USE OF LAND USE COEFFICIENTS TO FORECAST UTILITY SYSTEM DEMAND

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Abstract: Forecasts of water demands and wastewater flows have traditionally been made as a function of population within a defined service area. However, there are advantages to the use of an approach based on the water and wastewater demand characteristics of land use categories. This is particularly true in a rapidly changing environment where several divergent paths of future growth are possible, and where utility constraints are likely to be a significant factor limiting development. This approach has been used in Gwinnett County, Georgia, a suburban community in the eastern part of metropolitan Atlanta that has been one of the fastest growing counties in the nation over the past decade. Existing land uses were inventoried through field work and an analysis of aerial photographs, and the data were enumerated into eight principal drainage basins and 155 planning units. Historical water demand and wastewater flow data were correlated with existing land use data for each of several planning areas by matching utility customer classes to land use categories. After adjusting for changes in future development densities, the calculated utility coefficients were applied to three alternative future development scenarios (low, medium, and high density), and utility demands for each scenario were forecast.

The primary benefits of this approach include the ability to more accurately characterize future conditions; the provision of more specific information on the location of future demands for preliminary system planning; encouragement of a comprehensive land use planning effort; increased accuracy of preliminary cost estimates; and encouragement of closer communication between local planning and utilities departments.

OBJECTIVE OF MASTER PLANNING STRATEGY

Gwinnett County is a suburban community east of Atlanta, Georgia, with a population of about 350,000. From 1980 to 1989 Gwinnett County doubled its population and was one of the fastest growing counties in the United States. This rapid increase in population severely strained the County's infrastructure, especially with regard to water supply and wastewater treatment facilities. Existing wastewater treatment facilities are close to capacity and current projections of population by the Atlanta Regional Commission (ARC), the regional planning commission for the metropolitan Atlanta area, indicate that present sources of drinking water will be sufficient to meet demands only until about the year 2010.

In response to these conditions, the Gwinnett County Department of Public Utilities (DPU) has undertaken a long-term Water and Wastewater Master Plan for the provision of utility services to county residents. Because many components of utility infrastructure have long service lives, need proper space allotted for their installation, and require major capital investments, it is important to plan as carefully as possible to avoid over- or underestimating future demands. The objective of the master planning effort is to provide utility infrastructure during the County's major development phase that will support utility demands of the County at their eventual maximum levels.

FORECASTING METHODOLOGIES

Water and wastewater utility flows are most commonly forecast by extrapolating population and predicting unit water usage by per capita consumption (on a systemwide average basis). The advantage of this simplified deterministic approach is that it is quick, easy, and, provided the planner is confident in the population forecast and per capita usage estimate, has the potential for providing an accurate result. The disadvantage to this approach is that it has a high potential for not reflecting the development of the community or addressing the socioeconomic mix of development that may occur. Therefore, use of a simple extrapolation or population-based forecasting method is highly uncertain. Additionally, a conventional forecasting approach provides much less information to assist in water resources planning when evaluating different community development strategies. These considerations render a conventional forecasting approach unreliable for the Gwinnett County project.

A more appropriate heuristic forecasting method is to correlate water and wastewater demands to a land use basis. The utility demand coefficients can be individually scrutinized by land use and modified to reflect changes in development patterns to enhance reliability standards under the level of uncertainty about the demand characteristics. The forecasting strategy can then combine utility demand characteristics with different land use plans to generate utility demands that reflect different development patterns. Further, as the community land use plan evolves, a new utility expansion strategy can be derived to identify deviations from the budgeted capital improvements program.

The U.S. Corps of Engineers IWR-MAIN Water Use Use Forecasting Model was not used since the objective of this study was to evaluate utility demand characteristics with respect to generalized land use for master planning. The IWR-Main model uses more specific econometric data that could be generated once a land use plan was chosen for implementation. At that time, it would be appropriate to consider using the IWR-MAIN model to develop a more refined forecast.

PROJECT APPROACH TO ACHIEVE FORECASTING OBJECTIVES

To achieve a realistic and reliable utility forecast, the master plan is being prepared in concert with an update of the county's Land Use Plan. During the land use planning effort, a series of three alternative growth scenarios and associated land use forecasts were prepared by the County Department of Planning and Development (DPD). The scenarios describe alternative land use patterns for a time at which the County is expected to be fully developed and has reached its designated carrying capacity in terms of population, housing, and employment. For Gwinnett County this condition, known as "buildout," is approximated by the anticipated state of the County in 2040. Concurrently with the development of the land use projections, a model was developed to relate utility demands to land use patterns and to project ultimate water and wastewater demands as a function of the three alternative development scenarios. This approach of combining utility master planning with countywide land use planning provides a number of benefits over more conventional utility demand forecasting methods. A primary advantage is the ability to more accurately characterize future conditions, because information on anticipated density of land development provides a more detailed picture of the future than a single projection of population or employment. Demand characteristics can vary widely with the same total population and employment numbers, depending on the amount and type of nonresidential development and the density of residential development. A land use-based approach allows explicit consideration of these variables.

