

## **Summary**

### **Towards a Sustainable Use of Water in Agriculture: Assessment of an Investment Project for Irrigation District 005 Delicias/Chihuahua**

**Prepared for**

**World Wildlife Fund, México/Chihuahuan Desert Program**

**by**

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## **Introduction**

The World Wildlife Fund, (WWF) has set its Water Program as a priority. This program is based on a concern on water availability, which will be one of the main challenges facing humanity in the XXI<sup>st</sup> century, because a lack of this resource could become one of the key factors limiting growth. Water security is a pre-condition to any effective strategy for poverty reduction, meaning that each person should have access to an adequate and safe water volume at a reasonable cost to be able to carry on a productive and healthy life, and protecting the environment at the same.

The International Water Management Institute (IWMI) estimates that in 2025 world water use will be determined by water use efficiency in agriculture. Water use will increase by 57.3% and 24.8% when compared to 1990, respectively, for low and high efficiency scenarios. In the case of México, IWMI estimates for 2025, and for the same timeframe, increases of 62.2% and 7.2% for low and high efficiency scenarios for water use in agriculture, respectively. An IWMI projection estimates that some 50% of the increase in world water demand could be satisfied exclusively through an increase in efficiency of water use in agriculture.

WWF's Water Program is set in this context, and especially the "Programa del Desierto Chihuahuense" (Chihuahuan Desert Program). The present study constitutes a modest contribution to civil society and government organizations' effort towards sustainable water use in agriculture, using Irrigation District 005 Delicias in the State of Chihuahua as a case study. This study was made possible by a WWF, UK (HSBC) grant, to the support provided by the Gerencia de Distritos y Unidades de Riego y la Jefatura del Distrito de Riego 005 of the Comisión Nacional del Agua (CNA), by the Agencia Delicias of the Fideicomisos Instituidos en Relación con la Agricultura (FIRA) and by INIFAP's Campo Experimental Delicias.

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## I. Background

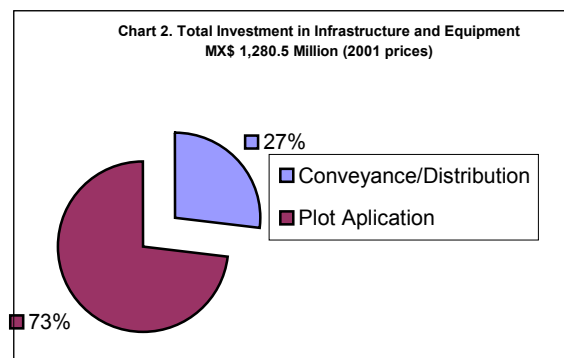
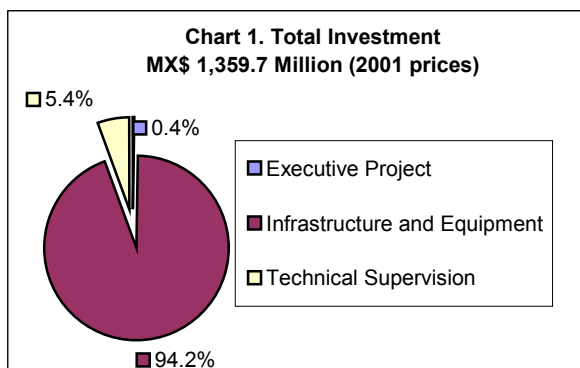
The Chihuahuan Desert Program of the World Wildlife Fund, Mexico, sets in its action strategy the relationship between water physical and economic components as a key factor to define and carry out actions for environment conservation/restoration. As part of this strategy, the first phase of a study on water economy was performed in 2002 and the paper “**Economía del Agua en los Distritos de Riego del Río Conchos, Chihuahua, 1990-2001**”<sup>1</sup> was published as a result. One of the main recommendations of that study was to carry out a second phase to assess the financial and economic viability of the Investment Project that the Comisión Nacional del Agua (CNA) had started and to identify and calculate possible water savings as a result of technological improvement.

Thus, in 2003 the second phase of this study was carried out, whose results are shown in the present document: “**Hacia un Uso Sustentable del Agua en la Agricultura: Evaluación del Proyecto de Inversión del Distrito de Riego 005 Delicias /Chihuahua**”<sup>2</sup>. In this document climate and financial risk of the current production pattern based on the results of the first phase is calculated, the Investment Project and its’ components is described and the potential water savings due to use of new technology and the impact on net profits of the production system as a result of yield increases are calculated. Based on this, the financial and economic profitability of the Investment Project through risk and deterministic analyses were assessed.

Results obtained in both phases provide, among other things, a basis to estimate a price for water in agriculture (main user) based both on its scarcity value and on its capacity to generate wealth.

## II. The Investment Project

The Comisión Nacional del Agua (CNA)<sup>3</sup> in its document “ Programa para el Uso Sustentable del Agua Superficial en la Cuenca del Río Bravo”<sup>4</sup> states it will carry out investments for MX\$1,360 million (US \$143.2 million) in Irrigation District 005 Delicias in 70,476 hectares (ha). Expenditure will be disbursed in four periods, 2002 (38.2%), 2003 (30.1%), 2004 (13.9%) and 2005 (17.8%). One of the main objectives of this program is to save agricultural water through an increase in the use of technology. A preliminary estimate by the CNA shows water savings of some 370.4 million cubic meters ( $10^6 \text{ m}^3$ ) equivalent to 38.5 % of a total  $961.8 \times 10^6 \text{ m}^3$  annual average gross water volume for the period 1990-2001. Of the total investment, 94.2% corresponds to infrastructure and equipment, of which 27% is allocated to water conveyance and distribution systems and the remaining 73% to water application systems in irrigation plots.



