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Texas Water Resources Institute
make every drop count

Economic and Conservation Evaluation of Capital Renovation Projects: Brownsville Irrigation District – 72" and 48" Pipeline Replacing Main Canal – Final

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Authors' Note:

The original analysis reporting on the Main Canal was contained in a one-component report (i.e., TR-231) which was published in July 2003 and subsequently reviewed by the Texas Water Development Board (TWDB) and the Bureau of Reclamation (BOR). Subsequent to the preliminary report's release, the Brownsville Irrigation District (BID) and their consulting engineer (i.e., Holdar Engineering Company) obtained improved estimates of water-savings (i.e., seepage and evaporation) and the initial construction cost. Also, an engineering design change resulted in the east and west forks of the Main Canal being replaced with 48" instead of 54" pipeline. This *Final* document incorporates the revised data, as well as minor edits to the text.

This and the aforementioned report (i.e., TR-231) were developed to assist BID in their submitting of project materials to the BOR, Border Environment Cooperation Commission, and North American Development Bank. Distribution of this report will initially be limited to BID and their consulting engineer, the BOR, and the TWDB. Only after the BOR has scored and finalized the next grouping of irrigation districts' proposed capital-rehabilitation projects will the final results for this BID project be made available to other stakeholders and the public. This is anticipated to occur sometime in late 2003 or early 2004.

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Rio Grande Basin Initiative is administered by the Texas Water Resources Institute of the Texas A&M University System with funds provided through a federal initiative, "Rio Grande Basin Initiative," administered by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement Numbers 2001-45049-01149 and 2003-34461-13278.

Preface[1]

Recognizing the seriousness of the water crisis in South Texas, the U.S. Congress enacted Public Law 106-576, entitled "The Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000 (Act)." In that Act, the U.S. Congress authorized water conservation projects for irrigation districts relying on the Rio Grande for supply of agricultural irrigation, and municipal and industrial water. Several phases of project planning, development, evaluation, prioritization, financing, and fund appropriation are necessary, however, before these projects may be constructed. The Bureau of Reclamation is the agency tasked with administering the Act, and it has issued a set of guidelines for preparing and reviewing such proposed capital renovation projects.

Based on language in the Act, the "Guidelines for Preparing and Reviewing Proposals for Water Conservation and Improvement Projects Under Public Law 106-576 (Guidelines)" require three economic measures as part of the Bureau of Reclamation's evaluation of proposed projects:

- Number of acre-feet of water saved per dollar of construction costs;
- Number of British Thermal Units (BTU) of energy saved per dollar of construction costs; and
- Dollars of annual economic savings per dollar of initial construction costs.

South Texas irrigation districts have an extensive system of engineered networks – including 24 major pumping stations, 800 miles of main canals, 1,700 miles of pipelines, and 700 miles of laterals that deliver water to agricultural fields and urban areas. Yet, many of these key components are more than 100 years old, outdated and in need of repair or replacement. Texas Agricultural Experiment Station and Texas Cooperative Extension economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the Bureau of Reclamation (BOR), and the Texas Water Development Board to perform economic and energy evaluations of the proposed capital improvement projects.

Proposed capital improvement projects include, among others, (a) meters for monitoring in-system flows and improving management of system operations; (b) lining for open-delivery canals and installing pipelines to reduce leaks, improve flow rates, and increase head at diversion points; and (c) pumping plant replacement.

The economists have developed a spreadsheet model, Rio Grande Irrigation District Economics (RGIDECON©), to facilitate the analyses. The spreadsheet's calculations are attuned to economic and financial principles consistent with capital budgeting procedures — enabling a comparison of projects with different economic lives. As a result, RGIDECON© is capable of providing valuable information for prioritizing projects in the event of funding limitations.

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1 This information is a reproduction of excerpts from a guest column developed by Ed Rister and Ron Lacewell and edited by Rachel Alexander for the first issue of the Rio Grande Basin Initiative newsletter published in *Rio Grande Basin Initiative Outcomes, 1*(1) (Rister and Lacewell).

Results of the analyses can be compared with economic values of water to conduct cost-benefit analyses. Methodology is also included in the spreadsheet for appraising the economic costs associated with energy savings. There are energy savings from pumping less water, in association with reducing leaks, and from improving the efficiency of pumping plants.

The economic water and energy savings analyses provide estimates of the economic costs per acre-foot of water savings and per BTU (kwh) of energy savings associated with one to five proposed capital improvement activity(ies) (each referred to as a component). An aggregate assessment is also supplied when two or more activities (i.e., components) comprise a proposed capital improvement project for a single irrigation district. The RGIDECON© model also accommodates "what if" analyses for irrigation districts interested in evaluating additional, non-Act authorized capital improvement investments in their water-delivery infrastructure.

The data required for analyzing the proposed capital improvement projects are assimilated from several sources. Extensive interactions with irrigation district managers and engineers are being used in combination with the Rio Grande Regional Water Planning Group Region M report and other studies to identify the information required for the economic and conservation investigations.

The RGIDECON© model applications will provide the basis for Texas Water Resources Institute reports documenting economic analysis of each authorized irrigation district project. An executive summary of the economic analysis of each authorized project will be provided to the irrigation districts for inclusion in their project report. The project reports will be submitted to the BOR for evaluation prior to being approved for funding appropriations from Congress.

Subsequent to the noted legislation and approval process developed by the BOR for evaluating legislation-authorized projects being proposed by Rio Grande Basin Irrigation Districts, the binational North American Development Bank (NADB) announced the availability of an $80 million Water Conservation Investment Fund for funding irrigation projects on both sides of the U.S.-Mexico border. The NADB also announced a merging of its board with that of the Border Environment Cooperation Commission (BECC), resulting in the latter assuming a facilitation role in assisting U.S. Irrigation Districts and other entities in applying for and being certified for the $40 million of the funding available on the U.S. side of the border. Similar to their efforts on the legislation-authorized projects, Texas Agricultural Experiment Station and Texas Cooperative Extension economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the BECC, and NADB and using RGIDECON© to develop supportive materials documenting the sustainability of the projects being proposed by Texas Irrigation Districts to BECC, NADB, and BOR.

The U.S. Bureau of Reclamation, in a letter dated July 24, 2002 (Walkoviak), stated that RGIDECON© satisfies the legislation authorizing projects and that the BOR will use the results for economic and energy evaluation. Subsequently, discussions with NADB and BECC management indicate these analyses are adequate and acceptable for documenting the sustainability aspects of the Districts' Stage 1 and 2 submissions.

About the Authors

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The authors are **Rister**, Professor and Associate Head, Department of Agricultural Economics, Texas A&M University and Texas Agricultural Experiment Station, College Station, TX.; **Lacewell**, Professor and Assistant Vice Chancellor, Department of Agricultural Economics, Texas Agricultural Experiment Station and Texas Cooperative Extension, College Station, TX.; **Sturdivant**, Extension Associate, Department of Agricultural Economics, Texas Cooperative Extension, Agricultural Research and Extension Center, Weslaco, TX.; **Robinson**, Extension Economist and Associate Professor, Department of Agricultural Economics, Texas Cooperative Extension, Agricultural Research and Extension Center, Weslaco, TX.; and **Popp**, Graduate Research Assistant, Department of Agricultural Economics, Texas Cooperative Extension, College Station, TX.

Acknowledgments

Many individuals have contributed to the methodology developed for the Rio Grande Basin Irrigation District economic analyses as described herein. We gratefully acknowledge and appreciate the input and assistance of the following:

- ***Joe Barrera, Sonny Hinojosa, Wayne Halbert, George Carpenter, Sonia Kaniger, Bill Friend, Rick Smith, Tito Nieto, Nora Zapata, Edd Fifer, Max Phillips, and Jesus Reyes***. These irrigation district managers have been and are a continual source of information and support as we work to develop an accurate, consistent, logical, efficient, and practical analytical approach for these investigations;

- ***Jim Holdar, Larry Smith, and Al Blair.*** These private consulting engineers have substantiated and extended the insights of the irrigation district managers, thereby strengthening the rigor of our methodology and enhancing the integrity of the data;

- ***Guy Fipps and Eric Leigh.*** These agricultural engineers and our colleagues in the Department of Biological and Agricultural Engineering at Texas A&M University and in the Texas Cooperative Extension have provided an extensive amount of background information, contacts, and wisdom;

- ***Jose Amador and Ari Michelsen.*** These Resident Directors of the Agricultural Research and Extension Centers at Weslaco and El Paso, respectively, have been very supportive in identifying contacts, alerting us to critical issues, and arranging meetings, among other collaboration efforts;

- ***Bob Hamilton and Randy Christopherson.*** These economists affiliated with the Bureau of Reclamation have served as reviewers of our methodology. They have also identified appropriate means of satisfying the data requirements specified in the legislative-mandated Bureau of Reclamation Guidelines for Public Law 106-576 authorizing the projects being analyzed, while also assuring principles of economics and finance are met;

- ***Ron Griffin.*** A Resource Economist in the Department of Agricultural Economics at Texas A&M University, Ron has provided insights regarding relevant resource issues, methods for appraising capital water-related projects, and observations on Texas water issues in general;

- ***John Penson and Danny Klinefelter.*** These agricultural economists specializing in finance in the Department of Agricultural Economics at Texas A&M University have served as mentors through our development of the methodology. They have been an excellent sounding board, reacting to an assortment of questions, ideas, and innovative applications of finance methods;

- ***Thomas Michalewicz, Larry Walkoviak, Mike Irlbeck, Debbie Blackburn, and James Allard.*** These individuals are with the Bureau of Reclamation in various management, engineering, and environmental roles. They have been instrumental in fostering a collaborative environment among several agencies and have taken the lead in bringing the Texas Water Development Board into planning and facilitating cooperation across State and Federal agencies;

- ***Rick Clark.*** Formerly in a management role with the U.S. Bureau of Reclamation, Rick was a great friend to Rio Grande irrigation district rehabilitation efforts and largely responsible for successful collaborative efforts of involved stakeholders. We wish him well with his new endeavors with the Montana Forestry Service;

- ***Danny Fox, Debbie Helstrom, Jeff Walker, and Nick Palacios.*** These engineers and managers with the Texas Water Development Board (TWDB) have provided valuable feedback on the methodology and data, as well as insights on accommodating the requirements of the TWDB on the irrigation districts with their receipt and use of State Energy Conservation Office funding for the development of their project proposals;

- ***Allan Jones and B. L. Harris.*** As Director and Executive Director of the Texas Water Resources Institute, respectively, they provide leadership and oversight for the Rio Grande Basin Initiative funded through a grant from Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture;

- ***Megan Stubbs and David Derry.*** As graduate students with the Bush School and Department of Agricultural Economics, respectively, at Texas A&M University, Megan and David have contributed useful insight and commentary while reviewing our work and during development of related materials on Rio Grande Basin irrigation districts;

- ***Jason Morris.*** A Student Technician in the Department of Agricultural Economics at Texas A&M University, Jason provides helpful computer support, data searches, etc.;

- ***Angela Catlin.*** An Administrative Secretary in the Department of Agricultural Economics at Texas A&M University, Angela provides background support for several of the team members involved in the Rio Grande Basin Task One activities. Her responsibilities and accomplishments are seamless, facilitating the team's efforts; and

- ***Michele Zinn.*** She is the glue that binds it all together! An Administrative Assistant in the Department of Agricultural Economics and in the Texas Agricultural Experiment Station at Texas A&M University, Michele assists in coordinating daily activities and travel, and provides editorial assistance during manuscript preparation.

Thanks to each and every individual noted above. Nonetheless, we, the authors of this manuscript, accept all responsibilities for any errors, omissions, and/or other oversights that are present in the manuscript and/or the economic spreadsheet model, RGIDECON©.

MER, RDL, AWS, JRCR, MCP

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Economic and Conservation Evaluation of Capital Renovation Projects: Brownsville Irrigation District – 72" and 48" Pipeline Replacing Main Canal – Final

Abstract

Initial construction costs and net annual changes in operating and maintenance expenses are identified for a single-component capital renovation project proposed by Brownsville Irrigation District to the North American Development Bank (NADB) and Bureau of Reclamation (BOR). The proposed project involves constructing a 72" and 48" pipeline to replace 2.31 miles of the “Main Canal.” Both nominal and real estimates of water and energy savings and expected economic and financial costs of those savings are identified throughout the anticipated 49-year useful life for the proposed project. Sensitivity results for both the cost of water savings and cost of energy savings are presented for several important parameters.

Annual water and energy savings forthcoming from the total project are estimated, using amortization procedures, to be **1,872 ac-ft of water** per year and **318,479,103 BTUs (93,341 kwh) of energy** per year. The calculated economic and financial cost of water savings is estimated to be **$27.98 per ac-ft**. The calculated economic and financial cost of energy savings is estimated at **$0.0001933 per BTU ($0.660 per kwh)**.

In addition, expected real (rather than nominal) values are indicated for the Bureau of Reclamation’s three principal evaluation measures specified in the United States Public Law 106-576 legislation. The initial construction cost per ac-ft of water savings measure is $58.60 per ac-ft of water savings. The initial construction cost per BTU (kwh) of energy savings measure is $0.0003444 per BTU ($1.175 per kwh). The ratio of initial construction costs per dollar of total annual economic savings is estimated to be -1.53.

Bureau of Reclamation's Endorsement of RGIDECON©

United States Department of the Interior
BUREAU OF RECLAMATION
Great Plains Region
OKLAHOMA - TEXAS AREA OFFICE
300 E. 8th Street, Suite G-169
Austin, Texas 78701-3225

IN REPLY
REFER TO:
TX-Clark
PRJ-8.00

JUL 24 2002

Dr. Ron Lacewell
Department of Agricultural Economics
Texas A&M University
College Station, TX 77843-2124

Subject: Economic Model for Use in Preparing Proposals for Water Conservation and Improvement Projects Under Public Law 106-576.

Dear Dr. Lacewell:

Having reviewed the formulas, calculations, and logic which support the "Economic Methodology for South Texas Irrigation Projects" (Model) developed by the Department of Agricultural Economics at Texas A&M University (TAMU), the Bureau of Reclamation (Reclamation) concludes that the Model adequately addresses the specific economic criteria contained in the *Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000* (P. L. 106-576). The results of the Model will fully satisfy the economic and conservation analyses required by the Act and it may be used by any irrigation district or other entity seeking to qualify a project for authorization and/or construction funding under P.L. 106-576.

We express our sincere appreciation to you, your colleagues, and to TAMU for this significant contribution to the efforts to improve the water supply in the Lower Rio Grande Valley.

If we may be of further assistance, please call me at (512) 916-5641.

Sincerely,

M L Martin

for Larry Walkoviak
Area Manager

A Century of Water for the West
1902-2002

Economic and Conservation Evaluation of Capital Renovation Projects: Brownsville Irrigation District – 72" and 48" Pipeline Replacing Main Canal – Final

Executive Summary

Introduction

Recognizing the seriousness of the water crisis in South Texas, the U.S. Congress enacted Public Law (PL) 106-576, entitled "The Lower Rio Grande Valley Water Conservation and Improvement Act of 2000 (Act)." Therein, Congress authorized investigation into four water conservation projects for irrigation districts relying on the Rio Grande for their municipal, industrial, and agricultural irrigation supply of water. Subsequent legislation entitled "Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2002" (i.e., PL 107-351) amended the previous Act by adding 15 irrigation-district conservation projects. Brownsville Irrigation District's project is included among those fifteen projects. Project authorization does not guarantee federal funding as several phases of planning, evaluation, etc. are necessary before these projects may be approved for financing and construction.

