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August 2003

Texas Water Resources Institute
make every drop count

Economic and Conservation Evaluation of Capital Renovation Projects: Cameron County Irrigation District No. 2 (San Benito) – Infrastructure Rehabilitation – Final

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Allen W. Sturdivant
John R. C. Robinson
Michael C. Popp

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Texas A&M University

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Authors' Note:

The original *Preliminary TR-230* report was published in July 2003 and subsequently reviewed by the Texas Water Development Board (TWDB) and the Bureau of Reclamation (BOR). During the revision process, it was determined unit prices for pipe used in preparing the initial construction cost estimates were higher than would normally be expected. This *Final* (revised) report incorporates updated prices as well as minor edits to the text. Other changes (e.g., amount of water savings) between the original *Preliminary* and this *Final* report were not required/made.

This report was developed to assist the Cameron County Irrigation District #2 (CCID #2) in their submitting of project materials to the BOR. Distribution of this report will initially be limited to CCID #2 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 CCID #2 project be made available to other stakeholders and the public. This is anticipated to occur sometime in late 2003.

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Texas A&M University

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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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Allen W. Sturdivant
John R. C. Robinson
Michael C. Popp

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:

- ***Sonia Kaniger, Wayne Halbert, George Carpenter, Sonny Hinojosa, Joe Barrera, Bill Friend, Rick Smith, Tito Nieto, Nora Zapata, and Edd Fifer.*** 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;

- ***James Allard, Larry Walkoviak, Mike Irlbeck, and Thomas Michalewicz.*** These individuals are with the U.S. Bureau of Reclamation in various management, engineering, and environmental roles. They have been instrumental in fostering a collaborative environment in which several agencies mutually fulfill their responsibilities and conduct related activities. They 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

Table of Contents

Table of Contents, continued

Table of Contents, continued

Table of Contents, continued

Table of Contents, continued

Item | **Page**

List of Exhibits

List of Tables

List of Tables, continued

Table **Page**

List of Tables, continued

<u>Table</u> **<u>Page</u>**

List of Tables, continued

Table **Page**

List of Tables, continued

List of Tables, continued

List of Tables, continued

Economic and Conservation Evaluation of Capital Renovation Projects: Cameron County Irrigation District No. 2 (San Benito) – Infrastructure Rehabilitation – Final

Abstract

Initial construction costs and net annual changes in operating and maintenance expenses are identified for a five-component capital renovation project proposed by Cameron County Irrigation District No. 2, (a.k.a. San Benito) to the Bureau of Reclamation. The proposed project involves rehabilitating 42+ miles of canals, laterals, and pipelines. Both nominal and real estimates of water and energy savings and expected economic and financial costs of those savings are identified throughout the anticipated useful lives for all five components of 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 **19,580 ac-ft of water** per year and **2,151,277,209 BTUs (630,503 kwh) of energy** per year. The calculated economic and financial cost of water savings is estimated to be **$40.68 per ac-ft**. The calculated economic and financial cost of energy savings is estimated at **$0.0003952 per BTU ($1.348 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 aggregate initial construction cost per ac-ft of water savings measure is $40.42 per ac-ft of water savings. The aggregate initial construction cost per BTU (kwh) of energy savings measure is $0.0003679 per BTU ($1.255 per kwh). The aggregate ratio of initial construction costs per dollar of total annual economic savings is estimated to be -8.47.

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: Cameron County Irrigation District No. 2 (San Benito) – Infrastructure Rehabilitation – 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. Cameron County Irrigation District No. 2 (i.e., the District)'s project is included among the original four 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.

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, and using RGIDECON© to develop supportive materials documenting the sustainability of the projects being proposed by Texas irrigation districts to the Bureau of Reclamation.[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 Bureau will use the results for economic and energy evaluation.

This report provides documentation of the economic and conservation analysis conducted for the Cameron County Irrigation District No. 2's infrastructure rehabilitation project proposal to the Bureau of Reclamation (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]

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1 This report contains economic and financial analysis results for a capital rehabilitation project proposed by the Cameron County Irrigation District No. 2 (a.k.a. San Benito) in the Rio Grande Basin. Readers interested in the methodological background and/or prior reports are directed to pp. 66-67 which identify related publications.

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.

District Description

The District's irrigation water right (class A) is 147,824 ac-ft per year, with the actual water available varying from year to year. In addition, the District holds municipal/domestic water rights of 5,518 ac-ft per year, municipal water rights of 6,390 ac-ft per year, and industrial water rights of 4,650 ac-ft per year. The District contracts for delivery of municipal water to the East Rio Hondo Water Supply and Arroyo Water Supply Corporations (458 ac-ft and 200 ac-ft per year, respectively). The District's primary municipal customers include the City of San Benito (5,500 ac-ft per year) and the City of Rio Hondo (890 ac-ft per year). The District's largest industrial customer is Central Power and Light (2,400 ac-ft per year). The District is currently the only source of water for these municipal and industrial users. Municipal and industry (M&I) water use has been fairly consistent, ranging from 7,305 to 8,494 ac-ft, with the five-year average at 7,904 ac-ft.

Recent years' *agricultural* water diversions in the District have been significantly hampered by deficit allocations. Comparing long-term historical water-diversion values (i.e., eleven years of data beginning in 1986) with recent years' agricultural water diversions (i.e., five years between 1997-2001) reveals significant variability and a down trend. Long-term historical values range from 45,229 to 94,889 ac-ft, with an average of 75,325 ac-ft. Recent *agricultural* water diversions during 1997-2001 have ranged from 45,229 to 80,922 ac-ft, with the five-year average at 66,323 ac-ft.

Proposed Project Components

The infrastructure rehabilitation capital improvement project proposed by the District to the BOR consists of five components which are estimated to save 20,497.0 ac-ft per year, which translates into an annuity-equivalent value of 19,580.0 ac-ft per year. Specifically, it includes:

- installing 13.98 miles of geomembrane lining overlain with a shotcrete cover in **Canals B, C, and D** – this will reduce seepage in the now earthen canals by 7,503.2 ac-ft per year;

- installing 11.40 miles of pipeline in the **Canal B laterals** and reconstructing the farm turnouts to facilitate the use of portable flow meters {and abandoning .24 miles of pipeline} – this will reduce seepage and evaporation in the mostly earthen laterals, and allow for improved water management to reduce losses and demand by a total of 6,089.2 ac-ft per year;

- installing 5.54 miles of pipeline in the **Canal C laterals**, installing .49 miles of lining, and reconstructing the farm turnouts to facilitate the use of portable flow meters {and abandoning 1.19 miles of canal} – this will reduce seepage, evaporation, and spills in the mostly earthen laterals, and allow for improved water management to reduce losses and demand by a total of 1,693.9 ac-ft per year;

- installing 9.15 miles of geomembrane lining overlain with a shotcrete cover in **Old District 13 Canals** {and abandoning .18 miles of Canal 13-A1} – this will reduce seepage and evaporation in the now leaky-lined and earthen canals by 4,535.8 ac-ft per year; and

- installing 2.04 miles of pipeline in **Old District 13 Canals**, and reconstructing the farm turnouts to facilitate the use of portable flow meters – this will reduce seepage and evaporation in the earthen canals, and allow for improved water management to reduce losses and demand by a total of 674.9 ac-ft per year.

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 analyses of up to five 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.[3]

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 annual 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.[4]

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3 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.

4 A major assumption made by the authors and embedded in this and other economic and conservation analyses of proposed capital rehabilitation projects is that only the local ID's 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.

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 project 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.

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 five components comprising the Cameron County Irrigation District No. 2, (i.e., San Benito)'s Bureau of Reclamation (BOR) infrastructure rehabilitation project, and then aggregated across all components. With regards to water and energy savings, areas or sources are first identified, with the subsequent discussion quantifying estimates for those sources.

Component #1: Canals B, C, and D [Lining]

Component #1 of the District's proposed BOR project is referred to as "Canals B, C, and D" and consists of lining approximately 13.98 miles of mostly earthen canal with a geomembrane liner overlain by shotcrete. 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 $3,296,000 ($235,786 per mile). Annual increases in O&M expenditures for the new lining of $34,365 are expected. Additionally, reductions in annual O&M expenditures of $38,362 are anticipated from discontinued maintenance associated with the existing earthen canals. Therefore, a net decrease in annual O&M costs of $3,997 is expected (basis 2003 dollars).[5]

Anticipated Water and Energy Savings

Only off-farm water savings are predicted to be forthcoming from component #1, with the nominal total being 367,657 ac-ft over the 49-year productive life of this component and the real 2003 total being 153,971 ac-ft. The annual *off-farm* water-savings estimate of 7,503.2 ac-ft per year is based on seepage savings only. Since there are no annual *on-farm* water savings, the *off-farm* value represents total annual water savings, with associated energy savings estimates of 40,395,788,613 BTU (11,839,328 kwh) in nominal terms over the 49-year productive life and 16,917,299,679 BTU (4,958,177 kwh) in real 2003 terms. Energy savings are based only on reduced diversions at the Rio Grande, as relifting of water is not involved.

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

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from component #1 is estimated to be $26.13 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 $187,264 (in 2003 terms) by the annuity equivalent of the total net water savings of 7,167 ac-ft (in 2003 terms). The economic and financial cost of energy savings are estimated at $0.0002627 per BTU ($0.896 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $206,901 (in 2003 terms) by the annuity equivalent of the total net energy savings of 787,503,691 BTU (230,804 kwh) (in 2003 terms).

Component #2: Canal B Laterals [Pipeline]

Component #2 of the District's proposed BOR project is referred to as "Canal B Laterals" and primarily consists of converting approximately 11.40 miles of lateral to 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 $4,396,000 ($377,339 per mile). Annual increases in O&M expenditures for the new pipeline of $3,557 are expected. Additionally, reductions in annual O&M expenditures of $28,422 are anticipated from discontinued maintenance associated with the existing earthen laterals. Therefore, a net decrease in annual O&M costs of $24,865 is expected (basis 2003 dollars).[6]

Anticipated Water and Energy Savings

Both off- and on-farm water savings are predicted to be forthcoming from component #2, with the nominal total being 298,371 ac-ft over the 49-year productive life of this component and the real 2003 total being 124,954 ac-ft. The annual *off-farm* water-savings estimate of 5,468.4 ac-ft per year are based on 5,374.4 ac-ft seepage savings and 94.0 ac-ft evaporation savings. Annual *on-farm* water savings of 620.8 ac-ft are based on a 10% savings of the current flood-irrigation water used in the project component area, as facilitated by the use of portable flow meters. Combined water savings are 6,089.2 ac-ft per year, with associated energy savings estimates of 32,783,084,020 BTU (9,608,172 kwh) in nominal terms over the 49-year productive life and 13,729,185,042 BTU (4,023,794 kwh) in real 2003 terms. Energy savings are based only on reduced diversions at the Rio Grande, as relifting of water is not involved.

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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 contractor's warranty is expected to cover any extraordinary repair-type expense (Allard).

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from component #2 is estimated to be $40.37 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 $234,845 (in 2003 terms) by the annuity equivalent of the total net water savings of 5,817 ac-ft (in 2003 terms). The economic and financial cost of energy savings are estimated at $0.0003924 per BTU ($1.339 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $250,781 (in 2003 terms) by the annuity equivalent of the total net energy savings of 639,096,316 BTU (187,308 kwh) (in 2003 terms).

Component #3: Canal C Laterals [Pipeline]

Component #3 of the District's proposed BOR project is referred to as "Canal C Laterals" and primarily consists of converting approximately 5.54 miles of lateral to 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 $2,646,000 ($366,344 per mile). Annual increases in O&M expenditures for the new pipeline of $2,931 are expected. Additionally, reductions in annual O&M expenditures of $14,480 are anticipated from discontinued maintenance associated with the existing earthen laterals. Therefore, a net decrease in annual O&M costs of $11,549 is expected (basis 2003 dollars).[7]

Anticipated Water and Energy Savings

Both off- and on-farm water savings are predicted to be forthcoming from component #3, with the nominal total being 83,001 ac-ft over the 49-year productive life of this component and the real 2003 total being 34,760 ac-ft. The annual *off-farm* water-savings estimate of 1,511.5 ac-ft per year are based on 1,440.4 ac-ft seepage savings, 51.1 ac-ft evaporation savings, and 20.0 ac-ft spillage savings. Annual *on-farm* water savings of 182.4 ac-ft are based on a 10% savings of the current flood-irrigation water used in the project component area, as facilitated by the use of portable flow meters. Combined water savings are 1,693.9 ac-ft per year, with associated energy savings estimates of 9,119,632,468 BTU (2,672,811 kwh) in nominal terms over the 49-year productive life and 3,819,198,999 BTU (1,119,343 kwh) in real 2003 terms. Energy savings are based only on reduced diversions at the Rio Grande, as relifting of water is not involved.

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

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from component #3 is estimated to be $93.34 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 $151,029 (in 2003 terms) by the annuity equivalent of the total net water savings of 1,618 ac-ft (in 2003 terms). The economic and financial cost of energy savings are estimated at $0.0008744 per BTU ($2.984 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $155,462 (in 2003 terms) by the annuity equivalent of the total net energy savings of 177,784,479 BTU (52,106 kwh) (in 2003 terms).

Component #4: Old District 13 Canals [Lining]

Component #4 of the District's proposed BOR project is referred to as "Old District 13 Canals - (Lining)" and primarily consists of installing a geomembrane and shotcrete lining in approximately 9.15 miles of both earthen and gunite-lined canals. 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 $2,996,000 ($320,987 per mile). Annual increases in O&M expenditures for the new lining of $22,499 are expected. Additionally, reductions in annual O&M expenditures of $24,532 are anticipated from discontinued maintenance associated with the existing canals. Therefore, a net decrease in annual O&M costs of $2,033 is expected (basis 2003 dollars).[8]

Anticipated Water and Energy Savings

Only off-farm water savings are predicted to be forthcoming from component #4, with the nominal total being 222,254 ac-ft over the 49-year productive life of this component and the real 2003 total being 93,078 ac-ft. The annual *off-farm* water-savings estimate of 4,535.8 ac-ft per year is based on 4,534.1 ac-ft seepage savings and 1.7 ac-ft evaporation savings. Since there are no annual *on-farm* water savings, the *off-farm* value represents total annual water savings, with associated energy savings estimates of 24,419,876,585 BTU (7,157,056 kwh) in nominal terms over the 49-year productive life and 10,226,768,297 BTU (2,997,294 kwh) in real 2003 terms. Energy savings are based only on reduced diversions at the Rio Grande, as relifting of water is not involved.

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

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from component #4 is estimated to be $41.19 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 $178,464 (in 2003 terms) by the annuity equivalent of the total net water savings of 4,333 ac-ft (in 2003 terms). The economic and financial cost of energy savings are estimated at $0.0003998 per BTU ($1.364 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $190,335 (in 2003 terms) by the annuity equivalent of the total net energy savings of 476,058,114 BTU (139,525 kwh) (in 2003 terms).

Component #5: Old District 13 Canals [Pipeline]

Component #5 of the District's proposed BOR project is referred to as "Old District 13 Canals - (Pipeline)" and primarily consists of converting approximately 2.04 miles of earthen canal to 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 $826,000 ($404,947 per mile). Annual increases in O&M expenditures for the new pipeline of $636 are expected. Additionally, reductions in annual O&M expenditures of $5,598 are anticipated from discontinued maintenance associated with the existing earthen canals. Therefore, a net decrease in annual O&M costs of $4,962 is expected (basis 2003 dollars).[9]

Anticipated Water and Energy Savings

Both off- and on-farm water savings are predicted to be forthcoming from component #5, with the nominal total being 33,070 ac-ft over the 49-year productive life of this component and the real 2003 total being 13,849 ac-ft. The annual *off-farm* water-savings estimate of 467.3 ac-ft per year are based on 456.2 ac-ft seepage savings and 11.1 ac-ft evaporation savings. Annual *on-farm* water savings of 207.6 ac-ft are based on a 10% savings of the current flood-irrigation water used in the project component area, as facilitated by the use of portable flow meters. Combined water savings are 674.9 ac-ft per year, with associated energy savings estimates of 3,633,532,058 BTU (1,064,927 kwh) in nominal terms over the 49-year productive life and 1,521,682,156 BTU (445,980 kwh) in real 2003 terms. Energy savings are based only on reduced diversions at the Rio Grande, as relifting of water is not involved.

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

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from component #5 is estimated to be $69.76 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 $44,972 (in 2003 terms) by the annuity equivalent of the total net water savings of 645 ac-ft (in 2003 terms). The economic and financial cost of energy savings are estimated at $0.0006598 per BTU ($2.251 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $46,738 (in 2003 terms) by the annuity equivalent of the total net energy savings of 70,834,609 BTU (20,760 kwh) (in 2003 terms).

Total Across All Components

The methodology used in evaluating the economic and conservation potential of the proposed project and the respective individual components accounts for timing of inflows and outflows of funds and the anticipated installation and productive time periods of the investments. The cost measures calculated for the individual components are first converted into 'annuity equivalents,' prior to being aggregated into the comprehensive measures. The 'annuity equivalent' calculations facilitate comparison and aggregation of capital projects with unequal useful lives, effectively serving as development of a common denominator. The finance aspect of the 'annuity equivalent' calculation as it is used in the RGIDECON© analysis is such that it represents an annual cost savings associated with one unit of water (or energy) each year extended indefinitely into the future. Zero salvage values and continual replacement of the respective technologies (i.e., linings and pipelines) with similar capital items as their useful life ends are assumed.

Initial and O&M Costs

The total capital investment cost required for all components amounts to $14,160,000. Combining these costs with the projected changes in annual O&M expenditures, and the useful lives of the respective project components results in an annuity equivalent of $796,573 cost per year for water savings associated with the total project. The similar measure for costs of energy savings is $850,218 per year.

Anticipated Water and Energy Savings

Both *off*- and *on-farm* water savings are expected from the five components with the nominal total being 1,004,353 ac-ft over their expected productive lives and the real 2003 total being 420,612 ac-ft. On an average annual basis (or annuity equivalent basis), this amounts to 19,580 ac-ft across the five project components, representing **26.4%** of the last 5-years average water diversion, **22.4%** of the last 13-years average water diversion, and **21.0%** of the "adjusted" average water diversion by the District.[10] Annual water savings estimates are based on reduced

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[10] Review of historic volumes of water diverted from the Rio Grande document an evident down trend in recent years reflecting reduced allocations to an amount such that recent years' volumes do not accurately reflect "normal" volumes the District would have pumped had water supplies been available. Therefore, the

canal/lateral seepage, reduced evaporation, reduced spills, and increased on-farm efficiency through improved water management as facilitated by portable flow meters. Associated energy savings estimates are 110,351,913,744 BTU (32,342,294 kwh) in nominal terms over their lives and 46,214,134,173 BTU (13,544,588 kwh) in real 2003 terms. On an average annual basis (or annuity equivalent basis), this amounts to 2,151,277,209 BTU (630,503 kwh) across the five project components. Combined energy savings are based only on reduced diversions at the Rio Grande (resulting in improved water supplies), as relifting of water is not involved with any of the five project components.

Cost of Water and Energy Savings

The aggregation of the economic and financial costs of water and energy savings for the individual project components into cost measures for the total comprehensive project results in estimates of **$40.68 per ac-ft** cost of water savings and **$0.0003952 per BTU ($1.348 per kwh)** cost of energy savings.

Summary

The table at the top of the next page summarizes key information regarding each of the components of Cameron County Irrigation District No. 2's BOR project, with a more complete discussion provided in the text of the complete report.

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 shows how sensitive results are to variances in other input factors. Key variables subjected to sensitivity analyses include (a) the amount of reduction in annual 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.

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various percentages are identified, including the *adjusted* diverted volume determined by statistical operations as discussed on page 3.

Table ES1. Summary of Component Data and Economic and Conservation Analysis Results for Cameron County Irrigation District No. 2's Infrastructure Rehabilitation Project Proposed to BOR, 2003.

	Project Component					
	Canals B, C, and D (Lining)	Canal B Laterals (Pipe)	Canal C Laterals (Pipe)	Old District 13 Canals (Lining)	Old District 13 Pipelines (Pipe)	Aggregate
Initial Investment Cost ($)	$3,296,000	$4,396,000	$2,646,000	$ 2,996,000	$ 826,000	$ 14,160,000
Expected Useful Life (years)	49	49	49	49	49	n/a
Net Changes in Annual O&M ($)	($ 3,997)	($ 24,865)	($ 11,549)	($ 2,033)	($ 4,962)	$ (47,406)
Annuity Equivalent of Net Cost Stream – Water Savings ($/yr)	$ 187,264	$ 234,845	$ 151,029	$178,464	$ 44,972	$ 796,573
Annuity Equivalent of Water Savings (ac-ft)	7,167	5,817	1,618	4,333	645	19,580
Calculated Cost of Water Savings ($/ac-ft)	**$ 26.13**	**$ 40.37**	**$ 93.34**	**$ 41.19**	**$ 69.76**	**$ 40.68**
Annuity Equivalent of Net Cost Stream – Energy Savings ($/yr)	$ 206,901	$ 250,781	$ 155,462	$ 190,335	$ 46,738	$ 850,218
Annuity Equivalent of Energy Savings (BTUs)	787,503,691	639,096,316	177,784,479	476,058,114	70,834,609	2,151,277,209
Annuity Equivalent of Energy Savings (kwhs)	230,804	187,308	52,106	139,525	20,760	630,503
Calculated Cost of Energy Savings ($/BTU)	**$ 0.0002627**	**$ 0.0003924**	**$ 0.0008744**	**$ 0.0003998**	**$ 0.0006598**	**$ 0.0003952**
Calculated Cost of Energy Savings ($/kwh)	**$ 0.896**	**$ 1.339**	**$ 2.984**	**$ 1.364**	**$ 2.251**	**$ 1.348**

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 (BOR) 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 cost 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. **Although each component in this project has the same expected useful life, that may not be the case in other multi-component capital rehabilitation projects. In the event of dissimilar component useful lives, comparison of these calculated values could lead to erroneous conclusions.**

The initial construction cost per ac-ft of water savings measure is $40.42 per ac-ft of water savings which is slightly lower than the comprehensive economic and financial value of **$40.68 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 $0.0003679 per BTU ($1.255 per kwh). These cost estimates are lower than the **$0.0003952 per BTU ($1.348 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 -8.47, 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) $8.47 of initial construction costs are expended for each such dollar reduction in O&M expenditures, with the latter represented in total real 2003 dollars accrued across the five project components' respective planning periods.

Economic and Conservation Evaluation of Capital Renovation Projects: Cameron County Irrigation District No. 2 (San Benito) – Infrastructure Rehabilitation – Final

Introduction

Cameron County Irrigation District No. 2 (a.k.a. San Benito) is included among the four irrigation districts authorized for water conservation projects in the Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000 (Act), or United States Public Law (PL) 106-576. As stated in the legislation, "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 five components (focused on canal, lateral, and pipeline rehabilitation) comprising Cameron County Irrigation District No. 2 (the District)'s project proposed to the Bureau of Reclamation (BOR) during the Summer of 2003.[1]

Irrigation District Description[2]

Twenty-eight irrigation districts exist in the Texas Lower Rio Grande Valley (**Exhibit 1**).[3] The Cameron County Irrigation District No. 2 office is located in San Benito, Texas (**Exhibits 2** and **3**). The District boundary covers 64,282 acres of Cameron County (**Exhibit 4**). Postal and street addresses are P.O. Box 687, 216 S. Sam Houston, San Benito, TX 78586. Telephone contact information is 956/399-2484 and the fax number is 956/399-4721. Sonia Kaniger is the District Manager, with James Allard of the Bureau of Reclamation, Oklahoma City, OK, 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. 66-67 which identify related publications.

2 The general descriptive information was assimilated from: documents provided by Sonia Kaniger (the District manager), the IDEA web site maintained by Guy Fipps and his staff in the Department of Biological and Agricultural Engineering at Texas A&M University, College Station, Texas, the Final Project Plan (by U.S. Bureau Reclamation May 2002), 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 57,439 acres of agricultural cropland within its district. Furrow irrigation accounts for approximately 90% of irrigation deliveries. Special turnout connections were historically provided to the small percentage (i.e., 10%) of district customers utilizing polypipe, gated pipe, etc. Flood irrigation is the norm for orchards, sugarcane, and pastures. The typical crop mix across the District is noted in **Table 1**, which illustrates the relative importance (on an acreage basis) of grain sorghum, cotton, sugarcane, citrus, 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 contracts 7,075 acre feet (ac-ft) of municipal water diversions to the cities of San Benito and Rio Hondo, and the East Rio Hondo and Arroyo Water Supply Corporations (**Exhibit 5**). The District holds 6,390 ac-ft of municipal water rights, as well as 5,518 ac-ft of municipal/domestic water rights. These rights are in addition to the irrigation and industrial water rights the District holds. 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

Review of the District's historical water-use data reveals useful information (**Table 2**). Recent historical values (i.e., 1997-2001) for M&I water use reflect a fairly consistent range from 7,305 to 8,494 ac-ft, with the five-year average at 7,904 ac-ft. These values are somewhat lower

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

and less variable than the long-term historical values (i.e., select, available data from 1986-2001) which range from 7,305 to 13,035 ac-ft, with an average of 9,290 ac-ft.

Recent years' *agricultural* water use in the District has been significantly hampered by deficit allocations. Comparing long-term historical water-use values (i.e., eleven years of data beginning in 1986) with recent years' agricultural water use (i.e., five years of data for 1997-2001) reveals significant variability and a down trend. *Long-term* historical values range from 45,229 to 94,889 ac-ft, with an average at 75,325 ac-ft. *Recent* agricultural water use during 1997-2001 has ranged from 45,229 to 80,922 ac-ft, with the five-year average at 66,323 ac-ft.

Adjusted Historic Pumping Volumes

Review of historic volumes of water pumped (and that subsequently available to agriculture) by the District from 1986 to 2001 document an evident down trend in recent years reflecting reduced allocations caused by regional drought and non-payment of water releases by Mexico.[5] Thus, recent years' pumped volumes do not accurately reflect "normal" volumes the District would have pumped had water supplies been available. Therefore, to accurately analyze the full water-diversion potential of the District, *adjusted* water-pumped volumes by the District are necessary.[6] Adjusting the historic volume upwards for Cameron County Irrigation District No. 2 is an objective action taken by the authors which adheres to marginal-economic principles. Within this report, "adjusted" volumes are only used to compare the percentage that the annual water savings (i.e., annuity equivalent value) is in relation to historic diversions (i.e., as a percent of the last 5-year average, the last 13-year average, and the "adjusted" average).[7] In a previous report for the District (i.e., Rister et al. 2003a), the "adjusted" diversions were used to estimate the potential energy savings with new pumps and motors associated with a proposed new pumping plant.

Various methods are available to estimate "normal" historic pumping volumes by Cameron County Irrigation District No. 2. The method incorporated herein was to use statistical methods to develop a distribution of probabilities, based on actual historical pumped volumes

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5 Mexico is currently non-compliant (as per a 1944 Treaty with the United States) with regards to releasing water which would be used by Rio Grande Valley agricultural producers. The discussion and prevalent details of that issue is beyond the scope of this analysis report.

