IMPLEMENTATION OF A DISTRICT MANAGEMENT SYSTEM IN THE LOWER RIO GRANDE VALLEY OF TEXAS (1)

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ABSTRACT

The Lower Rio Grande Valley of Texas is undergoing rapid population growth and industrial development. No additional water rights are available in the lower Rio Grande River Basin, and future development will depend on water transfers from agriculture. The potential for saving water in irrigation districts is being studied as part of a regional water resources planning project. An Irrigation District Management System (DMS) is under development to aid in this analysis. The DMS is built upon GIS-based maps and databases for organizing and displaying district information on water accounts, fields, and distribution systems. Various other components are being linked to the DMS or are under development to enhance its capabilities, including a crop growth and irrigation scheduling model for determining water use under various water supply scenarios, and a routing model for determining the ability of the distribution systems to deliver the volumes of water needed for each scenario. The implementation of the DMS in the Valley and its use in regional water planning is described.

INTRODUCTION

The Lower Rio Grande Valley is a four-county area along the Mexican border located at the south-most tip of Texas (Fig. 1). While usually referred to as the "Valley," the area is actually a delta of the Rio Grand River. It is known for mild winters, excellent hunting and fishing, rare and endangered wildlife, the unique "Tex-Mex" culture of the border region, and South Padre Island. Manufacturing is rapidly expanding on both sides of the border, and the area is among the fastest growing regions in the U.S. and Mexico.

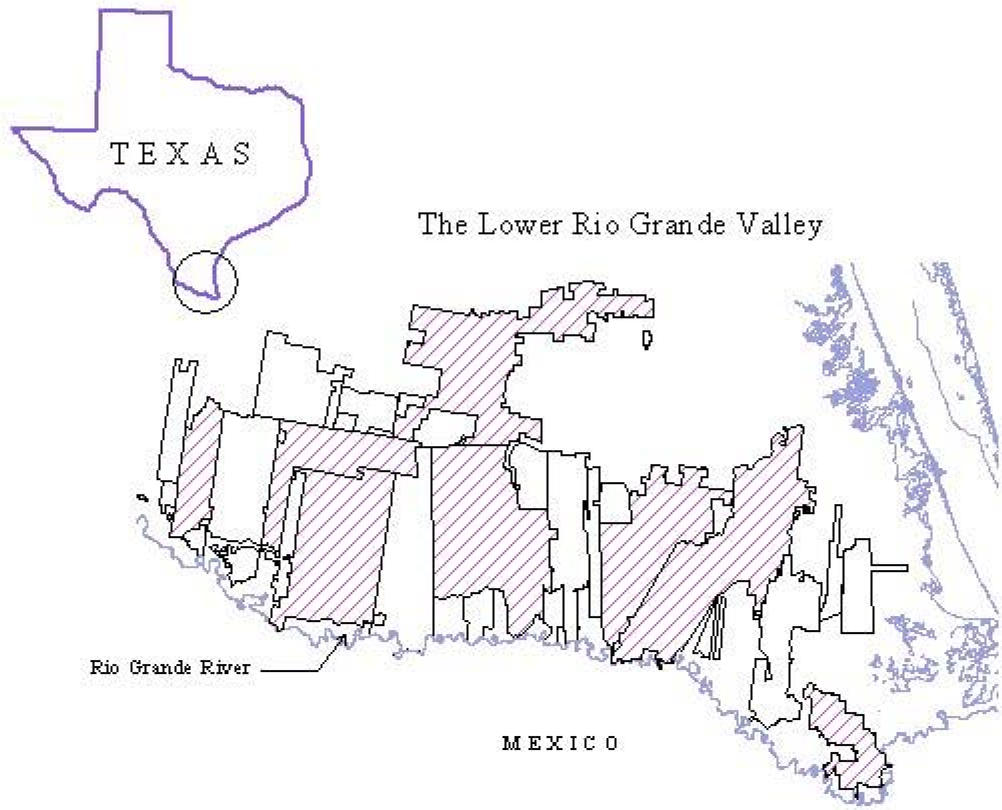

Figure 1. The 8 irrigation districts in the Lower Rio Grande Valley that have initiated GIS-based management systems.

The Valley is also an intensively irrigated region. Just two counties account for the bulk of the region's 740,000 irrigated acres. An irrigated area of similar size is located just across the border in Mexico. Ninety-eight percent of all the water used in the border region is from the Rio Grande (called the Rio Bravo in Mexico). Cotton and sorghum account for the most acreage, but the semi-tropical climate of the region supports a wide range of crops including citrus, sugar cane, vegetables, aloe vera and other specialities.

