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Allen W. Sturdivant
Ronald D. Lacewell
Ari M. Michelsen
M. Edward Rister
Naomi Assadian
Marian Eriksson
Roger Freeman
Jennifer H. Jacobs
W. Tom Madison
James T. McGuckin
Wendy Morrison
John R. C. Robinson
Chris Staats
Zhuping Sheng
R. Srinivasan
Joshua I. Villalobos

Texas Water Resources Institute

Texas A&M University

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Prepared by:

Texas Agriculture Experiment Station, and
Texas Water Resources Institute
of the Texas A&M University System

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Preface

After observing apparent deterioration in segments of its flood-control levee system, the United States Section of the International Boundary and Water Commission (USIBWC) performed engineering evaluations during 2001-2003. These evaluations confirmed that over time, portions of the infrastructure's flood-control capacity have diminished below original designs. The USIBWC responded with a RFP in March of 2004 indicating its desire for a rapid economic assessment of the flood-control benefits for certain IBWC Rio Grande projects (U.S. side only). Further, in submitting a request for federal funds to rehabilitate its infrastructure, USIBWC is expected by the U.S. Office of Management and Budget (OMB) to provide an economic assessment of benefits and an estimate of initial construction costs. This report presents results of an economic analysis using readily-available data intended to provide insight on potential losses in case of a failure in the flood-control system.

The agency originally known as the International Boundary Commission (IBC) was created by the Convention of 1889. It eventually became known as the IBWC with the signing of the 1944 Treaty, which provided for both a United States Section and a Mexican Section. The IBWC is the agency tasked with applying the boundary and water treaties between the two countries in a manner which "*... benefits the social and economic welfare of the peoples on the two sides of the boundary and improves relations between the two countries*." Specific IBWC tasks include: accounting for and distributing international waters of the Rio Grande; and overseeing the construction, maintenance, and operations of all infrastructure, including reservoirs, dams, hydroelectric energy-generation facilities, floodways, and levees downstream of Caballo Reservoir in New Mexico.

The international boundary between the United States (U.S.) and Mexico is over 1,952 miles in length, with the Rio Grande encompassing 1,254 miles of that total. Today, the boundary is characterized by fifteen pairs of sister cities sustained by agriculture, import-export trade, service and tourism, and in recent years, by a growing manufacturing sector. The entire borderlands' population (i.e., the entire 1,952 mile corridor encompassing cities' populations on both sides of the border) was estimated to be 10.6 million in 1995 (IBWC 2004a).

To estimate flood-control benefits for USIBWC Rio Grande projects, economists, soil and crop scientists, and geospatial information specialists considered four major economic reaches (or project areas) that stretch from Caballo Reservoir in New Mexico to Brownsville, TX. Limited time and a large geographic area necessitated an innovative approach to estimate the gross value of flood-control benefits. A two-foot flood-inundation depth across agriculture and urban land-use categories was assumed and, with the use of high-resolution map imagery, used in extrapolating representative damage values to a flood plain area based on the Federal Emergency Management (FEMA) 100-year flood area along the Rio Grande.

The data used were assimilated from several sources, including property assessment records, crop enterprise budgets, census data, etc., as well as from agencies such as FEMA. The analytical method used provides a rapid assessment of potential flood-control benefits for a single event for each of the four USIBWC flood-control project areas, and an aggregate estimate.

These damage estimates are in fiscal year 2004 dollars and represent expected losses as though the flood occurred in 2004. The damages avoided for agriculture and urban structures/contents for the four project areas is an estimated $323 million, increasing to $506 million with roads, vehicles, and other such items included.

Study Team

Allen W. Sturdivant
Ronald D. Lacewell
Ari M. Michelsen
M. Edward Rister
Naomi Assadian
Marian Eriksson
Roger Freeman
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Zhuping Sheng
R. Srinivasan
Joshua I. Villalobos

Project management provided by **Sturdivant**, Extension Associate [ab]; **Lacewell**, Professor, Assistant Vice Chancellor, and Associate Director [acd]; **Michelsen**, Professor and Resident Director [e]; and **Rister**, Professor and Associate Head [ac]. Other co-authors, in alphabetical order, are **Assadian**, Assistant Research Scientist [e]; **Eriksson**, Associate Professor [fg]; **Freeman**, Economic Consultant [h]; **Jacobs**, Research Associate [fg]; **Madison**, Research Assistant [ag]; **McGuckin**, Associate Professor [i]; **Morrison**, Postdoctoral Research Associate [e]; **Robinson**, Associate Professor and Extension Economist [ab]; **Staats**, Research Assistant [g]; **Sheng**, Assistant Professor [e]; **Srinivasan**, Associate Professor and Director [cfg]; and **Villalobos**, Research Associate [e].

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a Department of Agricultural Economics, Texas A&M University, College Station, TX.
b Texas Cooperative Extension, Agricultural Research and Extension Center, Weslaco, TX.
c Texas Agricultural Experiment Station, College Station, TX.
d Texas Cooperative Extension, College Station, TX.
e Texas A&M University Agricultural Research and Extension Center, El Paso, TX.
f Department of Forest Science, Texas A&M University, College Station, TX.
g Spatial Sciences Laboratory, Texas A&M University, College Station, TX.
h Formerly with the U.S. Army Corps of Engineers, Galveston, TX.
i Department of Economics, New Mexico State University, Las Cruces, NM.

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Estimated Benefits of IBWC Rio Grande Flood-Control Projects in the United States

Abstract

The International Boundary and Water Commission (IBWC) is responsible for maintaining a series of flood-control projects beginning in New Mexico and extending along the Rio Grande's international border dividing the United States and Mexico. A review by the USIBWC indicate that, over time, the flood-control capability of the levees has been compromised, possibly to the point where the level of protection is below original-design capacities. Prior to investing federal monies in the rehabilitation of major flood-system infrastructure, the U.S. Office of Management and Budget requires an economic analysis of expected benefits, or losses avoided with implemented protection measures. Recent flood events along the international border, resulting in significant economic damages and loss of human life, emphasized the need for a timely assessment of impacts of potential flood-control failure. Given a short project time line mandated by IBWC and the large geographic extent of the river- and floodway-levee system, innovative methods were developed to conduct a rapid and preliminary economic assessment of the flood-control infrastructure. Estimates for four major project areas relating only to the U.S.-side of the border only (stretching from Caballo Reservoir in New Mexico to the Rio Grande's mouth, near Brownsville, TX.) comprise the study's focus.

Millions populate the cities and towns along these economic reaches of the Rio Grande where extensive housing, commerce, industry, tourism, and irrigated agricultural production exist. Areas susceptible to flooding, along with land-use, were identified and quantified through high-resolution map imagery. Estimates of representative residential, commercial, and industrial property values and agricultural production values were developed from property assessment records, economic development councils, crop enterprise budgets and cropping patterns, census data, previous U.S. Army Corps of Engineers' flooding studies, etc. Gross economic values of flood-control benefits for a sample of each of the land-use types were determined and extrapolated to similar land-use areas in the flood zone. This analytical method provides a rapid

assessment of potential flood-control benefits for a single event for each of the four IBWC-designated flood-control project areas. An aggregate estimate arrived at by summing the potential benefits across all four project areas assumes avoidance of, or protection against, a simultaneous breach in all areas.

Baseline economic benefits for agriculture and developed property along the Rio Grande Canalization project are estimated at $13.7 million (basis FY 2004). Comparable estimates for the Rio Grande Rectification project are $139.1 million, while those for the Presidio Valley Flood Control project amount to $2.9 million. The Lower Rio Grande Flood Control project is estimated to provide $167.2 million in flood-control benefits.

Combined, the four project areas provide $322.9 million in flood-control protection benefits in the baseline analysis. When preliminary estimates of $183.0 million in other costs (i.e., emergency, roads, utilities, and vehicles) are added to the baseline estimate, the total flood-control protection benefits provided by the four project areas increases to $506.0 million.

Estimated Benefits of IBWC Rio Grande Flood-Control Projects in the United States

Introduction

The International Boundary and Water Commission (IBWC) has constructed and is responsible for maintaining a series of flood-control levees and other water-control infrastructure along the Rio Grande for flood protection on both sides of the U.S.-Mexico border. In response to observed levee degradation, USIBWC engineers evaluated the structural integrity of the levees and the flood-carrying capacity of certain project areas along the Rio Grande during 2001-2003. The USIBWC levee assessments suggested some levee segments are structurally deficient, while IBWC hydraulic analyses indicated flood-conveyance capacities are below original project-design criteria (Moehlig). The results of those evaluations indicate that extensive levee raising and overall structural rehabilitation may be necessary to restore the project areas to their original-design capacities (Stefanov). Further, an analysis of the economic benefits derived from these IBWC flood-control projects (on the U.S. side only) is required by the U.S. Office of Management and Budget (OMB) to comply with its capital programming, planning, and investment-control policies (IBWC 2004b). Finally, by comparing other exogenously-obtained *cost* information to this *benefit* information, the USIBWC can evaluate rehabilitation alternatives and efficiently allocate its limited financial resources.

Study Overview

This study evaluates the flood-protection benefits provided (for the U.S. side only) by the IBWC levees for four designated flood-control project areas (or economic reaches) along the Rio Grande. The scope of work for this analysis includes both individual and an aggregate estimate of gross economic benefits, in fiscal year 2004 dollars, for: (1) the Rio Grande Canalization project, (2) the Rio Grande Rectification project, (3) the Presidio Valley Flood-Control project, and (4) the Lower Rio Grande Flood-Control project areas (**Figure 1**) (Stefanov et al.).[1] This presented order of the four economic reaches[2] follows the flow of water as they start at the upper Rio Grande, beginning at Caballo Dam in southeastern New Mexico, and continue downstream and end near the Gulf of Mexico in far south Texas.

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1 These project names, as provided by Stefanov, are somewhat abbreviated from the full and formal project names provided in IBWC project-description documentation (i.e., IBWC 2004c), but they are the common names used by IBWC (Stefanov et al.) and are thus the convention adopted in this report.

2 Note the synonymous use of *project areas* and *economic reaches* as both terms are used interchangeably throughout this report.

Recent flood events (causing substantial economic damage and loss of life) along the Rio Grande,[3] combined with USIBWCs structural-integrity evaluations, have highlighted the need to promptly assess the potential economic impacts of a levee breach and/or failure of flood-control infrastructure. Further, the necessity for a prompt assessment is driven, in part, by the federal appropriations process. Given the limited project study horizon from IBWC and the large geographic extent of the river-levee and floodway-levee system, an innovative approach was developed to conduct a rapid economic assessment of an IBWC flood-control infrastructure failure along the Rio Grande.

The estimate of the potential damages (or alternatively phrased "*flood-protection benefits*") is limited to property damages only[4] and is based upon an analysis of four economic reaches. Though limited in time and scope, and by other resource limitations (e.g., dated land-use maps), this analysis report is based on the best information available at the time of this study and provides an excellent basis for a subsequent, more detailed, study.

This study is preliminary in nature and is expected to provide an underestimate of the total flood-protection benefits of certain IBWC flood-control infrastructure along the Rio Grande. Several benefit variables are not incorporated into the reported baseline estimates, hence, the results need to be interpreted considering the limitations of the study. These limitations, which are discussed later in this report, are indicative that future research and refinement efforts would provide for more accurate and defendable estimates.

Further, a very preliminary estimate of the benefits provided by IBWC flood-control infrastructure under an expanded set of potential damages (i.e., beyond agriculture crop and developed property) is provided in **Appendix D**. This appendix lists the assumptions used and extrapolates values from other studies, which results in a very preliminary, and "expanded," estimate of benefits provided by the IBWC flood-control infrastructure.

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3 For example, as reported in an April 6, 2004 National Situation Update by FEMA, a flash flood in the Mexican town of Piedras Negras (sister city to Eagle Pass, Texas) caused 31 deaths with a dozen others yet to be accounted for (FEMA).

Further, news media giant CNN reported on an August 24, 1998 flood event affecting Del Rio and Eagle Pass by reporting "a wall of water buried this Texas border town, causing flooding that washed homes away, killed seven people and left as many as 30 others missing, officials said." Continuing, the article reports "Meanwhile, the wall of water continued down the Rio Grande toward Eagle Pass, about 50 miles southeast of Del Rio, where its 300 residents were being evacuated. Authorities expected the Rio Grande to reach its high point there Monday evening. "*The flood wave is about a mile wide coming down the Rio Grande*," said Tom Millwee, state coordinator for the Texas Division of Emergency Management. "*We're going to see water in downtown Eagle Pass*."

Reporting on this same flood event in Del Rio/Eagle Pass, the Disaster Relief Organization covered the event with an article entitled "Del Rio, Southern Texas Clean Up After 500-Year Flood."

4 A complete discussion of the type of damage included, assumptions, etc. is provided in the "*Methodology*" and "*Assumed Values for Critical Parameters – Urban Land Use*" sections.

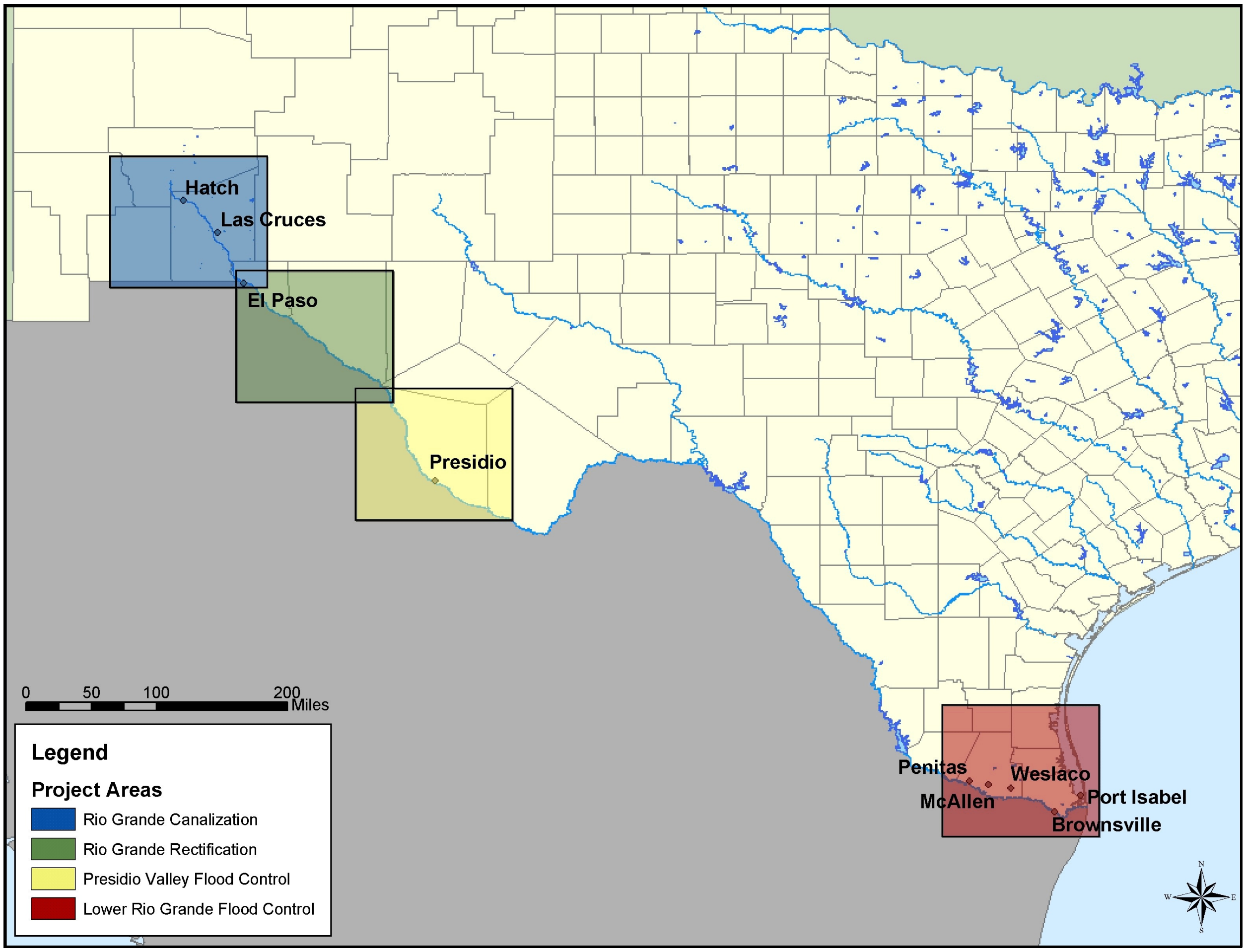

Figure 1. Location of Four IBWC Project Areas Along the Rio Grande, 2004.

Background: Project Study Areas

This analysis, aimed at estimating the gross economic flood-control benefits provided (on the U.S. side of the border only) by select USIBWC Rio Grande projects, is focused on four economic reaches. Descriptions of the four economic reaches are summarized below from unpublished information provided by the USIBWC.[5] The location of the reaches (or project areas) can be seen in **Figure 1**, with a synopsis of selected data provided in **Table 1**.