Subsequent to the noted original legislation (i.e., PL 106-576) and approval process developed by the U.S. Bureau of Reclamation (BOR) for evaluating legislation-authorized projects being proposed by Rio Grande Basin irrigation districts, the bi-national North American Development Bank (NADB) announced the availability of an $80 million Water Conservation Investment Fund for funding irrigation projects on both sides of the U.S.-Mexico border. The NADB also announced a merging of its board with that of the Border Environment Cooperation Commission (BECC), resulting in the latter assuming a facilitation role in assisting U.S. irrigation districts and other entities in applying for and being certified for the $40 million available on the U.S. side of the border. The Brownsville Irrigation District has submitted its BOR project to BECC/NADB and has received preliminary notification of a $1,178,000 grant from NADB, pending final certification of its project proposal. Thus, the analysis reported herein supports the Brownsville Irrigation District's BOR and BECC/NADB project proposals.

Similar to their efforts on the legislation-authorized projects, Texas Agricultural Experiment Station (TAES) and Texas Cooperative Extension (TCE) economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the BECC, and NADB and using RGIDECON© to develop supportive materials documenting the sustainability of the projects being proposed by Texas Irrigation Districts to BECC, NADB, and BOR.[1] The U.S. Bureau of Reclamation, in a letter dated July 24, 2002, stated that RGIDECON© satisfies the legislation-authorized projects and that the BOR will use the results for economic

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[1] This report contains economic and financial analysis results for a capital rehabilitation project proposed by the Brownsville Irrigation District in the Rio Grande Basin. Readers interested in the methodological background and/or prior reports are directed to pp. 26-27 which identify related publications.

and energy evaluation. Subsequently, the BECC has also acknowledged these analyses are adequate and acceptable for the Districts' Stage 1 and 2 submissions.

This report provides documentation of the economic and conservation analysis conducted for the Brownsville Irrigation District's project proposal toward its certification with BECC, as well as its proposal to the BOR. TAES/TCE agricultural economists have developed this analysis report as facilitated by the Rio Grande Basin Initiative and administered by the Texas Water Resources Institute of the Texas A&M University System.[2]

District Description

The District delivers water to about 10,600 acres of agricultural cropland each year with its 34,876.1 ac-ft of irrigation water rights (i.e., 33,949.5 ac-ft Class "A", plus 926.6 ac-ft Class "B"), with the actual water available varying each year. In addition, the District holds municipal water rights of 6,071.0 ac-ft per year, and mining water rights of 2.0 ac-ft per year. The District contracts for delivery of water to the City of Brownsville (4,232.0 ac-ft per year) and the El Jardin Water Supply Corporation (1,500.0 ac-ft per year). The District does not deliver water to any major industrial customer. Currently, the District is the only source of water for the El Jardin Water Supply Corporation and a supplemental supplier to the City of Brownsville.

Recent agricultural water use during fiscal years 1998-2002 for the District has ranged from 6,861 ac-ft to 10,584 ac-ft, with the five-year average at 8,482 ac-ft. Municipal and industry (M&I) water use during 1998-2002 has ranged from 1,400 to 2,230 ac-ft, with the five-year average at 1,870 ac-ft. Although the District relies upon the Rio Grande for its water, the District's agricultural water diversions during recent years have not been significantly hampered by deficit allocations. Thus, the five-year water use figures are appropriate for use in forecasting future diversions.

Proposed Project Components

The capital improvement project proposed by the District to BECC, NADB, and BOR consists of one component. Specifically, it includes:

- replacing 6,160 feet of the Main Canal with 72" RG/RC[3] pipeline, and replacing 6,042 feet of the Main Canal's east and west forks (3,542 and 2,500 feet, respectively) with 48" RG/RC pipeline – this will reduce seepage, evaporation, unauthorized takings, and canal "recharge" loss in the now earthen canal.

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2 This analysis report is based on the best information available at the time and is subject to an array of resource limitations. At times, District management's best educated estimates (or that of the consulting engineer) are used to base cost and/or savings' values well into the future. Obviously, this is imperfect, but given resource limitations, it is believed ample inquiry and review of that information were used to limit the degree of uncertainty.

3 Rubber-gasket, reinforced-concrete pipeline is abbreviated RG/RC.

Economic and Conservation Analysis Features of RGIDECON©

RGIDECON© is an Excel spreadsheet developed by TAES/TCE economists to investigate the economic and conservation merits of capital renovation projects proposed by Rio Grande Basin Irrigation Districts. RGIDECON© facilitates integration and analysis of information pertaining to proposed projects' costs, productive lives, water and energy savings, and resulting per unit costs of water and energy savings. RGIDECON© simplifies capital budgeting financial analyses of both individual capital components comprising a project and the overall, total project.

Cost Considerations: Initial & Changes in O&M

Two principal types of costs are analyzed for each component: (a) initial capital outlays and (b) changes in annual operating and maintenance (O&M) expenses. Results related to each type of expenditure for each component are presented in following sections.[4]

Anticipated Water and Energy Savings

Annual water and energy savings are calculated for each component separately and also as a combined total across all components, if applicable. Water savings are comprised of and associated with (a) reductions in Rio Grande diversions, (b) increased head at farm diversion points, (c) reduced seepage losses in canals, and (d) better management of water flow. Energy savings can result from reduced diversions, reduced relift pumping, and/or efficiency improvements with new pumps and motors, and are comprised of (a) the amount of energy used for pumping and (b) the cost (value) of such energy.[5]

Cost of Water and Energy Savings

The estimated cost per ac-ft of water saved and the estimated cost of energy saved resulting from a component's purchase, installation, and implementation is analyzed to gauge each component's merit. Results related to each type of cost for each component are presented in following sections, as well as totals across all components, if applicable.

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4 Due to numerical rounding, values as they appear herein may not reconcile exactly with hand calculations the reader may make. In all instances, RGIDECON© values are reported with appropriate rounding-off (as determined by the authors) of values which are in this analysis report.

5 A major assumption made by the authors and embedded in this and other economic and conservation analyses of irrigation districts' (IDs) proposed capital rehabilitation projects is that only the local IDs perspective is considered, i.e., activities external to the ID are ignored. In addition, all marginal water and energy savings are recognized, not withstanding that in actuality, the "savings" may continue to be utilized within (or outside) the District. The existence of "on-allocation" status for a District does not alter these assumptions.

Project Components

Discussion pertaining to costs (initial construction and subsequent annual O&M) and savings for both water and energy is presented below for the single component comprising the Brownsville Irrigation District's BOR and NADB project. With only one component comprising this project, aggregation of component results is not necessary/possible. With regards to water and energy savings, areas or sources are first identified, with the subsequent discussion quantifying estimates for those sources.

Component #1: Main Canal

The District's proposed BOR and NADB project, commonly called the "Main Pipeline" project, consists of replacing 6,160 feet of the Main Canal with 72" RG/RC pipeline, and replacing 6,042 feet of the Main Canal's east and west forks (3,542 and 2,500 feet, respectively) with 48" RG/RC pipeline. The installation period is projected to take one year with an ensuing expected useful life of 49 years. No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

Initial and O&M Costs

Estimated initial capital investment costs total $2,356,000 ($1,019,479 per mile). Annual increases in O&M expenditures for the new pipeline of $5,371 ($2,324 per mile) are expected. Additionally, reductions in annual O&M expenditures of $73,679 ($31,882 per mile) are anticipated from discontinued maintenance associated with the existing earthen canal. Therefore, a net decrease in annual O&M costs of $68,308 ($29,558 per mile) is expected (2003 dollars).[6]

Anticipated Water and Energy Savings

Only off-farm water savings are predicted to be forthcoming from the Main Canal pipeline project component, with the nominal total being 96,011 ac-ft over the 49-year productive life of this component and the real 2003 total being 40,208 ac-ft. The annual *off-farm* water-savings estimate of 1,959.4 ac-ft per year are based on 1,074.4 ac-ft of seepage and evaporation savings, 75.0 ac-ft of unauthorized-taking savings, and 810.0 ac-ft of canal "recharge" savings.[7] With no anticipated *on-farm* water savings, total savings equal the *off-farm* water savings estimate of 1,959.4 ac-ft per year, with associated energy savings estimates of 16,336,703,749 BTU (4,788,014 kwh) in nominal terms over the 49-year productive life and 6,841,626,877 BTU (2,005,166 kwh) in real 2003 terms. Energy savings are based only on reduced Rio Grande diversions as relifting of water within the District's delivery-system infrastructure is not involved with this project component.

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6 Note the 'pipeline - leak repair' expense is not included in determining O&M costs for the first two years as the contractor's warranty is expected to cover any extraordinary repair-type expense (Holdar).

7 On average, the District diverts water from the Rio Grande into the Main Canal 189 days a year, with pumping periods typically lasting 9-20 days (Barrera, Holdar). During non-pumping periods, water left in the canal is lost through seepage, evaporation, etc. The amount of water required to refill the canal is termed "recharge;" thus, the use of the water-savings category "recharge savings."

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from the Main pipeline is estimated to be **$27.98** per ac-ft. This value is obtained by dividing the annuity equivalent of the total net cost stream for water savings from all sources of $52,379 (in 2003 terms) by the annuity equivalent of the total net water savings of 1,872 ac-ft (in 2003 terms). The economic and financial cost of energy savings are estimated at **$0.0001933** per BTU (**$0.660** per kwh). These values are obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $61,564 (in 2003 terms) by the annuity equivalent of the total net energy savings of 318,479,103 BTU (93,341 kwh) (in 2003 terms).

Summary

The following table summarizes key information regarding the single-component of Brownsville Irrigation District's BOR and NADB project, with a more complete discussion provided in the text of the complete report.

Table ES1. Summary of Data and Economic and Conservation Analysis Results for Brownsville Irrigation District's BOR and NADB Project, 2003.

	Project Component
	72" and 48" Pipeline Replacing Main Canal
Initial Investment Cost ($)	$ 2,356,000
Expected Useful Life (years)	49
Net Changes in Annual O&M ($)	($ 68,308)
Annuity Equivalent of Net Cost Stream – Water Savings ($/yr)	$ 52,379
Annuity Equivalent of Water Savings (ac-ft)	1,872
Calculated Cost of Water Savings ($/ac-ft)	**$ 27.98**
Annuity Equivalent of Net Cost Stream – Energy Savings ($/yr)	$ 61,564
Annuity Equivalent of Energy Savings (BTU)	318,479,103
Annuity Equivalent of Energy Savings (kwh)	93,341
Calculated Cost of Energy Savings ($/BTU)	**$ 0.0001933**
Calculated Cost of Energy Savings ($/kwh)	**$ 0.660**

Sensitivity Analyses

Sensitivity results for both the costs of water and energy savings are presented within the main text whereby two parameters are varied with all others remaining constant. This permits testing of the stability (or instability) of key input values and illustrates how sensitive results are to variances in other input factors. Key variables subjected to sensitivity analyses include (a) the amount of reduction in Rio Grande diversions, (b) the expected useful life of the investment, (c) the initial capital investment cost, (d) the value of BTU savings (i.e., cost of energy), and (e) the amount of energy savings estimated.

Legislative Criteria

United States Public Law 106-576 (and the amending legislation U.S. Public Law 107-351) requires three economic measures be calculated and included as part of the information prepared for the Bureau of Reclamation's (BORs) evaluation of the proposed projects. According to the BOR, these measures are more often stated in their inverse mode:

- Dollars of construction cost per ac-ft of water saved;
- Dollars of construction cost per BTU (and kwh) of energy saved; and
- Dollars of construction cost per dollar of annual economic savings.

The noted legislated criteria involve a series of calculations similar to, but different from, those used in developing the cost measures cited in the main body of the full analysis report. Principal differences consist of the legislated criteria not requiring aggregation of the initial capital investment costs with the annual changes in O&M expenditures, but rather entailing separate sets of calculations for each type of costs relative to the anticipated water and energy savings. The approach used in aggregating the legislated criteria results presented in Appendix A into one set of uniform measures utilizes the present value methods followed in the calculation of the economic and financial results reported in the main body of the text, but does not include the development of annuity equivalent measures. These compromises in approaches are intended to maintain the spirit of the legislated criteria's intentions. Only real, present value measures are presented and discussed for the legislated criteria aggregate results, thereby designating all such values in terms of 2003 equivalents. **Differences in useful lives across project components are not fully represented, however, in these calculated BOR values.**

The initial construction costs per ac-ft of water savings measure is \$58.60 per ac-ft of water savings which is higher than the comprehensive economic and financial value of **\$27.98 per ac-ft** identified and discussed in the main body of the analysis report. The differences in these values are attributable to the incorporation of both initial capital costs and changes in operating expenses in the latter value, and its treatment of the differences in the useful lives of the respective component(s) of the proposed project.

The initial construction cost per BTU (kwh) of energy savings measure is \$0.0003444 per BTU (\$1.175 per kwh). These cost estimates are higher than the **\$0.0001933 per BTU (\$0.660 per kwh)** comprehensive economic and financial cost estimates identified for reasons similar to those noted above with respect to the estimates for costs of water savings.

The final legislated criterion of interest is the amount of initial construction costs per dollar of total annual economic savings. The estimate for this ratio measure is -1.53, indicating that (a) the net change in annual O&M expenditures is negative, i.e., a reduction in O&M expenditures is anticipated; and (b) \$1.53 of initial construction costs are expended for each such dollar reduction in O&M expenditures, with the latter represented in total real 2003 dollars for the project's 50-year single-component planning period.

Economic and Conservation Evaluation of Capital Renovation Projects: Brownsville Irrigation District – 72" and 48" Pipeline Replacing Main Canal – Final

Introduction

Brownsville Irrigation District's proposed Main Canal project is included among the fifteen irrigation-district projects authorized in the amending legislation entitled "Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2002 (Act)", or United States Public Law (PL) 107-351. This Act amended previous legislation which stated, "If the Secretary determines that ... meet[s] the review criteria and project requirements, as set forth in section 3 [of the Act], the Secretary may conduct or participate in funding engineering work, infrastructure construction, and improvements for the purpose of conserving and transporting raw water through that project" (United States Public Law 106-576). This report provides documentation of an economic and conservation analysis conducted for the single-component project comprising the Brownsville Irrigation District's proposed project to the Border Environment Cooperation Commission (BECC), the North American Development Bank (NADB), and the Bureau of Reclamation (BOR) during the Fall of 2003.[1]

Irrigation District Description[2]

Twenty-eight irrigation districts exist in the Texas Lower Rio Grande Valley (**Exhibit 1**).[3] The Brownsville Irrigation District office is located in Brownsville, Texas (**Exhibits 2** and **3**). The District boundary covers approximately 18,500 acres of Cameron County (**Exhibit 4**). Postal and street addresses are 6925 Coffee Port Road, Brownsville, TX 78521. Telephone contact information is 956/831-8462 and the fax number is 956/831-2632. Joe Barrera is the District Manager, with Jim Holdar of Holdar Engineering, Co., Brownsville, TX, serving as the lead consulting engineer for this project.

In addition to residential and commercial accounts, there are numerous agricultural irrigation accounts serviced by the District with the majority of agricultural acreage serviced under "as-needed" individual water orders for vegetable and field crops. Additionally, annual

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1 Readers interested in the methodological background and/or prior reports are directed to pp. 26-27 which identify related publications.

2 The general descriptive information presented was assimilated from several sources, including documents provided by Joe Barrera (the District manager), Engineering Report for the Conceptual Design for Brownsville Irrigation District's Main Canal Replacement (Holdar-Garcia & Associates, February 14, 2001), the Region M Rio Grande Regional Water Planning Group report, and Fipps' Technical Memorandum in the latter report (Fipps 2000).

3 Exhibits and Tables are presented at the end of the report, after the References and the Glossary and before the Appendices.

permits for orchards and commercial nurseries that use drip or micro-emitter systems are serviced. Lastly, accounts exist for lawn watering, golf courses, parks, school yards, and ponds.