Irrigation development began in the late 1800s by land development companies chartered by the state. Water conflicts among Texas growers, and between Texas and Mexico were common throughout the first half of the century. In the 1940s, treaties were signed between the U.S. and Mexico for the construction of two dams on the Rio Grande: Falcon and Amistad. Inflows into this reservoir system are divided between Texas and Mexico, with about 55 percent of inflows allocated to Texas and about 45 percent allocated to Mexico. The International Boundary and Water Commission was created to oversee and maintain the reservoir and river system.

Texas began to judicate water rights in the 1950s, a process that took to the mid- 1960s to complete. Texas established the Rio Grande Watermaster to authorize water releases from the reservoirs according to account balances of water rights holders. A few growers along the river have water rights and pump their own water. Additionally, 28 irrigation districts hold the agricultural water rights, pump the water from the Rio Grande, and deliver it to individual farms and municipalities through gravity-flow canals and underground pipelines.

There is very little water in the Rio Grande River which makes its way past the El Paso area. Much of the inflow for the lower Rio Grande comes from the Rio Conchos, which intersects the Rio Grande just north of Presidio. Some additional recharge occurs from the Pecos River and a number of streams, most of which are in Mexico. Thus, water supply in the Valley depends on rainfall in watersheds hundred of miles away.

DISTRICT MANAGEMENT SYSTEM

The development of an irrigation district management system (DMS) at Texas A&M University began in 1992. The vision was to create a decision support system for scheduling, water management and conservation planning. The DMS would incorporate field-level analysis of water demand with management of the overall distribution system. The format and components of the DMS have evolved significantly, due to advances in software, availability of digitized information, and input from Texas' irrigation districts. The three main components of the DMS are the Visual System, IRRDESS, and Distribution System Routing.

Visual System

In Texas, irrigation districts are units of government with locally elected directors. State regulations govern the organization of districts, election of directors, and certain financial matters. Otherwise, districts set their own policies and procedures for allocation of water to individual growers. In most districts, property owners are assessed a "flat fee" each year, and growers are charged for each irrigation. To order water, growers are required to turn in a "water ticket" form which includes information on the field, water account number, tenant's or owner's name, crops planted, etc. Most districts enter this information into a computer database. The purpose of the visual system is to allow easy access, analysis, and display of this information.

The basic design and functions of the visual system were developed cooperatively with the Harlingen Irrigation District during the period 1995-1997. A small portion of the District was selected for analysis. An aerial photograph of this portion of the district was digitized and geo-referenced, that is latitude and longitude coordinates were provided for each pixel comprising the photograph. Thus, each point of the photograph has exact coordinates which allows for easy integration with other maps and databases. Next, the individual water account or field boundaries were drawn using the photograph as a guide. This was done with the software ArcInfo which runs on a Unix platform. In ArcInfo terminology, a "coverage" was created of the water account boundaries (Note: recent releases of Windows-based ArcView now support the drawing of maps with this software, and such maps are referred to as "themes").

This coverage (i.e., map of field boundaries) was linked to the district's database, allowing all information in the database to be displayed using ArcView. By clicking on a field, database information is shown in a list box. Information can also be displayed using shading or color coding. For example, Figure 2 shows the number of times each field was irrigated in 1997. Also visible in this figure are the underlying aerial photograph and the "polygons" comprising the boundaries of each water account. Next, the distribution system in this portion of the district was mapped. A database of all information available on the distribution system was developed and linked to this coverage which can be displayed by ArcView in a list box.

IRDDESS

IRDDESS (Irrigation District Decision Support System) is a crop growth and irrigation district simulation model developed at Texas A&M University during the period 1992-1995. As a crop growth model, IRDDESS is similar to the family of models "WOFOST" developed at the Center for World Food Studies, the Netherlands (Driessen and van Diepen, 1986; Driessen and Konijn, 1992). Only a brief description is given here; for more information see Endale (1995) and Endale and Fipps (1996).

IRDDESS allows for the simulation of different crops on individual fields within an irrigation district. Soil type and related properties, and irrigation method and scheduling can vary from field to field. Daily crop growth is simulated based on climate, water availability, planting date, etc. Various water supply scenarios can be considered such as supplying full crop requirement, following a pre-established schedule, and irrigating according to soil moisture levels or depletion. The model tracks water demand at each field and in the distribution system, which may consist of primary, secondary and tertiary canals. Once daily water demand is determined at the field level, IRRDESS sums the required flows in each segment of the distribution system and checks the demand against the capacity.