#1 - Rio Grande Canalization

The sizable IBWC infrastructure inventory in the Rio Grande Canalization (RGC) project, which is entirely in the U.S., includes about 130 miles of levee (i.e., 57 miles of levee on the west side and 73 miles on the east side) from Percha Diversion Dam (2 miles below Caballo Dam in New Mexico) to American Dam (in El Paso, TX.).

5 Readers interested in the full descriptions can refer to IBWC 2004c, as listed in the *References* section.

Table 1. Selected Summary Characteristics of IBWC Project Areas, U.S. Side, 2004.

	Project Area (Economic Reach)				
	Rio Grande Canalization	Rio Grande Rectification	Presidio Valley Flood Control	Lower Rio Grande Flood Control	Total
			U.S. Side Only		
Flood Information					
flood design	100-Year	100-Year	25-Year	500-Year	- -
freeboard	2 feet	2 feet	4 feet	3 feet	- -
designed-flood flow (CFS)	22,200 /14,000	11,000	3,600 / 42,000	250,000	- -
- at location	at Leasburg Dam / at American Dam	El Paso, TX.	above / below Rio Conchos	Rio Grande City, TX.	- -
River Floodway					
- total miles of levee	130	93	15.18	102	340.18
- miles at risk of being overtopped	10	12	1.25	38	61.25
- miles subject to encroachment	60	38	1.25	64 [a]	163.25
Interior Floodway [b]					
- total miles of levee	0	0	0	172	172
- miles at risk of being overtopped	0	0	0	2	2
- miles subject to encroachment	0	0	0	24 [a]	24
Area In Revised FEMA Flood Plain (acres)					
- Agriculture	2,484	2,356	764	75,645	81,249
- Residential	1,836	2,643	320	3,237	8,036
- Commercial	65	2,759	0	605	3,429
- Industrial	0	32	0	0	32
Total [last four rows only]	4,385	7,790	1,084	79,487	92,746

Sources: IBWC 2004c, Jim Robinson and Albert Moehlig with the IBWC, and data calculations of project personnel.

[a] Note for the LRGFC project, values based on river levees having 3-foot of freeboard and floodway levees having a 2-foot freeboard.

[b] These values are summed for the left and right levees (i.e., with a downstream flow).

(**Figure 2**). Of this, a combined 10 miles are estimated to be overtopped (on the U.S. side) by water associated with a 100-year flooding, while 60 miles are subject to encroachment (IBWC 2003, Jim Robinson 2004b) (**Table 1**). The RGC project's purpose is to provide flood protection against a 100-year flood and convey water to American Dam where the U.S. diverts its allocated amount and passes Mexico's allocation through the Rio Grande in accordance with the 1906 Convention. Current flood-design capacities (after the original RGC project and subsequent improvements) are larger than before, and as defined by the IBWC, are flow rates of 22,200 CFS at Leasburg Dam and/or 14,000 CFS at American Dam (**Figure 2**) (IBWC 2004c) (**Table 1**).

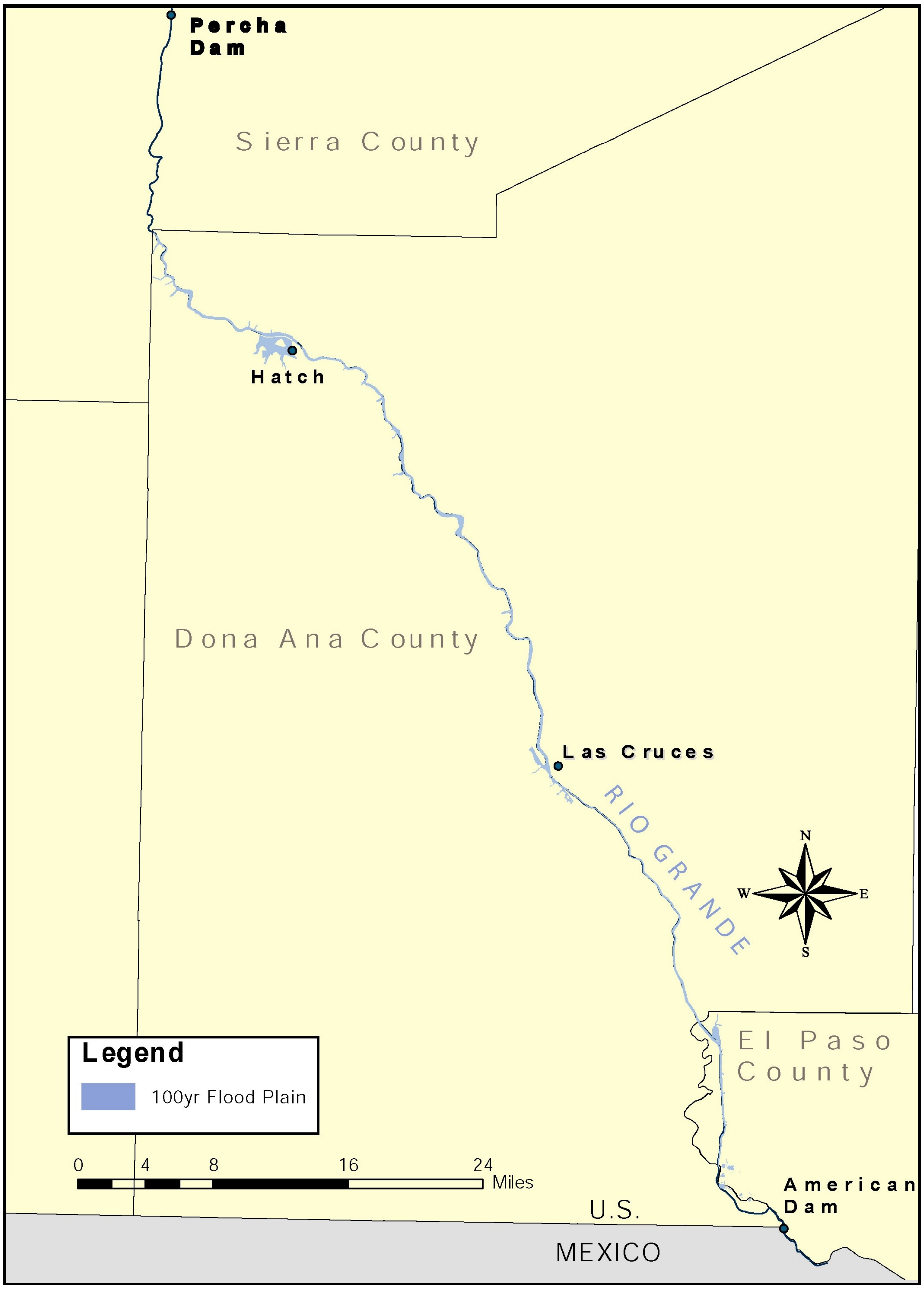

Figure 2. Location of the Rio Grande Canalization Project, 2004.

After the Elephant Butte Reservoir began storing water in 1915, the reduced downstream flow resulted in accumulated sediments and vegetation in the river's natural channel. With a shallowed channel, floodwaters from tributaries to the Rio Grande (downstream of Elephant Butte Dam) were able to overtop the banks and impact the adjoining region. Further, the accumulation was worsened by private landowners making unauthorized diversions along the river during times of low-flow releases. The combined effect made for a difficult task in regulating releases from upstream reservoirs to downstream users (i.e., in both the U.S. and Mexico) (IBWC 2004c). At the request of local interest groups, an engineering investigation was authorized by Congress in 1935. Based on this report, Public Law 648 was effected in June of 1936 authorizing the construction, operation, and maintenance of the RGC project's normal-flow channel and leveed floodway (IBWC 2004c).

#2 - Rio Grande Rectification

Today, the USIBWC infrastructure inventory in the Rio Grande Rectification (RGR) project includes 93 miles of river levee (on the U.S. side) between American Dam in El Paso and Fort Quitman (i.e., along El Paso and Hudspeth Counties) in the western-most reach of Texas (**Figure 3**). Originally, 155 miles of levee were present, but the RGR project, which was authorized by a 1933 Convention between the U.S. and Mexico, reduced the amount as the U.S. and Mexico sought to rectify and stabilize their boundary (IBWC 2004c). Another project (i.e., Chamizal Convention) further reduced the inventory of this reach to the current 93 miles (**Table 1**). Of this current total, a combined 12 miles are estimated to be overtopped (on the U.S. side) by water flow associated with a 100-year flood event, while 38 miles are subject to encroachment (IBWC 2003, Jim Robinson 2004b). The RGR project is designed to protect the area from waters associated with a 100-year flood (IBWC 2004c). For this project area, the IBWC defines such flooding as a flow rate of 11,000 CFS measured at American Dam in El Paso (**Figure 3**) (**Table 1**).

Prior to the RGR project, instability of the Rio Grande's channel enabled the river to meander through El Paso, Texas and Ciudad Juarez, Chihuahua. The instability was caused by a combination of heavy sediment loads, a flat gradient, and low river velocities (IBWC 2004c). Thus, the impetus for the RGR project was a bi-national desire to stabilize the international boundary line between the two countries. The 1933 Convention provided for the creation, operation, and maintenance of an artificial channel whose center line became the new international boundary. Surveys were undertaken and a rectified river channel established such that the total areas to be "cut" from each country were equal, with the cut areas ceded to the other country (IBWC 2004c). Costs of the project were prorated between the U.S. and Mexico based on an assessment of relative benefits received from the project. It was estimated that the U.S. would receive 88% of the benefits and Mexico 12%; costs were allocated to each country based on these values. The project included the creation of a river channel, U.S. and Mexican levees, the Caballo Dam, three bridges, and other miscellaneous structures.

Figure 3. Location of the Rio Grande Rectification Project, 2004.

#3 - Presidio Valley Flood Control

The IBWC infrastructure inventory in the Presidio Valley Flood-Control (PVFC) project includes 15.18 miles of levee (13.18 miles of Main levee, plus 2 miles of spur levee) stretching upstream and downstream of the tributary entry-point of the Rio Conchos into the Rio Grande (**Figure 4**). Of this total, 1.25 miles are estimated to be overtopped (on the U.S. side) by water

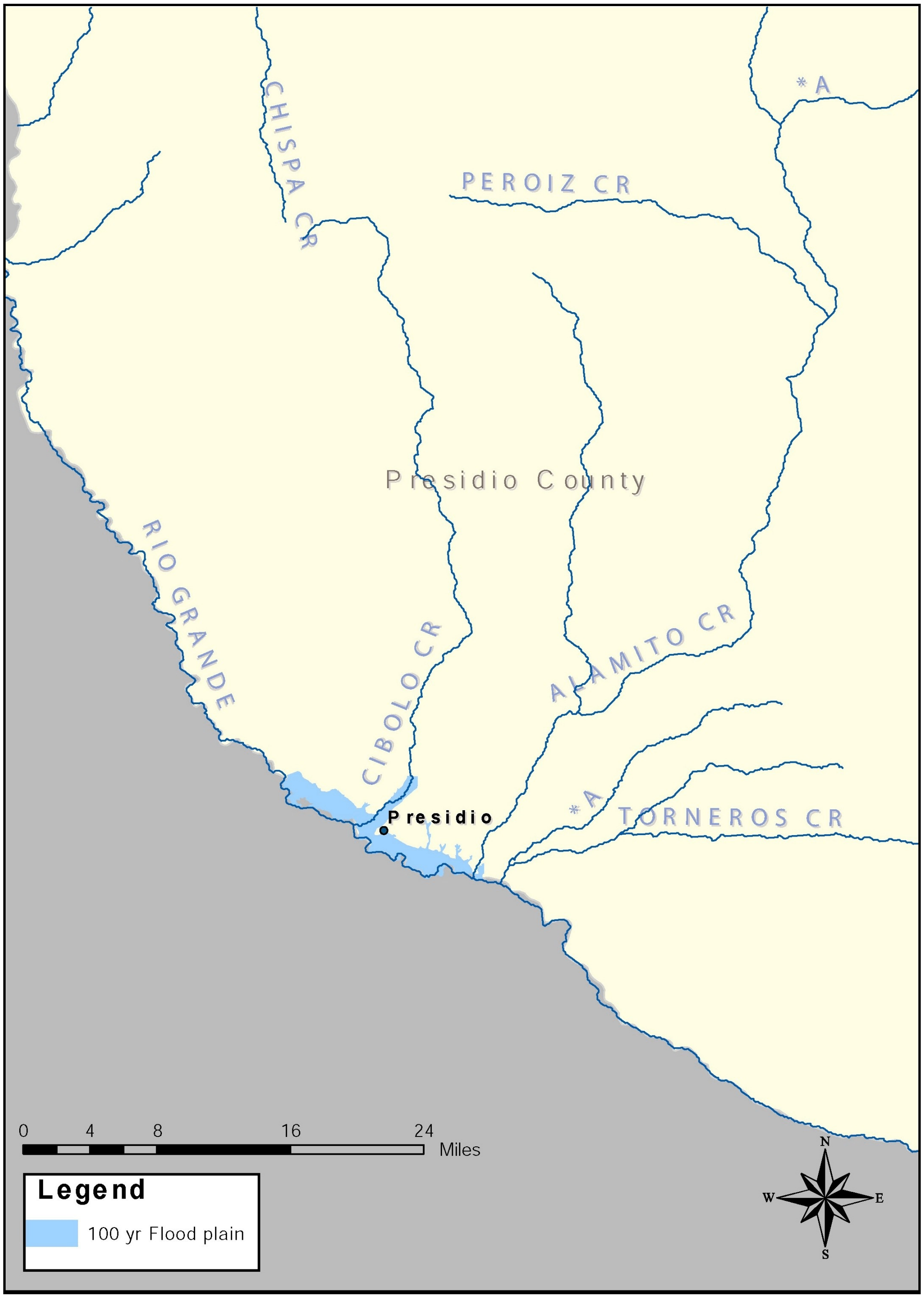

Figure 4. Location of the Presidio Valley Flood-Control Project, 2004.

flow associated with a 25-year flood event, while 1.25 miles are subject to encroachment (IBWC 2004c, Jim Robinson 2004b) (**Table 1**). The PVFC project's purpose is to protect 33,000 acres of agricultural land and the lower part of the city of Presidio, TX. The PVFC project is designed to protect the area from waters associated with a 25-year flood. For this project area, the IBWC defines such flooding as a flow rate of 3,600 CFS above the Rio Conchos, and/or 42,000 CFS below the Rio Conchos (**Table 1**). The Rio Conchos is a tributary to the Rio Grande entering near Presidio, TX.

For many years, insufficient levees and an inability of the U.S. and Mexico to agree upon the location of the international boundary prevented joint action towards a binational flood-control plan. As a result, many floods were allowed to repeatedly damage the area during the early and mid-1900s. The *status quo* remained until ratification of the 1970 Boundary Treaty which provided for excavation of channels to relocate the Rio Grande in the Presidio Valley. Subsequent to the Treaty, an IBWC report on flood control (dated June, 1971) paved the way for an international agreement of collaborative flood-control efforts in the Presidio-Ojinaga Valley. Based largely on this report, Title II of Public Law 92-549 (signed October 25, 1972) authorized construction, operation, and maintenance efforts with Mexico for the purpose of providing flood control to the Presidio Valley. The timing of the signing of the international flood-control agreement allowed for 15 miles of levee to be built concurrently with the channel relocation (as provided for by the 1970 Boundary Treaty). Four feet were added to the levee in 1979 after a major flood in 1978 necessitated emergency repairs. The U.S.-side of the PVFC levee is now designed to protect against a 25-year flood, with four feet of freeboard (IBWC 2004c).

#4 - Lower Rio Grande Flood Control

The Lower Rio Grande Flood Control (LRGFC) project extends 158 miles along the main channel of the Rio Grande from Penitas in Hidalgo County, Texas to a point 28 miles from the Gulf of Mexico (**Figure 5**). The USIBWC infrastructure inventory in the Lower Rio Grande Flood-Control (LRGFC) project includes some 274 miles of river and interior (i.e., off-river) floodway levees. Of this total, a combined 40 miles are estimated to be overtopped (on the U.S. side of the river and along the interior floodway) by water flow associated with a 500-year flood event (Moehlig), while 88 miles are subject to encroachment (IBWC 2003) (**Table 1**). The LRGFC project's purpose is to provide flood protection to urban, suburban, and high-value agriculture production in the area. The LRGFC project is designed to protect the area from waters associated with a 500-year flood (IBWC 2004c). For this project area, the IBWC defines such flooding as a flow rate of 250,000 CFS at Rio Grande City, TX. (**Table 1**).

Based on a 1932 IBWC report on flood control in the Lower Rio Grande, the U.S. and Mexico agreed on a coordinated plan to prevent the individual countries' flood-protection actions from exacerbating floods on the other side of the border. The U.S. portion of this project, covering Cameron, Hidalgo, and part of Willacy Counties, was authorized under Title II of the National Industrial Recovery Act (Act) of June 13, 1933 and the Act of August 19, 1935. The project involved the construction of a system of river levees and leveed-interior floodways in each country that would be maintained by the respective IBWC Section. Two diversion dams, Anzalduas and Retamal, divert floodwaters into the U.S. and Mexican interior floodways, respectively. The project's original flood-capacity design of 187,000 CFS (measured at Penitas, Texas) was increased to 250,000 CFS (measured at Rio Grande City, Texas) following extensive damages caused by Hurricane Beulah in 1967.