Another advantage of using land use information for forecasting utility demands is that it provides information not otherwise available on the relative costs of alternative development scenarios, which provides a planning tool for policy discussions with the public and elected officials, and results in a utility master plan that will support the county's land use plan and benefit from its perspective on the future.

PROJECTING FUTURE LAND USE PATTERNS

For each of the alternative future growth scenarios, preliminary ranges of population, number of households, and employment were established. These were modified from historical trend extrapolations using regression equations. Generalized growth scenarios were then identified for detailed analysis based upon the densities and character of several suburban U.S. counties: Mature Bedroom Community (low density), Balanced Growth (medium density), and Major Employment Center (high density). Land use prototypes were used to set a template of land uses for each planning unit.

Land use maps and small area projections were prepared for each scenario. The basic building blocks for the land use forecasts were eight land use prototypes, each of which has a fixed definition in each scenario. Each prototype is a characterization of subregions of metropolitan form shaped to approximate existing conditions in the suburbs of Atlanta. The land use prototypes were assigned to 155 irregularly shaped small areas of Gwinnett County called "planning units." The planning units averaged about 1,800 acres or 2.8 square miles, were identified from combinations of 1990 census blocks, and are subdivisions of the 1980 traffic analysis zones. The planning units were designed so that they can be aggregated to correspond to the eight drainage basins used by the DPU in wastewater system planning.

CORRELATION OF LAND USES WITH UTILITY DEMANDS

To make use of the existing and projected land use data developed by DPD, land use categories by DPD were correlated to the customer class categories used by DPU as depicted in Table 1. The objectives of this matching effort were to determine the most likely set of relationships between the two types of data and to estimate the water and wastewater demands associated with an acre of each type of land use. Several classifications in both data bases were combined to create categories suitable for utility demand forecasting. Seven combined customer class/land use groups were created: single family, multifamily, commercial, office, institutional, industrial, and wholesale.

The correlation of utility demands to land use patterns was performed for customers served by both the water and wastewater system. Customers on the water system alone were excluded because wastewater system customers were classified according to drainage basin, which facilitated correlation to land use data. The organization of these data also provided for a check on the utility data for each drainage basin. By comparing metered water consumption with metered wastewater flows at the treatment facilities, a judgment could be made as to whether the differences could be explained by known water use or system characteristics. While the demand characteristics of sewered and unsewered customers are not exactly identical, the majority of the County's water customers will be provided sewer service by buildout, so the demand patterns of currently sewered customers should provide a more accurate picture of the future than would forecasts based on the water system customers as a whole. A summary table of the data analysis is presented in Table 2.

APPLICATION OF COEFFICIENTS TO FUTURE SCENARIOS

Four of the eight major drainage basins were sufficiently developed in 1989 to produce reliable utility demand coefficients, so these basin-specific coefficients were applied to the future for these basins. The other four basins had too few customers to allow generalizing from 1989 into the future, so the countywide average coefficients were applied to these four basins.

Prior to the application of the 1989 coefficients to the projections of future land use, an adjustment was made to reflect changes in the density and intensity of use in each scenario. For residential classes, the adjustment reflected the percent change in households per acre, and the percentage change in persons per household. For the commercial type classes, the adjustment reflected the percent change in employment per acre.

The results found that use of this system yielded higher flows for some scenarios than per capita populations extrapolation alone would have yielded. The reason is that extrapolation of per capita consumption with respect to forecasted population does not reflect the changes in demand that can occur when jobs-population ratios change, or when a change in the employment mix occurs. Therefore, this system has benefits over more traditional methods when strategic land planning is being conducted.

