Special Publication SJ99-SP3

FINAL REPORT

DEVELOPMENT OF A POPULATION-BASED WATER USE MODEL

Submitted To The St. Johns River Water Management District

CONTRACT NO. 96H200

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June 16, 1998

EXECUTIVE SUMMARY

The population-based water use model was developed for the St. Johns River Water Management District (District) to help plan for future water demand. This raster GIS-based model distributes the county population projections of the Bureau of Economic and Business Research into square mile sections. It does this by calculating a weighted average of the growth rate (from 1981 through 1990) of each section, and factoring in the positive influence of spatial features such as roads, water bodies, and existing residential and commercial areas. It then excludes non-developable lands, including wetlands, conservation areas, inappropriate land uses, road rights-of-way, and areas that have already reached their maximum allowable density, or are "built out". The remaining areas are then allocated population growth by section according to the section's growth rate and proximity to spatial influences. This growth by section is then summarized by utility service area boundaries for comparison with utility and local government estimates.

The model was run on all 19 counties within the District, but Orange County was selected as the prototype to be analyzed in this report because of that county's large population and rapid growth. The results of a comparison to transportation analysis zone (TAZ)-based models are also discussed in this report.

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INTRODUCTION

Overview of Project Requirements

The St. Johns River Water Management District (District) covers a 19 county area, yet the model must estimate the population growth for units small enough to accurately project the future population of water utilities. The 33 different water-providing utilities in Orange County alone have an average service area of 2.78 square miles. This need for small area projections required small modeling units (the minimum units of measure for which the projections are made). Although highly regarded, the county-level projections made by the University of Florida Bureau of Economic and Business Research (BEBR) covered too large an area for the District's purposes. BEBR's municipal and Metropolitan Statistical Area (MSA)-level projections do not coincide with water supply service area boundaries and are therefore not appropriate for the District's needs. The square mile section demarcated by the Public Lands Survey System (PLSS) was the logical choice for the modeling unit given the budgetary and time constraints.

Overview of Historical Population Trends

In 1840, Senator John Randolph of Virginia opposed the admission of Florida to the Union. He called Florida a "land of swamps and quagmires, of frogs and alligators and mosquitoes....No one would want to immigrate there, even from hell." By 1994, Florida's population had reached 14 million, the fourth largest population among the states and more than twice that of Virginia. Between 1980 and 1990, Florida's population grew by almost 3.2 million, more than any other state except California. This 33 percent increase during the 1980s was the fourth highest among the states (Scoggins and Pierce, ed., 1995).

Between 1900 and 1980, average population growth by decade was 89 percent in the southern region of Florida (south of Lake Okeechobee), 53 percent in the central region, and 24 percent in the northern region (north of Ocala). However, recent trends indicate an end to the southward shift in population. During the 1980s, the central region grew much more rapidly than the southern one, and the northern region grew almost as quickly. Since 1990, the northern region has grown the fastest and the southern the slowest. By 1994, only 36 percent of Florida's population lived in the southern region, with 45 percent in the central region and 19 percent in the northern one (Scoggins and Pierce, ed., 1995). The 19 counties served by the St. Johns River Water Management District occupy the eastern portions of these rapidly growing northern and central regions.

The Impetus for Modeling Population Growth

The State of Florida is surrounded by water to its east, west, and south, yet it has a limited water supply. Florida ranks among the top six states in annual precipitation, fifth in inland surface water, second in coastal water and first in ground water. Despite this seemingly bountiful supply of water, 60 percent of Floridians live in regions with water use restrictions, and over 98 percent live in regions that have enacted water consumption controls in the last five years. This paradoxical situation stems from the extreme intrastate heterogeneity in population and water supply. Vast extremes exist between the sparsely populated, water rich North, and the densely populated, yet water poor Southeast. There is no region that could be considered the statewide average in terms of its water supply and demand issues (Scoggins and Pierce, ed., 1995).

This water supply problem combined with the rapidly growing population poses many problems for the state. Stanley K. Smith, director of BEBR as well as director of its Population Program, writes that the "future of Florida's economy, culture, political structure and natural environment is intimately tied to its population growth. Successful planning thus requires a realistic assessment of future population growth." (Scoggins and Pierce, ed., 1995: 50).

The District is one of the five Water Management Districts in the State of Florida charged with protecting the water supply and ensuring that it is sufficient to meet the future demand. For this reason, the District contracted with the University of Florida to develop a model for distributing projected future population growth, which the District could use to project future water use. A sophisticated user of Geographic Information Systems (GIS) technology, the District saw the value in using GIS as a tool for achieving this goal.

Overview of Geographic Information Systems (GIS)

A Geographic Information System (GIS) is defined by the National Science Foundation as "a computerized data base management system for capture, storage, retrieval, analysis, and display of spatial (locationally defined) data." (Huxhold, 1991: p. 29). Environmental Systems Research Institute (ESRI), the developer of the software with which the model was developed, expands the definition of a GIS to "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information." (ESRI, 1990: p. 1—2). A GIS is not comprised of simple maps—it is a database. ESRI explains that the "database concept is central to a GIS and is the main difference between a GIS and a simple drafting or computer mapping system which can only produce good graphic output." (ESRI, 1990: p. 1—10). It is a powerful tool for studying the relationships between spatial data, and was essential to meeting the objectives of this model.

There are many benefits generally attributed to a GIS. Wiggins and French listed some of the benefits for a planning effort such as this Project:

- "Improved productivity in providing public information;
- Improved efficiency in updating maps;
- The ability to track and monitor growth and development over time;
- Improved ability to aggregate data for specific subareas;
- The ability to perform and display different types of professional analyses that are too cumbersome or time consuming using manual methods; and
- Improved policy formulation." (Wiggins and French, 1991: p. 2).

In short, GIS is useful "for nearly all research that involves land based spatial analysis and modeling" (Scholten and Stillwell, 1990: p. 20).

<u>Vector Versus Raster-Based Geographic Information Systems</u>

There are two broad classes of Geographic Information Systems: vector based and raster based.

A vector-based system uses a topological data structure. This "topology" defines the relationships between map elements represented by points, lines, or polygons. It keeps track of things like which line segments are attached to each other, and which polygons are on either side of a line segment. This enables queries such as the determination of whether one line is connected to another or whether a point lies within a polygon (Wiggins and French, 1991).

A raster-based system has a grid or matrix-based data structure. "In a raster structure, a value for the parameter of interest....is developed for every cell in a (frequently regular) array over space" (Star and Estes, 1990: p. 33). Each point, line, or polygon feature layer is represented by a square-celled grid of some particular resolution, facilitating the combination of overlaid cell values. This data structure is "especially suited to representing geographic phenomena that vary continuously over space, and for performing spatial modeling and analysis of flows, trends, and surfaces" (ESRI, 1995) such as those required by this model.

<u>Analytical Capabilities</u>

A GIS facilitates certain types of analysis, and permits others that would not be feasible without it. The vast amount of data to be collected and analyzed for this project requires a GIS-based model. This model uses ARC/INFO® tools to calculate distances from features, determine the areas and densities of others, and combine multiple layers into a single surface. For example, it calculates within Grid™ which 30-meter cells within Orange County are closest to a combination of spatial features, a task that would be impossible without a tool of this type.

Visualization of Results

The display capabilities of a GIS software package like ARC/INFO® are very important to the success of the model. Input vector and raster and resulting raster layers can be displayed easily and effectively on the display or on a hardcopy map. Results can be clearly communicated to the modeler, the clients, and other stakeholders in the Project. For example, population growth may be classified and shaded from white to red as the density of that growth increases. Graphics included in the Methods and Results Sections further illustrate this benefit to using a GIS.

User Interaction

One of the goals of this Project is to develop a user-friendly interface with which to interactively run the model. Although ARC/INFO® is not intuitive, it can be customized with Arc Macro Language (AML) programs and menus to permit novice users to run and even make adjustments to a GIS-based model. The model AMLs can be run without the assistance of a GIS technician. However, a GIS technician will be required to take advantage of some of the options built in to the model AMLs (running multiple counties, only running parts of the model, doing TAZ analysis, etc.), and to address any updates of base data upon which the model is run. (Minor modifications may be required if data is altered, moved, etc.)

Future changes in the model could include more user interaction to adjust model parameters, such as increasing or decreasing the weight of a certain feature. This type of sensitivity analysis could enhance and further validate the model.

