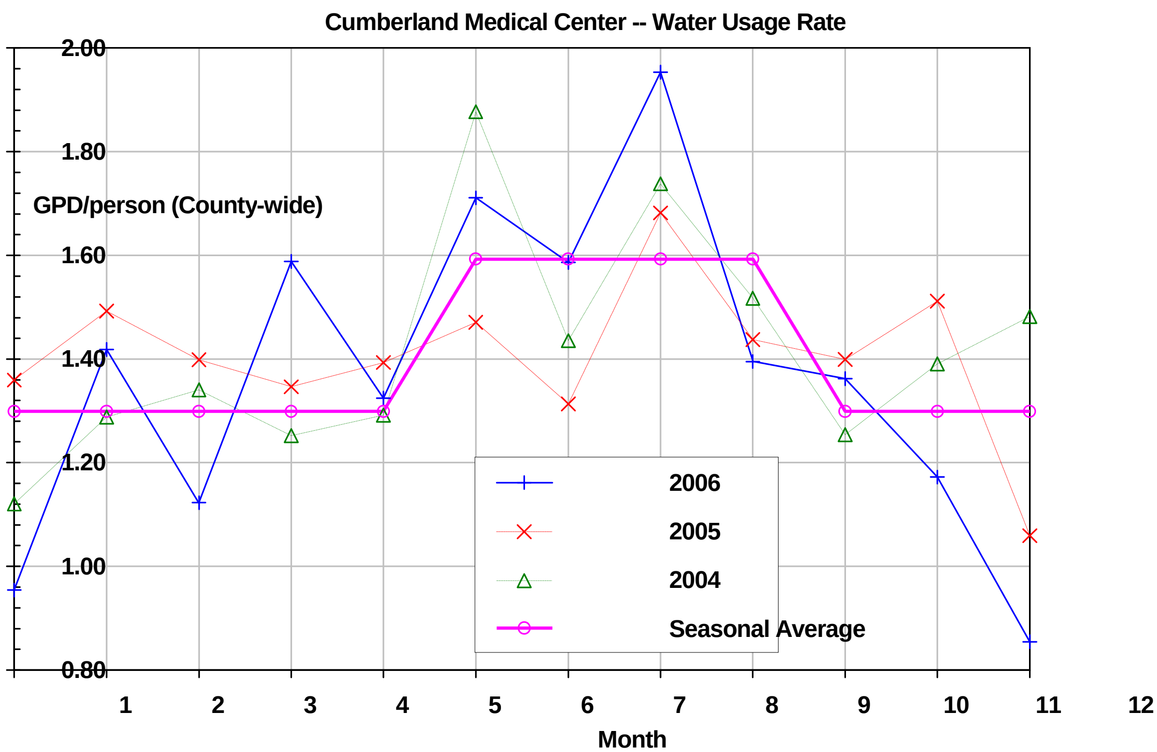

Figure 4 – Cumberland Medical Center water usage rate (2004 – 2006)

4.5 Unmetered/Unaccounted Water (UAW)

In any water system, it is inevitable that not all of the produced water reaches paying consumers. A combination of leaks, metering errors, accidental breaks, line flushing, and other losses make up what IWR-MAIN refers to as Unmetered/Unaccounted Water (UAW). For each study areas, we use the Unmetered/Unaccounted tool to set the year by year UAW percentage. (IWR-MAIN restricts the percentage is 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*[ii] selects a target loss percentage of 10% as worthy goal, rejecting engineering estimates ranging from 13 to 25%. The 1998 *Cumberland County Regional Water Supply Preliminary Engineering Report*[iii] 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, and for the baseline forecast, are constant in time. 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 10 shows the average monthly 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 10– Unaccounted-for-Water data by Utility District

Month	Crab Orchard	Crossville	South Cumb.	West Cumb.	Consumption Weighted Average
Jan	37.5%	16.2%	22.5%	32.5%	23.1%
Feb	35.4%	19.7%	20.0%	26.2%	23.2%
Mar	49.6%	25.4%	22.0%	26.8%	29.4%
Apr	32.2%	18.1%	18.3%	28.8%	21.9%
May	36.5%	19.0%	20.0%	23.4%	23.2%
Jun	28.4%	13.8%	23.1%	24.8%	19.0%
Jul	23.4%	14.3%	23.4%	17.5%	17.6%
Aug	27.6%	16.5%	20.1%	30.3%	20.9%
Sep	22.0%	13.5%	20.8%	21.3%	17.3%
Oct	35.9%	20.4%	22.5%	33.0%	24.8%
Nov	26.9%	20.1%	26.0%	30.3%	22.9%
Dec	39.8%	23.4%	22.3%	28.3%	26.1%
Annual	**32.9%**	**18.4%**	**21.7%**	**26.9%**	***22.4%***
Years of Data	4	11	4	4	

The loss figures in Table 10 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. 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 upcoming conservation measures to be evaluated will certainly include loss reduction programs, and their impact over time can best be assessed when compared to a steady baseline.

4.6 Scenarios

The Land Use Memo detailed three different growth scenarios to be used in forecasting future water use: Expected, Aggressive, and Slow. These different scenarios are modeled by using the Tools→ Sensitivity Analysis → User Count Values tool in IWR-MAIN. This is a sensitivity analysis which allows specifying alternative values for the user count values (i.e. counting units). The Slow growth projections were used for the low value, and Aggressive growth projections for the high value. No variation by month is assumed, and the sensitivity analysis is conducted by value (not percent).

5. Error Sources, Uncertainty Mitigation and Calibration

The Land Use Memo, and sections 3 – 4 or this report have described the methods, assumptions, and calculations necessary to build the Cumberland demand forecasting model in IWR-MAIN. Before presenting the results 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 there are actual water demand values in the forecast years.)

The largest source of error in this forecast is likely contained in the initial population projection in the Land Use Memo. By explicitly projecting Aggressive and Slow growth, we introduce bounds on the uncertainty of this projection. This is useful since the housing forecasts are calculated in tandem with the population projections, and the employment projections depend directly on population. In these projections, the assumed growth rates, people per house, and population per employee estimates all are sources of error. As an illustration of the potential error, Table 11 illustrates the consequences of a 0.5% deviation in the actual average population growth rate from the predicted rates. Results are shown in terms of number of units (e.g. people) in the forecast year per 1000 units in the base year.

Table 11– 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 11 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 error 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 are necessary. Any more complex model (such 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 uncertainty in the water use factors (especially in the monthly values). By averaging the months within 2 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.

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.