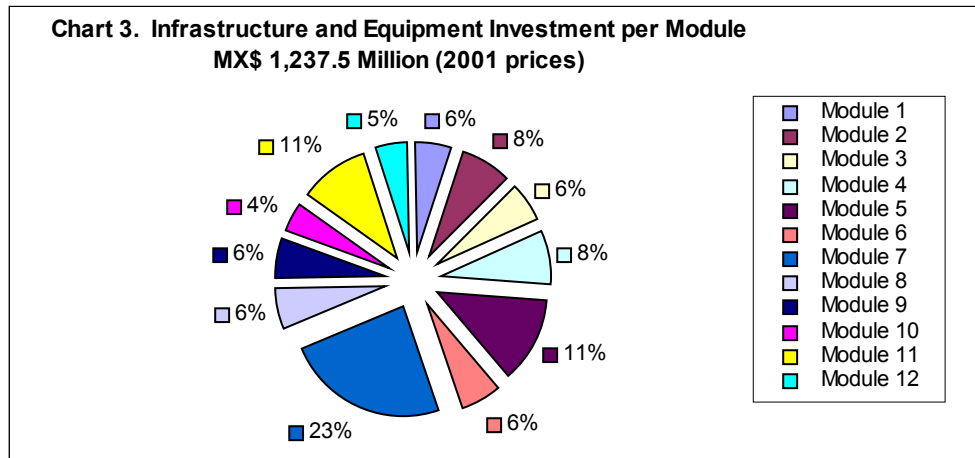
<sup>1</sup> “Water Economy in the Irrigation Districts in the Rio Conchos, Chihuahua, 2000-2001”

<sup>2</sup> “Towards a Sustainable Water Use in Agriculture: An Assessment for an Investment Project in Irrigation District 005 Delicias, Chihuahua”

<sup>3</sup> National Water Commission

<sup>4</sup> “Program for Sustainable Use of Surface Water in the Rio Bravo (Grande) Basin”

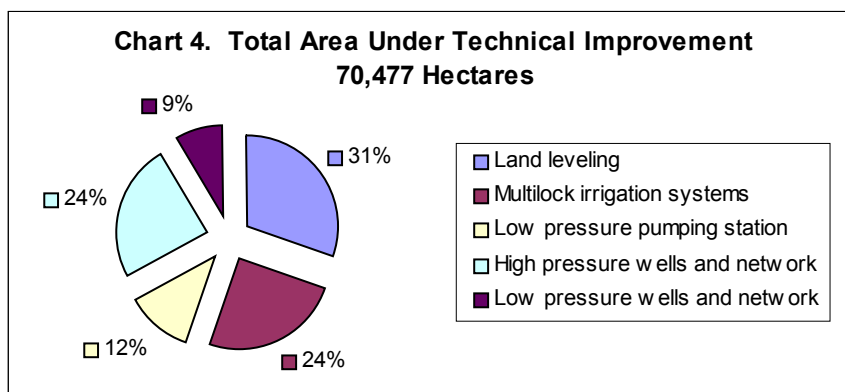
The investment to be carried out in infrastructure and equipment in all 12 modules of Irrigation District (ID) 005 (not including investments at the water-head and main distribution channels) amounts to MX\$1,238 million (US \$130.3 million). Most of the investment will be carried out in modules 5, 11 (11%) and 7 (23%).

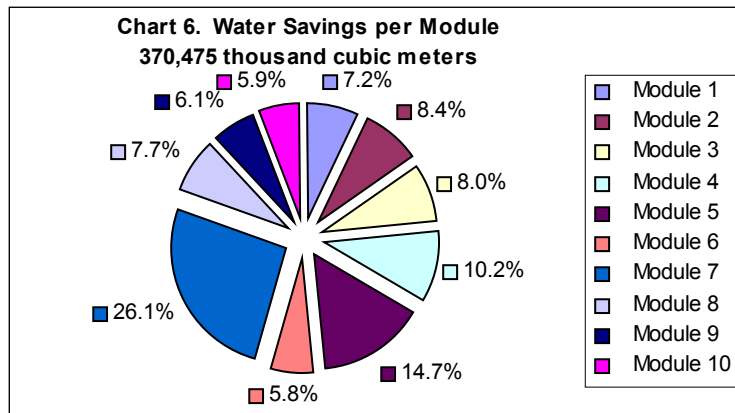
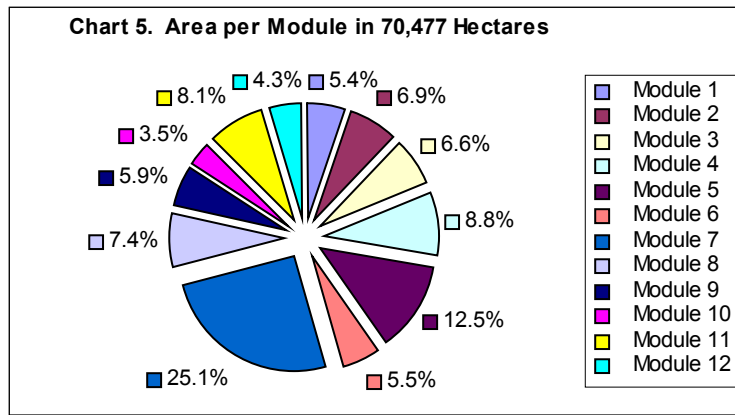


### II.1 Area under Technical Improvement

This investment will allow for an increase in the use of irrigation technology in 70,477 ha through land leveling, multi-lock and pressurized irrigation systems (high-pressure wells and networks, low-pressure wells and networks, low-pressure pumping stations). The main component for increased use of technology will be land leveling (31 % of the area) and multi-lock systems (24 %). Besides, spraying systems through high-pressure networks and wells constitute an important item (24 %).