Figure 5. Location of the Lower Rio Grande Flood Control Project, 2004.

Methodology

The standard protocol directing this analysis is referred to as the *Property Damages Avoided* (PDA) method, which has historically served as the U.S. Army Corps of Engineers' (USACE) initial screening criteria when considering flood-control benefits (Shabman et al.). The PDA method takes a practical approach as it measures flood damages based on estimated property restoration and repair costs. This is assumed to be consistent with individuals' willingness to pay for flood protection. In a study for the USACE entitled "Comparing Benefit Estimation Techniques: Residential Flood Hazard Reduction Benefits in Roanoke, Virginia," Shabman et al. compared the PDA approach to both the *Contingent Valuation* (CV) and *Hedonic Property* methods for assessing flood-control benefits. When comparing consistency, reproducibility, and credibility across the three methods, the authors did not find significant justification to deviate from the PDA benefit-estimation method, as long as its limitations were recognized.

Critiques of the PDA method include its failure to address other benefits-damages avoided (e.g., emotional impacts, community disruptions, ecosystem effects, etc.) and its reliance on several assumptions to ensure the value of damages avoided equate with willingness to pay. Shabman et al. determined that estimated values associated with the hedonic property method could be 3.75 times those of the PDA approach, while values calculated following the CV method could be 2.3 times greater. To address some of the criticisms of the PDA method, Appendix D is included in this report to address a larger set of potential damages (i.e., beyond the baseline damage estimates provided in the main body of this report).

As the PDA method directed the overall effort, the specific approach and tasks involved with obtaining, analyzing, and managing the requisite data varied slightly across the four economic reaches. As expected, however, natural variations in the exact source, file format, type, quality, quantity, etc. for certain variables did surface. Thus, the following discusses the overall methodology applied to all economic reaches, with appropriate exceptions noted. Due to the severe time constraints, several assumptions were made to expedite the analysis.

Defining Land-Use Categories and Types

Land-use categories and types were pre-assigned by IBWC (IBWC 2004b) and are applied to all four economic reaches. *Agriculture* land-use is singularly termed to represent all enterprises (e.g., row crops, vegetables, citrus, pasture, etc.) grown in each economic reach. *Urban* land-use is further separated, however, into residential, commercial, and industrial types. A partial listing of example enterprises and structures represented by each is provided in **Table 2**.

Table 2. Land-Use Types Assigned for Agricultural and Urban Categories, USIBWC Rio Grande Projects, 2004.

Land-Use Category and Type	Example Enterprises & Structures Included
Agriculture	[row crops, vegetables, citrus, pecans, pasture]
Urban	
- residential	[single-family houses, mobile homes, apartments]
- commercial	[retail outlets, restaurants, government buildings, offices, churches, auto dealers, public use]
- industrial	[manufacturing, processing, warehousing]

Geo-Referenced Mapping

An initial step in the implementation of the economic analysis involved assembling a set of GIS maps which included: digital orthophoto quarter-quadrangles (DOQQs), land-use maps based on 1992 data (where all the IBWC land uses are included in the database), and the Federal Emergency Management Agency's (FEMA) 100-year flood area. With these maps and associated geo-referenced data sets, a powerful tool was established for conducting the economic analysis. There were several iterations and some unique procedures associated with each of the project areas as described where appropriate.

Defining the Flood Plain Area

Defining the flood plain area entailed the use of a digital copy of the Federal Emergency Management Agency's (FEMAs) 100-year flood-plain map for each IBWC project region, which is based on rainfall events. As such, the total flooded area (estimated by FEMA) includes several disconnect areas (or low-lying land spaces which are disconnected from the river by a rise in the land-surface elevation) and would not be flooded with a structural failure of flood-protection infrastructure along the Rio Grande. Thus, to more accurately estimate the appropriate flood plain area associated with an infrastructure failure along the river, the disconnect areas in the FEMA map were excluded, thereby resulting in a revised FEMA flood-plain map used in this analysis.[6] Further, there are instances when certain individual properties lie partially in the flood plain. In these instances, the standard procedure was to include the "partially-in" properties

6 The importance of requiring an accurate area estimate (in acres) lies in the fact that damage values are determined on a per acre basis and extrapolated to the total acres by land use.

while defining the revised flood plain area,[7] as specific information about the placement of valuable structures on each property was unknown.

For Presidio County, the FEMA maps were available only for the unincorporated area. Working with the flood area from the FEMA map, insurance industry maps were used to define the region in the city that would flood.

Determining Land-Use Acres by Type

The basic area of interest is defined by the region expected to be inundated by the flood event(s) as described above. The areas, represented by a map layer in GIS, was then associated with the appropriate land-use map to calculate the number of acres of each land-use preassigned by IBWC. Through this method, the number of acres in each county for row crops, pasture, orchard, residential, commercial, and industrial purposes were all determined (**Appendix F**). With acres of each of these land uses determined, the issue for non-agriculture was establishing the value for structures and contents, by land-use type, in order to apply damage factors of expected losses due to flooding. There are several other land-use types in each area's flood plain that are not considered as vulnerable to flood damage (e.g., wetlands, drainage areas, water covered areas, grassy regions, etc.).

Determining Crop Damages for Agriculture

Dona Ana and El Paso Counties. These counties are associated with economic reaches 1 and 2, or the Rio Grande Canalization and Rio Grande Rectification projects. Determining crop damages for agriculture land-use areas first required a distinction to be made between alternative agricultural land-use types.[8] In Dona Ana County, this was done using the FEMA map in conjunction with a property parcel shape file (in GIS format) from the Dona Ana Assessors Office and satellite land-use image maps provided by the Spatial Sciences Lab (SSL) in the Texas Agricultural Experiment Station (TAES) at Texas A&M University.[9] A composite crop-use pattern was determined from New Mexico Agricultural Statistics, 2001. Yield and production cost data were obtained from New Mexico Cooperative Extension's Costs and Returns for Dona Ana, NM. projection for 2004. The assumption was that flood damages to the crops occurred at the most critical period of production; i.e., when there was the greatest expectation of a failure of flood-control infrastructure. Thus, for most crops, a total loss is assumed. Alfalfa production was assumed to lose one cutting (i.e., equivalent to 20% of normal yield), while pecan orchards were assumed to incur no damage. Crop prices were Economic Research Service, USDA normalized prices that are calculated for each year. These are the

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7 Property parcels located completely or partially within the designated flood area were linked to a spreadsheet of the property appraisal roll from Dona Ana County Appraisal District (i.e., 2004 data) by the account number of the property parcel.

8 Data processing tasks and limited time necessitated a limited amount of properties in the Rio Grande Canalization project area be included in the Rio Grande Rectification project.

9 The 30x30 meter resolution satellite images were used with spectral reflectance to identify land-use types.

typical prices used for agricultural products and are designed to eliminate the impact of farm programs. The results section presents input data and agriculture damage estimates.

El Paso County methods were very similar to Dona Ana County for agriculture. The crop mix was based on county statistics and include alfalfa, pima cotton, red chile, wheat, and pecans. Orchards were assumed to be pecans and the row crop acres were distributed across the crops above proportional to the county crop mix. The land use GIS map provided by the TAES SSL was used to obtain the acres of row crops and orchards. Texas Cooperative Extension (TCE) Crop and Livestock Enterprise budgets were applied to establish expected yield and harvest costs per unit of output. Where there is a yield loss, the costs to harvest are reduced in correspondence with that amount of yield. These calculated values are presented in tables in the results section.

Presidio County. This county is associated with economic reach 3, or the Presidio Valley Flood Control project. As above, the land-use map constrained to the flood zone area provides acres of row crops. There are no orchards in this region. For the acres of agriculture, discussions with the Presidio Agricultural County Agent provided insight on crops. Due to long-term drought and limited irrigation water, the only crops grown are alfalfa and other hay. The County Agent provided the allocation of total agricultural acres between the two crops with 80 percent being alfalfa and 20 percent being other hay. Again, TCE Crop and Livestock Enterprise budgets were applied to establish expected yield and harvest costs per unit of output. Where there is a yield loss, the costs to harvest are reduced in correspondence with that amount of yield.

Hidalgo and Cameron Counties These counties are associated with economic reach 4, or the Lower Rio Grande Flood Control project. This region was handled slightly different as there was a long history of research related to flood damages for agricultural crops in the region. That is, previous drainage projects of the U.S. Army Corps of Engineers (USACE) involved an agricultural component. In addition, an economic model was previously developed specifically for this region – the Agricultural Benefit Estimator (ABE) by Lacewell, et al. 1990. The potential agricultural losses are estimated by assessing the difference in net gross revenues that producers would realize between (a) a natural, non-flooded crop production and harvest year and (b) a year in which a 100-year flood event occurred, affecting production and/or harvest of crops in the designated flood-plain region. A composite acre approach is utilized for row crops, encompassing the LRGFC regional crop mix, with some adjustments incorporated to account for those crops not usually planted in the designated flood plain region, as well as for those crops for which the proportion of plantings is greater inside the designated flood plain region than outside that area. Citrus and pasture acreage are considered separately from the composite crop acre, but in a consistent manner otherwise. The composite acre is simply the proportion of each row crop that comprises a typical acre in the flood plain. This typical acre was developed through focus groups used for the USACE studies on benefits of drainage in this area (Lacewell et al. 1995).

Differences in normal versus flood-affected yields are based on percent loss in yield developed by focus groups as mentioned. The data for this region includes the expected non-flood yield, by crop, by soil type. The TCE Crop and Livestock Enterprise Budgets were used in determining per unit harvesting costs. Normalized crop prices were used along with the weighted yield, across relevant soil types, to identify the gross value of the harvested crop (with no quality damage assumed when flooded). The process is the same as for other regions where a damage factor from the ABE model is applied to the gross revenue for losses, but the harvest costs for the yield loss are eliminated. A last difference for this region is the inclusion of other costs associated with flooding of agricultural land beyond yield loss. This includes field reconstruction, laser leveling, infrastructure repairs, etc. These per acre values were included in the ABE model (Lacewell et al. 1990) and developed from focus groups (Lacewell et al 1995).

In summary, reductions in harvest and post-harvest processing costs are accounted for based on the TCE Crop and Livestock Enterprise Budgets, effectively reducing the apparent damages gauged by a comparison of gross revenues between the normal and flooded scenarios. The ABE Model (Lacewell et al. 1990) was used in the calculation process, incorporating the probabilities of flooding at different times of the year, and adjusting the potential loss estimates according to the respective production stages of the various crops. Multiplication of the respective crops' proportion in the estimated by total cropped flood plain acres results in acres of each crop. Applying the per acre losses identified in the above method multiplied by the total respective crop acres in the estimated flood plain (i.e., the FEMA map less "disconnect areas") yields the estimate of losses for each crop from flooding. Totaling the 57,879 acres of crops, 2,052 acres of citrus, and 15,714 acres of pasture identifies a total agricultural acreage of 75,645 subject to flooding in the study area. The calculated values are presented in the results section.

Determining Damages for Urban

Several steps were required for estimating structure, improvements, contents, and equipment damages due to flooding. After defining the flood plain area and estimating structural values, calculating damages involved: (1) estimating the dollar values of what was inside the structures, and (2) estimating the proportion of both (i.e., structures and what was inside) that would be damaged. This involved applying the value and damage factors adopted, of which the categories and proportions vary between residential, commercial, and industrial structures.[10]

Dona Ana and El Paso Counties. These counties are associated with economic reaches 1 and 2, or the Rio Grande Canalization and Rio Grande Rectification projects. Property values within the flood-plain area were delineated from GIS data provided by the Dona Ana County Assessors Office.[11] The GIS file was overlaid on the FEMA file and property values queried that were in the 100-year flood plain. These values were exported to an Excel file. Properties that were not adjacent to the river (i.e., flooded by rainfall events from arroyos) were deleted. Most of the remaining properties were within, or adjacent to, the Village of Hatch, NM. To determine land use, an on-site inspection was made of the Village of Hatch, with each property being assigned as agricultural, residential, commercial, or industrial. The advanced technology of data for these two counties greatly accelerated this phase of the study for this region. The values of all the structures and improvements within the flood zone were available in geo-referred files providing current appraised value for structures.

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10 For additional detail, refer to the *Assumed Values for Critical Parameters – Urban Land Use* section which explains the assigned values applied to all four economic reaches.

11 Data processing tasks and limited time necessitated a limited amount of properties in the Rio Grande Canalization project area be included in the Rio Grande Rectification project.

In summary, determining property values for urban[12] land-use areas entailed using the property parcel shape files in GIS format from the County of Dona Ana, NM. and El Paso, TX. which contain property values. This provided information on each property's area and structure, plus improvements value. This combined information was then reconciled with the revised FEMA 100-year flood plain map (i.e., the FEMA map less "disconnect areas") which enabled a sum of the total structure value for residential and commercial properties in the flood plain to be estimated. There were no significant industrial land uses in economic reach 1 and are thus not included. A concern related to these projects is the applicability of the FEMA 100-year flood zone map, which is discussed further in **Appendix E**.

Presidio County. This county is associated with economic reach 3, or the Presidio Valley Flood-Control project. The FEMA flood map was not available for the city of Presidio. Thus, in order to determine the flood zone area within the city of Presidio, a paper (i.e., printed) FIRM (Flood Insurance Rate Map) from the National Flood Insurance Program was used in determining the flood zone area for use in GIS. To determine the number of properties, the DOQQ for the area was overlaid onto the digitized flood zone (**Figure 6**). The project team then identified addresses (i.e., geographical locations) in the digitized flood area by using data from the 911 Regional Service Center.[13] This step involved deleting (or not counting) those properties which did not entirely lay within the digitized flood zone. Next, property value data from the Presidio Central Appraisal District was obtained and linked to the specified properties determined to be fully in the digitized flood zone; i.e., the number of properties determined by the 911 Regional Service Center matched the properties for which a value was obtained. By linking the addresses to the appraisal data, the total estimated value of structures within the area was estimated. It is this total structure value (property and improvements) that provides the basis of estimating damages for contents, equipment, etc. That is, a damage factor for each category is applied to the total structure value to give estimated damages (losses) due to the assumed two-foot inundation due to a breach of the infrastructure on the river.

Hidalgo and Cameron Counties. These counties are associated with economic reach 4, or the Lower Rio Grande Flood Control project. With the time constraints and breadth of the regions subject to flooding, an analysis of each structure's value was not possible for Hidalgo, and Cameron Counties. For these counties, the DOQQs were studied carefully, identifying areas of heavy residential, commercial, and industrial structures. For those areas, representative samples were selected by drawing a circle around the targeted locations. This included 11 sample areas for Hidalgo and Cameron Counties.[14] These sample areas were defined on the DOQQ and the number of each type of structure counted. In addition, the number of acres in each sample area of each type of structure was calculated from the land-use map.

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12 The various value factors and damage factors (i.e., for structure, contents, inventory, and equipment) adopted for use in determining damages for this reach are based on work analyzing stage-damage curves used by the U.S. Army Corps of Engineers (by Roger Freeman , a co-author of this report). Further explanation is provided in the *Assumed Values for Critical Parameters – Urban Land Use* section.

13 Note the addresses (i.e., geographic locations) provided in the 911 Regional Service Center's data were provided by sub-division, block, and lot. Further, since property-value data (as provided by the Presidio Central Appraisal District) were also provided in this manner, property values were matched to the specified properties.