Selection of GIS Software

ARC/INFO®, a robust GIS software developed by Environmental Systems Research Institute (ESRI), was selected for this project. It is widely used by the five Water Management Districts as well as the University of Florida for its wide range of features and analytical tools. ARC/INFO® has both vector and raster processing capabilities. The model is built primarily with Grid™, the raster component to ARC/INFO®.

MODEL METHODOLOGY

The model consists of two primary elements: one based on historical growth trends and one based on spatial features that influence growth. (See Figure 1) The Historical Element projects growth based on past growth trends, and the Spatial Element guides where the growth will be distributed within a given area. The combination of the two is essential to accurately distribute population into small areas.

Historical Element Overview

The model calculates historic population growth trends from property appraiser parcel data. This tabular data was collected from property appraisers throughout Florida, and compiled and standardized by the Florida Department of Revenue (DOR). These county parcel data tables include the generalized land use type, permitting the selection of non-vacant residential parcels. They include the year built for structures, enabling the calculation of historic growth trends. They also include the unique identifier for each section (referenced as TownshipRangeSection) within the County, allowing summaries of the data by section. This data is used to create the Base Year Population Grid and to make projections of future population growth using the methods described in the Historical Element Section.

These projections are normalized with county level projections made by BEBR. BEBR's projections are highly regarded throughout Florida, but county level projections are not spatially precise enough for the District. Because these projections are used to normalize the results of each modeling period, this model is more a distribution model than a projection model. Although it does project population growth, it more accurately projects the distribution of that growth within a given county.

Model Resolution: The Minimum Unit of Measure. For purposes of this model, the data is summarized by Public Lands Survey System section. Sections are generally one square mile (except for the occasional, irregularly shaped Spanish Land Grant), they are available in digital form, and their boundaries do not change over time as do census, TAZ, and parcel boundaries. While data at the parcel level can be quite useful, it is a finer resolution than is required for projecting future water demand. Also, digital parcel maps do not exist for a large part of the 19 county area, and where they do exist they are difficult to keep current (and thus costly to maintain). Census boundaries such as Tracts and Block Groups are commonly used modeling boundaries, but their size can vary considerably and they are subdivided as population grows. And considering that this model distributes projections out to 2020, high growth regions such as Central Florida could experience considerable growth in the very large, currently rural census boundaries. Traffic Analysis Zones (TAZs) were also investigated as a possible resolution for the model, but TAZs were only available in urban areas. In light of these issues, current data availability, and the overall goals of this modeling effort, sections are the best choice for the model's resolution.

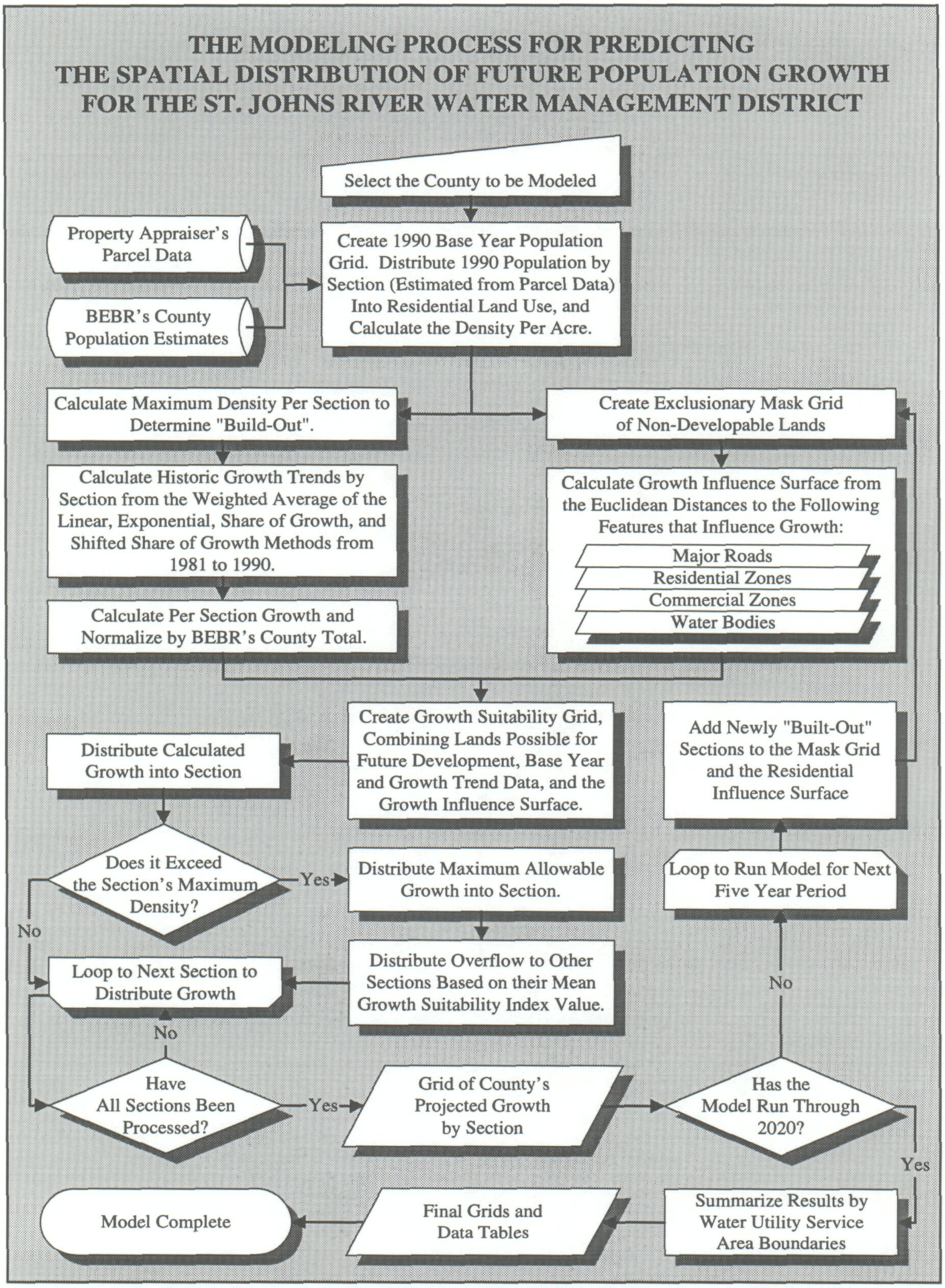

Figure 1. The Modeling Process for Predicting the Spatial Distribution of Future Population Growth for the St. Johns River Water Management District

Spatial Element Overview

The Spatial Element of the model helps to guide where growth is distributed within a given county. It consists of raster (cell-based) GIS layers of physical features (roads, land use, water bodies, etc.) that influence or restrict future growth. The Spatial Element has two main components: the Non-Developable Lands Mask that restricts growth, and the Growth Influence Surface that attracts it.

Land use (including water bodies) and major roads are the primary inputs to the Spatial Element. The level 2 land use was compiled at the St. Johns River Water Management District, and the major roads were developed by the Florida Department of Transportation.

Modeling Periods

The base year for the model is 1990 (due to a lack of more recent land use and tax data). This will be updated to 1995 as that data becomes available. Projections were made through the year 2020 in the following five year increments:

- 1991 through 1995
- 1996 through 2000
- 2001 through 2005
- 2006 through 2010
- 2011 through 2015
- 2016 through 2020

Base Year Grid

The base year of 1990 was selected for three reasons related to data availability: 1991 was the latest year in the revision of the DOR's property appraiser data available for this project in a usable form; it is approximately when the digital land use maps were last updated; and it was the year of the last official census count (providing better data for comparison than the between-census estimates).

Base Year Data Development

The GeoPlan Center at the University of Florida processed the DOR's property appraiser parcel data into an INFO format database file usable by this model. This large data file contains a record for every parcel in Orange County through 1991. (This is scheduled to be updated to 1996 data by the GeoPlan Center by Spring, 1998). Because the base year is 1990, only parcels with a year built of 1990 or earlier are selected. Then only non-vacant residential parcels are selected using the DOR's land use codes. Items for single and multi family units are added and calculated based on the land use codes (Multi family units are estimated at five units per parcel for low density and ten units per parcel for high density).

The INFO table with its new attributes is summarized by township, range, and section from the Public Lands Survey System. A Frequency for each occurrence of a unique section number is run on the table, creating a single record for each unique section in Orange County. The single and multi family units are summed for each section, creating a new INFO table containing the total single and multi family units per section. The total single and multi family units are summed for the entire County as well. That number is used to divide the County's base year (1990) BEBR population to determine the County's average household size. Single and multi family units per section are then translated to population per section based on the County's average household size.