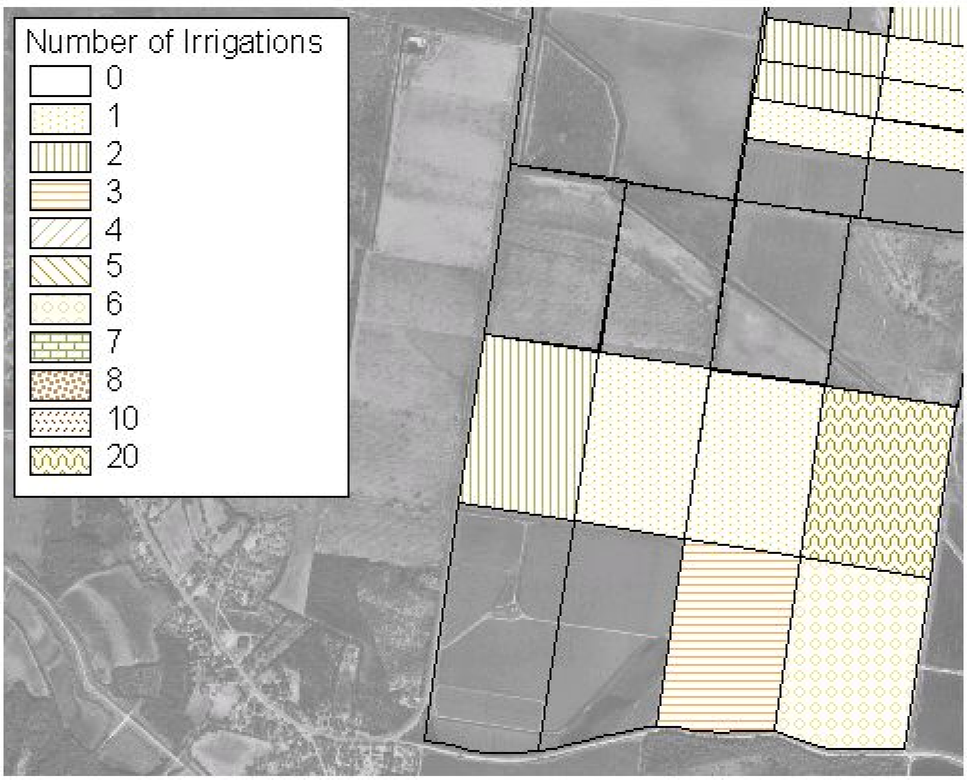

Figure 2. Water account boundaries drawn using an aerial photograph as a guide and linked to the district's data base to display the number of irrigations for each account during 1997.

Distribution System Routing and Accounting

We found that the original routing module of IRDDESS was too simple to handle the complicated distribution systems of real districts, and the code too cumbersome for incorporating into a GIS format. A more sophisticated procedure is under development. For the current analysis, we programmed a distribution system routing algorithm directly in ArcView using the script language Avenue. Fields are linked to a specific gate or valve. The distribution network serving the field is created by linking from gate to gate, back to the main diversion point.

THE LOWER RIO GRANDE VALLEY INTEGRATED WATER RESOURCES PLAN PROJECT

The lower Rio Grande River is over appropriated; that is, there are more water rights than firm yield. At the first of each year, the Rio Grande Watermaster allocates the available water to rights holders (following state regulations), with municipal and industrial water rights having priority over agriculture. As discussed earlier, the region is undergoing rapid population growth and industrialization. The Texas Water Development Board (TWDB, 1997) projects that by the year 2010, municipal water demand will increase by 66% and industrial water use by 19%. By 2050, municipal demand is expected to increase 171% and industrial 48% over current usage (note: these numbers do not included expected water demand increases on the Mexican side of the border).

The Lower Rio Grande Integrated Water Resources Plan - Phase II Project (IWRP) is a 1-year intensive study of multiple proposals for providing the additional water which will be needed. These proposals include a municipal supply pipeline from Falcon, a channel dam at Brownsville, conservation programs, as well as water savings in agriculture which would lead to the transfer of water rights. The project is scheduled to be completed in November 1998.