14 An example of one such area, for Hidalgo county, is provided in Appendix F.

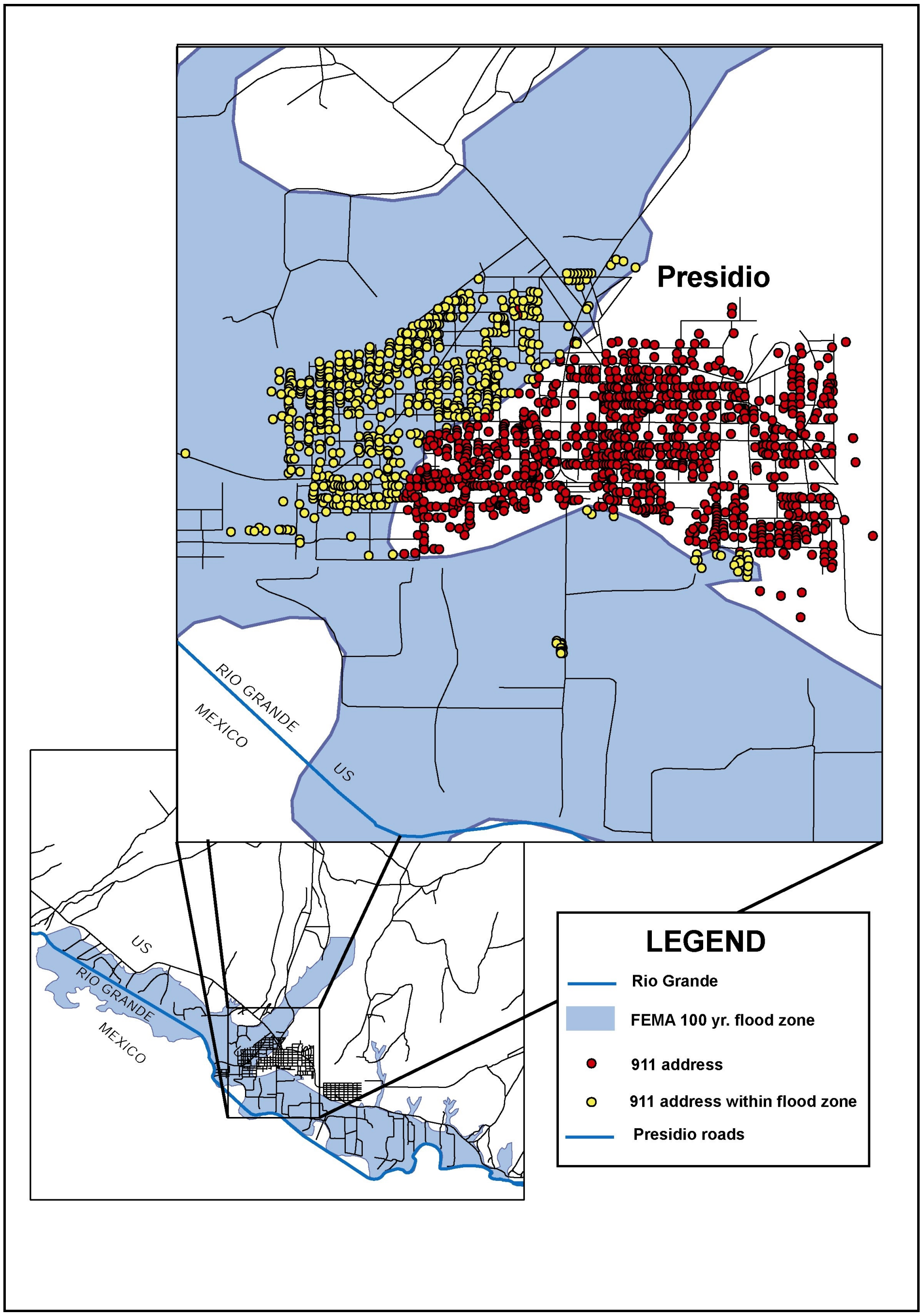

Figure 6. Depiction of the PVFC Project Area and Highlighting the Flood Plain and Residential Structure Inventory, 2004.

The project team then identified addresses in this region using the maps, as well as driving to the sample areas and visually collecting data. The county appraisal data were purchased for both counties. By linking the addresses to the appraisal data, the value for structures within the sample areas were estimated. By taking the total value of residences in the sample flood zone and dividing by the acres of each structural land use, the average value per acre was determined. The average per acre value of residential, commercial, and industrial structures was each multiplied by the total acres in that land use for each project which provided the estimated total value. It is this total value of structures and improvements that is the basis of estimating value of contents, equipment, etc. A damage factor for each category is applied to the total value to give estimated damages (losses) due to the assumed two-foot inundation caused by a breach of the infrastructure on the river. Concerns and limitations for these counties include:

- several residences with no address,
- duplicate street names,
- appraisal data files and difficulty of linking to property in the flood zone, and
- most current land-use map/data being dated (i.e., 1992) and significant development occurring in recent years, resulting in many structures not being included.

Due to these limitations and constraints, for several samples, structural values were gathered for a subset of the selected sample area and again used with acres of each land use in the subset. The total value of each type structure and associated total acres for each subset sample were added and as stated above, total value was divided by total acres to arrive at an average per acre structure value. This per acre value was extrapolated across total acres of the land use.

Assumed Values for Critical Parameters – Urban Land Use

This section presents the values assumed for parameters considered critical in their effects on the results for the urban land-use portion of the analysis. Since these values are applied consistently across all regions, a single discussion is appropriate. The value and damage factors (i.e., for structure, contents, inventory, and equipment) applied in determining damages are adopted from work analyzing stage-damage curves used by the U.S. Army Corps of Engineers (USACE) (i.e., by Roger Freeman, a co-author of this report).

Appraisal Values ($) – for Structures

The appraisal values for urban land-use structures are key determinants in the potential damage estimates and were separately determined for each economic reach. The assumed values were calculated from data obtained from various local data sources (e.g., central appraisal districts). Details are provided in the methodological sub-section for each economic reach.

Value Factors (%) – for Contents, Inventory, and Equipment

Content values, as applied in this report, apply only to residential structures and associated improvements, while inventory and equipment values apply to commercial and industrial structures. Though a range of rates exists, the residential contents value is assumed to be 50% of the appraised structural value. This proportion was obtained from the Institute for Water Resources (IWR) and represents their generic residential-contents value. This 50% rate is adopted for use in all four reaches of this study (**Tables 4, 7, 10,** and **13**). This value, for a two-foot flood inundation, is considered conservative and is commonly used by others (e.g., FEMA, USACE) with respect to single-family residences, without basements (Freeman).

Similarly, *inventory* and *equipment* proportions remain consistent across both commercial and industrial structures and are assumed to be 73% and 63%, respectively, of the appraised structural value (**Tables 4, 7, 10,** and **13**). Since there are no IWR generic curves available for the urban land-uses, an alternative method was required. Specifically, historical stage-damage relationships obtained from the USACE (Galveston District) for a two-foot inundation were analyzed by Standard Industrial Classification (SIC) divisions.

Damage Factors (%) – for Structure, Contents, Inventory, and Equipment

Urban land-use damage factors (or proportions of dollar values) are applied to structure, contents, inventory, and equipment values for residential, commercial, and industrial structures. In the main body of this report, the resulting urban land-use damages are added to the estimated agriculture land-use damages to arrive at a total baseline damage value.[15]

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15 There are other damages for which limited time was allowed for analysis. Thus, due to their preliminary nature, they are not discussed in the main body of this report, but are presented separately in **Appendix D**.

Residential: For residential structures, the process presented employs the residential stage-damage curves to compute damages/benefits. Generic stage-damage curves from the USACE are used to establish the expected damages associated with two feet of inundation.[16] The damage factor for single-family residential structures, without basements, is used for this analysis.[17] For residences, the *structural* damage factor is 32.1% of the appraised structural value, while the *contents* damage factor is 17.9% of the contents value (**Tables 4, 7, 10,** and **13**).

Commercial and Industrial: Commercial and industrial damages mirror each other and are calculated similar to those for residential properties. In addition to structural damage, commercial and industrial structures are assumed to incur two other categories of damages: inventory, and equipment.[18] For commercial structures, the *structural* damage factor is 11.1% of the appraised structural value, the *inventory* damage factor is 36.0% of the inventory value, and the *equipment* damage factor is 22.0% of the equipment value (**Tables 4, 7, 10,** and **13**).

The process required to obtain the various damage curves used herein required much effort and its own analysis. Specifically, an analysis was performed on the structure, inventory, and equipment curves for each of the 243 property curves listed in the USACE, Galveston District data sets (U.S. Army Corps of Engineers, unpublished). Each property curve is listed by its respective Standard Industrial Classification (SIC) Code. The data were first sorted into one of ten SIC Divisions for the structural curves for two feet of inundation. Likewise, the inventory and equipment were sorted into one of ten SIC Divisions.[19] This sorting process allowed deleting 26 sets of the curves, thereby reducing the total to 217 sets of curves.

A key reason for analyzing using this method was to establish the inventory value to structural value and the same for equipment. These sets of curves have individual property values for structure, inventory, and equipment. The assumption was made on the basis that bringing the values up to FY 2004 price levels would be to bring property values for structure, inventory, and equipment at an equal rate. Thus, the establishment of the value ratios using this method was valid and necessary to establish property values for inventory and equipment.

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16 The generic stage-damage curves provided in the U. S. Army Corps of Engineers *Economic Guidance Memorandum 04-01* (dated 10 October 2003) represent a substantive improvement over other generalized depth-damage functions; i.e., the Flood Insurance Administration (FIA) Rate Reviews. That is, the FIA curves are generalized and limited in scope as costs for flood clean-up, emergency, prevention, etc. are not included. The rationale being these costs should be developed using site-specific historical information.

17 Flood-damage studies can contain a myriad of residential distinctions, such as single- and multiple-family dwellings, high-raised homes, apartments, condominiums, etc. This study is limited, however, to a composite category assumed to represent single-story residences.

18 Commercial and industrial properties are aggregate terms used in this analysis to represent many different types of urban land-use categories (e.g., business trade, services, entertainment, etc.). For examples of each, the reader is referred to Table 2 in this report.

19 The divisions are: A-Agriculture, Forestry, and Fishing; B-Mining; Division C-Construction; D-Manufacturing; E-Transportation, Communications, Electronic, Gas, and Sanitary Service; F-Wholesale Trade; G-Retail Trade; H-Finance, Insurance, and Real Estate; I-Services; and J-Public Administration.

Results

The economic analysis results based on the afore-mentioned data are presented here. As discussed in other sections, these economic estimates assume a two-foot flood inundation depth and apply to only the U.S. side of the border. Further, they only include property damages, and do not consider potential damages for items such as loss of life, infrastructure, etc, and are thus considered conservative.[20] Results are first presented separately for each of the four economic reaches **(Tables 3-14**), followed by identification of the aggregate results (**Table 15**).

#1 - Rio Grande Canalization

Agriculture: Table 3 presents details of agricultural damage estimates due to flooding for the Rio Grande Canalization project. This table follows the discussion presented in the methodology section. The individual crops are listed with expected non-flood yield, yield loss due to flooding, crop price (normalized prices), revenue loss, reduced harvesting costs, and then net damage per acre.[21] The crop allocations across agriculture land, as defined in the land use GIS map, are used to calculate total acres of each crop. The total crop acres are 2,484. Note that cottonseed is a joint product with cotton lint. Across the agricultural component for this region, the total potential damages are an estimated $1.82 million or $733 per acre. This is an area of high-value crops that are vulnerable to being flooded.

Urban: Table 4 provides the details on the urban structures included in the analysis (residential, commercial, and industrial). With the shape file from the appraisal district linking values to structures, a total value was accumulated across the flood plain. Using the total value, the percent of total that comprised contents was calculated for residential as well as the inventory value and equipment value for commercial and industrial. The appropriate flood-damage coefficients were applied (to the value of the structure and improvements) to derive total damages for each of the classifications (i.e., contents, inventory, and equipment). In this case, the damages for residential were $6.78 million, $5.08 million for commercial, and $0 for industrial. Therefore, potential damages are an estimated $11.86 million for urban structures.

Total: As displayed in **Table 5**, land-use in this economic reach's flood plain is largely agriculture, with a modest number of residential structures and zero industrial structures on the estimated 4,385 acres. *The area most affected by a levee failure, however, is the estimated 1,901 acres of urban land use (i.e., found primarily in Hatch, NM. and Las Cruces, NM.) which will sustain about 87% of the total damage*. Although agricultural land use encompasses about 57% of the flood plain's land area, it is anticipated to only incur 13% of total damages. In summary, a levee failure along this economic reach is estimated to significantly damage approximately 2,484 acres of agricultural land and 464 residential and commercial structures, resulting in a total of $13,684,311 in economic damages (basis FY 2004).

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20 An initial effort to provide indication as to what "other" costs might be are provided in addition to these baseline estimates in the attached Appendix D.

21 For additional detail, the reader is referred to Appendix A in this report.

Table 3. Estimated Economic Damages for Agricultural Land Use Attributable to a Project Levee Failure in Economic Reach #1, Rio Grande Canalization, 2004.

Crop	Unit	Base Yield	Flood Yield	Yield Loss (units per acre)	Crop Price ($ per unit)	Harvest Costs ($ per unit)	Revenue Loss ($ per acre)	Increased Flood Cost ($ per acre)	Total Damage ($ per acre)	Reduced Harvest Costs ($ per acre)	Net Flood Damage ($ per acre)	Percent Acreage Allocation	Specific Crop Acres	Total Potential Damages
Row Crops														
Alfalfa	tons	8.5	6.8	1.7	$ 130.00	$ 11.89	$ 221.00	$ 0.00	$ 221.00	$ 20.22	$ 200.78	28 %	681	$ 136,662
Pima Cotton	lbs	1,030	0.0	1,030.0	$ 0.88	$ 0.16	$ 906.00	$ 0.00	$ 906.00	$ 168.15	$ 737.85	25 %	613	$ 451,990
Cottonseed	lbs	1,645	0.0	1,645.0	$ 0.05	$ 0.00	$ 82.25	$ 0.00	$ 82.25	$ 0.00	$ 82.25	n/a [a]	n/a [a]	$ 50,419
Red Chile	lbs	3,500	0.0	3,500.0	$ 0.68	$ 0.24	$ 2,380.00	$ 0.00	$ 2,380.00	$ 825.35	$ 1,554.65	13 %	306	$ 476,170
Wheat	bu	92	0.0	92.0	$ 3.75	$ 0.51	$ 345.00	$ 0.00	$ 345.00	$ 47.00	$ 298.00	3 %	68	$ 20,283
Corn Silage	tons	22.2	15.5	6.7	$ 28.00	$ 16.10	$ 186.48	$ 0.00	$ 186.48	$ 107.23	$ 79.25	19 %	476	$ 37,760
Lettuce	boxes	936	0.0	936.0	$ 6.47	$ 3.57	$ 6,055.92	$ 0.00	$ 6,055.92	$ 3,345.95	$ 2,709.97	6 %	136	$ 368,902
Onions	cwt	900	0.0	900.0	$ 5.85	$ 4.03	$ 5,265.00	$ 0.00	$ 5,265.00	$ 3,624.00	$ 1,641.00	7 %	170	$ 279,232
Other														
Pecans	lbs	2,000	2,000	0.0	$0.90	$ 0.35	$ 0.00	$ 0.00	$ 0.00	$ 0.00	$ 0.00		34	$ 0
												Total	2,484	$ 1,821,418
												Per Acre		$ 733

Source: New Mexico Cooperative Extension Service, "Costs and Returns for Dona Ana county, projected 2004."

[a] Cottonseed is a co-product of cotton production, thereby not requiring additional acreage.

Table 4. Estimated Economic Damages for Urban Land Use Attributable to a Project Levee Failure in Economic Reach #1, Rio Grande Canalization, 2004.

	Urban Land-Use			
	Residential [a]	Commercial	Industrial [b]	Total
Values				
Structure				
Number of Structures	397	67	0	464
Total Appraised Value	$ 16,513,549	$ 9,922,093	$ 0	$ 26,435,642
Average Value Per Structure	$ 41,596	$ 148,091	$ 0	$ 56,973
Contents, Inventory, Equipment				
Contents Value (% of appraised value)	50.0 %	--	--	--
Content Value ($)	$ 8,256,775	--	--	$ 8,256,775
Inventory Value (% of appraised value)	--	73.0 %	73.0 %	--
Inventory Value ($)	--	$ 7,243,128	$ 0	$ 7,243,128
Equipment Value (% of appraised value)	--	63.0 %	63.0%	--
Equipment Value ($)	--	$ 6,250,919	$ 0	$ 6,250,919
Damages				
Structure				
Damage Factor (% of appraised value)	32.1 %	11.1%	11.1 %	--
Damage Value ($)	$ 5,300,849	$ 1,101,352	$ 0	$ 6,402,202
Contents				
Damage Factor (% of content value)	17.9 %	--	--	--
Damage Value ($)	$ 1,477,963	--	--	$ 1,477,963
Inventory				
Damage Factor (% of inventory value)	--	36.0 %	36.0 %	--
Damage Value ($)	--	$ 2,607,526	$ 0	$ 2,607,526
Equipment				
Damage Factor (% of equipment value)	--	22.0 %	22.0 %	--
Damage Value ($)	--	$ 1,375,202	$ 0	1,375,202
Total Damages for Urban Land Use	$ 6,778,812	$ 5,084,080	$ 0	$ 11,862,892

[a] Buildings on Ag lands were assigned to residential. No other agricultural structures were identified by on-site inspection.

[b] There were no significant industrial land uses in this economic reach.

Table 5. Estimated Economic Flood-Control Benefits (FY 2004 dollars) Provided by the RGC Project, by Land-Use Category and Type, 2004.

Land-Use Category and Type	Estimated Area (acres)	% of Total Area	Estimated Damages ($ per acre)	Number of Structures	Estimated Damages Total ($)	% of Total Damages
Agriculture	2,484	57 %	$ 733	- -	$ 1,821,418	13 %
Urban						
- residential	1,836	42 %	$ 3,692	397	$ 6,778,812	50 %
- commercial	65	1 %	$ 78,217	67	$ 5,084,080	37 %
- industrial	0	0 %	$ 0	0	$ 0	0 %
sub-total	1,901	43 %	$ 6,240	464	$ 11,862,892	87 %
Total	**4,385**	**100 %**	**$ 3,121**	**464**	**$ 13,684,311**	**100 %**

#2 - Rio Grande Rectification

Agriculture: Table 6 presents details of agricultural damage estimates due to flooding for the Rio Grande Rectification project. This table follows the discussion presented in the methodology section. The individual crops are listed with expected non-flood yield, yield loss due to flooding, crop price (normalized prices), revenue loss, reduced harvesting costs, and then net damage per acre. The crop allocations across agricultural land, as defined in the land use GIS map, are used to calculate total acres of each crop. The total crop acres are 2,356. Note that cottonseed is a joint product with cotton lint. Across the agricultural component for this region, the total potential damages are an estimated $1.25 million or $530 per acre.