6 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 not realized with other irrigation district's analyses and reports completed thus far by the authors (e.g., Cameron County Irrigation District No. 1 (a.k.a. Harlingen), Hidalgo County Irrigation District No. 1 (a.k.a. Edinburg), and Hidalgo County Irrigation District No. 2 (a.k.a. San Juan). In fact, one district recently made a one-time sale of water (external to the District).

7 That is, none of the cost estimates are affected by or otherwise related to the assumed historic volumes of water diverted. This assumption is unlike that made for another district where water savings were calculated as a percentage of historic water volume diverted (Rister et al. 2002b).

(i.e., from 1986-2001). The result was an adjusted historical pumping volume estimate of 93,270 ac-ft. This value is 5,757 ac-ft more than that realized with a simple average over the same time-period.

Specifically, *Simetar*™ (a Microsoft Excel® add-in program developed by Richardson et al.) was used to calculate descriptive summary statistics (i.e., mean = 87,513 ac-ft; standard deviation = 16,272 ac-ft; min = 53,724 ac-ft; and max = 110,935 ac-ft) and a "normal" probability-based distribution for the actual 1986-2001 data. For example, according to the historic data, there is a 0% chance of total water diversions being equal to or below 53,718 ac-ft; a 50% chance of water use being equal to or below 93,270 ac-ft; and a 100% chance of water use being equal to or below 110,945 ac-ft (**Table 3**). As visualized by a histogram, *Simetar*™ determined the actual data distribution is skewed to the right. If the data followed a normal distribution, a 50% probability would be expected about the actual mean of 87,513 ac-ft. With the data skewed to the right, however, *Simetar*™ adjusted the expected values to a normal distribution of probabilities and determined 93,270 ac-ft to have a 50% probability of occurring (i.e., adjusted expected mean or "average").

Assessment of Technology and Efficiency Status

The District's pumping plant diverts water from the Rio Grande near the town of Los Indios (**Exhibit 5**). From there, the water flows into either the High-Line canal which provides water to the southern part of the District, or the Low-Line canal which provides water to the northern part of the District and two reservoirs adjacent to the pumping plant. The original pumping plant was built around 1910 and has a typical operating capacity of 430 cfs and a maximum of 510 cfs. More than 207 miles of canals, 15 miles of resacas, 5.5 miles of pipelines, 10 relift pumping stations, and two storage reservoirs (totaling 5,500 ac-ft holding capacity) comprise the majority of the District's delivery-system infrastructure.

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 initiated a Geographic Information System (GIS) program for linking a mapping system to a data base, indicating: where water has been ordered; for what types of crops; and various systems necessary to deliver the water. Volumetric pricing in water deliveries is not an important aspect of district operations as only about 1 percent of current agricultural water use is volumetrically measured. Producers' use of water-conserving methods and equipment is encouraged (Kaniger).

Water Rights Ownership and Sales

The District holds eight Certificates of Adjudication (i.e., #'s 0841-000 through 0841-006, and 0051-000 (**Table 4**). Additional M&I water rights (i.e., Certificates of Adjudication) for 2,075 ac-ft belong to the East Rio Hondo and Arroyo Water Supply Corporations and the City of San Benito, with the District providing diversion and delivery of the water. Further, users interested in acquiring additional water beyond their available allocations may acquire such water from parties interested in selling or leasing rights. Such external-to-the-District purchases and/or leases are subject to a transportation delivery loss charged by the District; that is, purchase or lease of one ac-ft from sources outside the District will result in users receiving some amount less than one ac-ft at their diversion point.

Water charges assessed irrigators within the District consist of an annual flat-rate maintenance and operations fee assessment of $30.00 for the first irrigated acre and $8.50 for every acre thereafter (which is paid for by the landowner) (**Table 4**). An additional $7.00 per acre per irrigation is assessed (either to the landowner-operator, or tenant-producer), with such irrigations approximated as using 0.5 ac-ft of water per acre. This equates to a variable charge of $14.00 per ac-ft of water. Volumetrically-priced irrigation water (i.e., only about 1% of agricultural irrigation use) is priced at $17.50 per ac-ft in the District (Kaniger) (**Table 4**).

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 (Kaniger). 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 improvements for this project focus on the rehabilitation of numerous canals, laterals, and pipelines representing over 42 miles of District infrastructure. The entire proposed infrastructure-rehabilitation project has been organized by BOR engineers into five separate project components.[8]

Component #1: Canals B, C, and D [Lining]

Canals B, C, and D are the main canals servicing the northern part of the District. Summary data for this component are presented in **Tables 5, 6,** and **7** with discussion of that data following.

Description

This project primarily consists of replacing approximately 13.98 miles of mostly earthen canals (i.e., B, C, and D) with a geomembrane liner overlain by shotcrete, and installing a ramp flume at the Canal C headworks. Once installed and brought on-line, this component is expected to (**Table 5**):

8 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.

a) reduce seepage estimated at 7,503.2 ac-ft per year; and
b) provide new flow-measurement data which will improve water management in the entire northern part of the District.

Installation Period

It is anticipated that it will take one year after purchase and project initiation for the lining 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 new lining (and ramp flume) 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 (Allard). 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 13.98 miles of lining total $3,296,000 ($235,786 per mile) in 2003 nominal dollars (**Tables 6** and **7**) (Allard). Sensitivity analysis on the total amount of all capital expenditures are 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) expenditures associated with the installed lining are expected to be different than those presently occurring for the earthen Canals B, C, and D. Annual O&M expenditures associated with the affected canals after installation of the lining are anticipated to be $34,365 (basis 2003 dollars) (**Table 6**). In the first two years after

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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©.

installation of the lining, the 'lining - leak repair' portion of O&M are assumed to be covered by the contractor's warranty (Allard).

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 savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.[10]

Off-farm savings are those occurring in the District's canal delivery system as a result of reduced seepage after Canals B, C, and D are lined. Bureau of Reclamation engineers incorporated existing surveys, wetted perimeter calculations, a 95% efficiency variable, etc. to estimate 7,503.2 ac-ft per year of water savings forthcoming from reduced seepage with the future lining of Canals B, C, and D (**Table 5**). 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 loss 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 (Allard), consistent with assumptions embedded in previous analyses (Rister et al. 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2003e, and 2003f).

Estimates of *off-farm* water savings do not include any conveyance losses that could potentially be realized during delivery of the water from the Rio Grande to the farm turnout gates. Thus, all noted water savings are based on a "delivered" basis, which is the same as the "diverted" basis for this project analysis.[11]

As shown in **Table 5**, *on-farm* water savings are not expected to be forthcoming from this component. Therefore, combining all water savings (without any additional conveyance loss included) results in 7,503.2 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 canals' productive lives to provide for a conservative analysis. Sensitivity analyses are performed on all water

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10 A major assumption made by the authors and embedded in this and other economic and conservation analyses of proposed capital rehabilitation projects is that only the local ID's 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 The District's system-wide conveyance loss is estimated to be 60% (Fipps and Pope), as determined by total water diversions minus total water sales (Allard). For the five components comprising the 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 canal system. That is, with water being saved at a component/project site, 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(s) (Allard).

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 a general sense, 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 canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below for component #1 of the District's five-component project. Energy savings associated with only reduced diversions are expected with this component 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.[12] Recent historic records for calendar years 1997-2001 are presented in **Table 8** (diversion energy) with electricity representing 96% of the District's total diversion-energy expense. The District's average lift at the Rio Grande diversion site is 20 feet (**Table 4**). On average, 109,874 BTU were used to pump each ac-ft of water diverted (**Table 8**). Multiplying this value by the anticipated 7,503.2 ac-ft of annual *off-farm* water savings results in anticipated annual irrigation energy savings of 824,403,849 BTU (241,619 kwh) (**Table 5**). Assuming the historical average cost of $0.061 per kwh (i.e., 1997-2001) (**Table 8**),[13] the estimated annual *off-farm* irrigation energy cost savings (associated with water savings) are $14,824 in 2003 dollars (**Table 5**). Since there are no *on-farm* savings, the *off-farm* values represent total savings for this component. 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. It is estimated that annual O&M expenses for the existing earthen canals amount to $38,362 (Kaniger). Thus, across the total 13.98 miles of Canals B, C, and D proposed for relining, a reduction of $3,997 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 #2: Canal B Laterals [Pipeline]

Canal B Laterals are supplied by Canal B in the northern part of the District. Summary data for this component are presented in **Tables 5, 6,** and **7** with discussion of that data following.

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12 Here and elsewhere in this report, it is assumed the current pumping plant remains in operation. That is, all energy values are based on the current pumping plant's efficiency.

13 This estimated value is calculated using District information provided by Sonia Kaniger which incorporates recognition of the sources of pumping power (i.e., electric and natural gas) and their costs.

Description

This project primarily consists of replacing approximately 11.40 miles of mostly earthen laterals (i.e., Canal B laterals) with pipeline and reconstructing the farm turnouts to facilitate use of portable flow meters. Once installed and brought on-line, this component is expected to (**Table 5**):

a) reduce seepage estimated at 5,374.4 ac-ft per year;
b) reduce evaporation estimated at 94.0 ac-ft per year; and
c) reduce demand in the project component area by an estimated 620.8 ac-ft per year as facilitated by the use of portable flow meters.

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[14] for the new 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 (Allard). 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 11.40 miles of pipeline total $4,396,000 ($377,339 per mile) in 2003 nominal dollars (**Tables 6** and **7**) (Allard). Sensitivity analysis on the total amount of all capital expenditures are utilized to examine the

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14 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©.

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) expenditures associated with the installed pipeline are expected to be different than those presently occurring for the earthen Canal B Laterals. Annual O&M expenditures associated with the affected laterals after installation of the pipeline are anticipated to be $3,557 (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 (Allard).

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 both off-farm and on-farm savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.[15]

Off-farm savings are those occurring in the District's canal delivery system as a result of reduced seepage and evaporation after the Canal B Laterals are replaced with pipeline. Bureau of Reclamation engineers incorporated existing surveys, wetted perimeter calculations, a 95% efficiency variable, etc. to estimate 5,468.4 ac-ft per year (i.e., 5,374.4 + 94.0) of water savings forthcoming from reduced seepage and evaporation with the future piping of the Canal B Laterals (**Table 5**). 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 loss 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 (Allard), consistent with assumptions embedded in previous analyses (Rister et al. 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2003e, and 2003f).

Annual *on-farm* savings of 620.8 ac-ft (**Table 5**) per year are expected from improved water management by using portable flow meters, which will be facilitated by the reconstructing of the farm turnouts in this project. The savings attributed to water-metering is based on a 10% savings of the current flood-irrigation water used on the affected acres serviced by this project component (Allard). The combined annual *off-farm* and *on-farm* water savings forthcoming from the Canal B Laterals project component are estimated at 6,089.2 ac-ft (**Table 5**) (i.e., 5,374.4 + 94.0 + 620.8).

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15 A major assumption made by the authors and embedded in this and other economic and conservation analyses of proposed capital rehabilitation projects is that only the local ID's 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.

Estimates of both *off-* and *on-farm* water savings do not include any conveyance losses that could potentially be realized during delivery of the water from the Rio Grande to the farm turnout gates. Thus, all noted water savings are based on a "delivered" basis, which is the same as the "diverted" basis for this project analysis.[16]

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 6,089.2 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 component'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-* and *on-farm* water savings for this project are expected to result in reduced Rio Grande diversions.

Energy. In a general sense, 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 canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below for component #2 of the District's five-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 records for calendar years 1997-2001 are presented in **Table 8** (diversion energy) with electricity representing 96% of the District's total diversion-energy expense. The District's average lift at the Rio Grande diversion site is 20 feet (**Table 4**). On average, 109,874 BTU were used to pump each ac-ft of water diverted (**Table 8**). Multiplying this value by the anticipated 5,468.8 ac-ft (5,374.4 + 94.0) of *off-farm* annual water savings results in anticipated annual irrigation energy savings of 600,832,979 BTU (176,094 kwh) (**Table 5**). Assuming the historical average cost of $0.061 per kwh (i.e., 1997-2001) (**Table 8**),[17] the estimated annual *off-farm* irrigation energy cost savings (associated with total water savings) are $10,804 in 2003 dollars (**Table 5**).

Savings anticipated for the *on-farm* reductions in water use, due to metering farm turnouts with portable flow meters, are determined in similar fashion and also appear in **Table 5**. Using the 109,874 BTU per ac-ft and multiplying by the 620.8 ac-ft of annual *on-farm* water

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16 The District's system-wide conveyance loss is estimated to be 60% (Fipps and Pope), as determined by total water diversions minus total water sales (Allard). For the five components comprising the 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 canal system. That is, with water being saved at a component/project site, 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(s) (Allard).

17 This estimated value is calculated using District information provided by Sonia Kaniger which incorporates recognition of the sources of pumping power (i.e., electric and natural gas) and their costs.

savings due to metering results in additional anticipated annual irrigation energy savings of 68,209,552 BTU (19,991 kwh). Again, assuming the historical average diversion-energy cost of $0.061/kwh, the estimated annual irrigation *on-farm* energy cost savings are $1,227 in 2003 dollars (**Tables 5** and **8**). Combining both the *off-* and *on-farm* water savings results in total anticipated irrigation energy cost savings of 669,042,531 BTU (196,085 kwh) or the equivalent of $12,030 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. It is estimated that annual O&M expenses for the existing mostly earthen Canal B Laterals are $28,422 (Kaniger). Thus, across the total 11.40 miles of Canal B Laterals proposed for replacing with pipeline, a reduction of $24,865 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 #3: Canal C Laterals [Pipeline]

Canal C Laterals are supplied by Canal C in the northern part of the District. Summary data for this component are presented in **Tables 5, 6,** and **7** with discussion of that data following.

Description

This project primarily consists of replacing approximately 5.54 miles of mostly earthen laterals (i.e., Canal C laterals) with pipeline and reconstructing the farm turnouts to facilitate use of portable flow meters. Once installed and brought on-line, this component is expected to (**Table 5**):

a) reduce seepage estimated at 1,440.4 ac-ft per year;
b) reduce evaporation estimated at 51.1 ac-ft per year;
c) reduce spills due to failure in Canal C adjacent to the Arroyo Colorado, which will save an estimated 20.0 ac-ft per year; and
d) reduce demand in the project area by an estimated 182.4 ac-ft per year as facilitated by the use of portable flow meters.

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[18] for the new 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 (Allard). 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 5.54 miles of pipeline total $2,646,000 ($366,344 per mile) in 2003 nominal dollars (**Tables 6** and **7**) (Allard). Sensitivity analysis on the total amount of all capital expenditures are 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) expenditures associated with the installed pipeline are expected to be different than those presently occurring for the earthen Canal C Laterals. Annual O&M expenditures associated with the affected laterals after installation of the pipeline are anticipated to be $2,931 (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 (Allard).

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 both off-farm and on-farm

18 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©.

savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.[19]

Off-farm savings are those occurring in the District's canal delivery system as a result of reduced seepage, evaporation, and spills after the Canal C Laterals are replaced with pipeline. Bureau of Reclamation engineers incorporated existing surveys, wetted perimeter calculations, a 95% efficiency variable, etc. to estimate 1,491.5 ac-ft per year (i.e., 1,440.4 + 51.1) of water savings forthcoming from reduced seepage and evaporation with the future piping of the Canals C Laterals (**Table 5**). 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 loss 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 (Allard), consistent with assumptions embedded in previous analyses (Rister et al. 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2003e, and 2003f). Additional *off-farm* water savings of 20.0 ac-ft per year (**Table 5**) are expected from reducing spills which will be realized after piping of the Canal C Laterals. Thus, total annual *off-farm* savings are 1,511.5 ac-ft (i.e., 1,440.4 + 51.1 + 20.0).

Annual *on-farm* savings of 182.4 ac-ft (**Table 5**) per year are expected from improved water management by using portable flow meters, which will be facilitated by the reconstructing of the farm turnouts in this project. The savings attributed to water-metering is based on a 10% savings of the current flood-irrigation water used on the affected acres serviced by this project component (Allard). The combined annual *off-farm* and *on-farm* water savings forthcoming from the Canal C Laterals project component are estimated at 1,693.9 ac-ft (**Table 5**) (i.e., 1,440.4 + 51.1 + 20.0 + 182.4).

Estimates of both *off-* and *on-farm* water savings do not include any conveyance losses that could potentially be realized during delivery of the water from the Rio Grande to the farm turnout gates. Thus, all noted water savings are based on a "delivered" basis, which is the same as the "diverted" basis for this project analysis.[20]

On-farm water savings from reduced percolation losses are <u>not</u> expected to be forthcoming from this component. Therefore, combining all *off-* and *on-farm* water savings (without any additional conveyance loss included) results in 1,693.9 ac-ft (**Table 5**) being

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19 A major assumption made by the authors and embedded in this and other economic and conservation analyses of proposed capital rehabilitation projects is that only the local ID's 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.

20 The District's system-wide conveyance loss is estimated to be 60% (Fipps and Pope), as determined by total water diversions minus total water sales (Allard). For the five components comprising the 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 canal system. That is, with water being saved at a component/project site, 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(s) (Allard).

analyzed in the base analysis. As with other estimated water savings, this value is held constant during each year of the component'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-* and *on-farm* water savings for this project are expected to result in reduced Rio Grande diversions.

Energy. In a general sense, 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 canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below for component #3 of the District's five-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 records for calendar years 1997-2001 are presented in **Table 8** (diversion energy) with electricity representing 96% of the District's total diversion-energy expense. The District's average lift at the Rio Grande diversion site is 20 feet (**Table 4**). On average, 109,874 BTU were used to pump each ac-ft of water diverted (**Table 8**). Multiplying this value by the anticipated 1,511.5 ac-ft of annual *off-farm* water savings results in anticipated annual irrigation energy savings of 166,073,998 BTU (48,674 kwh) (**Table 5**). Assuming the historical average cost of $0.061 per kwh (i.e., 1997-2001) (**Table 8**),[21] the estimated annual *off-farm* irrigation energy cost savings (associated with water savings) are $2,986 in 2003 dollars (**Table 5**).

Savings anticipated for the *on-farm* reductions in water use, due to metering farm turnouts with portable flow meters, are determined in similar fashion and also appear in **Table 5**. Using the 109,874 BTU per ac-ft and multiplying by the 182.4 ac-ft of annual *on-farm* water savings due to metering results in additional anticipated annual irrigation energy savings of 20,040,951 BTU (5,874 kwh). Again, assuming the historical average diversion-energy cost of $0.061/kwh, the estimated annual irrigation *on-farm* energy cost savings are $360 in 2003 dollars (**Tables 5** and **8**). Combining both the *off-* and *on-farm* water savings results in total anticipated irrigation energy cost savings of 186,114,948 BTU (54,547 kwh) or the equivalent of $3,347 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. It is estimated that annual O&M expenses for the existing mostly earthen Canal C Laterals are $14,480 (Kaniger). Thus, across the total 5.54 miles of Canal C Laterals proposed for replacing with pipeline, a reduction of $11,549 in O&M expense is anticipated (**Table 6**).

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21 This estimated value is calculated using District information provided by Sonia Kaniger which incorporates recognition of the sources of pumping power (i.e., electric and natural gas) and their costs.

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 #4: Old District 13 Canals [Lining]

The Old District 13 Canals which are proposed to be lined are supplied by Canal 13-A in the northeastern part of the District. Summary data for this component are presented in **Tables 5, 6,** and **7** with discussion of that data following.

Description

This project primarily consists of replacing approximately 9.15 miles of canals in an area known as 'Old District 13' with a geomembrane liner overlain by shotcrete. Once installed and brought on-line, this component is expected to (**Table 5**):

a) reduce seepage estimated at 4,534.1 ac-ft per year; and
b) reduce evaporation at 1.7 ac-ft per year.

Installation Period

It is anticipated that it will take one year after purchase and project initiation for the lining 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[22] for the new lining 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 (Allard). 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.

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22 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©.

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 9.15 miles of lining total $2,996,000 ($320,987 per mile) in 2003 nominal dollars (**Tables 6** and **7**) (Allard). Sensitivity analysis on the total amount of all capital expenditures are 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) expenditures associated with the installed lining are expected to be different than those presently occurring for the Old District 13 Canals. Annual O&M expenditures associated with the affected canals after installation of the lining are anticipated to be $22,499 (basis 2003 dollars) (**Table 6**). In the first two years after installation of the lining, the 'lining - leak repair' portion of O&M are assumed to be covered by the contractor's warranty (Allard).

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 savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.[23]

Off-farm savings are those occurring in the District's canal delivery system as a result of reduced seepage and evaporation after the subject Old District 13 Canals are lined. Bureau of Reclamation engineers incorporated existing surveys, wetted perimeter calculations, a 95% efficiency variable, etc. to estimate 4,535.8 ac-ft per year (i.e., 4,534.1 + 1.7) of water savings forthcoming from reduced seepage and evaporation with the future lining of the Old District 13 Canals (**Table 5**). 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 loss 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 (Allard), consistent with assumptions embedded in previous analyses (Rister et al. 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2003e, and 2003f).

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23 A major assumption made by the authors and embedded in this and other economic and conservation analyses of proposed capital rehabilitation projects is that only the local ID's 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.

Estimates of *off-farm* water savings do not include any conveyance losses that could potentially be realized during delivery of the water from the Rio Grande to the farm turnout gates. Thus, all noted water savings are based on a "delivered" basis, which is the same as the "diverted" basis for this project analysis.[24]

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 4,535.8 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 component'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 a general sense, 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 canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below for component #4 of the District's five-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 records for calendar years 1997-2001 are presented in **Table 8** (diversion energy) with electricity representing 96% of the District's total diversion-energy expense. The District's average lift at the Rio Grande diversion site is 20 feet (**Table 4**). On average, 109,874 BTU were used to pump each ac-ft of water diverted (**Table 8**). Multiplying this value by the anticipated 4,535.8 ac-ft of annual *off-farm* water savings results in anticipated annual irrigation energy savings of 498,364,828 BTU (146,062 kwh) (**Table 5**). Assuming the historical average cost of $0.061 per kwh (i.e., 1997-2001) (**Table 8**),[25] the estimated annual *off-farm* irrigation energy cost savings (associated with water savings) are $8,961 in 2003 dollars (**Table 5**). Since there are no *on-farm* savings, the *off-farm* values represent total savings for this component. 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.

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24 The District's system-wide conveyance loss is estimated to be 60% (Fipps and Pope), as determined by total water diversions minus total water sales (Allard). For the five components comprising the 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 canal system. That is, with water being saved at a component/project site, 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(s) (Allard).

25 This estimated value is calculated using District information provided by Sonia Kaniger which incorporates recognition of the sources of pumping power (i.e., electric and natural gas) and their costs.

Operating and Maintenance. It is estimated that annual O&M expenses for the existing Old District 13 Canals (proposed for lining) are $24,532 (Kaniger). Thus, across the total 9.15 miles of Old District 13 Canals proposed for lining, a reduction of $2,033 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 #5: Old District 13 Canals [Pipeline]

The Old District 13 Canals which are proposed to be converted to pipeline are supplied by Canal 13-A1 in the northeastern part of the District. Summary data for this component are presented in **Tables 5, 6,** and **7** with discussion of that data following.

Description

This project primarily consists of replacing approximately 2.04 miles of earthen canals in an area known as 'Old District 13' with pipeline and reconstructing the farm turnouts to facilitate use of portable flow meters. Once installed and brought on-line, this component is expected to (**Table 5**):

a) reduce seepage estimated at 456.2 ac-ft per year;
b) reduce evaporation estimated at 11.1 ac-ft per year; and
c) reduce demand in the project component area by an estimated 207.6 ac-ft per year as facilitated by the use of portable flow meters.

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[26] for the new 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 (Allard). Sensitivity analyses are utilized to examine

[26] 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©.

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 2.04 miles of pipeline total $826,000 ($404,947 per mile) in 2003 nominal dollars (**Tables 6** and **7**) (Allard). Sensitivity analysis on the total amount of all capital expenditures are 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) expenditures associated with the installed pipeline are expected to be different than those presently occurring for the earthen Old District 13 Canals. Annual O&M expenditures associated with the affected canals after installation of the pipeline are anticipated to be $636 (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 (Allard).

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 both off-farm and on-farm savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.[27]

Off-farm savings are those occurring in the District's canal delivery system as a result of reduced seepage and evaporation after the Old Canal 13 Canals are replaced with pipeline. Bureau of Reclamation engineers incorporated existing surveys, wetted perimeter calculations, a 95% efficiency variable, etc. to estimate 467.3 ac-ft per year (i.e., 456.2 + 11.1) of water savings forthcoming from reduced seepage and evaporation with the future piping of the Old District 13

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27 A major assumption made by the authors and embedded in this and other economic and conservation analyses of proposed capital rehabilitation projects is that only the local ID's 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.

Canals (**Table 5**). 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 loss 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 (Allard), consistent with assumptions embedded in previous analyses (Rister et al. 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2003e, and 2003f).

Annual *on-farm* savings of 207.6 ac-ft (**Table 5**) per year are expected from improved water management by using portable flow meters, which will be facilitated by the reconstructing of the farm turnouts in this project. The savings attributed to water-metering is based on a 10% savings of the current flood-irrigation water used on the affected acres serviced by this project component (Allard). The combined annual *off-farm* and *on-farm* water savings forthcoming from the 'Old District 13 Canals - Pipe' project component are estimated at 674.9 ac-ft (**Table 5**) (i.e., 456.2 + 11.1 + 207.6).

Estimates of both *off-* and *on-farm* water savings do not include any conveyance losses that could potentially be realized during delivery of the water from the Rio Grande to the farm turnout gates. Thus, all noted water savings are based on a "delivered" basis, which is the same as the "diverted" basis for this project analysis.[28]

On-farm water savings from reduced percolation losses are <u>not</u> expected to be forthcoming from this component. Therefore, combining all *off-* and *on-farm* water savings (without any additional conveyance loss included) results in 674.9 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 component'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-* and *on-farm* water savings for this project are expected to result in reduced Rio Grande diversions.

<u>Energy</u>. In a general sense, energy savings for a given project <u>may</u> 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 canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below for component #5 of the District's five-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

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28 The District's system-wide conveyance loss is estimated to be 60% (Fipps and Pope), as determined by total water diversions minus total water sales (Allard). For the five components comprising the 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 canal system. That is, with water being saved at a component/project site, 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(s) (Allard).

historic records for calendar years 1997-2001 are presented in **Table 8** (diversion energy) with electricity representing 96% of the District's total diversion-energy expense. The District's average lift at the Rio Grande diversion site is 20 feet (**Table 4**). On average, 109,874 BTU were used to pump each ac-ft of water diverted (**Table 8**). Multiplying this value by the anticipated 467.3 ac-ft of annual *off-farm* water savings results in anticipated annual irrigation energy savings of 51,343,949 BTU (15,048 kwh) (**Table 5**). Assuming the historical average cost of $0.061 per kwh (i.e., 1997-2001) (**Table 8**),[29] the estimated annual *off-farm* irrigation energy cost savings (associated with water savings) are $923 in 2003 dollars (**Table 5**).