Potential water savings in agriculture is being examined at all levels. At the farm level, these include water savings from metering, improvements in on-farm water management practices, conversion to sprinkler and drip irrigation, and changes in crop mix. At the district level, the analysis covers changes in irrigation district operation, management and infrastructure, which include lining canals, installing pipelines, sharing main canal systems between districts, and instituting various water pricing programs. IWRP includes technical feasibility and economic analyses.

For such water planning projects, a fully developed and implemented DMS could be used in several ways, including:

- allowing access to the districts' databases for analyzing past and current water use, trends in cropping patterns, and changes in district efficiency from past improvements;
- determining water demand under proposed irrigation technology, water management and crop mix scenarios;
- determining whether the existing distribution system can supply the volume of water needed under various scenarios; and
- analyzing the potential increases in conveyance losses if canals have to remain fully charged for longer periods to meet expected water demand.

IMPLEMENTATION OF DMS

We have taken a dual approach in implementing the DMS. We are working directly with eight districts (Fig. 1) to map their systems and interface the GIS-based maps with the districts' water accounting databases. We are also assembling a "Regional GIS" for analysis of the water saving potential from improvements in conveyance system efficiencies. In constructing the GIS maps of the districts, we are using DOQQs (digital orthographic quarter quads), which are obtainable from the USGS. We are using DOQQs with a scale of 1:12000 which provide a resolution of 1 m. These are aerial photographs taken in 1995, corrected for the earth's curvature, geo-referenced, and digitized.

To participate in the program, we required each district to provide a personal computer (equal to or faster than a Pentium II 233 MHZ, with 128 mb of RAM), purchase ArcView version 3.0, select or hire a person for GIS mapping, and obtain copies of the DOQQs of their districts. Two workshops were conducted to provide basic instruction on GIS mapping and theme construction in ArcView. Each district was instructed to begin by drawing their water accounts and/or field boundaries (Fig. 2). We choose to begin with water account boundaries in order to produce a useful tool that would immediately improve district management and bookkeeping.

Mapping distribution systems with ArcView, particularly canals, is relatively easy with the DOQQs as a guide, since all but very small canals (less than 1 m wide) are clearly visible. Even underground pipelines can be drawn using the stand pipes as a guide, which are also visible. However, assembling the attributes of the systems requires very detailed technical information as outlined in Table 1. Only two of the 24 major districts have complete sets of data assembled in a format that is easy to access. For the others, assembling this information will be a major task. One example is Cameron County ID#2 which had no technical information available on their canal system. The district had its canal riders assemble the data, which took approximately 3 weeks of full-time work by 7 individuals.

DMS IN WATER RESOURCES PLANNING

In the current phase of the regional water study, the DMS is being used primarily to develop maps and the attributes of the irrigation distribution systems. These resources will assist us in determining the potential water savings from lining and pipeline replacement of earthen canals, and from the elimination of canals expected due to urban growth and expansion. For example, Figure 3 shows the main distribution system for the Mercedes Irrigation District, the total extent of unlined canals, and the sizes (top widths) of the canals. Overlaying this information on a soils map will help identify unlined canals which may be candidates for field reconnaissance and further analysis.

Table 1. Examples of the Type of Data Needed for the Distribution System in Creating a GIS-based District Management System.

Water Delivery Systems

- Segment ID
- Category (primary, secondary, tertiary)
- Segment Length
- Starting Elevation
- Ending Elevation

Additional Data for Canal Segments

- Canal Shape
- Top Width
- Bottom Width (where applicable)
- Side Slope (where applicable)
- Depth
- Lining
- Normal Operating Depth
- Normal Operating Capacity
- Maximum Capacity
- Elevation of Top of Canal in Relation to Ground Level
- Condition, Maintenance, etc.

Additional Data for Pipeline Segments

- Diameter
- Capacity
- Material
- Condition

Main Pumping Plant and Relift Pumps

- Pump ID
- Maximum Pump Capacity
- Normal Operating Capacity
- Condition, Technical Specifications, etc.

Location and dimensions of Structures

- Gates
- Siphons/Culverts
- Valves/Outlets

Figures 4 and 5 show the effects of urban growth and expansion on the irrigation distribution systems. The total urbanized area is overlaid onto the map of the main irrigation distribution systems. Large areas in the Western portion of the Valley will be covered up by urbanization, and a number of districts will effectively be separated into northen and southern portions. To date, although we have mapped the main distribution systems of all the districts (Figure 4), we only have complete information (canal sizes, etc.) on about half of the distribution system (Tables 2 and 3). Maps of the secondary distribution system and the database of attributes for both the primary and secondary systems must be completed before more detailed analysis can be conducted.

