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An Impact Evaluation of India's Second and Third Andhra Pradesh Irrigation Projects

A Case of Poverty Reduction with Low Economic Returns

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Family harvesting crops in India. Photo by Curt Carnemark, courtesy of World Bank Photo Library.

Abbreviations

AP II	Second Andhra Pradesh Irrigation Project
AP III	Third Andhra Pradesh Irrigation Project
APERP	Andhra Pradesh Economic Restructuring Project
APFMIS	Andhra Pradesh Farmers Management of Irrigation Systems (Act)
CAD	Command area development
CADA	Command Area Development Authority
Cusecs	Cubic meters a second
DC	Distributary committee
ERR	Economic rate of return
ha	Hectares
I&CADD	Irrigation and Command Area Development Department
ICR	Implementation Completion Report
IEG	Independent Evaluation Group
IMT	Irrigation Management Transfer
O&M	Operations and maintenance
PIM	Participatory irrigation management
Rs	Rupees
RLP	Rural Livelihoods Project
SAR	Staff Appraisal Report
SRBC	Srisailam Right Branch Canal
SRSP	Sriramasager Project
WOP	Without project
WP	With project
WUA	Water user association

Watering a crop from a field canal in India. Photo by Ray Witlin, courtesy of World Bank Photo Library.

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This report was prepared by Howard White (task manager) and Edoardo Masset (consultant), with inputs from Nina Blöndal (consultant), under the guidance of Alain Barbu. Useful comments have been received from Keith Oblitas and Keith Pitman and the external reviewers Peter Hazell, Michael Lipton, and Richard Palmer-Jones. The report was edited by William Hurlbut and Heather Dittbrenner. Administrative support was provided by Soon-Won Pak.

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Workers digging irrigation ditch in India. Photo by Curt Carnemark, courtesy of World Bank Photo Library.

Foreword

Irrigation has made a major contribution to poverty reduction in the past decades, enabling higher yields and better nutrition. Despite these achievements, large-scale irrigation schemes have usually yielded low returns and attracted negative publicity because of their adverse environmental and social impacts. As a result, the Bank has largely switched its support for irrigation away from new construction toward rehabilitation and policy reform. This evaluation supports the need for reform but shows that there are substantial benefits from further investment in infrastructure.

This study analyzes these issues through an impact evaluation of one of the last "old generation" of projects in which the Bank directly supported creation of a new irrigation scheme: India's Second and Third Andhra Pradesh Irrigation Projects (AP II and AP III). Together these projects created a new command area, the Srisailem Right Branch Canal (SRBC), and rehabilitated an existing one that had been constructed with Bank assistance, the Sriramasagar Project.

The impact analysis, which uses a quasi-experimental design and is based on new survey data and reanalysis of existing data, confirms that irrigation has a substantial poverty-reducing impact: in the first year of receiving canal irrigation the poverty rate falls by a quarter. Although larger land owners benefit the most in absolute terms, the greatest income growth accrues further down the income distribution, mainly because of the growth in wage employment. The long-run poverty-reducing effects are greater still, as households become less vulnerable to rainfall fluctuations and so escape the poverty trap of periodic shocks undermining their asset base.

But the returns to investments anticipated at appraisal did not materialize: Yield increases were lower than forecast and the expected diversification did not occur; indeed, canal-irrigated farms have been less diversified than those without irrigation. The expectations at appraisal were overly optimistic on both yield and diversification. The return was further undermined for AP II and AP III by long delays and large cost overruns. These problems were most severe in the case of the SRBC project, for which the first water was received by farmers nearly 20 years after construction started—resulting in a rate of return of, at best, zero.

The return to the rehabilitation component was higher but was still less than 10 percent. In summary, the investments were efficacious but not efficient. Investments in large-scale construction need to establish mechanisms to ensure that construction is completed on time and on budget—the government of Andhra Pradesh is now adopting such measures. Part of avoiding delays is ensuring adequate preparation, which did not happen in this case, partly because the Bank raised new design issues once implementation had begun.

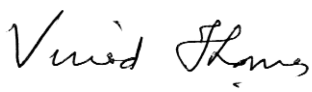
Andhra Pradesh has been at the forefront of participatory irrigation management through water user associations (WUAs). More than 10,000 WUAs were created across the state, with elections of officers being held in a single day. These WUAs have played an important role in improving the quality of rehabilitation works.

But WUAs cannot take full responsibility for operations and maintenance (O&M); they often lack the technical capacity to do so. They also lack the financial resources, as funds collected through the water cess are insufficient for adequate O&M, especially as collection rates remain low. In part this is because the problem of inadequate water at the tail ends has not been solved. WUAs are not able to solve problems of water allocation, especially those between communities. Excess water use in the head reaches, including sabotage of water control measures, remains prevalent. There will continue to be a role for government in water management, and further means of improving water allocation need to be considered.

Although the Independent Evaluation Group has engaged with the government of Andhra Pradesh throughout the study, the government does not share all the conclusions of this evaluation. In particular, it has pointed out that it has taken steps to rectify the construction inefficiencies that plagued these projects. The government has also stressed its continued commitment to developing WUAs, which it believes will overcome what it sees as "teething problems" in institutional development.

Among the key findings of the study are the following:

- Large-scale irrigation can—and in this case did—have a significant poverty-reduction impact.
- Large-scale construction yields low returns when there are cost overruns and delays. These can be avoided with more rationalized selection and planning and appropriate design and procurement procedures.
- WUAs can help improve water management but are not a panacea; there is a continued role for government in both technical aspects and facilitating equitable water distribution.



Vinod Thomas
Director-General, Evaluation

Preface

The Independent Evaluation Group (IEG) of the World Bank has undertaken impact evaluations of the Bank's support to irrigation in Andhra Pradesh, India (under AP Irrigation II and III), and of the U.K. Department for International Development-supported Rural Livelihoods Project (RLP).

This is one of a series of IEG impact evaluations (see appendix H). IEG's program of impact evaluation is in part carried out under a Department for International Development–IEG partnership agreement; hence the focus on RLP. However, survey villages are also covered by the Bank-supported DPIP project, so that the findings are also relevant to this project.

For this purpose, a first-round survey was conducted in June 2005 in the five RLP districts and the Warangal district, an area of recent irrigation expansion along the Kakatiya canal under the Sriramasagar Project, which was rehabilitated with World Bank support. A second-round survey was undertaken in Warangal in March 2006, along with qualitative data collection. This report presents an analysis of the economic and social impact of the two irrigation projects.

The report is the first IEG will publish concerning rural development in Andhra Pradesh. Subsequent reports will review the impact of RLP following a third survey round in June 2007 and compare the effectiveness of different interventions for reducing rural poverty. This next study will explicitly compare the effectiveness of large-scale irrigation investments, the subject of this study, with the smaller-scale groundwater-based interventions promoted by RLP, and it will review the empowerment route to poverty reduction embodied in both RLP and Indira Kranti Patham.

The findings presented in this report complement those in the recent IEG study *Water Management in Agriculture: Ten Years of World Bank Assistance, 1994–2004* (IEG 2006b). Many of the general lessons in that report concerning problems encountered in irrigation investments are exemplified by the two projects considered in this report. Building on the sector review, this report presents new evidence on the strengths and weaknesses of water user associations, which are an important part of the Bank's current approach to irrigation. This study also goes into greater detail than a typical IEG project assessment on social and economic impacts, using survey data to identify the distribution of both direct and indirect benefits from irrigation investments.

A draft of the report was discussed with officials of the government of Andhra Pradesh in Hyderabad in March 2007, and written comments were subsequently received (attached as appendix G, with an IEG response to the major points raised). These comments have been taken into account as appropriate in the final version of this report.

Building a main brick canal in India. Photo by Curt Carnemark, courtesy of World Bank Photo Library.

Executive Summary

The widespread expansion of irrigated farming has largely removed the threat of malnutrition and premature death for millions around the world and has had demonstrated poverty-reduction effects. Nonetheless, large irrigation projects have fallen out of favor, criticized for their costliness, their environmental impacts, the resettlement problems they cause, and particularly their poor sustainability record.

For many developing countries, the productivity of irrigation investments has been falling as a result of poor operations and maintenance (O&M). This problem has increasingly been addressed in development projects by putting users and communities in charge of O&M, an approach known as participatory irrigation management (PIM). However, the effect of this approach on equity, and hence its implications for poverty reduction, have yet to be fully explored.

The Independent Evaluation Group (IEG) of the World Bank has examined the paradoxical nature of irrigation projects by evaluating the impact of two such projects in the Indian state of Andhra Pradesh. Irrigation Projects II and III (AP II and AP III) aimed to irrigate 393,000 hectares (ha) of land—65,000 ha served by the Srisailam Right Bank Canal (SRBC), 163,000 ha served by a rehabilitated canal, and 165,000 ha gained from extending the system under the Sriramasagar Project (SRSP). Together these projects were expected to benefit more than 300,000 farm households.

The evaluation findings have implications for the management of irrigation projects. Although the World Bank has largely disengaged from financing new irrigation construction in India, the findings of the evaluation are of interest, as the government of Andhra Pradesh is planning major investments in new irrigation schemes. The findings are also relevant for community-driven development and other participatory approaches and to implementation of other reforms such as water pricing, both of which are part of the Bank's current irrigation agenda in India. Indeed, Bank finance for AP III was originally justified based on the support it provided to the reform process in Andhra Pradesh.

Andhra Pradesh has been a leader in the use of PIM since the late 1990s, when PIM was piloted in the SRSP. Previously, irrigation O&M was the responsibility of government agents whose salaries consumed so much of the O&M budget that little went to O&M itself. In 1997, an act of Parliament handed responsibility for water management to water user associations (WUAs), which were to assist in collecting water charges and were to receive a large share of this revenue to undertake O&M. The act also provided for the establishment of distributary committees and higher-level project committees to help manage the O&M. The World Bank has been closely involved in these reforms, financing WUA training and irrigation system rehabilitation undertaken with the involvement of WUAs.

Economic Impacts

The economic impacts of the irrigation projects were undermined by problems commonly encountered in large civil works programs: cost overruns and construction

delays. AP II did not complete any irrigation works and thus produced no benefits whatsoever. AP III completed the investments started under AP II. Although work started in 1988, no farmers were receiving water in the SRBC area when AP III closed in 2004. The planned area will be irrigated by 2007, nearly 20 years after the project started. Such long delays make the likelihood of an acceptable return on investments very remote.

There has been a positive impact on both crop yields and cropping intensity, but the expected diversification into high-value crops has not occurred. An IEG household survey in a newly irrigated area of the SRSP in the Warangal district found that irrigated farms are less diversified than those that are not irrigated. This lack of diversification is confirmed by other data sources for different parts of the command area. This is partly because the water pricing structure does not discourage excessive use and wastage, which means that, contrary to official policy, irrigated farms grow crops (mostly paddy) requiring large volumes of water, depriving farms in lower reaches of water. With the benefit of hindsight, the expectations at appraisal were overly optimistic on both yield and diversification.

The bulk of the direct benefits from higher farm income accrues to the top quarter of beneficiaries. Indirect benefits from higher employment are spread more evenly across the income distribution, although the poorest receive fewest benefits. These indirect benefits in particular cause irrigation to have a substantial one-off impact on poverty reduction (on the order of a 10 percentage point reduction in the poverty headcount as a result of irrigation reaching a village) and a small progressive impact on distribution. This is because **the greatest income growth from irrigation is experienced by the second wealth quartile, a situation that allows a substantial impact on poverty despite the skewed distribution of absolute benefits.**

The longer-run impact on poverty will be greater than the immediate impact, because irrigation ends the cycle of negative income and debt that undermines asset accumulation. One of the chief benefits of irrigation is the smoothing effect that it has on incomes, reducing year-to-year fluctuations in production caused by variations in rainfall.

The beneficial impacts are less than expected, as the projects suffered from overly optimistic appraisals. Yield increases average about half of appraisal estimates. Hence, given the other problems encountered by these projects, the overall return on the investment in SRBC and SRSP is just under 2 percent (compared with the appraisal estimate of 24 percent). Even allowing for more optimistic assumptions about future yields, the economic rate of return does not rise above 5 percent. Thus, the projects are a large subsidy to farmers, who do indeed benefit. Moreover, the distribution of benefits is skewed toward the better off. Herein lies the explanation for the falloff of support for irrigation despite its poverty-reducing effects: poverty reduction is achieved by the large transfer involved in irrigation financing.

This raises two questions. First, can large-scale irrigation schemes be self-financing and still reduce poverty? Second, is subsidizing large-scale irrigation the best use of a subsidy to reduce rural poverty? This study answers only the first question: schemes can both be self-financing and reduce poverty only if construction is efficiently implemented. Once a scheme is functioning, the benefits it provides (in good years) are more than sufficient to pay for the system's recurrent costs. **These conclusions support the Bank's shift to focusing on institutional issues in irrigation, including water pricing.** The second question will be the subject of a later IEG study that considers alternative investments in rural areas of Andhra Pradesh.

The economic impact findings from this study are similar to those of other IEG evaluations in the irrigation sector, including the recent sector review (IEG 2006b): **irrigation project outcomes are restrained by the failure to meet overly ambitious construction schedules, and in-**

vestment viability relies on overly optimistic estimates of benefits.

The expected economic rate of return at appraisal is often far above the ex post rate, which has rarely been above the 10 percent threshold. The Bank has responded to these problems in Andhra Pradesh, as it has elsewhere, by engaging in the reform agenda, one focus of which has been the creation of WUAs. Far less progress has been made on establishing a pricing policy that encourages optimal water usage. The emphasis on WUAs is consistent with the Bank's emphasis on community involvement. **But a growing body of evidence, including this report, suggests that community groups are unlikely to live up to the hopes invested in them.**

Social Impacts

Andhra Pradesh has been a leader in promoting WUAs, an approach that was nurtured under AP III. But the effectiveness of WUAs has not met expectations, and there is a need for a continuing government role if the irrigation system is to run efficiently.

The expansion and durability of WUAs has been influenced by political factors. Following the 1997 act of Parliament, more than 10,000 WUAs were created across Andhra Pradesh. This occurred in part because the chief minister at the time had a particular interest in promoting grassroots structures. However, WUAs ceased to function when elections were not held in 2002 at the end of WUA officials' first term of office. The planned election of management committees at the project level in irrigation schemes was shelved and has still not taken place, although elections are still planned.

WUA membership is not representative of the population served. According to the 1997 act, all cultivating households are WUA members. However, an IEG household survey in 18 villages in the Warangal district found that half of households with access to canal or tank irrigation were members, but just 19 percent of all cultivating households in the irrigation scheme areas were members. Membership was strongly skewed toward the better off, and leadership of WUAs was dominated by members of higher castes (notably the president, who often runs the WUA with little consultation). Although supporters of PIM claim it will benefit the poor, the landless—who are the poorest—are automatically excluded. Even among cultivators, it is the better off who are most likely to participate, partly because they have better access to irrigated plots.

A positive feature of irrigation development since the 1997 reforms has been rehabilitation of sections of the canal network: water now reaches more areas. WUAs were involved in the identification of these works and undertook most of the rehabilitation. This involvement has improved the effectiveness and efficiency of these works, even though WUA presidents often did not consult other members and benefited personally as contractors. The sustainability of the system, however, is open to question. Even though higher tariffs have been imposed, the water charges cannot fully finance the amounts needed for O&M. And with low collection rates, charges currently fall far short of costs. The reforms have not broken the vicious circle whereby many farmers will not pay for irrigation services because these services are poor; many others who do receive water do not pay either.