Savings anticipated for the *on-farm* reductions in water use, due to metering farm turnouts with portable flow meters, are determined in similar fashion and also appear in **Table 5**. Using the 109,874 BTU per ac-ft and multiplying by the 207.6 ac-ft of annual *on-farm* water savings due to metering results in additional anticipated annual irrigation energy savings of 22,809,766 BTU (6,685 kwh). Again, assuming the historical average diversion-energy cost of $0.061/kwh, the estimated annual irrigation *on-farm* energy cost savings are $410 in 2003 dollars (**Tables 5** and **8**). Combining both the *off-* and *on-farm* water savings results in total anticipated irrigation energy cost savings of 74,153,715 BTU (21,733 kwh) or the equivalent of $1,333 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. It is estimated that annual O&M expenses for the existing earthen Old District 13 Canals (proposed for conversion to pipe) are $5,598 (Kaniger). Thus, across the total 2.04 miles of Old District 13 Canals proposed for replacing with pipeline, a reduction of $4,962 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.

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29 This estimated value is calculated using District information provided by Sonia Kaniger which incorporates recognition of the sources of pumping power (i.e., electric and natural gas) and their costs.

Abbreviated Discussion of Methodology[30]

Texas Agricultural Experiment Station and Texas Cooperative Extension economists have developed an economic spreadsheet model, RGIDECON© (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 are attuned to 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 both from 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 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 Appendices A and B.

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30 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."

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.[31]

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.

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

[31] 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).

based both on the mathematical relationship presented above and analyses of several pertinent price index series and discussions with selected professionals.[32]

Pre-Project Annual Water Use by the District

Water availability and use in the District has varied considerably in recent years as a result of water shortages in the Rio Grande Basin. **Table 2** contains the District's historic water use among agricultural irrigation and M&I along with an indication of the total use for most years from 1986-2001. 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 Extension 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), 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 total water use has averaged 74,227 ac-ft during recent years from 1997-2001, and 87,513 ac-ft in the 16-year period from 1986-2001 (**Table 2**). Review of historic volumes of water pumped (and that subsequently available to agriculture) by the District from 1986 to 2001 reveals an evident down trend, reflecting reduced allocations. The down trend as evidenced in **Table 2** is, in the opinions of Texas Agricultural Experiment Station and Texas Cooperative Extension Service economists, significant enough to warrant *adjustments* for the purpose of acknowledgment in this analysis. To analyze the down trend, statistical methods based on a probability distribution of actual historical data were used to *adjust* water-pumped volumes up from their nominal average of 87,513 ac-ft to an adjusted estimate of 93,270 ac-ft (i.e., an increase of 5,757 ac-ft) (**Table 3**). This adjusted value is perceived as appropriate for gauging future water needs (Kaniger).

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, essentially stopping short of a complete cost-benefit analysis.[33] The results of this analysis can

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32 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.

33 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

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.[34] The historic average *diversion-energy* usage level of 109,874 BTU per ac-ft of water diverted by the District for calendar years 1997-2001 is used to estimate energy savings resulting when less water is diverted from the Rio Grande due to implementation of the proposed project components (**Table 8**). Thus, it is anticipated that 109,874 BTU will be saved when diversions from the Rio Grande are lessened by one ac-ft. 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 calendar years 1997-2001 indicate *diversion-energy* costs for the District have ranged from $1.31 to $2.67 per ac-ft diverted, with the average of $1.98 per ac-ft 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 individual project components. Results aggregated across the five project components are presented in a subsequent section.

Component #1: Canals B, C, and D [Lining]

The first component evaluated is the lining of 13.98 miles of Canals B, C, and D with a geomembrane/shotcrete cover. Results of the analysis for this component follow (**Table 9**).

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assessment requirements specified in the Public Law 106-576 legislation.

34 "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)

Quantities of Water and Energy Savings

Critical values in the analysis are the quantities of water and energy anticipated being saved during the 49-year productive life of the lining.[35] On a nominal (i.e., non-discounted) basis, 367,657 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component.[36] Thus, the total nominal water savings anticipated are 367,657 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 153,971 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 153,971 ac-ft (**Table 9**).

On a nominal (i.e., non-discounted) basis, 40,395,788,613 BTU (11,839,328 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 16,917,299,679 BTU (4,958,177 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.

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 lining project is $1,660,654 (**Table 9**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $2,900,884 (**Table 9**). This amount represents, across the total 50-year

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35 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©.

36 As noted previously, the District diverts water for both M&I and agricultural concerns, and technically one could allocate a proportionate share of the forecast water savings to M&I water use. That is, in the last 5-years, M&I water use has averaged 11% of total District diversions (i.e., 7,904 ac-ft of 74,227 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.

planning period, the total net costs, in 2003 dollars, of purchasing and installing the lining 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 positive nominal-value amount. This result occurs because in the nominal-value amount, the savings accruing from reduced energy use in the lengthy planning period are sufficient to offset a large portion of 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 367,657 ac-ft (**Table 9**). The corresponding total real water savings expressed in 2003 water quantities are 153,971 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 $2,900,884 correlates with the real water savings projection of 153,971 ac-ft. The estimated cost of saving one ac-ft of water using the lining system comprising this project component is $26.13 (**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 lining 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 annual Rio Grande diversions that will result from the purchase, installation, and implementation of the lining in the water-delivery system. Thus, the cost per ac-ft of water-saved sensitivity analysis consist of varying the off-farm water-savings dimension[37] of that factor across a range of 3,750 to 10,500 ac-ft (including the baseline 7,503 ac-ft) for the lining 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 sensitivity analyses are presented in **Tables 10, 11,** and **12**, respectively.

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[37] When present, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of a proposed component. Thus, as the off-farm water savings associated with a component is varied in the sensitivity analyses, the on-farm savings (as applicable) also vary.

Table 10 reveals a range of $17.89 to $116.70 cost per ac-ft of savings around the baseline estimate of $26.13. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the lining from as low as 3,750 ac-ft up to 10,500 ac-ft about the expected 7,503 ac-ft and by investigating a range of useful lives of the lining 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, lower off-farm water savings than the predicted 7,503 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 $14.67 to $64.03 per ac-ft of savings around the baseline estimate of $26.13. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the lining from as low as 3,750 ac-ft up to 10,500 ac-ft about the expected 7,503 ac-ft and by considering variations in the cost of the capital investment in the lining varying from $500,000 less than the expected $3,296,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $3,296,000 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 annual Rio Grande diversions arising from investment in lining and the cost of energy. **Table 12** is an illustration of the results of varying those parameters from as low as 3,750 ac-ft up to 10,500 ac-ft about the expected 7,503 ac-ft of off-farm water savings and across a range of $0.0300 to $0.0900 per kwh energy costs about the expected $0.0614 per kwh level. The resulting cost of water savings estimates ranged from a high of $56.42 per ac-ft down to a low of $16.61 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 lining 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.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the lining'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 is reduced. These reduced diversions associated with the proposed Canal B, C, and D's capital renovation will result in less water being pumped (i.e., 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 lining of Canals B, C, and D project is $2,940,572 (**Table 9**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $3,205,083 (**Table 9**). This amount represents, across the total 50-year planning period, the total net costs, in 2003 dollars, of purchasing and installing the lining 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 40,395,788,613 BTU (11,839,328 kwh) (**Table 9**). The corresponding total real energy savings expressed in 2003 energy quantities are 16,917,299,679 BTU (4,958,177 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 $3,205,083 correlates with the real energy savings projection of 16,917,299,679 BTU (4,958,177 kwh); the respective annuity equivalents are $206,901 and 787,503,691 BTU (230,804 kwh) (**Table 9**). The estimated cost of saving one BTU of energy using the lining comprising this project is $0.0002627 ($0.896 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 lining 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 Canal B, C, and D lining 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 109,874 BTU (32.20 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 lining. 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 $0.0001752 to $0.0006966 cost per BTU (and $0.598 to $2.377 per kwh) of energy savings around the baseline estimate of $0.0002627 per BTU ($0.896 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 109,874

BTU (32.20 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the lining 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, 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 \$0.0001478 to \$0.0003796 per BTU (and \$0.504 to \$1.295 per kwh) of energy savings around the baseline estimate of \$0.0002627 per BTU (\$0.896 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the lining varying from \$500,000 less than the expected \$3,296,000 up to \$500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated \$3,296,000 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 109,874 BTU (32.20 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 annual Rio Grande diversions arising from water savings from the Canal B, C, and D lining. **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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and from as low as 3,750 ac-ft up to 10,500 ac-ft about the expected 7,503 ac-ft off-farm water savings for the lining. The resulting costs of energy savings estimates ranged from a high of \$0.0006571 per BTU (\$2.242 per kwh) down to a low of \$0.0001252 per BTU (\$0.427 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.

Component #2: Canal B Laterals [Pipeline]

The second component evaluated is the replacing of 11.40 miles of Canal B Laterals with pipeline, and reconstructing of the farm turnouts to facilitate the use of portable flow meters. Results of the analysis for this component follow (**Table 19**).

Quantities of Water and Energy Savings

Critical values in the analysis are the quantities of water and energy anticipated being saved during the 49-year productive life of the pipeline.[38] On a nominal (i.e., non-discounted) basis, 298,371 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component.[39] Thus, the total nominal water savings anticipated are 298,371 ac-ft over the 49-year productive life of this component (**Table 19**). Using the 4% discount rate previously discussed, those nominal savings translate into 124,954 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 124,954 ac-ft (**Table 19**).

On a nominal (i.e., non-discounted) basis, 32,783,084,020 BTU (9,608,172 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 19**). 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 13,729,185,042 BTU (4,023,794 kwh) of real irrigation-related energy savings over the 49-year productive life of this project (**Table 19**).

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 #2.

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 pipeline project is $1,209,359 (**Table 19**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $3,637,960 (**Table 19**). This amount represents, across the total 50-

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38 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©.

39 As noted previously, the District diverts water for both M&I and agricultural concerns, and technically one could allocate a proportionate share of the forecast water savings to M&I water use. That is, in the last 5-years, M&I water use has averaged 11% of total District diversions (i.e., 7,904 ac-ft of 74,227 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.

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 positive 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 enough to offset a large portion of the initial investment costs. In the case of the real-value amount, however, the savings (O&M and energy) 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 298,371 ac-ft (**Table 19**). The corresponding total real water savings expressed in 2003 water quantities are 124,954 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 19**).

Cost per Acre-Foot of Water Saved. The real net cost estimate of $3,637,960 correlates with the real water savings projection of 124,954 ac-ft. The estimated cost of saving one ac-ft of water using the pipeline comprising this project component is $40.37 (**Table 19**). 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 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 annual Rio Grande diversions that will result from the purchase, installation, and implementation of the pipeline in the water-delivery system. Thus, the cost per ac-ft of water-saved sensitivity analysis consist of varying the off-farm water-savings dimension[40] of that factor across a range of 2,675 to 7,525 ac-ft (including the baseline 5,374 ac-ft) for the 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 sensitivity analyses are presented in **Tables 20, 21,** and **22**, respectively.

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40 When present, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of a proposed component. Thus, as the off-farm water savings associated with a component is varied in the sensitivity analyses, the on-farm savings (as applicable) also vary.

Table 20 reveals a range of $28.05 to $177.92 cost per ac-ft of savings around the baseline estimate of $40.37. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the pipeline from as low as 2,675 ac-ft up to 7,525 ac-ft about the expected 5,374 ac-ft and by investigating a range of useful lives of the 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, lower off-farm (and the linked on-farm) water savings than the predicted 5,374 ac-ft also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 21** is a presentation of a range of cost estimates varying from $24.09 to $95.03 per ac-ft of savings around the baseline estimate of $40.37. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings (and the linked on-farm savings) from the pipeline from as low as 2,675 ac-ft up to 7,525 ac-ft about the expected 5,374 ac-ft and by considering variations in the cost of the capital investment in the pipeline varying from $500,000 less than the expected $4,396,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $4,396,000 capital costs and/or higher-than-expected water savings contributed to lower cost estimates, while both higher investment costs and/or lower off-farm (and the linked on-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 annual Rio Grande diversions arising from investment in pipeline and the cost of energy. **Table 22** is an illustration of the results of varying those parameters from as low as 2,675 ac-ft up to 7,525 ac-ft about the expected 5,374 ac-ft of off-farm water savings and across a range of $0.0300 to $0.0900 per kwh energy costs about the expected $0.0614 per kwh level. The resulting cost of water savings estimates ranged from a high of $85.28 per ac-ft down to a low of $26.77 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 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.

<u>Cost of Energy Saved</u>

Besides the estimated cost per ac-ft of water saved as a result of the 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 both seepage and evaporation are reduced, and as improved water management (as facilitated by the use of portable flow meters) reduces demand at the affected farm turnouts. These reduced diversions associated with the proposed piping of Canal B Lateral's capital renovation will result in less water being pumped (i.e., 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 piping the Canal B Laterals project is $2,248,073 (**Table 19**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $3,884,833 (**Table 19**). 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, 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 32,783,084,020 BTU (9,608,172 kwh) (**Table 19**). The corresponding total real energy savings expressed in 2003 energy quantities are 13,729,185,042 BTU (4,023,794 kwh) over the 49-year productive life of this component, assuming the previously-identified discount rate of 4.00% (**Table 19**).

Cost per BTU & kwh Saved. The real net cost estimate of $3,884,833 correlates with the real energy savings projection of 13,729,185,042 BTU (4,023,794 kwh); the respective annuity equivalents are $250,781 and 639,096,316 BTU (187,308 kwh) (**Table 19**). The estimated cost of saving one BTU of energy using the pipeline comprising this project is $0.0003924 ($0.1.339 per kwh) (**Table 19**). 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 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 piping the Canal B Laterals 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 109,874 BTU (32.20 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 pipeline. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 23** and **24, 25** and **26,** and **27** and **28**, respectively.

Tables 23 and **24** reveal a range of $0.0002616 to $0.0010404 cost per BTU (and $0.893 to $3.550 per kwh) of energy savings around the baseline estimate of $0.0003924 per BTU ($1.339 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the 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, 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 25** and **26** are a presentation of a range of cost estimates varying from $0.0002279 to $0.0005536 per BTU (and $0.778 to $1.889 per kwh) of energy savings around the baseline estimate of $0.0003924 per BTU ($1.339 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the pipeline varying from $500,000 less than the expected $4,396,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $4,396,000 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 109,874 BTU (32.20 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 annual Rio Grande diversions arising from water savings from piping the Canal B Laterals. **Tables 27** and **28** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and from as low as 2,675 ac-ft up to 7,525 ac-ft about the expected 5,374 ac-ft off-farm water savings for the pipeline. The resulting costs of energy savings estimates ranged from a high of $0.0009855 per BTU ($3.362 per kwh) down to a low of $0.0001868 per BTU ($0.637 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm (and the linked on-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.

Component #3: Canal C Laterals [Pipeline]

The third component evaluated is the replacing of 5.54 miles of Canal C Laterals with pipeline, and reconstructing of the farm turnouts to facilitate the use of portable flow meters. Results of the analysis for this component follow (**Table 29**).

Quantities of Water and Energy Savings

Critical values in the analysis are the quantities of water and energy anticipated being saved during the 49-year productive life of the pipeline.[41] On a nominal (i.e., non-discounted) basis, 83,001 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component.[42] Thus, the total nominal water savings anticipated are 83,001 ac-ft over the 49-year productive life of this component (**Table 29**). Using the 4% discount rate previously discussed, those nominal savings translate into 34,760 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 34,760 ac-ft (**Table 29**).

On a nominal (i.e., non-discounted) basis, 9,119,632,468 BTU (2,672,811 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 29**). 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 3,819,198,999 BTU (1,119,343 kwh) of real irrigation-related energy savings over the 49-year productive life of this project (**Table 29**).

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 #3.

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 pipeline project is $1,359,043 (**Table 29**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $2,339,578 (**Table 29**). This amount represents, across the total 50-

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41 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©.

42 As noted previously, the District diverts water for both M&I and agricultural concerns, and technically one could allocate a proportionate share of the forecast water savings to M&I water use. That is, in the last 5-years, M&I water use has averaged 11% of total District diversions (i.e., 7,904 ac-ft of 74,227 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.

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 positive 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 enough to offset a large portion of 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 83,001 ac-ft (**Table 29**). The corresponding total real water savings expressed in 2003 water quantities are 34,760 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 29**).

Cost per Acre-Foot of Water Saved. The real net cost estimate of $2,339,578 correlates with the real water savings projection of 34,760 ac-ft. The estimated cost of saving one ac-ft of water using the pipeline comprising this project component is $93.34 (**Table 29**). 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 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 annual Rio Grande diversions that will result from the purchase, installation, and implementation of the pipeline in the water-delivery system. Thus, the cost per ac-ft of water-saved sensitivity analysis consist of varying the off-farm water-savings dimension[43] of that factor across a range of 725 to 2,025 ac-ft (including the baseline 1,440 ac-ft) for the 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 sensitivity analyses are presented in **Tables 30, 31,** and **32**, respectively.

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43 When present, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of a proposed component. Thus, as the off-farm water savings associated with a component is varied in the sensitivity analyses, the on-farm savings (as applicable) also vary.

Table 30 reveals a range of $65.60 to $399.06 cost per ac-ft of savings around the baseline estimate of $93.34. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the pipeline from as low as 725 ac-ft up to 2,025 ac-ft about the expected 1,440 ac-ft and by investigating a range of useful lives of the 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, lower off-farm (and the linked on-farm) water savings than the predicted 1,440 ac-ft also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 31** is a presentation of a range of cost estimates varying from $51.41 to $227.78 per ac-ft of savings around the baseline estimate of $93.34. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings (and the linked on-farm savings) from the pipeline from as low as 725 ac-ft up to 2,025 ac-ft about the expected 1,440 ac-ft and by considering variations in the cost of the capital investment in the pipeline varying from $500,000 less than the expected $2,646,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $2,646,000 capital costs and/or higher-than-expected water savings contributed to lower cost estimates, while both higher investment costs and/or lower off-farm (and the linked on-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 annual Rio Grande diversions arising from investment in pipeline and the cost of energy. **Table 32** is an illustration of the results of varying those parameters from as low as 725 ac-ft up to 2,025 ac-ft about the expected 1,440 ac-ft of off-farm water savings and across a range of $0.0300 to $0.0900 per kwh energy costs about the expected $0.0614 per kwh level. The resulting cost of water savings estimates ranged from a high of $189.54 per ac-ft down to a low of $64.32 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 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.

<u>Cost of Energy Saved</u>

Besides the estimated cost per ac-ft of water saved as a result of the 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, and spills are reduced, and as improved water management (as facilitated by the use of portable flow meters) reduces demand at the affected farm turnouts. These reduced diversions associated with the proposed piping of Canal C Lateral's capital renovation will result in less water being pumped (i.e., 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 Canal C Laterals project is $1,647,993 (**Table 29**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $2,408,253 (**Table 29**). 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, 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 9,119,632,468 BTU (2,672,811 kwh) (**Table 29**). The corresponding total real energy savings expressed in 2003 energy quantities are 3,819,198,999 BTU (1,119,343 kwh) over the 49-year productive life of this component, assuming the previously-identified discount rate of 4.00% (**Table 29**).

Cost per BTU & kwh Saved. The real net cost estimate of $2,408,253 correlates with the real energy savings projection of 3,819,198,999 BTU (1,119,343 kwh); the respective annuity equivalents are $155,462 and 177,784,479 BTU (52,106 kwh) (**Table 29**). The estimated cost of saving one BTU of energy using the pipeline comprising this project is $0.0008744 ($2.984 per kwh) (**Table 29**). 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 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 piping the Canal C Laterals 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 109,874 BTU (32.20 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 pipeline. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 33** and **34, 35** and **36,** and **37** and **38**, respectively.

Tables 33 and **34** reveal a range of $0.0005830 to $0.0023184 cost per BTU (and $1.989 to $7.910 per kwh) of energy savings around the baseline estimate of $0.0008744 per BTU ($2.984 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the 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, 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 35** and **36** are a presentation of a range of cost estimates varying from $0.0004619 to $0.0013200 per BTU (and $1.576 to $4.504 per kwh) of energy savings around the baseline estimate of $0.0008744 per BTU ($2.984 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the pipeline varying from $500,000 less than the expected $2,646,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $2,646,000 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 109,874 BTU (32.20 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 annual Rio Grande diversions arising from water savings from piping the Canal C Laterals. **Tables 37** and **38** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and from as low as 725 ac-ft up to 2,025 ac-ft about the expected 1,440 ac-ft off-farm water savings for the pipeline. The resulting costs of energy savings estimates ranged from a high of $0.0021716 per BTU ($7.410 per kwh) down to a low of $0.0004147 per BTU ($1.415 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm (and the linked on-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.

Component #4: Old District 13 Canals [Lining]

The fourth component evaluated is the lining of 9.15 miles of Old District 13 Canals. Results of the analysis for this component follow (**Table 39**).

Quantities of Water and Energy Savings

Critical values in the analysis are the quantities of water and energy anticipated being saved during the 49-year productive life of the lining.[44] On a nominal (i.e., non-discounted) basis, 222,254 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component.[45] Thus, the total nominal water savings anticipated are 222,254 ac-ft over the 49-year productive life of this component (**Table 39**). Using the 4% discount rate previously discussed, those nominal savings translate into 93,078 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 93,078 ac-ft (**Table 39**).

On a nominal (i.e., non-discounted) basis, 24,419,876,585 BTU (7,157,056 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 39**). 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 10,226,768,297 BTU (2,997,294 kwh) of real irrigation-related energy savings over the 49-year productive life of this project (**Table 39**).

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 #4.

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 lining project is $2,039,975 (**Table 39**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $2,764,563 (**Table 39**). This amount represents, across the total 50-

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44 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©.

45 As noted previously, the District diverts water for both M&I and agricultural concerns, and technically one could allocate a proportionate share of the forecast water savings to M&I water use. That is, in the last 5-years, M&I water use has averaged 11% of total District diversions (i.e., 7,904 ac-ft of 74,227 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.

year planning period, the total net costs, in 2003 dollars, of purchasing and installing the lining as well as payment of the net changes in O&M expenditures. Note that the positive real-value amount of costs is greater than the positive nominal-value amount. This result occurs because in the nominal-value amount, the savings accruing from reduced energy use in the lengthy planning period are sufficient to offset some 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 222,254 ac-ft (**Table 39**). The corresponding total real water savings expressed in 2003 water quantities are 93,078 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 39**).

Cost per Acre-Foot of Water Saved. The real net cost estimate of $2,764,563 correlates with the real water savings projection of 93,078 ac-ft. The estimated cost of saving one ac-ft of water using the lining system comprising this project component is $41.19 (**Table 39**). 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 lining 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 annual Rio Grande diversions that will result from the purchase, installation, and implementation of the lining in the water-delivery system. Thus, the cost per ac-ft of water-saved sensitivity analysis consist of varying the off-farm water-savings dimension[46] of that factor across a range of 2,275 to 6,350 ac-ft (including the baseline 4,534 ac-ft) for the lining 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 sensitivity analyses are presented in **Tables 40, 41,** and **42**, respectively.

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[46] When present, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of a proposed component. Thus, as the off-farm water savings associated with a component is varied in the sensitivity analyses, the on-farm savings (as applicable) also vary.

Table 40 reveals a range of $28.63 to $179.89 cost per ac-ft of savings around the baseline estimate of $41.19. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the lining from as low as 2,275 ac-ft up to 6,350 ac-ft about the expected 4,534 ac-ft and by investigating a range of useful lives of the lining 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, lower off-farm water savings than the predicted 4,534 ac-ft also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 41** is a presentation of a range of cost estimates varying from $23.31 to $99.66 per ac-ft of savings around the baseline estimate of $41.19. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the lining from as low as 2,275 ac-ft up to 6,350 ac-ft about the expected 4,534 ac-ft and by considering variations in the cost of the capital investment in the lining varying from $500,000 less than the expected $2,996,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $2,996,000 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 annual Rio Grande diversions arising from investment in lining and the cost of energy. **Table 42** is an illustration of the results of varying those parameters from as low as 2,275 ac-ft up to 6,350 ac-ft about the expected 4,534 ac-ft of off-farm water savings and across a range of $0.0300 to $0.0900 per kwh energy costs about the expected $0.0614 per kwh level. The resulting cost of water savings estimates ranged from a high of $86.21 per ac-ft down to a low of $27.35 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 lining 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.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the lining'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 is reduced. These reduced diversions associated with the proposed Old District 13 Canal lining capital renovation will result in less water being pumped (i.e., 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 lining of Old District 13 Canals project is $2,813,705 (**Table 39**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $2,948,456 (**Table 39**). This amount represents, across the total 50-year planning period, the total net costs, in 2003 dollars, of purchasing and installing the lining 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 24,419,876,585 BTU (7,157,056 kwh) (**Table 39**). The corresponding total real energy savings expressed in 2003 energy quantities are 10,226,768,297 BTU (2,997,294 kwh) over the 49-year productive life of this component, assuming the previously-identified discount rate of 4.00% (**Table 39**).

Cost per BTU & kwh Saved. The real net cost estimate of $2,948,456 correlates with the real energy savings projection of 10,226,768,297 BTU (2,997,294 kwh); the respective annuity equivalents are $190,335 and 476,058,114 BTU (139,525 kwh) (**Table 39**). The estimated cost of saving one BTU of energy using the lining comprising this project is $0.0003998 ($1.364 per kwh) (**Table 39**). 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 lining 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 Old District 13 Canal lining 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 109,874 BTU (32.20 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 lining. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 43** and **44, 45** and **46,** and **47** and **48**, respectively.

Tables 43 and **44** reveal a range of $0.0002665 to $0.0010600 cost per BTU (and $0.909 to $3.617 per kwh) of energy savings around the baseline estimate of $0.0003998 per BTU ($1.364 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 109,874

BTU (32.20 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the lining 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, 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 45** and **46** are a presentation of a range of cost estimates varying from $0.0002213 to $0.0005845 per BTU (and $0.755 to $1.994 per kwh) of energy savings around the baseline estimate of $0.0003998 per BTU ($1.364 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the lining varying from $500,000 less than the expected $2,996,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $2,996,000 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 109,874 BTU (32.20 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 annual Rio Grande diversions arising from water savings from the Old District 13 Canal lining. **Tables 47** and **48** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and from as low as 2,275 ac-ft up to 6,350 ac-ft about the expected 4,534 ac-ft off-farm water savings for the lining. The resulting costs of energy savings estimates ranged from a high of $0.0009960 per BTU ($3.398 per kwh) down to a low of $0.0001903 per BTU ($0.649 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.

Component #5: Old District 13 Pipelines [Pipeline]

The fifth component evaluated is the replacing of 2.04 miles of Old District 13 Canals with pipeline, and reconstructing of the farm turnouts to facilitate the use of portable flow meters. Results of the analysis for this component follow (**Table 49**).

Quantities of Water and Energy Savings

Critical values in the analysis are the quantities of water and energy anticipated being saved during the 49-year productive life of the pipeline.[47] On a nominal (i.e., non-discounted) basis, 33,070 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component.[48] Thus, the total nominal water savings anticipated are 33,070 ac-ft over the 49-year productive life of this component (**Table 49**). Using the 4% discount rate previously discussed, those nominal savings translate into 13,849 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 13,849 ac-ft (**Table 49**).

On a nominal (i.e., non-discounted) basis, 3,633,532,058 BTU (1,064,927 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 49**). 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 1,521,682,156 BTU (445,980 kwh) of real irrigation-related energy savings over the 49-year productive life of this project (**Table 49**).