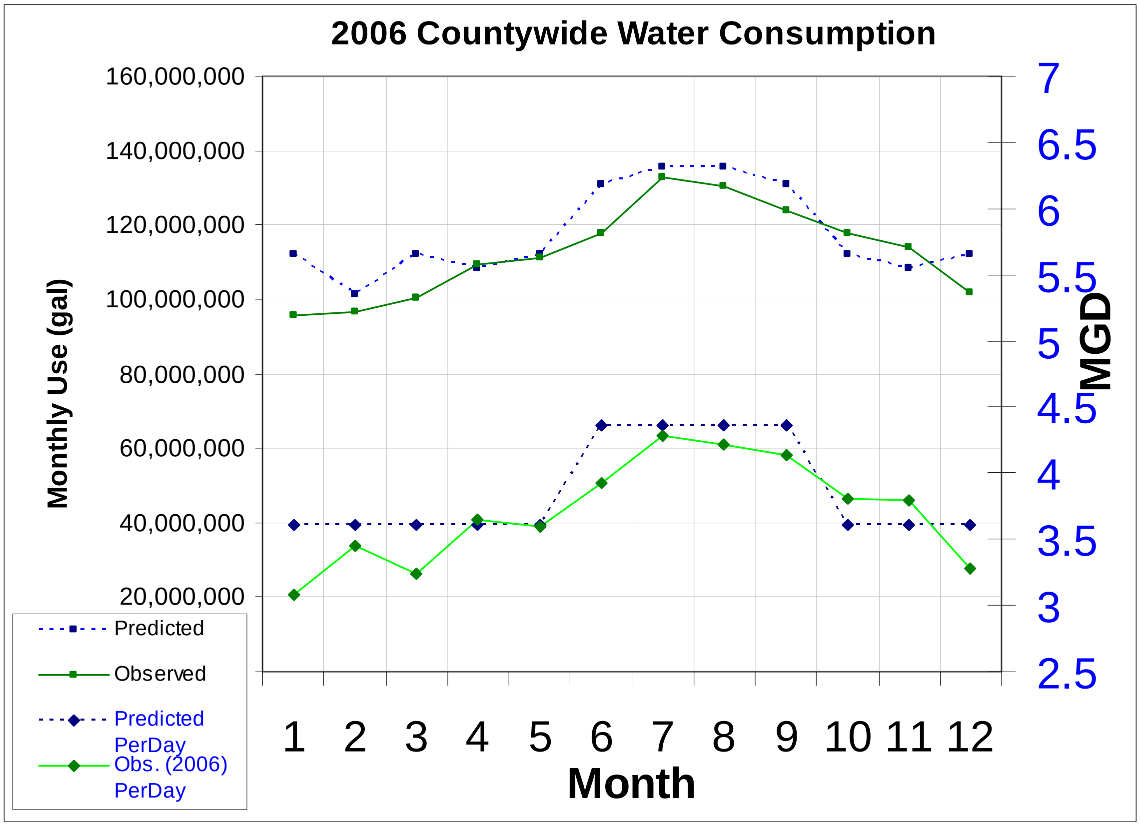

Figure 5 – Predicted versus Observed Countywide Water Consumption (excl. UAW)

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.

The agreement between the observed 2006 values and predicted values is slightly worse when the demand includes UAW. 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.

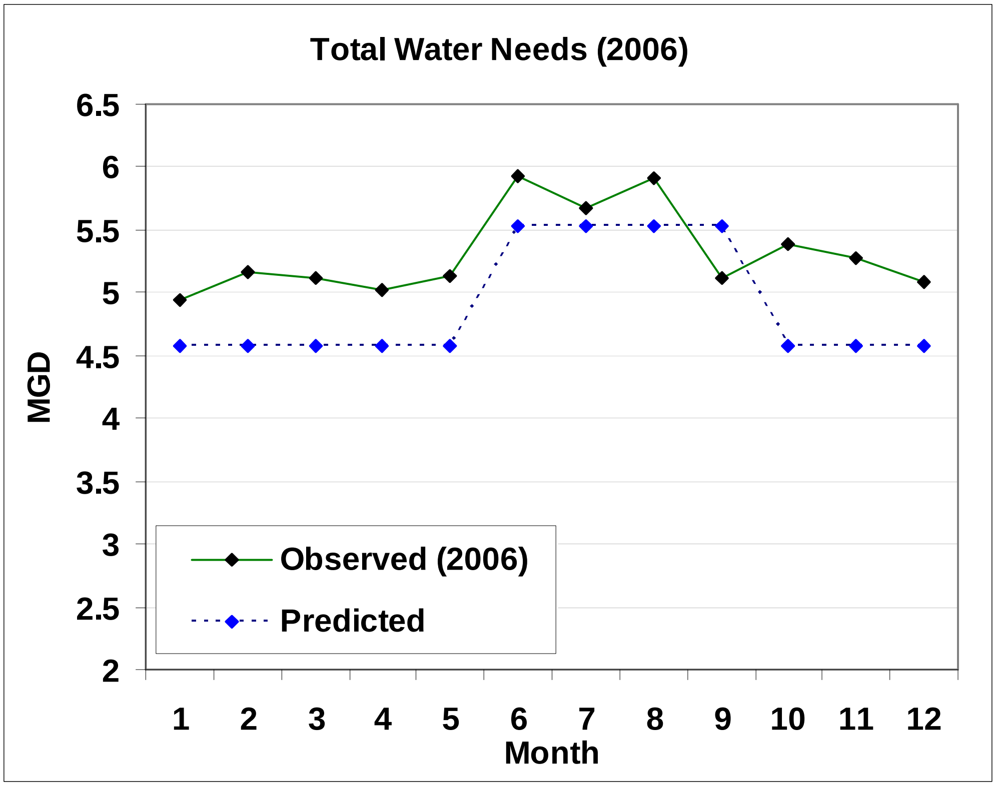

Figure 6 – Model predicted and observed Cumberland county water use in 2006.

6. 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. We present summary results here, but full results are available upon request.

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 demand, however, may be necessary for more advanced design of treatment capacity and conveyance. Peak demand estimates were not called for in the scope of services, but are presented in section 6.1 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.

6.1 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.

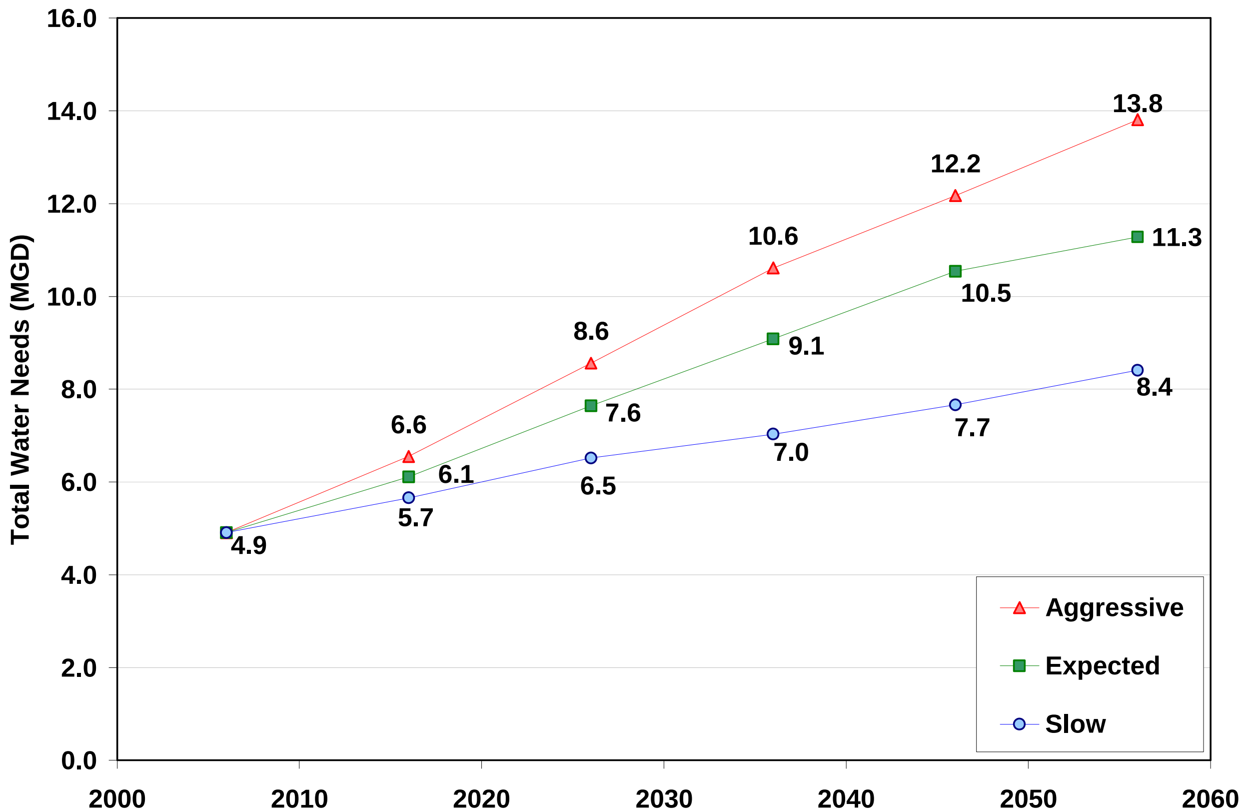

Figure 7 – Countywide daily average total water needs forecast for the slow, expected, and aggressive growth scenarios.