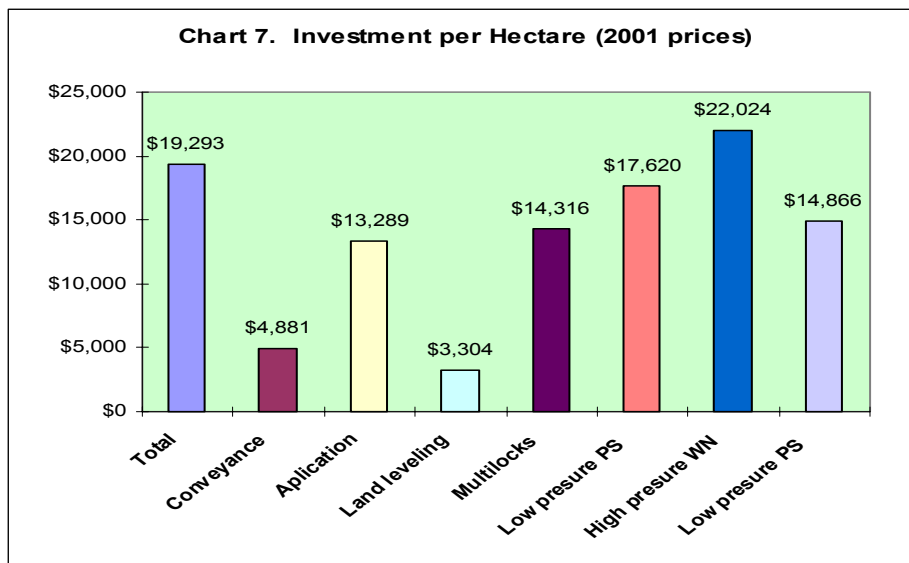
The greater area which will increase the use of technology is found in modules 7 (25 %) and 5 (13 %), which is consistent with the percentage of investment be carried out in them. Moreover, the higher savings in water shall be obtained in those modules (26.1 % in module 7 and 14.7 % in module 5).





## II.2 Investment per Hectare

Investment per area unit (ha) totals MX \$19,293 (US \$2,030). This investment per area unit is made up by 25.3% in conveyance and distribution systems, 68.9% in water application systems at the farm level and 5.8% in other items.



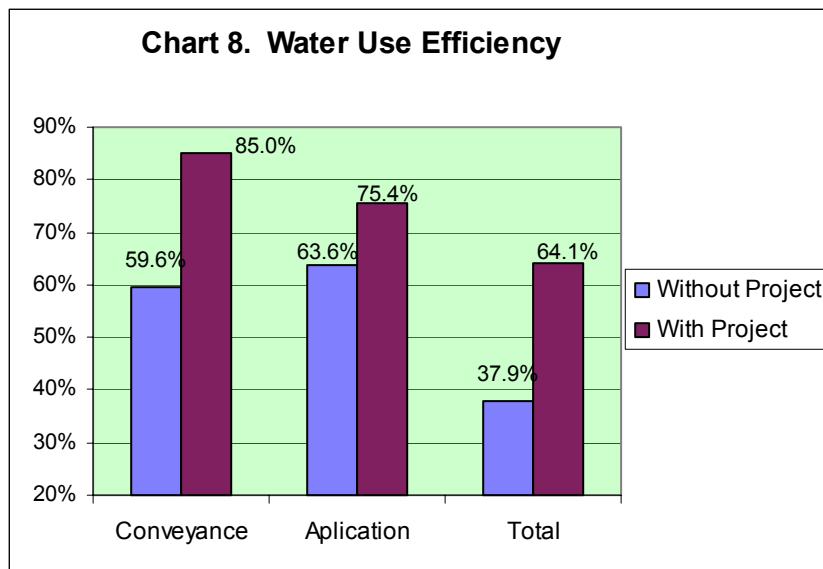
### III. Water Savings in the Production System

To assess this Investment Project a calculation of the possible impact in water savings based on a representative model of the production system was carried out. For the “Without Project” case, a 37.9 % global efficiency was calculated, as a result of 59.6 % conveyance and distribution efficiency and a 63.6 % water application efficiency at the farm level. For the “With Project” case, conveyance and distribution efficiency increases to 85 % because of channel coating and/or piping.

Efficiency calculation of water application at the farm level takes into account the following assumptions for operation of the different irrigation systems and their efficiencies at the project’s start:

- Leveling/multi-lock systems having a 70% water application efficiency to be used in wheat, forage oats, rye grass, cotton, peanuts, forage maize, grain maize, sorghum and soybeans.
- Spraying systems having an 80% water application efficiency to be used in alfalfa.
- Pressurized systems having an 85% water application efficiency to be used in vegetables and pecans.

The combination of all these efficiencies in different crops allows to estimate a 64.1 % total efficiency for the overall production system.



### IV. Assessment of the Investment Project

Based on a representative production model for a 76,000 ha area, water savings were estimated. The deterministic result of this calculation was a 302.7 million cubic meters ( $10^6 \text{ m}^3$ ) volume, which was used to assess the investment project.

## IV.1 Assumptions

Assumptions on harvested area and investments are based on information reported by CNA/ID005. On the other hand, assumptions on irrigation systems, gross water volume, yields and electricity are based on information reported by CNA/ID005, FIRA and INIFAP. Like this, assumptions are the following:

1. Investments are carried out in accordance with the established program.
2. Irrigation systems begin operating and reach their expected efficiencies in each crop.
3. Average depth irrigation water by each crop decreases between 20% and 50%.
4. Water savings reach their higher level in year 6 and remain stable after then.
5. Unit yields in crops increase between 15% and 30% because of better use of water and agrochemicals. Yields stabilize after year 5 in the rates of increase considered.
6. Harvested area increases to 70,500 ha in accordance with the CNA Investment Project.
7. Harvested area per irrigation system is adjusted to components of the CNA Investment Project.
8. Labor use increases because of an increase in yields.
9. Electricity is introduced as a service in production costs because pressurized systems begin operation.
10. Other factors use, inputs and services remain equal to the "Without Project" case.