Irrigated Acreage and Major Crops

The District delivers water to approximately 10,600 acres of agricultural cropland within its district. Furrow irrigation accounts for approximately 99% of irrigation deliveries. Special turnout connections are provided as requested to district customers utilizing polypipe, gated pipe, etc. Flood irrigation is the norm for orchards and pastures. The typical crop mix across the District is noted in **Table 1**, which illustrates the relative importance (on an acreage basis) of field crops, citrus, pasture, vegetables, etc. The crop mix distribution within a particular irrigation district may vary considerably depending on output prices and the relative available local water supplies. For example, in water-short years, sugarcane acreage, although a perennial crop, may "migrate" to districts and/or areas appearing to be water-rich, in a relative sense.

Municipalities Served

The District's priority in diverting water is to first meet the demands of residential and commercial users[4] within the District. To facilitate delivery, the District holds 6,071 acre feet (ac-ft) of water rights for M&I diversions to the city of Brownsville and El Jardin Water Supply Corporation (**Exhibit 5**). After fulfilling municipalities' requirements, needs of agricultural irrigators are addressed.

It is important to note that each irrigation district is responsible, under normal "non-allocation status" situations, for maintaining a fully-charged delivery system, thereby providing "push water" to facilitate delivery of municipal water. When on an "allocation status" and when individual irrigation district water supplies (including account balances) are inadequate for charging an irrigation district's delivery system to facilitate municipal water delivery, however, Rio Grande Valley-wide irrigation districts (i.e., as a collective group, drawing on all of their account balances) are responsible for providing the necessary water to facilitate delivery of municipal water in individual irrigation districts (Hill).

Historic Water Use

The most recent five years (i.e., 1998-2002) demonstrate a wide range of water use in the District (**Table 2**). Agricultural use has varied from 6,861 ac-ft to 10,584 ac-ft, with an average of 8,482 ac-ft. M&I water use has ranged from 1,400 to 2,230 ac-ft, with the average at 1,870 ac-ft. The average total water diverted within the District during this time period is 10,352 ac-ft, with a range from 8,961 to 11,984 ac-ft. Although the District relies upon the Rio Grande for its water, the District's agricultural water diversions during recent years have not been significantly

4 Hereafter, residential and commercial users are referred to as "M&I" (or Municipal & Industrial), a term more widely used in irrigation district operations.

hampered by deficit allocations forthcoming from the Rio Grande. Thus, the five-year water use figures are appropriate for use in forecasting future diversions (Barrera).[5]

Assessment of Technology and Efficiency Status

The District's pumping plant diverts water from the Rio Grande approximately 6.75 miles downstream from the Gateway Bridge in downtown Brownsville (**Exhibit 5**). The current pumping plant, which has an average lift at the Rio Grande of 22-24 feet (**Table 3**), was built in 1942 and has a typical operating capacity of 45 cfs and a maximum of 190 cfs. More than 2 miles of earthen canal, 183 miles of pipeline, 11 relift pumping stations, and 2,400 ac-ft of reservoir storage currently comprise the majority of the District's delivery-system infrastructure (Barrera).

The District has been aggressive in increasing the maximum amount of water deliverable to each turnout while also increasing its overall efficiency by reducing irrigation time requirements. The District has incorporated a computerized Geographic Information System (GIS) program for linking a mapping system to a database, indicating where water has been ordered, for what types of crops, the various systems necessary to deliver the water, etc. Approximately 99% of agricultural water use is volumetrically measured. Producers' use of water-conserving methods and equipment is encouraged by the District (Barrera).

Water Rights Ownership and Sales

The District holds four Certificates of Adjudication (i.e., No's. A8453-000, Irg01-03, M843-000, and B843-000) (**Table 3**). The District does not divert/deliver, on an on-going basis, toward other Certificates of Adjudication which may belong to other municipal and/or industrial entities. Further, users interested in acquiring additional water beyond their available allocations may acquire such water from parties interested in selling or leasing allocations (and possibly the water rights). Such purchases and/or leases are subject to a transportation delivery loss charged by the District; that is, purchase or lease of one ac-ft of water from sources inside or outside the District will result in users receiving some amount less than one ac-ft at their diversion point.

Volumetrically-priced charges (i.e., 99% of the District's irrigation assessments) assessed irrigators within the District consist of an annual flat-rate maintenance and operations fee of $6.00 per irrigated acre (which is paid for by the landowner) (**Table 3**), which includes the first irrigation of approximately 4-inches. Thereafter, an additional $2.00 per acre-inch is assessed

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5 The supply/demand balance within irrigation districts varies. In recent years, some districts have had appropriations matching their demands, while others have not. Having extreme unavailability of water supplied is an event realized with a previous irrigation-district analysis report (i.e., Cameron County Irrigation District No. 2 (a.k.a. San Benito)) completed thus far by the authors. Other Districts' analyses (i.e., Cameron County Irrigation District No. 1 (a.k.a. Harlingen) and Hidalgo County Irrigation District No. 1 (a.k.a. Edinburg), and Hidalgo County Irrigation District No. 2 (a.k.a. San Juan)) did not advise of incurring extreme water unavailability. In fact, one district recently made a significant one-time sale of water (external to the District).

(either to the landowner-operator or tenant-producer) (**Table 3**). Thus, this equates to an irrigation charge of $22.00 per acre on an acre-foot basis. Further, the District charges a delivery charge of $45.00 per ac-ft for Municipal water and $65.00 per year for lawn-watering accounts. Standard irrigation (i.e., non-volumetric) water is assessed a flat rate of $12.00 for approximately 4" and $2.00 per ac-inch thereafter; equating to $28.00 per acre on an acre-foot basis (Barrera).

In the event water supplies exceed District demands, current District policy is to sell annual water supplies, even on long-term agreement, rather than market a one-time sale of water rights (Barrera). The District has control over the irrigation water supplies, but the municipal rights holders control and realize any benefits accruing from sale or lease of their rights.

Project Data

As proposed by the District, the capital improvement for this project consists of replacing the Main Canal with 72" and 48" pipeline. Though often referred to as a component within this report, it is locally referred to as the "Main Pipeline Project" (Barrera) (**Table 4**).[6]

Component #1: Main Canal

The "Main Canal" is the initial delivery infrastructure which water traverses after it is diverted from the Rio Grande. After traveling approximately 6,160 feet, the Main Canal splits into an east and west fork, with both forks emptying into separate resacas. Thus, the Main Canal, in effect services the entire District. Summary data for the District's single-component proposed project, are presented in **Tables 4, 5, 6,** and **7** with discussion of that data following.

Description

This project consists of replacing 6,160 feet of the Main Canal with 72" RG/RC[7] pipeline, and replacing 6,042 feet of the Main Canal's east and west forks (3,542 and 2,500 feet, respectively) with 48" RG/RC pipeline. Once installed and brought on-line, this project is expected to (**Table 5**):

a) reduce seepage and evaporation estimated at 1,074.4 ac-ft per year;
b) reduce unauthorized takings estimated at 75.0 ac-ft per year; and
c) reduce canal recharge losses estimated at 810.0 ac-ft per year.[8]

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6 Due to numerical rounding, values as they appear herein may not reconcile exactly with hand calculations the reader may make. In all instances, RGIDECON© values are reported with appropriate rounding-off (as determined by the authors) of values which are in this analysis report.

7 Rubber-gasket, reinforced-concrete pipeline is abbreviated RG/RC.

8 On average, the District diverts water from the Rio Grande into the Main Canal 189 days a year, with pumping periods typically lasting 9-20 days (Barrera, Holdar). During non-pumping periods, water left in the canal is lost through seepage, evaporation, etc. The amount of water required to refill the canal is termed "recharge;" thus, the use of the water-savings category "recharge savings."

Installation Period

It is anticipated that it will take one year after purchase and project initiation for the pipeline to be installed and fully implemented (**Table 6**). No loss of operations or otherwise adverse impacts are anticipated during the installation period since it will occur in the off-season.

Productive Period

A useful life of 49 years[9] for the 72" and 48" pipeline is expected and assumed in the baseline analysis (**Table 6**). A shorter useful life is possible, but 49 years is considered reasonable and consistent with engineering expectations (Holdar). Sensitivity analyses are utilized to examine the effects of this assumption. The first year of the productive period is assumed to occur during year 2 of the 50-year planning period.

Projected Costs

Two principal types of costs are important when evaluating this proposed investment: the initial capital outlay and recurring operating and maintenance expenses. Assumptions related to each type of expenditure are presented below.

Initial. Based on discussions with BOR management, expenses associated with design, engineering, and other preliminary development of this project's proposal are ignored in the economic analysis prepared for the planning report. Such costs are to be incorporated, however, into the materials associated with the final design phase of this project.

Capital investment costs (i.e., excavate, purchase, install) for the 12,202 feet (2.31 miles) of pipeline total $2,356,000 ($1,019,479 per mile) in 2003 dollars (**Table 6**) (Holdar Engineering Company). Sensitivity analysis on the total amount of all capital expenditures is utilized to examine the effects of this assumption. All expenditures are assumed to occur on day one of this project component's inception, thereby avoiding the need to account for inflation in the cost estimate.

Recurring. Annual operating and maintenance (O&M) expenses associated with the 72" and 48" pipeline are expected to be different than those presently occurring for the earthen Main Canal. Annual O&M expenditures associated with the affected segment of the canal delivery system (i.e., after installation of the pipeline) are anticipated to be $5,371, or $2,324 per mile (basis 2003 dollars) (**Table 6**). In the first two years after installation of the pipeline, the 'pipeline - leak repair' portion of O&M are assumed to be covered by the contractor's warranty (Holdar).

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9 Actually, the estimated useful life is 50 years instead of 49 years. RGIDECON© was developed to consider up to a maximum 50-year planning horizon, with the perspectives that projections beyond that length of time are largely discounted and also highly speculative. Allowing for the one-year installation period on the front end reduces to 49 years the time remaining for productive use of the asset during the 50-year planning period allowed within RGIDECON©.

Projected Savings

Water. Water savings are reductions in diversions from the Rio Grande, i.e., how much less water will be used by the District as a result of this project component's installation and utilization? Estimates of such savings are comprised, in this case, of only off-farm agricultural irrigation savings; i.e., no savings related to M&I water use are anticipated.[10]

Off-farm savings include those occurring in the District's canal delivery system as a result of reduced seepage and evaporation after the Main Canal is replaced with pipeline. A recent ponding-test (in June, 2003) in the District by Leigh and Fipps, in the Main Canal, documented annual water losses of 3.14 gal/ft^2/day. Multiplying this value by the measured area of the canal water surface area of 589,900 sq. ft. (or 13.542 acres) and incorporating other data, along with the average 189 days per year that water is conveyed in the Main canal results in an annual savings of 1,074.4 ac-ft estimated from reduced seepage and evaporation (Holdar) (**Table 5**).[11] Existing estimates of these water losses via seepage are applicable to canals/laterals in their present state. It is highly likely that additional deterioration and increased water losses and associated O&M expenses should be expected as canals/laterals age (Carpenter; Halbert). While estimates of ever-increasing seepage losses over time could be developed, the analysis conservatively maintains a constant water savings (Holdar), consistent with assumptions embedded in previous analyses (Rister et al. 2002b-c, 2003a-j). Additional *off-farm* water savings of 75.0 ac-ft per year (**Table 5**) are expected from reducing unauthorized takings which will be realized with converting the earthen Main Canal to 72" and 48" pipeline.

Additional *off-farm* savings of 810.0 ac-ft (**Table 5**) per year are expected from reducing canal "recharge" losses. On average, the District diverts water from the Rio Grande into the Main Canal 189 days a year, with pumping periods typically lasting 9-20 days (Barrera, Holdar). That is, the pumping plant is turned on/off several times throughout the year which causes the water level in the Main Canal to rise/fall accordingly. During non-pumping periods, water left in the canal (that has not emptied into a resaca) is lost through seepage, evaporation, etc, until the time the pumping plant is turned back on. The amount of water which will no longer be required to refill (or recharge) the canal is the "recharge savings." The combined annual *off-farm* water savings forthcoming from the piping of the Main Canal are estimated at 1,959.4 ac-ft (**Table 5**) (i.e., 1,074.4 + 75.0 + 810.0).

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10 A major assumption made by the authors and embedded in this and other economic and conservation analyses of irrigation districts' (IDs) proposed capital rehabilitation projects is that only the local IDs perspective is considered, i.e., activities external to the ID are ignored. In addition, all marginal water and energy savings are recognized, not withstanding that in actuality, the "savings" may continue to be utilized within (or outside) the District. The existence of "on-allocation" status for a District does not alter these assumptions.

11 A key aspect in determining this value is the average number of days the Main Canal is conveying water. On an annualized basis, the estimated seepage/evaporation savings is 2,065 ac-ft. Since the District only pumps water through the canal for an average of 189 days per year, however, the estimated savings is adjusted to reflect that of 6 months (i.e., 189 days).

Estimates of the *off-farm* water savings do not include any conveyance loss that could potentially be realized during delivery of the water from the Rio Grande to the nearby resacas. Thus, all noted water savings are based on a delivered basis, which is the same as the diverted basis for this project analysis.[12]

As shown in **Table 5**, *on-farm* water savings from reduced percolation losses are not expected to be forthcoming from this component. Therefore, combining all *off-* and *on-farm* water savings (without any additional conveyance loss included) results in 1,959.4 ac-ft (**Table 5**) being analyzed in the base analysis. As with other estimated water savings, this value is held constant during each year of the Main Pipeline's productive life to provide for a conservative analysis. Sensitivity analyses are performed on all water savings to examine the implications of this estimate. Annual *off-farm* water savings for this project are expected to result in reduced Rio Grande diversions.

Energy. In general, energy savings for a given project may occur as a result of less water being pumped at the Rio Grande diversion site and/or because of lower relift pumping requirements at one or more points throughout the water-delivery system. The amount of such energy savings and the associated monetary savings are detailed below for the District's single-component project. Energy savings associated with only reduced diversions are expected with this project as relifting within the District's infrastructure is not involved.

Factors constituting energy savings associated with lessened diversion pumping are twofold: (a) less energy used for pumping and (b) the cost (or value) of such energy. Recent historic energy records for calendar years 1998-2002 are presented in **Table 8** with electricity representing 100% of the District's total diversion-energy expense. The District's average lift at the Rio Grande diversion site is approximately 22-24 feet (**Table 3**). On average, 170,155 BTU were used to pump each ac-ft of water diverted (**Table 8**). Multiplying this value by the anticipated 1,959.4 ac-ft of annual *off-farm* water savings results in anticipated annual irrigation energy savings of 333,402,117 BTU (97,715 kwh) (**Table 5**). Assuming the historical average cost of $0.071 per kwh (i.e., 1998-2002),[13] the estimated annual *off-farm* irrigation energy cost savings (associated with water savings) are $6,933 in 2003 dollars (**Table 5**). Sensitivity analyses are performed to examine the effects of the assumptions for both the amount of energy used (per ac-ft of water diverted) and the cost per unit of energy.

Operating and Maintenance. Annual O&M expenses for the existing earthen Main Canal are estimated to be $31,882 per mile (Barrera). Thus, across the total 12,202 feet (2.31

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12 The District's system-wide conveyance loss is estimated to be 10% (Fipps and Pope), as determined by total water diversions minus total water sales (Barrera). For the single-component project, additional water savings beyond the project-area attributed to conveyance loss are not claimed based on the assumption the claimed water savings will occur throughout the year and on the margin will not affect the "fullness" of the remainder of the canal system. That is, with water being saved at the component/project site, the remainder of the District's delivery-system infrastructure will remain fully charged as usual and will therefore not produce additional water savings beyond those realized at the component/project site (Holdar).

13 This estimated value is calculated using District information provided by Joe Barrera which incorporates recognition of the sole source of pumping power (i.e., electric) and its costs.

miles) of the Main Canal proposed for replacing with 72" and 48" pipeline, a reduction of $68,308 (or $29,558 per mile) in O&M expense is anticipated (**Table 6**).