The farmers' committee structure (WUAs, distributary committees, and project committees) is intended to ensure equitable allocation of water but has limited capacity to do this effectively, especially at higher levels, as the structure is incomplete. The creation of WUAs and higher-level distributary committees has not yet been able to prevent the age-old problem of farmers in the head reaches of an irrigation system taking more water than intended, thus depriving farmers in the tail reaches. This problem might have been addressed by project committees, but they were never formed, so the management structure was left incomplete. None of the tail-reach villages covered by the IEG study has received irrigation water. Within villages, canal water is frequently diverted to an existing tank, so farmers drawing water from that tank, who have their own WUA, are the ones who benefit. Breaches of the canal to take water are also common, and again WUAs seem powerless to act. Thus far, most WUAs seem unable to break the existing pattern of social and political relationships affecting who can and cannot access resources. Indeed, WUAs can act as vehicles for elite capture of these resources.

This report therefore supports the conclusion of IEG's recent sector study of irrigation (IEG 2006b), which states that the Bank has been overly optimistic regarding what may be achieved through WUAs and has underestimated the need for continued government involvement. This finding applies to technical issues such as the design of rehabilitation works as well as to the ability to intervene in water disputes and—for the time being at least—to continue subsidization of system operation. WUAs are still establishing their roles, so they may yet fill their potential, but support will be required for this to succeed.

Lessons

Should the Bank avoid financing large irrigation schemes? This has been the trend, but to abandon an activity with a large poverty impact is to sidestep the issues involved rather than to resolve them. For areas where there is unexploited irrigation potential, there are still lessons to be learned about the need to undertake realistic appraisals to avoid financing projects that are not viable.

On selecting irrigation investments

Many previous lessons "learned" still remain to be learned:

- Construction delays undermine the economic viability of investments, so large-scale construction needs to be accompanied by special measures (such as those currently being adopted in Andhra Pradesh) to avoid delays and cost overruns.
- Unrealistic appraisal estimates increase the likelihood of poor investments.
- The method of risk assessment used in appraisals understates the actual risk that the project may not be viable.
- All benefits and costs need to be valued.

On PIM

- Support for bottom-up development needs a strong lead from the top.
- PIM may alleviate the problems of large-scale irrigation schemes, but it cannot eliminate them.
- WUAs have only limited means to effectively resolve water allocation disputes.
- PIM is not intrinsically pro-poor.

On the impact of irrigation

- Irrigation raises output through higher yields and cropping intensity and stabilizes production, all of which contribute to lower poverty. But irrigation investments constitute a sizeable subsidy to farmers who are not among the poorest or even the poor.
- The direct income benefits to farmers from obtaining irrigation provide the potential for full cost recovery of the recurrent costs of the services provided.
- Incentive structures, including water pricing policy, can encourage water wastage.

Chapter 1

Evaluation Highlights

- It is paradoxical that irrigation projects are uneconomical and have negative social and environmental consequence—yet have had strong effects on poverty reduction.
- Overcoming this paradox requires addressing the causes of construction delays and cost overruns and ensuring adequate operations and maintenance.
- Andhra Pradesh did this through legislating water user associations, but the approach faltered and in any case could not tackle all the problems in the system.


Man walking across irrigated field. Photo by Ray Witlin, courtesy of World Bank Photo Library.

Introduction

Irrigation has been a powerful force for poverty reduction and has eliminated the scourge of malnutrition for millions of people. Across the developing world, average daily calorie availability has risen from 1,930 to 2,670[1] over a 42-year period (1961–2003).

This improvement has been made possible by a 30 percent increase in per capita grain production as irrigated area increased 250 percent. In India, the expansion of irrigation and adoption of new crops (the Green Revolution) went hand in hand, with gross cropped area[2] increasing from 23 million to 90 million hectares (World Bank 1997, p. i.).

The Irrigation Paradox

Many studies show the link among irrigation, higher farm incomes, and substantial multiplier effects benefiting other rural residents. In India, poverty rates in irrigated districts are one-third what they are in districts without irrigation (World Bank 2005).[3] An analysis of poverty trends in 36 villages in Andhra Pradesh found that irrigation was the main explanatory factor for one-quarter of all households that had escaped poverty. In some areas, that figure was more than half (Krishna and others 2004). Poverty rates are lower, and social indicators higher, in the coastal regions of the state that have the most irrigation coverage and have benefited most from major irrigation schemes.

The Independent Evaluation Group's (IEG) recent review of the irrigation subsector identified five channels through which irrigation can reduce poverty: direct impact on income, including own consumption, of poor farmers; increased agricultural employment and wages; multiplier effects through irrigation-induced growth; lower food prices; and empowerment through increasing the assets of the poor and their access to decision making through community organizations (IEG 2006b).

Despite the apparent role that it could play in achieving the Millennium Development Goals, irrigation has fallen out of favor. For example, World Bank lending for irrigation peaked in the 1980s and has been falling since.[4] In India, lending fell from the mid-1980s, and the number of active projects has remained stagnant at around 10 in each year over the past several decades. Lending rose again after the mid-1990s, but with a focus on rehabilitation and institutional reform rather than on new construction.

Though irrigation has been a powerful force for poverty reduction, it has fallen from favor.

This shift in attitude was prompted by, among other things, inefficiencies within irrigation systems resulting from poor operations and maintenance (O&M). Inefficiencies such as cost overruns have meant that where ex post rates of return have been calculated, they frequently fall well short of 10 percent (Thakkar 1999).[5]

In India, for example, IEG rated 8 of 10 irrigation projects over the years 1991–95 unsatisfactory on outcome. All 10 suffered implementation delays and had economic returns well below the appraisal estimates. The problems included overly optimistic appraisals with unrealistic timeframes; poor project design, poor management, and bad contractors; rent seeking associated with large-scale public investment programs; and initiation of follow-up projects before addressing existing problems.

These problems persisted despite reform attempts that included the adoption of a more holistic approach called command area development (CAD). CAD sought to develop the command area below the project outlets and organized farmers' groups to take part in system management. These farmer's groups were the forerunners of the water user associations (WUAs) that feature in the Bank's current support for participatory irrigation management (PIM), usually with a view to eventual irrigation management transfer (IMT).

Irrigation also has potentially adverse social and environmental impacts.

Irrigation lending has also been criticized for adverse social and environmental impacts. Some irrigation projects have been associated with inadequate resettlement programs (IEG 1998). Falling groundwater levels and waterlogging, as well as increasing salinity, have been among the negative environmental impacts of irrigation projects, impacts that undermine the benefits of the schemes themselves. These problems are acknowledged in the opening paragraph of the Bank's 2004 water resources sector strategy, which states that "50 percent of the world's wetlands have disappeared in the past century . . . with water tables already deep and dropping every year, and some damaged permanently by salinization" (World Bank 2004a).

It may seem that there is an "irrigation paradox," in that an investment that has done so much to reduce poverty has come to have such a bad name. And within this paradox is another, which is that large-scale irrigation schemes (see box 1.1) have attracted the most criticism, even though they are precisely the schemes supporters say are needed to bring the benefits of irrigation to all those who need it.

Attempts to overcome the paradox have addressed the reform agenda in water resource management.

The World Bank attempted to overcome this paradox by changing its approach to irrigation. Its new approach was embodied in its 1993 water resources management policy, which addressed the negative environmental impacts and lack of sustainability that had become apparent. The new strategy called for an integrated approach to water resources management and for reforms to improve the relevance, effectiveness, and sustainability of operations in the main water subsectors.

A 1997 report described these problems in the Indian context (World Bank 1997). The emphasis on new construction had diverted attention from quality of construction and operations and maintenance (O&M). What funds there were for O&M were inadequate and mostly used for the salaries of government agents, but government irrigation departments were inefficient and unaccountable. Poor-quality irrigation systems set off a vicious cycle in which cost recovery was weak, as farmers were unwilling to contribute much for poor services. Further expansion of the system was constrained physically (many states exhausted their irrigation potential), environmentally (growing environmental problems limited productivity), and fiscally, with irrigation attracting a lower budget share. The proposed reform program encompassed IMT and PIM, privatization of O&M, raising private funds for new investments, and appropriate pricing of water and related inputs. The Bank argued that these far-reaching reforms could support a second revolution of agricultural growth through productivity enhancement; the potential from the resulting scenario was much greater than from continued area expansion.

IEG's evaluation of the 1993 strategy found it had continuing relevance but had been only partially implemented (IEG 2002). In the irrigation subsector, progress had been made with IMT, but little progress was made on cost recovery and virtually none on addressing other subsidies that encouraged excessive water consumption,[6] such as low rural electricity tariffs. In line with these findings, the 2004 Water Resources Sector Strategy (World Bank 2004a) reinforced these messages, promoting further reform while stressing the importance of water resources for poverty reduction and emphasizing the need for reforms to encourage efficiency in resource use. The strategy

Box 1.1: Irrigation: The Basics

Irrigation sources may be either surface water or groundwater. **Surface water irrigation** draws from natural rivers, artificial canals, or tanks. Canal irrigation is a treelike system consisting of a main canal and major branches called distributary canals, from which minor (or tertiary) canals spread to reach field canals (or channels).

A canal system is divided into reaches. The *head reach* is nearest the water source, and the *tail reach* is farthest from it; the *middle reach* is between the two. The whole area covered by the irrigation system is called the *command area*.

Dams are used throughout the system to control flow. The main canal uses a dam to divert river water from its usual course so it flows into the canal. A gate at the head of each distributary and minor canal is used to control the flow of water through the system. Long main canals may have additional dams along their length to control the water flow in the lower reaches. Tanks are "minidams," collecting water from various sources; that water is then distributed by a minor canal network. Pumping is not usually required using canal or tank water, as that water flows from the field channels straight into the fields.

In Andhra Pradesh, irrigation schemes are designated as major, medium, and minor and according to their command area. *Major schemes* are those larger than 10,000 hectares (ha), *medium schemes* are between 2,000 and 10,000 ha, and *minor schemes* are smaller than 2,000 ha.

Groundwater irrigation uses boreholes or tubewells to extract water from aquifers using pumps. Pumps are now usually electric or diesel operated.

The benefit of large-scale irrigation schemes is that they distribute water over a large area, so that individual areas are less reliant on local water availability. Rain-fed agriculture that does not use irrigation is most sensitive to variations in water supply because it depends on rainfall fluctuations. But locally based irrigation also depends on the local watershed, and wells may dry up if the groundwater level falls too low.

Irrigation involves complicated resource distribution issues. Capturing water for irrigation deprives users who have been accustomed to a more plentiful supply. For this reason, the construction of major irrigation schemes has become a source of dispute between states. Yet the presence of a canal or tank raises the groundwater level in surrounding areas through seepage. Indeed, in Andhra Pradesh some of the older tanks have been converted into percolation dams by blocking the outlets. (A *percolation dam* or *tank* is a structure to collect water that then filters into the soil, recharging the aquifer.)

The costs of irrigation are the cost of constructing the water structure, maintenance costs, and charges for water use. In India most of these costs have traditionally been borne by the government. Revenue is collected from users by the water cess, which is charged according to the area cultivated rather than the amount of water used.

added that more needed to be done to enhance the poverty impact of irrigation (World Bank 2004a).

The change in emphasis of Bank lending for irrigation may be the appropriate response to the "irrigation paradox." Indeed, there may be no paradox at all: irrigation achieved great benefits in the past, but now returns are falling as the scope of major productivity increases has been exhausted. This would suggest there is no longer scope for new investments. That is not entirely true, even in South Asia, and certainly not in Africa. So consideration of the impact of investing in new infrastructure remains relevant.

This IEG impact study looks at two Bank-supported irrigation projects: the Second and Third Andhra Pradesh Irrigation Projects—AP II (1988–96) and AP III (1996–2004). The goal of AP II was to develop a new command area along the Srisailam Right Bank Canal (SRBC) and to rehabilitate and extend the command of the Kakatiya Canal under the Sriramasagar Project (SRSP). However, because of various problems, the works envisaged under AP II were not completed, so AP III was implemented in the same areas.

The Andhra Pradesh Context

Andhra Pradesh has an extensive irrigation network, including infrastructure constructed with World Bank support (table 1.1), which suffered many of the problems outlined above. By the mid-1990s the state's irrigation sector was clearly in crisis. The actual area irrigated had begun to fall during the 1980s as lack of maintenance left many distributaries and minor canals unusable. By 1995, 1.54 million ha were irrigated by canals, less than 25 years earlier and more than 15 percent less than the peak reached in 1983. Under both major and minor schemes (see box 1.2 for definitions), the state has an irrigation gap—that is, a gap between the area for potential irrigation with the existing system and the area actually irrigated—of about 1.5 million ha.

Irrigation in Andhra Pradesh was in crisis by the mid-1990s.

The government of Andhra Pradesh produced a white paper in 1996 identifying a series of problems, including a decline in net irrigated area as a result of poor O&M, inefficient and inequitable water distribution, low yields, and low farm income. These problems were to be addressed by the Andhra Pradesh Farmers' Management of Irrigation Systems Act (APFMIS Act), passed by the Legislative Assembly in April 1997. Water charges were more than tripled in the same month[7] and more than 10,000 WUAs created. The posts in the WUAs were filled through statewide elections on a single day in June 1997. Only five months later, 174 distributary committees were created.[8] With the APFMIS Act and the subsequent creation of the WUAs, Andhra Pradesh was one of the leading areas in the world implementing PIM.

Sustainability problems in Andhra Pradesh were addressed through legislation creating WUAs.

An early Bank study showcased the experience (Oblitas and others 1999). The creation of so many WUAs and the staging of statewide elections was indeed quite an achievement. However, nearly half of the elections were uncontested, at least in part because the government offered an incentive of 15,000 rupees (Rs 15,000) to each WUA that unanimously elected all its committee members and president (Mollinga, Doraiswamy, and Engbersen 2001).

The philosophy of PIM was consistent with the *Janmabhoomi* program launched by the ruling Telegu Desam Party in 1997. *Janmabhoomi* was labeled by the state government as a "people-centered participatory development process" through which the chief minister wanted to transform the role of the government from service provider and regulator to facilitator. Under such a philosophy, the role of the Irrigation and Com-

Table 1.1: Bank-Supported Irrigation Projects in Andhra Pradesh

Project	Dates	Amount (US$ millions)	Command	ICR/PCR and PPAR rating[a]
Pochampad Irrigation	1971–79	41	Pochampad Dam and command, now called SRSP	n.a.
Godvari Barrages	1976–81	45	Barrage to replace weir for Godvari Estuary	n.a.
AP Irrigation and CAD Composite Project (AP I)	1976–85	136	Nagarjunasava Reservoir	n.a.
AP II	1988–94	118	SRBC and SRSP	ICR: Highly unsatisfactory PPAR: Highly unsatisfactory
AP III	1997–2004	272	SRBC and SRSP	ICR: Satisfactory
Economic Restructuring Project	1999–2006	142[b]	Support for reform and institutional development across the state	Project not yet closed

Source: IEG project database.