**Table 1. Investment Project for Irrigation District 005 Delicias**

Components	With Project			
	Year 1	Year 2	Year 3	Year 4
<b>I. Executive Project</b>	<b>5,201,000</b>			
<b>II. Infrastructure and Equipment</b>	<b>487,673,000 386,765,291 178,132,087 227,968,674</b>			
Water head and main channels	43,000,000			
Coating and/or tubing of channels	108,200,000	94,100,000	43,300,000	55,400,000
Multilock irrigation systems	88,411,000	76,899,546	35,427,676	45,344,334
High pressure wells and network	136,016,000	118,306,191	54,503,748	69,760,040
Low pressure wells and network	32,135,000	27,951,622	12,877,191	16,479,297
Low pressure pumping station	54,408,000	47,326,397	21,803,374	27,905,288
Land leveling	25,503,000	22,181,535	10,220,097	13,079,715
<b>III. Technical Supervision</b>	<b>26,567,000 23,108,000 10,646,000 13,625,000</b>			
Channel coating	9,743,000	8,475,000	3,904,000	4,997,000
Plot improvement at the farm level	16,824,000	14,633,000	6,742,000	8,628,000

## IV.2 Financial assessment

The financial assessment of the Investment Project is based on the components determined by the CNA. As has been mentioned already, a total investment of MX\$1,359.7 million (2001 prices) to be disbursed in 4 years is considered.

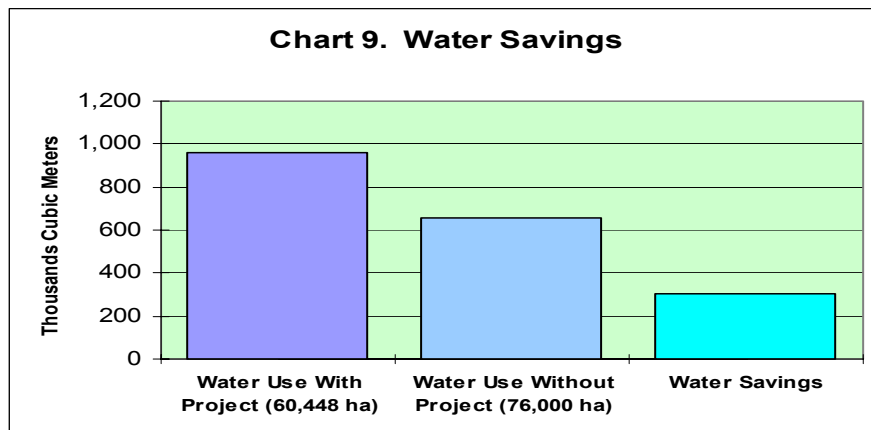
**Table 2. Production System Net Financial Profit Without and With Project**

	Without Project	With Project		
		Year 1	Year 5	Year 20
Area (ha)	59,002	76,000	76,000	76,000
System value of output (\$)	871,931,556	977,046,061	1,397,504,080	1,397,504,080
System production cost (\$)	669,495,694	727,586,218	959,948,312	959,948,312
System net profit (\$)	202,435,862	249,459,843	437,555,768	437,555,768
<b>Incremental net benefit (\$)</b>		<b>47,023,981</b>	<b>235,119,906</b>	<b>235,119,906</b>

In order to assess the effects of an increase in the use of irrigation technology, a production model developed especially for ID 005 is used. The production model “Without Project” generates in a 59,002 ha (1990-2001 average) area an estimated MX \$ 202.4 million (US \$ 21.3 million) annual net profit (excluding direct government support). When the changes described above are introduced the “With Project” production model generates an estimated net profit for a 76,000 harvested area of MX\$ 249.5 million (US \$ 24.7 million) in year 1 which increases to MX\$ 437.6 million (US \$ 46.1 million) from year 5 to year 20.

Like this, the incremental net profit (the difference between total net profit “With Project” and “Without Project”) in the stabilization period is of MX\$ 235.1 million (US \$ 24.7 million) annually. When investment (expenditure) is combined with incremental net profits (income), the financial profitability indicators for the Investment Project are obtained.

An important additional benefit of this project is the volume of water saved due to an increase in the use of technology. An estimate for year 6 indicates that the maximum can be reached then and a volume of  $302.7 \cdot 10^6 \text{ m}^3$  volume could be saved annually. Taking into account a current price of water of MX\$ 80/1,000  $\text{m}^3$  (US \$ 8.4/1,000  $\text{m}^3$ ), annual savings of MX\$ 24.2 million (US \$ 2.5 million) could be achieved.



### IV.3 Assessment of 20-year scenarios

**Scenario 1:** Producer’s profitability with government support in the initial MX\$ 1,360 million investment to be disbursed in the first 4 years. Producers pay for the necessary investments in irrigation systems replacement (spray and pressurized), from year 5 onwards. In this scenario, the financial evaluation does not take into account government investment as expenditure, only that of producers.

From the producers’ perspective, this Investment Project will be highly profitable because their annual net profit will increase by some real 106.6 % (215.8/202.4). The 8 % real discount rate considered which is equivalent (when the inflation rate is added) to the banks’ commercial rate applied to agricultural loans. In this scenario, it is not possible to estimate an IRR because no negative net profit is obtained.

**Scenario 2:** Profitability of the total investment taking into account both government and producers’ investment. This scenario evaluates the Investment Project’s financial viability from the joint government and producers’ perspective. This Investment Project is financially viable showing a real 17.8 % IRR, double than the real 8 % discount rate. Even if producers paid for the total investment, the net annual profit would increase by 42.1 % in real terms (85.3/302.4).