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 #5.

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 pipeline project is $282,291 (**Table 49**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $696,657 (**Table 49**). This amount represents, across the total 50-year

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47 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©.

48 As noted previously, the District diverts water for both M&I and agricultural concerns, and technically one could allocate a proportionate share of the forecast water savings to M&I water use. That is, in the last 5-years, M&I water use has averaged 11% of total District diversions (i.e., 7,9040 ac-ft of 74,227 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.

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 positive 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 enough to offset a large portion of 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 33,070 ac-ft (**Table 49**). The corresponding total real water savings expressed in 2003 water quantities are 13,849 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 49**).

Cost per Acre-Foot of Water Saved. The real net cost estimate of $696,657 correlates with the real water savings projection of 13,849 ac-ft. The estimated cost of saving one ac-ft of water using the pipeline comprising this project is $69.76 (**Table 49**). 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 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 annual Rio Grande diversions that will result from the purchase, installation, and implementation of the pipeline in the water-delivery system. Thus, the cost per ac-ft of water-saved sensitivity analysis consist of varying the off-farm water-savings dimension[49] of that factor across a range of 225 to 650 ac-ft (including the baseline 456 ac-ft) for the 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 sensitivity analyses are presented in **Tables 50, 51,** and **52**, respectively.

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49 When present, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of a proposed component. Thus, as the off-farm water savings associated with a component is varied in the sensitivity analyses, the on-farm savings (as applicable) also vary.

Table 50 reveals a range of $48.14 to $305.96 cost per ac-ft of savings around the baseline estimate of $69.76. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings from the pipeline from as low as 225 ac-ft up to 650 ac-ft about the expected 456 ac-ft and by investigating a range of useful lives of the 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, lower off-farm (and the linked on-farm) water savings than the predicted 456 ac-ft also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 51** is a presentation of a range of cost estimates varying from $13.00 to $245.76 per ac-ft of savings around the baseline estimate of $69.76. These calculated values were derived by varying the reduction in annual Rio Grande diversions arising from off-farm water savings (and the linked on-farm savings) from the pipeline from as low as 225 ac-ft up to 650 ac-ft about the expected 456 ac-ft and by considering variations in the cost of the capital investment in the pipeline varying from $500,000 less than the expected $826,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $826,000 capital costs and/or higher-than-expected water savings contributed to lower cost estimates, while both higher investment costs and/or lower off-farm (and the linked on-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 annual Rio Grande diversions arising from investment in pipeline and the cost of energy. **Table 52** is an illustration of the results of varying those parameters from as low as 225 ac-ft up to 650 ac-ft about the expected 456 ac-ft of off-farm water savings and across a range of $0.0300 to $0.0900 per kwh energy costs about the expected $0.0614 per kwh level. The resulting cost of water savings estimates ranged from a high of $145.65 per ac-ft down to a low of $46.86 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 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.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the 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 both seepage and evaporation are reduced, and as improved water management (as facilitated by the use of portable flow meters) reduces demand at the affected farm turnouts. These reduced diversions associated with the proposed piping of Old District 13 Canals capital renovation will result in less water being pumped (i.e., 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 Old District 13 Canals project is $397,417 (**Table 49**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $724,019 (**Table 49**). 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, 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 3,633,532,058 BTU (1,064,927 kwh) (**Table 49**). The corresponding total real energy savings expressed in 2003 energy quantities are 1,521,682,156 BTU (445,980 kwh) over the 49-year productive life of this component, assuming the previously-identified discount rate of 4.00% (**Table 49**).

Cost per BTU & kwh Saved. The real net cost estimate of $724,019 correlates with the real energy savings projection of 1,521,682,156 BTU (445,980 kwh); the respective annuity equivalents are $46,738 and 70,834,609 BTU (20,760 kwh) (**Table 49**). The estimated cost of saving one BTU of energy using the pipeline comprising this project is $0.0006598 ($2.251 per kwh) (**Table 49**). 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 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 piping the Old District 13 Canals 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 109,874 BTU (32.20 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 pipeline. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 53** and **54, 55** and **56,** and **57** and **58**, respectively.

Tables 53 and **54** reveal a range of $0.0004399 to $0.0017494 cost per BTU (and $1.501 to $5.969 per kwh) of energy savings around the baseline estimate of $0.0006598 per BTU ($2.251 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the 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, 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 55** and **56** are a presentation of a range of cost estimates varying from $0.0001361 to $0.0013944 per BTU (and $0.464 to $4.758 per kwh) of energy savings around the baseline estimate of $0.0006598 per BTU ($2.251 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 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the pipeline varying from $500,000 less than the expected $826,000 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $826,000 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 109,874 BTU (32.20 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 annual Rio Grande diversions arising from water savings from piping the Old District 13 Canals. **Tables 57** and **58** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 109,874 BTU (32.20 kwh) current average usage per ac-ft of water savings and from as low as 225 ac-ft up to 650 ac-ft about the expected 456 ac-ft off-farm water savings for the pipeline. The resulting costs of energy savings estimates ranged from a high of $0.0016723 per BTU ($5.706 per kwh) down to a low of $0.0003087 per BTU ($1.053 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm (and the linked on-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.

Economic and Financial Evaluation Results Aggregated Across Components

According to Bureau of Reclamation management (Shaddix), a comprehensive, aggregated measure is required to assess the overall potential performance of a proposed project consisting of multiple components. That is, projects are to be evaluated in the form submitted by Districts and when two or more components comprise a project, one general measure should be determined to represent the total project. Discussions of such comprehensive measures follow for both the cost of water saved and the cost of energy saved. ***Aggregations of only the baseline***

cost measures are presented; that is, the various sensitivity analyses previously presented and discussed for each individual project component are not duplicated here.

Following the methodology documented in Rister et al. (2002a), the cost measures calculated for the individual components are expressed in 'annuity equivalents.' The 'annuity equivalent' calculations facilitate comparison and aggregation of capital projects with unequal useful lives, effectively serving as development of a common denominator. The finance aspect of the 'annuity equivalent' calculation as it is used in the RGIDECON© analyses is such that it represents an annual cost savings associated with one unit of water (or energy) each year extended indefinitely into the future. Zero salvage values and continual replacement of the respective technologies with similar capital items as their useful life ends are assumed.

Cost of Water Saved

Table 59 provides aggregated information on the cost of water saved, based on calculated values previously discussed, for the five canal/lateral and pipeline rehabilitation components. The individual component measures are displayed in the table and then aggregated in the far-right column, indicating that the overall cost of water saved is **$40.68 per ac-ft**.

Canals B, C, and D [Lining]

The initial capital investment associated with the "Canals B, C, and D" capital renovation is $3,296,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $2,900,884 value noted at the top of the 'Canals B, C and D (Lining)' column in **Table 59**. The nominal water savings anticipated during the 50-year planning period total 367,657 ac-ft; discounted into a real 2003 value, those savings are estimated to be 153,971 ac-ft (**Table 9**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $187,264 to achieve 7,167 ac-ft of water savings per year (**Table 59**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $26.13 per ac-ft of water savings for the lining of 'Canals B, C, and D' capital renovation (**Table 59**).

Canal B Laterals [Pipeline]

The initial capital investment associated with the "Canal B Laterals (Pipe)" capital renovation is $4,396,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $3,637,960 value noted at the top of the 'Canal B Laterals (Pipe)' column in **Table 59**. The nominal water savings anticipated during the 50-year planning period total 298,371 ac-ft; discounted into a real 2003 value, those savings are estimated to be 124,954 ac-ft (**Table 19**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $234,845 to achieve 5,817 ac-ft of water savings per year (**Table 59**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $40.37 per ac-ft of water savings for the piping of 'Canal B Laterals' capital renovation (**Table 59**).

Canal C Laterals [Pipeline]

The initial capital investment associated with the "Canal C Laterals (Pipe)" capital renovation is $2,646,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $2,339,578 value noted at the top of the 'Canal C Laterals (Pipe)' column in **Table 59**. The nominal water savings anticipated during the 50-year planning period total 83,001 ac-ft; discounted into a real 2003 value, those savings are estimated to be 34,760 ac-ft (**Table 29**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $151,029 to achieve 1,618 ac-ft of water savings per year (**Table 59**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $93.34 per ac-ft of water savings for the piping of 'Canal C Laterals' capital renovation (**Table 59**).

Old District 13 Canals [Lining]

The initial capital investment associated with the "Old District 13 Canals (Lining)" capital renovation is $2,996,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $2,764,563 value noted at the top of the 'Old District 13 Canals (Lining)' column in **Table 59**. The nominal water savings anticipated during the 50-year planning period total 222,254 ac-ft; discounted into a real 2003 value, those savings are estimated to be 93,078 ac-ft (**Table 39**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $178,464 to achieve 4,333 ac-ft of water savings per year (**Table 59**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $41.19 per ac-ft of water savings for the lining of 'Old District 13 Canals' capital renovation (**Table 59**).

Old District 13 Canals [Pipeline]

The initial capital investment associated with the "Old District 13 Canals (Pipe)" capital renovation is $826,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $696,657 value noted at the top of the 'Old District 13 Canals (Pipe)' column in **Table 59**. The nominal water savings anticipated during the 50-year planning period total 33,070 ac-ft; discounted into a real 2003 value, those savings are estimated to be 13,849 ac-ft (**Table 49**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $44,972 to achieve 645 ac-ft of water savings per year (**Table 59**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $69.76 per ac-ft of water savings for the piping of 'Old District 13 Canals' capital renovation (**Table 59**).

Aggregate Measure of Cost of Water Savings

Combining the costs of the five components of the District's proposed project results in a total NPV net cost (i.e., both initial investments and changes in O&M expenditures) estimate of $12,339,641 which translates into an annuity cost equivalent of $796,573 per year (**Table 59**). The total NPV of water savings is 420,612 ac-ft, representing an annuity equivalent of **19,580 ac-ft of water savings** (**Table 59**), representing **26.4%** of the last 5-years average water diversion, **22.4%** of the last 13-years average water diversion, and **21.0%** of the "adjusted" average water diversion by the District. Performing the same math as used in calculating the costs of water savings for the individual components (i.e., dividing the annuity of the net cost stream by the annuity amount of water savings) produces the **$40.68 per ac-ft** water savings aggregate cost measure (**Table 59**).

Cost of Energy Saved

Table 60 provides aggregated information on the cost of energy saved, based on calculated values previously discussed, for the proposed project components. The individual component measures are displayed in the table and then aggregated in the far-right column, indicating that the overall cost of water saved is **$0.0003952 per BTU (or $1.348 per kwh)**.

Canals B, C, and D [Lining]

The initial capital investment associated with the 'Canals B, C, and D (Lining)' capital renovation is $3,296,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $3,205,083 value noted at the top of the 'Canals B, C, and D (Lining)' column in **Table 60.** This value is again higher than the corresponding $2,900,884 value in **Table 59** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved'. The nominal energy savings anticipated during the 50-year planning period total 40,395,788,613 BTU (11,839,328 kwh) (**Table 9**). Discounted into a real 2003 value, those savings are estimated to be 16,917,299,679 BTU (4,958,177 kwh) (**Table 9**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $206,901 to achieve 787,503,691 BTU (230,804 kwh) of energy savings per year (**Table 60**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0002627 per BTU ($0.896 per kwh) of energy savings for the lining of 'Canals B, C, and D' capital renovation (**Table 60**).

Canal B Laterals [Pipeline]

The initial capital investment associated with the 'Canal B Laterals (Pipe)' capital renovation is $4,396,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $3,884,833 value noted at the top of the 'Canal B Laterals (Pipe)' column in **Table 60.** This value is again higher than the corresponding $3,637,960 value in **Table 59** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved'. The nominal energy savings anticipated during the 50-year planning period total 32,783,084,020 BTU (9,608,172 kwh) (**Table 19**). Discounted into a real 2003 value, those savings are estimated to be 13,729,185,042 BTU (4,023,794 kwh) (**Table 19**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $250,781 to achieve 639,096,316 BTU (187,308 kwh) of energy savings per year (**Table 60**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0003924 per BTU ($1.339 per kwh) of energy savings for the piping of 'Canal B Laterals' capital renovation (**Table 60**).

Canal C Laterals [Pipeline]

The initial capital investment associated with the 'Canal C Laterals (Pipe)' capital renovation is $2,646,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $2,408,253 value noted at the top of the 'Canal C Laterals (Pipe)' column in **Table 60.** This value is again higher than the corresponding $2,339,578 value in **Table 59** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved'. The nominal energy savings anticipated during the 50-year planning period total 9,119,632,468 BTU (2,672,811 kwh) (**Table 29**). Discounted into a real 2003 value, those savings are estimated to be 3,819,198,999 BTU (1,119,343 kwh) (**Table 29**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $155,462 to achieve 177,784,479 BTU (52,106 kwh) of energy savings per year (**Table 60**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0008744 per BTU ($2.984 per kwh) of energy savings for the piping of 'Canal C Laterals' capital renovation (**Table 60**).

Old District 13 Canals [Lining]

The initial capital investment associated with the 'Old District 13 Canals (Lining)' capital renovation is $2,996,000 in 2003 nominal dollars (**Table 6**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $2,948,456 value noted at the top of the 'Old District 13 Canals (Lining)' column in **Table 60**. This value is again higher than the corresponding $2,764,563 value in **Table 59** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved'. The nominal energy savings anticipated during the 50-year planning period total 24,419,876,585 BTU (7,157,056 kwh) (**Table 39**). Discounted into a real 2003 value, those savings are estimated to be 10,226,768,297 BTU (2,997,294 kwh)

(**Table 39**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $190,335 to achieve 467,058,114 BTU (139,525 kwh) of energy savings per year (**Table 60**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0003998 per BTU ($1.364 per kwh) of energy savings for the lining of Old District 13 Canals' capital renovation (**Table 60**).

<u>Old District 13 Canals [Pipeline]</u>

The initial capital investment associated with the 'Old District 13 Canals (Pipe)' capital renovation is $826,000 in 2003 nominal dollars (**Table 6)**. Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $724,019 value noted at the top of the 'Old District 13 Canals (Pipe)' column in **Table 60**. This value is again higher than the corresponding $696,657 value in **Table 59** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved'. The nominal energy savings anticipated during the 50-year planning period total 3,633,532,058 BTU (1,064,927 kwh) (**Table 49**). Discounted into a real 2003 value, those savings are estimated to be 1,521,682,156 BTU (445,980 kwh) (**Table 49**). Converting both of the real 2003 values into annuity equivalents per the methodology presented in Rister et al. (2002a) results in an annual cost estimate of $46,738 to achieve 70,834,609 BTU (20,760 kwh) of energy savings per year (**Table 60**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0006598 per BTU ($2.251 per kwh) of energy savings for the piping of 'Old District 13 Canals' capital renovation (**Table 60**).

<u>Aggregate Measure of Cost of Energy Savings</u>

Combining the costs of the five components of the District's proposed project results in a total NPV net cost (i.e., both initial investments and changes in O&M expenditures) estimate of $13,170,644 which translates into an annuity cost equivalent of $850,218 per year (**Table 60**). The total NPV of energy savings is 46,214,134,173 BTU, representing an annuity equivalent of **2,151,277,209 BTU (630,503 kwh)** of energy savings. Performing the same math as used in calculating the costs of energy savings for the individual components (i.e., dividing the annuity of the net cost stream by the annuity amount of energy savings) produces the **$0.0003952 per BTU ($1.348 per kwh)** of energy savings aggregate cost measure (**Table 60**).

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 cast aside.

- 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 issue of the 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 is 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 would provide an overall impact of the proposed renovations, thereby enhancing 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 five components: Canals B, C, and D (Lining); Canal B Laterals (Pipeline); Canal C Laterals (Pipeline); Old District 13 Canals (Lining); and Old District 13 Canals (Pipeline). Their required respective capital investment cost are $3,296,000, $4,396,000, $2,646,000, $2,996,000, and $826,000 (i.e., total of $14,160,000). A one-year installation period with an ensuing 49-year useful life (total of 50-year planning period) for each of the project components is expected. Net annual O&M expenditures are expected to decrease by $47,406 (**Table 6**).

Off-farm water savings are predicted to be forthcoming from component #1 (Canals B, C, and D) with its expected water savings over its 49-year useful life being 367,657 nominal ac-ft, which translate into a 2003 basis of 153,971 real ac-ft (**Table 9**). *Off-* and *on-farm* water savings are predicted to be forthcoming from component #2 (Canals B Laterals) with its expected water savings over its 49-year useful life being 298,371 nominal ac-ft, which translate into a 2003 basis of 124,954 real ac-ft (**Table 19**). *Off-* and *on-farm* water savings are predicted to be forthcoming from component #3 (Canal C Laterals) with its expected water savings over its 49-year useful life being 83,001 nominal ac-ft, which translate into a 2003 basis of 34,760 real ac-ft (**Table 29**). Only *off-farm* water savings are predicted to be forthcoming from component #4 (Old District 13 Canals - Lining) with its expected water savings over its 49-year useful life being 222,254 nominal ac-ft, which translate into a 2003 basis of 93,078 real ac-ft (**Table 39**). *Off-* and *on-farm* water savings are predicted to be forthcoming from component #5 (Old District 13 Canals - Pipeline) with its expected water savings over its 49-year useful life being 33,070 nominal ac-ft, which translate into a 2003 basis of 13,849 real ac-ft (**Table 49**). Across the total project, nominal water savings are **1,004,353** ac-ft (**Tables 9, 19, 29, 39, and 49**) and real 2003 savings are 420,612 ac-ft. On an average, annual, real basis, this totals **19,580 ac-ft** across all five components (**Table 59**).

Energy savings estimates associated with the **Canals B, C, and D** component are 40,395,788,613 BTU (11,839,328 kwh) in nominal terms and 16,917,299,679 BTU (4,958,177 kwh) in real 2003 terms (**Table 9**). Energy savings estimates associated with the **Canal B Laterals** component are 32,783,084,020 BTU (9,608,172 kwh) in nominal terms and 13,729,185,042 BTU (4,023,794 kwh) in real 2003 terms (**Table 19**). Energy savings estimates associated with the **Canal C Laterals** component are 9,119,632,468 BTU (2,672,811 kwh) in nominal terms and 3,819,198,999 BTU (1,119,343 kwh) in real 2003 terms (**Table 29**). Energy savings estimates associated with the **Old District 13 Canals - Lining** component are 24,419,876,585 BTU (7,157,056 kwh) in nominal terms and 10,226,768,297 BTU (2,997,294 kwh) in real 2003 terms (**Table 39**). Energy savings estimates associated with the **Old District 13 Canals - Pipeline** component are 3,633,532,058 BTU (1,064,927 kwh) in nominal terms and 1,521,682,156 BTU (445,980 kwh) in real 2003 terms (**Table 49**). For the total project, nominal energy savings are 110,351,913,744 BTU (32,342,294 kwh) and real 2003 savings are 46,214,134,173 BTU (13,544,588 kwh) (**Table 9**, **19**, **29**, **39**, **49** and **60**). On an average, annual, real basis, this totals **2,151,277,209 BTU (630,503 kwh)** across all five components (**Table 60)**.

Economic and financial costs of *water* savings forthcoming from component #1 are estimated at $26.13 per ac-ft (**Table 9**); those for component #2 are estimated at $40.37 per ac-ft (**Table 19**); those for component #3 are estimated at $93.34 per ac-ft (**Table 29**); those for component #4 are estimated at $41.19 per ac-ft (**Table 39**); and those for component #5 are estimated at $69.76 per ac-ft (**Table 49**). Sensitivity analyses indicate these estimates can be affected by variances in (a) the amount of reduction in annual Rio Grande diversions resulting from the purchase, installation, and implementation of the project component; (b) the expected useful lives of the project component; (c) the initial capital investment costs of the project component; and (d) the value of BTU savings (i.e., cost of energy).

Economic and financial costs of *energy* savings forthcoming from component #1 are estimated at $0.0002627 per BTU ($0.896 per kwh) (**Table 9**); those for component #2 are estimated at $0.0003924 per BTU ($1.339 per kwh) (**Table 19**); those for component #3 are estimated at $0.0008744 per BTU ($2.984 per kwh) (**Table 29**); those for component #4 are estimated at $0.0003998 per BTU ($1.364 per kwh) (**Table 39**); and those for component #5 are estimated at $0.0006598 per BTU ($2.251 per kwh) (**Table 49**). Sensitivity analyses indicate factors of importance are (a) the amount of energy savings resulting from the purchase, installation, and implementation; (b) the expected useful life of the investment; (c) the initial capital investment costs; and (d) the amount of *off*- and *on-farm* water savings.

Aggregation of the economic and financial costs of water and energy savings for the individual project components into cost measures for the total project result in estimates of **$40.68 per ac-ft** cost of water savings (**Table 59**) and **$0.0003952 per BTU ($1.348 per kwh)** cost of energy savings (**Table 60**). These estimates, similar to the other economic and financial cost estimates identified here, are based on methods described in Rister et al. (2002a).

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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

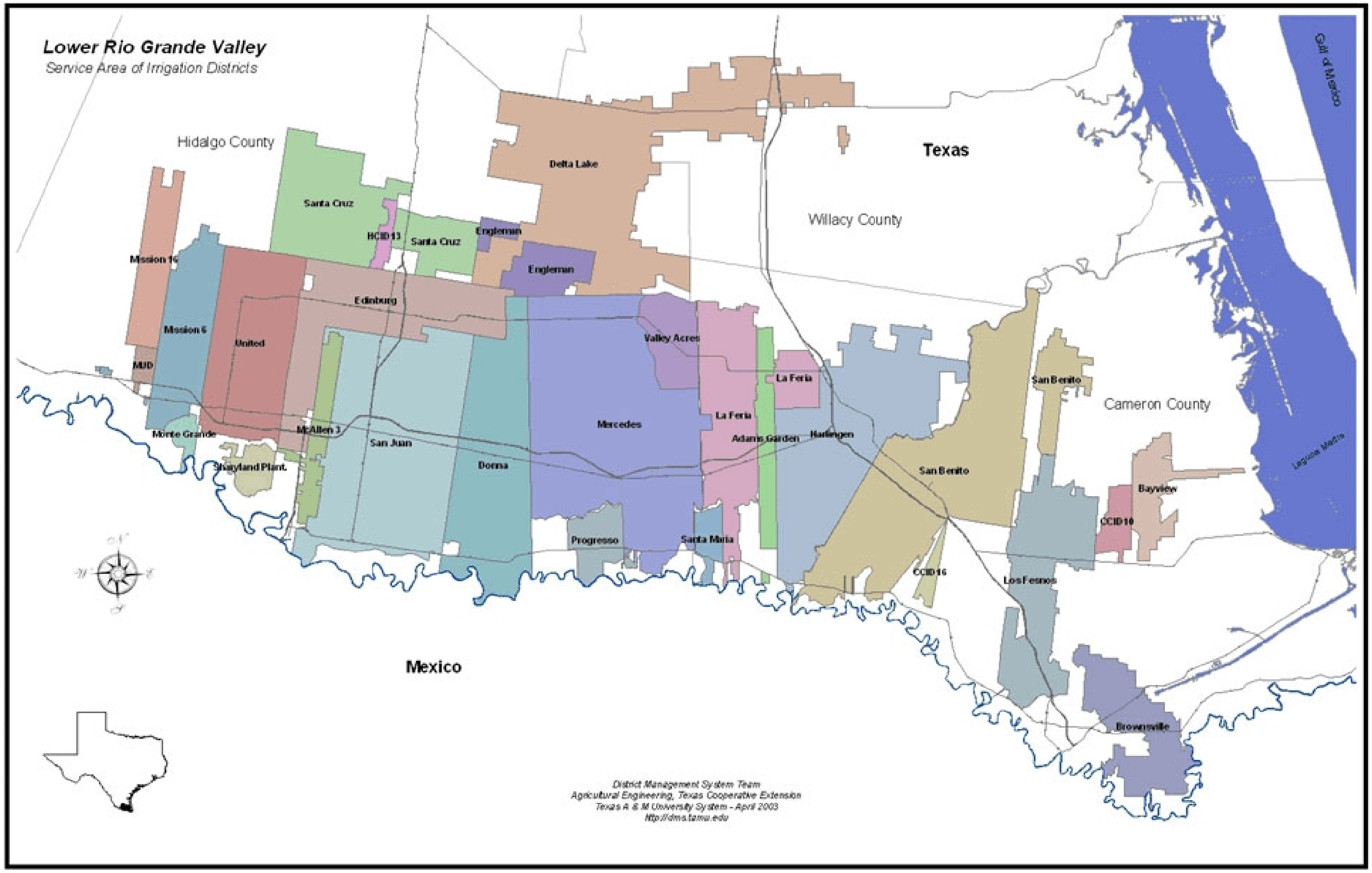

Exhibit 1. Illustration of Twenty-Eight Irrigation Districts in the Texas Lower Rio Grande Valley (Fipps et al.).

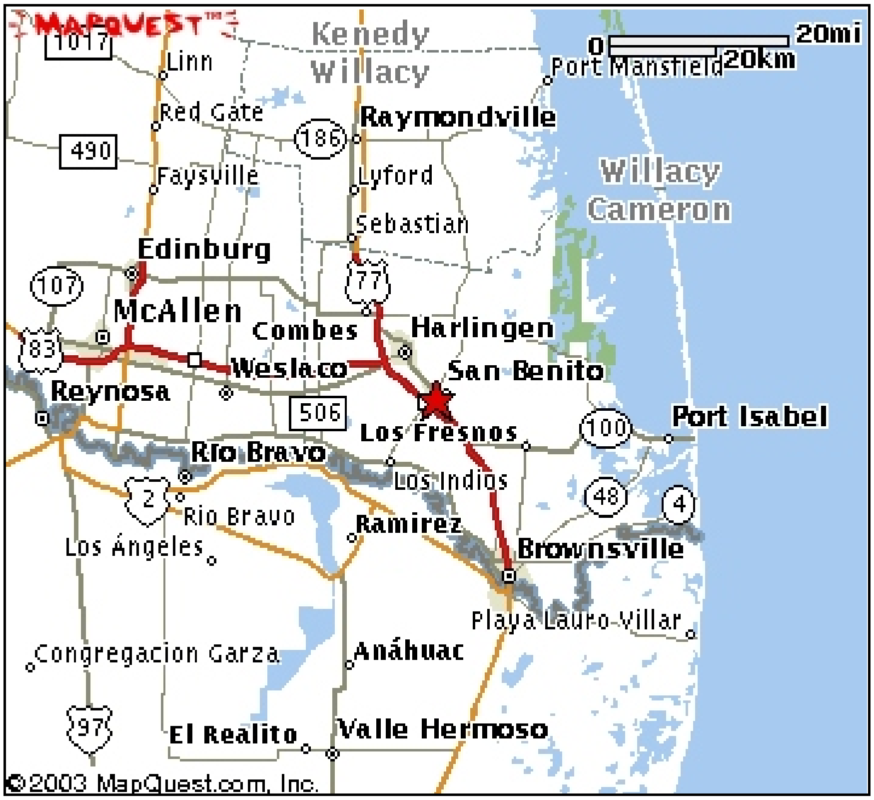

Exhibit 2. San Benito, TX – Location of Cameron County Irrigation District No. 2 Office (MapQuest).