Note: AP = Andhra Pradesh; PCR = Project Completion Report; ICR = Implementation Completion Report; PPAR = Project Performance Assessment Report; n.a. = not applicable.

a. The Bank's ICR, formerly known as the PCR and the PPAR, is an independent review prepared by IEG. Ratings were not assigned in earlier projects.

b. Irrigation component only.

mand Area Development Department (I&CADD) would shift from management of the irrigation system to provision of technical support to WUAs. WUAs would now collect water charges, undertake O&M, and be responsible for management of the system—up to command level—through the three-tier structure of WUAs, distributary committees, and project committees. However, many observers saw a political motivation behind the creation of new structures at the grassroots level;[9] they provided an opportunity to build a power base for the Telegu Desam Party outside of the formal structure of village governments (the *Gram Panchayats*), which were dominated by the Congress Party.

However, changing political circumstances temporarily reduced the momentum of PIM. New WUA elections were not held on schedule when the terms of office of the WUA officers elected in 1997 expired; many WUAs became moribund until elections eventually took place in 2005–06.[10]

This momentum has been somewhat restored in the last two years. However, the new Congress Party government came to power on a platform of promoting agricultural development, central to which are new irrigation schemes. Unlike many other areas in India, Andhra Pradesh has reached only about half its irrigation potential. The latest five-year plan envisages substantial investments in new irrigation (appendix table D.1). But the Bank has been reluctant to commit to a substantial program without improved efficiency in the existing system. This evaluation thus feeds directly into the very relevant question of the viability of large-scale irrigation investments in Andhra Pradesh. Central to the study, therefore, are the underlying questions on the role of the Bank in promoting PIM and how the adoption of PIM improves the viability of irrigation investments.

Evaluation Questions

The study considers six questions:

- Do investments in irrigated agriculture increase production in Andhra Pradesh?
- What are the impacts of PIM on incomes and poverty alleviation, and who benefits?
- Is investment in major canal irrigation economical?
- Was the Bank's support for canal irrigation relevant and appropriate?
- Do WUAs facilitate greater participation by the poor and by disadvantaged groups in water management and access to irrigation?
- Are WUAs an effective means of providing sustainable O&M?

Box 1.2: Some Local Terminology

Caste: Castes are hereditary social groups, the members of which were traditionally restricted in the activities they could perform. The 1950 constitution of a newly independent India included a schedule of castes and tribes thought to be the most disadvantaged—hence the name scheduled tribes and castes—who benefited from reservation of certain positions, including members of Parliament, where they alone were allowed to stand. The 1980 Mandal Commission proposed to extend reservation to other backward castes, that is, group less well off than the remaining other castes, though not as underprivileged as the scheduled tribes and castes. These recommendations were implemented, against considerable protests, in 1990.

Mandals: Each state is divided into districts and each district further divided into subdistricts, which in Andhra Pradesh are called mandals. Andhra Pradesh has 18 districts and 786 mandals.

Rain and Cropping Season: There are two main cropping seasons in Andhra Pradesh: *kharif*, for which planting is immediately after the monsoon in July/August, and *rabi*, in the first months of the year. Rain-fed areas have only a *kharif* season, whereas those with irrigation may plant in *rabi* and possibly a third, summer, season. Alternatively, some crops can be cultivated twice a year but do not fall within a specific season.

Study Approach and Overview

The study uses a quasi-experimental design, as did IEG's recent impact evaluations (IEG 2006b, 2005, 2004, 2000). Undertaking an impact study for a project that had closed and for which there were no baseline data was a challenge.[11] But although the SRBC project closed in 2004, many farmers were still not connected to water in the new command area. The IEG team was informed that approximately 44,000 ha of the SRBC command would be irrigated by the 2005 *kharif* season, with another 21,000 ha to be connected

Andhra Pradesh still has irrigation potential, but the Bank has drawn attention to the need to address efficiency.

Box 1.3: The IEG Survey

The IEG survey consisted of two rounds: one in June 2005 and the second in March 2006. The first round, just before the 2005 *kharif* season started, asked questions about production in three preceding seasons (2004 *kharif* and 2004–05 *rabi* and summer 2005). The second survey asked about the three subsequent seasons: *kharif* in 2005, *rabi* in 2005–06, and expectations regarding summer 2006. Fifty households were surveyed in 18 villages, making a total sample size of 900 households. The same households were interviewed in both rounds. A village questionnaire and a questionnaire for the WUA chairman were included. A separate qualitative study team was fielded in six villages in March 2006.

Data were collected on income, farm budgets, irrigation, and various aspects of social and political life in the village.

The analysis presented in this report uses data from a number of sources—both primary and secondary—in addition to the IEG survey.

the following year. This phasing-in of irrigation suited IEG's sample design, which was based on the "pipeline approach" of selecting control areas to be treated that were as yet untreated (see appendix A).[12]

The Andhra Pradesh projects offered an opportunity for a before-and-after impact analysis.

The first round of the survey, carried out in June 2005 (see box 1.3), would in effect be a baseline for areas to be irrigated (treated) for the first time in the month immediately after the survey. The second round of the survey, in March 2006, would capture the impact of the first two cropping seasons (*kharif* and *rabi*) for these newly irrigated areas. Unfortunately for both the study and the farmers, the Irrigation Department's figures were something of an exaggeration (see chapter 2). A far smaller area of the SRBC command had been irrigated—and this by test waters—and the full command was only due to be completed by mid-2007. The lack of irrigation under the SRBC command made it unsuitable for the survey; indeed, it means that impact estimates for the SRBC command cannot be based on actual data.

The survey was carried out in the Warangal district, toward the tail reaches of the SRSP command below Lower Manair Dam.[13] This system had been both rehabilitated and extended under AP II and AP III. But five years of drought meant that in the 2004–05 season no water was released in the SRSP canal for the first time since it had opened. Groundwater levels were low so that other irrigation sources were also yielding less than in previous years.

In contrast, rainfall from the monsoon season of 2005–06 was very good. The survey provides ample evidence of how the rains improved agricultural performance and reduced poverty. But these factors do make it more of a challenge to identify the impact of the irrigation projects. This difficulty is compounded by the lack of measurement of water releases below the head of the distributary canal (and even these data are not compiled centrally), so there are no accurate means of measuring water use. For evaluators, the disruption of canal water supplies in 2004–05 provides a "natural experiment,"[14] whereby a before-versus-after comparison (in fact, after versus before) of normally irrigated areas can provide additional indicators of irrigation impact.

The use of data from two survey rounds allows for double-difference estimates of project impact to be made, that is, impact calculated as the change in outcome in the project area less the change in outcome in the comparison group (see appendix C). Many households received canal water through recharging of the village tanks. Hence, project beneficiaries are identified as those using both canal and tank waters.

Comparisons between beneficiaries and nonbeneficiaries were made at three levels: plot, household, and village. For the plot and household comparisons, comparisons were made between those who had newly acquired canal or tank irrigation between the two rounds of the survey and those who had not. Those who had not made up two separate comparison groups: those who had no irrigation at all in 2005 or 2006 and those who continued to use the same source. The former is the more appropriate control and is best compared with the subsample of the treatment group that had no irrigation in 2005. However, the sample size does not always permit this comparison. The comparisons of village-level averages compare villages that received canal irrigation for the first time between the two surveys with villages that have no access to canal irrigation.[15]

The sample for IEG's survey was selected to facilitate examination of the impact of new irrigation. But the surveyed area is clearly not representative of the project area as a whole; the area below Lower Manair Dam is notably different in cropping patterns because of a relative continued water scarcity. Therefore, the impact analysis in this report is based on a number of different sources, such as the AP III baseline data, various data from the government of Andhra Pradesh, and the figures used by World Bank operational staff in the completion report for AP III.

Overview of the Report

Chapter 2 describes the two projects studied: AP II and AP III. The following two chapters discuss the workings of WUAs (chapter 3) and the economic impact of the project (chapter 4). Chapter 5 lists lessons learned.

Chapter 2

Evaluation Highlights

- AP II suffered from a faulty and incomplete appraisal and failed.
- AP III aimed to complete the work started by AP II.
- AP III adopted a participatory process that relied on WUAs for irrigation management.
- The works supported by the project expanded the area under irrigation, but many farmers have yet to receive water, nearly 20 years after construction started.
- Despite improved service, water allocation issues still exist; for example, irrigation water often does not reach tail-enders.

Indian women working in cotton field. Photo by Ray Witlin, courtesy of World Bank Photo Library.

The Projects

AP II started in 1988 and was the fourth Bank-supported irrigation project in Andhra Pradesh (see table 1.1). With the objective of increasing agricultural production and farm incomes, AP II was to bring irrigation to two poor, drought-prone areas through two subcomponents.

Second Andhra Pradesh Irrigation Project

First, SRSP was a renovation and extension of the system, with modernization of 165,000 hectares (ha) in the command area already supported by the Bank under the Pochampad Irrigation Project (1971– 79). A further 163,000 ha were to be developed below the Lower Manair Dam, located at kilometer (km) 146 on the Katakiya canal. Second, the SBRC irrigation scheme involved constructing a main canal 143 km long with a capacity of 750 cubic feet per second, with block development to irrigate an area of about 65,000 ha.

These main canal works were to be supplemented by supporting activities, such as the provision of training facilities and training of professional and support staff required for project implementation, training of farmers, resettlement activities, and construction of feeder roads.

In accordance with the project objectives, the principal project benefits expected were higher agricultural value and farm employment. However, these benefits were not realized because the project ran into serious construction problems. There were both substantial cost overruns (of 326 percent for SRSP and 175 percent for SRBC) and delays in carrying out work. Although some major construction was implemented, or at least partly implemented, no contiguous portion of new or rehabilitated canal or command area was completed before the project closed. Just over one-third (38 percent) of the planned civil works were completed in the SRBC command, and only about one-fifth (21 percent) of those planned in SRSP were completed. Thus, no irrigation—either modernized or new—was provided under AP II.

AP II ran into severe construction problems and failed.

The project's failure can be attributed to problems in both design and implementation. The design underestimated costs, notably for the amount of hard rock excavation that was required to construct the SRBC main canal. The problem was made worse by government-estimated unit costs (used in the project cost estimates) that were well below the market values for such works. The selection of contractors was poorly done, and they performed badly, exacerbating the cost overruns. Project documents also speak of "rent seeking" associated with construction activities, although no direct evidence is provided.[1]

Project design also took inadequate account of two issues. The first was the difficulty of acquiring land. Second, because water supply was limited, the state government's policy was that all new surface irrigation projects in the two regions would be designed and operated to satisfy the requirements of irrigated dry crops, requiring an enforced change in the cropping pattern because of reduced water allocation (a policy known as localization, which dated from colonial times). Specifically, under AP II, water would be required to fill Lower Manair Dam to provide irrigation in the newly developed areas below the dam. This water previously had been available to farmers in the SRSP command above Lower Manair Dam, so those farmers were accustomed to irrigated wet agriculture, notably paddy, which is the preferred crop in the region.

Costs were underestimated and the difficulty of acquiring land and of achieving a change in cropping patterns was neglected.

However, attempts to force changes in cropping patterns have a poor record in Andhra Pradesh, including the failure of this policy in an area adjacent to SRBC in the first irrigation scheme in Andhra Pradesh. These difficulties were a manifestation of a problem well entrenched in Indian irrigation. Schemes are designed with the widest possible coverage, partly to help ensure food security and partly for political reasons. But the system design is overly optimistic, not taking account of likely cropping patterns and actual system losses. Hence, there is insufficient water for all users. In the absence of allocation through pricing, the result is head-enders taking more water and tail-enders going without.[2] There has been conflict at times.

Overall, the Bank's preproject assessment of AP II was severely flawed: the Bank accepted the government's inaccurate cost estimates and a design the Bank itself later questioned. Moreover, the Bank also accepted projections of the area to be covered, future yields, and crop mix, all of which proved optimistic—a situation that should have been expected given earlier experience.[3]

Substantial problems were also caused by the Bank's management of the project. Design changes were required after the first contracts had been issued. It took time to come up with the revised designs, but the Bank then commissioned studies that supported the original design. There was a protracted dispute over the sufficiency of the water allocation for SRBC, during which the Bank informally suspended the credit. Finally, lack of familiarity with Bank procedures among government officials slowed procurement.

AP III was undertaken to complete the unfinished work of AP II.

With slow progress, the Bank cancelled $145 million of its $271 million contribution to the project. However, there was agreement that a new project (AP III) would support completion of the works.

Third Andhra Pradesh Irrigation Project

The overall objective of AP III (1996–2004) was to complete the irrigation development and rehabilitation work begun under the previous project and thus realize the potential for increasing agricultural productivity and rural incomes in two economically backward regions of Andhra Pradesh. This was to be achieved through a number of activities.

The project was scaled back, with the following elements dropped: irrigation development and rehabilitation works (80 percent of cost) for completion of the irrigation network and feeder roads of the 65,000-ha SRBC irrigation project; rehabilitation of 253,000 ha of the SRSP scheme's irrigation system, of which 88,000 ha were below Lower Manair Dam, up to km 234; and extension of the canal beyond km 234.

Agricultural support services (2.5 percent of cost) would foster agricultural diversification and productivity through irrigation agronomy research and improved command area extension services, and improve irrigation services by PIM through the establishment of WUAs. This component had three subcomponents: (i) an irrigation agronomy program, (ii) a WUA promotion program, and (iii) a farmer training program. Support to WUAs in the SRSP command was, for the Bank, piloting an approach that was to be expanded statewide in the irrigation component of the Andhra Pradesh Economic Restructuring Project.[4] Activities supported under AP III were expected to serve as a model for the rest of the state with respect to aspects such as collection of water charges.

The project also included a resettlement and rehabilitation program (5 percent of cost), an environmental management plan (7.5 percent of cost), and dam rehabilitation and safety assurance works (5 percent of cost).

Project Implementation

SRSP

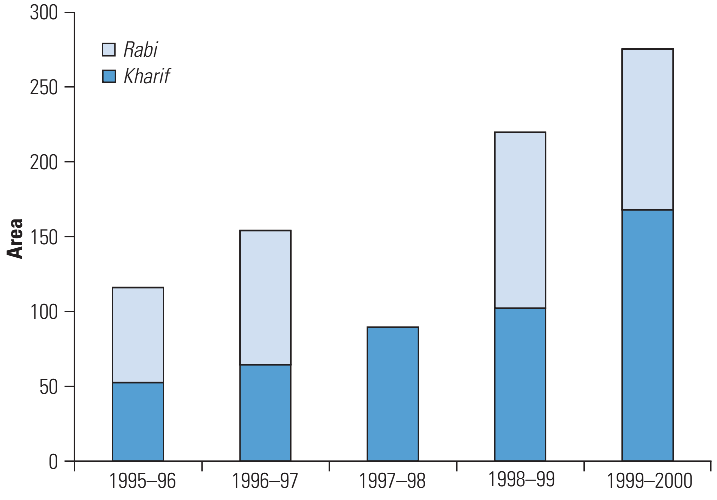
The rehabilitation works for SRSP were completed. This resulted in an increase in the carrying capacity of the main canal and the command irrigated area of 115,000 ha from 1995–99 (figure 2.1); by 2005, the area irrigated above Lower Manair Dam had reached the target of 165,000 ha. Rehabilitation works above Lower Manair Dam have enabled water to flow for a greater distance down distributaries and minor canals, so that more areas get water. Actual irrigation in the SRSP command as a percentage of that planned rose from an average of 50 percent in 1995–96 to nearly 90 percent five years later (appendix table D.2). The works below Lower Manair Dam have been completed, with the most recent data showing an irrigated area of 90,000 ha, slightly above the 88,000 ha expected at appraisal.[5]

However, it is likely that the additional irrigated area is in fact short of that expected under AP III. The figures reported here are for the area I&CADD *believes* will be irrigated, which overestimates the actual area irrigated. Revenue Department estimates of irrigated area are typically 40 percent lower than those of I&CADD (Jairath 2000).[6] Although Revenue Department estimates may be biased downward,[7] I&CADD figures are likely to overestimate the area by at least 20 percent. The actual area covered is invariably less than the potential reported, owing to the failure of water to reach tail-enders because of system losses (a well-known problem, confirmed by the field work for this study) and excess use by farmers in higher reaches.[8]

Excess use in higher reaches is discussed later in this report. Regarding system losses, the "baseline" survey found the water flow in the main canal to be 90 percent of capacity on average, ranging from 100 percent in higher reaches to 76 percent toward the tail end. The average capacity of the distributaries is less. The failure to realize full capacity results from buildup of silt, land slippages around cuttings and embankments, and damaged linings. These data were collected shortly after the completion of the rehabilitation financed by AP III, so the situation is likely to have worsened since then.