Base Year Residential Population Grid

The Base Year Population Grid is created by attaching the new INFO table created from the property appraiser data with the Public Lands Survey System Sections Grid and the Level 2 Land Use Grid. Residential land uses are selected from the Land Use Grid and overlaid with the Township, Range, and Section boundaries of the Public Lands Survey System Grid. This Residential Area Section Grid is then linked to the INFO table of non-vacant, residential parcels selected from the DOR tax records and summarized by section. Only sections with residential land use are allocated population.

Because some people live outside residentially zoned areas, the section totals are normalized to offset the lost population. This occurs when population exists within agricultural, military, conservation, and other areas in a section that has no residential land use. For example, if 2% of the County's population lives outside residential land use, the populated sections will divided by 0.98 (1 - 0.02) to make up for the difference.

Historical Element

The Historical Element to the model consists of the Historic Growth Trends Grid and the Maximum Density Determination, or "Build-Out" Phase. The Historic Growth Trends Grid distributes future growth based on the extrapolation of past growth trends, and the Maximum Density Determination prevents the growth from exceeding a section's maximum density. The projections are then normalized using BEBR's county level projections for each of the five year periods through 2020. The BEBR's projections used in the model were updated on April 1, 1997. (Smith and Nogle, 1998: pp. 4-8).

Historic Growth Trends Grid

The historic population growth trends are based on growth rates over the following historical periods (with the latter period receiving additional weight):

- 1981 through 1985
- 1986 through 1990

The historic population growth trends are derived from an average of four methods: Linear, Exponential, Share of Growth, and Shifted Share of Growth. The Linear and Exponential techniques employ a bottom-up approach, extrapolating the historic growth trends of each section with no consideration for the county's overall growth. The Share of Growth and Shifted Share of Growth techniques employ a top-down approach, allocating a portion of the total projected county growth to each section based on that section's percentage of county growth over the historical period. Each of the four methods is a good predictor of growth in different situations and growth patterns, so an average of the four was the best way to avoid the largest possible errors resulting from the "worst" techniques for each section within the 19 county area (Sipe and Hopkins, 1984: p. 23). This methodology is very similar to that used by BEBR, and is well suited for small area population projections. The results of each of the four projection methods varied from section to section, but there were some general trends that can be identified.

Linear Projection Method. The Linear Projection Method assumes that future population change for each section will be the same as over the historic period (Sipe and Hopkins, 1984: p. 25). The last five years of the historic period (1986 through 1990) are weighted more heavily than the first five years (1981 through 1985). The total population projected using the Linear method (LIN) is calculated with the formula (using 1995 as an example):

$$LIN = [0.25 * (Pop85 - Pop80)] + [0.75 * (Pop90 - Pop85)] + Pop90$$

The Linear Method tends to be a good predictor of sectional growth in areas with a fairly steady growth rate, especially in rural areas. These projections were generally lower than that of the Exponential Method, except when growth rates are negative (where the negative numbers are exponentially higher), or in cases when the growth from 1981 through 1985 was considerably higher than the growth from 1986 through 1990. The linear projections are conservative estimates of growth, and no section had a net minus in growth over the thirty-year period. The Linear estimates summarized at the county level were on average five percent higher than BEBR's estimates over the course of the thirty-year period.

However, Alexander, Et. Al., explain the limitation of a purely linear model. Paraphrasing Forrester, they explain that all external effects on the system in a linear model are purely additive. Although a linear trend may hold true for a continuously growing area, they contend that "it can not be used to inspect the limits of growth or the transition from growth to another state" (Alexander, Et. Al, 1984: p. 127). Paraphrasing Pfeiffer, they conclude that "even the foremost proponents of linear systems analysis suggest that they are working with linear systems in a nonlinear world" (Alexander, Et. Al., 1984: p. 127). Because of the limitations to the linear method and because of the heterogeneity of the areas being modeled, three other methods for projecting future growth are employed in the model.

Exponential Projection Method. The Exponential Projection Method assumes that population will continue to change at the same rate as over the historic period (Sipe and Hopkins, 1984: p. 26). The total population projected using the Exponential method (EXP) is calculated with the formula (using 1995 as an example):

EXP = [(Pop90 / Pop80) / 2 * Pop90] + Pop90

The Exponential Method tends to be a good predictor of sectional growth in faster growing urban and suburban areas with additional capacity for future growth, new Developments of Regional Impact (DRIs), and sections that were already approaching build-out over the historic period (where growth rates are rapidly decreasing.) This technique produced the highest total growth for the county despite the number of sections with negative growth. For most sections, the Exponential Method generally produced the highest growth of the four methods, except when negative or decreasing over the historical period. There are many sections that had a net minus in growth over the thirty-year period, but the positive peaks were higher to more than offset this somewhat unexpected result. The Exponential estimates summarized at the county level were on average 14 percent higher than BEBR's estimates over the course of the thirty-year period.

Share of Growth Projection Method. The Share of Growth Projection Method assumes that each section's percentage of the county's total growth will be the same as over the historic period (Sipe and Hopkins, 1984: p. 23). The last five years of the historic period (1986 through 1990) are weighted more heavily than the first five years (1981 through 1985). The total population projected using the Share of Growth method (SOG) is calculated with the formula (using 1995 as an example):

SOG = [0.25 * (Pop85 - Pop80) / (Co. Pop85 - Co. Pop80)
+ 0.75 * (Pop90 - Pop85) / (Co. Pop90 - Co. Pop85)]
* (Projected Co. Pop95 - Co. Pop90) + Pop90

This method tends to be a good predictor of sectional growth in counties experiencing a significant increasing or decreasing percentage of future growth from that of the historic period. (Many counties experience decreasing growth rates due to increases in total population. For example, a county growing by 10,000 persons each period would result in a decreasing percentage growth, due to the increasing total population.)

Shifted Share of Growth Projection Method. The Shifted Share of Growth Projection Method assumes that each section's percentage of the county's total growth will change at the same rate as over the historic period. It makes a linear extrapolation of the change in each section's share of the county population over the historic period (Sipe and Hopkins, 1984: p. 25). The total population projected using the Shifted Share of Growth method (SSH) is calculated with the formula (using 1995 as an example):

SSH = [(Pop90 - Pop85) / (Co. Pop90 - Co. Pop85)
- (Pop85 - Pop80) / (Co. Pop85 - Co. Pop80)
+ (Pop90 - Pop85) / (Co. Pop90 - Co. Pop85)]
* (Projected Co. Pop95 - Co. Pop90) + Pop90

This method tends to be a good predictor of growth in sections experiencing significant increases or decreases in the growth rate. (Many sections with larger populations experience decreasing growth rates due to increases in total population and decreases in land available for development.)

By their definitions, the "Share of Growth" and the "Shifted Share of Growth" Methods will project sectional population that will add up to the county total. Differences at the section level varied, but like the Exponential Method, the Shifted Share of Growth projection could be significantly lower than the Share of Growth projection if the growth from 1981 through 1985 was considerably higher than the growth from 1986 through 1990. The county summaries of the estimates made with the Share of Growth and Shifted Share of Growth Methods roughly equaled BEBR's estimates (by their definitions). They were off within a fraction of a percentage point due to rounding over the thirty-year period.

Average of the Four Projection Methods. The four methods are then averaged to account for the considerable variation in growth rates and patterns over all of the sections within the 19 county area (Sipe and Hopkins, 1984: p. 26). All four methods are weighted equally, so the Average is calculated with the basic formula:

AVG = (LIN + EXP + SOG + SSH) / 4

The Average of the Four Projection Methods smoothed the highest and lowest projections, preventing the largest possible errors resulting from the "worst" techniques for each section. Although it has been suggested that some of the four methods may not be appropriate for certain areas (i.e. Exponential for rural areas), this averaging precludes the need for location-specific modeling methods. The averages of the four methods summarized at the county level were on average five percent higher than BEBR's estimates over the course of the thirty-year period. This average of the four estimates was later normalized with BEBR's county total for each section over each period.