Urban: Table 7 provides the details on the urban structures included in the analysis (residential, commercial, and industrial). With the shape file from the appraisal district linking values to structures, a total value was accumulated across the flood plain. Using the total value, the percent of total that comprised contents was calculated for residential as well as the inventory value and equipment value for commercial and industrial. The appropriate flood-damage coefficients were applied (to the value of the structure and improvements) to derive total damages for each of the classifications (i.e., contents, inventory, and equipment). In this case, the damages for residential are $108.60 million, $26.85 million for commercial, and $2.39 million for industrial. Therefore, potential damages are an estimated $137.85 million for urban.

Total: As displayed in **Table 8**, land-use in this economic reach's flood plain is evenly dispersed between agriculture, residential, and commercial uses across the estimated 7,790 acres. *The area most affected by a levee failure, however, is the estimated 2,643 acres of residences (i.e., found primarily in El Paso, TX.) which will sustain about 78% of the total damage.* Although agriculture land use encompasses about 30% of the flood plain's land area, it is anticipated to only incur 1% of total damages. In summary, a levee failure along this economic reach is estimated to significantly damage approximately 2,356 acres of agricultural land and 4,591 residential, commercial, and industrial structures, resulting in a total of $139,096,639 in economic damages (basis FY 2004).

Table 6. Estimated Economic Damages for Agricultural Land Use Attributable to a Project Levee Failure in Economic Reach #2, Rio Grande Rectification, 2004.

Crop	Unit	Base Yield	Flood Yield	Yield Loss (units per acre)	Crop Price ($ per unit)	Harvest Costs ($ per unit)	Revenue Loss ($ per acre)	Increased Flood Cost ($ per acre)	Total Damage ($ per acre)	Reduced Harvest Costs ($ per acre)	Net Flood Damage ($ per acre)	Percent Acreage Allocation	Specific Crop Acres	Total Potential Damages
Row Crops														
Alfalfa	tons	4.9	3.9	0.98	$ 152.00	$11.89	$ 148.96	$ 0	$ 148.96	$11.65	$137.31	14 %	330	$ 45,289
Pima Cotton	lbs.	1,067	0	1,067	$ 0.88	$ 0.16	$ 938.55	$ 0	$ 938.55	$ 174.19	$ 764.36	58 %	1,366	$ 1,044,480
Cottonseed	lbs.	1,645	0	1,645	$ 0.05	$ 0.00	$ 82.25	$ 0	$ 82.25	$ 0.00	$ 82.25	n/a [a]	n/a [a]	$ 112,393
Red Chile	tons	1.2	0	1.2	$ 1,375.00	$ 0.24	$ 1,650.00	$ 0	$ 1,650.00	$ 0.28	$ 1,649.72	1 %	24	$ 38,867
Wheat	bu.	29	0	29	$ 3.00	$ 0.51	$ 87.00	$ 0	$ 87.00	$ 14.82	$ 72.18	5 %	118	$ 8,503
Other														
Pecans	lbs	2,000	2,000	0	$ 0.90	$ 0.35	$ 0.00	$ 0	$ 0.00	$ 0.00	$ 0.00	22 %	518	$ 0
												Total	2,356	$ 1,249,533
												Per Acre		$ 530

Source: Texas Agricultural Statistics. 2002 Texas Agricultural Statistics Service, Annual Bulletin. http://www.nass.usda.gov/tx/mbullpdf.htm

[a] Cottonseed is a co-product of cotton production, thereby not requiring additional acreage.

Table 7. Estimated Economic Damages for Urban Land Use Attributable to a Project Levee Failure in Economic Reach #2, Rio Grande Rectification, 2004.

	Urban Land-Use			
	Residential	Commercial	Industrial	Total
Values				
Structure				
Number of Structures	4,251	339	1	4,591
Total Appraised Value	$ 264,563,951	$ 52,401,530	$ 4,670,297	$ 321,635,778
Average Value Per Structure	$ 62,236	$ 154,577	$ 4,670,297	$ 70,058
Contents, Inventory, Equipment				
Contents Value (% of appraised value)	50.0 %	--	--	--
Content Value ($)	$ 132,281,976	--	--	$ 132,281,976
Inventory Value (% of appraised value)	--	73.0 %	73.0 %	--
Inventory Value ($)	--	$ 38,253,117	$ 3,409,317	$ 41,662,434
Equipment Value (% of appraised value)	--	63.0 %	63.0%	--
Equipment Value ($)	--	$ 33,012,964	$ 2,942,287	$ 35,955,251
Damages				
Structure				
Damage Factor (% of appraised value)	32.1 %	11.1%	11.1 %	--
Damage Value ($)	$ 84,925,028	$ 5,816,570	$ 518,403	$ 91,260,001
Contents				
Damage Factor (% of content value)	17.9 %	--	--	--
Damage Value ($)	$ 23,678,474	--	--	$ 23,678,474
Inventory				
Damage Factor (% of inventory value)	--	36.0 %	36.0 %	--
Damage Value ($)	--	$ 13,771,122	$ 1,227,354	$ 14,998,476
Equipment				
Damage Factor (% of equipment value)	--	22.0 %	22.0 %	--
Damage Value ($)	--	$ 7,262,852	$ 647,303	$ 7,910,155
Total Damages for Urban Land Use	$ 108,603,502	$ 26,850,544	$ 2,393,060	$ 137,847,106

Table 8. Estimated Economic Flood-Control Benefits (FY 2004 dollars) Provided by the RGR Project, by Land-Use Category and Type, 2004.

Land-Use Category and Type	Estimated Area (acres)	% of Total Area	Estimated Damages ($ per acre)	Number of Structures	Estimated Damages Total ($)	% of Total Damages
Agriculture	2,356	30 %	$ 530	- -	$1,249,533	1 %
Urban						
- residential	2,643	34 %	$ 41,091	4,251	$ 108,603,502	78 %
- commercial	2,759	35 %	$ 9,732	339	$ 26,850,544	19 %
- industrial	32	0 %	$ 74,783	1	$ 2,393,060	2 %
sub-total	5,434	70 %	$ 25,368	4,591	$ 137,847,106	99 %
Total	**7,790**	**100 %**	**$ 17,856**	**4,591**	**$ 139,096,639**	**100 %**

#3 - Presidio Valley Flood Control

Agriculture: **Table 9** presents details of agricultural damage estimates due to flooding for the Presidio Valley Flood Control project. This table follows the discussion presented in the methodology section. There is only alfalfa and other hay listed with expected non-flood yield, yield loss due to flooding, crop price (normalized prices), revenue loss, reduced harvesting costs, and then net damage per acre. The crop allocations are 80 % alfalfa and 20% other hay. The total crop acres are 764. Across the agricultural component for this region, the total potential damages are an estimated $90 thousand or $118 per acre.

Urban: **Table 10** provides the details on the urban structures included in the analysis (residential, commercial, and industrial). Using the total value, the percent of total that comprised contents was calculated for residential as well as the inventory value and equipment value for commercial and industrial. The appropriate flood-damage coefficients were applied (to the value of the structure and improvements) to derive total damages for each of the classifications (i.e., contents, inventory, and equipment). In this case, the damages for residential were $2.84 million, with no commercial or industrial properties in the flood zone. Therefore, potential damages are an estimated $2.84 million for urban structures.

Total: As displayed in **Table 11**, land-use in this economic reach's flood plain is largely agriculture across the estimated 1,084 acres. *The area most affected by a levee failure, however, is the estimated 320 acres of residences (i.e., found primarily in Presidio, TX.) which will sustain about 97% of the total damage*. Although agriculture land use encompasses about 70% of the flood plain's land area, it is anticipated to only incur 3% of total damages. In summary, a levee failure along this economic reach is estimated to significantly damage approximately 764 acres of agricultural land and 589 residential structures, resulting in a total of $2,934,329 in economic damages (basis FY 2004).

Table 9. Estimated Economic Damages for Agricultural Land Use Attributable to a Project Levee Failure in Economic Reach #3, Presidio Valley Flood Control, 2004.

Crop	Unit	Base Yield	Flood Yield	Yield Loss (units per acre)	Crop Price ($ per unit)	Harvest Costs ($ per unit)	Revenue Loss ($ per acre)	Increased Flood Cost ($ per acre)	Total Damage ($ per acre)	Reduced Harvest Costs ($ per acre)	Net Flood Damage ($ per acre)	Percent Acreage Allocation	Specific Crop Acres	Total Potential Damages
Row Crops														
Alfalfa	tons	5.0	4.0	1.00	$ 152.00	$ 11.89	$ 152.00	$ 0	$ 152.00	$ 11.89	$ 140.11	80 %	614	$ 86,027
Other Hay	tons	2.4	1.9	0.48	$ 69.00	$ 11.89	$ 33.12	$ 0	$ 33.12	$ 5.71	$ 27.41	20%	150	$ 4,112
												Total	764	$ 90,139
												Per Acre		$ 118

Source: Texas Agricultural Statistics. 2002 Texas Agricultural Statistics Service, Annual Bulletin. http://www.nass.usda.gov/tx/mbullpdf.htm

Table 10. Estimated Economic Damages for Urban Land Use Attributable to a Project Levee Failure in Economic Reach #3, Presidio Valley Flood Control, 2004.

	Urban Land-Use			
	Residential	Commercial [a]	Industrial [a]	Total
Values				
Structure				
Number of Structures	589	0	0	589
Total Appraised Value	$ 6,928,600	$ 0	$ 0	$ 6,928,600
Average Value Per Structure	$ 11,763	$ 0	$ 0	$ 11,763
Contents, Inventory, Equipment				
Contents Value (% of appraised value)	50.0 %	--	--	--
Content Value ($)	$ 3,464,300	--	--	$ 3,464,300
Inventory Value (% of appraised value)	--	73.0 %	73.0 %	--
Inventory Value ($)	--	$ 0	$ 0	$ 0
Equipment Value (% of appraised value)	--	63.0 %	63.0%	--
Equipment Value ($)	--	$ 0	$ 0	$ 0
Damages				
Structure				
Damage Factor (% of appraised value)	32.1 %	11.1%	11.1 %	--
Damage Value ($)	$ 2,224,081	$ 0	$ 0	$ 2,224,081
Contents				
Damage Factor (% of content value)	17.9 %	--	--	--
Damage Value ($)	$ 620,110	--	--	$ 620,110
Inventory				
Damage Factor (% of inventory value)	--	36.0 %	36.0 %	--
Damage Value ($)	--	$ 0	$ 0	$ 0
Equipment				
Damage Factor (% of equipment value)	--	22.0 %	22.0 %	--
Damage Value ($)	--	$ 0	$ 0	$ 0
Total Damages for Urban Land Use	$ 2,844,190	$ 0	$ 0	$ 2,844,190

[a] There were no significant commercial or industrial land uses in this economic reach.

Table 11. Estimated Economic Flood-Control Benefits (FY 2004 dollars) Provided by the PVFC Project, by Land-Use Category and Type, 2004.

Land-Use Category and Type	Estimated Area (acres)	% of Total Area	Estimated Damages ($ per acre)	Number of Structures	Estimated Damages Total ($)	% of Total Damages
Agriculture	764	70 %	$ 118	- -	$ 90,139	3 %
Urban						
- residential	320	30 %	$ 8,888	589	$ 2,844,190	97 %
- commercial	0	0 %	$ 0	0	$ 0	0 %
- industrial	0	0 %	$ 0	0	$ 0	0 %
sub-total	320	30 %	$ 8,888	589	$ 2,844,190	97 %
Total	**1,084**	**100 %**	**$ 2,707**	**589**	**$ 2,934,329**	**100 %**

#4 - Lower Rio Grande Flood Control

Agriculture: **Table 12** presents details of agricultural damage estimates due to flooding for the Lower Rio Grande Valley Flood Control project. This table follows the discussion presented in the methodology section. The crop distribution is listed based on the composite acre from previous studies showing expected non-flood yield, yield loss due to flooding, crop price (normalized prices), revenue loss, reduced harvesting costs, and net damage per acre. The total crop acres are 75,645. Across the agricultural component for this region, the total potential damages are an estimated $17.52 million or $232 per acre.

Urban: Table 13 provides the details on the urban structures included in the analysis (residential, commercial, and industrial). Using the total value, the percent of total that comprised contents was calculated for residential as well as the inventory value and equipment value for commercial and industrial. The appropriate flood-damage coefficients were applied (to the value of the structure and improvements) to derive total damages for each of the classifications (i.e., contents, inventory, and equipment). In this case, the damages for residential were $102.63 million, $47.07 million for commercial, and $0 for industrial. Therefore, potential damages are an estimated $149.70 million for urban.

Total: As displayed in **Table 14**, land-use in this economic reach's flood plain is largely agriculture, with numerous residential and commercial structures and zero industrial structures on the estimated 79,487 acres. *The area most affected by a levee failure, however, is the estimated 3,842 acres of urban land use (i.e., primarily found in several of the municipalities in Hidalgo and Cameron counties) which will sustain about 90% of the total damage*. Although agriculture land use encompasses about 95% of the flood plain's land area, it is anticipated to only incur 10% of total damages. In summary, a levee failure along this economic reach is estimated to significantly damage approximately 75,645 acres of agricultural land and 6,523 residential and commercial structures, resulting in a total of $167,215,516 in economic damages (basis FY 2004).

Table 12. Estimated Economic Damages for Agricultural Land Use Attributable to a Project Levee Failure in Economic Reach #4, Lower Rio Grande Flood Control, 2004.

Crop	Unit	Base Yield	Flood Yield	Yield Loss (units per acre)	Crop Price [a] ($ per unit)	Harvest Costs ($ per unit)	Revenue Loss ($ per acre)	Increased Flood Cost ($ per acre)	Total Damage ($ per acre)	Reduced Harvest Costs ($ per acre)	Net Flood Damage ($ per acre)	Percent Acreage Allocation	Specific Crop Acres	Total Potential Damages
Row Crops [b]														
Cotton	lbs.	988.7	511.2	477.5	$ 0.5440	$ 0.2013	$ 259.76	$ 32.90	$ 292.66	$ 96.12	$ 196.54	33.56%	19,424.19	$ 3,817,635
Cottonseed	lbs.	1601.7	828.1	773.6	$ 0.0556	$ 0.0000	$ 43.04	$ 0.00	$ 43.04	$ 0.00	$ 43.04	n/a [c]	n/a [c]	$ 835,948
Sorghum	cwt.	62.0	28.8	33.2	$ 3.8100	$ 0.6000	$ 126.49	$ 26.22	$ 152.71	$ 19.92	$ 132.79	19.19%	11,106.98	$ 1,474,918
Corn	bu.	134.5	94.1	40.4	$ 2.5000	$ 0.3300	$ 101.00	$ 64.64	$ 165.64	$ 13.33	$ 152.31	28.83%	16,686.52	$ 2,541,490
Sugarcane	tons	53.9	43.1	10.8	$ 26.1900	$ 0.0000	$ 282.85	$ 0.00	$ 282.85	$ 0.00	$ 282.85	4.49%	2,598.77	$ 735,066
Vegetables	sacks	392.9	253.1	139.8	$ 8.2900	$ 3.6500	$ 1,158.94	$ 199.12	$ 1,358.06	$ 510.27	$ 847.79	13.93%	8,062.54	$ 6,835,361
Other														
Citrus	tons	21.5	19.4	2.1	$ 102.7500	$ 0.0000	$ 215.78	$ 29.95	245.73	$ 0.00	$ 245.73		2,052.00	$ 504,228
Pasture	aum.	13.6	9.5	4.1	$ 12.0000	$ 0.0000	$ 49.20	$ 0.00	49.20	$ 0.00	$ 49.20		15,714.00	$ 773,129
												Total	75,645.00	$17,517,775
												Per Acre		$ 232

Source: Based on applications of the ABE model (Agricultural Benefit Estimator; 'South Main Channel') by Lacewell et al. 1990 and as revised for this study during meetings of Lacewell, Freeman, Madison, Robinson, Rister, and Sturdivant in McAllen, TX., July 2, 2004 and July 13-14, 2004.

[a] Normalized crop prices from Economic Research Service, USDA, 2003 except for vegetables and pasture which are 2004 market prices (John Robinson, 2004).

[b] Total row crop acreage in the study area is 57,879 acres as per FEMA (1985) and Land Use (1990-92) data (by Jacobs and Madison).

[c] Cottonseed is a co-product of cotton lint production and thus does not require additional acreage.

Table 13. Potential Estimated Economic Damages for Urban Land Use for Economic Reach #4, Lower Rio Grande Flood Control, 2004.