Nonetheless, the greater carrying capacity of the main canal has made possible the expansion of the command area; under SRSP Stage II, the state government is extending the main canal a further 62 km, the distributaries of which will eventually irrigate 440,000 ha. In the areas covered by IEG's survey, which included the newly irrigated areas between km 234 and km 284 of the main canal, the area irrigated by canal or tank doubled from 13 percent of all cultivated land in 2004–05 to 26 percent in 2005–06 (figure 2.2; see also appendix table D.3).

Figure 2.1: Irrigated Area in SRSP (000s of ha)



Source: SRSP baseline.

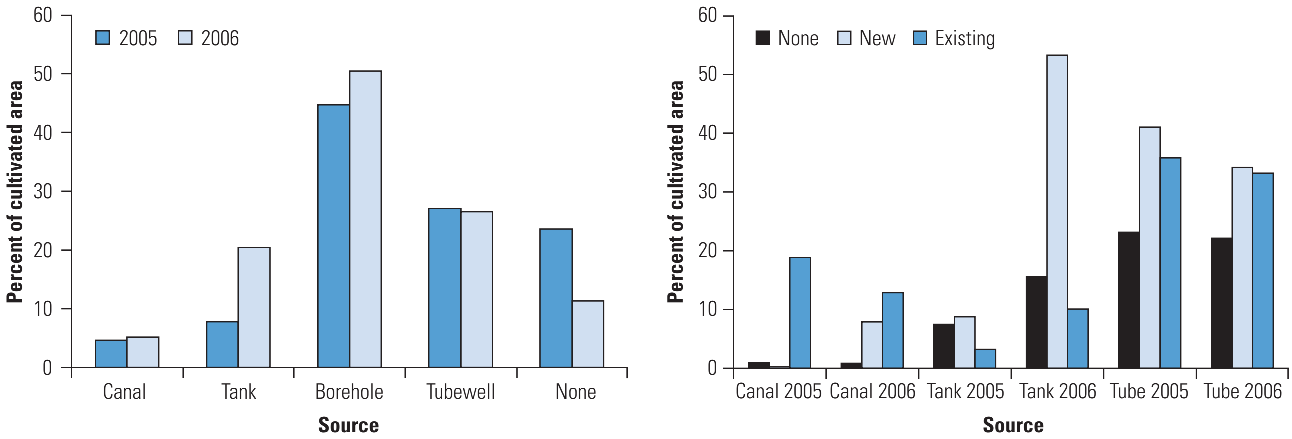
Notes: No water was released in rabi 1997–98. ha = hectares; SRSP = Sriramasager Project.

The rehabilitated works for SRSP successfully increased the irrigated area.

The bulk of this increase is from tanks. This is partly because tanks are quickly recharged by good rains, such as occurred in the monsoon between the two survey rounds. But it is also because in the majority of the surveyed villages, the canal water is fed into the tank and distributed via the tank's minor irrigation system. This practice is very evident in those villages newly connected to the canal system between the two rounds: the percentage of cultivated area receiving water from a tank jumped from 9 to 53 percent, compared with 0 to 8 percent receiving water directly from the canal. South India has a well-developed

The area covered may still be below what was expected because of flawed estimates.

Figure 2.2: Irrigation Sources, 2005 and 2006



Source: Appendix table D.2.

system of tank irrigation, with some tanks dating back centuries; existing tanks are sometimes incorporated into the canal system. However, as discussed below, the storage of canal water in tanks has implications for water allocation and thus can be contentious.

SRBC

In SRBC, although the main canals and distributaries were completed, the minor works were only about 20 percent complete as of June 2005, one year after the project closed. The state government is completing the works with its own funds, estimating that the works will be finished by 2007. In 2005, some test water had been released, and farmers had breached the main canal to irrigate their fields. Officially, only 7,880 ha had been irrigated, compared with the planned amount of 65,000 ha.

Delays in the completion of SRBC have undermined project viability.

As noted in chapter 1, the IEG study originally intended to undertake a survey in the SRBC command based on information from I&CADD (also given in the Bank's Implementation Completion Report), that 44,000 ha had already been irrigated. This study found that the 44,000 ha refers to irrigation from all sources. Counting all irrigation in the command area, whether sourced by the canal or not, is apparently common practice (Jairath 2000) and contributes to the overestimation of irrigated area and consequent overestimation of benefits and underestimation of the true per hectare costs of irrigation through major irrigation schemes.[9]

These delays seriously affect the project's viability, even if it eventually reaches its full potential. The Bank's Staff Appraisal Report (SAR) estimated the economic rate of return (ERR) for the SRBC subcomponent to be 13.7 percent. Assuming the benefits are as stated in the SAR but subject to the delays that have in fact taken place, this return drops to 4.1 percent and becomes negative (–1.0 percent) once the original investment costs under AP II are taken into account.[10]

Summary

The AP II project was to newly irrigate 65,000 ha under SRBC and 163,000 ha under SRSP, as well as to modernize the system serving a further 165,000 ha under SRSP. However, problems in implementation meant that no works were finished, so no farmers received irrigation as a result of the project. With positive costs and zero benefits, the rate of return to the project is negative infinity.

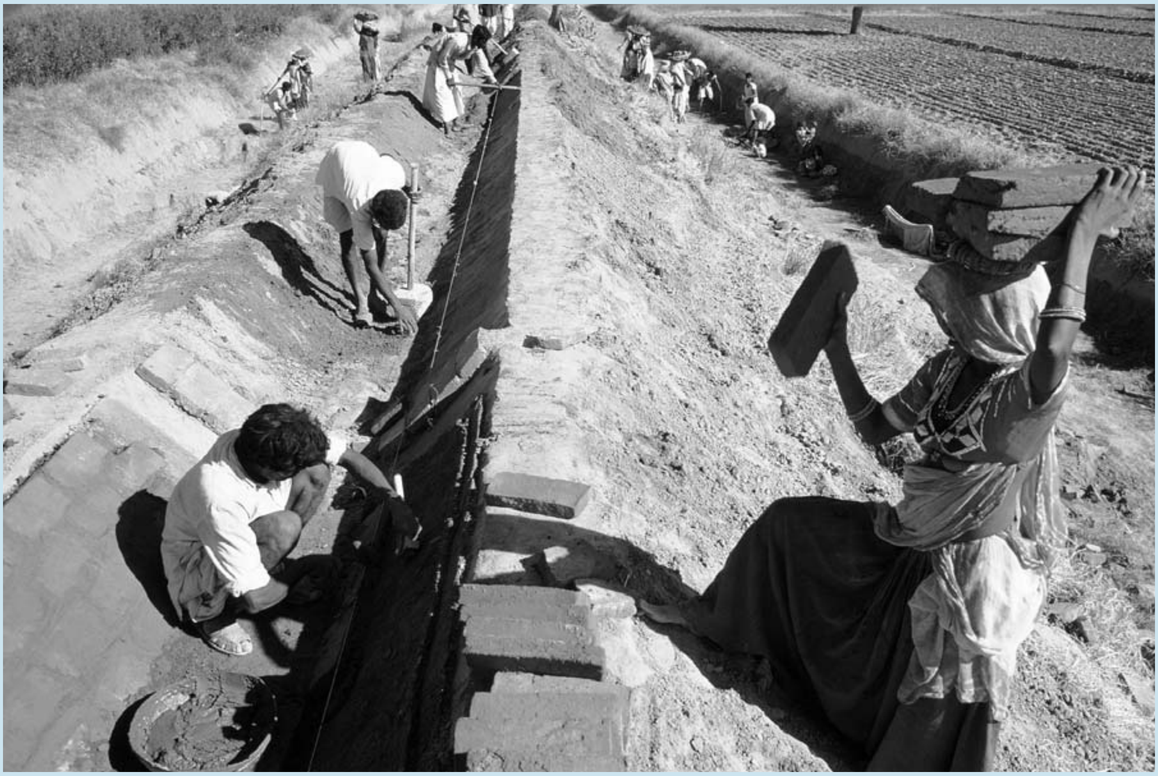
AP III was to complete the works started by AP II. At the time of this study, the bulk of the connections in the SRBC command had yet to be made. They are currently expected to be completed by June 2007, nearly 20 years after the work started.[11] Such serious delays, which pervade irrigation investments across India and elsewhere,[12] seriously undermine the viability of the investment in the SRBC command, which will be negative even if all intended benefits are eventually realized.

Progress has been made in AP III, where the increased carrying capacity of the main canal has made possible a further extension of the system. However, the areas irrigated have not reached those planned at appraisal, and, even immediately after rehabilitation, actual water flow in the main canal was 90 percent of capacity (and less in the distributaries) as a result of siltation, land slippages, and damaged linings.

Chapter 3

Evaluation Highlights

- PIM is classified as pro-poor because it involves the poor in irrigation management and raises agricultural incomes and employment.
- Both membership and leadership of WUAs are biased toward those who are better off.
- The design of the irrigation system and management by the WUAs have in some cases adversely affected water distribution.
- Only a small percentage of non-WUA members believe water is fairly distributed.
- The reforms have not ended the cycle of poor irrigation services and unwillingness to pay for O&M.



Building a canal for irrigation in India. Photo by Ray Witlin, courtesy of World Bank Photo Library.

Water User Associations

User management of irrigation is not a new idea. Indeed, users traditionally have managed their own water resources through indigenous institutions.[1] However, the growth of large-scale schemes financed by the government shifted management responsibilities to the irrigation bureaucracy.

Origins of PIM in Andhra Pradesh

A first attempt to change this in India came in 1973 with the initiation of CAD, which relied on farmers' organizations for water management and O&M below the distributary level. During the 1970s and 1980s, the Indian government promoted CAD across India, with Bank support, through the National Water Management Program. As today, Andhra Pradesh was a leading state in those reforms, with the former commissioner for SRSP successfully lobbying for the creation of a separate CAD Department and becoming its secretary for its first seven years (Sivamohan and Scott 2005).

These early experiences offer two lessons. First, in Andhra Pradesh, more than 3,000 farmers' organizations were formed by 1981; they soon disbanded, because of insufficient funding and an inability to solve water distribution issues. The same problems affect WUAs today.

Second, most reforms are based on earlier policy changes, which often lay the foundation for later, more far-reaching, changes. Indeed, despite the failure of the farmer group aspect of CAD, lobbying for the approach continued, leading to the promotion of WUAs since 1997.

The Current Wave of PIM

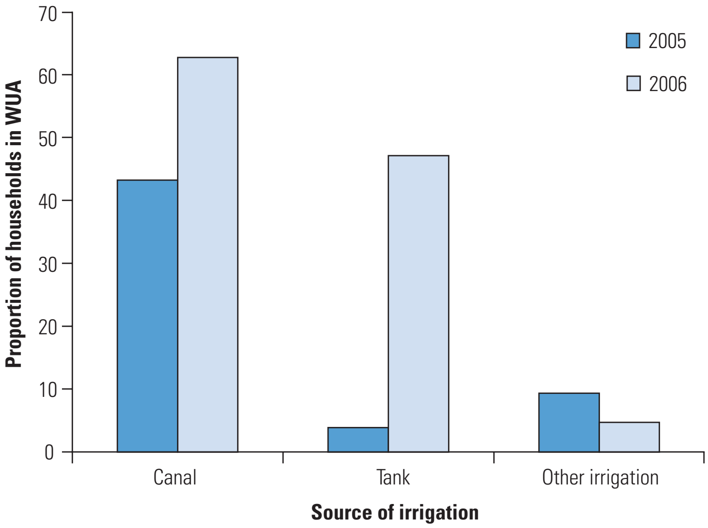
The World Bank supported the promotion of WUAs through AP III and then across the state through the Andhra Pradesh Economic Restructuring Project (APERP), which included training in PIM for WUA and government officials. More than 10,000 WUAs were created following the passage of the APFMIS Act, which devolved powers for system management from I&CADD to farmers.

Specifically, farmers were to assist in collecting water fees and would receive 90 percent of the funds collected to undertake O&M.[2] WUAs were also to determine local water distribution through the *warabandi* statement (a schedule of water releases). In principle, farmers were to control water releases throughout the system through the three-part committee structure (WUA, distributary committee, and project committee), but this has not happened.

A 1997 act devolved irrigation system management to farmers.

The reforms were not without opponents. Although there was strong support from the top of both the state government and I&CADD, lower levels of the bureaucracy were opposed—one reason project committees have not yet been created. Under the changes, the lower-level officials known as *lascars* ("gate keepers"), each of whom is responsible for canal operation and water management across an area of approximately 800 ha, were to become accountable to the WUAs. This proposal was challenged in the courts by 3,500 *lascars* across the state (Raju 2001). Although efforts were made to build cross-party support, the opposition accused the government of deferring to

Figure 3.1: Households Accessing Canal and Tank Irrigation Systems Most Likely to Be in a WUA



Source: IEG survey.

donor agencies by accepting the conditions of the World Bank, which included the promotion of PIM (Sivamohan and Scott 2005).[3]

This move was expected to increase system efficiency. Many supporters of PIM also claim that it makes irrigation more equitable, ensuring a greater spread of benefits to the poor—though that was not an explicit objective in either of the two projects under review.[4] PIM is claimed to be pro-poor for two reasons. First, the involvement of the poor in irrigation management through WUAs ensures that irrigation benefits are not captured solely by those who are better off. Second, the improved functioning of the irrigation system under PIM results in higher agricultural income and employment. This chapter reviews the state of WUAs nearly a decade after their creation by the APFMIS Act.

Only 10 percent of cultivating households were members of WUAs.

WUA Membership

According to the Act, all water users are members of the WUA; "water users" are defined as those using water from a government or Andhra Pradesh Water Corporation source.[5] The Act states that cultivating households using such water for *any* purpose, not just agriculture, are to be members. However, when asked in June 2005 if they or anyone in the household was a WUA member, just 10 percent of respondents in cultivating households replied positively.