Under any growth scenario the projected demand increases significantly. 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. Future work on conservation measures will more directly assess the effects of reducing UAW.

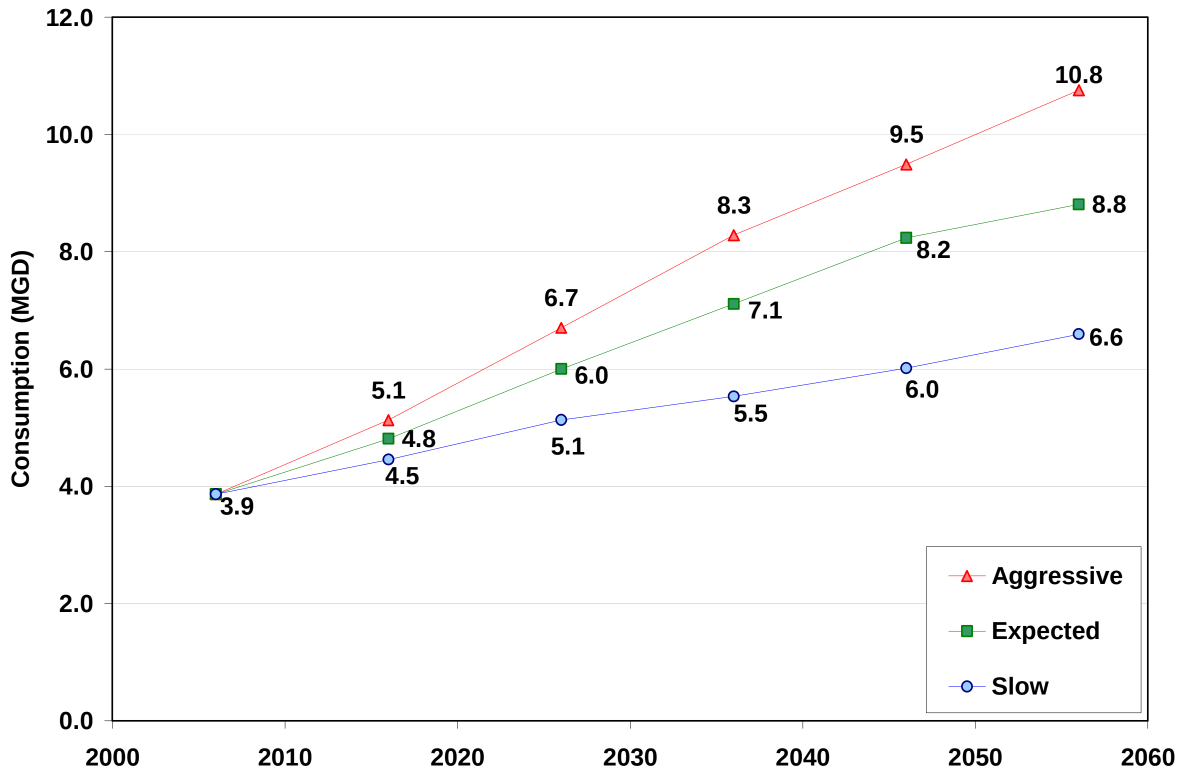

Figure 8 – Countywide daily average projected water consumption (excludes UAW)

Additionally, there are seasonal variations in expected demand. While the existing usage data could not support variations in usage factors by month, we did vary the usage 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% above the annual average, and winter usage is always roughly 6% below. This is a result of the cumulative effects of the winter and summer use factors for each of the subsectors and study areas described in section 4.4. Table 12 displays the countywide daily demand by season.

Table 12– Seasonal variations and peak projected total demand (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 12 also displays the projected peak demands, which reflect a 1.35 peakage factor applied 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.

6.2 By Subsector

Table 13 indicates the annual average daily demand by subsector for the entire county.

Table 13– 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**	**4.91**	**6.55**	**8.56**	**10.61**	**12.18**
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**	**4.91**	**6.11**	**7.64**	**9.08**	**10.54**
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**

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 more significant water 'use' than the nonresidential sector under the aggressive scenario and the expected scenario at the 50 year time horizon. While the UAW percentage is based on the best available current loss estimates, we view this sector as most likely to be a high estimate of actual future UAW. The impact of loss reduction measures will be treated in the upcoming conservation measures analysis.

6.3 By Study Area

In contrast with past studies, this study not only attempts to forecast the aggregate total water needs, but also the water use within several study areas. Section 4 detailed several ways in which the geographic differences in water demand were included in the model. By viewing the results of the forecasts by study area, the differences between the growth scenarios become more evident.

Figure 9, Figure 10, and Figure 11 present the results by study area for the slow, expected, and aggressive growth scenarios, respectively. The effects of the study area specific limitations of growth become immediately apparent. The aggressive scenario clearly shows the land use limitations on growth become important for every study area except the Remaining County. The city of Crossville rapidly reaches its growth limit, though it should be noted that the Remaining County study area includes the majority of the Crossville suburbs.

Additionally, there appears to be a shift in the demand centers of the county over time. Notably, Fairfield Glade's rapid growth puts its water use on par with Crossville after 30-50 years. Lake Tansi and Cumberland Cove show significant increases with respect to their initial values, but never make up a very large portion of the countywide demand. Under the Aggressive growth scenario, it is clear that Remaining County area will absorb an increasing amount of growth as the other areas reach their growth limits.