Table 2. Canal Sizes, Extent, and Lining Classification for the Primary Irrigation Distribution Systems in the Lower Rio Grande Valley.

Top Width (feet)	**Canal Type (or lining material) (miles)**	
	concrete	**earth**
< 10	41.6	1.0
10 - 20	98.0	11.9
20 - 30	25.2	52.2
30 - 40	3.8	35.1
40 - 50	1.1	60.1
50 - 75	1.4	30.9
75 - 100	0	11.1
> 100	0	9.7
Unknown Widths	99	134.5
Total Miles	270.1	346.4

(1)		

(1) no size or lining information is available on an additional 25.4 miles of canals

Table 3. Miles of Canals, Pipelines and Resacas of the Primary Irrigation Distribution Systems in the Lower Rio Grande Valley.

canals (miles)	pipelines (miles)	resacas (miles)	unknown (miles)	total (miles)
641.9	9.7	44.6	0.1	696.3

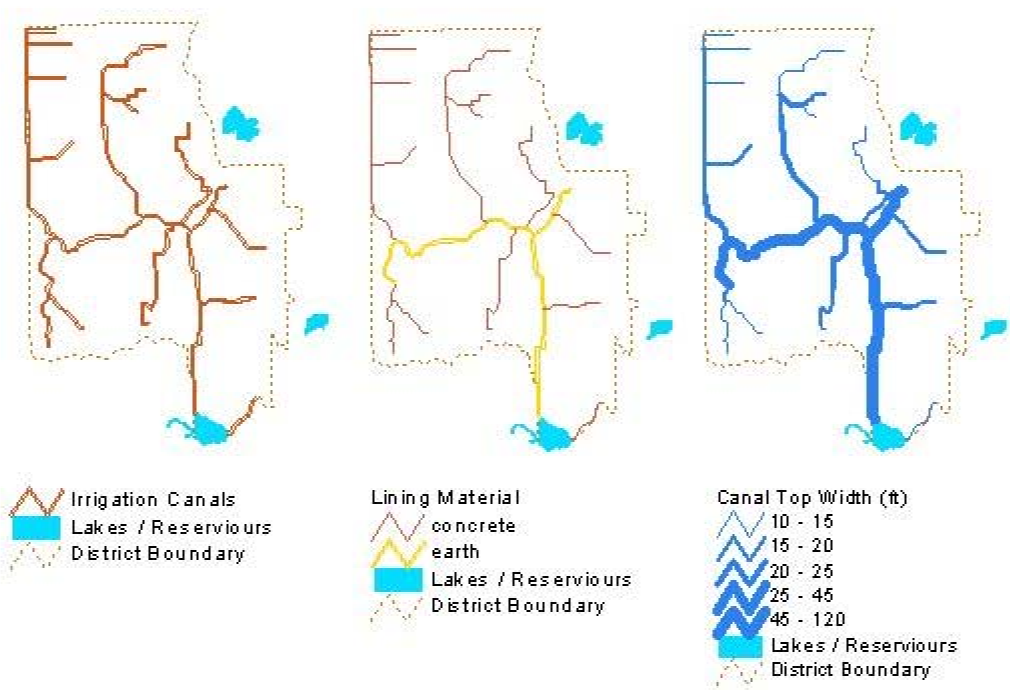

Figure 3. The main distribution system of the Mercedes Irrigation District and various ways of displaying its attributes for analysis, including the lining classification and canal size.