Reclaimed Property. No real property will be reclaimed in association with this project (**Table 6**). Consequently, there is no realizable cash income to claim as a credit against the costs of this project component.

Abbreviated Discussion of Methodology[14]

Texas Agricultural Experiment Station and Texas Cooperative Extension economists have developed an economic spreadsheet model, RGIDECON© (or, Rio Grande Irrigation District Economics), to facilitate economic and conservation analyses of the capital renovation projects proposed by South Texas irrigation districts. The spreadsheet's calculations embody economic and financial principles consistent with capital budgeting procedures for evaluating projects of different economic lives, thereby "leveling the playing field" and allowing "apples to apples" comparisons across projects. As a result, RGIDECON© also is capable of providing valuable information for implementing a method of prioritization of projects in the event of funding limitations.

The results of a RGIDECON© analysis can be used in comparisons to exogenously-specified economic values of water to easily provide for implications of a cost-benefit analysis. Methodology similar to that presented for water savings also is included in the spreadsheet for appraising the economic costs associated with energy savings (both on a BTU and kwh basis). That is, there are energy savings from both pumping less water (caused by reducing water losses) and from improving the efficiency of pumping operations/facilities.

RGIDECON©'s economic and energy savings analysis provide an estimate of the economic costs per ac-ft of water savings and per BTU (kwh) of energy savings associated with each proposed capital improvement activity (i.e., an individual component). An aggregate assessment is also provided for those proposed projects consisting of two or more activities (i.e., components). Lastly, the RGIDECON© model has been designed to accommodate "what if" analyses for Districts interested in evaluating additional, non-Act authorized capital improvement investments in their water delivery infrastructure.

Public Law 106-576 legislation requires a variation of economic analyses in which the initial construction costs and annual economic savings are used independently in assessing the

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14 The publication, "Economic Methodology for South Texas Irrigation Projects – RGIDECON©," Texas Water Resources Institute TR-203 (Rister et al. 2002a), provides a more extensive documentation of the methodology employed in conducting the analysis presented in this report. Excerpts from that publication are included in this section; several of the authors of this report are co-authors of TR-203. The methodology documented in Rister et al. (2002a) was endorsed in July, 2002, as expressed by Larry Walkoviak, Area Manager of the Oklahoma-Texas Office of the Bureau of Reclamation, "The results of the model will fully satisfy the economic and conservation analyses required by the Act and it may be used by any irrigation district or other entity seeking to qualify a project for authorization and/or construction funding under P.L. 106-576."

potential of capital renovations proposed by irrigation districts (Bureau of Reclamation). In addition, all calculations are performed on a nominal rather than real basis (Hamilton).

Detailed results for the economic and financial analysis following the methodology presented in Rister et al. (2002a) appear in subsequent sections of the main body of this report. Results for the legislative criteria appear in Appendix A.

Assumed Values for Critical Parameters

This section of the report presents the values assumed for several parameters which are considered critical in their effects on the overall analysis results. This discussion is isolated here to emphasize the importance of these parameters and to highlight the values used.[15]

Discount Rates and Compound Factors

The discount rate used for calculating net present values of the different cost streams represents a firm's required rate of return on capital (i.e., interest) or, as sometimes expressed, an opportunity cost on its capital. The discount rate is generally considered to contain three components: a risk-free component for time preference (i.e., social time value), a risk premium, and an inflation premium (Rister et al. 1999).

One estimate of such a discount rate from the District's perspectives would be the cost at which it can borrow money (Hamilton). Griffin notes, however, that because of the potential federal funding component of the project, it could be appropriate to ignore the risk component of the standard discount rate as that is the usual approach for federal projects. Hamilton notes that the Federal discount rate consists of two elements, time value of money and inflation, but that the rate is routinely used as a real rate, ignoring the inflationary component. After considering those views and interacting with Penson and Klinefelter, Texas A&M University agricultural economists specializing in finance, the 2002 Federal discount rate of 6.125% was adopted for use in discounting all financial streams for projects analyzed in 2002. In order to maintain consistency, this same rate is adopted for projects analyzed in 2003.

Recognition of the potential for uneven annual flows of water and energy savings associated with different project components and different projects encourages normalizing such flows through calculation of the net present value of water and energy savings. In the absence of complete cost-benefit analysis and the associated valuation of water and energy savings, it is acknowledged that there is no inflationary influence to be accounted for during the discounting process (Klinefelter), i.e., only the time value (t) should be recognized in the discounting process. Accordingly, a lower rate than the 6.125% 2002 Federal discount rate is desired. Consultations with Griffin and Klinefelter contributed to adoption of the 4% rate used by Griffin and Chowdhury for the social time value in these analyses.

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15 As was the case in the previous "Abbreviated Discussion of Methodology" section, some of the text in this section is a capsulated version of what is presented in Rister et al. (2002a).

As presented in Rister et al. (2002a), use of an overall discount rate of 6.125% in conjunction with a 4% social time value and the assumption of a 0% risk premium infers a 2.043269% annual inflation rate. Such an inferred rate is consistent with recent and expected rates of nominal price increases for irrigation construction, O&M, and energy costs (Rister et al. 2002a). Thus, a 2.043269% rate is used to compound 2003 nominal dollar cost estimates forward for years in the planning period beyond 2003. The rationale for assuming this rate is based both on the mathematical relationship presented above and analyses of several pertinent price index series and discussions with selected professionals.[16]

Pre-Project Annual Water Use by the District

Water availability and use in the District has varied some in recent years. **Table 2** contains the District's historic water use for agricultural irrigation and M&I along with the total use for each of the five most recent years (1998-2002). Rather than isolate one particular year as the baseline on which to base estimates of future water savings, Bureau of Reclamation, Texas Water Development Board, Texas Agricultural Experiment Station, and Texas Cooperative Service representatives agreed during the summer of 2002 to use the average levels of use during a five-year period as a proxy for the baseline (Clark et al. 2002a). At a subsequent meeting (Clark et al. 2002b), consideration was directed to recognizing, when appropriate, how allocation restrictions in recent years may have adversely affected the five-year average to the extent the values do not adequately represent potential irrigated acreage in future years during the project's planning period. Where an irrigation district has been impacted by allocation restriction(s), and its estimated water savings from its project are based on historical diversions (i.e., a percentage of the total or agricultural irrigation diversions), a more-lengthy time series of water use is to be used to quantify representative water use and/or water savings.

As discussed in more detail earlier in this report, this District's agricultural irrigation use has averaged 8,482 ac-ft during the designated 5-year period. M&I use averages 1,870 ac-ft. The average total water use within the District (including conveyance loss) during 1998-2002 is 10,352 ac-ft. These values are perceived as appropriate for gauging future use during this project's planning period (Barrera). Since water savings are based on other criteria (i.e., not a % of historical diversions), historical diversions have no impact on the expected water savings anticipated forthcoming from this project.

Value of Water Savings per Acre-Foot of Water

The analysis reported in this report focuses on identifying the costs per ac-ft of water saved and per BTU and kwh of energy saved. The value of water is ignored in the analysis,

16 Admittedly, excessive precision of accuracy is implied in this assumed value for the rate of annual cost increases. Such accuracy of future projections is not claimed, however, but rather that this precise number is that which satisfies the multiplicative elements of the overall discount rate calculation discussed in Rister et al. (2002a), assuming the noted values for risk and time value.

essentially stopping short of a complete cost-benefit analysis.[17] The results of this analysis can be used, however, in comparisons to exogenously-specified economic values of water to easily provide for implications of a cost-benefit analysis.

Energy Usage per Acre-Foot of Water

This analysis includes calculating the cost of energy savings and also crediting the value of such savings as a reduction in O&M expenditures when evaluating the cost of water savings associated with the project.[18] The historic average diversion-energy usage level of 170,155 BTU per ac-ft of water diverted by the District for fiscal years 1998-2002 is used to estimate energy savings resulting when less water is diverted from the Rio Grande due to implementation of the proposed project (**Table 8**). Another important assumption is there are 3,412 BTU per kwh (Infoplease.com). This equivalency factor allows for converting the energy savings information into an alternative form for readers of this report.

Value of Energy Savings per BTU/kwh

Correspondingly, historic average costs of diversion energy are used to transform the expected energy savings into an economic dollar value. Records for fiscal years 1998-2002 indicate diversion-energy costs for the District have ranged from $2.67 to $4.68 per ac-ft diverted, with the average of $3.54 per ac-ft ($0.0000208/BTU; $0.071/kwh) used in this analysis report (**Table 8**). Sensitivity analyses are utilized to examine the implications of this estimate.

Economic and Financial Evaluation Results

The economic and financial analysis results forthcoming from an evaluation of the afore-mentioned data using RGIDECON© (Rister et al. 2002a) are presented in this section for this single-component project. Given there are not multiple components to the District's proposed project, discussion of aggregated results are not provided, as was the case with previous irrigation districts' economic analyses reports.[19]

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17 RGIDECON© includes opportunities for the value of agricultural irrigation water and the incremental differential value associated with M&I water to be specified, thereby facilitating comprehensive cost-benefit analyses. For the purposes of this study, however, such values are set at $0.00, thereby meeting the assessment requirements specified in the Public Law 106-576 legislation.

18 "There are interests in identifying mutually-exclusive estimates of the costs per unit of (a) water saved and (b) energy saved for the respective projects and their component(s). 'Mutually-exclusive' refers to each respective estimate being calculated independent of the other. The measures are not intended to be additive ... – they are single measures, representing different perspectives of the proposed projects and their component(s)." (Rister et al. 2002a)

19 This report contains economic and financial analysis results for a single-component capital rehabilitation project proposed by the Brownsville Irrigation District. Prior reports containing multiple-component projects are identified on pp. 26-27 which identify related publications.

Component #1: Main Pipeline

The only component evaluated in this analysis is the replacing of the Main Canal (i.e., the main reach and the east and west forks of the Main Canal) with 12,202 feet (2.31 miles) of 72" and 48" RG/RC pipeline. Results of the analysis for this single-component project follow (**Table 9**).

Quantities of Water and Energy Savings

Critical values in the analysis are the amount of water and energy savings during the 49-year productive life of the pipeline.[20] On a nominal (i.e., non-discounted) basis, 96,011 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component.[21] Thus, the total nominal water savings anticipated are 96,011 ac-ft over the 49-year productive life of this component (**Table 9**). Using the 4% discount rate previously discussed, those nominal savings translate into 40,208 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 40,208 ac-ft (**Table 9**).

On a nominal (i.e., non-discounted) basis, 16,336,703,749 BTU (4,788,014 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 9**). Since there are no M&I-related energy savings, these values represent the total energy savings for this project. Using the 4% discount rate previously discussed, those nominal savings translate into 6,841,626,877 BTU (2,005,166 kwh) of real irrigation-related energy savings over the 49-year productive life of this project (**Table 9**).

Cost of Water Saved

One principal gauge of a proposed project component's merit is the estimated cost per ac-ft of water saved as a result of the project component's inception, purchase, installation, and implementation. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #1 (the sole component analyzed).

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20 As noted previously, the estimated useful life is 50 years instead of 49 years. RGIDECON© was developed to consider up to a maximum 50-year planning horizon, with the perspectives that projections beyond that length of time are largely discounted and also highly speculative. Allowing for the one-year installation period on the front end reduces to 49 years the time remaining for productive use of the asset during the 50-year planning period allowed within RGIDECON©.

21 As noted previously, the District diverts water for both M&I and agricultural concerns, and technically one could allocate a proportionate share of the forecasted water savings to M&I water use. That is, in the last 5 years, M&I water use has averaged 18% of total District diversions (i.e., 1,870 ac-ft of 10,352 ac-ft) and one could allocate that proportion of the projected savings to M&I. In this instance, however, RGIDECON© results will not change and the authors have opted to simplify and not allocate water savings between M&I and agriculture uses. Under existing legislation and irrigation district operating procedures, municipal users are 'guaranteed' their water rights, leaving agriculture as the residual claimant on available water allocations to the District. Thus, any marginal, additional water supplies (e.g., water savings) are assumed to accrue to agriculture. In this case, it (agriculture) is credited with all of the water savings from this project component.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, changes in O&M expenditures, and credits for energy savings, the nominal total cost of the 50-year planning period for the 72" and 48" pipeline project is $(4,141,081) (**Table 9**). This negative value infers a net economic savings (as opposed to a net economic cost), on a nominal basis. Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $811,403 (**Table 9**). This amount represents, across the total 50-year planning period, the total net costs, in 2003 dollars, of purchasing and installing the pipeline as well as payment of the net changes in O&M expenditures. Note that the positive real-value amount of costs is substantially greater than the negative nominal-value amount. This result occurs because in the nominal-value amount, the savings accruing from reduced O&M expenses and reduced energy use in the lengthy planning period are sufficient to more than offset the initial investment costs. In the case of the real-value amount, however, the savings occurring during the latter years of the planning period are discounted significantly and thus do not offset as much of the initial investment costs.

NPV of All Water Savings. As detailed above, the total nominal water savings anticipated are 96,011 ac-ft (**Table 9**). The corresponding total real water savings expressed in 2003 water quantities are 40,208 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 9**).

Cost per Acre-Foot of Water Saved. The real net cost estimate of $811,403 correlates with the real water savings projection of 40,208 ac-ft; the respective annuity equivalents are $52,379 and 1,872 ac-ft (**Table 9**). The estimated cost of saving one ac-ft of water using the 72" and 48" pipeline comprising this project is $27.98 (**Table 9**). This value can be interpreted as the cost of leasing one ac-ft of water in year 2003. It is not the cost of purchasing the water right of one ac-ft. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002a), this value represents the costs per year in present-day dollars of saving one ac-ft of water each year into perpetuity through a continual replacement series of the 72" and 48" pipeline with all of the attributes previously indicated.

Sensitivity Results. The results presented above are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per ac-ft of water saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis is considered to be that pertaining to the amount of reduction in Rio Grande diversions that will result from the purchase, installation, and implementation of the 72" and 48" pipeline in the water-delivery system. Thus, the cost per ac-ft of water-saved sensitivity analysis consists of varying the off-farm water-savings dimension[22] of that factor across a range of 525 to 1,500 ac-ft (including the baseline 1,074 ac-ft) for the new pipeline paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) value of BTU savings (i.e., cost of energy). Results for these three sets of paired sensitivity analyses are presented in **Tables 10, 11,** and **12**, respectively.

Table 10 reveals a range of $18.65 to $132.36 cost per ac-ft of savings around the baseline estimate of $27.98. These calculated values were derived by varying the reduction in Rio Grande diversions arising from off-farm water savings from the 72" and 48" pipeline from as low as 525 ac-ft up to 1,500 ac-ft about the expected 1,074 ac-ft and by investigating a range of useful lives of the new pipeline down from the expected 49 years to as short as only 10 years. As should be expected, shorter-useful lives than the anticipated 49-year productive life resulted in higher cost estimates, while lower off-farm water savings than the predicted 1,074 ac-ft also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 11** is a presentation of a range of cost estimates varying from $6.30 to $97.70 per ac-ft of savings around the baseline estimate of $27.98. These calculated values were derived by varying the reduction in Rio Grande diversions arising from off-farm water savings from the 72" and 48" pipeline from as low as 525 ac-ft up to 1,500 ac-ft about the expected 1,074 ac-ft and by considering variations in the cost of the capital investment in the new pipeline varying from $500,000 less than the expected $2,356,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $2,356,000 capital costs and/or higher-than-expected water savings contributed to lower cost estimates, while both higher investment costs and/or lower off-farm water savings than the predicted amounts increased the cost estimates.