**Table 3. Financial Appraisal of the Investment Project**

	Water Market Price		
	Scenario 1	Scenario 2	Scenario 3
Total Net Present Value (2001 prices)	\$2,071,993,938	\$819,409,001	\$1,000,388,860
Annual Net Present Value (2001 prices)	\$215,751,813	\$85,323,115	\$104,168,119
Annual Net Benefit Increase	106.6%	42.1%	51.5%
Real Internal Rate of Return		17.8%	19.8%

Scenario 1: Producer profitability with government support in the initial investment.

Scenario 2: Total investment profitability.

Scenario 3: Total investment profitability with saved water valuation.

**Scenario 3:** Profitability of the total investment plus appraisal of water savings as an additional benefit. The financial assessment of this scenario is equal to that of the previous scenario with the only difference being the introduction of valued water savings at market prices. With this additional profit flow, real IRR increases to 19.8 %. If producers paid for all the investments and could sell the water saved at market prices, their annual net profit would increase by 51.5 % in real terms (104.2/202.4) when compared to the annual net profits “Without Project”.



**Scenario 4:** This scenario is similar to scenario 3 but the water financial price (paid by producers) is substituted by a water efficiency (shadow) price estimated at MX\$ 122/1,000 m<sup>3</sup>. In this scenario, real IRR is equal to 16.2 %, also double that of capital's opportunity cost. That is to say, this investment project continues to be profitable for producers, who increase their annual net profit by 34.9 % in real terms.

**Table 4. Economic Appraisal of the Investment Project**

	Water Efficiency Price
	Scenario 4
Total Net Present Value (2001 prices)	\$677,614,693
Annual Net Present Value (2001 prices)	\$70,558,410
Annual Net Benefit Increase	34.9%
Real Internal Rate of Return	16.2%

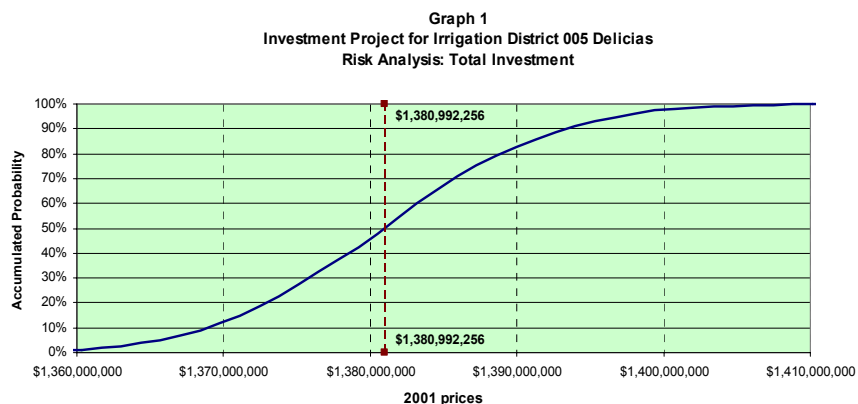
Scenario 4: Total investment profitability with economic valuation of saved water.

## V. Risk Assessment of the Investment Project

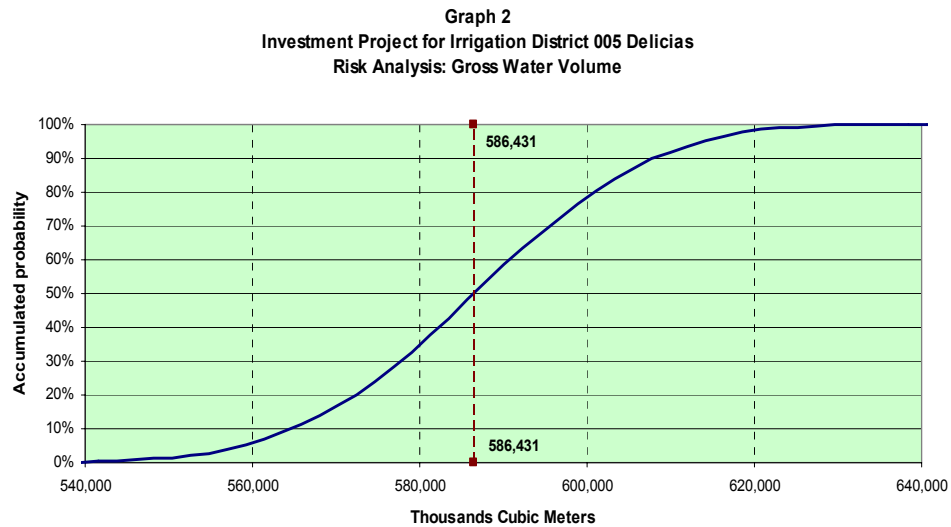
A risk assessment of this Investment Project was carried out taking into account the uncertainty of the main variables: total investment, water availability, harvested area, product prices, yields and production costs. Financial indicators used to calculate investment profitability in the production system were Total Net Present Value, Annual Net Present Value and Net Profit's increase, applied to the same scenarios as those of the deterministic assessment.