Maximum Density Determination

The current method for determination of when a section reaches maximum density, or becomes "built-out", is based on statistical calculations using the section's base year population density. The base year per acre population density is calculated for each section by dividing the section's population by its total residential acreage. The county's base year mean population density is also calculated by dividing the county's population by its total residential acreage. An amount equal to two standard deviations above the county's mean is added to each section's existing density. This figure is multiplied times each section's available acreage to determine the total growth capacity per section. Each period over which the model is run tests each section's calculated growth for that period against this number. If the growth exceeds the available capacity, the growth is calculated to be the capacity less the current population. The additional "lost" growth is stored and later distributed to sections with the available capacity and high Growth Influence Surface values. This Growth Influence Surface will be described in detail in the discussion on the Spatial Element in the next section.

Spatial Element

The Spatial Element deals with the relationship of spatial features to future population growth. For example, the density calculations described earlier are based on residential densities calculated from the residential land use map layer, a part of the Spatial Element. This Element consists of two primary components: "the Non-Developable Lands Exclusionary Mask Grid" and the "Growth Influence Surface". The Non-Developable Lands Exclusionary Mask Grid identifies areas where future growth is very unlikely to occur based on physical features (such as water bodies) and land uses/restrictions (such as conservation lands). The Growth Influence Surface is a composite of four other grids identifying areas where future growth is likely to occur also based on proximity to physical features (such as along major roads) and land use types (such as near commercial zones).

The Spatial Element was originally intended as an "equal partner" with the Historical Element in the model. Although the Spatial Element has continued to be a key component to influencing, restricting, and capping growth, over the course of the Project it lost some of its influence on determining the raw projections. The Non-Developable Lands Exclusionary Mask Grid still eliminates lands from receiving future growth, but the Growth Influence Surface currently only chooses which sections are allocated the extra growth from built-out sections. Its function may be broadened later in the Project.

Non-Developable Lands Exclusionary Mask Grid

The Non-Developable Lands Exclusionary Mask Grid excludes future growth from physical features and land uses/restricted lands that are unlikely to be developed for residential use. The data layers included in the Mask are listed in Table 1:

Data Layer	Data Source, Date Developed
Water Bodies	United States Geological Survey (USGS) Digital Line Graphs (DLG) 1:100,000 Scale Hydrology
Wetlands	District Level 2 Land Use, 1990-91
Conservation and Other Public Lands	Conservation and Other Public Lands from the University of Florida's GeoPlan Center and the District, 1997
Major Road Rights-of-Way	Florida Department of Transportation (FDOT) Primary and Secondary Roads, 1996
Built-Out Residential Areas	District Level 2 Land Use, 1990-91

Table 1. Data Layers in Exclusionary Mask Grid

Growth Influence Surface

The Growth Influence Surface is developed from physical features and land uses that significantly attract future population growth.

Data Layer	Data Source
Major Roads	Florida Department of Transportation (FDOT) Primary and Secondary Roads, 1996
Residential Areas	District Level 2 Land Use, 1990-91
Commercial Areas	District Level 2 Land Use, 1990-91
Water Bodies	United States Geological Survey (USGS) Digital Line Graphs (DLG) 1:100,000 Scale Hydrology

Table 2. Data Layers in Growth Influence Surface

The Growth Influence Surface is created based upon the proximity to the above listed features. The Euclidean distance is calculated from the center of the source cell to the center of each of the surrounding cells by measuring the hypotenuse of a triangle with the X and Y distances as the other two legs (ESRI, 1995). This true Euclidean, rather than cell distance, is calculated outward from each feature independently, and then the four surfaces are combined into a single one. The mean influence value (based on the combined Euclidean distance values) is then calculated per square mile section. This value is then used to determine which sections receive the overflow growth of built-out sections.

Growth Suitability Grid

The Growth Influence Surface is then combined with the Historical Growth Trends Grid to create the Growth Suitability Grid. Existing residential land uses and other land uses that may be anticipated for conversion to residential are used to create a new grid in which future growth can be distributed. Those land uses include agricultural, forested, range, and open lands. The per section Historical Growth Trends and the mean values from the Growth Suitability Surface are then attached to the new Grid.

This new grid has considerably more land area in which to distribute future growth. This is due to the fact that when growth is distributed in currently non-residential land uses, there is no way to determine the spatial extent of that growth within the section, so all of the land available for development is shown. Section build-out can still be calculated, but densities within each section are not known.

Distribution of Growth by Section

The growth is calculated for each section over the specified period using the per section growth rates from the Historic Growth Trends Grid. This adjusted average growth is added to the base year population for each section to derive the future distribution of that growth within the county. At this point, where the growth is occurring is actually more important than the total growth numbers.

As was anticipated, the majority of the projected growth moved further away from the current urban areas with each succeeding period. Over the earlier periods (1991 through 1995, 1996 through 2000, and 2001 through 2005), most of the projected growth was still clustered around current urban areas. Over the later periods however (2006 through 2010, 2011 through 2015, and 2016 through 2020), much of the growth was projected to occur well outside the current urban areas.

Of course these estimates are based on current densities and development patterns, but as yet there is little indication that these are likely to change in the near future. Consumer preferences and developer costs drive these development patterns and densities. Until the supply of land becomes scarce enough, thus increasing the cost of land, or governmental regulations encourage denser development, we must assume that there will be no fundamental change in current development patterns and densities at least for the near future.

Normalize Growth with BEBR's County Total. Now that the relative distribution of the growth has been determined, this projected growth is then normalized using BEBR's county population estimates. All the sections in the county are totaled. The model's projected growth for each section is divided by this raw total and multiplied by BEBR's county estimate.

Test for Build-Out. Each section is then tested to determine if it has exceeded its maximum capacity, or is built-out. If the base year population plus the projected growth does exceed the section's growth capacity, the growth will be calculated to equal the capacity minus the base year population. A field in the table is then calculated equal to the excess projected growth. This field containing the excess projected growth is summed for all the sections in the county.

Redistribute Any Growth Exceeding Capacity. Sections that have not exceeded their capacity for growth are then selected one at a time in the order of their mean growth influence value. Each is again normalized to absorb any excess projected growth. If a section becomes built-out at this stage, the additional projected growth is distributed to the section with the highest suitability value that can absorb that growth.

Single and Multi Family Unit Calculations. When the growth is fully distributed, the end year total population is calculated. Single family and multi family units are then estimated from the population change to compare with projections from utilities that measure growth in units as well as in population.

Updates in Model Inputs from Prior Model Periods

Each period over which the model is run for Orange County results in population growth. This additional population may cause one or more sections to become built-out. If this occurs, those areas are added to the Non-Developable Lands Exclusionary Mask Grid and to the Growth Influence Surface.

Integration of Built-Out Sections with the Mask Grid

The sections that have become built-out from the previous modeling period are then put into a new mask grid to exclude them from receiving growth in future periods.

Integration of Built-Out Sections with the Growth Influence Surface

This new Exclusionary Mask Grid is also added to the Residential Land Use Grid, so that the Residential Proximity Surface may be recalculated for future periods. This will increase the growth potential of sections that are near built-out areas in future model runs.

Final Output of Model

The final grids containing the distribution of population growth by section are then summarized by Utility Service Area Boundaries. These boundaries are the Service Area Boundaries of water-providing utility companies. Because these boundaries generally overlap section lines, further processing of the data is required.

The assumption of population being evenly distributed within a given section split by a Utility Service Area Boundary did not appear to be a significant problem. In most cases, the Utility Service Area boundaries spanned many sections, so any errors due to this forced assumption were diluted by the growth from sections completely contained within the boundaries.

Utility Service Area Growth Summary Grids

For each period, the population and dwelling unit growth and end year totals by section are divided by the number of 30-meter grid cells within the section to derive per-cell growth and per-cell end year population and unit totals. The Utility Service Area Boundaries are then overlaid, and the per-cell values are re-aggregated to these boundaries. Separate grids are created for each population, single family, and multi family growth period and each end year total, which are then joined together and exported to a dBASE file for later import into Microsoft Excel.

This methodology assumes an even distribution within the section. Although population distributions within a given section could vary a great deal, it is not possible using this data to account for varied densities within a given section.

Output Tables

The spatial results (the final Utility Service Area Growth and Population Grids) can be displayed to indicate projected patterns of future growth, but the output tables (the grid Value Attribute Tables) are important without their Spatial Element. The tables are used to "plug in" to the St. Johns River Water Management District's Future Water Demand Model, and they are useful for comparison with projections made by the water-providing utility companies. For this reason, the tabular results are further manipulated to facilitate these efforts.