Exhibit 3. Detailed Location of Cameron County Irrigation District No. 2 Office in San Benito, TX (MapQuest).

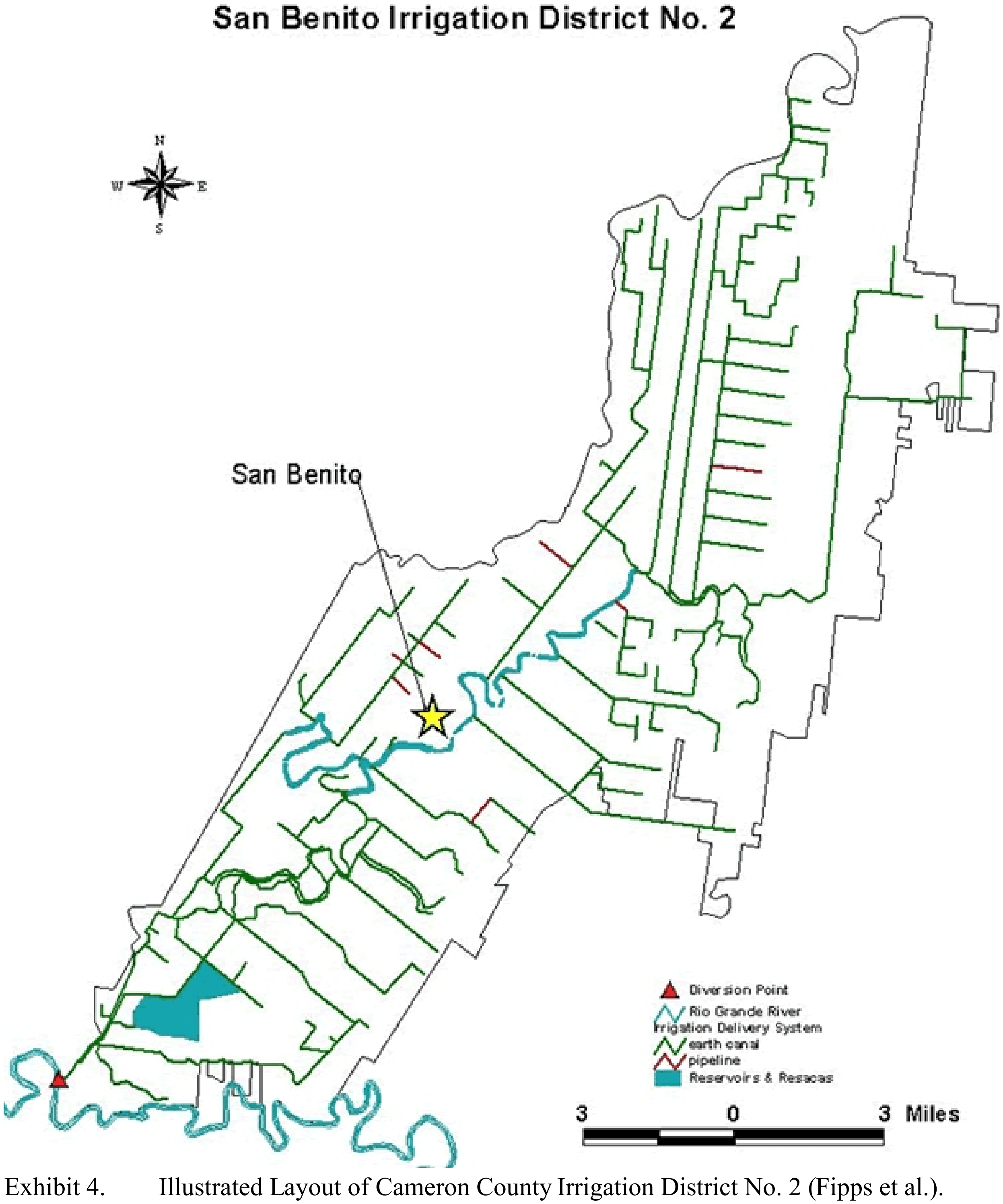

Exhibit 4. Illustrated Layout of Cameron County Irrigation District No. 2 (Fipps et al.).

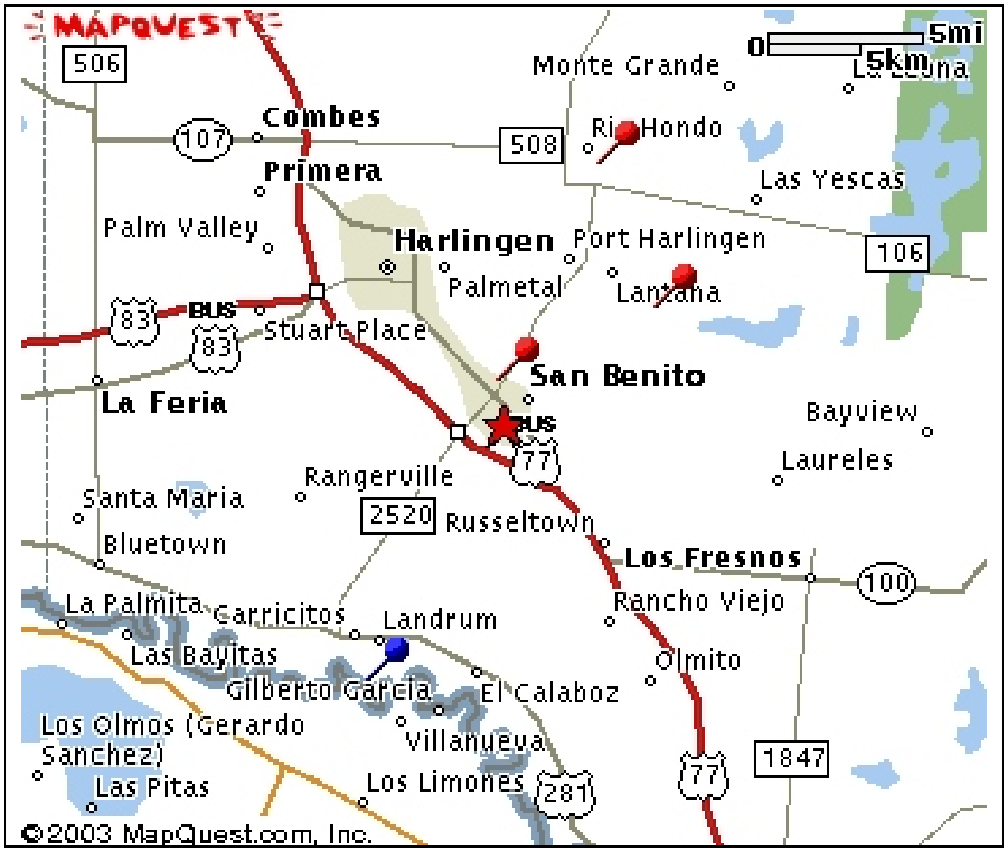

Exhibit 5. Location of Pumping Plant and the Municipalities, Water Supply Corporations, and Industrial Users Served by Cameron County Irrigation District No. 2 (MapQuest).

Tables

Table 1. Average Acreage Irrigated by Cameron County Irrigation District No. 2 as per District Records for Calendar Years 1998-2002 (Kaniger).

Category / Enterprise	crop year 1998	1999	2000	2001	2002	5-year average acres	%
Field crops - annual							
SORGHUM	11,754	8,021	12,524	15,710	8,803	11,362	49.6 %
COTTON	11,101	5,953	2,942	8,515	3,322	6,367	27.8 %
CORN[a]							
MISC. FIELD CROPS[a]							
OATS[a]							
						17,729	77.5 %
Field Crops - perennial							
SUGAR CANE	4,986	1,906	6,617	4,783	4,941	4,646	20.3 %
						4,646	20.3 %
Fruit							
CITRUS	571	317	468	629	586	514	2.2 %
OTHER FRUITS[a]							
						514	2.2 %
Vegetables[a]							
ONIONS							
CABBAGE							
CARROTS							
PICKLES							
GREENS							
BEANS							
BEETS							
BROCCOLI							
TOMATOES							
PEPPERS							
OTHER VEGETABLES							
SQUASH							
CUCUMBERS							
LETTUCE							
CILANTRO							
CELERY							
CAULIFLOWER							
LEEKS							
Pasture / Open[a]							
OPEN LAND							
PASTURE							
Hay[a]							
OTHER HAY							
ALFALFA HAY							
OTHER GRASSES							
Other[a]							
YARD-ACRES							
YARD-LOTS							
PALM-TREES							
OTHER TREES							
LAKE							
GOLF COURSE							
Melons[a]							
CANTALOUPES							
WATERMELONS							
HONEYDEW, ETC.							
Total	28,412	16,196	22,550	29,637	17,653	22,890	100 %

[a] Insignificant acreage not reported for these crops.

Table 2. Historic Water-Use Volume (acre-feet), Cameron County Irrigation District No. 2 (Kaniger).

Year	M&I (ac-ft)	Ag (ac-ft)	Total (ac-ft)
1986	13,034.60	80,235.73	93,270.33
1987	10,815.32	82,455.01	93,270.33[a]
1988	7,906.78	64,731.60	72,638.38
1989	8,437.90	91,699.82	100,137.72
1990	11,587.70	94,888.61	106,476.31
1991	10,883.30	82,945.59	93,828.89
1992	-[b]	-[b]	-[c]
1993	-[b]	-[b]	-[c]
1994	-[b]	-[b]	-[c]
1995	-[b]	-[b]	110,934.54
1996	-[b]	-[b]	95,978.26
1997	7,880.77	78,214.96	86,095.73
1998	8,494.28	45,229.22	53,723.50
1999	7,305.28	68,700.28	76,005.56
2000	7,696.34	80,921.70	88,618.04
2001	8,145.80	58,548.28	66,694.08
5 year avg. ('97-'01)	7,904.49	66,322.89	74,227.38
16 year avg. ('86-'01)[d]	9,289.82	75,324.62	87,513.21

[a] Total volume for 1987 was unavailable from District and water master records. Thus, 1986 total volume was replicated for 1987 with the actual 1987 M&I water usage subtracted to determine an estimated agricultural water-use volume for that year (Kaniger).

[b] Data for this use and year missing and ignored in summary calculations.

[c] Data for this year missing. Water use during these years ignored in calculations documented in Table 3 toward estimating a historical average total water use by the District.

[d] Averages reported are for those years in the sixteen-year series for which data are available.

Table 3. Statistical Distribution of Rio Grande Diversion Levels, Cameron County Irrigation District No. 2, 2003.[a]

Measurement Point/Year	Water Diversions (ac-ft/yr)	Cumulative Probability
generated by Simetar™	53,718.12	0.0%
1998	53,723.50	3.8%
2001	66,694.08	11.5%
1988	72,638.38	19.2%
1999	76,005.56	26.9%
1997	86,095.73	34.6%
2000	88,618.04	42.3%
1986/7[b]	93,270.33	50.0%
1986/7[b]	93,270.33	57.7%
1991	93,828.89	65.4%
1996	95,978.26	73.1%
1989	100,137.72	80.8%
1990	106,476.31	88.5%
1995	110,934.54	96.2%
generated by Simetar™	110,945.63	100.0%

[a] Calculated using Simetar™ (Richardson et al.), assuming a 'normal' probability-based distribution for available data during 1986-2001 period.

[b] The values for 1986 and 1987 are identical inasmuch as the 1986 value was replicated for 1987 during the process of data analysis.

Table 4. Selected Summary Information for Cameron County Irrigation District No. 2, 2003 (Kaniger).

Item	Description / Data
Certificates of Adjudication (Type Use \\ ac-ft):	0841-000 (Municipal/Domestic, \\ 5,517.500 ac-ft); 0841-001 (Municipal (San Benito) \\ 5,500.000 ac-ft); 0841-002 (Municipal (Rio Hondo) \\ 890.000 ac-ft); 0841-003 (Industrial (CP&L) \\ 1,500.000 ac-ft) - - owned by CP&L; 0841-004 (Industrial (CP&L) \\ 2,400.000 ac-ft); 0841-005 (Irrigation \\ 147,823.650 ac-ft); 0841-006 (Industrial (CP&L) \\ 750.000 ac-ft) - - owned by CP&L; and 0051-000 (Irrigation \\ 13.725 ac-ft) - - class "B".
Municipalities Served (Total Delivery in ac-ft):	City of San Benito (6,000.000 ac-ft); City of Rio Hondo (890.000 ac-ft); East Rio Hondo Water Supply Corp (485.000 ac-ft); and Arroyo Water Supply Corp (200.000 ac-ft).
District Water Rates:	Flat Rate - ($30.00 per acre for the first irrigated acre); Flat Rate - ($8.50 per acre for every acre thereafter); Irrigation - ($7.00 per acre per irrigation; approximated at 0.5 ac-ft each); Volumetrically priced Irrigation - ($17.50 per ac-ft); Lawn Water - ($80.00 per year); and Municipal - ($0.160 per 1,000 gal).
Average Lift at Rio Grande:	20 '

Table 5. Summary of Annual Water and Energy Savings Data (basis 2003) for Five Components Comprising the Infrastructure Rehabilitation Project Proposed to BOR, Cameron County Irrigation District No. 2, 2003 (Allard, Kaniger).

Component / Savings	Amount of Water Savings by Type				Total Water Savings (ac-ft)	Associated Energy Savings		
	Reduced Seepage (ac-ft)	Reduced Spills (ac-ft)	Reduced Evaporation (ac-ft)	Metering[a] (ac-ft)		BTU	kwh	$
Annual Energy & Water Savings								
Agricultural Irrigation Use:								
Canals B, C, and D (Lining)	7,503.2	0.0	0.0	0.0	7,503.2	824,403,849	241,619	$ 14,824
Canal B Laterals (Pipe)	5,374.4	0.0	94.0	620.8	6,089.2	669,042,531	196,085	12,030
Canal C Laterals (Pipe)	1,440.4	20.0	51.1	182.4	1,693.9	186,114,948	54,547	3,347
Old District 13 Canals (Lining)	4,534.1	0.0	1.7	0.0	4,535.8	498,364,828	146,062	8,961
Old District 13 Canals (Pipe)	456.2	0.0	11.1	207.6	674.9	74,153,715	21,733	1,333
Sub-total	19,308.3	20.0	157.9	1,010.8	20,497.0	2,252,079,872	660,047	$ 40,496
Municipal and Industrial Use:								
Canals B, C, and D (Lining)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canal B Laterals (Pipe)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canal C Laterals (Pipe)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Old District 13 Canals (Lining)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Old District 13 Canals (Pipe)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19,308.3	20.0	157.9	1,010.8	20,497.0	2,252,079,872	660,047	$ 40,496

[a] "Metering" water savings is considered *on-farm* savings, while the other three categories are considered *off-farm* water savings categories.

Table 6. Summary of Project Cost and Expense Data (2003 dollars), by Component and Aggregated Across Components of the Infrastructure Rehabilitation Project Proposed to BOR, Cameron County Irrigation District No. 2 (Allard, Kaniger).

Item	All Yrs.	Component #1 Canals B, C, and D (Lining)[a] Total Expenses / Revenues ($'s)	Component #1 ($/mile)	Component #2 Canal B Laterals (Pipe)[b] Total Expenses / Revenues ($'s)	Component #2 ($/mile)	Component #3 Canal C Laterals (Pipe)[c] Total Expenses / Revenues ($'s)	Component #3 ($/mile)	Component #4 Old District 13 Canals (Lining)[d] Total Expenses / Revenues ($'s)	Component #4 ($/mile)	Component #5 Old District 13 Canals (Pipe)[e] Total Expenses / Revenues ($'s)	Component #5 ($/mile)	Aggregate ($'s)
Installation Period	1											
Useful Life	49											
Planning Period	50											
Initial Capital Investment Costs		$3,296,000	$235,786	$4,396,000	$377,339	$2,646,000	$366,344	$2,996,000	$320,987	$826,000	$404,947	$14,160,000
Annual Increases in O&M Expenses		$34,365	$2,458	$3,557	$305	$2,931	$406	$22,499	$2,410	$636	$312	$63,987
Annual Decreases in O&M Expenses		$38,362	$2,744	$28,422	$2,440	$14,480	$2,005	$24,532	$2,628	$5,598	$2,744	$111,393
Net Changes in Annual O&M Expenses		$(3,997)	$(286)	$(24,865)	$(2,134)	$(11,549)	$(1,599)	$(2,033)	$(218)	$(4,962)	$(2,432)	$(47,406)
Value of Reclaimed Property (revenue)		$0		$0		$0		$0		$0		$0

a Component #1 is primarily installing 13.98 miles of geomembrane/shotcrete lining in earthen Canals B, C, and D.
b Component #2 is primarily installing 11.40 miles of pipeline and reconstructing farm turnouts in the mostly earthen Canal B Laterals.
c Component #3 is primarily installing 5.54 miles of pipeline and reconstructing farm turnouts in the mostly earthen Canal C Laterals.
d Component #4 is primarily installing 9.15 miles of geomembrane/shotcrete lining in the Old District 13 Canals.
e Component #5 is primarily installing 2.04 miles of pipeline and reconstructing farm turnouts in the Old District 13 Canals.

Table 7. Details of Cost Estimates for All Five Components and the Aggregate (basis 2003 dollars) of the Infrastructure Rehabilitation Project Proposed to BOR, Cameron County Irrigation District No. 2, (Allard).

Item	Item Cost ($'s)					Aggregate
	Component #1 Canals B, C, and D (Lining)[a]	Component #2 Canal B Laterals (Pipe)[b]	Component #3 Canal C Laterals (Pipe)[c]	Component #4 Old District 13 Canals (Lining)[d]	Component #5 Old District 13 Canals (Pipe)[e]	
Cost to Purchase, Mobilize, and Install	$2,600,000	$3,273,000	$2,010,000	$2,360,000	$615,000	$10,858,000
Unlisted Items (10%)	260,000	327,000	200,000	240,000	60,000	1,087,000
Contingencies (10%)	287,000	365,000	219,600	260,000	70,800	1,202,400
Construction Management (5%)	143,000	180,000	111,000	130,000	33,500	597,500
In Kind	0	245,000	99,400	0	40,700	385,100
NHPA Mitigation[f]	6,000	6,000	6,000	6,000	6,000	30,000
Total[g]	$3,296,000	$4,396,000	$2,646,000	$2,996,000	$826,000	$14,160,000

[a] Component #1 is primarily installing 13.98 miles of geomembrane/shotcrete lining in earthen Canals B, C, and D.
[b] Component #2 is primarily installing 11.40 miles of pipeline and reconstructing farm turnouts in the mostly earthen Canal B Laterals.
[c] Component #3 is primarily installing 5.54 miles of pipeline and reconstructing farm turnouts in the mostly earthen Canal C Laterals.
[d] Component #4 is primarily installing 9.15 miles of geomembrane/shotcrete lining in the Old District 13 Canals.
[e] Component # is primarily installing 2.04 miles of pipeline and reconstructing farm turnouts in the Old District 13 Canals.
[f] The most comprehensive national policy on historic preservation was established by Congress with passage of the National Historic Preservation Act of 1966 (NHPA). Major provisions of the NHPA aim to ensure historic properties are appropriately considered in planning federal initiatives and actions.
[g] Note all dollar values are provided by Bureau of Reclamation (BOR) engineers and incorporate numerical rounding as per BOR guidelines.

Table 8. Summary of Water Diversions, and Energy Use and Expenses for Cameron County Irrigation District No. 2 's Rio Grande Diversion Pumping Plant, per District Records (Kaniger).

Item	Calendar Year 1998	1999	2000	2001	2002	Average
Electricity - Diverted:						
- kwh used	1,646,880	1,514,400	2,130,000	2,449,200	2,146,800	1,977,456
- Btu equivalent	5,619,154,560	5,167,132,800	7,267,560,000	8,356,670,400	7,324,881,600	6,747,079,872
- total electric expense	$ 100,354	$ 87,435	$ 191,435	$ 157,216	$ 172,182	$ 141,724
Natural Gas - Diverted:						
- kwh used	886,870	596,424	699,179	11,020	0	438,699
- Btu equivalent	3,026,000,000	2,035,000,000	2,385,600,000	37,600,000	0	1,496,840,000
- total natural gas expense	$12,332	$8,386	$11,663	$190	$0	$6,514
Total Energy - Diverted:						
- kwh used	2,533,750	2,110,824	2,829,179	2,460,220	2,146,800	2,416,155
- Btu equivalent	8,645,154,560	7,202,132,800	9,653,160,000	8,394,270,400	7,324,881,600	8,243,919,872
- total energy expense	$112,686	$95,821	$203,098	$157,406	$172,182	$148,239
Water - Diverted:						
- CFS pumped	43,407	27,085	38,319	44,678	35,650	37,828
- ac-ft equivalent	86,096	53,724	76,006	88,618	70,712	75,031
Calculations (diverted water):						
- kwh / ac-ft	29.43	39.29	37.22	27.76	30.36	32.20
- Btu / ac-ft	100,413	134,059	127,006	94,724	103,588	109,874
- avg. cost per kwh ($/kwh)	$0.044	$0.045	$0.072	$0.064	$0.080	$0.061
- avg. cost per Btu ($/Btu)	$0.0000130	$0.0000133	$0.0000210	$0.0000188	$0.0000235	$0.0000180
- avg. cost of water pumped ($/ac-ft)	$1.31	$1.78	$2.67	$1.78	$2.43	$1.98

Table 9. Economic and Financial Evaluation Results Across Component #1's Useful Life, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining) Project Component for BOR, 2003.

Results	Nominal	Real[a]
Water Savings (ac-ft)		
Agriculture Irrigation	367,657	153,971
M&I	0	0
Total ac-ft	367,657	153,971
annuity equivalent		7,167
Energy Savings (BTU)		
Agriculture Irrigation	40,395,788,613	16,917,299,679
M&I	0	0
Total BTU	40,395,788,613	16,917,299,679
annuity equivalent		787,503,691
Energy Savings (kwh)		
Agriculture Irrigation	11,839,328	4,958,177
M&I	0	0
Total kwh's	11,839,328	4,958,177
annuity equivalent		230,804
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings	$1,660,654	$2,900,884
annuity equivalent		$187,264
Cost of Water Savings ($/ac-ft)		$26.13
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings	$2,940,572	$3,205,083
annuity equivalent		$206,901
Cost of Energy Savings ($/BTU)		$0.0002627
Cost of Energy Savings ($/kwh)		$0.896

[a] Determined using a 4% discount factor.

Table 10. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 13.98 Miles of Canals B, C, and D and Expected Useful Life of the Capital Investment, Cameron County Irrigation District No. 2, Lining Earthen Canals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 13.98 miles of earthen canal to be lined									
		3,750	4,500	5,250	6,000	6,750	**7,503**	8,250	9,000	9,750	10,500
Expected Useful life of Investment (years)	10	$116.70	$96.28	$81.70	$70.76	$62.25	$55.42	$49.87	$45.23	$41.31	$37.94
	20	$75.08	$61.94	$52.56	$45.52	$40.05	$35.65	$32.09	$29.10	$26.58	$24.41
	25	$67.43	$55.64	$47.21	$40.89	$35.97	$32.02	$28.82	$26.14	$23.87	$21.92
	30	$62.68	$51.71	$43.88	$38.00	$33.43	$29.76	$26.79	$24.29	$22.19	$20.38
	40	$57.40	$47.36	$40.19	$34.80	$30.62	$27.26	$24.53	$22.25	$20.32	$18.66
	49	$55.02	$45.39	$38.52	$33.36	$29.35	**$26.13**	$23.51	$21.33	$19.48	$17.89

Table 11. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 13.98 Miles of Canals B, C, and D and Initial Cost of the Capital Investment, Cameron County Irrigation District No. 2, Lining Earthen Canals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 13.98 miles of earthen canal to be lined									
		3,750	4,500	5,250	6,000	6,750	**7,503**	8,250	9,000	9,750	10,500
Initial Capital Investment Cost ($)	$(500,000)	$46.01	$37.88	$32.08	$27.73	$24.34	$21.62	$19.42	$17.57	$16.01	$14.67
	$(250,000)	$50.51	$41.64	$35.30	$30.54	$26.85	$23.88	$21.47	$19.45	$17.74	$16.28
	$(100,000)	$53.22	$43.89	$37.23	$32.23	$28.35	$25.23	$22.70	$20.58	$18.78	$17.24
	$ -	$55.02	$45.39	$38.52	$33.36	$29.35	**$26.13**	$23.51	$21.33	$19.48	$17.89
	$100,000	$56.82	$46.89	$39.80	$34.49	$30.35	$27.03	$24.33	$22.08	$20.17	$18.53
	$250,000	$59.52	$49.15	$41.73	$36.18	$31.85	$28.38	$25.56	$23.20	$21.21	$19.50
	$500,000	$64.03	$52.90	$44.95	$38.99	$34.35	$30.63	$27.61	$25.08	$22.94	$21.11

Table 12. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 13.98 Miles of Canals B, C, and D and Value of Energy Savings, Cameron County Irrigation District No. 2, Lining Earthen Canals, for BOR Project, 2003.

	ac-ft of water loss (seepage) for 13.98 miles of earthen canal to be lined										
		3,750	4,500	5,250	6,000	6,750	**7,503**	8,250	9,000	9,750	10,500
Value of Energy Savings ($/kwh)	$0.0300	$56.42	$46.79	$39.92	$34.76	$30.75	$27.53	$24.91	$22.73	$20.88	$19.29
	$0.0450	$55.75	$46.12	$39.25	$34.09	$30.08	$26.86	$24.24	$22.06	$20.21	$18.62
	$0.0550	$55.30	$45.68	$38.80	$33.64	$29.63	$26.41	$23.80	$21.61	$19.76	$18.17
	$0.0614	$55.02	$45.39	$38.52	$33.36	$29.35	**$26.13**	$23.51	$21.33	$19.48	$17.89
	$0.0675	$54.74	$45.12	$38.24	$33.08	$29.07	$25.85	$23.24	$21.05	$19.20	$17.61
	$0.0800	$54.19	$44.56	$37.68	$32.53	$28.52	$25.29	$22.68	$20.49	$18.64	$17.06
	$0.0900	$53.74	$44.11	$37.24	$32.08	$28.07	$24.85	$22.23	$20.05	$18.20	$16.61

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, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$0.0006966	$0.0006192	$0.0005866	$0.0005715	$0.0005573	$0.0005437	$0.0005307	$0.0005066	$0.0004458	$0.0003715
	20	$0.0004482	$0.0003984	$0.0003774	$0.0003677	$0.0003585	$0.0003498	$0.0003415	$0.0003259	$0.0002868	$0.0002390
	25	$0.0004025	$0.0003578	$0.0003390	$0.0003303	$0.0003220	$0.0003142	$0.0003067	$0.0002927	$0.0002576	$0.0002147
	30	$0.0003741	$0.0003325	$0.0003150	$0.0003070	$0.0002993	$0.0002920	$0.0002850	$0.0002721	$0.0002394	$0.0001995
	40	$0.0003426	$0.0003046	$0.0002885	$0.0002811	$0.0002741	$0.0002674	$0.0002611	$0.0002492	$0.0002193	$0.0001827
	49	$0.0003284	$0.0002919	$0.0002766	$0.0002695	**$0.0002627**	$0.0002563	$0.0002502	$0.0002388	$0.0002102	$0.0001752