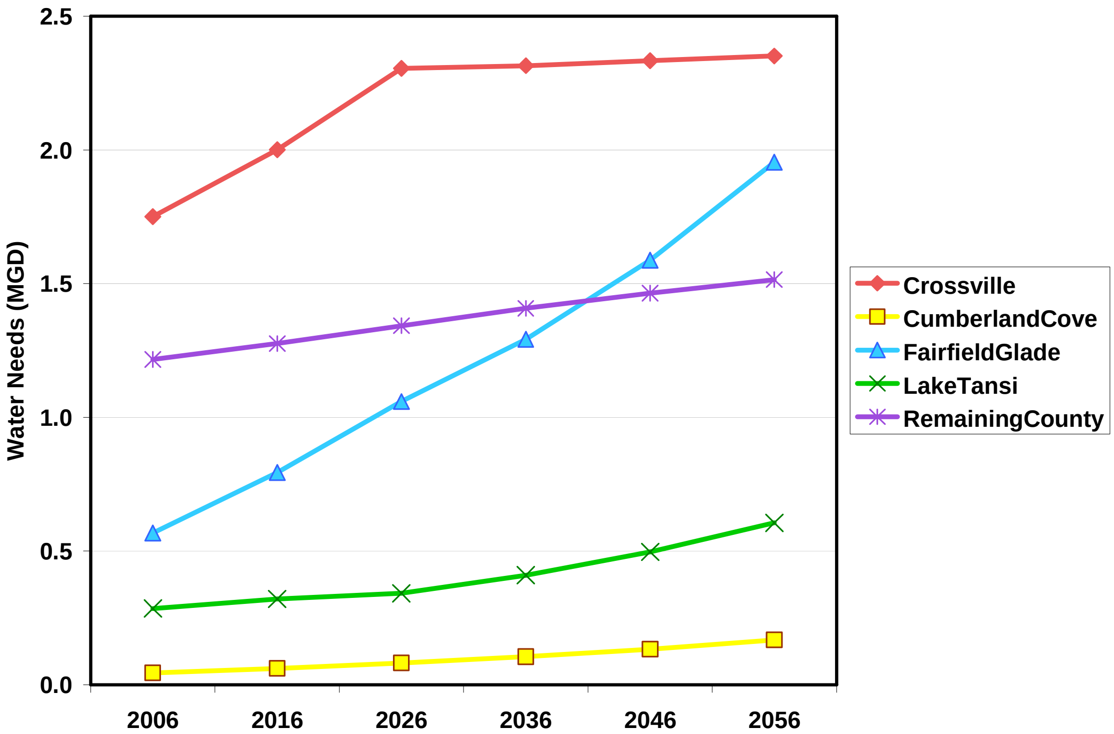

Figure 9 – Average daily total water needs by study area for the "Slow" growth scenario

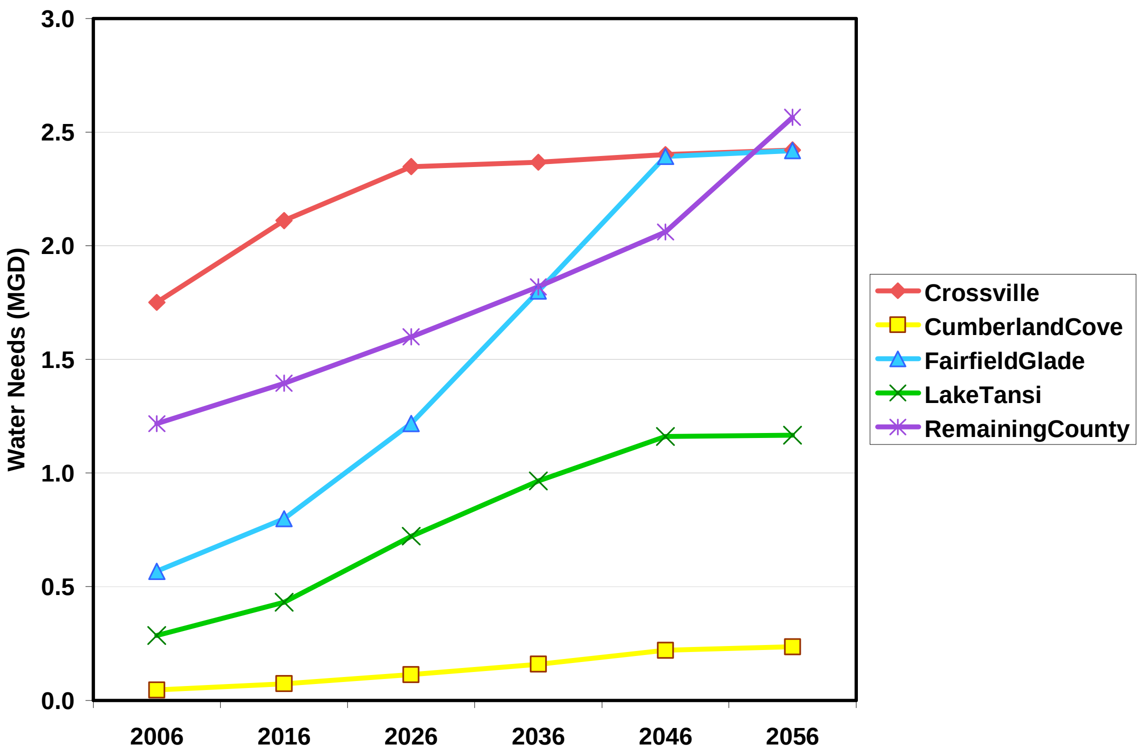

Figure 10 - Average daily total water needs by study area for the "Expected" growth scenario

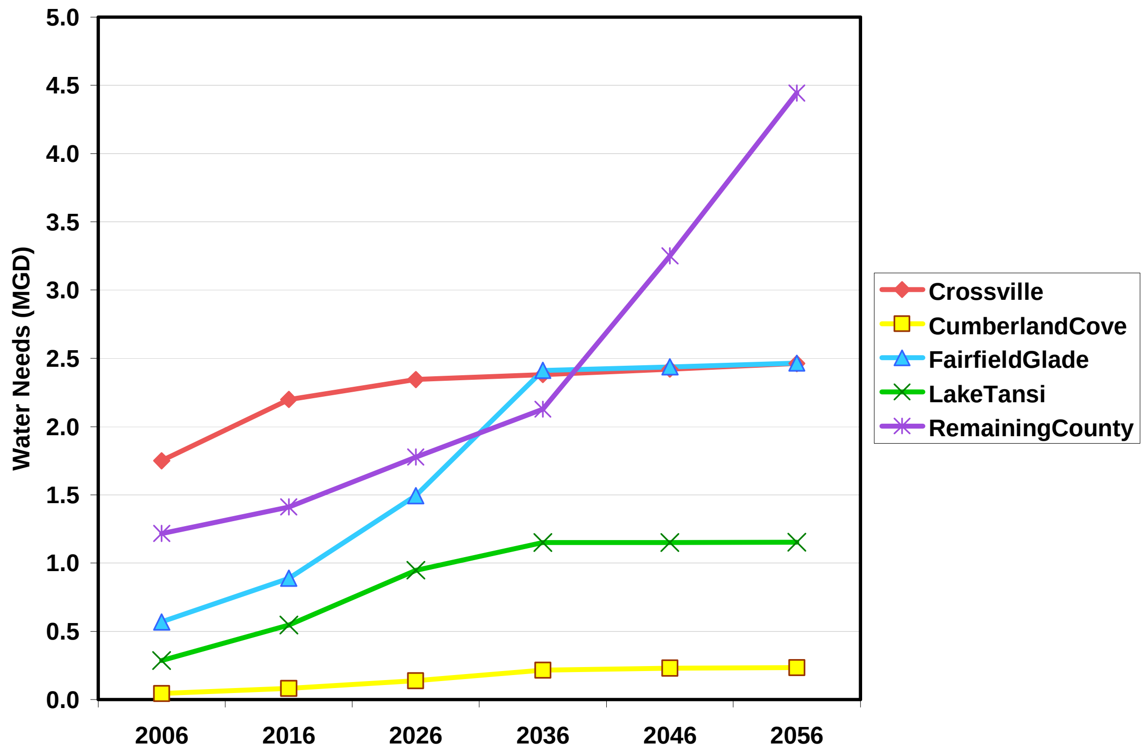

Figure 11 -Average daily total water needs by study area for the "Aggressive" growth scenario

The effects of growth limits can clearly be seen in Figures 9 through 11. Most notably, Crossville and Fairfield Glade both reach a saturation point in both the Expected and Aggressive growth scenarios. Lake Tansi shows a similar trend, but arrives at a somewhat lower saturation point for total water use.

6.4 Comparisons to other projections

The water needs projections presented in Sections 6.1 – 6.3 are based on the forecasts, calculations and assumptions described in this report and the Land Use Memo. Previous reports by BDY&A and the Corps have used a variety of independent approaches to project water for Cumberland County. Though the methods used are highly varied, it is useful to compare the projections to get a sense of the range of possible forecasted water demands.