The Value Attribute Tables of all 12 final Utility Service Area growth and population grids are joined together. A Frequency is run on the combined Value Attribute Table, resulting in a table with a unique record for each utility company. The resulting Frequency table is then exported in ARC/INFO® to a dBASE file. The dBASE file is imported into Microsoft Excel, formatted, and e-mailed to the St. Johns River Water Management District. There it is used to "plug in" to their Future Water Demand Model and for comparison with projections received from the water-providing utility companies.

The acreage for each of the service areas was included to compare with the growth. Some of the projections are very small, but eight of the service areas in Orange County alone are less than ten acres. The District required growth numbers, but the growth results may be more meaningfully compared if normalized by acreage (growth density).

Verification of Results

The model results are then compared with other projections made by BEBR, local planning agencies, and the utilities themselves.

BEBR. Before the model's projections are normalized, this county total is compared with BEBR's county total. The average of the four methods was five percent higher on average than BEBR's estimate. Although the model was designed to allocate rather than project population, achieving only a slight difference in projections inspires confidence and is worth noting.

Utility Companies and Local Planning Agencies. The growth estimates of the TAZ-based models employed by many of the various utility companies and local planning agencies are compared with model results. These are perhaps the most important comparisons, because future permitting is done at this level

To compare the model results with those of TAZ-based models, the TAZ results were summarized by Utility Service Area boundaries, and these were compared with the model results (which were already summarized by Utility Service Area boundaries). Tables 3 and 4 contain the model results for Orange and Volusia Counties (respectively), Tables 5 and 6 contain the TAZ numbers for Orange and Volusia Counties, and Tables 7 and 8 contain the percentage differences between the two models.

UTILITY/WATER PROVIDER	ACRES	MOD90	MOD95	MOD00	MOD05	MOD10	MOD15	MOD20
ANGLES REAL ESTATE MGT CO	78	1,332	1,283	1,229	1,174	1,119	1,061	1,000
APOPKA CITY OF	1,533	26,559	31,801	37,593	43,523	49,383	55,507	62,034
COTTLE GARY	12	28	29	31	33	35	37	39
DAY JOHN H	2	145	158	172	187	201	216	232
EAST CENTRAL FLA SERVICES INC	5,908	83	89	96	104	111	118	126
EATONVILLE TOWN OF	58	2,153	2,231	2,317	2,405	2,491	2,582	2,679
ECON UTILITIES INC	65	1,081	1,664	2,310	2,971	3,624	4,307	5,035
FLORIDA WATER SERVICES CORP	228	7,669	9,533	11,596	13,709	15,796	17,978	20,303
INTERCOASTAL COMMUNITIES	8	57	59	61	62	64	66	68
MAITLAND CITY OF	357	9,733	10,068	10,331	10,601	10,868	11,146	11,443
MONAHAM JAIN	11	575	643	718	794	870	949	1,033
NODATA_VOID_POLY	258	2,829	2,836	2,841	2,849	2,855	2,862	2,869
OAKLAND TOWN OF	19	359	413	473	535	595	659	727
OCOEE CITY OF	914	17,577	20,633	24,015	27,478	30,899	34,475	38,287
ORANGE COUNTY RES & DEV	103	2,673	2,768	2,870	2,975	3,078	3,186	3,300
ORANGE COUNTY UTILITIES	32,260	192,100	234,897	280,383	324,681	368,208	413,882	461,417
ORLANDO UTILITIES COMMISSION	11,712	324,680	348,796	375,036	401,872	428,391	453,667	476,856
PARK MANOR WATER WORKS	44	1,805	2,049	2,320	2,596	2,870	3,156	3,462
REEDY CREEK	1,764	234	235	237	238	239	240	241
SUN RESORTS INC	13	656	729	810	893	974	1,060	1,151
TANGERINE WATER COMPANY	7	76	87	100	113	126	139	154
UNIVERSITY OF CENTRAL FLORIDA	101	806	788	768	747	727	705	682
WILLIAMS MICHAEL J	3	47	74	104	135	166	198	232
WINTER GARDEN CITY OF	304	8,615	9,008	9,442	9,887	10,326	10,785	11,274
WINTER PARK CITY OF	1,282	71,103	73,055	75,209	77,415	79,596	81,848	84,214
ZELLWOOD STATION UTILITIES	135	65	82	101	120	138	157	179
ZELLWOOD WATER ASSOCIATION	48	410	419	428	438	448	458	469
TOTALS:	57,227	673,450	754,427	841,591	928,535	1,014,198	1,101,444	1,189,506

Table 3: District Model Results for Orange County by Utility Service Area

UTILITY/WATER PROVIDER	ACRES	MOD90	MOD95	MOD00	MOD05	MOD10	MOD15	MOD20
ASTOR PARK WATER ASSOCIATION	949	49	48	48	47	46	45	44
DAYTONA BEACH CITY OF	3,778	58,081	59,582	61,209	63,793	66,334	68,938	71,584
DELAND CITY OF	4,856	36,982	38,667	40,483	43,340	46,146	49,016	51,933
EDGEWATER CITY OF	2,421	22,712	25,397	28,263	32,768	37,187	41,701	45,892
FLORIDA WATER SERVICES CORP	1,662	49,678	60,922	72,470	73,138	73,747	74,347	74,952
HOLLY HILL CITY OF	241	9,290	9,540	9,811	10,241	10,664	11,098	11,539
NEW SMYRNA BEACH CITY OF	2,425	34,456	36,577	38,868	42,511	46,090	49,758	53,487
NODATA_VOID_POLY	454	13,171	13,544	13,939	14,471	14,996	15,531	16,075
ORANGE CITY CITY OF	668	7,263	7,656	8,081	8,752	9,412	10,088	10,776
ORMOND BEACH CITY OF	5,807	52,811	54,767	56,886	60,251	63,560	66,938	70,341
PIERSON TOWN OF	734	766	831	908	1,011	1,117	1,229	1,340
PORT ORANGE CITY OF	4,437	51,078	57,520	64,511	75,628	86,555	97,568	108,702
VOLUSIA COUNTY & NOT	2,025	16,911	19,069	21,411	25,073	28,644	32,284	35,986
TOTALS:	30,457	353,248	384,120	416,883	451,024	484,498	518,541	552,651

Table 4: District Model Results for Volusia County by Utility Service Area

UTILITY/WATER PROVIDER	ACRES	TAZ90	TAZ95	TAZ00	TAZ05	TAZ10	TAZ15	TAZ20
ANGLES REAL ESTATE MGT CO	78	1,233	1,218	1,203	1,187	1,172	1,157	1,166
APOPKA CITY OF	1,533	23,051	32,398	41,747	51,090	60,434	69,784	80,192
COTTLE GARY	12	262	401	539	678	817	955	1,103
DAY JOHN H	2	159	155	151	146	142	138	137
EAST CENTRAL FLA SERVICES INC	5,908	1,145	1,438	1,731	2,024	2,317	2,610	2,941
EATONVILLE TOWN OF	58	2,771	2,936	3,100	3,263	3,427	3,592	3,983
ECON UTILITIES INC	65	81	115	148	182	216	250	286
FLORIDA WATER SERVICES CORP	228	7,840	8,610	9,381	10,149	10,919	11,688	12,692
INTERCOASTAL COMMUNITIES	8	162	197	232	267	302	336	373
MAITLAND CITY OF	357	12,461	13,440	14,422	15,398	16,376	17,358	19,280
MONAHAM JAIN	11	475	575	675	776	876	977	1,085
NODATA_VOID_POLY	258	1,588	1,543	1,498	1,451	1,406	1,362	1,503
OAKLAND TOWN OF	19	131	171	211	250	290	330	378
OCOEE CITY OF	914	16,036	18,074	20,114	22,147	24,185	26,224	28,952
ORANGE COUNTY RES & DEV	103	3,271	3,436	3,602	3,767	3,931	4,096	4,299
ORANGE COUNTY UTILITIES	32,260	191,104	238,414	285,744	333,005	380,303	427,629	481,934
ORLANDO UTILITIES COMMISSION	11,712	328,662	351,566	374,509	397,332	420,192	443,137	482,112
PARK MANOR WATER WORKS	44	1,593	1,914	2,234	2,553	2,873	3,193	3,544
REEDY CREEK	1,764	582	588	595	602	608	614	737
SUN RESORTS INC	13	218	232	246	260	274	288	305
TANGERINE WATER COMPANY	7	30	33	37	40	44	47	51
UNIVERSITY OF CENTRAL FLORIDA	101	1,167	1,195	1,223	1,250	1,278	1,306	1,392
WILLIAMS MICHAEL J	3	53	87	121	155	189	223	261
WINTER GARDEN CITY OF	304	9,632	10,142	10,652	11,158	11,666	12,177	13,359
WINTER PARK CITY OF	1,282	72,692	72,780	72,885	72,953	73,036	73,134	76,859
ZELLWOOD STATION UTILITIES	135	29	31	35	38	41	43	50
ZELLWOOD WATER ASSOCIATION	48	329	328	328	327	326	325	334
TOTALS:	57,227	676,757	762,017	847,363	932,448	1,017,640	1,102,973	1,219,308