The final set of sensitivity analysis conducted for the costs of water savings accounted for varying both the reduction in Rio Grande diversions arising from investment in 72" and 48" pipeline and the cost of energy. **Table 12** is an illustration of the results of varying those parameters from as low as 525 ac-ft up to 1,500 ac-ft about the expected 1,074 ac-ft of off-farm water savings and across a range of $0.0350 to $0.1050 per kwh energy costs about the expected $0.0710 per kwh level. The resulting cost of water savings estimates ranged from a high of $64.89 per ac-ft down to a low of $16.30 per ac-ft. The lower cost results are associated with high water savings and high energy costs – the two factors combined contribute to substantial energy cost savings which substantially offset both the initial capital costs of the new pipeline plus the anticipated changes in O&M expenses. The opposite effect is experienced with low energy usage per ac-ft of water savings and low water savings, i.e., higher costs estimates are calculated for these circumstances.

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22 Other off-farm water savings (i.e., unauthorized takings and recharge savings) are linked to off-farm (i.e., seepage) water savings within RGIDECON©'s assessment of this proposed project. Thus, as the off-farm (seepage) water savings associated with the 72" and 48" pipeline replacing the earthen Main Canal is varied in the sensitivity analyses, the other off-farm savings (i.e., unauthorized takings and recharge savings) also vary proportionately.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the 72" and 48" pipeline's inception, purchase, installation, and implementation, another issue of interest is the cost of energy savings. Reduced water diversions from the Rio Grande will result as seepage, evaporation, unauthorized takings, and canal recharge losses are reduced. These reduced diversions associated with the proposed Main Canal's capital renovation will result in less water being diverted, translating into energy savings. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessment and sets of sensitivity analyses for several pairs of the data parameters are presented below for the proposed project.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, and changes in O&M expenditures, the nominal total cost of the 50-year planning period for the 72" and 48" Main pipeline project is ($3,542,457) (**Table 9**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $953,679 (**Table 9**). This amount represents, across the total 50-year planning period, the total net costs, in 2003 dollars, of purchasing and installing the new pipeline as well as payment of the net changes in O&M expenditures, ignoring the changes in energy costs and allowing no credits for the water savings.

NPV of All Energy Savings. As detailed above, the total nominal energy savings anticipated are 16,336,703,749 BTU (4,788,014 kwh) (**Table 9**). The corresponding total real energy savings expressed in 2003 energy quantities are 6,841,626,877 BTU (2,005,166 kwh) over the 49-year productive life of this component, assuming the previously-identified discount rate of 4.00% (**Table 9**).

Cost per BTU & kwh Saved. The real net cost estimate of $953,679 correlates with the real energy savings projection of 6,841,626,877 BTU (2,005,166 kwh); the respective annuity equivalents are $61,564 and 318,479,103 BTU (93,341 kwh) (**Table 9**). The estimated cost of saving one BTU of energy using the 72" and 48" pipeline comprising this project is $0.0001933 ($0.660 per kwh) (**Table 9**). An interpretation of this value is that it is the cost of saving one BTU (kwh) of energy in year 2003. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002a), this value represents the costs per year in present-day dollars of saving one BTU (kwh) of energy into perpetuity through a continual replacement series of the 72" and 48" pipeline with all of the attributes previously indicated.

Sensitivity Results. As with the cost of water-savings estimates, the results presented above for energy savings are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per BTU (or kwh) saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) again is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis in this respect is considered to be that pertaining to the amount of energy savings that will result from the purchase, installation, and implementation of the 72" and 48" Main pipeline in the water-delivery infrastructure system. Thus, the cost per BTU (or kwh) of energy-saved sensitivity analyses consists of varying the amount of energy savings across a range of 80.0 percent up to 150.0 percent of the baseline 170,155 BTU (49.87 kwh) current average usage per ac-ft of water savings paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) off-farm water savings of the new pipeline. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 13** and **14, 15** and **16,** and **17** and **18**, respectively.

Tables 13 and **14** reveal a range of $0.0001289 to $0.0005125 cost per BTU (and $0.440 to $1.749 per kwh) of energy savings around the baseline estimate of $0.0001933 per BTU ($0.660 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 170,155 BTU (49.87 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the 72" and 48" pipeline down from the expected 49 years to as short as only 10 years. As should be expected, shorter-useful lives than the anticipated 49-year productive life resulted in higher cost estimates, while lower energy savings than the predicted 100% of current average usage also increased cost estimates, and higher-than-expected energy savings contributed to lower cost estimates.

Similarly, **Tables 15** and **16** are a presentation of a range of cost estimates varying from $0.0000613 to $0.0003683 per BTU (and $0.209 to $1.257 per kwh) of energy savings around the baseline estimate of $0.0001933 per BTU ($0.660 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 170,155 BTU (49.87 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the 72" and 48" pipeline varying from $500,000 less than the expected $2,356,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $2,356,000 capital costs and/or higher-than-expected energy savings contributed to lower cost estimates, while both higher investment costs and/or lower energy savings than the expected 170,155 BTU (49.87 kwh) increased the cost estimates.

The final set of sensitivity analysis conducted for the costs of energy savings accounted for varying both the amount of energy used per ac-ft of water savings and the reduction in Rio Grande diversions arising from water savings from the 72" and 48" Main pipeline. **Tables 17** and **18** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 170,155 BTU (49.87 kwh) current average usage per ac-ft of water savings and from as low as 525 ac-ft up to 1,500 ac-ft about the expected 1,074 ac-ft off-farm water savings for the new Main pipeline. The resulting costs of energy savings estimates ranged from a high of $0.0004945 per BTU ($1.687 per kwh) down to a low of $0.0000923 per BTU ($0.315 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm water savings – the two factors combined contribute to substantial energy cost savings. The opposite effect is experienced with low energy usage per ac-ft of water savings and low off-farm water savings, i.e., higher costs estimates are calculated for these circumstances.

Limitations

The protocol and implementation of the analysis reported in this report are robust, providing insightful information regarding the potential performance of the project proposed by the District. There are limitations, however, to what the results are and are not and how they should and should not be used. The discussion below addresses such issues.

- The analysis is conducted from a District perspective, ignoring income and expense impacts on both water users (i.e., farmers and M&I consumers) and third-party beneficiaries (i.e., the indirect economic impact effects). The spatial component and associated efficiency issues of 28 independent Districts supplying water to an array of agricultural, municipal, and industrial users in a relatively concentrated area are ignored.

- The analysis is *pro forma* budgeting in nature, based on forecasts of events and economic forces extending into the future several years. Obviously, there is imperfect information about such conditions, contributing to a degree of uncertainty as to the appropriate exact input values. Necessarily, such uncertainty contributes to some ambiguity surrounding the final result measures.

- Constrained financial resources, limited data availability, and a defined time horizon prohibit (a) extensive field experimentation to document all of the engineering- and water-related parameters; and (b) prolonged assimilation of economic costs and savings parameters. The immediate and readily-apparent status of needs for improvement across a wide array of potential projects and the political atmosphere characterizing the U.S.-Mexico water treaty situation discourage a slow, deliberate, elaborate, extensive evaluation process.

- Although the analysis's framework is deterministic, sensitivity analyses are included for several of the dominant parameters in recognition of the prior two limitations.

- Beyond the sensitivity analyses mentioned above, there is no accounting for risk in this analysis.

- The economic appraisal of the proposed project is objective and relatively simple in nature, providing straightforward estimates of the cost of water and energy saved. No benefit value of the water savings is conjectured to be forthcoming from the proposed project, i.e., a complete cost-benefit procedure is not applied. Consequently, the comprehensive net value of the proposed project is not addressed in this report.

- An individual project proposed by a District is evaluated in the positive, objective form noted earlier independent of other District's proposals. Should there be cause for comparison of potential performance across two or more proposed projects, such appraisals need to be conducted exogenous to this report. The results presented in the main body of this report could be useful for such prioritization processes, however, as discussed in Rister et al. (2002a).

- No possible capital renovations to the District besides those contained in the designated proposal are evaluated in comparison to the components of this project proposal. That is, while there may be other more economical means of saving water and energy within the District, those methods are not evaluated here.

- The analysis of the proposed project are conditional on existing District, Rio Grande Valley, State, and Federal infrastructure, policies (e.g., Farm Bill, U.S.-Mexico Water Treaty, etc.), and other institutional parameters (e.g., Domestic, Municipal, and Industrial (DMI) reserve levels, water rights ownership and transfer policies, priority of M&I rights, etc.). The implicit assumption is that the 28 irrigation districts in the Rio Grande Valley will retain their autonomy, continuing to operate independently, with any future collaboration, merger, other form of reorganization, and/or change in institutional policies to have no measurable impacts on the performance of the proposed project.

- The projects analyzed in this and other forthcoming reports are limited to those authorized by the Congress as a result of processes initiated by individual Districts or as proposed for other funding should that occur. That is, no comprehensive *a priori* priority systematic plan has been developed whereby third-party entities identify and prioritize projects on a Valley-wide basis, thereby providing preliminary guidance on how best to allocate appropriated funding in the event such funds are limited through time.

While such caveats indicate real limitations, they should not be interpreted as negating of the results contained in this report. These results are bonafide and conducive for use in the appraisal of the proposed projects affiliated with Public Law 106-576 and Public Law 107-351 legislation as well as those projects being proposed to the BECC and NADB. The above issues are worthy of consideration for future research and programs of work, but should not be misinterpreted and/or misapplied to the extent of halting efforts underway at this time.

Recommended Future Research

The analysis presented in this report are conditioned on the best information available, subject to the array of resource limitations and other problematic issues previously mentioned. Considering those circumstances, the results are highly useful for the Bureau of Reclamation's appraisal and prioritization of the several Rio Grande Basin projects already or potentially authorized by the Congress or submitted in a formal manner. Similarly, the results attend to the needs of BECC and NADB in their review and certification of proposed projects. Nonetheless, there are opportunities for additional research and/or other programs of work that would provide valuable insight in a holistic manner of the greater issue of water resource management in the immediate Rio Grande Valley Basin area and beyond. These issues are related in large part to addressing the concerns noted in the "Limitations" section.

- A comprehensive economic impact study of the proposed renovations would enhance the economic strength of the analyses. Necessarily, it is suggested such an effort encompass a full cost-benefit assessment and potential alterations in cropping patterns, impacts of projected urban growth, distribution of water use across the Basin, etc. It is relevant to note that evaluation of Federal projects often employ a national perspective and consider such local impacts negligible. A more-localized perspective in the level of analyses results in greater benefits being estimated along with increased attention to the identity of 'winners' and 'losers' in the resulting adjustments that are anticipated. For example, while on a national perspective the issue of the 1.7 million ac-ft of water now owed to the U.S. may not be a high-priority issue, it certainly is viewed as a critical issue within the immediate Rio Grande Valley area.

- A continued, well-defined program akin to the Federal Rio Grande Basin Initiative would enhance information availability in regards to the engineering- and water-related parameters and related economic costs and savings parameters associated with capital renovations using existing and future technologies. It would be valuable to extend such efforts to District infrastructure and farm operations. A similar research agenda should be developed and implemented for the M&I sector of water users.

- Evaluating economies of size for optimal District operations, with intentions of recognizing opportunities for eliminating duplication of expensive capital items (e.g., pumping plants) and redundant O&M services would provide insight into potential for greater efficiency.

- Integration of risk would be useful in future analyses, including incorporation of stochastic elements for and correlation among the numerous parameters of consequence affecting the costs of water and energy measurements of interest. Such recognition of risk could extend beyond the immediate District factors to also allow for variance in the DMI reserve level policy under stochastic water availability scenarios and/or consideration of the effects of agricultural water rights being purchased by M&I users and converted, albeit at a less than 100% rate, from 'soft' to 'firm' rates.

- Attention is needed in identifying an explicit prioritization process for ranking projects competing for limited funds. Such a process could attend to distinguishing distinct components comprising a single project into separate projects and provide for consideration of other opportunities besides those proposed by an individual District whereby such latter projects are identified in the context of the total Rio Grande Basin as opposed to an individual District. Consideration of the development of an economic mixed-integer programming model (Agrawal and Heady) is suggested as a reasonable and useful complement to ongoing and future-anticipated engineering activities. Such an effort would provide a focal point for identifying and assimilating data necessary for both individual and comprehensive, Valley-wide assessments in a timely fashion.

- The issues of water rights ownership and transfer policies, priority of M&I rights, sources and costs of push water, etc. are admittedly contentious, but still should not be ignored as

M&I demands accelerate and agricultural economic dynamics affect current and future returns to water used in such ventures.

- Development of a Valley- or Basin-wide based strategic capital investment plan is suggested, thereby providing preliminary guidance on how best to allocate appropriated funding; both agricultural and M&I use should be considered in such a plan.

- Detailed studies of Districts' water pricing (e.g., flat rates versus volumetric) policies, effects of water rights, conventions on sales and leasing of water rights, and various other issues relating to economic efficiency of water use could contribute insights on improved incentives for water conservation and capital improvement financing.

- Consideration of including M&I users as responsible parties for financing capital improvements is warranted.

Clearly, this is not a comprehensive list of possible activities germane to water issues in the Rio Grande Basin and/or the management of irrigation districts therein. The items noted could facilitate development, however, of proactive approaches to addressing current and emerging issues in the Rio Grande Basin area and beyond.

Summary and Conclusions

The District's project proposal consists of a single component: 72" and 48" pipeline replacing the Main Canal. The required capital investment cost is $2,356,000. A one-year installation period with an ensuing 49-year useful life (total of 50-year planning period) for the project is expected. Net annual O&M expenditures are expected to decrease (**Table 6**).

Off-farm water savings are predicted to be forthcoming from the single-component project. Expected water savings over the 49-year useful life are 96,011 nominal ac-ft, which translate into a 2003 basis of 40,208 real ac-ft (**Table 9**). Energy savings estimates associated with the Main pipeline are 16,336,703,749 BTU (4,788,014 kwh) in nominal terms and 6,841,626,877 BTU (2,005,166 kwh) in real 2003 terms (**Table 9**).

Economic and financial costs of *water* savings forthcoming from the Main pipeline are estimated at **$27.98** per ac-ft (**Table 9**). Sensitivity analyses indicate this estimate can be affected by variances in (a) the amount of reduction in Rio Grande diversions resulting from the purchase, installation, and implementation of the pipeline; (b) the expected useful life of the pipeline; (c) the initial capital investment costs of the pipeline; and (d) the value of BTU savings (i.e., cost of energy).

Economic and financial costs of *energy* savings forthcoming from the pipeline are estimated at **$0.0001933** per BTU (**$0.660** per kwh) (**Table 9**). Sensitivity analyses indicate factors of importance are (a) the amount of energy savings resulting from the purchase, installation, and implementation of the investment; (b) the expected useful life of the investment; (c) the initial capital investment costs; and (d) the amount of *off- farm* water savings.

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Glossary

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.

Annuity equivalents: Expression of investment costs (from project components with differing life spans) in relation to water (or energy) savings expressed on an annualized basis into perpetuity. As used in this report/analysis, a form of a common denominator used to establish values for capital investments of unequal useful lives on a common basis so that comparisons across investment alternatives can be made, as well as combined into an aggregate measure when two or more components comprise a total proposed project.

BTU: British Thermal Unit, a standard measure of energy equal to 0.0002931 kilowatts; or, 3,412 BTU equals 1 kilowatt.

Canal lining: Concrete and/or a combination of concrete and synthetic plastic material placed in an earthen canal to prevent seepage, resulting in increase flow rates.

Capital budgeting analysis: Financial analysis method which discounts future cash flow streams into a consistent, present-day, real value, facilitating comparison of capital investment projects having different planning horizons (i.e., years) and/or involving uneven annual cost streams.

Charged system: Condition when canals are "full" and have enough water to facilitate the flow of water to a designated delivery point.

Component: One independent capital investment aspect of a District's total proposed capital renovation project.

Delivery system: The total of pumping stations, canals, etc. used to deliver water within an irrigation district.

Diversion points: Point along a canal or pipeline where end users appropriate water, using either pumping or gravity flow through a permanent valve apparatus.

DMI Reserve: Domestic, municipal, and industrial surplus reserves held in the Falcon and Amistad reservoirs per Allocation and Distribution of Waters policy (Texas Natural Resource Conservation Commission).