	Urban Land-Use			
	Residential	Commercial	Industrial [a]	Total
Values				
Structure				
Number of Structures	5,773	750	0	6,523
Total Appraised Value	$ 250,015,517	$ 91,854,745	$ 0	$ 341,870,262
Average Value Per Structure	$ 43,308	$ 122,473	$ 0	$ 52,410
Contents, Inventory, Equipment				
Contents Value (% of appraised value)	50.0 %	--	--	--
Content Value ($)	$ 125,007,759	--	--	$ 125,007,759
Inventory Value (% of appraised value)	--	73.0 %	73.0 %	--
Inventory Value ($)	--	$ 67,053,964	$ 0	$ 67,053,964
Equipment Value (% of appraised value)	--	63.0 %	63.0%	--
Equipment Value ($)	--	$ 57,868,489	$ 0	$ 57,868,489
Damages				
Structure				
Damage Factor (% of appraised value)	32.1 %	11.1%	11.1 %	--
Damage Value ($)	$ 80,254,981	$ 10,195,877	$ 0	$ 90,450,858
Contents				
Damage Factor (% of content value)	17.9 %	--	--	--
Damage Value ($)	$ 22,376,389	--	--	$ 22,376,389
Inventory				
Damage Factor (% of inventory value)	--	36.0 %	36.0 %	--
Damage Value ($)	--	$ 24,139,427	$ 0	$ 24,139,427
Equipment				
Damage Factor (% of equipment value)	--	22.0 %	22.0 %	--
Damage Value ($)	--	$ 12,731,068	$ 0	$ 12,731,068
Total Damages for Urban Land Use	$ 102,631,370	$ 47,066,371	$ 0	$ 149,697,741

[a] There were no significant industrial land uses in this economic reach.

Table 14. Estimated Economic Flood-Control Benefits (FY 2004 dollars) Provided by the LRGFC Project, by Land-Use Category and Type, 2004.

Land-Use Category and Type	Estimated Area (acres)	% of Total Area	Estimated Damages ($ per acre)	Number of Structures	Estimated Damages Total ($)	% of Total Damages
Agriculture	75,645	95 %	$ 232	- -	$ 17,517,775	10 %
Urban						
- residential	3,237	4 %	$ 31,706	5,773	$ 102,631,370	61 %
- commercial	605	1 %	$ 77,796	750	$ 47,066,371	28 %
- industrial	0	0 %	$ 0	0	$ 0	0 %
sub-total	3,842	5 %	$ 38,963	6,523	$ 149,697,741	90 %
Total	**79,487**	**100 %**	**$ 2,104**	**6,523**	**$ 167,215,516**	**100 %**

Aggregate Results

As depicted in **Table 15**, the estimated gross value for economic benefits (or damages avoided) provided by IBWC flood-control infrastructure, on the U.S. side of the border for the four economic reaches analyzed, total $322,930,794 for agriculture crop and developed property.[22] There is a wide range in the damages along individual economic reaches, with the heaviest-populated project area (and most developed) being the Lower Rio Grande Flood Control with $167,215,516 of economic benefits. The infrastructure along the Rio Grande Rectification project also provides significant benefits with an estimated $139,096,639 in agriculture-crop and developed-property protection. Receiving the least amount of economic benefits across the four reaches is the Presidio Valley Flood Control area with an estimate of $2,934,329 (**Table 15**).

As suspected, the urban land-use category receives the largest amount of economic benefits provided by IBWC flood-control infrastructure with a total of $302,251,929 (i.e., $322,930,794 minus $20,678,865) (**Table 15**). In particular, residential structures are provided an estimated $220,857,874 in economic benefits, while commercial and industrial are provided $79,000,996 and $2,393,060, respectively (**Table 15**). Similarly, the number of structures benefitting from levee protection is comparable across urban land use. It is estimated 11,010 residential structures are in the revised flood plain (i.e., FEMA less "disconnect" areas). The commercial and industrial types have lower estimates, with 1,156 and 1 structure(s), respectively.

Agriculture land use, though less affected (in terms of dollars) than urban land use, does receive an estimated $20,678,865 in benefit from levees and other flood-control infrastructure protecting an estimated 81,249 acres. In terms of dollars, agriculture land use only eclipses industrial land-use when comparing benefits received across the four land-use types.

22 Additional preliminary estimates with other costs (i.e., besides agriculture crop and developed property) are provided in Appendix D.

Table 15. Summary of Estimated Economic Benefits Provided by USIBWC Rio Grande Projects Along Four Economic Reaches, 2004.

	Total Property Damage [a]										
	Ag Land Use		Urban Land Use								
	Composite [b]		Residential		Commercial		Industrial		Total Property		
Economic Reach	# of acres	sub-total damage ($)	# of structures	sub-total damage ($)	# of structures	sub-total damage ($)	# of structures	sub-total damage ($)	# of structures	Total Damages ($)	% of Total Damages
Rio Grande Canalization	2,484	$ 1,821,418	397	$ 6,778,812	67	$ 5,084,080	0	$ 0	464	$ 13,684,311	4.2 %
Rio Grande Rectification	2,356	$1,249,533	4,251	$ 108,603,502	339	$ 26,850,544	1	$ 2,393,060	4,591	$ 139,096,639	43.1 %
Presidio Valley Flood Control	764	$ 90,139	589	$ 2,844,190	0	$ 0	0	$ 0	589	$ 2,934,329	0.9 %
Lower Rio Grande Flood Control	75,645	$ 17,517,775	5,773	$ 102,631,370	750	$ 47,066,371	0	$ 0	6,523	$ 167,215,516	51.8 %
Total	81,249	$ 20,678,865	11,010	$ 220,857,874	1,156	$ 79,000,996	1	$ 2,393,060	12,167	$ 322,930,794	100 %
% of Total Damages		6.4 %		68.4 %		24.5 %		0.7 %		100 %	

[a] These gross-value estimates only account for agriculture-crop and developed-property damages on only the U.S. side of the U.S. and Mexico border.

[b] The specific crops differ by reach and includes varying proportions of row crops, vegetables, citrus, etc. as displayed in Tables 3, 6, 9, and 12.

Study Baseline Estimates – Assumptions and Issues

The baseline gross-value estimates of flood-control infrastructure benefits contained herein are applicable towards a complete cost-benefit analysis. With a brief study period and other limiting constraints, however, the authors needed to make several broad-based assumptions on key issues. Specifically:

- Only levees in the U.S. are considered in the analysis. Any relationship with levees on the Mexican side of the border are ignored.
- The gross-value estimates are in FY 2004 dollars; i.e., assume flooding occurred in 2004.
- Since flood inundation maps were not available for all areas, the flood zone was estimated for each economic reach. This entailed the use of digital copies of FEMAs 100-year flood maps and Flood Insurance Rate Maps which provided a starting point to make extrapolations and adjustments to the amount of area and specific land uses for each economic reach.
- The flood-inundation depth is unknown for the hypothetical flooding, but is assumed to be two feet across the estimated flood-inundation area. Other depths are not analyzed since there are no hydrological analyses nor data provided.
- The results are point estimates (i.e., deterministic and without sensitivity analyses or stochastic elements) based on a hypothetical flooding event of which the input data are not completely known and/or obtainable given the study's scope. As such, there is no accounting for risk and/or uncertainty about the actual range in the data input.
- The estimates are based upon a single flood event without probabilities of location, timing, severity, duration, etc. The damage estimates are for the year any such event might occur.
- The results, as presented for four individual economic reaches, are reported in a manner which correlate with the four project areas identified by the IBWC.
- The average property values in the flood plain, including improvements, were used (i.e., rather than the median or mode) without a prior statistical analysis being performed. Thus, any impact from potential extreme values observed at one end of the data range is ignored.

While these caveats highlight real limitations, they should not be interpreted as negating the usefulness of the results as they are bonafide and conducive for use in a cost-benefit appraisal. As with the limitations discussed in the next section, these items are worthy of consideration for future research, but should not prevent the use of the results at this time.

Study Baseline Estimates – Cost Category and Type Limitations[23]

This report provides an estimate of the gross value of flood-control infrastructure benefits provided by IBWCs Rio Grande projects. There are limitations, however, as to what the baseline estimates encompass. **The gross-value estimates account for agriculture crop and developed-property damages only**. As such, the following categories and types of loss are not included (except as might be noted in Appendix D):

- loss of human life;
- loss of livestock;
- loss of transportation and transportation infrastructure
  - » vehicles
  - » roads and highways
  - » bridges and dams;
- other economic costs
  - » individuals' temporary loss of jobs
  - » businesses' lost sales and project delays
  - » flood clean-up
  - » rescue and security/assistance deployment (e.g., national guard, food bank);
- other agriculture costs
  - » farm equipment (e.g., tractors, underground wells, tillage implements)
  - » loss and/or displacement of topsoil;
- environmental
  - » impacts to wildlife and endangered species
  - » spills of raw sewage, gasoline, and other underground; and
- negative externalities (or intangible)
  - » disruption of public services (e.g., police, fire, ambulance)
  - » increased incidents of mosquitoes, snakes, varmints, etc.
  - » lifestyle disruptions and increased living expenses (e.g., hotel).

While the above-mentioned limitations do highlight significant cost variables not considered as determinants in the reported estimates, the reader should not be dissuaded. The reported estimates of benefits accruing to IBWC flood-control infrastructure should be viewed considering the limitations defined. These limitations are indicative, however, that future research and refinement efforts would provide for more accurate and, likely, substantially higher estimates.

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23 Supplemental to the baseline estimates, certain costs listed in this section are addressed (at least in a preliminary fashion) in *Appendix D - Estimates of Other Costs/Damage* of this report.

Recommended Future Research

Though the presented research complies with the original scope of work and agreement made with the USIBWC, there are, as mentioned in the two previous sections, limitations as to what the results represent. Continued research efforts targeting one or more of the study's shortcomings would enable a more detailed and accurate estimate of benefits provided by IBWC flood-control infrastructure along the Rio Grande. Though all areas of shortcomings discussed could be targeted, the authors would consider efforts focusing on the following to be the most effective:

- development of and refinement of flood-inundation maps, supported by appropriate hydrological and hydraulic studies focused on levee and dam failure would result in improved elevation data and a more accurate estimate of the flooded area and associated depth variations;

- detailed field surveys of structures within the flood plain would provide an improved estimate of actual inventory of structures likely to flood as rapid urbanization, slightly-aged DOQQs (i.e., 1996 used in this study), and the use of only topographical views without comprehensive ground truthing combine to limit accuracy;

- development of detailed stage-damage curves (specific to the study area) for an expanded set of urban land-use types (i.e., multiple residential, commercial, and industrial types) would increase accuracy by reducing the use of broad assumptions and generalized parameter values;

- development of more recent satellite imagery (than the 1992 land-use maps available for use in this study) combined with inclusion of a broader set of urban land-use types and their associated values would increase accuracy of the damage estimate; and

- development and refinement of other economic, socio-economic, and environmental cost estimates for the specified study area (e.g., flood clean up, lost jobs and sales, transportation, lifestyle disruption, wildlife and endangered species, sewage and fuel spills, etc.) would provide a more comprehensive estimate.

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Glossary

100-Year flood: A term applied by federal and state agencies describing an inundation level/volume associated with an event in which the risk of flooding is estimated at 1.0 percent in a given year. Similarly, the risk with a 50-year flood is estimated at 2.0 percent in a given year.

Acre-feet: A measure of water contained in an area of one acre square and one foot deep which is equal to 325,851 gallons.

CFS: Acronym for *cubic feet per second* where one CFS equals 450 gallons per minute, or 646,360 gallons per day, or 1.983 acre-feet.

Composite acre: A representation of the proportional mix of crops planted within a region on a percentage basis, with the total equaling 100%.

DOQQ: Acronym for *digital orthophoto quarter-quadrangle*; a digital image of an aerial photograph which includes the geometric aspects of a related map which facilitates the effective management and use of geographic information systems in various spatial applications.

Economic reach: Referring to the economic aspects represented by a segment or geographic-limited portion along a river.

Encroachment: Near or absolute infringement upon a boundary, such as the top of a levee.

FEMA: Acronym for *Federal Emergency Management Agency*; the U. S. agency tasked with planning for and responding to natural disasters so as to reduce loss of life and damages.

Flood-affected yields: Yield amounts assumed to occur as a result of reductions in normal yields in association with prolonged flooded conditions occurring during production and/or harvest stages of the crop in association with a 100-year flood event.

Flood plain: A low-lying and typically flat area along (or near) a river which is naturally subject to flooding.

Floodway: A low-lying and typically flat area sometimes along (or near) a river which is intentionally designed to convey flood waters.

Freeboard: An amount of "cushion" or vertical distance beyond the maximum designed flood level provided by a levee; the vertical distance from the top of the water level (at its maximum designed flood level) to the top of a levee.

Geographic Information System (GIS): Spatial information systems involving extensive, satellite-guided mapping associated with computer database overlays.

Gross value: A dollar value for an agricultural crop calculated by multiplying the harvested yield by the per unit price of the crop.

IBWC: Acronym for *International Boundary and Water Commission*; the agency tasked with overseeing the boundary and water treaties between the United States and Mexico.

Inundation: An excessive flow, or flood, of water covering a specified area.

Levee: Typically earthen, an embankment elevated used to prevent flooding and to confine the flow path of water.

Net gross revenues: Values calculated by multiplying harvested yield units by (crop price less per unit harvest and other post-harvest processing costs).

NLCD: An acronym for *National Land Cover Data*; from the U.S. Geological Survey (USGS), a land use/land-cover dataset derived from 1992 Landsat 5 Thematic Mapper (TM) imagery through a process of unsupervised clustering. The scale for this dataset is 1:24,000.

Normal yields: Yield amounts assumed to be expected under standard production technology and common soil types in the flood-prone areas of the study region.

Normalized crop prices: Annual agricultural crop prices calculated by the United States Department of Agriculture's Economic Research Service (USDA-ERS) based on a 5-year moving average of actual market prices (i.e., 1997-2001 for 2003 normalized prices) which smooths out the effects of short-term fluctuations and deletes impacts of U.S. federal support programs. State-level prices for 2003 were calculated by multiplying the national-level normalized prices by the average ratios of the State prices to the national prices for 1999-2001.

Overtopped: An instance where the water level exceeds a levee's elevation.

Quality damage: A deterioration of attributes of an agricultural crop such that market value is lessened.

Reach: A segment or geographic-limited portion along a river.

USACE: Acronym for *U. S. Army Corps of Engineers* whose civil mission includes providing engineering services to the nation (e.g., planning, designing, building, etc.) and operating civil-works projects (e.g., navigation, flood control, environmental protection, etc.)

USBR: Acronym for *U. S. Bureau of Reclamation*; the U.S. agency tasked with managing, developing, and protecting water and related resources (U. S. Bureau of Reclamation).

USIBWC: Acronym used when referring to the U. S. Section of the *International Boundary and Water Commission* (IBWC).

Appendices

Appendix A: Procedures for Estimating Agricultural Damages

An Example Using: Lower Rio Grande Flood-Control (LRGFC) Project

This section provides additional information regarding how agricultural damages were determined especially for the LRGFC project. Key calculations involved with determining the estimated damages are presented in **Tables 3, 6, 9,** and **12** and discussed below. The details for **Table 12** (i.e., the LRGFC project or economic reach #4) is used as an example as it would be largely repetitive to provide the same for **Tables 3, 6,** and **9**.

Land use areas required a distinction be made between alternative land-use types. For the LRGFC project, this was accomplished by using 1992 satellite image maps provided by the Spatial Sciences Laboratory at Texas A&M University. After total agricultural land uses were determined in the study areas, a compilation of the acreage for each crop in the FEMA 100-year flood plain was computed. Total crop acres of 75,645 are summed for Hidalgo and Cameron Counties as provided by the Spatial Sciences Laboratory at Texas A&M University. Total crop acreage can be classified as follows: row crops-57,879, citrus-2,052, vegetables-8,063, and pasture-15,714 (**Table 12**). Below are column-specific information pertaining to the determination of agricultural damages for the LRGFC project:

Column 1 - The *crops* listed come from Table 6, page 97, of the South Main Channel Agricultural Benefits Study (Lacewell et al. 1995). For this economic reach, there are row crops (i.e., cotton, sorghum, corn, sugar cane and vegetables), orchards, (i.e., citrus), and pasture/hay.

Column 2 - *Unit* measurements are self-explanatory.

Column 3 - *Base yield* comes from the county soil surveys for Hidalgo and Willacy Counties based upon improved management. It is also given in Table 6, page 97, of Lacewell et al. 1995.

Column 4 - *Flood yield* also comes from Table 6, page 97, of Lacewell et al. 1995 and represents production for only flooded acres.

Column 5 - *Yield loss* is the difference between base yield and flood yield.

Column 6 - *Crop prices* for cotton, cottonseed, sorghum, corn, sugar cane, and citrus (oranges and grapefruit) come from 2003 USDA normalized prices. Current market prices are used for vegetables and pasture. Note that the U. S. Department of Agriculture, Economic Research Service (USDA-ERS) annually calculates normalized prices for evaluating alternative development and management plans for water and related land resources. Normalized prices smooth out the effects of short-term fluctuations so that plans can be evaluated on a more realistic basis rather than using current prices, which may be lower or higher than normal because of short-lived phenomena. Since 1993, ERS has estimated these prices based on 5-year moving averages of actual market prices (e.g., 1997-2001 for 2003 normalized prices). State-level prices for 2003 were calculated by multiplying the national-level normalized prices by the average ratios of the state prices to the national prices for 1999-2001.