This low rate is explained by two factors. First, although virtually all plots are irrigated in one way or another,[6] a minority use canals and tanks for irrigation. Membership in WUAs is notably higher among the latter: in 2006, half of such households were in WUAs, compared with less than 10 percent of households using other forms of irrigation (figure 3.1). Second, many WUAs had ceased to function because political problems had delayed new elections[7] and because the lack of water meant that whether the WUA functioned may be thought irrelevant.[8] But new elections were held in some villages between the survey rounds, and water was released along the length of the SRSP command in July–August 2005. By March 2006 the proportion of cultivating households claiming WUA membership had risen to 19 percent.

The second factor behind low participation rates is that, although all households using the water resources are meant to be members, households using canal or tank irrigation are most likely to join a WUA. The bulk of the increase in membership has come from tank WUAs, reflecting the fact that tank irrigation has been revitalized as heavy rain and canal water have recharged tanks in the survey area.

The fact that not all farm households participate in WUAs raises questions about the pattern of participation. Claims that WUAs ensure the participation of the poor in irrigation management must first carry the caveat that the landless, who make up the bulk of the poorest, are excluded. This practice contrasts with the approach adopted in the Andhra Pradesh Rural Livelihoods Project, supported by the U.K. Department for International Development. In the Rural Livelihoods Project, receipt of funds for watershed development activities is conditional on first implementing schemes to benefit the landless and marginal farmers. Moreover, in principle, these latter groups are meant to lead the watershed planning process, though this rarely happens in practice.

Alternatively, as has happened in other countries, irrigation projects may include subprojects, such as fish ponds, that allow the landless to indirectly benefit from irrigation. Finally, tradable water rights can be allocated to all households in the catchment area—strategies to develop this approach are part of the Bank's most recent guidelines for lending to the irrigation sector in India.

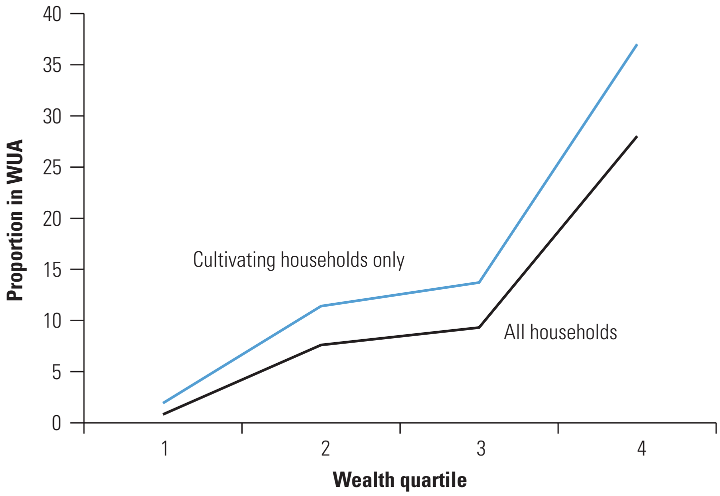
But the bias against the poorest is only partly a result of the exclusion of the landless. Figure 3.2 shows the proportion of each wealth quartile that holds membership in a WUA.[9] Less than 1 percent of households in the poorest quartile hold WUA membership, compared with 28 percent of the top quartile. Restricting the sample to households involved in cultivation reduces the bias, but not by much: only 1 in 50 poor households engaged in cultivation is in a WUA, compared with more than 1 in 3 of the better-off households.

Despite the apparent neutrality of the Act with respect to caste, landholding, and so forth, there are also biases in the pattern with respect to other classifications (appendix table D.4). These biases are more marked if all households are considered rather than just farm households, but they are still present among the latter. Those households with no education are least likely to be in a WUA. Large landowners are most likely to be members, though marginal farmers are more likely to join than small farmers (figure 3.3). Households from the top castes are most likely to be in WUAs and those from scheduled tribes least likely.[10] Using multivariate analysis, the most robust determinants of WUA membership are wealth and education (appendix table B.1).

Two factors explain the biases noted. Ownership of land with access to canal and tank irrigation is more heavily concentrated among the better off than is overall land ownership (figure 3.4).[11] In 2006, the Gini coefficient for overall land ownership was 0.34, but it was 0.45 for ownership of land with access to canal or tank irrigation (appendix tables D.4 and D.5). The second reason behind the bias is that WUAs operate within the existing social context, influencing participation in ways that often benefit those who are better off. Such findings are hardly surprising because they are a well-documented aspect of rural development programs in India. The surprise is that more

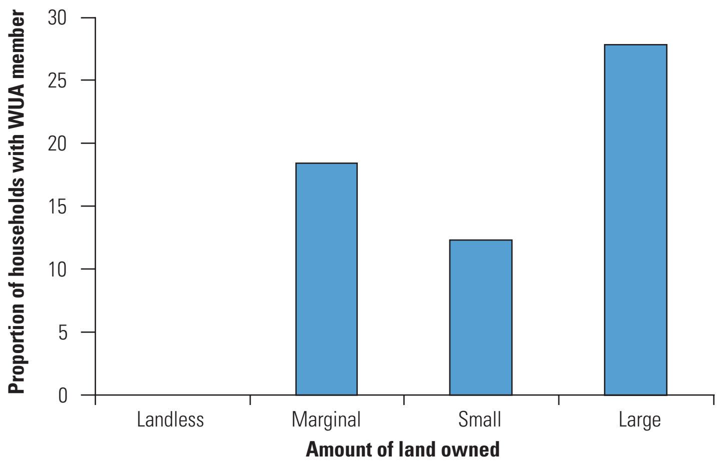
WUAs exclude the poorest from decision making because most of them are landless.

Figure 3.2: Likelihood of WUA Membership Increases Sharply with Wealth



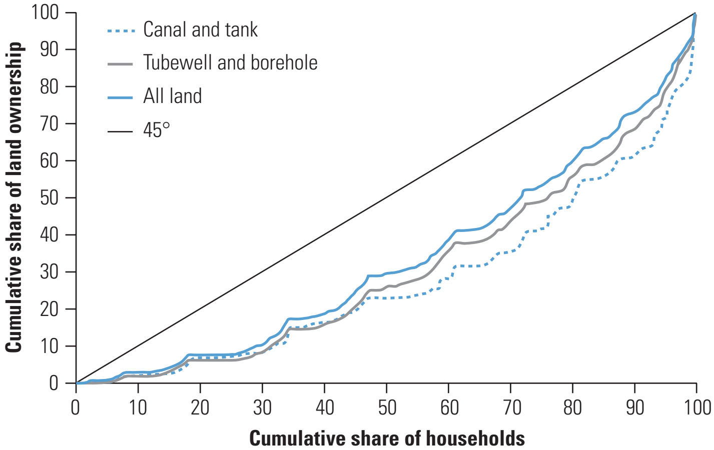
Source: IEG survey.

Figure 3.3: Large Landowners Most Likely to Be WUA Members; Marginal Farmers also Active



Source: IEG survey.

Figure 3.4: Lorenz Curve for Land Ownership by Irrigation Source



Source: IEG survey.

Note: Households are ranked by a wealth index.

It is not surprising that the better off are more involved, but it is surprising that the projects did so little to address the issue.

was not done to address these known biases. A better understanding of the social context in which WUAs operate would help inform policy so that the objectives of reform are achieved.

What Do WUAs Do and Who Does It?

The APFMIS Act gives WUAs wide-ranging powers, as they are intended to manage the irrigation systems.[12] However, large parts of these powers have not been realized, with the Irrigation Department retaining functions intended to be devolved to the WUAs. For example, the WUAs are not involved in revenue collection. Furthermore, funds allocated to WUAs, financed by APERP, were used on renovation works, with little or none being used on group development activities.

The Irrigation Department retains control of sanctioning works supposedly under the control of WUAs; the availability of rents in the contracting process (Wade 1988), as well as bureaucratic inertia, limit chances that the Irrigation Department will give up its own power unless there is a major political push from the top—an opportunity that was lost once the momentum behind the reforms faltered. The failure to establish the project committees reflects this unwillingness to relinquish control.

Water allocation

WUAs do have a role in water allocation at the local level, a process that is frequently marked by rivalry, both within and between communities. In a majority of the communities covered by the IEG survey, most of the irrigation water from the canal is being channeled into tanks. Tanks have been important in irrigation in South Asia for centuries, and incorporating them into the canal system is a sensible use of existing water distribution channels. Tanks are also included in the system as balancing reservoirs (that is, to store water until it is time for release).

However, evidence from IEG's field work shows that storing water in tanks can adversely affect water distribution. The practice excludes farmers outside the tank irrigation scheme and sometimes prevents water from reaching those farther down the canal (see box 3.1): 3 of the 16 villages surveyed are in the tail reaches of their respective distributaries—none of these villages is receiving canal water. Another village is not receiving canal water because the Irrigation Department is opposed to farmers' requests to direct the water to the village tank.[13] Those farmers not participating in WUAs—those who are not among the better off—are most likely those excluded from benefits, including the half of canal and tank users who do not participate in WUA activities.

Participation and management

Virtually all WUA members participated in WUA elections, although this is a minority of those eligible to vote, because many eligible households do not participate in the WUA (table 3.1). One-third of members regularly take part in meetings;[14] somewhat more have participated in O&M. A smaller number, approximately 17 percent, say they take part in WUA decision making or believe they influence water management. This translates into just 3 percent of cultivators feeling that they have a say.

Participation in these various activities is not uniform across members, but varies according to the same biases that affect membership. With respect to attending meetings, either at all or regularly, the multivariate analysis found that the uneducated are least likely to participate (appendix table B.2). When it comes to taking part in decisions or influencing water management, the wealth variables are significant; indeed, no one in the bottom quartile replied positively with respect to either of these questions (appendix table D.7). For voting, as this is near universal, there are no significant biases among members; again, members are the minority.

Differential influence is reflected in the pattern of WUA leadership, which is dominated by the better off. In a survey of 222 WUAs in 22 districts, 88 percent of leaders of canal system WUAs were from higher castes and 11 percent from backward castes; just 1 percent were from scheduled tribes or scheduled castes. Large landowners accounted for 88 percent of canal WUA presidents.

Elite domination is less marked for tank systems but still present: 86 percent of presidents are from higher castes or backward castes and 56 percent are large landowners (Reddy and Reddy 2005). Membership in the WUA committee is more representative (for example, ORG 2005), but in many cases the president runs the WUA with little consultation: in a survey of 214 WUAs, the majority was not meeting regularly (ORG 2005).[15]

Irrigation Department officials say that canal design is determined technically and so cannot be subject to political interference. Design of the micro-network ideally is done in consultation with local communities, but this is not what happens in practice. Indeed, in one IEG study village, politically well-connected families are not among those who will benefit and are mobilizing people against the completion of the canal and obstructing land sales. Nonetheless, there is substantial scope for extracting more water than envisaged in the system's design.

The impact of WUA management on water allocation was captured in a question that asked if the respondent believed water to be fairly distributed within the community. Only 15 percent of non-WUA members believe that water is fairly distributed, compared with 55 percent of members, suggesting that WUA members are able to enjoy better access than nonmembers. In a multivariate analysis of the response, only one socioeconomic characteristic is significant: the larger a person's landholding is, the more likely he or she is to believe that water is fairly distributed (figure 3.5; regression results in appendix table B.3).[16]

The finding that WUA members are significantly more likely to say that water is fairly distributed than nonmembers is robust. In contrast, the presence of an active WUA in the village (measured by the village-level WUA membership rate) has at best no impact on perceived fairness. In some model specifications it increases the likelihood that

Box 3.1: Diversion of Water to Tanks Limits the Number of Beneficiaries

In one village in Warangal district, the canal water is diverted to a tank, depriving two other villages farther down the canal of water. This has caused clashes between the villages.

In another village, the canal water flows into five tanks, each of which has a functioning WUA. There is also a canal WUA, but it is not operational.

Sources: IEG field visits.

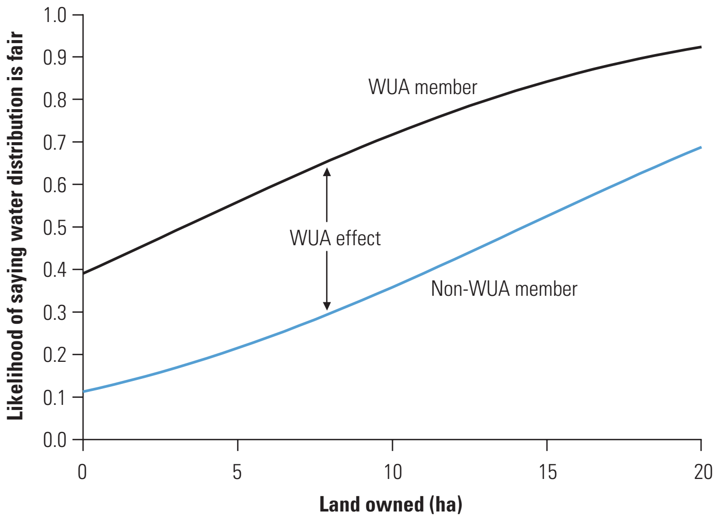
Because much of the irrigation water is stored in tanks managed by WUAs, water distribution has been adversely affected.

Table 3.1: Participation in WUA Activities, 2006 (percent)

	All cultivating households	Households with access to canal or tank irrigation	WUA members only
Attend meeting	10.8	30.2	58.3
Attend at least six meetings a year	5.8	15.1	31.0
Participate in O&M	7.3	20.5	39.0
Take part in decision making	3.3	9.1	16.8
Influence water management	3.1	9.4	17.6
Voted for WUA president	17.9	49.0	96.1
Voted for committee chair	17.1	46.5	91.7
Number	557	150	99

Source: IEG survey.

Figure 3.5: Larger Landholders More Likely to Think Water Is Fairly Distributed, as Are WUA Members



Source:

Only 15 percent of non-WUA members believe water is fairly distributed, compared with 55 percent of members.

WUAs lack the power they need to enforce equitable water distribution.

people will say that water is *not* fairly distributed. The explanation for this finding is clear. Being in a WUA provides access to water, which is shared among WUA members. This process excludes nonmembers, who thus feel that water is not being fairly shared. Hence, the more active the WUA, the more likely nonmembers are to feel that water is not shared fairly.

Although it is expected to ensure equitable water distribution, the WUA lacks the powers of enforcement needed to do this.[17] Field work found that canal breaches are common practice, meaning that excess water is taken off in higher reaches, leaving tail-enders without enough water. Such matters should be broached in the WUA and distributary committee and sometimes are. But the farmers' groups have no mechanism for resolving the dispute. Those breaching the canal may be connected to powerful families, making it difficult to challenge them in an open forum. In one surveyed village, the Irrigation Department is taking the farmers to court for breaches.

Higher reaches also use more water than intended as a result of the preponderance of paddy cultivation (see next chapter). They can also capture a larger amount of water by diverting the canal into their village tanks. Of the 18 villages in the IEG survey, one was not receiving water at all because of diversion upstream, and two others were diverting water and were therefore in conflict with downstream villages that were not receiving water.

The distributary committee should resolve these disputes but cannot.[18] Such problems are a manifestation of the fact that decentralization is often best accompanied by an element of central control.[19]

O&M

WUAs can claim more success with O&M, although questions might be raised regarding its sustainability. In SRSP, WUAs were involved in identifying repair works, though Irrigation Department staff are responsible for repair design. This approach was adopted statewide in the late 1990s, partly using World Bank financing. Most studies are positive about the works carried out at that time (Jairath 2000; Reddy and Reddy 2005).