Drip/Micro emitter systems: Irrigation systems used in horticultural systems which, relative to furrow irrigation, use smaller quantities of water at higher frequencies.

Flood irrigation: Common form of irrigation whereby fields are flooded through gravity flow.

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

Head: Standard unit of measure of the flow rate of water; represents 3 cubic feet per second (Carpenter; Fipps 2001-2002).

Lateral: Smaller canal which branch off from main canals, and deliver water to end users.

Lock system: A system to lift water in a canal to higher elevations.

M&I: Municipal and industrial sources of water demand.

Mains: Large canals which deliver water from pumping stations to/across an irrigation district.

No-Charge Water: An amount of water, considered as excess flow, which can be diverted, quantified, and added to improve a District's water supply without being counted against its Watermaster-controlled allocation.

Nominal basis: Refers to non-inflation adjusted dollar values.

O&M: Operations and maintenance activities that represent variable costs.

Off-farm savings: Conserved units of water or energy that otherwise would have been expended in the irrigation district, i.e., during pumping or conveyance through canals.

On-farm savings: Conserved units of water or energy realized at the farm level.

Percolation losses: Losses of water in a crop field during irrigation due to seepage into the ground, below the root zone.

Polypipe: A flexible, hose-like plastic tubing used to convey water from field diversion points directly to the field.

Pro forma: Refers to projected financial statements or other performance measures.

Proration: Allocation procedure in which a quantity of water that is smaller than that authorized by collective water rights is distributed proportionally among water rights holders.

Push water: Water filling a District's delivery system used to propel (or transport) "other water" from the river-side diversion point to municipalities.

Real values: Numbers which are expressed in time- and sometimes inflation-adjusted terms.

Relift pumping: Secondary pumping of water to enable continued gravity flow through a canal.

Rio Grande Valley: A geographic region in the southern tip of Texas which is considered to include Cameron, Hidalgo, Starr, and Willacy counties.

Sensitivity analyses: Used to examine outcomes over a range of values for a given parameter.

Telemetry: Involving a wireless means of data transfer.

Turnout: Refers to the yield of water received by the end user at the diversion point.

Volumetric pricing: Method of pricing irrigations based on the precise quantity of water used, as opposed to pricing on a per-acre or per-irrigation basis.

Watermaster: An employee for the Texas Commission on Environmental Quality who is responsible for the allocation and accounting of Rio Grande water flows and compliance of water rights.

Water Right: A right acquired under the laws of the State of Texas to impound, divert, or use state water.

Exhibits

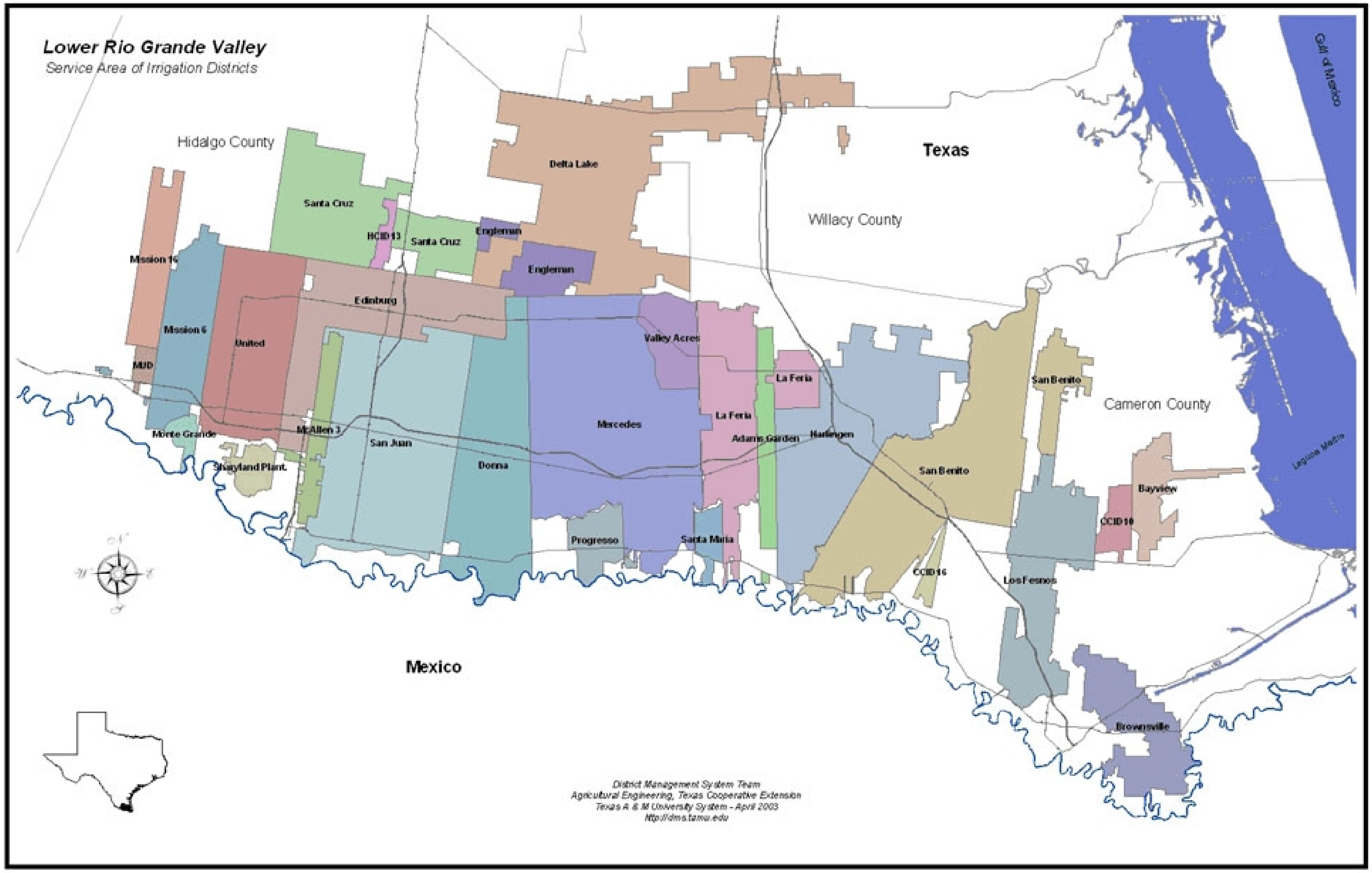

Exhibit 1. Illustration of Twenty-Eight Irrigation Districts in the Texas Lower Rio Grande Valley (Fipps et al.).

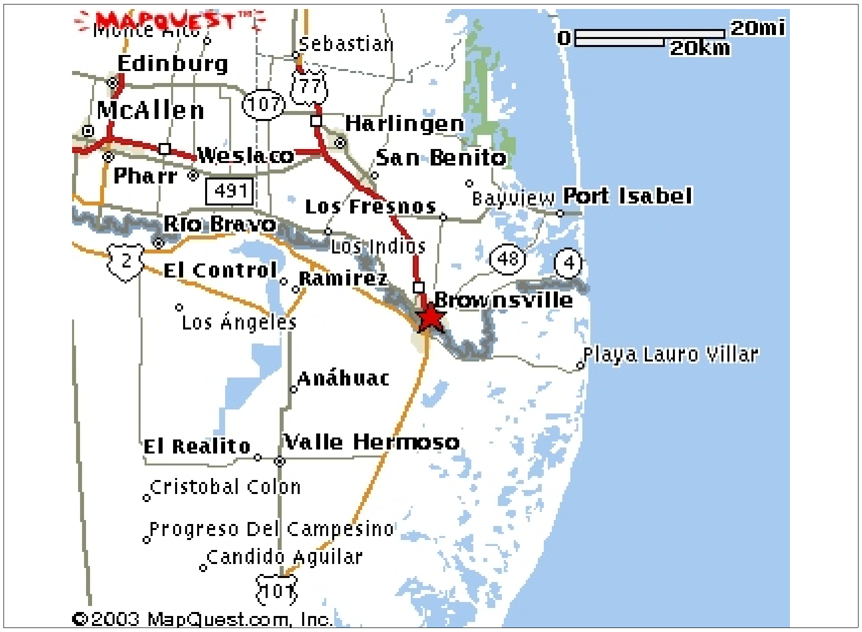

Exhibit 2. Brownsville, TX – Location of Brownsville Irrigation District Office (MapQuest).

Exhibit 3. Detailed Location of Brownsville Irrigation District Office in Brownsville, TX (MapQuest).

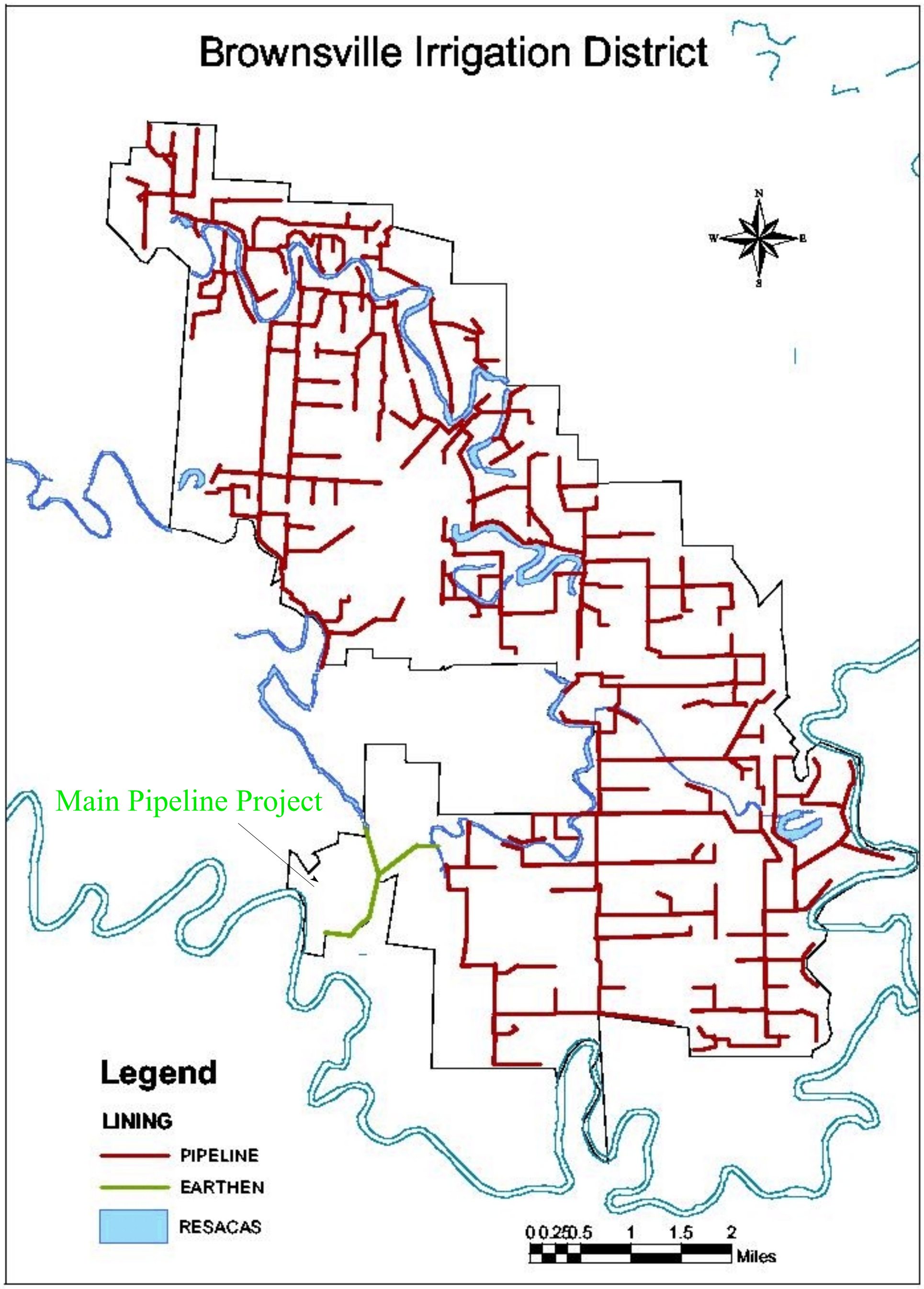

Exhibit 4. Illustrated Layout of Brownsville Irrigation District (Fipps et al.).

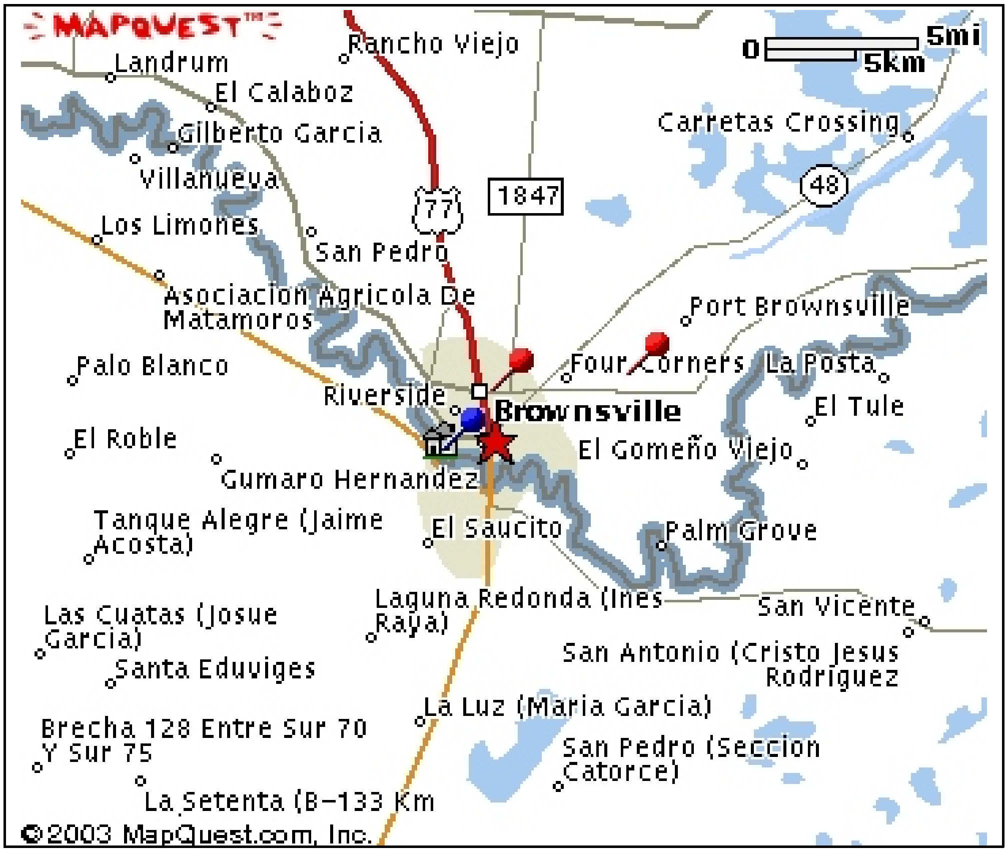

Exhibit 5. Location of Pumping Plant, and the Municipalities and Water Supply Corporations Served by Brownsville Irrigation District (MapQuest).

Tables

Table 1. Average Acreage Irrigated by Brownsville Irrigation District as per District Records for Fiscal Years 1998-2002 (Barrera).