Column 7 - *Harvest costs* come from John Robinson's 2004, "Crop and Livestock Enterprise Budgets for the Lower Rio Grande Valley," Texas Agricultural Extension Service, Weslaco, TX.

Column 8 - *Revenue loss* is simply the crop price (column 5) times the yield loss (column 6).

Column 9 - *Increased flood costs* come from the Table of Costs on page 146 of Appendix B in Lacewell et al. 1995. These are costs associated with flooding that caused producers to incur additional costs such as re-seeding, insecticides, land leveling, etc. These costs were identified during a series of focus group meetings in 1995 and are presented in Table 6, page 97, of Lacewell et al. 1995. Appendix C of the Lacewell et al. 1995 report (pages 147-157) also identifies additional production costs attributable to flooding.

Column 10 - *Total damages* are the revenue lost (column 8) plus increased flood costs (column 9).

Column 11 - *Reduced harvest costs* are the yield lost (column 5) times the harvest cost (column 7).

Column 12 - *Net flood damage* is the total damage (column 10) minus the reduced harvesting cost (column 11).

Column 13 - *Percent acreage allocation* of row crops comes from the cropping patterns from Table 10 (Appendix B, page 100) of Lacewell et al. 1995. This table was redistributed for the FEMA 100-year watershed.

Column 14 - *Specific crop acres* are established by multiplying the total row crop acres of 57,879 by the proportional allocation of row crops (i.e., column 13). Citrus and pasture acreages were taken directly from land use provided by the Spatial Analysis Laboratory at Texas A&M University.

Column 15 - *Total potential damages* are obtained by multiplying the net flood loss (column 12) by the specific crop acres (column 14).

Appendix B: Land-Use Types, Lower Rio Grande Flood-Control Project (LRGFC)

These tables (i.e., Hidalgo and Cameron counties) provide the basis for determining land use for the LRGFC economic reach. The data were determined from the revised FEMA 100-year flood plain zone (i.e., FEMA map less “disconnect areas”) and 1992 land-use map/data.

Table B1. Hidalgo County Land Use Categories for Revised FEMA 100-Year Flood Plain Area, 2004.

Value	Type	Pixel Count	Area (square meters)	Area (square miles)	Area (acres)
11	Open Water	20,703	18,632,700	7.19	4,604
21	Low Intensity Residential	2,155	1,939,500	0.75	479
22	High Intensity Residential	1,527	1,374,300	0.53	340
23	Commercial/Industrial/Transportation	1,681	1,512,900	0.58	374
31	Bare Rock/Sand/Clay	8,989	8,090,100	3.12	1,999
41	Deciduous Forest	22,588	20,329,200	7.85	5,023
42	Evergreen Forest	18,287	16,458,300	6.35	4,067
43	Mixed Forest	74	66,600	0.03	17
51	Shrub land	92,326	83,093,400	32.08	20,533
61	Orchards/Vineyards/Other	7,889	7,100,100	2.74	1,755
71	Grasslands/Herbaceous	11,152	10,036,800	3.88	2,480
81	Pasture/Hay	50,206	45,185,400	17.45	11,166
82	Row Crops	154,017	138,615,300	53.52	34,252
85	Urban/Recreational Grasses	436	392,400	0.15	97
92	Emergent Herbaceous Wetlands	729	656,100	0.25	162
xx	Unknown/Non-Categorized				285
	Total				87,632

Source: Calculated by co-authors Jacobs and Madison, using data from the revised flood-plain map.

Table B2. Cameron County Land Use Categories for Revised FEMA 100-Year Flood Plain Area, 2004.

Value	Type	Pixel Count	Area (square meters)	Area (square miles)	Area (acres)
11	Open Water	39,979	359,811,000	138.92	88,911
21	Low Intensity Residential	377	339,300	0.13	84
22	High Intensity Residential	329	296,100	0.11	73
23	Commercial/Industrial/Transportation	8,871	7,983,900	3.08	1,973
31	Bare Rock/Sand/Clay	30,870	27,783,000	10.73	6,865
41	Deciduous Forest	7,346	6,611,400	2.55	1,634
42	Evergreen Forest	9,920	8,928,000	3.45	2,206
43	Mixed Forest	526	473,400	0.18	117
51	Shrub land	68,842	61,957,800	23.92	15,310
61	Orchards/Vineyards/Other	1,339	1,205,100	0.47	298
71	Grasslands/Herbaceous	227,309	204,578,100	78.99	50,552
81	Pasture/Hay	20,454	18,408,600	7.11	4,549
82	Row Crops	106,237	95,613,300	36.92	23,626
83	Small Grains	10	9,000	0.00	2
85	Urban/Recreational Grasses	182	163,800	0.06	41
91	Woody Wetlands	3,430	3,087,000	1.19	763
92	Emergent Herbaceous Wetlands	179,988	161,989,200	62.54	40,028
xx	Unknown/Non-Categorized				172
	Total				237,203

Source: Calculated by co-authors Jacobs and Madison, using data from the revised flood-plain map.

Appendix C: NLCD 1992 Classification System

The following National Land Cover Data (NLCD) 1992 Classification System codes (EPA) provide definitions to the "value" column in **Tables B1** and **B2** (i.e., Appendix B) (USEPA).

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10. Water - All areas of open water or permanent ice/snow cover.

11. Open Water - All areas of open water, generally with less than 25% cover of vegetation/land cover.

12. Perennial Ice/Snow - All areas characterized by year-long surface cover of ice and/or snow.

20. Developed - Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g., asphalt, concrete, buildings, etc).

21. Low Intensity Residential - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential - Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to l00 percent of the cover.

23. Commercial/Industrial/Transportation - Includes infrastructure (e.g., roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

30. Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay - Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.

33. Transitional - Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clear cuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g., fire, flood, etc.).

40. Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species' maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

50. Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking.
Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland - Areas dominated by shrubs; shrub canopy accounts for 25-1 00 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g., herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

60. Non-Natural Woody - Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

70. Herbaceous Upland - Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

80. Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. Fallow - Areas used for the production of crops that do not exhibit visible vegetation as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

90. Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water.

91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

Appendix D: Estimates of Other Costs/Damages

As discussed, limitations in this study impose uncertainty about the accuracy of the baseline damage estimates simply because many costs are not included in the estimate. The *Study Baseline Estimates – Cost Category and Type Limitations* section elaborates on those costs not included in the reported $322,930,794 of potential total gross property damages (**Table 15**). In this section, however, some very broad-based assumptions and rough estimates are extrapolated from other flooding events and used to address certain shortcomings mentioned in the main body of this report. Here, the authors attempt to provide some reasonable estimate of what some "other" costs/damages might be, given the same flood event (e.g., two-foot flood inundation, etc.) assumed for the baseline estimate. Although the authors believe the following values to be useful, the reader should note that the authors' degree of certainty about these estimates are, in a relative sense, less than that for the baseline estimate. This exercise does point out, however, significant benefits that are not included.

As with the baseline estimate provided in the main body of this report, stage-damage coefficients are used to compute "other" damages (i.e., emergency, roads, utilities, and vehicles). Remember, for three of the four reaches, the revised FEMA 100-year flood maps (i.e., FEMA 100-year flood-map area minus the "disconnect" areas) were overlain with GIS land-use maps to determine the area subject to flooding in the baseline estimate - - the exception being the PVFC reach (i.e., #3) which used Flood Insurance Rate Maps. From these maps the number of both residential and commercial structures were determined. Only the number of residential structures are used, however, in the following computations for "other" damages (**Table D1**).

Emergency Costs: Damages for potential emergency costs of $6,867 (basis FY 2004) per residential structure are estimated and applied to all four economic reaches. This value was obtained from a relatively recent survey of flood victims within the Cypress Creek and Greens Bayou watersheds in Harris County (i.e., general area of Houston, TX.). This survey revealed other costs associated with flooding that lacked prior quantification (Davis). These costs include lodging and travel, food, clean up, moving and storing furniture, vandalism and looting, and medical costs all associated directly with the flood experience (Davis).

Roads: Costs for potential road damages of $9,191 (basis FY 2004) per mile are estimated and applied to the miles of road in the revised FEMA 100-year flood plain. This value was calculated using stage-damage relationships for roads from data collected by FEMA for both the April 1979 Montgomery County flood, and the 1997 Tropical Storm *Claudette* flood. Road damages include repair for roads, bridges, street signs, and street lighting. There is an estimated 653 miles of improved roads across the four flood zones.

Utilities: Costs for potential utility damages of $125 (basis FY 2004) per residential structure are estimated and applied to all four economic reaches. This value was calculated (and updated to reflect current values) using stage-damage relationship estimates obtained after the July 1979 Tropical Storm *Claudette*, which flooded the Texas counties of Harris, Brazoria and Galveston. The utility damages include losses to electrical transformers and transmission lines, telephone company lines and switchboxes, and water and gas pipelines.

<u>Vehicles</u>: Costs for potential vehicle damages of $9,086 (basis FY 2004) per residential structure are estimated and applied to all four economic reaches. This value was obtained from a relatively recent survey of flood victims within the Cypress Creek and Greens Bayou watersheds in Harris County (i.e., general area of Houston, TX.). This survey revealed that, on average, each surveyed household lost one vehicle to flooding, regardless of property value (Davis). Though most residences have multiple vehicles, only a one-for-one correlation was used for estimating vehicle damages in this study. Flood damage to vehicles includes the labor and parts to dry out and replace materials, as necessary, whenever a vehicle is inundated.

The aggregate baseline economic benefits for agriculture and developed property for the four project areas comprising this study are estimated at $322.9 million (basis FY 2004). When preliminary estimates of $183.0 million in other costs (i.e., emergency, roads, utilities, and vehicles) are added, the total flood-control protection benefits provided by the four project areas increases to $506.0 million (**Table D1**). Thus, the baseline estimate is increased 157% when the expanded set of costs are included.

Table D1. Estimated Economic Flood-Control Benefits (FY 2004 dollars) Provided by IBWC Rio Grande Projects – "Other" Damage Categories Added to Baseline Damages, 2004.

	- - - Economic Reach - - -				
Damage Category	Rio Grande Canalization	Rio Grande Rectification	Presidio Valley Flood Control	Lower Rio Grande Flood Control	Total
Baseline Damages [a]					
Total Agriculture Land-Use Damages	$ 1,821,418	$1,249,533	$ 90,139	$ 17,517,775	$ 20,678,865
Total Urban Land-Use Damages	$ 11,862,892	$ 137,847,106	$ 2,844,190	$ 149,697,741	$ 302,251,930
sub-total ($)	$ 13,684,311	$ 139,096,639	$ 2,934,329	$ 167,215,516	$ 322,930,794
Emergency Costs					
Amount Per Residential Structure	$ 6,867	$ 6,867	$ 6,867	$ 6,867	$ 6,867 [c]
Number of Units (in revised flood plain)	397	4,251	589	5,773	11,010
sub-total ($)	$ 2,726,199	$ 29,191,617	$ 4,044,663	$ 39,643,191	$ 75,605,670
Road Costs					
Amount Per Mile	$ 9,191	$ 9,191	$ 9,191	$ 9,191	$ 9,191 [c]
Number of Miles (in revised flood plain) [b]	40	95	18	500	653
sub-total ($)	$ 367,640	$ 873,145	$ 165,438	$ 4,595,500	$ 6,001,723
Utilities Costs					
Amount Per Residential Structure	$ 125	$ 125	$ 125	$ 125	$ 125 [c]
Number of Units (in revised flood plain)	397	4,251	589	5,773	11,010
sub-total ($)	$ 49,625	$ 531,375	$ 73,625	$ 721,625	$ 1,376,250
Vehicle Costs					
Amount Per Residential Structure	$ 9,086	$ 9,086	$ 9,086	$ 9,086	$ 9,086 [c]
Number of Units (in revised flood plain)	397	4,251	589	5,773	11,010
sub-total ($)	$ 3,607,142	$ 38,624,586	$ 5,351,654	$ 52,453,478	$ 100,036,860
Total Damages - Baseline and Other	$ 20,434,917	$ 208,317,362	$ 12,569,709	$ 264,629,310	$ 505,951,297

a Total gross values as per Table 15.

b Without any hydrological/hydraulic data, the milage is informally approximated. Subsequently, the dollar estimate contains much uncertainty.

c Value is not the total for the row, but rather represents the average value across the previous four columns.

Appendix E: Alternative Flood Plains – Comparison of FEMA to USBR

Below, a comparison of two alternative maps (and their respective flooded areas) is made with brief discussion of the potential consequences to the estimate of economic benefits. That is, concerns and limitations specific to the data assimilation and tasks/methods used in estimating economic benefits for economic reaches #1 and #2 (i.e., Rio Grande Canalization and Rio Grande Rectification) were encountered. Specifically, the FEMA flood map used to determine area for these two reaches may under-estimate the actual flooded area if a levee failed. That is, FEMA flood mapping is based on rainfall and as a result, includes distant flood-impacted areas which are higher in elevation than the river (i.e., arroyos and arroyo alluvial fans) (**Figure E1**). Another study by the U.S. Bureau of Reclamation (USBR) for this area (USBR 2004) suggests potential for a larger flooded area.

The USBR study used digital elevation maps to identify the flooded area resulting from a 100-year precipitation event and a structural failure of either Caballo Dam (344,000 acre-feet capacity), or Caballo Dam and Elephant Butte (2.2 million acre-feet capacity). Either of these events would result in a structural failure of downstream IBWC flood-control levees along these two economic reaches. When compared to the revised FEMA flood map used in this study, the USBR-estimated flood area would be significantly wider near the river and would not include the arroyos and alluvial fans included in the FEMA map. For these reasons, the USBR estimated flood area may more accurately reflect the inundation resulting from a levee failure.[24]

To obtain an indication of damages under the USBR "flood and dam break" scenario, a small sample area in the USBR flooded area consisting of only residential properties in west El Paso, TX. (i.e., a sample representative of economic reach #1) was selected (**Figures E2** and **E3**). Compared to the revised FEMA flood-impact values, indications are that damage values for residences could be 200% greater than the baseline estimate reported for this economic reach. That is, the residential damage estimate is two times greater in the west El Paso, TX. area when a flood and dam failure precipitates a levee failure, as compared to just an intense rain event (as assumed in the FEMA 100-year flood map).

Similar comparisons for residential properties in the lower valley of El Paso, TX. (i.e., a sample representative of economic reach #2) were selected (**Figures E2** and **E4**). Here, compared to the revised FEMA flood-impact values, indications are that damage values for residences could be 325% greater than the baseline estimate reported for this economic reach. That is, the residential damage estimate is three and one-quarter times greater in the lower valley of El Paso, TX. area when a flood and dam failure precipitates a levee failure, as compared to just an intense rain event (as assumed in the FEMA 100-year flood map).

24 The USBR "flood and dam break" scenario is informative for the first two reaches, but is not used in the baseline analysis because of the authors' wishes for consistency in methodology across all four reaches.

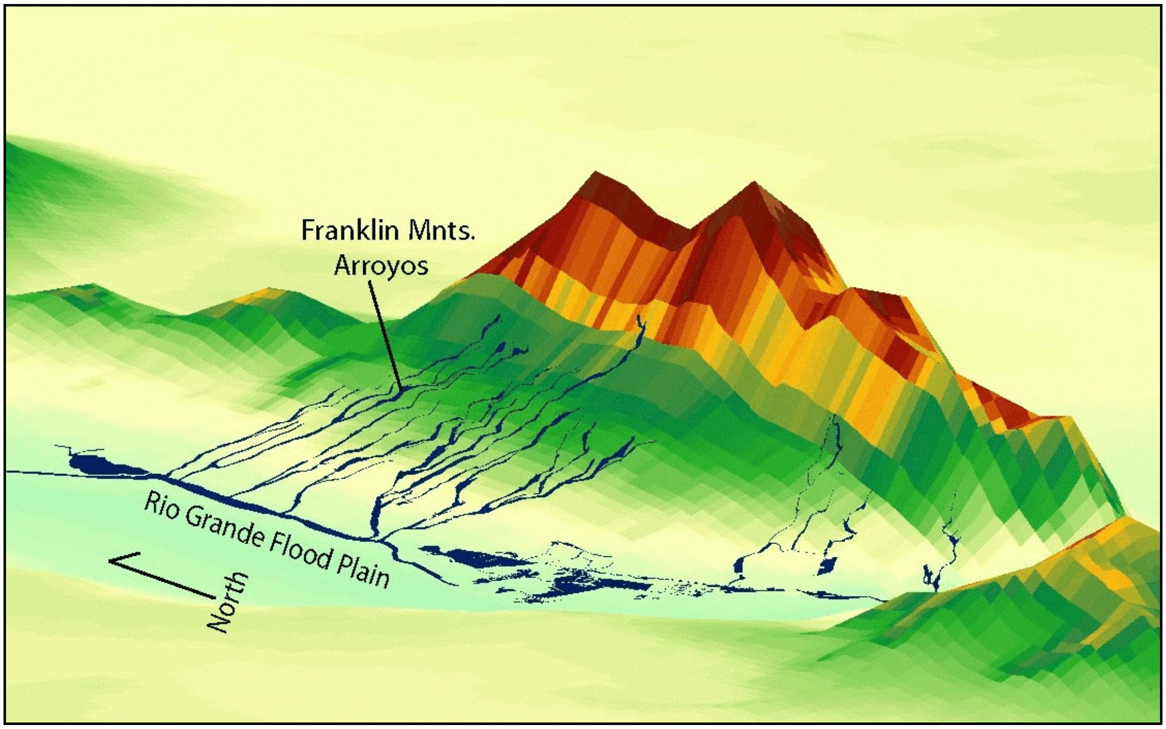

Figure E1. Digital Elevation Map Depicting Arroyos Which Flood Under FEMAs 100-Year Map, Rio Grande Canalization and Rectification Projects, 2004.