It is argued that the involvement of the WUAs in identifying the works ensured that priority activities were undertaken and forced a change in I&CADD's preferred way of carrying out maintenance on minor canals (Oblitas and others 1999). One consequence of this was that minor canals would be in a very poor state before they would be repaired. Moreover, it is also claimed that cost savings of about 20 percent were realized as a result of avoiding rent-seeking by public officials at various levels (Raju 2001).[20]

A further cost saving is that the assumption of these responsibilities by WUAs means that I&CADD can operate with lower staffing levels. However, the decisions were usually made by the WUA president, with little or no consultation with other committee members, let alone ordinary WUA members.[21] Moreover, WUA presidents are themselves frequently contractors: in one study of eight WUAs, at least six presidents—and possibly all eight—were contractors who undertook canal rehabilitation.[22]

Although it is too early to make a fully informed judgment, it seems doubtful that WUAs will be effective in carrying out O&M because the financing system is unsustainable. Following the reforms, the government allocated Rs 200 per acre to major schemes. This figure balances with the water fee of Rs 200.

But the apparent balance gives a false picture of financial sustainability for several reasons. First, 10 percent of the fee revenue goes to local government rather than any of the water committees. Second, in major schemes, 20 percent is allocated to project committees, but there are no such committees and these funds are not being paid out.[23] Most important, collection remains poor. The amount collected has risen somewhat as a result of tariff increases, but this probably disguises an actual reduction in collection rates.

The reforms have failed to break the vicious cycle of poor irrigation services, making farmers unwilling to pay for O&M. Specifically, tail-enders continue to receive little or no water and are thus unwilling to pay the water fee. But even farmers in head reaches frequently do not pay. Collection rates have been estimated at less than 10 percent of the amount due (Jairath 2000); data from the SRSP command show an average of 12 percent for the period 1998–99 to 2001–02 (I&CADD 2004). Hence, over the period 1997–2002 only one-third of the money allocated to canal WUAs and distributary committees was financed from water charges.[24]

Moreover, less than half of WUA members believe that repair works are a WUA responsibility (Reddy and Reddy 2005). For that reason, prospects are not good for WUAs sustaining O&M so that the canal network does not fall victim to the same problems of poor maintenance. The positive counterpoint is that (as is shown in the next chapter) in good years, farm income is easily sufficient to cover even higher water charges.

Summary

WUA involvement in O&M has shifted to address priority problems.

The financial sustainability of O&M is doubtful and may undermine WUA success in that area.

The APFMIS Act was intended to provide the basis for transferring management of the irrigation system from public servants to farmers. The government at the time was heavily committed to the reform and provided support to WUA formation. But reforms lost momentum with the change of government, and the transfer has not taken place. The Irrigation Department has retained overall control of the command areas because project committees have not been formed. WUAs are not involved in revenue collection, and most farmers see O&M as a government responsibility rather than one for themselves or the WUAs.

Supporters of PIM claim that it is a channel for representing the voice of the poor. This has not been the case for several reasons. First, the poorest are excluded because they do not themselves engage in cultivation. But even among farm households, a tiny minority of poor households participate in WUAs, compared with a sizable proportion of the better off.

Among WUA members there are also biases in the pattern of participation. The uneducated are less likely to participate in meetings, and the better off are most likely to feel they have a role in decision making and influencing water management. Leadership of WUAs is heavily concentrated among higher castes. For these reasons, WUAs can become a channel for elite capture rather than for empowerment of the poor. Evidence from the field supports the argument that WUAs can become hostage to local politics, which may mean elite capture but can also mean capture of project benefits by one group or locale at the expense of others.

Water is not being fairly distributed either within or between communities, and WUAs have only limited ability to do anything about this. Many of these findings reflect similar findings for other community-based initiatives supported by the Bank.

In summary, the Bank has been overly optimistic about what may be achieved through WUAs (this supports the conclusion of IEG's sector study, IEG 2002, pp. 43–45), underestimating the need for continued government involvement. This applies to technical issues, such as the design of rehabilitation works, as well as to the ability to intervene in water disputes. For the time being at least, it also applies to continued subsidization of system operation. At the same time, the reasons for decentralizing WUAs need to be remembered, in particular, the weaknesses of government irrigation departments in efficient management of the irrigation system. Successful reform needs to address these weaknesses with a realistic assessment of what WUAs can and cannot do.

Chapter 4

Evaluation Highlights

- The impacts of irrigation on crop yields were strong, but not as significant as appraisal estimates put them.
- The impact of irrigation on cropping diversity was minimal, overridden by a strong preference for cultivating rice.
- Cropped area and cropping intensity increased, though not as much as appraisal estimates predicted.
- Irrigation increased farm incomes and smoothed income from year to year.
- Employment of nonhousehold labor increased with irrigation, benefiting women the most.
- The ERR to investments in these projects was negative.
- Risk calculations in Bank appraisals are too simplistic.

Two men working in an irrigated field in India. Photo by Ray Witlin, courtesy of World Bank Photo Library.

Economic Benefits

Direct production benefits accrue to farm households accessing irrigation. Once the SRBC project is completed, the investments undertaken by AP II and AP III will provide these direct benefits to approximately 212,000 households.[1]

Direct Production Impacts

These production impacts come from three sources: higher yields, diversification into higher-value crops, and increased cropping intensity.[2]

Higher yields

At appraisal, the main income benefits of irrigation were expected to come from higher yields, which would result in higher net farm income. For example, in the SRSP command below Lower Manair Dam (which includes the areas covered by the survey), the SAR predicted that paddy yields would rise from 3.2 metric tons per ha without the project to 5.4 metric tons with it.[3] That is, the SAR assumed a 69 percent increase in paddy yields. This percentage increase is toward the upper end of impact estimates, with the likely value somewhat less. But it is also important to note that the "without project" yield is high given actual yields.[4] This matters because it is the absolute increase in yields that determines the absolute increase in net farm income, which is the main project benefit.

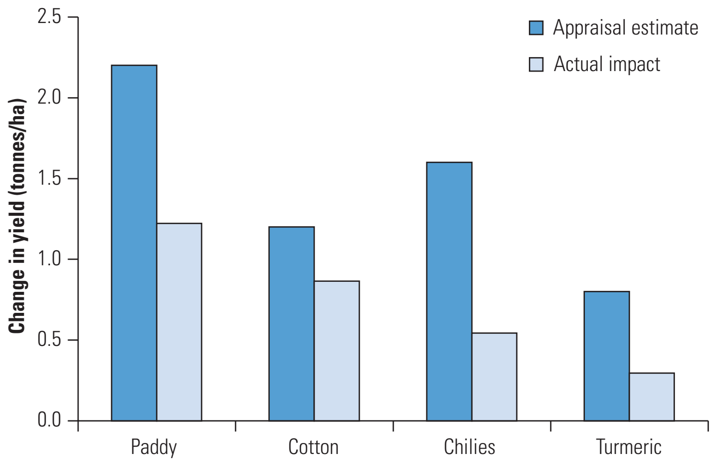
This study used several sources to estimate the impact on yields. The IEG survey data were used to calculate double-difference estimates (see appendix C).[5] These data came only from the reach below Lower Manair Dam, so additional data from the Implementation Completion Report (ICR), SRSP baseline data, and data collected by IEG from various official sources in Andhra Pradesh were used to make impact estimates for the higher reaches,[6] though these estimates are single differences. These two approaches give consistent results of an increase in paddy yields of 1–1.5 tons per ha, that is, around 20 percent–50 percent.[7] The yield increases for turmeric and chilies are less in absolute terms but in a similar range in percentage terms. Cotton has a larger percentage increase of around 80 percent and is the only crop for which the impact on yields appears to come close to that assumed at appraisal.

Estimates of impact on yield found a consistent 20 percent–50 percent increase—substantial, but well below appraisal estimates.

An alternative approach is to simply compare crop yields for the same year on plots without irrigation with those with access to canal or tank water. This analysis was done for paddy in 2006.[8] The results show that the impact of irrigation on yield was relatively small in the 2005–06 *kharif* season (which is to be expected, because the monsoon was good) but larger in the *rabi* season. Averaging over these results gives a similar result to that found in the double-difference analysis.[9] Finally, the "natural experiment" of comparing the year in which no water was released in SRSP with earlier years gives an impact on rice yields of just 14 percent in the *kharif* season but 66 percent in the *rabi* season.

The analysis offers two clear findings. First, access to irrigation has a significant impact on yields (figure 4.1). But, second, these increases are less than those assumed at appraisal, ranging from one-third for the high-value chilies and turmeric (34 and 37 percent, respectively) to just under three-quarters (72 percent) for cotton. For paddy,

Figure 4.1: Irrigation Increases Yields . . . But by Less than Assumed at Appraisal (change in yield, tons/ha)



Source: IEG survey.

Households with irrigated plots were found to have less diversified cropping patterns.

the most important crop, the assumed impact at appraisal was almost twice what has actually been realized.[10] Compared with appraisal expectations, these shortfalls in yields are the norm rather than the exception in irrigation projects.[11] Because no data are available for the SRBC command (few farmers have been connected to the canal system), similar reductions in expected yield are applied to that case (see appendix C).

Assuming everything else remained as assumed in the appraisal report, then halving yields compared with their expected values reduces the ERR in the SRSP (below Lower Manair Dam) area from the 21 percent calculated at appraisal to 12 percent.[12] Applying the same 50 percent reduction in yields to the whole project reduces the overall ERR from 24 percent to 8 percent.[13]

Diversification

Irrigation is intended to promote agricultural diversification, which helps reduce poverty by introducing higher-value crops. Also, a diversified production portfolio is more resilient to negative external shocks. The economic analysis in the SARs for the two projects assumes a diversified production structure on farms receiving canal irrigation, notably the production of a broader range of high-value cash crops, although it is stated that agricultural support services are necessary to attain diversification.

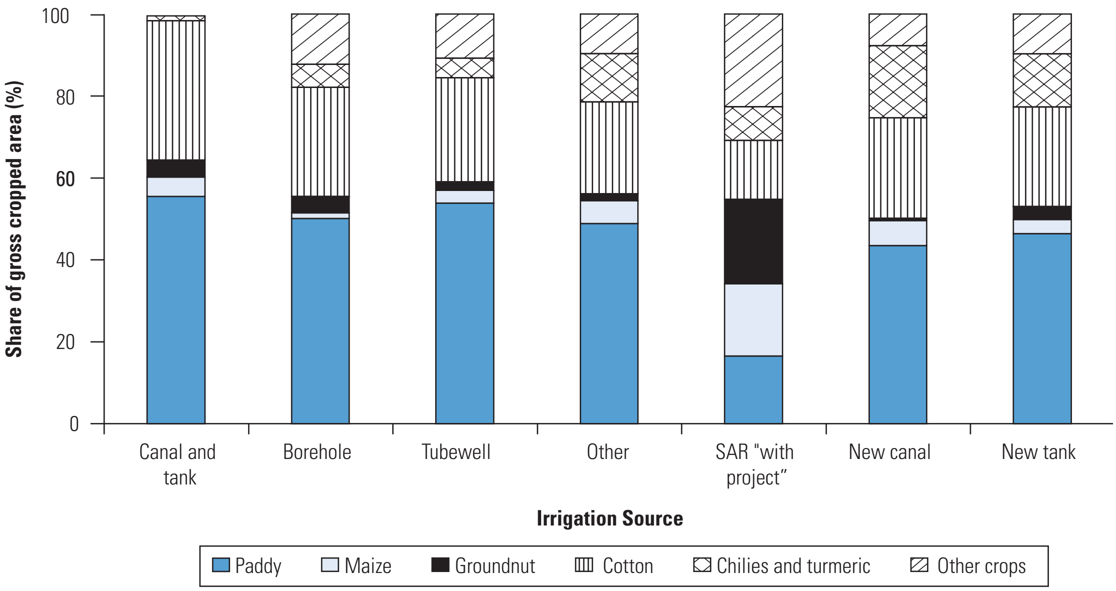
However, the survey data show that households with irrigated plots have *less* diversified cropping patterns, and farms with access to canal and tank irrigation are less diversified than those depending on boreholes and tubewells. The lower level of diversification reflects the greater reliance on rice by those with access to irrigation schemes. These findings can be shown in several ways.

Figure 4.2 shows the share of cropped area, classifying households by the type of irrigation to which they have access. The figure also shows the crop shares that the Bank assumed would be adopted in project areas, with clearly considerably more diversification being assumed than has been realized. Those with tank and canal irrigation devote the highest share (55 percent of gross cropped area) to paddy, 6 percent more than do farmers without irrigation. The share of rice in total crop income in 2006 was about 15 percent greater for farmers with canal or tank irrigation and more than 20 percent higher than the year before (appendix table D.9).[14] Single-difference estimates using the IEG data put the share of paddy in areas with canal irrigation at up to 30 percent more than in other areas, and double-difference estimates suggest this increase is 10 percent to 20 percent. Data from the ICR show the share of paddy in gross cropped area up to 39 percent higher in irrigated areas than in areas without irrigation.

These figures partly reflect differences in the share of households that depend exclusively on rice. Compared with other households, twice as many households with access to canal and tank irrigation cultivate paddy exclusively (47 percent in 2005 and 37 percent in 2006). Other than rice, canal- and tank-irrigated farmers mostly grow cotton; they do not diversify into groundnut, maize, or high-value crops.

The lack of diversification is not an especially surprising outcome because Andhra Pradesh farm-

Figure 4.2: Cropping Pattern by Irrigation Source, 2006 (share of gross cropped area)



Source: IEG survey.

ers are known to have a strong preference for cultivating rice. Explanations for this preference range from its reputation as an "easy crop" to food security and the fact that it enjoys a government-supported price, whereas other crops may experience much more price volatility.[15]

Moreover, if a farmer chooses a wet crop, especially paddy, then farmers in neighboring fields have little choice but to follow suit, as water leakage means their own soil will be unsuitable for other crops. What is surprising is not the lack of diversification, but the extent to which it was believed at appraisal that farmers would diversify despite strong evidence to the contrary. That evidence has included repeated failure of the government to enforce production of less water-intensive crops in the upper reaches of irrigation systems. The failure to diversify is unique neither to this project nor to Andhra Pradesh (see, for example, Plusquellec 2002).

Diversification was expected to result from extension services, but the data show that few farmers have received such services (appendix table D.10). The main area of advice has concerned seeds and use of fertilizer, but this has still reached only about 7 percent of households and has come mostly from community workers (most likely through the Restoration of Livelihoods Program or the Indira Kranti Patham Program) rather than government extension officers. Construction delays meant that the support the projects gave to extension services took place long before farmers received water, so that support would have been of limited relevance. But even then such services were limited: the intended small budget share for agricultural support services at just 2 percent was squeezed out, falling to just 0.6 percent. The claims that effective extension services help support higher yields and diversification may be true, but this cannot be tested in the virtual absence of such services in the areas surveyed.

The data confirm a known strong preference among Andhra Pradesh farmers for cultivating rice.

Although extension services were intended to help, few farmers received such services.

The lack of diversification may not matter much to those receiving a direct income benefit from irrigation, because rice generates a reasonable and safe net income and provides food security. But the additional water requirements of paddy production have adverse implications for two other groups of cultivators, most likely to be the poorer cultivators.