Table 5: TAZ-Based Model Results for Orange County by Utility Service Area

UTILITY/WATER PROVIDER	ACRES	TAZ90	TAZ95	TAZ00	TAZ05	TAZ10	TAZ15	TAZ20
ASTOR PARK WATER ASSOCIATION	949	182	171	159	147	136	124	113
DAYTONA BEACH CITY OF	3,778	71,297	81,101	90,847	100,651	110,400	119,701	128,952
DELAND CITY OF	4,856	38,977	42,609	46,198	49,837	53,423	56,946	60,415
EDGEWATER CITY OF	2,421	18,283	21,241	24,186	27,147	30,095	32,985	35,860
FLORIDA WATER SERVICES CORP	1,662	37,505	39,539	41,559	43,593	45,611	47,550	49,475
HOLLY HILL CITY OF	241	11,276	11,899	12,512	13,130	13,741	14,338	14,922
NEW SMYRNA BEACH CITY OF	2,425	21,390	24,252	27,097	29,965	32,815	35,600	38,372
NODATA_VOID_POLY	454	15,685	17,574	19,456	21,349	23,232	25,070	26,900
ORANGE CITY CITY OF	668	9,903	10,858	11,809	12,767	13,716	14,644	15,564
ORMOND BEACH CITY OF	5,807	42,500	47,704	52,889	58,099	63,279	68,342	73,380
PIERSON TOWN OF	734	618	632	645	659	673	685	697
PORT ORANGE CITY OF	4,437	45,485	51,472	57,434	63,419	69,380	74,011	78,615
VOLUSIA COUNTY & NOT	2,025	17,981	19,274	20,546	21,840	23,119	24,365	25,596
TOTALS:	30,457	331,082	368,326	405,332	442,603	479,620	514,361	548,861

Table 6: TAZ-Based Model Results for Volusia County by Utility Service Area

UTILITY/WATER PROVIDER	ACRES	%DIFF90	%DIFF95	%DIFF00	%DIFF05	%DIFF10	%DIFF15	%DIFF20
ANGLES REAL ESTATE MGT CO	78	8.0%	5.3%	2.2%	1.1%	4.5%	8.3%	14.2%
APOPKA CITY OF	1,533	15.2%	1.8%	10.0%	14.8%	18.3%	20.5%	22.6%
COTTLE GARY	12	89.3%	92.8%	94.2%	95.1%	95.7%	96.1%	96.5%
DAY JOHN H	2	8.8%	1.9%	13.9%	28.1%	41.5%	56.5%	69.3%
EAST CENTRAL FLA SERVICES INC	5,908	92.8%	93.8%	94.5%	94.9%	95.2%	95.5%	95.7%
EATONVILLE TOWN OF	58	22.3%	24.0%	25.3%	26.3%	27.3%	28.1%	32.7%
ECON UTILITIES INC	65	1234.6%	1347.0%	1460.8%	1532.4%	1577.8%	1622.8%	1660.5%
FLORIDA WATER SERVICES CORP	228	2.2%	10.7%	23.6%	35.1%	44.7%	53.8%	60.0%
INTERCOASTAL COMMUNITIES	8	64.8%	70.1%	73.7%	76.8%	78.8%	80.4%	81.8%
MAITLAND CITY OF	357	21.9%	25.1%	28.4%	31.2%	33.6%	35.8%	40.6%
MONAHAM JAIN	11	21.1%	11.8%	6.4%	2.3%	0.7%	2.9%	4.8%
NODATA_VOID_POLY	258	78.1%	83.8%	89.7%	96.3%	103.1%	110.1%	90.9%
OAKLAND TOWN OF	19	174.0%	141.5%	124.2%	114.0%	105.2%	99.7%	92.3%
OCOEE CITY OF	914	9.6%	14.2%	19.4%	24.1%	27.8%	31.5%	32.2%
ORANGE COUNTY RES & DEV	103	18.3%	19.4%	20.3%	21.0%	21.7%	22.2%	23.2%
ORANGE COUNTY UTILITIES	32,260	0.5%	1.5%	1.9%	2.5%	3.2%	3.2%	4.3%
ORLANDO UTILITIES COMMISSION	11,712	1.2%	0.8%	0.1%	1.1%	2.0%	2.4%	1.1%
PARK MANOR WATER WORKS	44	13.3%	7.1%	3.8%	1.7%	0.1%	1.2%	2.3%
REEDY CREEK	1,764	59.8%	60.0%	60.2%	60.5%	60.7%	60.9%	67.3%
SUN RESORTS INC	13	200.9%	214.2%	229.3%	243.5%	255.5%	268.1%	277.4%
TANGERINE WATER COMPANY	7	153.3%	163.6%	170.3%	182.5%	186.4%	195.7%	202.0%
UNIVERSITY OF CENTRAL FLORIDA	101	30.9%	34.1%	37.2%	40.2%	43.1%	46.0%	51.0%
WILLIAMS MICHAEL J	3	11.3%	14.9%	14.0%	12.9%	12.2%	11.2%	11.1%
WINTER GARDEN CITY OF	304	10.6%	11.2%	11.4%	11.4%	11.5%	11.4%	15.6%
WINTER PARK CITY OF	1,282	2.2%	0.4%	3.2%	6.1%	9.0%	11.9%	9.6%
ZELLWOOD STATION UTILITIES	135	124.1%	164.5%	188.6%	215.8%	236.6%	265.1%	258.0%
ZELLWOOD WATER ASSOCIATION	48	24.6%	27.7%	30.5%	33.9%	37.4%	40.9%	40.4%
TOTALS:	57,227	92.4%	97.9%	105.1%	111.3%	116.1%	121.6%	124.4%

Table 7: Differences Between District Model Results and TAZ-Based Model Results for Orange County by Utility Service Area

UTILITY/WATER PROVIDER	ACRES	%DIFF90	%DIFF95	%DIFF00	%DIFF05	%DIFF10	%DIFF15	%DIFF20
ASTOR PARK WATER ASSOCIATION	949	73.1%	71.9%	69.8%	68.0%	66.2%	63.7%	61.1%
DAYTONA BEACH CITY OF	3,778	18.5%	26.5%	32.6%	36.6%	39.9%	42.4%	44.5%
DELAND CITY OF	4,856	5.1%	9.3%	12.4%	13.0%	13.6%	13.9%	14.0%
EDGEWATER CITY OF	2,421	24.2%	19.6%	16.9%	20.7%	23.6%	26.4%	28.0%
FLORIDA WATER SERVICES CORP	1,662	32.5%	54.1%	74.4%	67.8%	61.7%	56.4%	51.5%
HOLLY HILL CITY OF	241	17.6%	19.8%	21.6%	22.0%	22.4%	22.6%	22.7%
NEW SMYRNA BEACH CITY OF	2,425	61.1%	50.8%	43.4%	41.9%	40.5%	39.8%	39.4%
NODATA_VOID_POLY	454	16.0%	22.9%	28.4%	32.2%	35.5%	38.0%	40.2%
ORANGE CITY CITY OF	668	26.7%	29.5%	31.6%	31.4%	31.4%	31.1%	30.8%
ORMOND BEACH CITY OF	5,807	24.3%	14.8%	7.6%	3.7%	0.4%	2.1%	4.1%
PIERSON TOWN OF	734	23.9%	31.5%	40.0%	53.4%	66.0%	79.4%	92.3%
PORT ORANGE CITY OF	4,437	12.3%	11.8%	12.3%	19.3%	24.8%	31.8%	38.3%
VOLUSIA COUNTY & NOT	2,025	6.0%	1.1%	4.2%	14.8%	23.9%	32.5%	40.6%
TOTALS:	30,457	26.3%	28.0%	30.4%	32.7%	34.6%	36.9%	39.0%

Table 8: Differences Between District Model Results and TAZ-Based Model Results for Volusia County by Utility Service Area

To translate the section-level results to Utility Service Area boundaries requires the assumption of an even distribution of population within the developable areas of each section. A section could have the majority of its population on the part of the section within one service area, but the model would only allocate the section's average population per grid cell times the section's total developable grid cells in that Utility Service Area. For example, if 20 percent of a section's developable area and 90 percent of a section's population fell into a particular service area, only 20 percent of the population would be allocated. This limitation is more likely to affect the results for utilities with smaller service areas, as they have less margin for error.