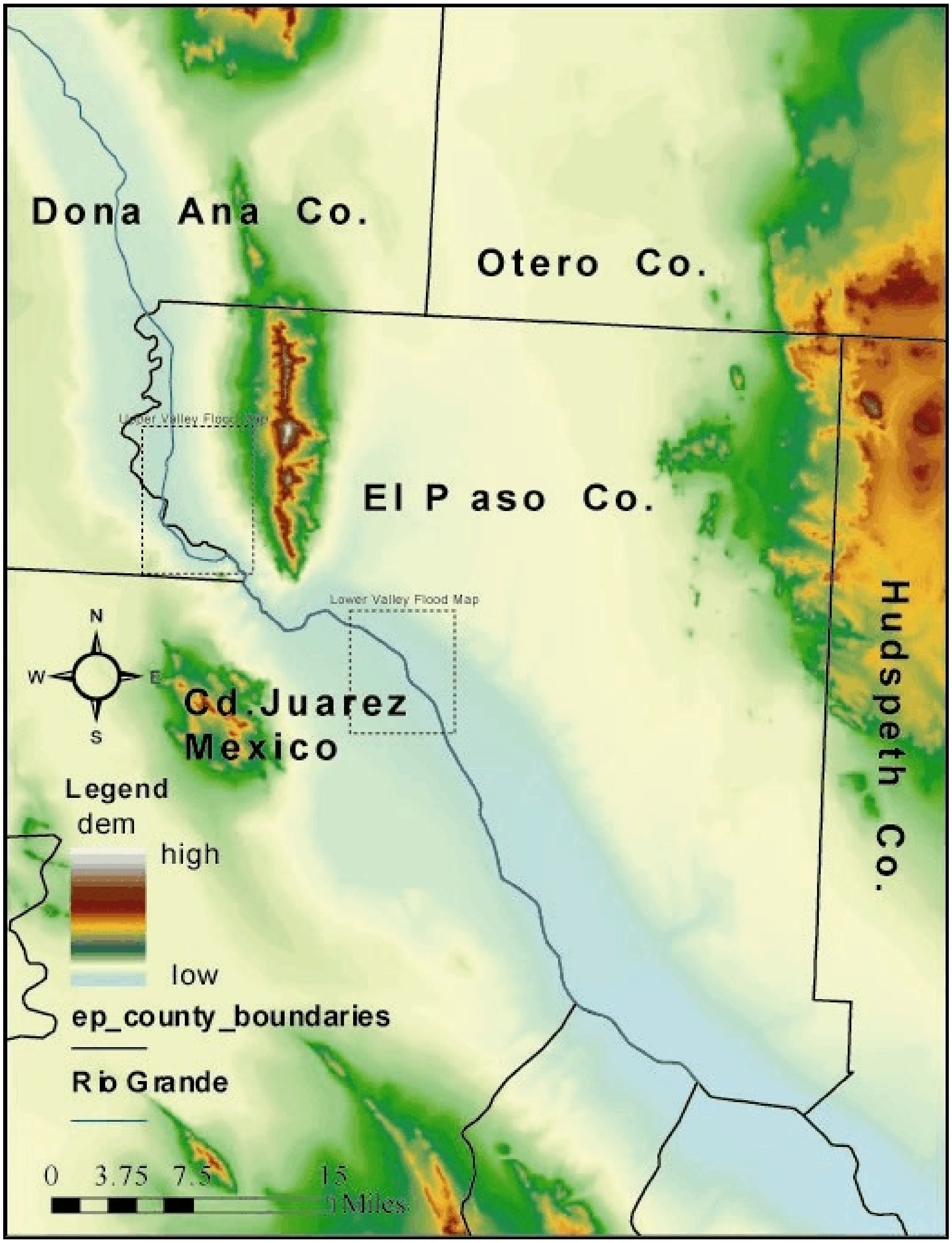

Figure E2. Map Depicting the Location of Sample Areas Used to Determine Damages Under the USBR "Flood and Dam Break" Scenario, Rio Grande Canalization and Rectification Projects, 2004.

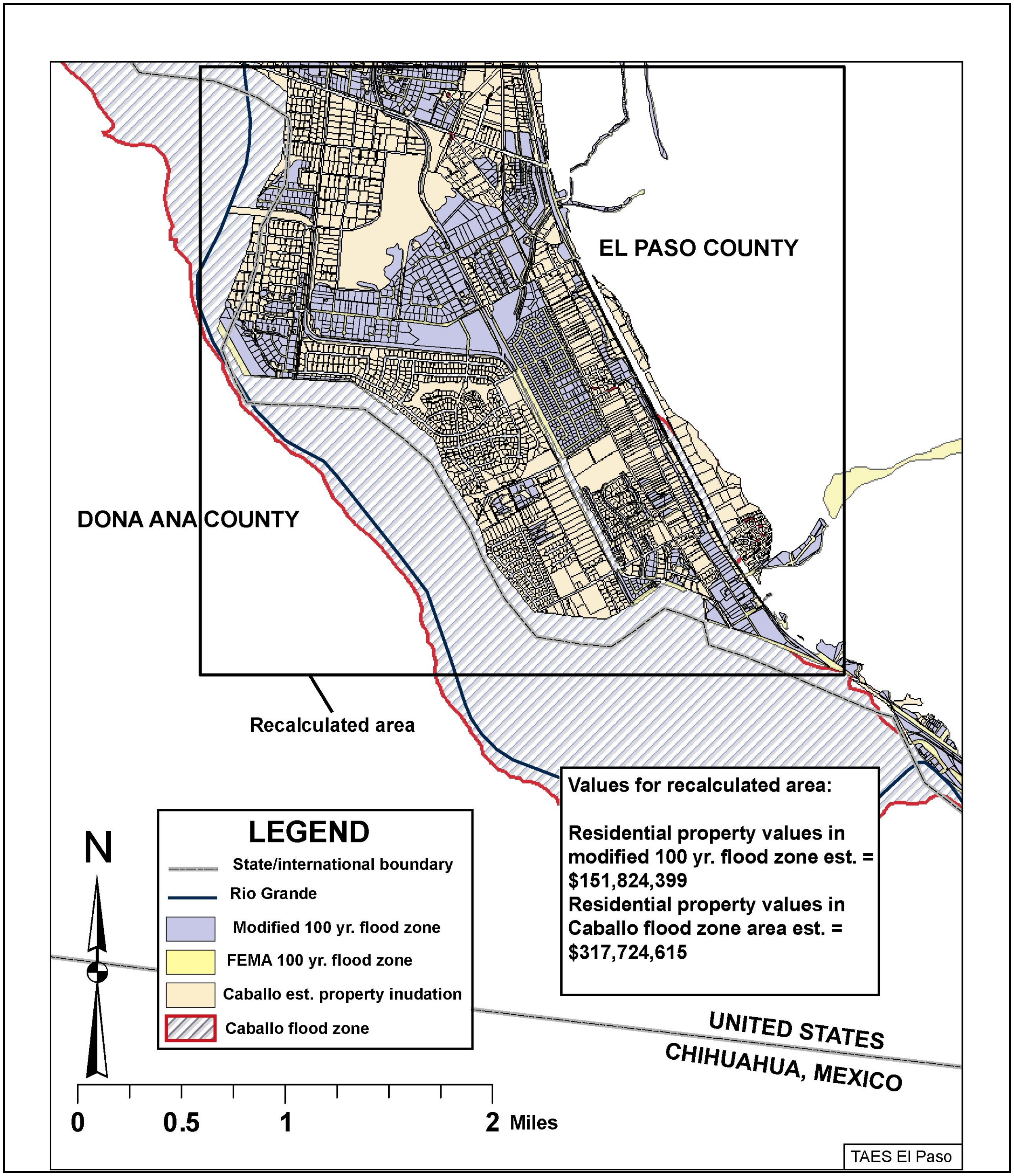

Figure E3. Depiction of Re-sampled Residential Area (west El Paso, TX. area) Indicating Higher Damages Assuming the USBR "Flood and Dam Break" Scenario's Larger Flooded Area, Rio Grande Canalization Project, 2004.

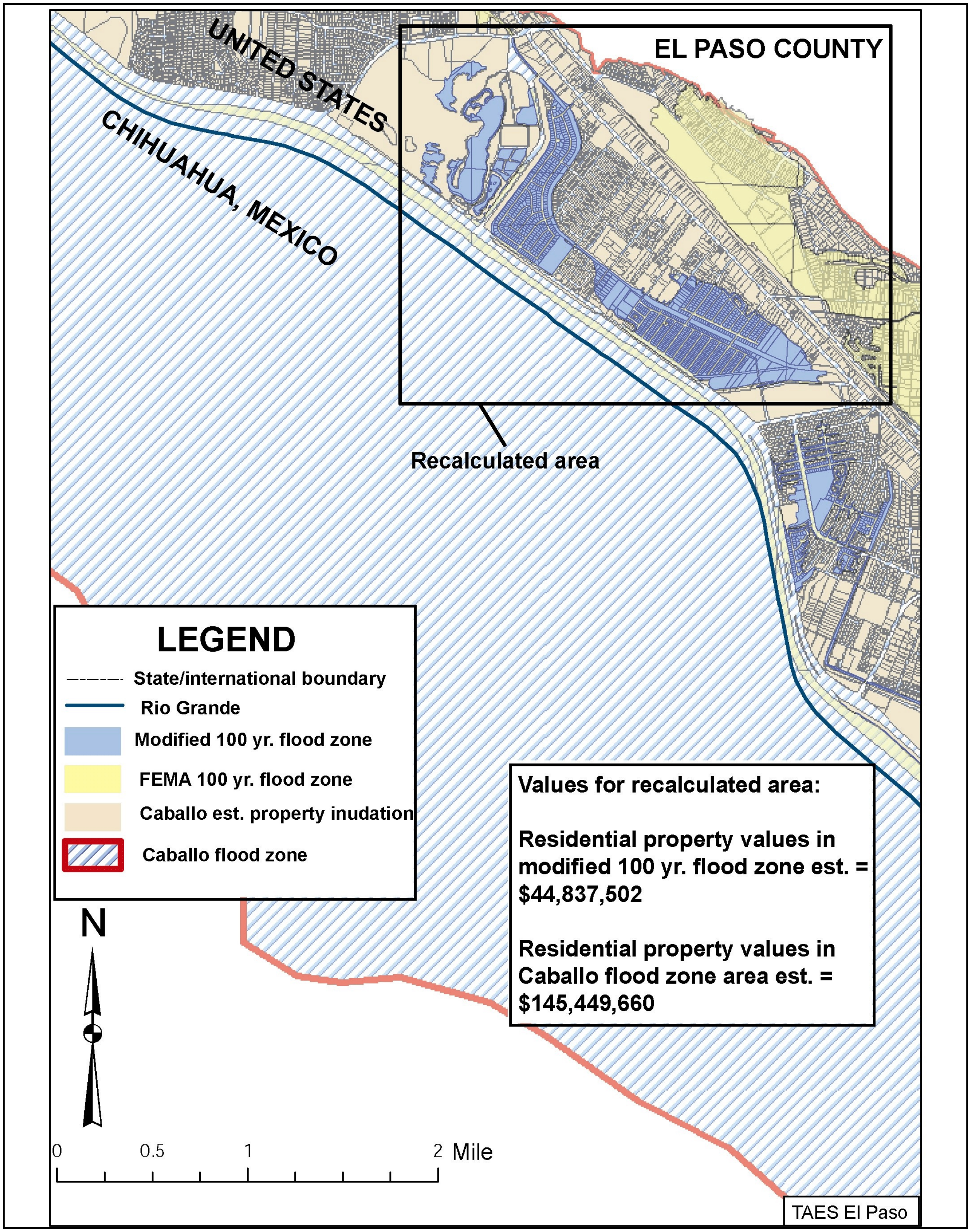

Figure E4. Depiction of Re-sampled Residential Area (lower valley of El Paso) Indicating Higher Damages Assuming the USBR "Flood and Dam Break" Scenario's Larger Flooded Area, Rio Grande Rectification Project, 2004.

Appendix F: Additional Map – Example Flood Zone With Land Use

This map image provides an example of the flood zone (i.e., revised FEMA 100-year flood map less disconnect areas) after being overlain with land use for a segment of Hidalgo county.

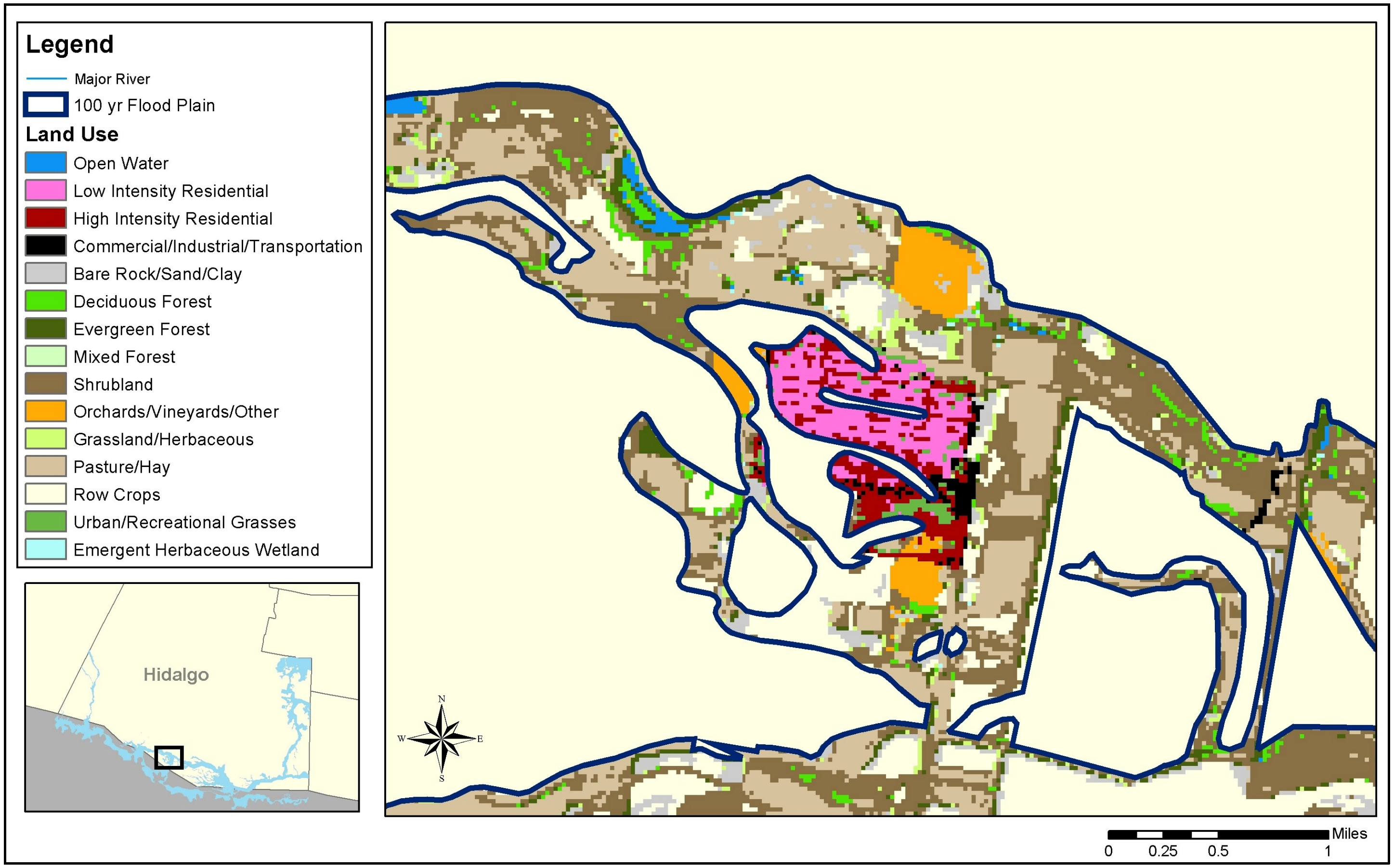

Figure F1. Example Land-Use Map Image Depicting the Flood Zone (i.e., FEMA 100-year less disconnect areas), Focused on a Residential Area, Along the Rio Grande, Hidalgo County, 2004.

— Notes —