Category / Enterprise	1998	1999	2000	2001	2002	5-year average acres	5-year average %
Field crops - annual							
COTTON	3,835	2,474	3,870	3,568	4,015	3,552	32.2 %
SORGHUM	4,578	2,647	2,991	2,550	2,907	3,135	28.4 %
SOYBEAN	1,772	2,000	1,328	567	153	1,164	10.5 %
CORN	398	171	1,259	1,970	717	903	8.2 %
SUNFLOWER	193	104	390	279	204	234	2.1 %
WHEAT	0	0	661	0	208	174	1.6 %
MISC. FIELD CROPS	0	0	0	0	0	0	0.0 %
OATS	0	0	0	0	0	0	0.0 %
						9,162	83.0 %
Citrus / Fruit							
CITRUS	819	747	1,131	1,019	971	937	8.5 %
OTHER FRUITS	0	0	0	0	0	0	0.0 %
						937	8.5 %
Pasture / Open							
PASTURE	1,088	258	649	670	801	693	6.3 %
OPEN LAND	0	0	0	0	0	0	0.0 %
						693	6.3 %
Other							
ALL OTHER	728	97	61	119	99	221	2.0 %
YARD-ACRES	0	0	0	0	0	0	0.0 %
YARD-LOTS	0	0	0	0	0	0	0.0 %
PALM-TREES	0	0	0	0	0	0	0.0 %
OTHER TREES	0	0	0	0	0	0	0.0 %
LAKE	0	0	0	0	0	0	0.0 %
GOLF COURSE	0	0	0	0	0	0	0.0 %
						221	2.0 %
Vegetables							
OTHER VEGETABLES	0	0	0	0	107	21	0.2 %
CABBAGE	0	0	0	0	0	0	0.0 %
CARROTS	0	0	0	0	0	0	0.0 %
PICKLES	0	0	0	0	0	0	0.0 %
GREENS	0	0	0	0	0	0	0.0 %
BEANS	0	0	0	0	0	0	0.0 %
BEETS	0	0	0	0	0	0	0.0 %
BROCCOLI	0	0	0	0	0	0	0.0 %
TOMATOES	0	0	0	0	0	0	0.0 %
PEPPERS	0	0	0	0	0	0	0.0 %
ONIONS	0	0	0	0	0	0	0.0 %
SQUASH	0	0	0	0	0	0	0.0 %
CUCUMBERS	0	0	0	0	0	0	0.0 %
LETTUCE	0	0	0	0	0	0	0.0 %
CILANTRO	0	0	0	0	0	0	0.0 %
CELERY	0	0	0	0	0	0	0.0 %
CAULIFLOWER	0	0	0	0	0	0	0.0 %
LEEKS	0	0	0	0	0	0	0.0 %
						21	0.2 %
Field Crops - perennial							
SUGAR CANE	0	0	0	0	0	0	0.0 %
Hay							
OTHER HAY	0	0	0	0	0	0	0.0 %
ALFALFA HAY	0	0	0	0	0	0	0.0 %
OTHER GRASSES	0	0	0	0	0	0	0.0 %
							0.0 %
Melons							
CANTALOUPES	0	0	0	0	0	0	0.0 %
WATERMELONS	0	0	0	0	0	0	0.0 %
HONEYDEW, ETC.	0	0	0	0	0	0	0.0 %
							0.0 %
Total	13,411	8,498	12,340	10,742	10,182	11,035	100.00%

Table 2. Historic Water Use (acre-feet), Brownsville Irrigation District, 1998-2002 (Barrera).

Use	Fiscal Year[a] (values in annual ac-ft) 1998	1999	2000	2001	2002	5-year average
M&I Use	1,400	2,230	2,121	1,500	2,100	1,870
Ag Irrigation Use	10,584	8,597	8,017	8,350	6,861	8,482
Total	11,984	10,827	10,138	9,850	8,961	10,352

[a] The District's fiscal year is the period August 1 - July 31.

Table 3. Selected Summary Information for Brownsville Irrigation District, 2003 (Barrera).

Item	Description / Data
Certificates of Adjudication (Type Use \\ ac-ft):	**Class "A"** A8453-000 (Irrigation \\ 33,949.5 ac-ft); M843-000 (Municipal (Brownsville) \\ 6,071.0 ac-ft); Irg01-03 (Mining \\ 2.0 ac-ft); and **Class "B"** B843-000 (Irrigation \\ 926.6 ac-ft).
Municipalities Served (Total Delivery in ac-ft):	City of Brownsville (4,232.0 ac-ft); El Jardin Water Supply Corporation (1,500.0 ac-ft).
District Water Rates:	Volumetric-priced Irrigation: Flat Rate ($6.00 per acre) for 1st 4" of water; Volumetric-priced Irrigation: Irrigation Rate ($2.00 per ac-inch after 1st 4"); Standard Irrigation: Flat Rate ($12.00 per acre) for 1st 4" of water; Standard Irrigation: Irrigation Rate ($2.00 per ac-inch after 1st 4"); Lawn Water: ($65.00 per year); and Municipal Delivery: ($45 per ac-ft).
Average Lift at Rio Grande:	22-24 feet.

Table 4. Selected Summary Characteristics of Proposed 48" and 72" Pipeline Replacing Main Canal for BOR and NADB Project, Brownsville Irrigation District, 2003 (Barrera, Holdar).

Characteristic Item	Description / Data
Project Name:	Main Pipeline
Project Type:	Pipeline Installation
Proposed Activity Description:	Replace the main stretch of the Main Canal (i.e., earthen canal) with 6,160 feet of 72" rubber-gasket, reinforced-concrete pipeline, and replace the east and west forks of the Main Canal with 6,042 feet of 48" rubber-gasket, reinforced-concrete pipeline.
Canal / Project Length:	
- feet	12,202
- miles	2.31

Table 5. Summary of Annual Water and Energy Savings Data (basis 2003) for 48" and 72" Pipeline Replacing Main Canal for BOR and NADB Project, Brownsville Irrigation District, 2003 (Barrera, Holdar).

Item/Savings	Amount of Annual Water Savings by Type			Total Water Savings (ac-ft)	Associated Annual Energy Savings		
	Reduced Evaporation & Seepage (ac-ft)	Reduced Takings (ac-ft)	Reduced Recharge (ac-ft)		BTU	kwh	$
Annual Energy & Water Savings							
Agricultural Irrigation Use:							
Off-farm (reduced seepage/evaporation)	1,074.4	0.0	0.0	1,074.4	182,814,757	53,580	$ 3,802
Off-farm (reduced unauthorized taking)	0.0	75.0	0.0	75.0	12,761,641	3,740	265
Off-farm (reduced recharging)	0.0	0.0	810.0	810.0	137,825,720	40,394	2,866
Off-farm (relift pumping)	0.0	0.0	0.0	0.0	0	0	0
On-farm (reduced percolation)	0.0	0.0	0.0	0.0	0	0	0
Sub-total	1,074.4	75.0	810.0	**1,959.4**	333,402,117	97,715	$ 6,933
Municipal and Industrial Use:							
Off-farm	0.0	0.0	0.0	0.0	0	0	0
On-farm	0.0	0.0	0.0	0.0	0	0	0
Sub-total	0.0	0.0	0.0	0.0	0	0	0
Total	1,074.4	75.0	810.0	**1,959.4**	333,402,117	97,715	$ 6,933

Table 6. Summary of Project Cost and Expense Data for 48" and 72" Pipeline Replacing Main Canal for BOR and NADB Project (2003 dollars), Brownsville Irrigation District (Holdar, Barrera).

Item	Component #1 (72" & 48" Pipeline) [a]		
	Years	Expenses / Revenues	
		(total $'s)	($/mile)
Installation Period	1		
Productive Period	49		
Planning Period	50		
Initial Capital Investment Costs [b]		$ 2,356,000	$ 1,019,479
Annual Increases in O&M Expenses		$ 5,371	$ 2,324
Annual Decreases in O&M Expenses		$ 73,679	$ 31,882
Net Changes in Annual O&M Expenses		$ (68,308)	$ (29,558)
Value of Reclaimed Property (revenue)		$ 0	$ 0

[a] Component #1- Main Canal is 12,202 feet (2.31 miles) of 72" and 48" pipeline replacing earthen canal. This is the only project component; thus, there are no aggregate values across multiple components to display and/or discuss.

[b] This value is the cost used in this economic and conservation analysis and report. Based on discussions with Bureau of Reclamation management (April 9, 2002; Austin, TX), expenses associated with design, engineering, and other preliminary development of this project's proposal are ignored in the economic analysis prepared for the planning report. Such costs are to be incorporated, however, into the materials associated with the final design phase of this project.

Table 7. Details of Cost Estimate for 48" and 72" Pipeline Replacing Main Canal for BOR and NADB Project (2003 dollars), Brownsville Irrigation District (Holdar Engineering Company).

Item	($)'s
Purchase and Install Pipeline	$ 1,994,378
Unlisted Items	0
Construction Management	26,000
Contingencies	335,622
In-Kind:	0
Total Project Costs [a]	$ 2,356,000

[a] This value is the cost used in this economic and conservation analysis and report. Based on discussions with Bureau of Reclamation management (April 9, 2002; Austin, TX), expenses associated with design, engineering, and other preliminary development of this project's proposal are ignored in the economic analysis prepared for the planning report.

Table 8. Summary of Water Diversions, and Energy Use and Expenses for Brownsville Irrigation District's Rio Grande Diversion Pumping Plant, per District Records (Barrera).

Item	Fiscal Year 1998	1999	2000	2001	2002[a]	Average
Electricity - Diverted:						
- kwh used	531,000	496,773	561,000	585,444	407,017	516,247
- Btu equivalent	1,811,772,000	1,694,988,452	1,914,132,000	1,997,533,904	1,388,742,314	1,761,433,734
- total electric expense	$31,970	$29,217	$42,969	$46,056	$32,938	$36,630
Natural Gas - Diverted:						
- kwh used	0	0	0	0	0	0
- Btu equivalent	0	0	0	0	0	0
- total natural gas expense	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Energy - Diverted:						
- kwh used	531,000	496,773	561,000	585,444	407,017	516,247
- Btu equivalent	1,811,772,000	1,694,988,452	1,914,132,000	1,997,533,904	1,388,742,314	1,762,433,734
- total energy expense	$31,970	$29,217	$42,969	$46,056	$32,938	$36,630
Water - Diverted:						
- CFS pumped	6,042	5,458	5,111	4,966	4,517	5,219
- ac-ft equivalent	11,984	10,827	10,138	9,850	8,961	**10,352**
Calculations (diverted water):						
- kwh / ac-ft	44.31	45.88	55.34	59.44	45.42	49.87
- Btu / ac-ft	151,183	156,552	188,808	202,795	154,983	**170,155**
- avg. cost per kwh ($/kwh)	$0.060	$0.059	$0.077	$0.079	$0.081	$0.071
- avg. cost per Btu ($/Btu)	$0.0000176	$0.0000172	$0.0000224	$0.0000231	$0.0000237	$0.0000208
- avg. cost of water pumped ($/ac-ft)	$2.67	$2.70	$4.24	$4.68	$3.68	**$3.54**

[a] Figures for fiscal year 2002 are annualized, based on the first eleven months of the fiscal year (i.e.,August 1, 2002 through June 30, 2003).

Table 9. Economic and Financial Evaluation Results Across the Project Component's Useful Life, Brownsville Irrigation District, 48" and 72" Main Pipeline Project for BOR and NADB, 2003.

Results	Nominal	Real[a]
Water Savings (ac-ft)		
Agriculture Irrigation	96,011	40,208
M&I	0	0
Total ac-ft	96,011	40,208
annuity equivalent		1,872
Energy Savings (BTU)		
Agriculture Irrigation	16,336,703,749	6,841,626,877
M&I		0
Total BTU	16,336,703,749	6,841,626,877
annuity equivalent		318,479,103
Energy Savings (kwh)		
Agriculture Irrigation	4,788,014	2,005,166
M&I	0	0
Total kwh's	4,788,014	2,005,166
annuity equivalent		93,341
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings	$ (4,141,081)	$ 811,403
annuity equivalent		$ 52,379
Cost of Water Savings ($/ac-ft)		$ 27.98
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings	$ (3,542,457)	$ 953,679
annuity equivalent		$ 61,564
Cost of Energy Savings ($/BTU)		$ 0.0001933
Cost of Energy Savings ($/kwh)		$ 0.660

[a] Determined using a 4% discount factor.

Table 10. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 12,202 Feet (2.31 Miles) of Earthen Main Canal and Expected Useful Life of the Capital Investment, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		ac-ft of annual water loss (seepage & evaporation) for 12,202 feet of earthen Main Canal									
		525	650	750	850	975	**1,074**	1,175	1,300	1,400	1,500
Expected Useful life of Investment (years)	10	$132.36	$104.91	$89.53	$77.78	$66.47	$59.36	$53.38	$47.25	$43.13	$39.56
	20	$85.16	$67.50	$57.60	$50.04	$42.77	$38.19	$34.35	$30.40	$27.75	$25.45
	25	$76.49	$60.62	$51.74	$44.94	$38.41	$34.30	$30.85	$27.30	$24.92	$22.86
	30	$71.09	$56.34	$48.09	$41.77	$35.70	$31.88	$28.67	$25.38	$23.17	$21.25
	40	$65.11	$51.60	$44.04	$38.26	$32.70	$29.20	$26.26	$23.24	$21.22	$19.46
	49	$62.41	$49.46	$42.21	$36.67	$31.34	**$27.98**	$25.17	$22.28	$20.34	$18.65

Table 11. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 12,202 Feet (2.31 Miles) of Earthen Main Canal and Initial Cost of the Capital Investment, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		ac-ft of annual water loss (seepage & evaporation) for 12,202 feet of earthen Main Canal									
		525	650	750	850	975	**1,074**	1,175	1,300	1,400	1,500
Initial Capital Investment Cost ($)	$(500,000)	$27.11	$20.96	$17.51	$14.87	$12.34	$10.74	$9.40	$8.02	$7.10	$6.30
	$(250,000)	$44.76	$35.21	$29.86	$25.77	$21.84	$19.36	$17.28	$15.15	$13.72	$12.48
	$(100,000)	$55.35	$43.76	$37.27	$32.31	$27.54	$24.54	$22.02	$19.43	$17.69	$16.18
	$ -	$62.41	$49.46	$42.21	$36.67	$31.34	**$27.98**	$25.17	$22.28	$20.34	$18.65
	$100,000	$69.46	$55.16	$47.15	$41.03	$35.14	$31.43	$28.32	$25.13	$22.98	$21.12
	$250,000	$80.05	$63.71	$54.56	$47.57	$40.84	$36.61	$33.05	$29.40	$26.95	$24.83
	$500,000	$97.70	$77.97	$66.92	$58.47	$50.34	$45.23	$40.94	$36.53	$33.57	$31.00

Table 12. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 12,202 Feet (2.31 Miles) of Earthen Canal and Value of Energy Savings, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		ac-ft of annual water loss (seepage & evaporation) for 12,202 feet of earthen Main Canal									
		525	650	750	850	975	**1,074**	1,175	1,300	1,400	1,500
Value of Energy Savings ($/kwh)	$0.0350	$64.89	$51.95	$44.70	$39.15	$33.82	$30.47	$27.66	$24.76	$22.82	$21.14
	$0.0500	$63.85	$50.91	$43.66	$38.12	$32.79	$29.43	$26.62	$23.73	$21.78	$20.10
	$0.0650	$62.82	$49.87	$42.62	$37.08	$31.75	$28.40	$25.58	$22.69	$20.75	$19.06
	$0.0710	$62.41	$49.46	$42.21	$36.67	$31.34	**$27.98**	$25.17	$22.28	$20.34	$18.65
	$0.0800	$61.78	$48.84	$41.59	$36.04	$30.71	$27.36	$24.54	$21.65	$19.71	$18.03
	$0.0900	$61.09	$48.14	$40.89	$35.35	$30.02	$26.67	$23.85	$20.96	$19.02	$17.34
	$0.1050	$60.05	$47.11	$39.86	$34.31	$28.98	$25.63	$22.81	$19.92	$17.98	$16.30