The differences by Utility Service Area in Orange and Volusia Counties were quantified and studied. Clearly a certain percentage of these differences is due to boundary errors. This problem is greatest with smaller Utility Service Areas, suggesting that the variation in the densities within sections straddling Utility Service Area boundaries is a major factor in the discrepancies between the model and the utility projections.

When only considering utilities with 1,000 or more acres, this boundary error decreases significantly. The average error in 1990 drops from 92.4% to 28.6% in Orange County, and from 26.3% to 23.0% in Volusia County.

UTILITY/WATER PROVIDER	ACRES	%DIFF90	%DIFF95	%DIFF00	%DIFF05	%DIFF10	%DIFF15	%DIFF20
APOPKA CITY OF	1,533	15.2%	1.8%	10.0%	14.8%	18.3%	20.5%	22.6%
EAST CENTRAL FLA SERVICES INC	5,908	92.8%	93.8%	94.5%	94.9%	95.2%	95.5%	95.7%
ORANGE COUNTY UTILITIES	32,260	0.5%	1.5%	1.9%	2.5%	3.2%	3.2%	4.3%
ORLANDO UTILITIES COMMISSION	11,712	1.2%	0.8%	0.1%	1.1%	2.0%	2.4%	1.1%
REEDY CREEK	1,764	59.8%	60.0%	60.2%	60.5%	60.7%	60.9%	67.3%
WINTER PARK CITY OF	1,282	2.2%	0.4%	3.2%	6.1%	9.0%	11.9%	9.6%
TOTALS:	54,459	28.6%	26.4%	28.3%	30.0%	31.4%	32.4%	33.4%

Table 9: Differences Between District Model Results and TAZ-Based Model Results for Orange County for Utility Service Areas of 1,000 Or More Acres

UTILITY/WATER PROVIDER	ACRES	%DIFF90	%DIFF95	%DIFF00	%DIFF05	%DIFF10	%DIFF15	%DIFF20
DAYTONA BEACH CITY OF	3,778	18.5%	26.5%	32.6%	36.6%	39.9%	42.4%	44.5%
DELAND CITY OF	4,856	5.1%	9.3%	12.4%	13.0%	13.6%	13.9%	14.0%
EDGEWATER CITY OF	2,421	24.2%	19.6%	16.9%	20.7%	23.6%	26.4%	28.0%
FLORIDA WATER SERVICES CORP	1,662	32.5%	54.1%	74.4%	67.8%	61.7%	56.4%	51.5%
NEW SMYRNA BEACH CITY OF	2,425	61.1%	50.8%	43.4%	41.9%	40.5%	39.8%	39.4%
ORMOND BEACH CITY OF	5,807	24.3%	14.8%	7.6%	3.7%	0.4%	2.1%	4.1%
PORT ORANGE CITY OF	4,437	12.3%	11.8%	12.3%	19.3%	24.8%	31.8%	38.3%
VOLUSIA COUNTY & NOT	2,025	6.0%	1.1%	4.2%	14.8%	23.9%	32.5%	40.6%
TOTALS:	27,411	23.0%	23.5%	25.5%	27.2%	28.5%	30.7%	32.5%

Table 10: Differences Between District Model Results and TAZ-Based Model Results for Volusia County for Utility Service Areas of 1,000 Or More Acres

When only considering utilities with 10,000 or more acres in Orange County and 4,000 or more acres in Volusia County, this boundary error further decreases. The average error in 1990 drops from 92.4% to 0.9% in Orange County, and from 26.3% to 13.9% in Volusia County.

UTILITY/WATER PROVIDER	ACRES	%DIFF 90	%DIFF 95	%DIFF 00	%DIFF 05	%DIFF 10	%DIFF 15	%DIFF 20
ORANGE COUNTY UTILITIES	32,260	0.5%	1.5%	1.9%	2.5%	3.2%	3.2%	4.3%
ORLANDO UTILITIES COMMISSION	11,712	1.2%	0.8%	0.1%	1.1%	2.0%	2.4%	1.1%
TOTALS:	43,972	0.9%	1.1%	1.0%	1.8%	2.6%	2.8%	2.7%

Table 11: Differences Between District Model Results and TAZ-Based Model Results for Orange County for Utility Service Areas of 10,000 Or More Acres

UTILITY/WATER PROVIDER	ACRES	%DIFF 90	%DIFF 95	%DIFF 00	%DIFF 05	%DIFF 10	%DIFF 15	%DIFF 20
DELAND CITY OF	4,856	5.1%	9.3%	12.4%	13.0%	13.6%	13.9%	14.0%
ORMOND BEACH CITY OF	5,807	24.3%	14.8%	7.6%	3.7%	0.4%	2.1%	4.1%
PORT ORANGE CITY OF	4,437	12.3%	11.8%	12.3%	19.3%	24.8%	31.8%	38.3%
TOTALS:	15,100	13.9%	11.9%	10.7%	12.0%	12.9%	15.9%	18.8%

Table 12: Differences Between District Model Results and TAZ-Based Model Results for Volusia County for Utility Service Areas of 4,000 Or More Acres

CONCLUSION AND DISCUSSION

This model was a success in that it developed a methodology to distribute county level projections to an area small enough to be useful to the St. Johns River Water Management District. The raw projections, before normalization, were encouraging in that the results at the county level were very close to those developed by BEBR. Further testing will be required to adequately validate this model, but the results compare favorably to those of most of the larger utilities. As expected, growth in Orange County is projected to be strongest around the urban fringe around Orlando, particularly west and northwest of Orlando. The same phenomenon was seen in Volusia County, where the highest growth rates were north, south, and west of Daytona's core urban area.

<u>Integration of Built-Out Sections with the Mask Grid.</u> Although the rates at which sections become built-out produces reasonable results, no attempts to validate these results have been made as yet. The method used to calculate build-out will change somewhat when digital future land use maps are integrated into this step later in the Project. Validation will occur after this change is made.

<u>Integration of Built-Out Sections with the Influence Surface.</u> It is also reasonable to assume that as residential development occurs, it generally attracts further development: commercial, industrial, and more residential. Existing employment opportunities, services, and infrastructure all contribute to the increased "attractiveness" of land near existing developed areas. Although land farther away from current developed areas is generally cheaper, and although it is attractive to some for its pristine qualities, the possibility of development is less than that of similar areas in closer proximity to current development. For this reason, the added weight given to built-out areas by adding them to the Growth Influence Surface at the end of each period in the model is justified.

Final Output of Model

The utility companies have used different methods for projecting future demand in their service areas. Some utilities made their own projections, but many used projections from local planning agencies or hired consultants to make the projections for them. Some of the projections may be good and some may not. The comparison of this model's results against those of the utility companies is useful, but even if the estimates are very close does not mean they are accurate. Future investigation into the methods of each utility would be useful in gauging the reliability of their results.

Although the utilities have more knowledge of their service area, it is believed that this model is a more comprehensive measure of the factors influencing population growth. If local information such as Developments of Regional Impact (DRIs), building permit activity, local tastes and preferences, etc., is integrated with the model at a later date, any discrepancies between the model and the utilities should not lessen confidence in the model.

However, the TAZ-based models are likely a more accurate reflection of the base year population. The model's projections are generally close to those made by the TAZ-based models. When only considering the larger utilities (thus reducing boundary errors), the average error in 1990 is 0.9% in Orange County and 13.9% in Volusia County. However, the discrepancies among the smaller utilities are much larger. This gives evidence to the conclusion that the variation in the densities within sections straddling Utility Service Area boundaries is a major factor in the discrepancies between the model and the utility projections.

Future Improvements to the Model

Any future improvements to the model should include updates in the data sets used in the model, further refinements in the methodology, and the enhancement of the user interface.