We present both the forecasted consumption and total water use (production). The consumption figures do not include UAW. The reported total water use values for the BDY&A and Corps reports are computed by adding on the 10 % loss assumed in those reports. (This is equivalent to 11.1% of consumption.) Figure 12 reports the consumption values, and Figure 13 reports the total demand including unaccounted for water.

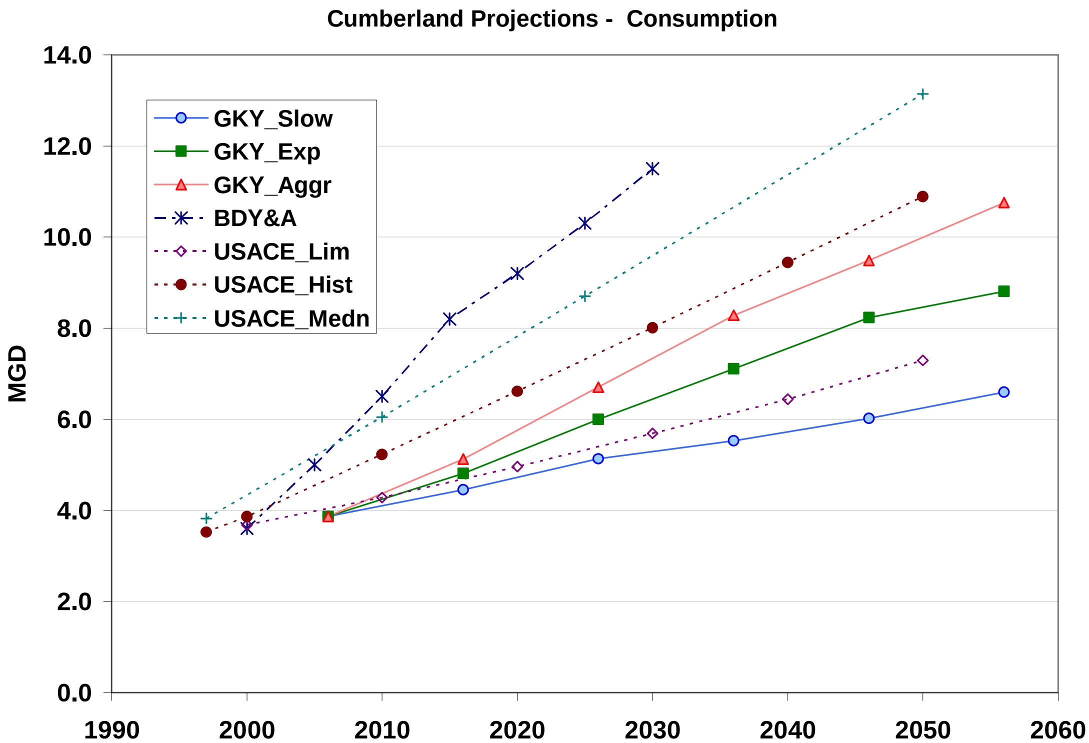

Figure 12 – Projections of average daily water consumption for Cumberland County by three different studies. (GKY= GKY & Associates, 2008; BDY & A = Breedlove, Dennis, Young and Associates, 2002; USACE = US Army Corps of Engineers and Ogden Environmental and Energy Services, 1998)

Figure 12 shows that the projections are generally in reasonable agreement, especially the USACE and GKY studies. The BDY&A study appears to have the most aggressive growth, which may be explained by modeling the water use factors as increasing proportionally with population. The USACE study used several different methods, which won't be described here, but the results seemed to fall within the same general range as the GKY estimates. The USACE projections are quite linear, however, in comparison to the GKY estimates which increase more rapidly as first and then level off (slightly) in response to reaching saturation points in the residential sector.

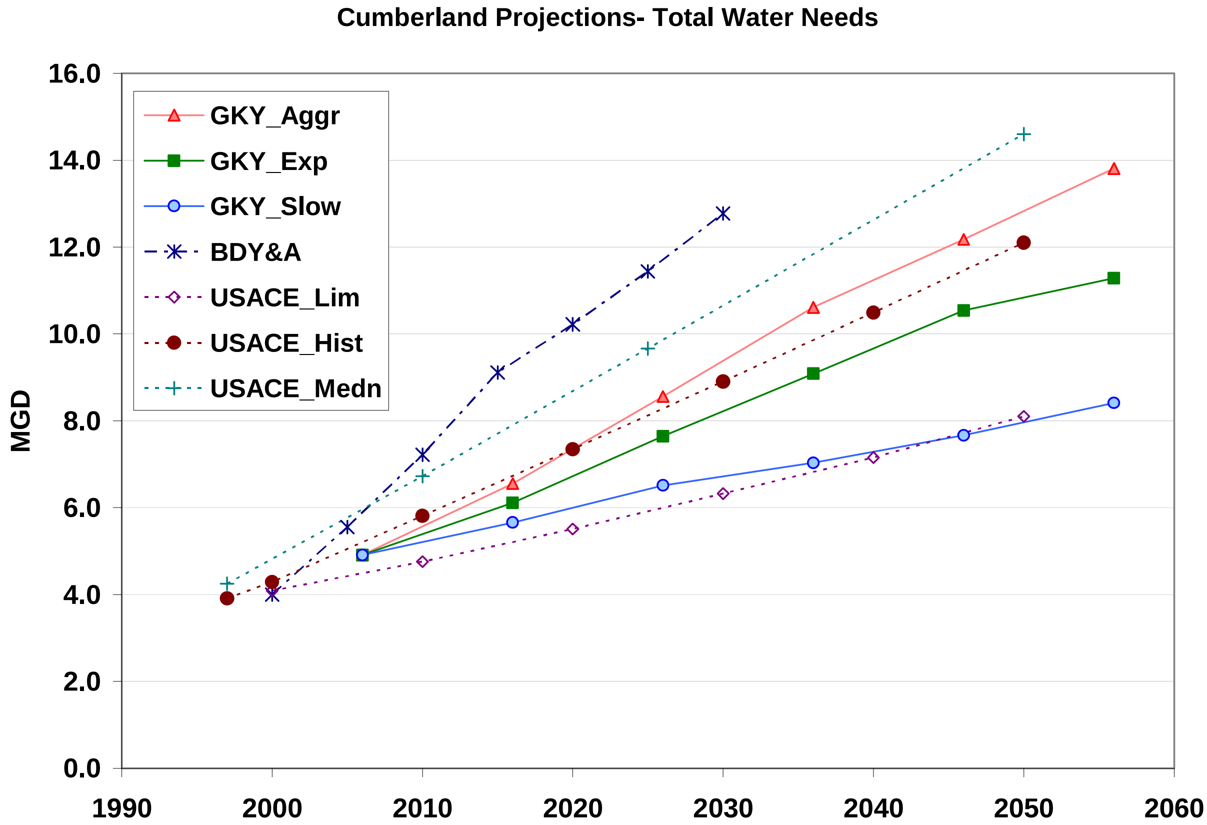

Figure 13 – Projections of average daily total water demand (includes UAW) for Cumberland County by three different studies.

Figure 13 displays the results of the same studies but includes the UAW in the forecasts, which makes these projections more reflective of required water production. The results are similar to those of the previous graph, but the GKY projections are comparatively higher with respect to the other projections. This may be explained by the higher UAW percentage used in the GKY study as compared to the other 2 studies.

Of note in the comparison is that the older studies seem to have mostly overestimated demand growth from their base year to present day. This is especially evident in the consumption chart. Most notably, the BDY&A study presents a very high estimate of demand. This is a 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 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 in a much higher proportion than the existing residences than it is in 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. Continued growth of these use factors can lead to extremely high use forecasts, especially when population continues rapid growth.