Table 13. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		variation in BTU of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		136,124	153,140	161,647	165,901	**170,155**	174,409	178,663	187,171	212,694	255,233
Expected Useful life of Investment (years)	10	$0.0005125	$0.0004556	$0.0004316	$0.0004205	$0.0004100	$0.0004000	$0.0003905	$0.0003727	$0.0003280	$0.0002733
	20	$0.0003297	$0.0002931	$0.0002777	$0.0002706	$0.0002638	$0.0002574	$0.0002512	$0.0002398	$0.0002110	$0.0001759
	25	$0.0002962	$0.0002632	$0.0002494	$0.0002430	$0.0002369	$0.0002311	$0.0002256	$0.0002154	$0.0001895	$0.0001579
	30	$0.0002753	$0.0002447	$0.0002318	$0.0002259	$0.0002202	$0.0002148	$0.0002097	$0.0002002	$0.0001762	$0.0001468
	40	$0.0002521	$0.0002241	$0.0002123	$0.0002069	$0.0002017	$0.0001968	$0.0001921	$0.0001833	$0.0001613	$0.0001345
	49	$0.0002416	$0.0002148	$0.0002035	$0.0001983	**$0.0001933**	$0.0001886	$0.0001841	$0.0001757	$0.0001546	$0.0001289

Table 14. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		variation in BTU of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		136,124	153,140	161,647	165,901	**170,155**	174,409	178,663	187,171	212,694	255,233
Expected Useful life of Investment (years)	10	$1.749	$1.554	$1.473	$1.435	$1.399	$1.365	$1.332	$1.272	$1.119	$0.933
	20	$1.125	$1.000	$0.947	$0.923	$0.900	$0.878	$0.857	$0.818	$0.720	$0.600
	25	$1.010	$0.898	$0.851	$0.829	$0.808	$0.789	$0.770	$0.735	$0.647	$0.539
	30	$0.939	$0.835	$0.791	$0.771	$0.751	$0.733	$0.716	$0.683	$0.601	$0.501
	40	$0.860	$0.765	$0.724	$0.706	$0.688	$0.671	$0.655	$0.626	$0.551	$0.459
	49	$0.824	$0.733	$0.694	$0.676	**$0.660**	$0.643	$0.628	$0.600	$0.528	$0.440

Table 15. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		variation in BTU of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		136,124	153,140	161,647	165,901	**170,155**	174,409	178,663	187,171	212,694	255,233
Initial Capital Investment Cost ($)	$(500,000)	$0.0001149	$0.0001022	$0.0000968	$0.0000943	$0.0000920	$0.0000897	$0.0000876	$0.0000836	$0.0000736	$0.0000613
	$(250,000)	$0.0001783	$0.0001585	$0.0001501	$0.0001463	$0.0001426	$0.0001392	$0.0001358	$0.0001297	$0.0001141	$0.0000951
	$(100,000)	$0.0002163	$0.0001923	$0.0001821	$0.0001775	$0.0001730	$0.0001688	$0.0001648	$0.0001573	$0.0001384	$0.0001154
	$ -	$0.0002416	$0.0002148	$0.0002035	$0.0001983	**$0.0001933**	$0.0001886	$0.0001841	$0.0001757	$0.0001546	$0.0001289
	$100,000	$0.0002670	$0.0002373	$0.0002248	$0.0002191	$0.0002136	$0.0002084	$0.0002034	$0.0001942	$0.0001709	$0.0001424
	$250,000	$0.0003050	$0.0002711	$0.0002568	$0.0002502	$0.0002440	$0.0002380	$0.0002324	$0.0002218	$0.0001952	$0.0001627
	$500,000	$0.0003683	$0.0003274	$0.0003102	$0.0003022	$0.0002947	$0.0002875	$0.0002806	$0.0002679	$0.0002357	$0.0001964

Table 16. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		variation in BTU of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		136,124	153,140	161,647	165,901	**170,155**	174,409	178,663	187,171	212,694	255,233
Initial Capital Investment Cost ($)	$(500,000)	$0.392	$0.349	$0.330	$0.322	$0.314	$0.306	$0.299	$0.285	$0.251	$0.209
	$(250,000)	$0.608	$0.541	$0.512	$0.499	$0.487	$0.475	$0.463	$0.442	$0.389	$0.324
	$(100,000)	$0.738	$0.656	$0.621	$0.606	$0.590	$0.576	$0.562	$0.537	$0.472	$0.394
	$ -	$0.824	$0.733	$0.694	$0.676	**$0.660**	$0.643	$0.628	$0.600	$0.528	$0.440
	$100,000	$0.911	$0.810	$0.767	$0.747	$0.729	$0.711	$0.694	$0.662	$0.583	$0.486
	$250,000	$1.041	$0.925	$0.876	$0.854	$0.832	$0.812	$0.793	$0.757	$0.666	$0.555
	$500,000	$1.257	$1.117	$1.058	$1.031	$1.005	$0.981	$0.957	$0.914	$0.804	$0.670

Table 17. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Main Canal, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		variation in BTU of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		136,124	153,140	161,647	165,901	**170,155**	174,409	178,663	187,171	212,694	255,233
ac-ft of annual water loss (seepage & evap.) for 12,202 feet of earthen Main Canal	525	$0.0004945	$0.0004396	$0.0004164	$0.0004057	$0.0003956	$0.0003859	$0.0003768	$0.0003596	$0.0003165	$0.0002637
	650	$0.0003994	$0.0003550	$0.0003363	$0.0003277	$0.0003195	$0.0003117	$0.0003043	$0.0002905	$0.0002556	$0.0002130
	750	$0.0003461	$0.0003077	$0.0002915	$0.0002840	$0.0002769	$0.0002702	$0.0002637	$0.0002517	$0.0002215	$0.0001846
	850	$0.0003054	$0.0002715	$0.0002572	$0.0002506	$0.0002443	$0.0002384	$0.0002327	$0.0002221	$0.0001955	$0.0001629
	975	$0.0002663	$0.0002367	$0.0002242	$0.0002185	$0.0002130	$0.0002078	$0.0002029	$0.0001936	$0.0001704	$0.0001420
	1,074	$0.0002416	$0.0002148	$0.0002035	$0.0001983	**$0.0001933**	$0.0001886	$0.0001841	$0.0001757	$0.0001546	$0.0001289
	1,175	$0.0002209	$0.0001964	$0.0001861	$0.0001813	$0.0001768	$0.0001724	$0.0001683	$0.0001607	$0.0001414	$0.0001178
	1,300	$0.0001997	$0.0001775	$0.0001682	$0.0001639	$0.0001598	$0.0001559	$0.0001522	$0.0001452	$0.0001278	$0.0001065
	1,400	$0.0001854	$0.0001648	$0.0001562	$0.0001522	$0.0001483	$0.0001447	$0.0001413	$0.0001349	$0.0001187	$0.0000989
	1,500	$0.0001731	$0.0001538	$0.0001457	$0.0001420	$0.0001385	$0.0001351	$0.0001319	$0.0001259	$0.0001108	$0.0000923

Table 18. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Main Canal, Brownsville Irrigation District, 72" and 48" Pipeline Replacing Main Canal, for BOR and NADB Project, 2003.

		variation in BTU of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		136,124	153,140	161,647	165,901	**170,155**	174,409	178,663	187,171	212,694	255,233
ac-ft of annual water loss (seepage & evap.) for 12,202 feet of earthen Main Canal	525	$1.687	$1.500	$1.421	$1.384	$1.350	$1.317	$1.285	$1.227	$1.080	$0.900
	650	$1.363	$1.211	$1.148	$1.118	$1.090	$1.064	$1.038	$0.991	$0.872	$0.727
	750	$1.181	$1.050	$0.995	$0.969	$0.945	$0.922	$0.900	$0.859	$0.756	$0.630
	850	$1.042	$0.926	$0.878	$0.855	$0.834	$0.813	$0.794	$0.758	$0.667	$0.556
	975	$0.908	$0.808	$0.765	$0.745	$0.727	$0.709	$0.692	$0.661	$0.581	$0.485
	1,074	$0.824	$0.733	$0.694	$0.676	**$0.660**	$0.643	$0.628	$0.600	$0.528	$0.440
	1,175	$0.754	$0.670	$0.635	$0.619	$0.603	$0.588	$0.574	$0.548	$0.482	$0.402
	1,300	$0.681	$0.606	$0.574	$0.559	$0.545	$0.532	$0.519	$0.496	$0.436	$0.363
	1,400	$0.633	$0.562	$0.533	$0.519	$0.506	$0.494	$0.482	$0.460	$0.405	$0.337
	1,500	$0.591	$0.525	$0.497	$0.485	$0.472	$0.461	$0.450	$0.429	$0.378	$0.315

Appendix

Appendix A: Legislated Criteria Results[23]

United States Public Law 106-576 legislation requires three economic measures be calculated and included as part of the information prepared for the Bureau of Reclamation's evaluation of the proposed projects (Bureau of Reclamation):

- Number of ac-ft of water saved per dollar of construction costs;
- Number of BTU of energy saved per dollar of construction costs; and
- Dollars of annual economic savings per dollar of initial construction costs.

Discussions with Bob Hamilton of the Denver Bureau of Reclamation office on April 9, 2002 indicated these measures are often stated in an inverse mode, i.e.,

- Dollars of construction cost per ac-ft of water saved;
- Dollars of construction cost per BTU (and kwh) of energy saved; and
- Dollars of construction cost per dollar of annual economic savings.

Hamilton's suggested convention is adopted and used in the RGIDECON© model section reporting the Public Law 106-576 legislation's required measures. It is on that basis that the legislated criteria results are presented in Appendix A of this report.

The noted criteria involve a series of calculations similar to, but different than, those used in developing the cost measures cited in the main body of this report. Principal differences consist of the legislated criteria not requiring aggregation of the initial capital investment costs with the annual changes in O&M expenditures, but rather entailing separate sets of calculations for each type of cost relative to the anticipated water and energy savings. While the legislated criteria do not specify the need for discounting the nominal values into real terms, both nominal and real values are presented in Appendix A. With regards to the annual economic savings referred to in the third criteria, these are summed into a single present value quantity inasmuch as the annual values may vary through the planning period. Readers are directed to Rister et al. (2002a) for more information regarding the issues associated with comparing capital investments having differences in length of planning periods.

Component #1: Main Pipeline

The District's BOR and NADB project consists of replacing the Main Canal with 12,202 feet (2.31 miles) of 72" and 48" rubber-gasket, reinforced-concrete pipeline. Details on the cost estimates and related projections of water and energy savings are presented in the main body of this report (**Tables 5, 6, 7,** and **9**). Below, a summary of the calculated values and results

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23 Unlike other irrigation districts' proposed projects with two or more components, the Brownsville Irrigation District's project consists of a single component. Thus, only one appendix (i.e., Appendix A) is provided as presentation and discussion of aggregate legislative criteria (in an Appendix B) is not necessary.

corresponding to the legislated criteria are presented, with nominal and their discounted (i.e., real) transformations presented.

The principal evaluation criteria specified in the United States Public Law 106-576 legislation, transformed according to Hamilton, are presented in **Table A2** (as determined by the calculated values reported in **Table A1**, which are derived in RGIDECON©, using the several input parameters described in the main body of this report).

Summary Calculated Values

The initial construction costs associated with the purchase and installation of the 72" and 48" pipeline amount to $2,356,000. It is assumed all costs occur on the first day of the planning period, thus, the nominal and real values are equal because there are no future costs to discount.

A total of 96,011 ac-ft of nominal *off-farm* water savings are projected to occur during the productive life of the 72" and 48" pipeline, with associated energy savings of 16,336,703,749 BTU (4,788,014 kwh). Using the 4% discount rate, the present or real value of such anticipated savings become 40,208 ac-ft and 6,841,626,877 BTU (2,005,166 kwh) (**Table A1**).

The accrued annual net changes in O&M expenditures over the 72" and 48" pipeline's productive life are a total decrease of $6,497,081. Using the 2002 Federal discount rate of 6.125%, this anticipated net decrease in expenditures represents a real cost reduction of $1,544,597 (**Table A1**). As noted in the main body of the text, this anticipated net cost savings stems from energy savings and anticipated changes in O&M expenditures.

Criteria Stated in Legislated Guidelines

The estimated initial construction costs per ac-ft of water saved are $24.54 in a nominal sense and $58.60 in real terms, while the initial construction costs per BTU (kwh) of energy saved are $0.0001442 ($0.492) in a nominal sense and $0.0003444 ($1.175) in real terms (**Table A2**). The estimated real values are higher (than the nominal values) because future water and energy savings are discounted and construction costs are not because they occur at the onset, i.e., with the real or present values, the discounting of the denominators (i.e., ac-ft of water; BTU (or kwh) of energy) increases the ratio of $/water saved and $/energy saved.

Changes in both energy savings and other O&M expenditures forthcoming from the pipeline installation result in anticipated net decreases in annual costs (**Table A1**). Dividing the initial construction costs by the decreases in operating costs results in a ratio measure of -0.36 of construction costs per dollar reduction in nominal operating expenditures, suggesting construction costs are less than the expected nominal decreases in O&M costs during the planning period for the installed 72" and 48" pipeline. On a real basis, this ratio measure is -1.53 (**Table A2**), signifying construction costs are higher than the expected real values of economic savings in O&M during the planning period.

The proper interpretation of the ratio (i.e., initial construction cost divided by economic savings) can be somewhat difficult and involves recognition that the most desired value is negative and close to zero. That is, a negative ratio signifies a net real reduction in future expenses (i.e., O&M and energy), while a positive ratio signifies a net real increase in future expenses. Also, whether the value of the ratio is *less than* or *greater than* negative 1 makes a difference. That is, if greater than negative one (e.g., -3.45), it infers that construction costs are *greater than* the sum of real expected annual economic savings (which are on a "current dollar basis"). Likewise, if the value is less than negative one (e.g., -.74), it infers construction costs are *less than* the sum of real expected annual economic savings. Of course, if the value is positive (i.e., greater than zero), it infers that in addition to initial construction costs, the project component will incur net increases in real future operating and maintenance costs (i.e., not realize net real economic savings over the life of the project). Finally, a negative value close to zero indicates a relatively low required investment to achieve a dollar of savings in O&M expenses.

Although an interpretation of the third legislative criteria is provided above, ranking and/or comparing this ratio measure across project components (either within or across irrigation districts' projects) solely by this ratio should be approached with caution due to criticisms of the ratio's very nature. That is, it is difficult to determine the rank order of components since either a low initial construction cost and/or a high increase in O&M expenses result in a low ratio of the calculated values. Similarly, a high construction cost requirement and/or a low increase in O&M expenditures result in a high ratio of the calculated values. The resulting paradox is apparent.

Notably, the legislated criteria results differ for the single component comprising the District's proposed BOR and NADB project. The numbers are dissimilar to the results presented in the main body of this report due to the difference in mathematical approaches, i.e., construction costs and O&M expenditures are not comprehensively evaluated per ac-ft of water savings and per BTU (kwh) of energy savings here.

Appendix Tables

Table A1. Summary of Calculated Values for 72" and 48" Pipeline Replacing Main Canal, Brownsville Irrigation District's BOR and NADB Project, 2003.

Item	Nominal PV	Real NPV
Dollars of Initial Construction Costs	$ 2,356,000	$ 2,356,000
Ac-Ft of Water Saved	96,011	40,208
BTU of Energy Saved	16,336,703,749	6,841,626,877
kwh of Energy Saved	4,788,014	2,005,166
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ (6,497,081)	$ (1,544,597)

Table A2. Legislated Evaluation Criteria for 72" and 48" Pipeline Replacing Main Canal, Brownsville Irrigation District's BOR and NADB Project, 2003.

Criteria	Nominal PV	Real NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 24.54	$ 58.60
Dollar of Initial Construction Costs per BTU of Energy Saved	$0.0001442	$0.0003444
Dollar of Initial Construction Costs per kwh of Energy Saved	$0.492	$1.175
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-0.363	-1.525

— Notes —