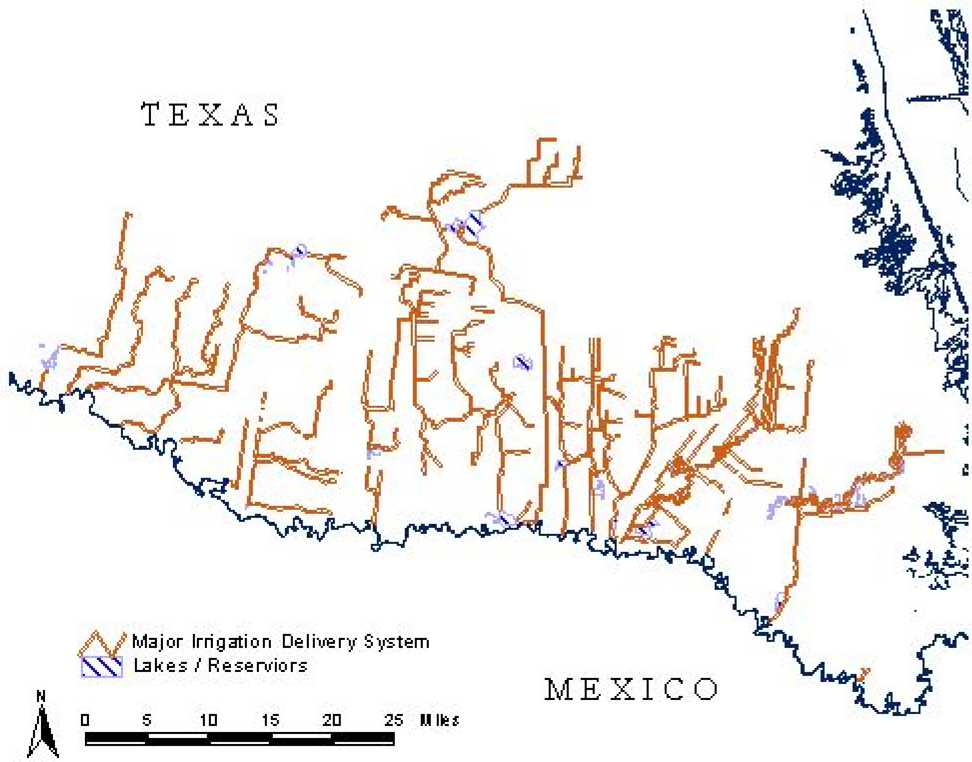

Figure 4. Main irrigation distribution systems in the Lower Rio Grande Valley.

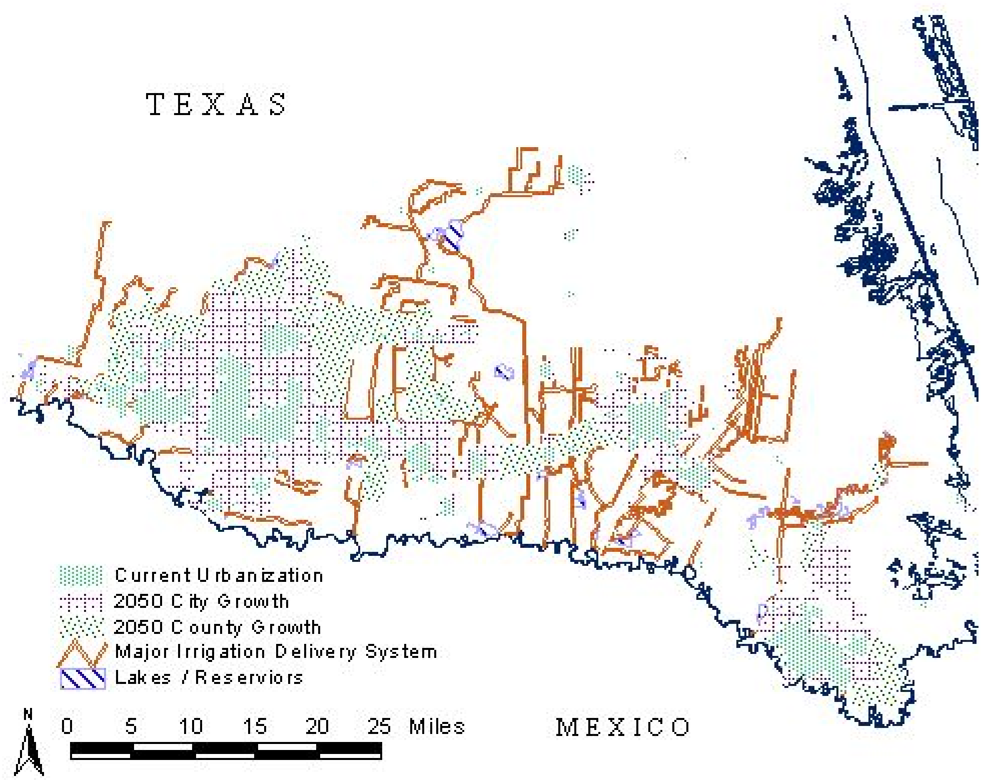

Figure 5. Current and expected growth in the Lower Rio Grande Valley.

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