Instead of using aggregrate countywide use factors, GKY determines the factors based on averages of actual customer water usage (for the residential use factors). Additionally, by considering non-residential use separately, this study can capture the effects of county-wide economic expansions without increasing use factors.

The GKY study also presents lower water use estimates than previous studies due to a more realistic accounting for changes in water use efficiency. Gleick et al. (2003)[iv] 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.

We note that 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 have chosen to analyze these effects much more thoroughly and explicitly in the Water Conservation Plan.

6.5 Self-supply residential water use projections

None of the previously reported results in this section include the usage of self-supplied residential units. Two study areas, Cumberland Cove and Remaining County, have a significant number of self-supplied households. Though it has no real impact on the county water demand, we report the expected water use for these dwellings. The self-supplied houses are assumed to have the same water use factors as the public supply units. Furthermore, no variation is assumed by scenario, so all changes in the water usage can be explained by the forecasted changes in number of counting units which were presented in Table 5. The water usage by study year for the self-supplied houses is shown below in Table 14.

Table 14– Residential self-supply water use (MGD)

	2006	2016	2026	2036	2046	2056
Cumberland Cove	0.026	0.019	0.014	0.011	0.008	0.006
Remaining County	0.455	0.336	0.248	0.183	0.135	0.099
Total	0.482	0.355	0.262	0.193	0.142	0.105

7. Discussion

This study presents a baseline 50 year water needs assessment for Cumberland County's future water needs. Every effort was made to make the forecast reflect the current and expected future patterns of water use in the county with respect to historical water use, demographic data, and informed judgment of county officials and stakeholders. While long forecasts are inherently uncertain, great care was taken to reduce unnecessary uncertainty by making assumptions only where adequate data could reasonably support them. As this is a baseline forecast, the assumptions made are generally slightly conservative throughout the model. Moreover, the three scenarios in the model are designed to make handle uncertainty more explicitly, and better illustrate the known variability in the forecast.

The results of the IWR-MAIN modeling indicate that average water use in Cumberland County should at least double and potentially more than triple over the next 50 years. This baseline forecast provides a starting point from which to make decisions about infrastructure and water management strategies.

GKY & Associates invites your comments on this baseline water needs assessment.

8. Acknowledgments

We would like to thank the many people involved in this process for their continued insights and support. Notably, we would like to thank Walter Green, Parvathi Gaddipatti, and Ben Rohrbach of the Nashville district of the Army Corps of Engineers for their coordination efforts, advice, and assistance. Additionally, we would like to thank the managers and staff of the Cumberland UDs, notably:

- Everett Bolin, Crab Orchard Utility District
- Tim Begley and Sally Oglesby, City of Crossville Utility District
- Sandy Brewer, South Cumberland Utility District
- David Bell, West Cumberland Utility District

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[i] Planning and Management Consultants, Ltd. *IWR-MAIN Water Demand Management Suite: Forecast Manager*. 2006.

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

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

[iv] 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.

Appendix A – The End Use Model

This appendix describes the relevant background on the IWR-MAIN Conservation Manager software, and the selections made for the Cumberland County Water Needs Assessment.

The essential components of the forecasting model were presented at the beginning of Section 4. The end use model builds upon that model by subdividing the water use factor, *q*, into end uses. An *end use* generally refers a particular use of water that makes up a measurable portion of the total water use of a given counting unit. For example, for a household, dishwashers, toilets, showers, and lawn irrigation are all end uses. IWR-MAIN's end use model calculates the per unit water usage for an end use within a given subsector. As shown in (A.1), the total water use factor for a subsector (ss) is a sum of the water use factor for each end use.

$$q_{ss} = \sum_{i}^{n} q_{ei} \qquad \text{(A.1)}$$

Where:
q_{ss} - water use factor of the subsector
$q_{e,i}$ - water use factor for end use i
n - number of end uses in the subsector

An end use water use factor is determined by the *mechanical parameters* of each end use and the distribution of units in the subsector among different efficiency classes. Conservation Manager allows the definition of three efficiency classes for each end use: *Nonconserving, Conserving, and Ultraconserving.* Each class has its own mechanical parameters. For the purpose of this study, mechanical parameters have equivalent units to water use factors (gpd/unit). The distribution of units in the efficiency classes is determined by saturation parameters. Equation (A.2) displays the structure of the end use model, and defines the variables.

$$q_e = \left[\left(M_1 S_1 + M_2 S_2 + M_3 S_3\right) \cdot U_N\right] \cdot A_N \qquad \text{(A.2)}$$

Where:
q_e is the water use rate for end use, e
M_1, M_2, M_3 are the nonconserving, conserving, ultraconserving mechanical parameters, respectively
S_1, S_2, S_3 are the saturation parameters of the units among the nonconserving, conserving, and ultraconserving efficiency classes, respectively, where $S_1+S_2+S_3=1$
U_N is the intensity of usage parameter
A_N is the saturation rate of the end use within the subsector

For this needs assessment, end uses are aggregated since there is little data available about the saturation of particular end uses among homes and businesses in Cumberland County. As a result, end uses are aggregated into indoor uses and outdoor uses for all subsectors except the Cumberland Medical Center, for which all water use is considered a single (indoor) end use.

The percentage of indoor versus outdoor use within each subsector is determined by the minimum month method. The minimum monthly use in the subsector is assumed to the portion attributed to indoor uses in non-summer months. This same proportion is ascribed to the use factor in a given subsector to get the indoor use non-conserving mechanical parameter. The winter outdoor usage is therefore the difference between the overall water use factor and the indoor use.

Indoor residential end uses are further disaggregated into potable and non-potable uses. The mechanical parameters for indoor use in the residential units were determined by average values national reported in Mayer et al., 1999. Table 1 displays the average daily per capita indoor water use by end uses for the average users, and the potential reduction if the users used the best practical fixtures and appliances.

Table 1 Average daily per capita use by end uses, and lifetimes of end use fixtures

End Use	Lifetime *	NonConserving		Best Practical		Pot/NonPot
		gpd/cap	%total	gpd/cap	%total	
Showers	15	11.6	16.8%	8.8	19.5%	Potable
Baths	15	1.2	1.7%	1.2	2.7%	Potable
Faucets	17	10.9	15.7%	10.8	23.9%	Potable
Leaks	-	9.5	13.7%	4	8.8%	Potable
Toilets	30+	18.5	26.7%	8.2	18.1%	NonPotable
Clothes Washer	10	15	21.7%	10	22.1%	NonPotable
Other	13	1.6	2.2%	1.6	3.5%	NonPotable
DishWasher	9	1	1.4%	0.7	1.5%	NonPotable
Potable		*33.2*	*47.9%*	*24.8*	*54.7%*	
Non-potable		*36.1*	*52.1%*	*20.5*	*45.3%*	

* *from NAHB/Bank of America Home Equity Study of Life Expectancy of Home Components,Feb. 2007*

For this study, since end uses are relatively aggregated, A_N is assumed to be one (a one hundred percent penetration rate) for all end uses. Furthermore, the sum of S1, S2, and S3 is also one. Shifts between the classes are achieved as new units are built with more efficient end use technology, and as existing units replace less conserving fixtures with newer ones through natural replacement. These shifts are achieved by modifying the "S" parameters.

Table 2 displays the mechanical parameters corresponding to each efficiency class within each subsector. Ultraconserving mechanical parameters reflect the same percentage reductions as shown in Table 1 between nonconserving and best practical technology. The conserving mechanical parameters are merely the average of the non-conserving and ultraconserving values.