First, the system is designed to provide adequate water for the cultivation of irrigated dry crops, such as groundnuts, cotton, and maize. Areas can be declared as reserved for irrigated dry crops. However, as the results show, the policy is not enforced. Canal water charges are on an area basis rather than volumetric basis, and collection of even those charges is weak, so farmers have no incentive to change cropping patterns. Indeed, rice is a high-margin crop, providing a more stable income because the government guarantees the price. Hence, the lower reaches of the command will only receive water in very good years, resulting in the shortages and disputes described in the previous chapter and reducing project benefits.

The increase in paddy cultivation adversely affects farmers who cultivate other crops.

The second group of losers comprises households dependent on rain-fed agriculture. The failure of irrigated farmers to switch to high-value cash crops means they remain as competitors to rain-fed farmers, who suffer from lower prices as a result. But landless households and marginal farmers who are net food buyers benefit from these lower food prices. Within the survey area, just over 40 percent of households (including noncultivators) do not grow rice at all; another 10 percent grow insufficient amounts to meet their own consumption needs and so are net buyers. Thus, half the households will gain from the irrigation-induced price reduction, although the result might instead be fiscal savings.[16]

The increased cropping intensity was from an increase in the number of growing seasons rather than from multicropping.

Cropped area and cropping intensity

Irrigation increases the area planted with crops both by allowing cultivation of previously uncultivated areas and by increasing cropping intensity. Cropping intensity can be increased by adding growing seasons or by multicropping (planting more than one crop on the same plot at the same time, although this is not common on irrigated land). The area of actual land cultivated is the net cultivated area; gross cultivated area refers to the total with double counting (or more) of land that is multicropped or cultivated in more than one season.

The net area cropped by the households surveyed increased by nearly 10 percent between 2005 and 2006; cropping intensity increased by nearly 4 percent, adding up to a 13 percent increase in gross cropped area (appendix table D.11). Different approaches to assessing project impact in the SRSP area give estimates of an increase in cropping intensity from 10 percent to 23 percent (appendix table C.18).[17]

The increase in cropping intensity comes from both greater intensity of individual irrigation sources and the adoption of new irrigation sources that have higher cropping intensity. The main shift is away from unirrigated plots with low cropping intensity toward higher-intensity tank irrigation (figure 4.3).

Canal and tank irrigation are associated with cropping intensities of 200 and 150 percent, respectively (appendix table D.12), an increase that comes from the possibility of a second, or even third, crop per year. Double-difference estimates suggest that canal irrigation increases cropping intensity by 40 percent and tank irrigation increases it by 20 percent. This average increase of around 30 percent is somewhat above the single-difference estimates from elsewhere in SRSP and at the upper end from experience elsewhere. However, it is the number of sources rather than the specific source that is the primary determinant of cropping intensity.[18]

The survey data show that the increase in cropping intensity comes from the increase in the number of growing seasons rather than multicropping (figure 4.4). The survey found a 17 percent increase in the number of crops being grown (separate crops reported on the plot-by-plot collection of production data). This increase came entirely from the expansion of production beyond the *kharif* season: in 2005, 96 percent of all crops were grown in the *kharif* season, compared with 71 percent in 2006. There was no increase in multicropping between the years. Double-difference estimates suggest that canal irrigation raises the number of crops grown on a plot by 0.5, and tank irrigation increases that number by 0.15 (corresponding to increases in cropping intensity of 38 percent and 12 percent, respectively).

Direct Income Effects: Higher Farm Income

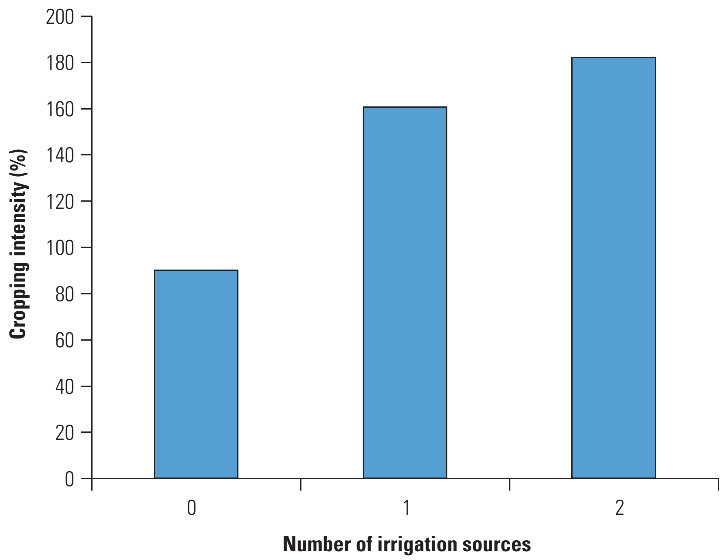
Output effects are estimated by calculating the double-difference value of farm output using 2005 prices for both 2005 and 2006 (see appendix C). The results show that access to irrigation increases the constant price gross value of output, although the estimates span a large range. Access to canal irrigation is found to increase gross revenue by 20 percent, and tank irrigation increases it by 5 percent.

Farm income is affected by the changing level and composition of output, as well as by changing input and output prices. In 2005, at the height of the drought, the rice price was high; it fell between 2005 and 2006. However, prices of cash crops rose between survey rounds (see appendix table D.13). This study does not attempt to attribute these price changes directly to the project.

In general, however, the increase in paddy production, as well as increased labor demand, will decrease margins, partly offsetting the yield benefits from irrigation. But given the substantial rise in cash crop prices, notably those of turmeric and chilies, the double-difference impact of irrigation on incomes appears substantial, reaching 75 percent for canal irrigation.

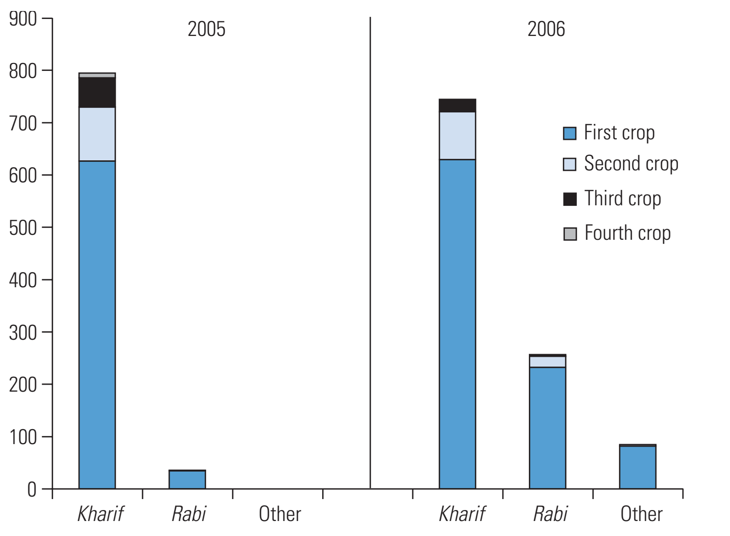
The farm model finds that irrigation increases net farm income by 110 percent. About half of this increase comes from increased cropping intensity and most of the remainder from higher yields, with only a small part attributable to changes in the crop mix. However, these increases are smaller than those anticipated in the SAR, which estimated that income would more than double in areas where canals were rehabilitated and nearly triple in newly irrigated areas.

Figure 4.3: Cropping Intensity by Number of Irrigation Sources, 2006



Source: IEG survey.

Figure 4.4: Increased Cropping Intensity Comes from Additional Growing Seasons



Source: IEG survey.

In general, irrigation, especially large-scale schemes that are not dependent on the local watershed for water, guarantees water supply and so smooths annual variations in production. Crop

Irrigation substantially smoothed crop income from year to year.

failures should occur less on irrigated land than on unirrigated. However, because of the prolonged drought, in the 2004–05 season no water was released in the SRSP command for the first time since it opened. Falling groundwater levels meant that local irrigation sources were also either dry or that they provided less water than usual. In 2005, 10 percent of cultivating households got no crop income at all (compared with less than 0.5 percent in 2006), and the crop failed on 10 percent of all plots.

Well-based irrigation also has high returns, though lower than from canal or tank irrigation.

The rise of farmer suicides in the state has been linked to crop failure. In many instances, farmers could not repay loans they took to construct a tubewell, which then ran dry. But unirrigated plots were four times more likely to experience crop failure, except compared with tank irrigation (table 4.1). In 2006 there were virtually no crop failures on irrigated land. In contrast, on unirrigated land, crops failed on 5 percent of plots. The data do not allow further investigation of this issue, but evening out crop income is a substantial benefit from irrigation.

Farm-level returns from irrigation

The returns to the farmer using canal and tank irrigation are high, as there are substantial benefits and very low costs. The investment costs for higher yields and cropping intensity are low, as the farmer is responsible only for the field canals, which distribute the canal water around the household's fields. Moreover, canal water is normally released into the field by a free intake (flooding), so most farmers can avoid pumping costs (equipment and running costs).[19] The recurrent costs associated with canal and tank irrigation are the water fees and contribution of labor to O&M undertaken by the WUA. Even after the rate increase, the water fee is only a fraction (less than 3 percent) of the value of the incremental farm income from gaining access to irrigation. The fee is often not paid, and few WUAs organize maintenance work.

Table 4.1: Crop Failure by Irrigation Source (% of plots)

Source	2005	2006
Canal	6.1	0.0
Tank	15.6	0.0
Tubewell	5.5	0.0
Borehole	4.9	1.3
None	20.6	5.1

Source: IEG survey.

The farm model (appendix E) shows an average 61 percent increase in net farm income from canal and tank irrigation.

Tubewell or borewell irrigation also has a high rate of return, although lower than from canal or tank irrigation. With this type of irrigation, the farmer bears the initial investment cost and the recurrent costs of pump operation.

These costs are lowered by the state government's policy of a zero tariff for agricultural electricity connections; this is essentially a regressive subsidy, as it is enjoyed by the better-off farmers. When it was introduced, the policy could be defended because many farmers were enduring severe economic hardship from years of drought. But in normal and good years, the benefits from irrigation easily cover the actual cost of electricity. Unfortunately, the impact of the policy is simply to encourage overuse of water, to the detriment of groundwater levels and hence of other users.

The fact that canal irrigation has sizeable benefits but low costs—and indeed no initial costs to farmers other than constructing field canals, which can be done using household labor during slack periods—means that there are potentially great benefits for poorer farm households that cannot access boreholes or tubewells because of the high initial costs. Those same high private benefits make the wells attractive to poor and non-poor alike, so the non-poor will seek to assert influence to gain access. This occurs in two ways. First, head-enders use more water than allowed so that tail-enders get little or no water. Second, canal water is diverted to tanks so that only farmers with access to the existing tank system get water.

Indirect Income Effects: Employment Generation

The indirect benefits of irrigation are commonly referred to as multiplier effects and are often claimed to be substantial for irrigation.[20] These effects include increased labor supply and demand for other inputs.

If a macro model, such as a computable general equilibrium model, is used to calculate these effects, then all rounds of consumption and production multipliers are included. But it is not clear that these multiplier effects should be included in a project-level analysis. Such indirect benefits exist for all projects, not just irrigation, and are rarely calculated, certainly not beyond the second round. Hence, resorting to multiplier effects to boost the benefit stream will undermine comparability between irrigation and other investments. More critically, multiplier calculations have a risk of double counting. Proper use of shadow prices is preferred.

Take the example of additional employment. If the labor demand is fully additional, that is, if the workers would be otherwise unemployed, then the appropriate shadow wage rate is zero, and the wage benefits do get included in the benefit stream.[21] There is a complication only if distributional weights are being used, as the wage benefit should be weighted by the wage workers' weight, not that of the farm owner. This report does not use distributional weights but in this section looks at who gets the benefits from irrigation.

The principle spillover benefit of irrigation is expanded employment opportunities for members of landless and marginal households. Agricultural employment rose markedly between the two survey years, from 155 days per household each year to 223 days (see appendix table D.15). Much of this increase resulted from the revival of agricultural fortunes following the 2005 monsoon season. More detailed analysis is required to determine how much of the increase can be attributed to irrigation.

The data show that employment of nonhousehold labor (from outside the household) increases with the adoption of irrigation. The double-difference estimate shows that access to canal irrigation increases employment of nonhousehold labor by approximately 60–80 days a year. Tank irrigation appears to increase employment somewhat less, with increases from borehole and tubewell irrigation falling between the two. It may be the case that canal irrigation required additional labor for the construction or rehabilitation of field canals. Tubewell and borehole irrigation systems have a greater number of waterings each season, which can explain the higher labor demand with respect to tank irrigation.

The lower costs to farmers for canal irrigation have potentially great benefits for the poor.

It might be expected that the additional labor demand would be muted by households making greater use of domestic labor. This is not the case. The double-difference estimates suggest that irrigation in fact reduces domestic labor use. To understand this result, one must understand the general situation, in which use of domestic labor fell on average from 336 to 317 days[22] between 2005 and 2006. This decrease may be in part an income effect, substituting leisure for work as income rises. The more likely explanation is that households hire out their labor in response to the greater labor demand by other households.[23]

Given the lack of alternative employment in 2005, domestic labor was absorbed into the family farm, but not in an efficient manner: labor productivity was nearly 20 percent lower in 2005 than in 2006.[24] With the good rains improving agricultural performance in 2006, combined with new irrigation, there was greater labor demand. Each household supplied on average 223 days of agricultural labor in 2006, compared with 155 in 2005. The increase in demand for labor led to an increase in average wages of 10 percent for women and 5 percent for men; the greater increase in women's wages reflects the disproportionate demand for female labor.[25] Women's wages rose the most in areas of new irrigation.

The survey found that employment of nonhousehold labor increased with irrigation.

Women account for the majority of hired labor in Indian agriculture, with women's share typically ranging between 55 and 66 percent (Upadhyay 2004). In the IEG survey, women accounted for 63 percent of hired agricultural labor (share of days hired) in 2005 and 64 percent in 2006 (appendix table D.17). In other words, close to two-thirds of the employment benefits accrue to women,

Women gained most from the increase in employment.

Irrigation also smoothed seasonal fluctuations in employment.

reflecting reliance on female labor for key tasks in paddy production, in particular weeding and harvesting. A considerable body of evidence shows that women's income has a larger impact on child welfare (health and education) than does men's income, even allowing for the fact that engaging in labor removes the primary caregiver from the home.

The employment benefits are not just more employment but its distribution across the year. There is much migration from areas of rain-fed agriculture (mainly to urban areas) because of lack of income opportunities in rural areas. In 2005, because there was little production in the *rabi* season, the average employment of outside labor during the *rabi* season was just 2 days. In 2006, this figure rose to 46 days (appendix table D.16). The impact analysis shows that the largest part of the employment effect indeed comes in the *rabi* season, thus smoothing the seasonal fluctuation in employment (figure 4.5). Despite the monsoon in July–August 2005 that brought rain, *rabi* season agricultural employment was negligible in villages without irrigation in 2006—but significant in villages with new irrigation. These figures confirm that a large part of the additional employment is an "irrigation effect," which reduces the need for seasonal migration.