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, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$2.377	$2.113	$2.001	$1.950	$1.901	$1.855	$1.811	$1.729	$1.521	$1.268
	20	$1.529	$1.359	$1.288	$1.255	$1.223	$1.193	$1.165	$1.112	$0.979	$0.816
	25	$1.373	$1.221	$1.157	$1.127	$1.099	$1.072	$1.046	$0.999	$0.879	$0.732
	30	$1.276	$1.135	$1.075	$1.047	$1.021	$0.996	$0.973	$0.928	$0.817	$0.681
	40	$1.169	$1.039	$0.984	$0.959	$0.935	$0.912	$0.891	$0.850	$0.748	$0.624
	49	$1.121	$0.996	$0.944	$0.919	**$0.896**	$0.875	$0.854	$0.815	$0.717	$0.598

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, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.0002772	$0.0002464	$0.0002334	$0.0002274	$0.0002217	$0.0002163	$0.0002112	$0.0002016	$0.0001774	$0.0001478
	$(250,000)	$0.0003028	$0.0002692	$0.0002550	$0.0002484	$0.0002422	$0.0002363	$0.0002307	$0.0002202	$0.0001938	$0.0001615
	$(100,000)	$0.0003182	$0.0002828	$0.0002679	$0.0002611	$0.0002545	$0.0002483	$0.0002424	$0.0002314	$0.0002036	$0.0001697
	$ -	$0.0003284	$0.0002919	$0.0002766	$0.0002695	**$0.0002627**	$0.0002563	$0.0002502	$0.0002388	$0.0002102	$0.0001752
	$100,000	$0.0003387	$0.0003010	$0.0002852	$0.0002779	$0.0002709	$0.0002643	$0.0002580	$0.0002463	$0.0002167	$0.0001806
	$250,000	$0.0003540	$0.0003147	$0.0002981	$0.0002905	$0.0002832	$0.0002763	$0.0002697	$0.0002575	$0.0002266	$0.0001888
	$500,000	$0.0003796	$0.0003375	$0.0003197	$0.0003115	$0.0003037	$0.0002963	$0.0002893	$0.0002761	$0.0002430	$0.0002025

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, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.946	$0.841	$0.796	$0.776	$0.757	$0.738	$0.721	$0.688	$0.605	$0.504
	$(250,000)	$1.033	$0.918	$0.870	$0.848	$0.827	$0.806	$0.787	$0.751	$0.661	$0.551
	$(100,000)	$1.086	$0.965	$0.914	$0.891	$0.868	$0.847	$0.827	$0.790	$0.695	$0.579
	$ -	$1.121	$0.996	$0.944	$0.919	**$0.896**	$0.875	$0.854	$0.815	$0.717	$0.598
	$100,000	$1.156	$1.027	$0.973	$0.948	$0.924	$0.902	$0.880	$0.840	$0.740	$0.616
	$250,000	$1.208	$1.074	$1.017	$0.991	$0.966	$0.943	$0.920	$0.879	$0.773	$0.644
	$500,000	$1.295	$1.151	$1.091	$1.063	$1.036	$1.011	$0.987	$0.942	$0.829	$0.691

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 Canals, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 13.98 miles of earthen canal	3,750	$0.0006571	$0.0005841	$0.0005534	$0.0005392	$0.0005257	$0.0005129	$0.0005007	$0.0004779	$0.0004205	$0.0003505
	4,500	$0.0005476	$0.0004867	$0.0004611	$0.0004493	$0.0004381	$0.0004274	$0.0004172	$0.0003982	$0.0003505	$0.0002920
	5,250	$0.0004694	$0.0004172	$0.0003953	$0.0003851	$0.0003755	$0.0003663	$0.0003576	$0.0003414	$0.0003004	$0.0002503
	6,000	$0.0004107	$0.0003651	$0.0003458	$0.0003370	$0.0003286	$0.0003205	$0.0003129	$0.0002987	$0.0002628	$0.0002190
	6,750	$0.0003651	$0.0003245	$0.0003074	$0.0002995	$0.0002920	$0.0002849	$0.0002781	$0.0002655	$0.0002336	$0.0001947
	7,503	$0.0003284	$0.0002919	$0.0002766	$0.0002695	**$0.0002627**	$0.0002563	$0.0002502	$0.0002388	$0.0002102	$0.0001752
	8,250	$0.0002987	$0.0002655	$0.0002515	$0.0002451	$0.0002389	$0.0002331	$0.0002276	$0.0002172	$0.0001912	$0.0001593
	9,000	$0.0002738	$0.0002434	$0.0002306	$0.0002247	$0.0002190	$0.0002137	$0.0002086	$0.0001991	$0.0001752	$0.0001460
	9,750	$0.0002527	$0.0002247	$0.0002128	$0.0002074	$0.0002022	$0.0001973	$0.0001926	$0.0001838	$0.0001617	$0.0001348
	10,500	$0.0002347	$0.0002086	$0.0001976	$0.0001926	$0.0001877	$0.0001832	$0.0001788	$0.0001707	$0.0001502	$0.0001252

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 Canals, Cameron County Irrigation District No. 2, Canals B, C, and D (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 13.98 miles of earthen canal	3,750	$2.242	$1.993	$1.888	$1.840	$1.794	$1.750	$1.708	$1.631	$1.435	$1.196
	4,500	$1.868	$1.661	$1.573	$1.533	$1.495	$1.458	$1.424	$1.359	$1.196	$0.996
	5,250	$1.601	$1.424	$1.349	$1.314	$1.281	$1.250	$1.220	$1.165	$1.025	$0.854
	6,000	$1.401	$1.246	$1.180	$1.150	$1.121	$1.094	$1.068	$1.019	$0.897	$0.747
	6,750	$1.246	$1.107	$1.049	$1.022	$0.996	$0.972	$0.949	$0.906	$0.797	$0.664
	7,503	$1.121	$0.996	$0.944	$0.919	**$0.896**	$0.875	$0.854	$0.815	$0.717	$0.598
	8,250	$1.019	$0.906	$0.858	$0.836	$0.815	$0.795	$0.776	$0.741	$0.652	$0.544
	9,000	$0.934	$0.830	$0.787	$0.767	$0.747	$0.729	$0.712	$0.679	$0.598	$0.498
	9,750	$0.862	$0.767	$0.726	$0.708	$0.690	$0.673	$0.657	$0.627	$0.552	$0.460
	10,500	$0.801	$0.712	$0.674	$0.657	$0.641	$0.625	$0.610	$0.582	$0.512	$0.427

Table 19. Economic and Financial Evaluation Results Across Component #2's Useful Life, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe) Project Component for BOR, 2003.

Results	Nominal	Real[a]
Water Savings (ac-ft)		
Agriculture Irrigation	298,371	124,954
M&I	0	0
Total ac-ft	298,371	124,954
annuity equivalent		5,817
Energy Savings (BTU)		
Agriculture Irrigation	32,783,084,020	13,729,185,042
M&I	0	0
Total BTU	32,783,084,020	13,729,185,042
annuity equivalent		639,096,316
Energy Savings (kwh)		
Agriculture Irrigation	9,608,172	4,023,794
M&I	0	0
Total kwh's	9,608,172	4,023,794
annuity equivalent		187,308
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings	$1,209,359	$3,637,960
annuity equivalent		$234,845
Cost of Water Savings ($/ac-ft)		$40.37
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings	$2,248,073	$3,884,833
annuity equivalent		$250,781
Cost of Energy Savings ($/BTU)		$0.0003924
Cost of Energy Savings ($/kwh)		$1.339

[a] Determined using a 4% discount factor.

Table 20. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 11.40 Miles of Canal B Laterals and Expected Useful Life of the Capital Investment, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Laterals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 11.40 miles of earthen lateral to be replaced with pipeline									
		2,675	3,225	3,750	4,300	4,850	**5,374**	5,900	6,450	6,975	7,525
Expected Useful life of Investment (years)	10	$177.92	$146.58	$125.25	$108.49	$95.52	$85.64	$77.49	$70.39	$64.65	$59.50
	20	$114.47	$94.31	$80.58	$69.80	$61.46	$55.10	$49.86	$45.29	$41.60	$38.28
	25	$102.81	$84.70	$72.38	$62.69	$55.20	$49.48	$44.78	$40.67	$37.36	$34.38
	30	$95.56	$78.73	$67.27	$58.27	$51.30	$45.99	$41.62	$37.80	$34.72	$31.96
	40	$87.52	$72.10	$61.61	$53.36	$46.99	$42.12	$38.12	$34.62	$31.80	$29.27
	49	$83.88	$69.11	$59.05	$51.15	$45.04	**$40.37**	$36.53	$33.18	$30.48	$28.05

Table 21. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 11.40 Miles of Canal B Laterals and Initial Cost of the Capital Investment, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Laterals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 11.40 miles of earthen lateral to be replaced with pipeline									
		2,675	3,225	3,750	4,300	4,850	**5,374**	5,900	6,450	6,975	7,525
Initial Capital Investment Cost ($)	$(500,000)	$72.73	$59.86	$51.10	$44.21	$38.89	$34.83	$31.48	$28.56	$26.21	$24.09
	$(250,000)	$78.31	$64.49	$55.07	$47.68	$41.96	$37.60	$34.01	$30.87	$28.34	$26.07
	$(100,000)	$81.65	$67.26	$57.46	$49.76	$43.81	$39.26	$35.52	$32.26	$29.63	$27.26
	$ -	$83.88	$69.11	$59.05	$51.15	$45.04	**$40.37**	$36.53	$33.18	$30.48	$28.05
	$100,000	$86.11	$70.96	$60.64	$52.53	$46.27	$41.48	$37.54	$34.11	$31.34	$28.85
	$250,000	$89.46	$73.73	$63.03	$54.61	$48.11	$43.15	$39.06	$35.50	$32.62	$30.03
	$500,000	$95.03	$78.36	$67.00	$58.08	$51.19	$45.92	$41.59	$37.81	$34.76	$32.02

Table 22. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 11.40 Miles of Canal B Laterals and Value of Energy Savings, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Laterals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 11.40 miles of earthen lateral to be replaced with pipeline									
		2,675	3,225	3,750	4,300	4,850	**5,374**	5,900	6,450	6,975	7,525
Value of Energy Savings ($/kwh)	$0.0300	$85.28	$70.51	$60.45	$52.55	$46.44	$41.77	$37.93	$34.58	$31.88	$29.45
	$0.0450	$84.61	$69.84	$59.78	$51.88	$45.77	$41.10	$37.26	$33.92	$31.21	$28.78
	$0.0550	$84.17	$69.39	$59.33	$51.43	$45.32	$40.66	$36.82	$33.47	$30.76	$28.34
	$0.0614	$83.88	$69.11	$59.05	$51.15	$45.04	**$40.37**	$36.53	$33.18	$30.48	$28.05
	$0.0675	$83.61	$68.84	$58.78	$50.87	$44.76	$40.10	$36.26	$32.91	$30.21	$27.78
	$0.0800	$83.05	$68.28	$58.22	$50.31	$44.20	$39.54	$35.70	$32.35	$29.65	$27.22
	$0.0900	$82.60	$67.83	$57.77	$49.87	$43.76	$39.10	$35.25	$31.91	$29.20	$26.77

Table 23. 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, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$0.0010404	$0.0009248	$0.0008761	$0.0008536	$0.0008323	$0.0008120	$0.0007927	$0.0007566	$0.0006658	$0.0005549
	20	$0.0006694	$0.0005950	$0.0005637	$0.0005492	$0.0005355	$0.0005224	$0.0005100	$0.0004868	$0.0004284	$0.0003570
	25	$0.0006012	$0.0005344	$0.0005063	$0.0004933	$0.0004809	$0.0004692	$0.0004580	$0.0004372	$0.0003848	$0.0003206
	30	$0.0005588	$0.0004967	$0.0004705	$0.0004585	$0.0004470	$0.0004361	$0.0004257	$0.0004064	$0.0003576	$0.0002980
	40	$0.0005117	$0.0004549	$0.0004309	$0.0004199	$0.0004094	$0.0003994	$0.0003899	$0.0003722	$0.0003275	$0.0002729
	49	$0.0004905	$0.0004360	$0.0004131	$0.0004025	**$0.0003924**	$0.0003828	$0.0003737	$0.0003567	$0.0003139	$0.0002616

Table 24. 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, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$3.550	$3.155	$2.989	$2.913	$2.840	$2.771	$2.705	$2.582	$2.272	$1.893
	20	$2.284	$2.030	$1.923	$1.874	$1.827	$1.783	$1.740	$1.661	$1.462	$1.218
	25	$2.051	$1.823	$1.727	$1.683	$1.641	$1.601	$1.563	$1.492	$1.313	$1.094
	30	$1.906	$1.695	$1.605	$1.564	$1.525	$1.488	$1.453	$1.387	$1.220	$1.017
	40	$1.746	$1.552	$1.470	$1.433	$1.397	$1.363	$1.330	$1.270	$1.117	$0.931
	49	$1.674	$1.488	$1.409	$1.373	**$1.339**	$1.306	$1.275	$1.217	$1.071	$0.893

Table 25. 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, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.0004274	$0.0003799	$0.0003599	$0.0003507	$0.0003419	$0.0003336	$0.0003256	$0.0003108	$0.0002735	$0.0002279
	$(250,000)	$0.0004589	$0.0004079	$0.0003865	$0.0003766	$0.0003671	$0.0003582	$0.0003497	$0.0003338	$0.0002937	$0.0002448
	$(100,000)	$0.0004779	$0.0004248	$0.0004024	$0.0003921	$0.0003823	$0.0003730	$0.0003641	$0.0003475	$0.0003058	$0.0002549
	$ -	$0.0004905	$0.0004360	$0.0004131	$0.0004025	**$0.0003924**	$0.0003828	$0.0003737	$0.0003567	$0.0003139	$0.0002616
	$100,000	$0.0005031	$0.0004472	$0.0004237	$0.0004128	$0.0004025	$0.0003927	$0.0003833	$0.0003659	$0.0003220	$0.0002683
	$250,000	$0.0005221	$0.0004641	$0.0004396	$0.0004284	$0.0004177	$0.0004075	$0.0003978	$0.0003797	$0.0003341	$0.0002784
	$500,000	$0.0005536	$0.0004921	$0.0004662	$0.0004543	$0.0004429	$0.0004321	$0.0004218	$0.0004026	$0.0003543	$0.0002953

Table 26. 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, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$1.458	$1.296	$1.228	$1.196	$1.167	$1.138	$1.111	$1.060	$0.933	$0.778
	$(250,000)	$1.566	$1.392	$1.319	$1.285	$1.253	$1.222	$1.193	$1.139	$1.002	$0.835
	$(100,000)	$1.631	$1.449	$1.373	$1.338	$1.304	$1.273	$1.242	$1.186	$1.044	$0.870
	$ -	$1.674	$1.488	$1.409	$1.373	**$1.339**	$1.306	$1.275	$1.217	$1.071	$0.893
	$100,000	$1.717	$1.526	$1.446	$1.409	$1.373	$1.340	$1.308	$1.248	$1.099	$0.916
	$250,000	$1.781	$1.583	$1.500	$1.462	$1.425	$1.390	$1.357	$1.295	$1.140	$0.950
	$500,000	$1.889	$1.679	$1.591	$1.550	$1.511	$1.474	$1.439	$1.374	$1.209	$1.007

Table 27. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Lateral, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 11.40 miles of earthen lateral	2,675	$0.0009855	$0.0008760	$0.0008299	$0.0008086	$0.0007884	$0.0007692	$0.0007508	$0.0007167	$0.0006307	$0.0005256
	3,225	$0.0008174	$0.0007266	$0.0006883	$0.0006707	$0.0006539	$0.0006380	$0.0006228	$0.0005945	$0.0005231	$0.0004360
	3,750	$0.0007030	$0.0006249	$0.0005920	$0.0005768	$0.0005624	$0.0005487	$0.0005356	$0.0005113	$0.0004499	$0.0003749
	4,300	$0.0006131	$0.0005449	$0.0005163	$0.0005030	$0.0004904	$0.0004785	$0.0004671	$0.0004459	$0.0003924	$0.0003270
	4,850	$0.0005435	$0.0004831	$0.0004577	$0.0004460	$0.0004348	$0.0004242	$0.0004141	$0.0003953	$0.0003479	$0.0002899
	5,374	$0.0004905	$0.0004360	$0.0004131	$0.0004025	**$0.0003924**	$0.0003828	$0.0003737	$0.0003567	$0.0003139	$0.0002616
	5,900	$0.0004468	$0.0003972	$0.0003763	$0.0003666	$0.0003574	$0.0003487	$0.0003404	$0.0003249	$0.0002860	$0.0002383
	6,450	$0.0004087	$0.0003633	$0.0003442	$0.0003353	$0.0003270	$0.0003190	$0.0003114	$0.0002972	$0.0002616	$0.0002180
	6,975	$0.0003779	$0.0003359	$0.0003183	$0.0003101	$0.0003024	$0.0002950	$0.0002880	$0.0002749	$0.0002419	$0.0002016
	7,525	$0.0003503	$0.0003114	$0.0002950	$0.0002874	$0.0002803	$0.0002734	$0.0002669	$0.0002548	$0.0002242	$0.0001868

Table 28. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Lateral, Cameron County Irrigation District No. 2, Canal B Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 11.40 miles of earthen lateral	2,675	$3.362	$2.989	$2.832	$2.759	$2.690	$2.624	$2.562	$2.445	$2.152	$1.793
	3,225	$2.789	$2.479	$2.349	$2.288	$2.231	$2.177	$2.125	$2.028	$1.785	$1.487
	3,750	$2.399	$2.132	$2.020	$1.968	$1.919	$1.872	$1.827	$1.744	$1.535	$1.279
	4,300	$2.092	$1.859	$1.761	$1.716	$1.673	$1.633	$1.594	$1.521	$1.339	$1.116
	4,850	$1.855	$1.648	$1.562	$1.522	$1.484	$1.447	$1.413	$1.349	$1.187	$0.989
	5,374	$1.674	$1.488	$1.409	$1.373	**$1.339**	$1.306	$1.275	$1.217	$1.071	$0.893
	5,900	$1.524	$1.355	$1.284	$1.251	$1.220	$1.190	$1.162	$1.109	$0.976	$0.813
	6,450	$1.394	$1.240	$1.174	$1.144	$1.116	$1.088	$1.062	$1.014	$0.892	$0.744
	6,975	$1.290	$1.146	$1.086	$1.058	$1.032	$1.006	$0.983	$0.938	$0.825	$0.688
	7,525	$1.195	$1.062	$1.007	$0.981	$0.956	$0.933	$0.911	$0.869	$0.765	$0.637

Table 29. Economic and Financial Evaluation Results Across Component #3's Useful Life, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe) Project Component for BOR, 2003.

Results	Nominal	Real[a]
Water Savings (ac-ft)		
Agriculture Irrigation	83,001	34,760
M&I	0	0
Total ac-ft	83,001	34,760
annuity equivalent		1,618
Energy Savings (BTU)		
Agriculture Irrigation	9,119,632,468	3,819,198,999
M&I	0	0
Total BTU	9,119,632,468	3,819,198,999
annuity equivalent		177,784,479
Energy Savings (kwh)		
Agriculture Irrigation	2,672,811	1,119,343
M&I	0	0
Total kwh's	2,672,811	1,119,343
annuity equivalent		52,106
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings	$1,359,043	$2,339,578
annuity equivalent		$151,029
Cost of Water Savings ($/ac-ft)		$93.34
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings	$1,647,993	$2,408,253
annuity equivalent		$155,462
Cost of Energy Savings ($/BTU)		$0.0008744
Cost of Energy Savings ($/kwh)		$2.984

[a] Determined using a 4% discount factor.

Table 30. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 5.54 Miles of Canal C Laterals and Expected Useful Life of the Capital Investment, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Laterals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 5.54 miles of earthen lateral to be replaced with pipeline									
		725	875	1,000	1,150	1,300	**1,440**	1,575	1,725	1,875	2,025
Expected Useful life of Investment (years)	10	$399.06	$329.65	$287.72	$249.43	$219.98	$197.97	$180.56	$164.35	$150.74	$139.14
	20	$256.75	$212.09	$185.12	$160.48	$141.53	$127.37	$116.17	$105.74	$96.98	$89.52
	25	$230.60	$190.49	$166.26	$144.14	$127.12	$114.40	$104.34	$94.97	$87.11	$80.40
	30	$214.33	$177.05	$154.53	$133.97	$118.15	$106.33	$96.97	$88.27	$80.96	$74.73
	40	$196.29	$162.15	$141.53	$122.69	$108.21	$97.38	$88.82	$80.84	$74.15	$68.44
	49	$188.14	$155.42	$135.65	$117.60	$103.71	**$93.34**	$85.13	$77.49	$71.07	$65.60

Table 31. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 5.54 Miles of Canal C Laterals and Initial Cost of the Capital Investment, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Laterals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 5.54 miles of earthen lateral to be replaced with pipeline									
		725	875	1,000	1,150	1,300	**1,440**	1,575	1,725	1,875	2,025
Initial Capital Investment Cost ($)	$(500,000)	$148.51	$122.58	$106.92	$92.62	$81.61	$73.39	$66.88	$60.83	$55.74	$51.41
	$(250,000)	$168.33	$139.00	$121.28	$105.11	$92.66	$83.36	$76.01	$69.16	$63.41	$58.51
	$(100,000)	$180.22	$148.85	$129.90	$112.60	$99.29	$89.35	$81.48	$74.16	$68.00	$62.76
	$ -	$188.14	$155.42	$135.65	$117.60	$103.71	**$93.34**	$85.13	$77.49	$71.07	$65.60
	$100,000	$196.07	$161.99	$141.40	$122.60	$108.14	$97.33	$88.78	$80.82	$74.13	$68.44
	$250,000	$207.96	$171.84	$150.02	$130.09	$114.77	$103.31	$94.25	$85.82	$78.73	$72.70
	$500,000	$227.78	$188.26	$164.38	$142.59	$125.82	$113.29	$103.37	$94.14	$86.39	$79.79

Table 32. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 5.54 Miles of Canal C Laterals and Value of Energy Savings, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Laterals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 5.54 miles of earthen lateral to be replaced with pipeline									
		725	875	1,000	1,150	1,300	**1,440**	1,575	1,725	1,875	2,025
Value of Energy Savings ($/kwh)	$0.0300	$189.54	$156.82	$137.05	$119.00	$105.11	$94.74	$86.53	$78.89	$72.47	$67.00
	$0.0450	$188.87	$156.15	$136.38	$118.33	$104.45	$94.07	$85.86	$78.22	$71.80	$66.33
	$0.0550	$188.43	$155.71	$135.93	$117.88	$104.00	$93.62	$85.41	$77.77	$71.35	$65.89
	$0.0614	$188.14	$155.42	$135.65	$117.60	$103.71	**$93.34**	$85.13	$77.49	$71.07	$65.60
	$0.0675	$187.87	$155.15	$135.38	$117.33	$103.44	$93.06	$84.85	$77.21	$70.79	$65.33
	$0.0800	$187.31	$154.59	$134.82	$116.77	$102.88	$92.51	$84.29	$76.65	$70.24	$64.77
	$0.0900	$186.87	$154.14	$134.37	$116.32	$102.44	$92.06	$83.85	$76.21	$69.79	$64.32

Table 33. 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, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$0.0023184	$0.0020608	$0.0019523	$0.0019023	$0.0018547	$0.0018095	$0.0017664	$0.0016861	$0.0014838	$0.0012365
	20	$0.0014916	$0.0013259	$0.0012561	$0.0012239	$0.0011933	$0.0011642	$0.0011365	$0.0010848	$0.0009546	$0.0007955
	25	$0.0013397	$0.0011908	$0.0011282	$0.0010992	$0.0010718	$0.0010456	$0.0010207	$0.0009743	$0.0008574	$0.0007145
	30	$0.0012452	$0.0011068	$0.0010486	$0.0010217	$0.0009961	$0.0009718	$0.0009487	$0.0009056	$0.0007969	$0.0006641
	40	$0.0011404	$0.0010137	$0.0009603	$0.0009357	$0.0009123	$0.0008901	$0.0008689	$0.0008294	$0.0007299	$0.0006082
	49	$0.0010931	$0.0009716	$0.0009205	$0.0008969	**$0.0008744**	$0.0008531	$0.0008328	$0.0007949	$0.0006996	$0.0005830

Table 34. 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, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$7.910	$7.031	$6.661	$6.491	$6.328	$6.174	$6.027	$5.753	$5.063	$4.219
	20	$5.089	$4.524	$4.286	$4.176	$4.072	$3.972	$3.878	$3.701	$3.257	$2.714
	25	$4.571	$4.063	$3.849	$3.751	$3.657	$3.568	$3.483	$3.324	$2.925	$2.438
	30	$4.249	$3.776	$3.578	$3.486	$3.399	$3.316	$3.237	$3.090	$2.719	$2.266
	40	$3.891	$3.459	$3.277	$3.193	$3.113	$3.037	$2.965	$2.830	$2.490	$2.075
	49	$3.729	$3.315	$3.141	$3.060	**$2.984**	$2.911	$2.842	$2.712	$2.387	$1.989

Table 35. 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, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.0008661	$0.0007699	$0.0007294	$0.0007107	$0.0006929	$0.0006760	$0.0006599	$0.0006299	$0.0005543	$0.0004619
	$(250,000)	$0.0009796	$0.0008707	$0.0008249	$0.0008038	$0.0007837	$0.0007646	$0.0007463	$0.0007124	$0.0006269	$0.0005224
	$(100,000)	$0.0010477	$0.0009313	$0.0008822	$0.0008596	$0.0008381	$0.0008177	$0.0007982	$0.0007619	$0.0006705	$0.0005588
	$ -	$0.0010931	$0.0009716	$0.0009205	$0.0008969	**$0.0008744**	$0.0008531	$0.0008328	$0.0007949	$0.0006996	$0.0005830
	$100,000	$0.0011384	$0.0010119	$0.0009587	$0.0009341	$0.0009108	$0.0008885	$0.0008674	$0.0008280	$0.0007286	$0.0006072
	$250,000	$0.0012065	$0.0010725	$0.0010160	$0.0009900	$0.0009652	$0.0009417	$0.0009193	$0.0008775	$0.0007722	$0.0006435
	$500,000	$0.0013200	$0.0011733	$0.0011116	$0.0010831	$0.0010560	$0.0010302	$0.0010057	$0.0009600	$0.0008448	$0.0007040

Table 36. 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, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$2.955	$2.627	$2.489	$2.425	$2.364	$2.306	$2.252	$2.149	$1.891	$1.576
	$(250,000)	$3.342	$2.971	$2.815	$2.742	$2.674	$2.609	$2.547	$2.431	$2.139	$1.783
	$(100,000)	$3.575	$3.177	$3.010	$2.933	$2.860	$2.790	$2.724	$2.600	$2.288	$1.906
	$ -	$3.729	$3.315	$3.141	$3.060	**$2.984**	$2.911	$2.842	$2.712	$2.387	$1.989
	$100,000	$3.884	$3.453	$3.271	$3.187	$3.107	$3.032	$2.960	$2.825	$2.486	$2.072
	$250,000	$4.117	$3.659	$3.467	$3.378	$3.293	$3.213	$3.136	$2.994	$2.635	$2.196
	$500,000	$4.504	$4.003	$3.793	$3.695	$3.603	$3.515	$3.431	$3.276	$2.882	$2.402

Table 37. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Lateral, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 5.54 miles of earthen lateral	725	$0.0021716	$0.0019303	$0.0018287	$0.0017819	$0.0017373	$0.0016949	$0.0016546	$0.0015794	$0.0013898	$0.0011582
	875	$0.0017994	$0.0015994	$0.0015152	$0.0014764	$0.0014395	$0.0014044	$0.0013709	$0.0013086	$0.0011516	$0.0009597
	1,000	$0.0015744	$0.0013995	$0.0013258	$0.0012918	$0.0012595	$0.0012288	$0.0011996	$0.0011450	$0.0010076	$0.0008397
	1,150	$0.0013691	$0.0012170	$0.0011529	$0.0011233	$0.0010953	$0.0010685	$0.0010431	$0.0009957	$0.0008762	$0.0007302
	1,300	$0.0012111	$0.0010765	$0.0010199	$0.0009937	$0.0009689	$0.0009453	$0.0009227	$0.0008808	$0.0007751	$0.0006459
	1,440	$0.0010931	$0.0009716	$0.0009205	$0.0008969	**$0.0008744**	$0.0008531	$0.0008328	$0.0007949	$0.0006996	$0.0005830
	1,575	$0.0009996	$0.0008886	$0.0008418	$0.0008202	$0.0007997	$0.0007802	$0.0007616	$0.0007270	$0.0006398	$0.0005331
	1,725	$0.0009127	$0.0008113	$0.0007686	$0.0007489	$0.0007302	$0.0007124	$0.0006954	$0.0006638	$0.0005841	$0.0004868
	1,875	$0.0008397	$0.0007464	$0.0007071	$0.0006890	$0.0006718	$0.0006554	$0.0006398	$0.0006107	$0.0005374	$0.0004478
	2,025	$0.0007775	$0.0006911	$0.0006547	$0.0006379	$0.0006220	$0.0006068	$0.0005924	$0.0005655	$0.0004976	$0.0004147

Table 38. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Lateral, Cameron County Irrigation District No. 2, Canal C Laterals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 5.54 miles of earthen lateral	725	$7.410	$6.586	$6.240	$6.080	$5.928	$5.783	$5.645	$5.389	$4.742	$3.952
	875	$6.139	$5.457	$5.170	$5.037	$4.912	$4.792	$4.678	$4.465	$3.929	$3.274
	1,000	$5.372	$4.775	$4.524	$4.408	$4.298	$4.193	$4.093	$3.907	$3.438	$2.865
	1,150	$4.671	$4.152	$3.934	$3.833	$3.737	$3.646	$3.559	$3.397	$2.990	$2.491
	1,300	$4.132	$3.673	$3.480	$3.391	$3.306	$3.225	$3.148	$3.005	$2.645	$2.204
	1,440	$3.729	$3.315	$3.141	$3.060	**$2.984**	$2.911	$2.842	$2.712	$2.387	$1.989
	1,575	$3.411	$3.032	$2.872	$2.799	$2.729	$2.662	$2.599	$2.481	$2.183	$1.819
	1,725	$3.114	$2.768	$2.622	$2.555	$2.491	$2.431	$2.373	$2.265	$1.993	$1.661
	1,875	$2.865	$2.547	$2.413	$2.351	$2.292	$2.236	$2.183	$2.084	$1.834	$1.528
	2,025	$2.653	$2.358	$2.234	$2.177	$2.122	$2.070	$2.021	$1.929	$1.698	$1.415

Table 39. Economic and Financial Evaluation Results Across Component #4's Useful Life, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining) Project Component for BOR, 2003.