### IV.1 Physical variables

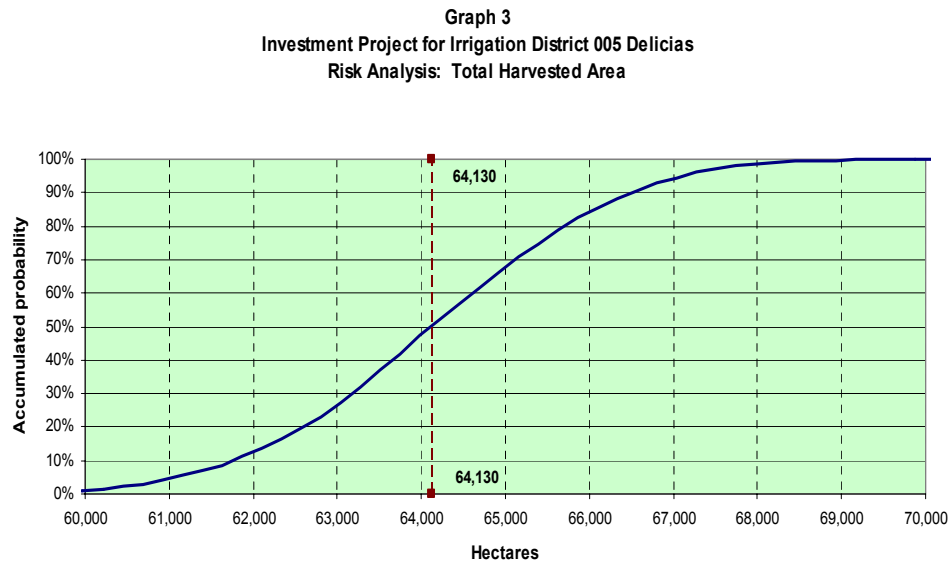
Total Investment. The result of the Monte Carlo simulation indicate that the expected value is MX\$ \$1,381 million (US\$ 145.4 million) showing a standard deviation (sd) of MX\$ 9.5 million (US\$1.0 million) and a 0.7 % coefficient of variation (cv).



Water availability. Based on average depth irrigation water applied by crop and efficiency assumptions, the simulation of Gross Water Volume available for irrigation was carried out. The result is a expected value of 586.4 million cubic meters showing a sd of 16.6 million cubic meters and a cv of 2.8 %.

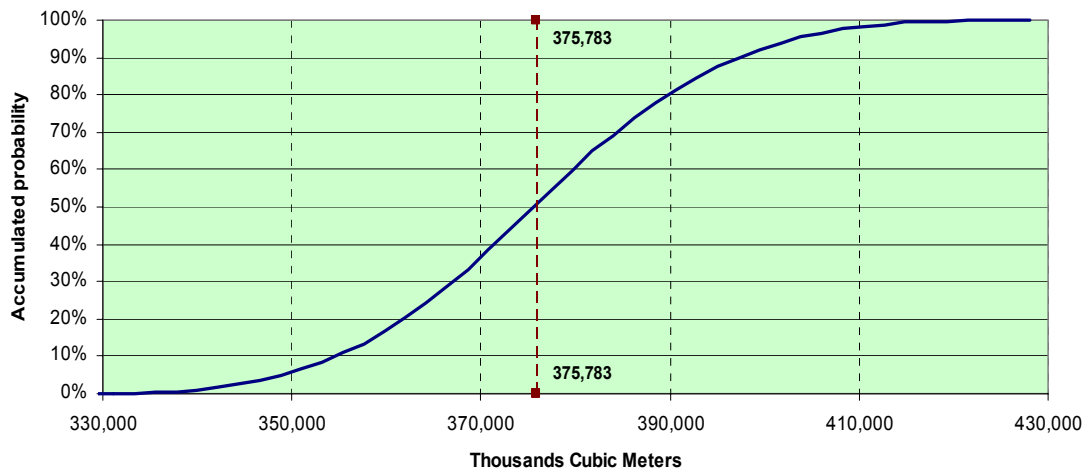


Harvested Area. Based on water availability, a 64,130 ha harvested area expected value is obtained in the Monte Carlo simulation, showing a sd of 1,814 ha and a cv of 2.8 %



Water Savings. As a result of the Monte Carlo simulation for gross water volume and harvested area, the saved water volume simulation shows a 375.8 million cubic meters expected value, presenting a sd of 16.3 million cubic meters and a cv of 4.3%. This expected value is similar to the CNA's estimate of 370.4 million cubic meters.

**Graph 4**  
**Investment Project for Irrigation District 005 Delicias**  
**Risk Analysis: Saved Water Volume**



**V.2. Economic variables**

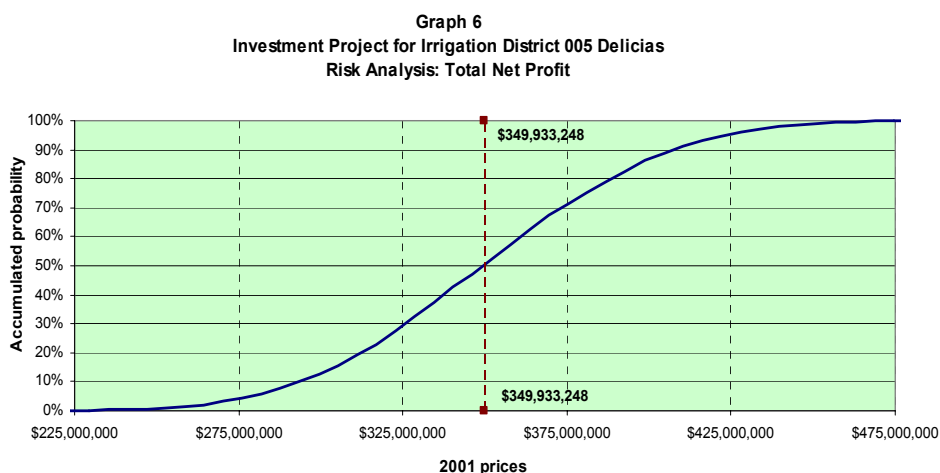
To obtain the Unit Net Profit range associated to the production system's probabilities of the Investment Project, the starting point should be probability distributions modeling for product prices, yields and production costs for the 19 crops under analysis.

Unit Net Profit. The joint distribution of the Unit Net Profit for the production system "With Project" shows a MX \$ 5,458/ha (US\$ 574.5/ha) expected value with a sd of MX\$ 685/ha and a cv of 12.6%.