Table 2 Mechanical parameters and summer intensity factors by subsector and end use

StudyArea	Subsector	EndUse	Name	Non-conserving (gpd/unit)	Conserving (gpd/unit)	Ultra-conserving (gpd/unit)	Summer Intensity Factor
Crossville	Non-Residential	Outdoor	Cr_NR_out	49.97	42.47	34.98	*1.41*
Cumberland Cove	Non-Residential	Outdoor	CC_NR_out	5.79	4.63	4.05	*1.90*
Fairfield Glade	Non-Residential	Outdoor	FG_NR_out	5.20	4.42	3.64	*1.90*
LakeTansi	Non-Residential	Outdoor	LT_NR_out	1.91	1.62	1.33	*2.34*
Remaining County	Non-Residential	Outdoor	RC_NR_out	4.00	3.40	2.80	*1.90*
Crossville	Non-Residential	Indoor	Cr_NR_in	158.22	134.49	110.76	*1.13*
Cumberland Cove	Non-Residential	Indoor	CC_NR_in	14.89	11.91	10.42	*1.28*
Fairfield Glade	Non-Residential	Indoor	FG_NR_in	16.45	13.99	11.52	*1.28*
LakeTansi	Non-Residential	Indoor	LT_NR_in	6.03	5.13	4.22	*1.44*
Remaining County	Non-Residential	Indoor	RC_NR_in	12.65	10.76	8.86	*1.28*
All except Fairfield Glade	Residential	Outdoor	ExFG_RES_out	16.64	14.15	11.65	*1.50*
	Residential	Indoor-potable	ExFG_RES_p	46.64	40.74	34.84	*1.09*
	Residential	Indoor-nonpotable	ExFG_RES_np	50.72	39.76	28.80	*1.08*
Fairfield Glade	Residential	Outdoor	FG_RES_out	15.81	13.44	11.07	*2.01*
	Residential	Indoor-potable	FG_RES_p	44.31	38.71	33.10	*1.18*
	Residential	Indoor-nonpotable	FG_RES_np	48.19	37.77	27.36	*1.17*
Crossville	CMC	all	CMC_all	1.30	1.30	1.30	*1.22*

Section 4.4 presented the summer and winter use factors for the study areas and subsectors. Seasonality is controlled for each end use by the intensity of usage parameter (U_N). For the winter season, the base value of U_N is 1. The water use factor for the summer months is the product of the winter use factor and U_N. In the summer season, the increase in the U_N parameter varies by end use, but the total for each subsector adds up to the summer water use factor reported in Section 4.4. Intensity factors are determined by apportioning the summer increase among the end uses. In general, 50% of the increase goes to outdoor usage. The rest is apportioned equally among indoor uses, which reflects increased summer time usage by part-time residents and visitors.

For the baseline forecast, no units are assumed to be allocated to the ultraconserving class within the study period. In the base year (2006), all units are assumed to be in the nonconserving class in all subsectors. After 2009, all new units (except in Crossville) are attributed to the conserving class due to natural shifts in the available fixtures and the probable implementation of a plumbing code in Cumberland County. Since Crossville already has a plumbing code, new units begin as in the conserving class starting in 2006.

Finally, a natural replacement rate for fixtures and appliances of roughly 6.5% per year was calculated by making a use-weighted average of inverse of the lifetimes for the end uses in Table 1. Several utility district managers indicated that Cumberland county users were likely to wait slightly longer than the nation as a whole to replace fixtures. Thus, a conservative 5% natural replacement rate (equivalent to a 20 year life) was assumed as the yearly rate at which existing nonconserving units are shifted from nonconserving to conserving efficiency classes for all end uses.

Appendix B - Full results

B.1 Aggressive Scenario Full Needs Assessment (MGD)

Study Area	Data	Subsector	2006	2016	2026	2036	2046	2056
Crossville	Annual	RES_PS	0.57	0.71	0.74	0.74	0.74	0.75
		NonRES	1.11	1.39	1.47	1.47	1.48	1.48
		CMC	0.07	0.10	0.13	0.17	0.20	0.23
		UAW	0.41	0.52	0.55	0.56	0.57	0.58
	Summer	RES_PS	0.62	0.77	0.81	0.81	0.81	0.82
		NonRES	1.24	1.56	1.65	1.65	1.66	1.66
		CMC	0.08	0.11	0.15	0.19	0.22	0.26
		UAW	0.46	0.57	0.61	0.62	0.63	0.64
	Winter	RES_PS	0.54	0.68	0.71	0.71	0.71	0.72
		NonRES	1.04	1.30	1.38	1.38	1.39	1.39
		CMC	0.07	0.09	0.12	0.15	0.18	0.21
		UAW	0.39	0.49	0.52	0.53	0.54	0.54
Cumberland Cove	Annual	RES_PS	0.03	0.06	0.11	0.17	0.18	0.19
		NonRES	0.01	0.02	0.03	0.05	0.05	0.05
		UAW	0.01	0.02	0.04	0.06	0.07	0.07
	Summer	RES_PS	0.03	0.07	0.12	0.18	0.20	0.20
		NonRES	0.02	0.03	0.04	0.06	0.06	0.06
		UAW	0.02	0.03	0.05	0.07	0.08	0.08
	Winter	RES_PS	0.03	0.06	0.10	0.16	0.17	0.18
		NonRES	0.01	0.02	0.03	0.04	0.04	0.04
		UAW	0.01	0.02	0.04	0.06	0.06	0.07
Fairfield Glade	Annual	RES_PS	0.49	0.77	1.29	2.09	2.11	2.13
		NonRES	0.08	0.12	0.20	0.32	0.33	0.33
		UAW	0.17	0.27	0.45	0.72	0.73	0.74
	Summer	RES_PS	0.58	0.91	1.53	2.46	2.49	2.52
		NonRES	0.09	0.15	0.25	0.41	0.41	0.41
		UAW	0.20	0.32	0.53	0.86	0.87	0.88
	Winter	RES_PS	0.45	0.70	1.18	1.90	1.92	1.94
		NonRES	0.07	0.10	0.17	0.28	0.29	0.29
		UAW	0.15	0.24	0.40	0.65	0.66	0.67
Lake Tansi	Annual	RES_PS	0.26	0.50	0.87	1.06	1.06	1.07
		NonRES	0.02	0.04	0.08	0.09	0.09	0.09
		UAW	0.09	0.16	0.28	0.34	0.34	0.34
	Summer	RES_PS	0.29	0.55	0.95	1.16	1.16	1.17
		NonRES	0.03	0.06	0.10	0.12	0.12	0.12
		UAW	0.09	0.18	0.32	0.38	0.38	0.38
	Winter	RES_PS	0.25	0.48	0.83	1.01	1.01	1.02
		NonRES	0.02	0.04	0.06	0.07	0.07	0.07
		UAW	0.08	0.15	0.27	0.32	0.32	0.32
RemainingCounty	Annual	RES_PS	0.95	1.12	1.44	1.74	2.68	3.68
		NonRES	0.27	0.29	0.33	0.38	0.57	0.77
		UAW	0.36	0.42	0.53	0.64	0.97	1.33
	Summer	RES_PS	1.04	1.22	1.58	1.91	2.93	4.02
		NonRES	0.33	0.37	0.42	0.48	0.71	0.96
		UAW	0.41	0.47	0.60	0.71	1.09	1.49
	Winter	RES_PS	0.91	1.07	1.38	1.66	2.55	3.50
		NonRES	0.23	0.26	0.29	0.34	0.50	0.67
		UAW	0.34	0.39	0.50	0.60	0.91	1.25

B.2 Expected Scenario Full Needs Assessment (MGD)