Results	Nominal	Real[a]
Water Savings (ac-ft)		
Agriculture Irrigation	222,254	93,078
M&I	0	0
Total ac-ft	222,254	93,078
annuity equivalent		4,333
Energy Savings (BTU)		
Agriculture Irrigation	24,419,876,585	10,226,768,297
M&I	0	0
Total BTU	24,419,876,585	10,226,768,297
annuity equivalent		476,058,114
Energy Savings (kwh)		
Agriculture Irrigation	7,157,056	2,997,294
M&I	0	0
Total kwh's	7,157,056	2,997,294
annuity equivalent		139,525
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings	$2,039,975	$2,764,563
annuity equivalent		$178,464
Cost of Water Savings ($/ac-ft)		$41.19
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings	$2,813,705	$2,948,456
annuity equivalent		$190,335
Cost of Energy Savings ($/BTU)		$0.0003998
Cost of Energy Savings ($/kwh)		$1.364

[a] Determined using a 4% discount factor.

Table 40. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 9.15 Miles of Old District 13 Canals and Expected Useful Life of the Capital Investment, Cameron County Irrigation District No. 2, Lining Canals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 9.15 miles of canal to be lined									
		2,275	2,725	3,175	3,625	4,075	**4,534**	4,975	5,450	5,900	6,350
Expected Useful life of Investment (years)	10	$179.89	$149.22	$127.25	$110.73	$97.86	$87.36	$79.11	$71.71	$65.79	$60.72
	20	$115.74	$96.01	$81.87	$71.24	$62.96	$56.21	$50.90	$46.13	$42.33	$39.07
	25	$103.95	$86.23	$73.53	$63.99	$56.55	$50.48	$45.71	$41.44	$38.02	$35.09
	30	$96.61	$80.14	$68.34	$59.47	$52.56	$46.92	$42.49	$38.51	$35.34	$32.61
	40	$88.49	$73.40	$62.59	$54.47	$48.14	$42.97	$38.91	$35.27	$32.36	$29.87
	49	$84.81	$70.35	$59.99	$52.21	$46.14	**$41.19**	$37.30	$33.81	$31.02	$28.63

Table 41. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 9.15 Miles of Old District 13 Canals and Initial Cost of the Capital Investment, Cameron County Irrigation District No. 2, Lining Canals, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 9.15 miles of canal to be lined									
		2,275	2,725	3,175	3,625	4,075	**4,534**	4,975	5,450	5,900	6,350
Initial Capital Investment Cost ($)	$(500,000)	$69.96	$57.96	$49.36	$42.89	$37.85	$33.74	$30.51	$27.61	$25.29	$23.31
	$(250,000)	$77.39	$64.16	$54.67	$47.55	$41.99	$37.46	$33.90	$30.71	$28.16	$25.97
	$(100,000)	$81.84	$67.87	$57.87	$50.34	$44.48	$39.70	$35.94	$32.57	$29.87	$27.56
	$ -	$84.81	$70.35	$59.99	$52.21	$46.14	**$41.19**	$37.30	$33.81	$31.02	$28.63
	$100,000	$87.78	$72.83	$62.12	$54.07	$47.80	$42.68	$38.65	$35.05	$32.16	$29.69
	$250,000	$92.23	$76.55	$65.31	$56.86	$50.28	$44.91	$40.69	$36.91	$33.88	$31.29
	$500,000	$99.66	$82.75	$70.63	$61.52	$54.43	$48.64	$44.09	$40.00	$36.74	$33.95

Table 42. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 9.15 Miles of Old District 13 Canals and Value of Energy Savings, Cameron County Irrigation District No. 2, Lining Canals, for BOR Project, 2003.

	ac-ft of water loss (seepage) for 9.15 miles of canal to be lined										
		2,275	2,725	3,175	3,625	4,075	**4,534**	4,975	5,450	5,900	6,350
Value of Energy Savings ($/kwh)	$0.0300	$86.21	$71.75	$61.39	$53.61	$47.54	$42.59	$38.70	$35.21	$32.42	$30.03
	$0.0450	$85.54	$71.08	$60.72	$52.94	$46.87	$41.92	$38.03	$34.54	$31.75	$29.36
	$0.0550	$85.09	$70.64	$60.28	$52.49	$46.42	$41.47	$37.58	$34.09	$31.30	$28.91
	$0.0614	$84.81	$70.35	$59.99	$52.21	$46.14	**$41.19**	$37.30	$33.81	$31.02	$28.63
	$0.0675	$84.54	$70.08	$59.72	$51.93	$45.86	$40.91	$37.02	$33.53	$30.74	$28.35
	$0.0800	$83.98	$69.52	$59.16	$51.37	$45.31	$40.36	$36.46	$32.97	$30.19	$27.79
	$0.0900	$83.53	$69.07	$58.71	$50.93	$44.86	$39.91	$36.02	$32.53	$29.74	$27.35

Table 43. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$0.0010600	$0.0009422	$0.0008927	$0.0008698	$0.0008480	$0.0008273	$0.0008076	$0.0007709	$0.0006784	$0.0005653
	20	$0.0006820	$0.0006062	$0.0005743	$0.0005596	$0.0005456	$0.0005323	$0.0005196	$0.0004960	$0.0004365	$0.0003637
	25	$0.0006125	$0.0005445	$0.0005158	$0.0005026	$0.0004900	$0.0004781	$0.0004667	$0.0004455	$0.0003920	$0.0003267
	30	$0.0005693	$0.0005061	$0.0004794	$0.0004671	$0.0004555	$0.0004443	$0.0004338	$0.0004140	$0.0003644	$0.0003036
	40	$0.0005214	$0.0004635	$0.0004391	$0.0004278	$0.0004171	$0.0004070	$0.0003973	$0.0003792	$0.0003337	$0.0002781
	49	$0.0004998	$0.0004442	$0.0004209	$0.0004101	**$0.0003998**	$0.0003901	$0.0003808	$0.0003635	$0.0003199	$0.0002665

Table 44. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$3.617	$3.215	$3.046	$2.968	$2.893	$2.823	$2.756	$2.630	$2.315	$1.929
	20	$2.327	$2.068	$1.960	$1.909	$1.862	$1.816	$1.773	$1.692	$1.489	$1.241
	25	$2.090	$1.858	$1.760	$1.715	$1.672	$1.631	$1.592	$1.520	$1.338	$1.115
	30	$1.943	$1.727	$1.636	$1.594	$1.554	$1.516	$1.480	$1.413	$1.243	$1.036
	40	$1.779	$1.581	$1.498	$1.460	$1.423	$1.389	$1.355	$1.294	$1.139	$0.949
	49	$1.705	$1.516	$1.436	$1.399	**$1.364**	$1.331	$1.299	$1.240	$1.091	$0.909

Table 45. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.0004150	$0.0003689	$0.0003495	$0.0003405	$0.0003320	$0.0003239	$0.0003162	$0.0003018	$0.0002656	$0.0002213
	$(250,000)	$0.0004574	$0.0004066	$0.0003852	$0.0003753	$0.0003659	$0.0003570	$0.0003485	$0.0003326	$0.0002927	$0.0002439
	$(100,000)	$0.0004828	$0.0004292	$0.0004066	$0.0003962	$0.0003863	$0.0003768	$0.0003679	$0.0003511	$0.0003090	$0.0002575
	$ -	$0.0004998	$0.0004442	$0.0004209	$0.0004101	**$0.0003998**	$0.0003901	$0.0003808	$0.0003635	$0.0003199	$0.0002665
	$100,000	$0.0005167	$0.0004593	$0.0004351	$0.0004240	$0.0004134	$0.0004033	$0.0003937	$0.0003758	$0.0003307	$0.0002756
	$250,000	$0.0005421	$0.0004819	$0.0004565	$0.0004448	$0.0004337	$0.0004231	$0.0004131	$0.0003943	$0.0003470	$0.0002891
	$500,000	$0.0005845	$0.0005196	$0.0004922	$0.0004796	$0.0004676	$0.0004562	$0.0004453	$0.0004251	$0.0003741	$0.0003117

Table 46. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$1.416	$1.259	$1.192	$1.162	$1.133	$1.105	$1.079	$1.030	$0.906	$0.755
	$(250,000)	$1.561	$1.387	$1.314	$1.281	$1.248	$1.218	$1.189	$1.135	$0.999	$0.832
	$(100,000)	$1.647	$1.464	$1.387	$1.352	$1.318	$1.286	$1.255	$1.198	$1.054	$0.879
	$ -	$1.705	$1.516	$1.436	$1.399	**$1.364**	$1.331	$1.299	$1.240	$1.091	$0.909
	$100,000	$1.763	$1.567	$1.485	$1.447	$1.410	$1.376	$1.343	$1.282	$1.128	$0.940
	$250,000	$1.850	$1.644	$1.558	$1.518	$1.480	$1.444	$1.409	$1.345	$1.184	$0.987
	$500,000	$1.994	$1.773	$1.679	$1.636	$1.596	$1.557	$1.520	$1.450	$1.276	$1.064

Table 47. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Canals, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 9.15 miles of canal	2,275	$0.0009960	$0.0008854	$0.0008388	$0.0008173	$0.0007968	$0.0007774	$0.0007589	$0.0007244	$0.0006375	$0.0005312
	2,725	$0.0008316	$0.0007392	$0.0007003	$0.0006823	$0.0006652	$0.0006490	$0.0006336	$0.0006048	$0.0005322	$0.0004435
	3,175	$0.0007137	$0.0006344	$0.0006010	$0.0005856	$0.0005710	$0.0005570	$0.0005438	$0.0005191	$0.0004568	$0.0003806
	3,625	$0.0006251	$0.0005556	$0.0005264	$0.0005129	$0.0005001	$0.0004879	$0.0004763	$0.0004546	$0.0004001	$0.0003334
	4,075	$0.0005561	$0.0004943	$0.0004683	$0.0004563	$0.0004449	$0.0004340	$0.0004237	$0.0004044	$0.0003559	$0.0002966
	4,534	$0.0004998	$0.0004442	$0.0004209	$0.0004101	**$0.0003998**	$0.0003901	$0.0003808	$0.0003635	$0.0003199	$0.0002665
	4,975	$0.0004555	$0.0004049	$0.0003836	$0.0003737	$0.0003644	$0.0003555	$0.0003470	$0.0003313	$0.0002915	$0.0002429
	5,450	$0.0004158	$0.0003696	$0.0003501	$0.0003412	$0.0003326	$0.0003245	$0.0003168	$0.0003024	$0.0002661	$0.0002217
	5,900	$0.0003841	$0.0003414	$0.0003234	$0.0003151	$0.0003073	$0.0002998	$0.0002926	$0.0002793	$0.0002458	$0.0002048
	6,350	$0.0003568	$0.0003172	$0.0003005	$0.0002928	$0.0002855	$0.0002785	$0.0002719	$0.0002595	$0.0002284	$0.0001903

Table 48. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Canals, Cameron County Irrigation District No. 2, Old District 13 Canals (Lining), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 9.15 miles of canal	2,275	$3.398	$3.021	$2.862	$2.789	$2.719	$2.652	$2.589	$2.472	$2.175	$1.813
	2,725	$2.837	$2.522	$2.389	$2.328	$2.270	$2.214	$2.162	$2.063	$1.816	$1.513
	3,175	$2.435	$2.165	$2.051	$1.998	$1.948	$1.901	$1.855	$1.771	$1.558	$1.299
	3,625	$2.133	$1.896	$1.796	$1.750	$1.706	$1.665	$1.625	$1.551	$1.365	$1.138
	4,075	$1.897	$1.687	$1.598	$1.557	$1.518	$1.481	$1.446	$1.380	$1.214	$1.012
	4,534	$1.705	$1.516	$1.436	$1.399	**$1.364**	$1.331	$1.299	$1.240	$1.091	$0.909
	4,975	$1.554	$1.381	$1.309	$1.275	$1.243	$1.213	$1.184	$1.130	$0.995	$0.829
	5,450	$1.419	$1.261	$1.195	$1.164	$1.135	$1.107	$1.081	$1.032	$0.908	$0.757
	5,900	$1.310	$1.165	$1.104	$1.075	$1.048	$1.023	$0.998	$0.953	$0.839	$0.699
	6,350	$1.218	$1.082	$1.025	$0.999	$0.974	$0.950	$0.928	$0.886	$0.779	$0.649

Table 49. Economic and Financial Evaluation Results Across Component #5's Useful Life, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe) Project Component for BOR, 2003.

Results	Nominal	Real[a]
Water Savings (ac-ft)		
Agriculture Irrigation	33,070	13,849
M&I	0	0
Total ac-ft	33,070	13,849
annuity equivalent		645
Energy Savings (BTU)		
Agriculture Irrigation	3,633,532,058	1,521,682,156
M&I	0	0
Total BTU	3,633,532,058	1,521,682,156
annuity equivalent		70,834,609
Energy Savings (kwh)		
Agriculture Irrigation	1,064,927	445,980
M&I	0	0
Total kwh's	1,064,927	445,980
annuity equivalent		20,760
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings	$282,291	$696,657
annuity equivalent		$44,972
Cost of Water Savings ($/ac-ft)		$69.76
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings	$397,417	$724,019
annuity equivalent		$46,738
Cost of Energy Savings ($/BTU)		$0.0006598
Cost of Energy Savings ($/kwh)		$2.251

[a] Determined using a 4% discount factor.

Table 50. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 2.04 Miles of Old District 13 Canals and Expected Useful Life of the Capital Investment, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Canal, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 2.04 miles of earthen canal to be replaced with pipeline									
		225	275	325	375	400	**456**	500	550	600	650
Expected Useful life of Investment (years)	10	$305.96	$249.28	$210.03	$181.25	$169.56	$147.96	$134.49	$121.73	$111.10	$102.11
	20	$196.85	$160.38	$135.13	$116.62	$109.09	$95.19	$86.53	$78.32	$71.48	$65.70
	25	$176.80	$144.05	$121.37	$104.74	$97.98	$85.50	$77.71	$70.34	$64.20	$59.01
	30	$164.33	$133.88	$112.80	$97.35	$91.07	$79.47	$72.23	$65.38	$59.67	$54.84
	40	$150.50	$122.62	$103.31	$89.16	$83.41	$72.78	$66.15	$59.88	$54.65	$50.23
	49	$144.25	$117.53	$99.02	$85.46	$79.94	**$69.76**	$63.41	$57.39	$52.38	$48.14

Table 51. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 2.04 Miles of Old District 13 Canals and Initial Cost of the Capital Investment, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Canal, for BOR Project, 2003.

		ac-ft of water loss (seepage) for 2.04 miles of earthen canal to be replaced with pipeline									
		225	275	325	375	400	**456**	500	550	600	650
Initial Capital Investment Cost ($)	$(500,000)	$42.74	$34.47	$28.75	$24.55	$22.84	$19.69	$17.73	$15.87	$14.32	$13.00
	$(250,000)	$93.50	$76.00	$63.89	$55.00	$51.39	$44.72	$40.57	$36.63	$33.35	$30.57
	$(100,000)	$123.95	$100.92	$84.97	$73.27	$68.52	$59.74	$54.27	$49.09	$44.77	$41.11
	$ -	$144.25	$117.53	$99.02	$85.46	$79.94	**$69.76**	$63.41	$57.39	$52.38	$48.14
	$100,000	$164.55	$134.14	$113.08	$97.64	$91.36	$79.77	$72.54	$65.70	$60.00	$55.17
	$250,000	$195.01	$159.05	$134.16	$115.91	$108.49	$94.79	$86.25	$78.16	$71.42	$65.71
	$500,000	$245.76	$200.58	$169.30	$146.36	$137.04	$119.82	$109.09	$98.92	$90.45	$83.28

Table 52. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings for 2.04 Miles of Old District 13 Canals and Value of Energy Savings, Cameron County Irrigation District No. 2, Pipeline Replacing Earthen Canal, for BOR Project, 2003.

	ac-ft of water loss (seepage) for 2.04 miles of earthen canal to be replaced with pipeline										
		225	275	325	375	400	**456**	500	550	600	650
Value of Energy Savings ($/kwh)	$0.0300	$145.65	$118.93	$100.42	$86.86	$81.34	$71.16	$64.81	$58.79	$53.78	$49.54
	$0.0450	$144.98	$118.26	$99.75	$86.19	$80.67	$70.49	$64.14	$58.12	$53.11	$48.87
	$0.0550	$144.54	$117.81	$99.31	$85.74	$80.23	$70.04	$63.69	$57.68	$52.67	$48.43
	$0.0614	$144.25	$117.53	$99.02	$85.46	$79.94	**$69.76**	$63.41	$57.39	$52.38	$48.14
	$0.0675	$143.98	$117.25	$98.75	$85.18	$79.67	$69.48	$63.13	$57.12	$52.11	$47.87
	$0.0800	$143.42	$116.69	$98.19	$84.62	$79.11	$68.92	$62.57	$56.56	$51.55	$47.31
	$0.0900	$142.97	$116.25	$97.74	$84.18	$78.66	$68.48	$62.13	$56.11	$51.10	$46.86

Table 53. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$0.0017494	$0.0015550	$0.0014732	$0.0014354	$0.0013995	$0.0013654	$0.0013329	$0.0012723	$0.0011196	$0.0009330
	20	$0.0011255	$0.0010005	$0.0009478	$0.0009235	$0.0009004	$0.0008785	$0.0008575	$0.0008186	$0.0007203	$0.0006003
	25	$0.0010109	$0.0008986	$0.0008513	$0.0008294	$0.0008087	$0.0007890	$0.0007702	$0.0007352	$0.0006470	$0.0005391
	30	$0.0009396	$0.0008352	$0.0007912	$0.0007709	$0.0007516	$0.0007333	$0.0007159	$0.0006833	$0.0006013	$0.0005011
	40	$0.0008605	$0.0007649	$0.0007246	$0.0007061	$0.0006884	$0.0006716	$0.0006556	$0.0006258	$0.0005507	$0.0004589
	49	$0.0008248	$0.0007331	$0.0006946	$0.0006767	**$0.0006598**	$0.0006437	$0.0006284	$0.0005998	$0.0005279	$0.0004399

Table 54. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Expected Useful life of Investment (years)	10	$5.969	$5.306	$5.026	$4.898	$4.775	$4.659	$4.548	$4.341	$3.820	$3.183
	20	$3.840	$3.414	$3.234	$3.151	$3.072	$2.997	$2.926	$2.793	$2.458	$2.048
	25	$3.449	$3.066	$2.905	$2.830	$2.759	$2.692	$2.628	$2.508	$2.207	$1.840
	30	$3.206	$2.850	$2.700	$2.630	$2.565	$2.502	$2.442	$2.331	$2.052	$1.710
	40	$2.936	$2.610	$2.472	$2.409	$2.349	$2.292	$2.237	$2.135	$1.879	$1.566
	49	$2.814	$2.501	$2.370	$2.309	**$2.251**	$2.196	$2.144	$2.047	$1.801	$1.501

Table 55. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.0002552	$0.0002268	$0.0002149	$0.0002094	$0.0002042	$0.0001992	$0.0001944	$0.0001856	$0.0001633	$0.0001361
	$(250,000)	$0.0005400	$0.0004800	$0.0004547	$0.0004431	$0.0004320	$0.0004215	$0.0004114	$0.0003927	$0.0003456	$0.0002880
	$(100,000)	$0.0007109	$0.0006319	$0.0005986	$0.0005833	$0.0005687	$0.0005548	$0.0005416	$0.0005170	$0.0004550	$0.0003791
	$ -	$0.0008248	$0.0007331	$0.0006946	$0.0006767	**$0.0006598**	$0.0006437	$0.0006284	$0.0005998	$0.0005279	$0.0004399
	$100,000	$0.0009387	$0.0008344	$0.0007905	$0.0007702	$0.0007510	$0.0007326	$0.0007152	$0.0006827	$0.0006008	$0.0005006
	$250,000	$0.0011096	$0.0009863	$0.0009344	$0.0009104	$0.0008877	$0.0008660	$0.0008454	$0.0008070	$0.0007101	$0.0005918
	$500,000	$0.0013944	$0.0012394	$0.0011742	$0.0011441	$0.0011155	$0.0010883	$0.0010624	$0.0010141	$0.0008924	$0.0007437

Table 56. 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, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
Initial Capital Investment Cost ($)	$(500,000)	$0.871	$0.774	$0.733	$0.714	$0.697	$0.680	$0.663	$0.633	$0.557	$0.464
	$(250,000)	$1.842	$1.638	$1.552	$1.512	$1.474	$1.438	$1.404	$1.340	$1.179	$0.983
	$(100,000)	$2.425	$2.156	$2.042	$1.990	$1.940	$1.893	$1.848	$1.764	$1.552	$1.294
	$ -	$2.814	$2.501	$2.370	$2.309	**$2.251**	$2.196	$2.144	$2.047	$1.801	$1.501
	$100,000	$3.203	$2.847	$2.697	$2.628	$2.562	$2.500	$2.440	$2.329	$2.050	$1.708
	$250,000	$3.786	$3.365	$3.188	$3.106	$3.029	$2.955	$2.884	$2.753	$2.423	$2.019
	$500,000	$4.758	$4.229	$4.006	$3.904	$3.806	$3.713	$3.625	$3.460	$3.045	$2.537

Table 57. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Canal, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 2.04 miles of earthen canal	225	$0.0016723	$0.0014865	$0.0014082	$0.0013721	$0.0013378	$0.0013052	$0.0012741	$0.0012162	$0.0010703	$0.0008919
	275	$0.0013682	$0.0012162	$0.0011522	$0.0011227	$0.0010946	$0.0010679	$0.0010425	$0.0009951	$0.0008757	$0.0007297
	325	$0.0011577	$0.0010291	$0.0009749	$0.0009499	$0.0009262	$0.0009036	$0.0008821	$0.0008420	$0.0007410	$0.0006175
	375	$0.0010034	$0.0008919	$0.0008449	$0.0008233	$0.0008027	$0.0007831	$0.0007645	$0.0007297	$0.0006422	$0.0005351
	400	$0.0009407	$0.0008361	$0.0007921	$0.0007718	$0.0007525	$0.0007342	$0.0007167	$0.0006841	$0.0006020	$0.0005017
	456	$0.0008248	$0.0007331	$0.0006946	$0.0006767	**$0.0006598**	$0.0006437	$0.0006284	$0.0005998	$0.0005279	$0.0004399
	500	$0.0007525	$0.0006689	$0.0006337	$0.0006175	$0.0006020	$0.0005873	$0.0005734	$0.0005473	$0.0004816	$0.0004013
	550	$0.0006841	$0.0006081	$0.0005761	$0.0005613	$0.0005473	$0.0005339	$0.0005212	$0.0004975	$0.0004378	$0.0003649
	600	$0.0006271	$0.0005574	$0.0005281	$0.0005145	$0.0005017	$0.0004894	$0.0004778	$0.0004561	$0.0004013	$0.0003345
	650	$0.0005789	$0.0005145	$0.0004875	$0.0004750	$0.0004631	$0.0004518	$0.0004410	$0.0004210	$0.0003705	$0.0003087

Table 58. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduced Water Losses in Earthen Canal, Cameron County Irrigation District No. 2, Old District 13 Canals (Pipe), for BOR 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									
		87,899	98,886	104,380	107,127	**109,874**	112,620	115,367	120,861	137,342	164,810
ac-ft of water loss (seepage) for 2.04 miles of earthen canal	225	$5.706	$5.072	$4.805	$4.682	$4.565	$4.453	$4.347	$4.150	$3.652	$3.043
	275	$4.668	$4.150	$3.931	$3.830	$3.735	$3.644	$3.557	$3.395	$2.988	$2.490
	325	$3.950	$3.511	$3.326	$3.241	$3.160	$3.083	$3.010	$2.873	$2.528	$2.107
	375	$3.424	$3.043	$2.883	$2.809	$2.739	$2.672	$2.608	$2.490	$2.191	$1.826
	400	$3.210	$2.853	$2.703	$2.633	$2.568	$2.505	$2.445	$2.334	$2.054	$1.712
	456	$2.814	$2.501	$2.370	$2.309	**$2.251**	$2.196	$2.144	$2.047	$1.801	$1.501
	500	$2.568	$2.282	$2.162	$2.107	$2.054	$2.004	$1.956	$1.867	$1.643	$1.369
	550	$2.334	$2.075	$1.966	$1.915	$1.867	$1.822	$1.778	$1.698	$1.494	$1.245
	600	$2.140	$1.902	$1.802	$1.756	$1.712	$1.670	$1.630	$1.556	$1.369	$1.141
	650	$1.975	$1.756	$1.663	$1.621	$1.580	$1.542	$1.505	$1.436	$1.264	$1.053

Table 59. Economic and Financial Evaluation Results for Cost of Water Saved, Aggregated Across All Five Components Comprising Cameron County Irrigation District No. 2's Infrastructure Rehabilitation Project Proposed to BOR, 2003.