**Graph 5**  
**Investment Project for Irrigation District 005 Delicias**  
**Risk Analysis: Net Profit per Hectare**

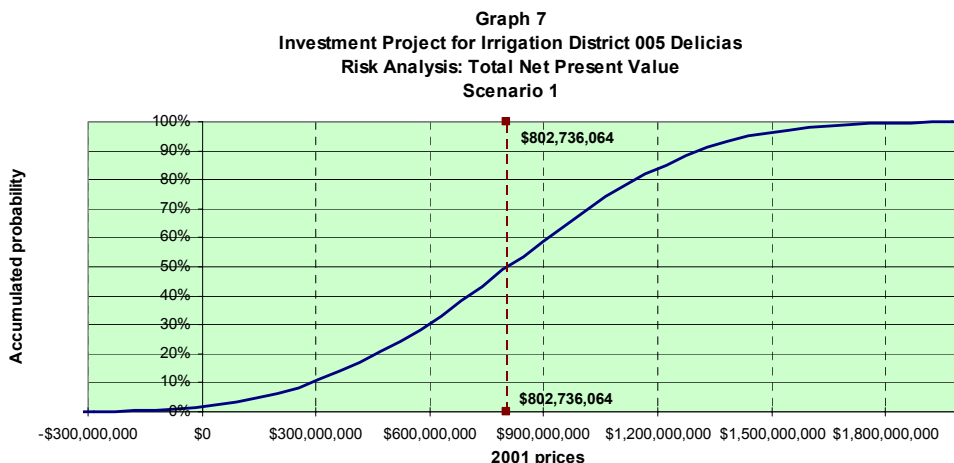


**Total Net Profit.** Based on probability distribution of Gross Water Volume, Harvested Area and unit Net Profit, the joint distribution of Total Net Profit (TNP) of the production system “With Project” is obtained. TNP expected value is MX\$ 349.9 million (US\$ 36.5 million) showing a sd of MX\$ 43.9 million and a cv of 12.5 %.

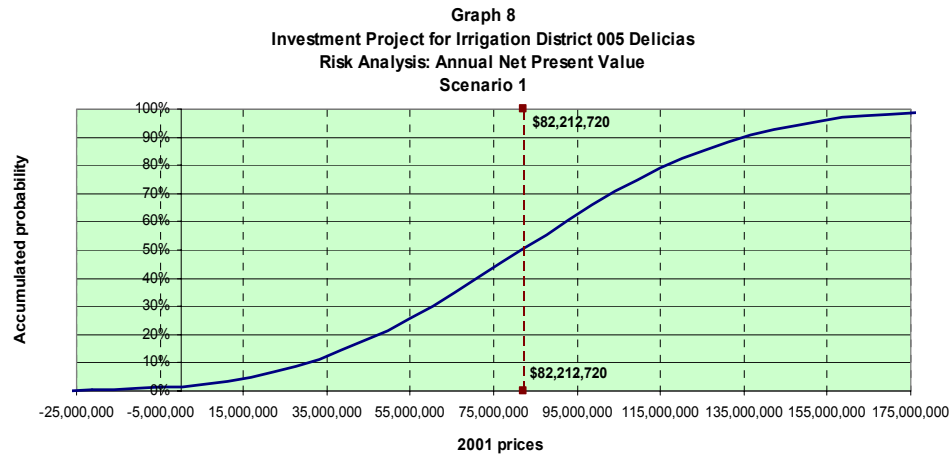


**Project Financial Profitability.** Probability for a negative Total Net Present Value (TNPV) is 1 % for Scenario 1, 88.7 % for scenario 2 and 75.3 % for Scenario 3. Like this, when risk is introduced, financial viability is found only when investments are paid for by the Federal Government during the first four years and producers pay for irrigation equipment replacement from year 5 onwards. Taking this into account, Scenario 1 should be taken as the only one relevant one for this analysis.

In Scenario 1, TNPV is MX\$ 802.7 million (US\$ 84.5 million) accumulated throughout the 20 years useful life period being considered, with a sd of MX \$ 390.9 million (US\$ 41.1 million) and a cv of 48.7 %. This means that it is a high risk project due to its high variability. With a 68 % probability, TNPV range lies between MX\$ 411.8 million (US\$ 43.3 million) and MX\$ 1,193.0 million (US\$ 125.6 million), and if a 95 % probability is considered, the range for TNPV lies between MX\$ 20.9 (US\$ 2.2 million) and MX\$ 1,584.5 million (US \$ 166.8 million). TNPV is equivalent to MX\$ 82.2 million (US \$ 8.7 million) per year with a sd of MX\$ 40.4 million (US\$ 4.3 million) and a cv of 49.1%.

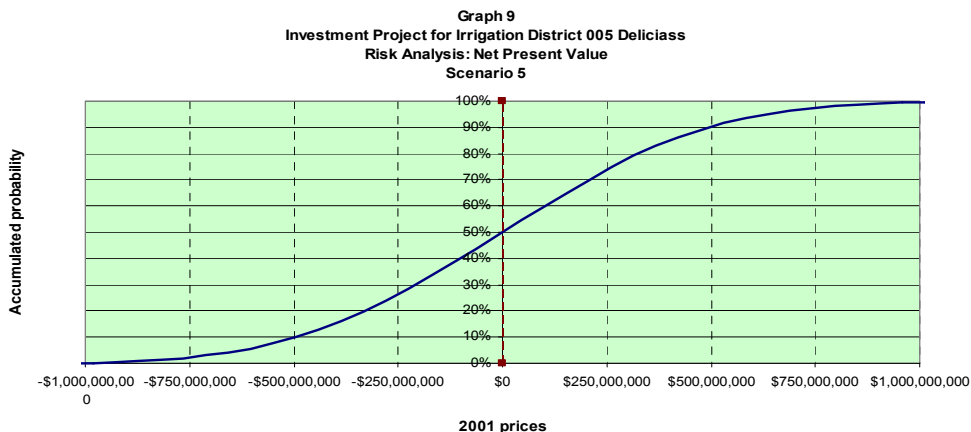


This means that the production system "With Project" should generate an average Annual Net Present Value (ANPV) of MX\$82.2 million (US\$ 8.7 million) additional to the MX\$ 202.4 million (US\$ 21.3 million) Total Net Profit generated currently by the production system "Without Project". This ANPV is equivalent to an average 40.6 % annual increase in real terms. This represents a highly attractive alternative for producers. With a 68 % probability the ANPV should fluctuate between MX\$ 41.8 million (US\$ 4.4 million) and MX \$ 122.6 million (US\$ 12.9 million) annually, and taking into consideration a 95 % probability, the ANPV range should lie between MX \$ 1.4 million (US \$ 0.150 million) and MX\$ 163.0 million (US \$ 17.2 million) annually