Data Updates

Some of the data sets used in this model are out of date. They were used because they are the best data currently available, but many can be updated in the near future.

Department of Revenue's Property Appraiser Data. The GeoPlan Center at the University of Florida will be receiving the 1996 update of the Property Appraiser data set from the Florida DOR in the next few months. When this becomes available, the base year can be changed to 1995.

Level 2 Land Use. The District is in the process of updating its land use data, and the new version should be ready by late 1998 or early 1999. This is especially important if the base year is changed to 1995, so that the residential land use will be current.

Future Land Use. This has recently become available from the District Planning Department. It was created from local government future land use maps (FLUMs), and can be used to enhance the methodology for calculating build-out.

USGS 1:24,000 Hydrology. The 1:24,000 hydrology layer has recently been made available from the United States Geological Survey (USGS). It is more accurate than the 1:100,000 hydrology currently being used by the model, so it can replace the old hydrology in the very near future.

Conservation Lands. The conservation lands are updated frequently by the District and the GeoPlan Center. Any additions to this layer are extremely important and can be integrated into the model as they become available.

Refinement of Methodology

Currently the model makes good section level projections, but is not yet a true forecasting model. Although some local knowledge is integrated into the methodology, it does not presently incorporate enough local knowledge of DRIs, building permit activity, local tastes and preferences, and the like. Andrew M. Isserman writes that "forecasting should be an interactive process, involving local information, staff participation, and citizen involvement. Data and methods can focus and discipline the effort, but in the end forecasting is also part history, part storytelling." (Isserman, 1993). Robert Hopkins adds that a true forecast "predicts the most likely future, a future which may well be a continuation of existing trends or may predict a marked change in direction." (Hopkins, 1992). Any such marked change could put the planners at the District at a disadvantage. Any continued work done on the model should focus on this important effort of incorporating local knowledge and comments, bridging the gap between a projection model and a true forecasting model.

Determination of Build-Out. Neither the future land use maps nor the current methodology alone inspires a great deal of confidence in determining build-out. The best method given the available data and budget and time constraints would be a combination of the two methods. The current statistical method based on existing densities would act as a check and balance for the future land use, which in many cases is unrealistic. The future land use could be useful, although the accuracy is somewhat variable. In some areas, the future land use present a more aggressive rate of population growth than observed in the BEBR county population projections.

Adjust Base Year Grid. Because the TAZ-based models are likely more accurate reflections of base year population, the model's base year grid with population estimated from parcels will be adjusted with either TAZ data or the original census block data.

Improvement of User Interface

Future improvements to the model could make it both easier to use and more functional. Porting the model to a Windows-based software package would enable non-technical users to run the model. Adding more menus for user input would allow users with knowledge of the area being modeled to influence model results.

Conversion to ArcView® 3.0 GIS. All of the functionality provided by ARC/INFO® to run the model can be replicated using ArcView® 3.0 GIS. ArcView is a user-friendly desktop software package that is a fraction of the cost of ARC/INFO®. It has an easy-to-learn windows interface, so that managers and planners who are not GIS experts may run the model themselves on their own PCs. The model could be automated through Avenue™, ArcView's object oriented programming language. It could also be demonstrated at public meetings much more easily than the UNIX ARC/INFO®-based model. the District intends to eventually port this model to ArcView.

Additional Menus for User Input. Future plans for the model also include providing for additional input from users. Menus to allow users to increase or decrease the influence of a particular feature and/or method or to add an entirely new feature will provide further sensitivity analysis for these features and/or methods. For example, if a local government official was aware of a new DRI or a considerable increase in building permit activity in a particular area, the user could digitize the feature or area, weight it accordingly, and input it directly to the model.

The Future of Growth Modeling and GIS

The tools for creating, processing, analyzing and outputting digital data are advancing geometrically. Increased processing power and data availability coupled with improvements in software applications make possible projects that were only recently unthinkable. As the tools improve, so will the information and models that they are designed to build.

This will be true of future efforts to model population growth as well. Better models will be developed to forecast growth over very small areas that will use existing, current, high quality data sets. Many will allow a high level of user interaction for sensitivity analysis and calibration. They will also be easy to use, because the end users in most cases are manager or planners not well skilled in GIS.

Better information leads to better decisions. Too often decisions are made on insufficient or in accurate information. The future promises more and better information, and more and better tools to create, process, and analyze that information. Huxhold affirms that "the value of information increases the more it is shared and disseminated" and points out that "information that is not used is useless" (Huxhold, 1991: p.4). As valuable as good estimates of future growth are, there will be a premium on accurate models for forecasting population growth in the years ahead.

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APPENDIX A
ARC MACRO LANGUAGE (AML) PROGRAMS

The model was built using ARC/INFO® GIS software developed by Environmental Systems Research Institute (ESRI). The Arc Macro Language (AML) programs written for the model described are as follows:

1. SETUP.AML. Copies input coverages, grids, and INFO tables from various sources to be used in the model. Converts coverages to grids, and attaches vector attributes.
2. START.AML. Prompts the user to select the county or counties to be modeled, sets path variables, and calls other AMLs to be run.
3. SETWIN.AML. Sets initial Grid settings. Called by other AMLs when Grid command is issued.
4. MOD.AML. Main model AML. Creates grid and dBASE file of population and growth by square mile section.
5. SUM_WSA.AML. Summarizes section numbers created by MOD.AML by water utility service area boundaries.
6. SUM_TAZ_BY_WSA.AML. Summarizes TAZ-based model results by water utility service area boundaries (to compare against the District model results).
7. SUM_TAZ.AML. Summarizes section numbers created by MOD.AML by TAZ boundaries. Originally written to compare the District model's section numbers against TAZ-based model results. Later concluded that summarizing the TAZ-based model results by utility service area made more sense, so this is no longer used.

Additional AMLs and menus used during the modeling process are organized into the following workspaces:

1. W_OLD_AMLS. Contains older versions of model AMLs for future reference.
2. W_OLD_MENUS. Contains menus no longer used (to graphically select the county to be run, to click on the period to be run, etc.). It was determined that the model will be run in advance of viewing/analyzing the results, and that the model will normally be run by a District employee familiar with ARC/INFO®. Therefore, a batch process is preferable to an interactive, menu-driven one.
3. W_UTILITIES. Contains utility AMLs for use with model data sets (to project or reproject, copy, kill, etc.). Projection files area included in the W_PRJ_FILES directory under W_UTILITIES.

Anyone familiar with ARC/INFO® and AML programming will be able to use the above AMLs. In some cases, minor edits may be required to accommodate for future changes in input data attributes, locations, etc. This should not present a problem, as the programs are well-commented and easy to follow. The following pages are printouts of the AML programs.

APPENDIX B
DISK STORAGE AND DATA REQUIREMENTS

The data sets (including the tax data) varies per county from 30 MBs (Baker) to 300 MBs (Orange), totaling approximately 1.8 GBs for the 18 county area. Additional memory is required for processing, so a minimum of 2.0 GB should be reserved for the model.

The required input data sets to run the model are contained in Table 13.

Data Layer	Name	Data Source
Tax Data INFO Table	TAX_DATA	Florida Department of Revenue
County Boundaries Coverage	BOUNDARY	United States Census Bureau TIGER Line Files
Section Boundaries Coverage (from the Public Land Survey System Township, Range, and Section lines)	PLSS	Florida Resources and Environmental Analysis Center
Major Roads Coverage (Primary and Secondary)	DOTRDS	Florida Department of Transportation
Level 2 Land Use Coverage	LULEVEL2	St. Johns River Water Management District
Water Bodies Coverage	HYDRO	United States Geological Survey Digital Line Graphs (DLG) 1:100,000 Scale Hydrology
Conservation and Recreation Lands Coverage	CLAND	GeoPlan Center and various Water Management Districts
Water Utility Service Area Boundaries Coverage	WSA	St. Johns River Water Management District
Transportation Analysis Zone Boundaries Coverage	TAZ	St. Johns River Water Management District from the East Central Florida Regional Planning Council

Table 13. Input Data Layers Required to Run Model

The location of the input data layers are shown in Table 14.

Location	Data Layer Name
%rootpath%<countyname>/data/info_tables	TAX_DATA
%rootpath%<countyname>/data/covers	PLSS, DOTRDS, LULEVEL2, HYDRO, CLAND
%rootpath% District/data/covers	WSA
%rootpath%<countyname>/model/taz	TAZ

Table 14. Location of Input Data Layers Required to Run Model