StudyArea	Data	Subsector	2006	2016	2026	2036	2046	2056
Crossville	Annual	RES_PS	0.57	0.68	0.74	0.74	0.74	0.75
		NonRES	1.11	1.34	1.49	1.49	1.49	1.49
		CMC	0.07	0.09	0.12	0.14	0.16	0.18
		UAW	0.41	0.50	0.55	0.56	0.56	0.57
	Summer	RES_PS	0.62	0.74	0.81	0.81	0.81	0.82
		NonRES	1.24	1.53	1.70	1.69	1.70	1.70
		CMC	0.08	0.11	0.13	0.16	0.19	0.20
		UAW	0.46	0.56	0.62	0.62	0.63	0.64
	Winter	RES_PS	0.54	0.65	0.71	0.71	0.71	0.72
		NonRES	1.04	1.25	1.38	1.38	1.39	1.39
		CMC	0.07	0.09	0.11	0.13	0.15	0.16
		UAW	0.39	0.46	0.52	0.52	0.53	0.53
Cumberland Cove	Annual	RES_PS	0.03	0.05	0.09	0.12	0.17	0.19
		NonRES	0.01	0.02	0.03	0.03	0.05	0.05
		UAW	0.01	0.02	0.03	0.05	0.07	0.07
	Summer	RES_PS	0.03	0.06	0.10	0.14	0.19	0.20
		NonRES	0.02	0.02	0.03	0.04	0.06	0.06
		UAW	0.02	0.02	0.04	0.05	0.07	0.08
	Winter	RES_PS	0.03	0.05	0.08	0.12	0.17	0.18
		NonRES	0.01	0.02	0.02	0.03	0.04	0.04
		UAW	0.01	0.02	0.03	0.04	0.06	0.07
Fairfield Glade	Annual	RES_PS	0.49	0.69	1.05	1.55	2.06	2.09
		NonRES	0.08	0.11	0.17	0.25	0.33	0.33
		UAW	0.17	0.24	0.36	0.54	0.71	0.72
	Summer	RES_PS	0.58	0.79	1.20	1.77	2.36	2.38
		NonRES	0.09	0.14	0.21	0.31	0.41	0.41
		UAW	0.20	0.28	0.42	0.62	0.83	0.84
	Winter	RES_PS	0.45	0.64	0.98	1.44	1.92	1.94
		NonRES	0.07	0.10	0.14	0.22	0.29	0.29
		UAW	0.15	0.22	0.34	0.50	0.66	0.67
Lake Tansi	Annual	RES_PS	0.26	0.39	0.66	0.88	1.06	1.07
		NonRES	0.02	0.04	0.06	0.08	0.10	0.10
		UAW	0.09	0.13	0.22	0.29	0.35	0.35
	Summer	RES_PS	0.29	0.43	0.72	0.97	1.16	1.17
		NonRES	0.03	0.05	0.08	0.11	0.14	0.14
		UAW	0.09	0.14	0.24	0.32	0.39	0.39
	Winter	RES_PS	0.25	0.37	0.63	0.84	1.01	1.02
		NonRES	0.02	0.03	0.05	0.07	0.08	0.08
		UAW	0.08	0.12	0.20	0.27	0.33	0.33
RemainingCounty	Annual	RES_PS	0.95	1.12	1.30	1.49	1.69	2.12
		NonRES	0.27	0.28	0.30	0.33	0.37	0.45
		UAW	0.36	0.42	0.48	0.54	0.62	0.77
	Summer	RES_PS	1.04	1.22	1.42	1.63	1.85	2.31
		NonRES	0.33	0.35	0.38	0.42	0.46	0.56
		UAW	0.41	0.47	0.54	0.61	0.69	0.86
	Winter	RES_PS	0.91	1.06	1.23	1.42	1.61	2.02
		NonRES	0.23	0.24	0.27	0.29	0.32	0.39
		UAW	0.34	0.39	0.45	0.51	0.58	0.72

B.3 Slow Scenario Full Needs Assessment (MGD)

StudyArea	Data	Subsector	2006	2016	2026	2036	2046	2056
Crossville	Annual	RES_PS	0.57	0.65	0.74	0.74	0.74	0.75
		NonRES	1.11	1.27	1.47	1.47	1.48	1.48
		CMC	0.07	0.08	0.09	0.10	0.11	0.12
		UAW	0.41	0.47	0.54	0.54	0.55	0.55
	Summer	RES_PS	0.62	0.71	0.81	0.81	0.81	0.82
		NonRES	1.24	1.43	1.65	1.65	1.66	1.66
		CMC	0.08	0.09	0.11	0.11	0.12	0.14
		UAW	0.46	0.52	0.60	0.61	0.61	0.61
	Winter	RES_PS	0.54	0.62	0.71	0.71	0.71	0.72
		NonRES	1.04	1.19	1.38	1.38	1.39	1.39
		CMC	0.07	0.08	0.09	0.09	0.10	0.11
		UAW	0.39	0.44	0.51	0.51	0.52	0.52
Cumberland Cove	Annual	RES_PS	0.03	0.05	0.06	0.08	0.10	0.13
		NonRES	0.01	0.02	0.02	0.02	0.03	0.03
		UAW	0.01	0.02	0.02	0.03	0.04	0.05
	Summer	RES_PS	0.03	0.05	0.07	0.09	0.11	0.15
		NonRES	0.02	0.02	0.02	0.03	0.04	0.04
		UAW	0.02	0.02	0.03	0.04	0.04	0.06
	Winter	RES_PS	0.03	0.04	0.06	0.08	0.10	0.13
		NonRES	0.01	0.01	0.02	0.02	0.02	0.03
		UAW	0.01	0.02	0.02	0.03	0.04	0.05
Fairfield Glade	Annual	RES_PS	0.49	0.69	0.92	1.13	1.38	1.71
		NonRES	0.08	0.10	0.14	0.17	0.20	0.25
		UAW	0.17	0.24	0.32	0.39	0.47	0.58
	Summer	RES_PS	0.58	0.81	1.09	1.33	1.63	2.01
		NonRES	0.09	0.13	0.17	0.21	0.25	0.31
		UAW	0.20	0.28	0.38	0.46	0.56	0.69
	Winter	RES_PS	0.45	0.63	0.84	1.03	1.26	1.55
		NonRES	0.07	0.09	0.12	0.15	0.18	0.22
		UAW	0.15	0.21	0.29	0.35	0.43	0.53
Lake Tansi	Annual	RES_PS	0.26	0.29	0.31	0.38	0.45	0.55
		NonRES	0.02	0.03	0.03	0.03	0.04	0.05
		UAW	0.09	0.10	0.10	0.12	0.15	0.18
	Summer	RES_PS	0.29	0.32	0.34	0.41	0.50	0.61
		NonRES	0.03	0.04	0.04	0.05	0.06	0.07
		UAW	0.09	0.11	0.11	0.14	0.17	0.20
	Winter	RES_PS	0.25	0.28	0.30	0.36	0.43	0.53
		NonRES	0.02	0.02	0.02	0.03	0.04	0.04
		UAW	0.08	0.09	0.10	0.12	0.14	0.17
RemainingCounty	Annual	RES_PS	0.95	1.02	1.08	1.14	1.20	1.25
		NonRES	0.27	0.26	0.26	0.26	0.27	0.27
		UAW	0.36	0.38	0.40	0.42	0.44	0.45
	Summer	RES_PS	1.04	1.11	1.18	1.25	1.31	1.36
		NonRES	0.33	0.32	0.32	0.33	0.34	0.34
		UAW	0.41	0.43	0.45	0.47	0.49	0.51
	Winter	RES_PS	0.91	0.97	1.03	1.09	1.14	1.19
		NonRES	0.23	0.23	0.23	0.23	0.23	0.24
		UAW	0.34	0.36	0.38	0.39	0.41	0.42