Economic Profitability of the Project. The economic assessment of the investment project was calculated for the Scenario in which producers pay a MXN \$ 122.0/1,000 m<sup>3</sup> (US \$ 12.8/1,000 m<sup>3</sup>) water efficiency price while the water saved and use by other economic sectors is estimated at MX\$ 200.0/1,000 m<sup>3</sup> (US\$ 21.1/1,000 m<sup>3</sup>).

Considering these prices, the expected TNPV is equal to MX\$ 0.0, that is to say total investment costs are recovered and the IRR is equal to the 8 % discount rate in real terms. However, the probability for a negative TNPV equals 50 %.



Water Rights Modification. Currently, producers own water rights for a 1,171,578 thousand cubic meters water volume stored in dams. The National Water Commission (CNA) estimates that this volume should be reduced by 31.6 % to 801,103 thousand cubic meters, as a result of water savings estimated at 370,474 thousand cubic meters. This modification to Water Rights should become effective after year 4, once a comprehensive assessment of the achieved saved water volume is completed.

## VI. Conclusions and Recommendations

### Conclusions

This case study includes a deterministic analysis as well as a probabilistic analysis of the “With Project” and “Without Project” scenarios. Values obtained through deterministic analysis were higher than those obtained through probabilistic analysis for Gross Water Volume, Harvested Area and Total Net Profit. Therefore, wishing to present conservative results associated to probabilities, conclusions and recommendations are based on results of the probabilistic analysis.

- As a result of the Investment Project, Gross Water Volume should decrease from 932,600 thousand cubic meters to 586,400 thousand cubic meters, Harvested Area should increase from 57,912 ha to 64,130 ha and Total Net Profit should increase from MX\$189.5 million (US\$ 19.4 million) to MX\$ 349.9 million (US \$ 36.8 million). Besides, in the “With Project” case, water savings should total 375,800 thousand cubic meters.
- Deterministic analysis of financial indicators of the Investment Project show acceptable values for profitability. However, probabilistic analysis shows that the Investment Project is economically and financially viable only for Scenario 1, that is to say, when the Federal Government pays for the total investment for the first four years, and producers pay for irrigation systems replacement from year 5 onwards.
- Probabilistic results of the financial analysis indicate that producers will receive, as an average, an additional Total Net Profit of 40.6 % in real terms than in scenario “Without Project”, for the 20 year useful life period considered for this project.
- Annual Net Present Value is on average MX\$ 82.2 million (US\$ 8.7 million) with a cv of 49.1%. That is to say, nevertheless the investment project being viable, ANPV is highly volatile (it means risky) and at the same time, highly profitable for producers.
- In order that profits of the investment project cover Federal Government and producers’ investment expenditure, weighted price for water inside and outside agriculture (saved volume) should be MX\$ 152.5 (US \$ 16.1) per thousand cubic meters. The fact that this investment project is viable only for Scenario 1 implies that the financial scheme applied in this case will not be reproducible in other Irrigation Districts because, either the total initial investment should be disbursed by the Federal Government or the price of water should be raised substantially.
- The Investment Project in DDR 005 should generate water savings in the range from 300,000 to 380,000 thousand cubic meters, equivalent to 30 – 40 % of Gross Water Volume used currently in agriculture, which should favorably impact the environment if adequate measures are taken to ensure that water be carried through its natural streams. If these savings are achieved, reservoirs should then be able to store a higher water volume thus facilitating other economic activities, as fishing, tourism and others related to the leisure industry, and other of non-economic nature activities as native flora and fauna conservation.

### Recommendations

- Water savings, besides their hydraulic components, should take into consideration also an agronomic component, especially in the following aspects: i) new crop varieties that demand less water, ii) crop diversification to include oilseeds (canola, safflower) that require less water and iii) conservation tillage, especially in grains.

- Increase the current price of water (2001 prices) from MX \$80.0 (US\$ 8.0) /1,000 m<sup>3</sup> to its efficiency price of MX \$ 122.0 (US\$ 12.8) /1,000 m<sup>3</sup> for farmers and of MX \$ 200.0 (US \$ 21.0) /1,000 m<sup>3</sup> to other users, and directing these financial resources to soil conservation activities in the higher areas of the basin, and for possible payments for environmental services to those communities that inhabit the rainfall reception areas.
- Remove all constraints that limit sale of water rights, to foster the creation of a water markets, which should allocate water use to activities with greater economic value inside and outside agriculture (including the environment).
- This Investment Project is of high risk in terms of expected technical achievements needed to recover the total expenditure through profits. Therefore, a strong training program for producers on efficient irrigation management should be provided to be able to achieve the expected water application efficiencies.
- Besides, extensive research, extension and technical support programs on the necessary adjustments to production technology for the different crops should be carried out and made available to users. This should ensure that projected yields be achieved.
- Ensure that pressurized irrigation equipment corresponds to producers' specific needs, because they constitute the main component for the project's success. Therefore, an efficient follow-up system on their performance should be set up.
- Set up a system to assess water savings in specific locations along the Conchos River course to determine efficiency of infrastructure and irrigation equipment.

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