Economic and Conservation Measures	Project Component					Aggregate
	Canals B, C, and D (Lining)	Canal B Laterals (Pipe)	Canal C Laterals (Pipe)	Old District 13 Canals (Lining)	Old District 13 Canals (Pipe)	
NPV of Net Cost Stream, Including Both Initial Investment Cost and Changes in O&M Expenditures ($)	$ 2,900,884	$ 3,637,960	$ 2,339,578	$ 2,764,563	$ 696,657	$ 12,339,641
Annuity Equivalent of Net Cost Stream for Calculating of Annuity Equivalents ($/yr)	$ 187,264	$ 234,845	$ 151,029	$ 178,464	$ 44,972	$ 796,573
NPV of All Water Savings (ac-ft)	153,971	124,954	34,760	93,078	13,849	420,612
Annuity Equivalent of All Water Savings Stream for Weighting of Annuity Equivalents (ac-ft/yr)	7,167	5,817	1,618	4,333	645	19,580
Annuity Equivalent of Costs per ac-ft of Water Savings, Assuming Perpetual Timeline and Replacement with Identical Technology	$ 26.127	$ 40.375	$ 93.338	$ 41.189	$ 69.757	$ 40.684

Table 60. Economic and Financial Evaluation Results for Cost of Energy Saved, Aggregated Across All Five Components of Cameron County Irrigation District No. 2's Infrastructure Rehabilitation Project Proposed to BOR, 2003.

Economic and Conservation Measures	Project Component					Aggregate
	Canals B, C, and D (Lining)	Canal B Laterals (Pipe)	Canal C Laterals (Pipe)	Old District 13 Canals (Lining)	Old District 13 Canals (Pipe)	
NPV of Net Cost Stream, Including Both Initial Investment Cost and Changes in O&M Expenditures ($)	$ 3,205,083	$ 3,884,833	$ 2,408,253	$ 2,948,456	$ 724,019	$ 13,170,644
Annuity Equivalent of Net Cost Stream for Calculating of Annuity Equivalents ($/yr)	$ 206,901	$ 250,781	$ 155,462	$ 190,335	$ 46,738	$ 850,218
NPV of All Energy Savings (BTU)	16,917,299,679	13,729,185,042	3,819,198,999	10,226,768,297	1,521,682,156	46,214,134,173
Annuity Equivalent of All Energy Savings Stream for Weighting of Annuity Equivalents (BTU/yr)	787,503,691	639,096,316	177,784,479	476,058,114	70,834,609	2,151,277,209
Annuity Equivalent of All Energy Savings Stream for Weighting of Annuity Equivalents (kwh/yr)	230,804	187,308	52,106	139,525	20,760	630,503
Annuity Equivalent of Costs per BTU of Energy Savings, Assuming Perpetual Timeline and Replacement with Identical Technology ($)	$ 0.0002627	$ 0.0003924	$ 0.0008744	$ 0.0003998	$ 0.0006598	$ 0.0003952
Annuity Equivalent of Costs per kwh of Energy Savings, Assuming Perpetual Timeline and Replacement with Identical Technology ($)	$ 0.896	$ 1.339	$ 2.984	$ 1.364	$ 2.251	$ 1.348

Appendices

Appendix A: Legislated Criteria Results – By Component

United States Public Law 106-576 legislation (and the amending Public Law 107-351 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 (BOR) 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 and 107-351 legislation's required measures. It is on that basis that the legislated criteria results are presented in both Appendices A and B of this report. Appendix A is focused on results for the individual capital renovation components comprising the total proposed project. Aggregated results for the total project are presented in Appendix B.

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 to account for the differences in length of planning periods across multiple components of a single project and across different projects. 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. Only real results are presented in Appendix B since the aggregation of results requires combining of results for the different components, necessitating a common basis of evaluation. 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: Canals B, C, and D [Lining]

The 'Canals B, C, and D' component of the District's BOR project primarily consists of installing 13.98 miles of geomembrane lining overlain with a shotcrete cover in Canals B, C, and D. Details on the cost estimates and related projections of water and energy savings are presented in the main body of this report (**Tables 5** and **9**). A summary of the calculated values and results corresponding to the legislated criteria are presented in the next section, with nominal and their discounted (i.e., real) transformations presented.

The principal evaluation criteria specified in the United States Public Law 106-576 and 107-351 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 lining amount to $3,296,000. 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 367,657 ac-ft of nominal *off-farm* water savings are projected to occur during the productive life of the lining, with associated energy savings of 40,395,788,613 BTU (11,839,328 kwh). Using the 4% discount rate, the present or real value of such anticipated savings become 153,971 ac-ft and 16,917,299,679 BTU (4,958,177 kwh) (**Table A1**).

The accrued annual net changes in O&M expenditures over the lining's productive life are a total decrease of $1,635,346. Using the 2002 Federal discount rate of 6.125%,[50] this anticipated net decrease in expenditures represents a real cost reduction of $395,116 (**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 $8.96 in a nominal sense and $21.41 in real terms, while the initial construction costs per BTU (kwh) of energy saved are $0.0000816 ($0.278) in a nominal sense and $0.0001948 ($0.665) 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 lining 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 -2.02 of construction costs per dollar reduction in nominal operating expenditures, suggesting construction costs are more than the expected nominal decreases in O&M costs during the planning period for the installed pipeline. On a real basis, this ratio measure is -8.34 (**Table A2**),

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50 In order to maintain consistency across projects being analyzed by the authors in calendar years 2002 and 2003, the 2002 Federal discount rate of 6.125% is also applied to this and other reports analyzed in 2003.

signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Component #2: Canal B Laterals [Pipeline]

The 'Canal B Laterals' component of the District's BOR project primarily consists of replacing 11.40 miles of mostly earthen laterals with pipeline, and reconstructing the farm turnouts to facilitate the use of portable flow meters. Details on the cost estimates and related projections of water and energy savings are presented in the main body of this report (**Tables 5** and **19**). A summary of the calculated values and results corresponding to the legislated criteria are presented in the next section, with nominal and their discounted (i.e., real) transformations presented.

The principal evaluation criteria specified in the United States Public Law 106-576 and 107-351 legislation, transformed according to Hamilton, are presented in **Table A4** (as determined by the calculated values reported in **Table A3**, which are derived in RGIDECON©, using the several input parameters described in the main body of this report).

<u>Summary Calculated Values</u>

The initial construction costs associated with the purchase and installation of the pipeline amount to $4,396,000. 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 298,371 ac-ft of nominal *off-* and *on-farm* water savings are projected to occur during the productive life of the pipeline, with associated energy savings of 32,783,084,020 BTU (9,608,172 kwh). Using the 4% discount rate, the present or real value of such anticipated savings become 124,954 ac-ft and 13,729,185,042 BTU (4,023,794 kwh) (**Table A3**).

The accrued annual net changes in O&M expenditures over the pipeline's productive life are a total decrease of $3,186,641. Using the 2002 Federal discount rate of 6.125%,[51] this anticipated net decrease in expenditures represents a real cost reduction of $758,040 (**Table A3**). 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.

<u>Criteria Stated in Legislated Guidelines</u>

The estimated initial construction costs per ac-ft of water saved are $14.73 in a nominal sense and $35.18 in real terms, while the initial construction costs per BTU (kwh) of energy saved are $0.0001341 ($0.458) in a nominal sense and $0.0003202 ($1.093) in real terms (**Table A4**). 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,

51 In order to maintain consistency across projects being analyzed by the authors in calendar years 2002 and 2003, the 2002 Federal discount rate of 6.125% is also applied to this and other reports analyzed in 2003.

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 A3**). Dividing the initial construction costs by the decreases in operating costs results in a ratio measure of -1.38 of construction costs per dollar reduction in nominal operating expenditures, suggesting construction costs are more than the expected nominal decreases in O&M costs during the planning period for the installed pipeline. On a real basis, this ratio measure is -5.80 (**Table A4**), signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Component #3: Canal C Laterals [Pipeline]

The 'Canal C Laterals' component of the District's BOR project primarily consists of replacing 5.54 miles of mostly earthen laterals with pipeline, and reconstructing the farm turnouts to facilitate the use of portable flow meters. Details on the cost estimates and related projections of water and energy savings are presented in the main body of this report (**Tables 5** and **29**). A summary of the calculated values and results corresponding to the legislated criteria are presented in the next section, with nominal and their discounted (i.e., real) transformations presented.

The principal evaluation criteria specified in the United States Public Law 106-576 and 107-351 legislation, transformed according to Hamilton, are presented in **Table A6** (as determined by the calculated values reported in **Table A5**, 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 pipeline amount to $2,646,000. 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 83,001 ac-ft of nominal *off-* and *on-farm* water savings are projected to occur during the productive life of the pipeline, with associated energy savings of 9,119,632,468 BTU (2,672,811 kwh). Using the 4% discount rate, the present or real value of such anticipated savings become 34,760 ac-ft and 3,819,198,999 BTU (1,119,343 kwh) (**Table A5**).

The accrued annual net changes in O&M expenditures over the pipeline's productive life are a total decrease of $1,286,957. Using the 2002 Federal discount rate of 6.125%,[52] this anticipated net decrease in expenditures represents a real cost reduction of $306,422 (**Table A5**). 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.

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[52] In order to maintain consistency across projects being analyzed by the authors in calendar years 2002 and 2003, the 2002 Federal discount rate of 6.125% is also applied to this and other reports analyzed in 2003.

Criteria Stated in Legislated Guidelines

The estimated initial construction costs per ac-ft of water saved are $31.88 in a nominal sense and $76.12 in real terms, while the initial construction costs per BTU (kwh) of energy saved are $0.0002901 ($0.990) in a nominal sense and $0.0006928 ($2.364) in real terms (**Table A6**). 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 A5**). Dividing the initial construction costs by the decreases in operating costs results in a ratio measure of -2.06 of construction costs per dollar reduction in nominal operating expenditures, suggesting construction costs are more than the expected nominal decreases in O&M costs during the planning period for the installed pipeline. On a real basis, this ratio measure is -8.64 (**Table A6**), signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Component #4: Old District 13 Canals [Lining]

The 'Old District 13 Canals (Lining)' component of the District's BOR project primarily consists of installing 9.15 miles of geomembrane lining overlain with a shotcrete cover in Old District 13 Canals. Details on the cost estimates and related projections of water and energy savings are presented in the main body of this report (**Tables 5** and **39**). A summary of the calculated values and results corresponding to the legislated criteria are presented in the next section, with nominal and their discounted (i.e., real) transformations presented.

The principal evaluation criteria specified in the United States Public Law 106-576 and 107-351 legislation, transformed according to Hamilton, are presented in **Table A8** (as determined by the calculated values reported in **Table A7**, 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 lining amount to $2,996,000. 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 222,254 ac-ft of nominal *off-farm* water savings are projected to occur during the productive life of the lining, with associated energy savings of 24,419,876,585 BTU (7,157,056 kwh). Using the 4% discount rate, the present or real value of such anticipated savings become 93,078 ac-ft and 10,226,768,297 BTU (2,997,294 kwh) (**Table A7**).

The accrued annual net changes in O&M expenditures over the lining's productive life are a total decrease of $956,025. Using the 2002 Federal discount rate of 6.125%,[53] this anticipated net decrease in expenditures represents a real cost reduction of $231,437 (**Table A7**). 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.

<u>Criteria Stated in Legislated Guidelines</u>

The estimated initial construction costs per ac-ft of water saved are $13.48 in a nominal sense and $32.19 in real terms, while the initial construction costs per BTU (kwh) of energy saved are $0.0001227 ($0.419) in a nominal sense and $0.0002930 ($1.000) in real terms (**Table A8**). 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 lining installation result in anticipated net decreases in annual costs (**Table A7**). Dividing the initial construction costs by the decreases in operating costs results in a ratio measure of -3.13 of construction costs per dollar reduction in nominal operating expenditures, suggesting construction costs are more than the expected nominal decreases in O&M costs during the planning period for the installed lining. On a real basis, this ratio measure is -12.95 (**Table A8**), signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Component #5: Old District 13 Canals [Pipeline]

The 'Old District 13 Canals (Pipe)' component of the District's BOR project primarily consists of replacing 2.04 miles of earthen canals with pipeline, and reconstructing the farm turnouts to facilitate the use of portable flow meters. Details on the cost estimates and related projections of water and energy savings are presented in the main body of this report (**Tables 5** and **49**). A summary of the calculated values and results corresponding to the legislated criteria are presented in the next section, with nominal and their discounted (i.e., real) transformations presented.

The principal evaluation criteria specified in the United States Public Law 106-576 and 107-351 legislation, transformed according to Hamilton, are presented in **Table A10** (as determined by the calculated values reported in **Table A9**, which are derived in RGIDECON©, using the several input parameters described in the main body of this report).

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53 In order to maintain consistency across projects being analyzed by the authors in calendar years 2002 and 2003, the 2002 Federal discount rate of 6.125% is also applied to this and other reports analyzed in 2003.

Summary Calculated Values

The initial construction costs associated with the purchase and installation of the pipeline amount to $826,000. 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 33,070 ac-ft of nominal *off-* and *on-farm* water savings are projected to occur during the productive life of the pipeline, with associated energy savings of 3,633,532,058 BTU (1,064,927 kwh). Using the 4% discount rate, the present or real value of such anticipated savings become 13,849 ac-ft and 1,521,682,156 BTU (445,980 kwh) (**Table A9**).

The accrued annual net changes in O&M expenditures over the pipeline's productive life are a total decrease of $543,709. Using the 2002 Federal discount rate of 6.125%,[54] this anticipated net decrease in expenditures represents a real cost reduction of $129,343 (**Table A9**). 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 $24.98 in a nominal sense and $59.64 in real terms, while the initial construction costs per BTU (kwh) of energy saved are $0.0002273 ($0.776) in a nominal sense and $0.0005428 ($1.852) in real terms (**Table A10**). 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 A9**). Dividing the initial construction costs by the decreases in operating costs results in a ratio measure of -1.52 of construction costs per dollar reduction in nominal operating expenditures, suggesting construction costs are more than the expected nominal decreases in O&M costs during the planning period for the installed pipeline. On a real basis, this ratio measure is -6.39 (**Table A10**), signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Summary of Legislated Criteria Results for the Individual Components

Notably, the legislated criteria results differ for the five components comprising the District's proposed 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

54 In order to maintain consistency across projects being analyzed by the authors in calendar years 2002 and 2003, the 2002 Federal discount rate of 6.125% is also applied to this and other reports analyzed in 2003.

expenditures are not comprehensively evaluated per ac-ft of water savings and per BTU (kwh) of energy savings here.

In the main body of this report, the comprehensive assessment indicates that a "lining" component (i.e., component #1 - 'Canals B, C, and, D') is the most economical source of water savings, with a "pipeline" component (i.e., component #2 - 'Canal B Laterals - Pipeline') ranking a distant second (**Table A11**). Thereafter, the comprehensive assessment ranks the other "lining" component and the other two "pipeline" components, as the third, fourth, and fifth most economical as: component #4, component #5, and component #3, respectively (**Tables 59** and **A11**). The comprehensive costs of energy savings yielded the exact same rankings (**Tables 60** and **A11**).

With the legislated-criteria results, a similar but slightly different ranking is observed in terms of the (a) dollars of initial construction costs per ac-ft of water savings criteria, and (b) dollars of initial construction costs per BTU (kwh) of energy saved criteria (**Tables A11** and **B2**). With these two legislative criteria, components #2 and #4 "swap" in their ranked order, when compared to the comprehensive economic-assessment measures' rankings.

Ranking the project components with regards to the third (and main) legislated criteria (i.e., dollars of initial construction costs per dollar of annual economic savings), however, yields different results. In order to rank the components with the third criteria, one must first understand how to properly interpret the ratio (i.e., construction cost divided by economic savings). The interpretation 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.

Rankings per the main legislative criteria suggest net realized real economic savings are forecast for each component (i.e., the ratio for each reveals a negative, or cost savings, value).

Here, the second and fifth components (i.e., pipeline replacements) are ranked ahead of the two lining components (i.e., component #'s 1 and 4), with component #4 ranking last (**Table A11**).

Recall, however, that according to the legislated guidelines, a project proposed by a District is to be evaluated in its entirety as proposed rather than on the merits of each individual component. Appendix B contains a commentary addressing the likely aggregate performance of the total project proposed by the District, using the legislated criteria modified to account, somewhat but not completely, for the differences in useful lives of the respective project components.

Appendix B: Legislated Criteria Results – Aggregated Across Components

As noted in Rister et al. (2002a), aggregation of evaluation results for independent projects into an appraisal of one comprehensive project is not a common occurrence. Adaptations in analytical methods are necessary to account for the variations in useful lives of the individual components. 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. Here in Appendix B, only real, present value measures are presented and discussed, thereby designating all values in terms of 2003 equivalents. **Differences in useful lives across project components are not fully represented, however, in these calculated values.**

Table B1 contains the summary measures for the five respective individual components and a summed aggregate value representing the total project for each respective measure. The project as a whole requires an initial capital construction investment of $14,160,000. In total, 420,612 ac-ft of real water savings are estimated. Real energy savings are anticipated to be 46,214,134,173 BTUs (13,544,588 kwh). The net change in real total annual O&M expenditures is a decrease of $1,820,359.

Derivation of the aggregate legislated criteria measures for the project as a whole entails use of the Aggregate column values presented in **Table B1** and calculations similar to those used to arrive at the measures for the independent project components. The resulting aggregate initial construction costs per ac-ft of water savings measure is $40.42 per ac-ft of water savings (**Table B2**). Note that this amount is slightly lower than the comprehensive economic and financial value of **$40.68 per ac-ft** identified in **Table 59** and discussed in the main body of this report. The difference in these values is attributable both 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 components of the proposed project.

The resulting aggregate initial construction costs per BTU (kwh) of energy savings measure is $0.0003679 per BTU ($1.255 per kwh) (**Table B2**). These cost estimates are lower than the **$0.0003952 per BTU ($1.348 per kwh)** comprehensive economic and financial cost estimates identified in **Table 60** for reasons similar to those noted above with respect to the estimates of costs of water savings.

The final aggregate 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 -8.47, 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) $8.47 of initial construction costs are expended for each such dollar reduction in O&M expenditures, with the latter represented in total real dollars accrued across the five project components' respective planning periods.

Appendix Tables

Table A1. Summary of Calculated Values for Component #1 - Canals B, C, and D (Lining), Cameron County Irrigation District No. 2's BOR Project, 2003.

Item	Nominal PV	Real NPV
Dollars of Initial Construction Costs	$ 3,296,000	$ 3,296,000
Ac-Ft of Water Saved	367,657	153,971
BTU of Energy Saved	40,395,788,613	16,917,299,679
kwh of Energy Saved	11,839,328	4,958,177
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ (1,635,346)	$ (395,116)

Table A2. Legislated Evaluation Criteria for Component #1 - Canals B, C, and D (Lining), Cameron County Irrigation District No. 2's BOR Project, 2003.

Criteria	Nominal PV	Real NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 8.96	$ 21.41
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0000816	$ 0.0001948
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.278	$ 0.665
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-2.02	-8.34

Table A3. Summary of Calculated Values for Component #2 - Canal B Laterals (Pipe), Cameron County Irrigation District No. 2's BOR Project, 2003.

Item	Nominal PV	Real NPV
Dollars of Initial Construction Costs	$ 4,396,000	$ 4,396,000
Ac-Ft of Water Saved	298,371	124,954
BTU of Energy Saved	32,783,084,020	13,729,185,042
kwh of Energy Saved	9,608,172	4,023,794
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ (3,186,641)	$ (758,040)

Table A4. Legislated Evaluation Criteria for Component #2 - Canal B Laterals (Pipe), Cameron County Irrigation District No. 2's BOR Project, 2003.

Criteria	Nominal PV	Real NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 14.73	$ 35.18
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0001341	$ 0.0003202
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.458	$ 1.093
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-1.38	-5.80

Table A5. Summary of Calculated Values for Component #3 - Canal C Laterals (Pipe), Cameron County Irrigation District No. 2's BOR Project, 2003.

Item	Nominal PV	Real NPV
Dollars of Initial Construction Costs	$ 2,646,000	$ 2,646,000
Ac-Ft of Water Saved	83,001	34,760
BTU of Energy Saved	9,119,632,468	3,819,198,999
kwh of Energy Saved	2,672,811	1,119,343
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ (1,286,957)	$ (306,422)

Table A6. Legislated Evaluation Criteria for Component #3 - Canal C Laterals (Pipe), Cameron County Irrigation District No. 2's BOR Project, 2003.

Criteria	Nominal PV	Real NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 31.88	$ 76.12
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0002901	$ 0.0006928
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.990	$ 2.364
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-2.06	-8.64

Table A7. Summary of Calculated Values for Component #4 - Old District 13 Canals (Lining), Cameron County Irrigation District No. 2's BOR Project, 2003.

Item	Nominal PV	Real NPV
Dollars of Initial Construction Costs	$ 2,996,000	$ 2,996,000
Ac-Ft of Water Saved	222,254	93,078
BTU of Energy Saved	24,419,876,585	10,226,768,297
kwh of Energy Saved	7,157,056	2,997,294
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ (956,025)	$ (231,437)

Table A8. Legislated Evaluation Criteria for Component #4 - Old District 13 Canals (Lining), Cameron County Irrigation District No. 2's BOR Project, 2003.

Criteria	Nominal PV	Real NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 13.48	$ 32.19
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0001227	$ 0.0002930
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.419	$ 1.000
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-3.13	-12.95

Table A9. Summary of Calculated Values for Component #5 - Old District 13 Canals (Pipe), Cameron County Irrigation District No. 2's BOR Project, 2003.

Item	Nominal PV	Real NPV
Dollars of Initial Construction Costs	$ 826,000	$ 826,000
Ac-Ft of Water Saved	33,070	13,849
BTU of Energy Saved	3,633,532,058	1,521,682,156
kwh of Energy Saved	1,064,927	445,980
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ (543,709)	$ (129,343)

Table A10. Legislated Evaluation Criteria for Component #5 - Old District 13 Canals (Pipe), Cameron County Irrigation District No. 2's BOR Project, 2003.

Criteria	Nominal PV	Real NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 24.98	$ 59.64
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0002273	$ 0.0005428
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.776	$ 1.852
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-1.52	-6.39

Table A11. Summary of Ranking Order by Comprehensive Economic Criteria and Legislative Criteria, Across All Five Components Comprising Cameron County Irrigation District No. 2's Infrastructure Rehabilitation Project Proposed to BOR, 2003.

	Comprehensive Economic Criteria		Legislative Criteria (P.L. 106-576)		
Component / Ranking Measure	**Water Savings**	**Energy Savings**	**$ ICC per ac-ft[a] Water Saved**	**$ ICC per BTU Energy Saved**	**$ ICC per $ Annual Economic Savings**
#1 Canals B, C, and D (Lining)	1st	1st	1st	1st	3rd
#2 Canal B Laterals (Pipeline)	2nd	2nd	3rd	3rd	1st
#3 Canal C Laterals (Pipeline)	5th	5th	5th	5th	4th
#4 Old District 13 Canals (Lining)	3rd	3rd	2nd	2nd	5th
#5 Old District 13 Canals (Pipeline)	4th	4th	4th	4th	2nd

[a] Note the abbreviation ICC stands for 'Initial Construction Cost'; the abbreviation allows for a more user-friendly table heading. Also, the legislative-criteria rankings are as per Hamilton's suggested convention, as discussed in Appendix A.

Table B1. Summary of Calculated Values, By Component and Aggregated Across All Five Components Comprising Cameron County Irrigation District No. 2's Infrastructure Rehabilitation Project Proposed to BOR, 2003.

Economic and Conservation Measures	Project Component					Aggregate
	Canals B, C, and D (Lining)	Canal B Laterals (Pipe)	Canal C Laterals (Pipe)	Old District 13 Canals (Lining)	Old District 13 Canals (Pipe)	
Dollars of Initial Construction Costs ($)	$ 3,296,000	$ 4,396,000	$ 2,646,000	$ 2,996,000	$ 826,000	$ 14,160,000
Ac-Ft of Water Saved (ac-ft)	153,971	124,954	34,760	93,078	13,849	420,612
BTU of Energy Saved (BTU)	16,917,299,679	13,729,185,042	3,819,198,999	10,226,768,297	1,521,682,156	46,214,134,173
kwh of Energy Saved (kwh)	4,958,177	4,023,794	1,119,343	2,997,294	445,980	13,544,588
$ of Annual Economic Savings (- represents net savings and + represents net added costs) ($)	($ 395,116)	($ 758,040)	($ 306,422)	($ 231,437)	($ 129,343)	($ 1,820,359)

Table B2. Legislated Results Criteria, Real Values, By Component and Aggregated Across All Five Components Comprising Cameron County Irrigation District No. 2's Infrastructure Rehabilitation Project Proposed to BOR, 2003.

	Project Component					
Economic Measure	**Canals B, C, and D (Lining)**	**Canal B Laterals (Pipe)**	**Canal C Laterals (Pipe)**	**Old District 13 Canals (Lining)**	**Old District 13 Canals (Pipe)**	**Aggregate**
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$21.41	$35.18	$76.12	$32.19	$59.64	$40.42
Dollar of Initial Construction Costs per BTU of Energy Saved	$0.0001948	$0.0003202	$0.0006928	$0.0002930	$0.0005428	$0.0003679
Dollar of Initial Construction Costs per kwh of Energy Saved	$0.665	$1.093	$2.364	$1.000	$1.852	$1.255
$ of Initial Construction Costs per $ of Annual Economic Savings (- represents net savings and + represents net added costs)[a]	(8.34)	(5.80)	(8.64)	(12.95)	(6.39)	(8.47)

[a] Negative values are indicative of expected net reductions in O&M expenditures during the planning horizon relative to current practices and capital installations.

— Notes —