Table 1
Match of DPU Customer Classes to DPD Land Use Categories

Combined Customer Class	DPU Customer Classes	DPD Current Land Use Categories	DPD Future Land Use Categories	Notes
Single Family	R--Res. owned S--Res. rented L--Res. lawns	LDR--Low-Density Residential	LDRS--Low Density with Sewer	
Multi-Family	M--Multi-Family A--Apartments	MDR--Med.-Density Residential HDR--High-Density Residential	MDR HDR	MDR is mostly apartment style units. includes duplexes and townhomes
Commercial	C--Commercial K--Comm. Irrig. H--Hotels	C/R--Comm./Retail CBD--Central Business District	CRE--Commercial Retail	CBD is a mixture of old houses & old 1-2 story retail (old downtown)
Office	O--Office	O/P--Office/Professional	OP	
Institutional	I--Institutional	I/P--Institution/Public TCU--Transportation Communic. Pub. Utilities	VP--Vacant Public	VP includes property developed by governments
Industrial	D--Distribution N--Manufacturing	LI--Light Ind. HI--Heavy Ind. OBP--Ofc. Bus. Pk.	LM--Light Manuf. HM--Heavy manuf. OBP	OBP is 25% ofc. & 75% warehouse
Wholesale	W--Wholesale	No land use code applies		Wholesale areas will be isolated by planning unit
Vacant	No service	VAC--Vacant	LDR--Low-Density Residential VO--Vacant Other VU--Vacant Undevelopable	LDR is agricultural with housing and no sewer service. VO is undeveloped, but developable VU is land that cannot be developed

NOTE: Combined customer class reflects a grouping of DPU's current customer classification with DPD's current and future land use classifications.

Table 2
Water Demand and Wastewater Flow Coefficients
(Annual Average Daily Flows)
Gwinnett County, Georgia, 1989

	Land Use Acres(a)	Average Percent of Land Sewered(b)	Land Sewered Acres(c)	Total Water Demand (mgd)(d)	Water Demand Coefficient (Water Per Sewered Acre) (gpd)(e)	Metered Irrigation (mgd)(f)	Remainder Returned to Sewer (Percent)(g)	Wastewater Flow (mgd)(h)	Wastewater Coefficient (Flow per Sewered Acre) (gpd)(i)
Single Family	58,978	21	12,257	6.00	489	0.37	90	5.09	415
Multi-Family	6,012	82	4,933	4.42	896	0.00	95	4.20	851
Commercial	3,015	65	1,949	3.01	1,546	0.56	95	2.33	1,196
Office	1,172	66	772	0.53	684	0.00	95	0.50	650
Institutional	26,587	54	14,278	0.43	30	0.00	95	0.41	29
Industrial	6,131	62	3,775	0.17	46	0.00	95	0.16	43
Unsewered	137,317	0	0	0.00	0	0.00	0	0.00	0
TOTALS	239,212		37,963	14.56	384	0.93	0	12.69	334
Wholesale water (sewered)(j)				2.40			85	2.04	
Wholesale water (unsewered)(j)				1.86			0	0.00	
Wholesale water outside of county(j)				3.75			0	0.00	
Retail water (unsewered)(k)				16.66			0	0.00	
Unaccounted for water (l)				7.73			0	0.00	
Process waste(l)				2.17			0	0.00	
Total water demand				49.13					
Estimated infiltration and inflow(m)								5.23	
Observed annual average inflow(n)								1.74	
Total wastewater flow(o)								21.70	

NOTES:

(a) Data from Gwinnett County Department of Planning and Development, for portion of county served by DPU (excludes areas served by wholesale customers of DPU).
(b) Estimated for each basin by DPU staff from the "housecount" project. Numbers shown are weighted averages of percentages from each drainage basin.
(c) Defined = [a times b]
(d) Data from Gwinnett County DPU "Facility Reports" (WTP 672), Jan-Dec 1989, AADF
(e) Defined = [d divided by c]
(f) Data from Gwinnett County DPU "Facility Reports" (WTP 672), Jan-Dec 1989, AADF
(g) Estimated by CH2M HILL and Gwinnett County DPU to reflect the percent of regular metered water that is delivered to the wastewater system.
(h) Defined = [(d minus f) times g]
(i) Defined = [(h times 1,000,000) divided by c]
(j) Data from Gwinnett County DPU Report WTP 680, Jan-Dec 1989
(k) Data from Gwinnett County DPU "Facility Reports" (WTP 672), Jan-Dec 1989
(l) Estimated from Gwinnett County DPU monthly "Director's Reports" from 1989. Approximately 15 percent of finished water is unaccounted for, and 4 percent of raw water is process waste.
(m) From Table 7-2-4. Base I/I is estimated from water consumption records by drainage basin.
(n) Calculated as the difference between base I/I and observed flows at plants.
(o) Excludes flows from DeKalb County.