Who Benefits? Poverty Reduction and Distributional Effects of New Irrigation

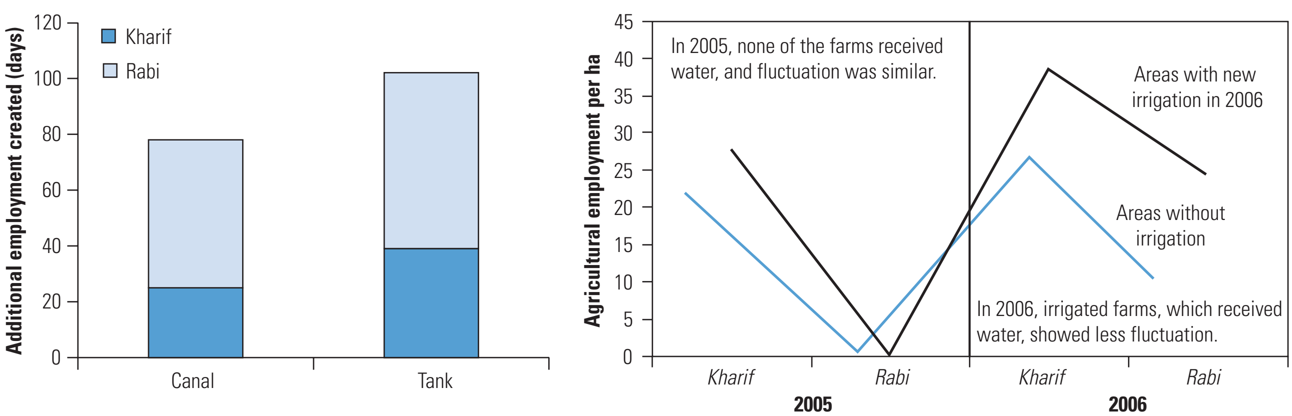
The income benefits from irrigation accrue in the form of higher net income for cultivating households and wage income for those they employ, which in turn is made up of higher wages and increased employment. The farm model (appendix E) produces figures for both of these benefits for a typical hectare of irrigated land. To see how these benefits are distributed, the incremental farm income is allocated among wealth quartiles according to access to irrigation, the income from incremental employment to share of the marginal employment, and wage increases across all employees. The results are shown in figure 4.6.

The results show that, in absolute terms, the benefits from irrigation are skewed toward those who are better off. Those in the poorest quartile ben-

Figure 4.5: Seasonal Employment Effects

(a) Largest share of the employment increase from irrigation comes in the *rabi* season.

(b) Seasonal employment fluctuation is reduced in irrigated areas.



Source: Appendix C.

Notes: (a) is based on household data and (b) on the village-level comparisons.

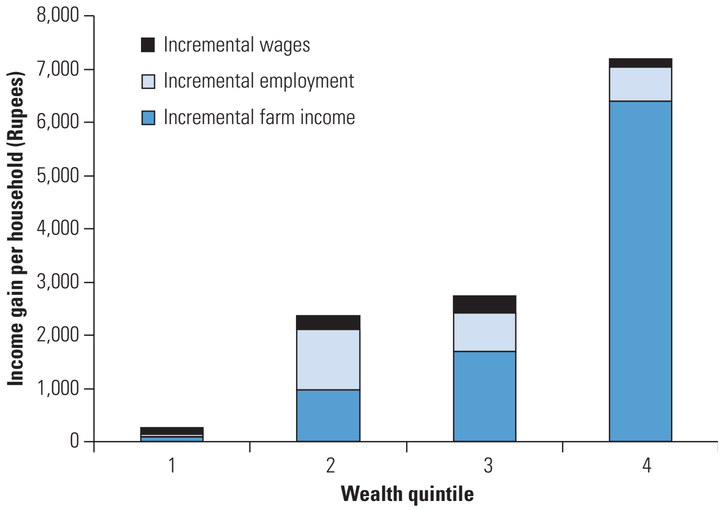
efit least from higher net income because few of them have land to irrigate. Larger farmers are concentrated in the top quartile, which captures the bulk of the higher farm income.

This bias is only partially offset by increased employment opportunities for two reasons. First, the incremental wages (additional employment plus higher wages) account for only a minor share (25 percent) of the total benefits, most of which are additional employment rather than a wage increase.[26] Second, those in the poorest quartile benefited little from expanded employment, which went mainly to households from the second and third quartiles. The poorest quartile does not benefit from expanded employment for a number of reasons, including the fact that it includes elderly and those suffering from disabilities who are unable to engage in such work.

Because the benefits to the poorest quartile are limited, the impact of irrigation on poverty depends a great deal on where the poverty line is drawn. If it is set at a level such that only those in the bottom quartile are poor, then the impact is small (figure 4.7). But with a higher poverty line, there is a notable impact: bringing irrigation to a village results in a one-off reduction in poverty of 10 percentage points, equal to a 25 percent fall. As discussed below, the dynamic impact on poverty as a result of reduced vulnerability will be greater still. There is, however, little impact on the poverty gap using either poverty line because of the limited benefits to the poorest.

Although the top quartile benefits most in absolute terms, in relative terms the largest benefit goes to the second quartile, members of which experience income growth of 30 percent. Despite their low benefit, their already low income means that the poorest quartile also experiences income growth of 20 percent, compared with 19 percent growth in the top two quartiles. These effects mean that irrigation has just a modest positive impact on distribution. However, another major effect on distribution comes from the dynamic effects.

Figure 4.6: Distribution of Irrigation Benefits Skewed toward the Better Off



Source: IEG data.

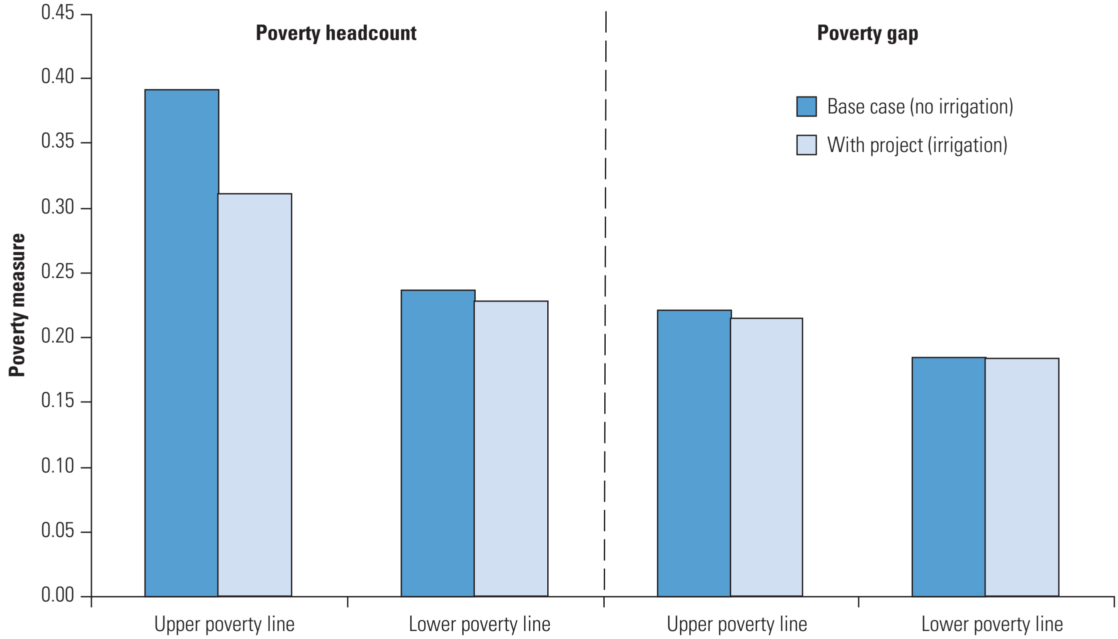
Analysis of the Lorenz curves for income between 2005 and 2006 shows a dramatic reduction in inequality. This is because many more households had zero or negative income in 2005 than in 2006 (figure 4.8a). This change was mainly brought about by the end of the drought. But it was shown that irrigation reduces the chance of crop failure, which pushes otherwise well-off families to the bottom of the income distribution. This fact is shown in reverse in figure 4.8b, which plots the Lorenz curve for 2005 and the distribution of income for 2006 with households ranked by 2005 income. The bottom 10 percent of households in 2005 got 10 percent of income in 2006 and 20 percent of farm income (not shown).

The benefits from irrigation are skewed toward the better off.

So, although comparing "with" versus "without" irrigation for a normal or good year will show a modest impact on the income distribution, bad years will be marked by an extreme worsening in income inequality, as many farmers experience negative income. The presence of irrigation can mute this effect. This reduction in vulnerability

The impact of irrigation on poverty depends heavily on where the poverty line is drawn.

Figure 4.7: Poverty Impact of Irrigation



Source: IEG data.

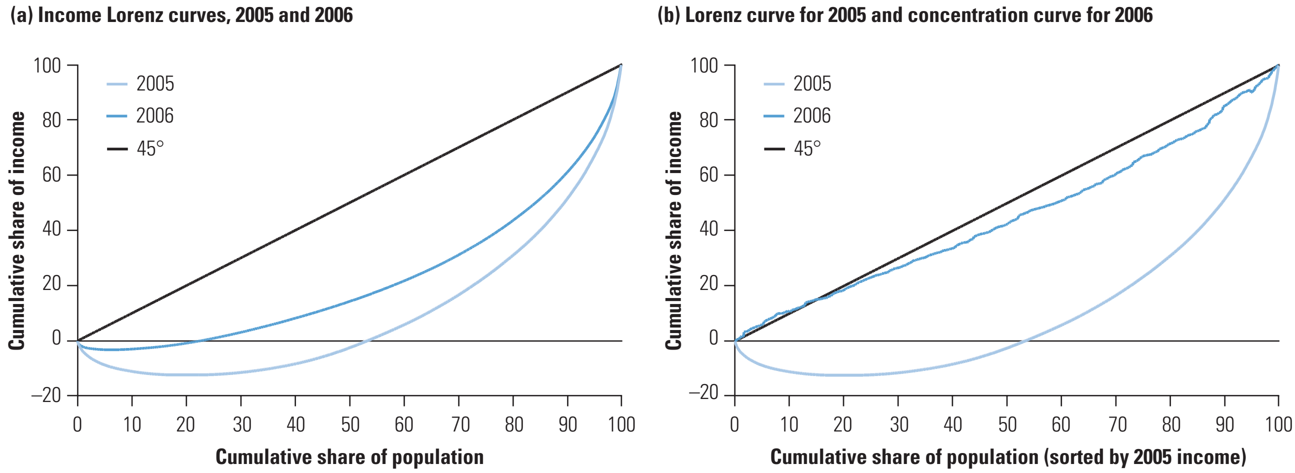
has a dynamic effect that is not possible to demonstrate empirically with IEG's data. Households subject to repeated negative shocks become heavily indebted and deplete their assets, constraining their ability to undertake productive investments. Reducing the impact of bad years thus aids asset accumulation and helps households grow out of poverty.

The overall impact on intravillage income distribution appears modest and may even be positive, but the intervillage impact may be less beneficial. At the simplest level, villages with irrigation grow faster than those without it, thus creating spatial inequality. This tendency is reinforced by the fact that villages in head reaches take excess water, thus depriving those in the tail end, which are usually worse off to begin with.[27] This tendency toward spatial inequality is offset (1) to the extent that those in poorer villages perform labor in irrigated villages, though this seems limited; (2) from lower food prices if markets are sufficiently integrated; and (3) by other multiplier effects (a frequently claimed but little quantified benefit from irrigation).

Revisiting the ERR

A number of factors served to undermine the economic viability of AP III. First, it was saddled with the sunk costs of AP II, which need to be taken into account in assessing the return to the whole investment in the irrigation scheme. Second, AP III was affected by the same cost overruns and construction delays that had affected AP II. In addition to these problems, the assumptions made in the SAR regarding yields and diversification were rather optimistic. Combining all these factors means that the ERR on the money that the government of Andhra Pradesh and the Bank have spent in SRSP and SRBC has been considerably less than was expected at appraisal. The revised economic analysis for this study finds an ERR of just 2 percent, compared with the 19 percent expected at appraisal (table 4.2).[28]

Figure 4.8: Income Distribution Improved between 2005 and 2006



Source: IEG survey.

A Bank study of irrigation in India (World Bank 2003) points out that there are other nonagricultural benefits to irrigation, such as industrial uses and domestic purposes (drinking water). Data are not available to quantify these benefits, but the study shows that for SRSP, 88 percent of the canal water is used for irrigation purposes. Therefore, an approximation including the nonagricultural benefits inflates the benefit stream by 13 percent.[29] This raises the overall ERR from 2 to 3 percent (and from 6 to 7 percent excluding AP II costs).

The yield estimates used in this study are derived from a number of sources, with remarkable consistency between those sources. IEG's final-estimates of the yield impact are higher than those used by the Bank's irrigation specialists in preparing their final review of AP III. Nonetheless, it might be argued that, with time, irrigated farmers will achieve better yields. Additional calculations (table 4.3) show that even if yields with irrigation are assumed to be 20 percent higher than the increase already estimated, the overall ERR is still only 4 percent. It remains lower than 10 percent even once AP II costs are excluded and additional yields are combined with the nonagricultural benefits. Even considering the investments from AP III alone (that is, ignoring AP II costs as sunk costs), the ERR does not reach the 10 percent threshold.

The revised analysis finds an ERR of only 2 percent, compared with the 19 percent expected at appraisal.

The ERR for SRBC is negative, reaching only zero even when the costs of AP II are excluded, and 3 percent under the best possible scenario. All estimates of the ERR for the two components (that is, those in the SAR and ICR) have shown

Table 4.2: Estimates of the Economic Rate of Return

	SAR			IEG	
	All costs	Excluding AP II	ICR	All costs	Excluding AP II
SRBC	9	14	12	–2	0
SRSP	31	34	16	5	11
Whole project	19	24	15	2	6

Source: World Bank data and IEG calculations.

Table 4.3: Alternative Estimates of the Economic Rate of Return

	SRSP		SRBC		Whole project	
	All costs	Excluding AP II	All costs	Excluding AP II	All costs	Excluding AP II
Base case	5	11	–2	0	2	6
Phased yield increase[a]	6	13	0	2	4	8
Higher yields	6	14	0	2	4	8
Higher yields + nonagricultural benefits	7	16	0	3	5	9

Source: World Bank data and IEG calculations.

a. Base yield increases in first two years of irrigation, 10 percent higher in years 3–4, and 20 percent higher in years 5 and on.

The appraisal estimate underestimated risk because the Bank's standard sensitivity analysis is too simplistic.

this same pattern—of SRBC having a lower return than SRSP, despite SRSP serving tail-end users.

Several reasons explain this difference. First, SRBC was new construction, whereas SRSP was rehabilitation (the SRSP new construction component of AP II being dropped under AP III), and rehabilitation is expected to yield higher returns than construction. In addition, SRBC was expensive new construction even before the cost overruns, because the scheme will irrigate a relatively small area for the length of the main canal.[30] This difference in performance between the two components has been exacerbated by the greater delay surrounding the SRBC component.

These delays in realizing any benefits in the SRBC command area mean that any realistic set of assumptions about benefits will not yield a satisfactory rate of return (unlike SRSP, which nudges toward an acceptable return as the assumptions become more generous). Saddled with the cost overruns from AP II, the aggregate investment in SRBC never had a chance of achieving economic viability (figure 4.9).

The analysis illustrates the irrigation paradox: high private rates of return contributing to poverty reduction, but low ERR.

A major implication of this analysis is the need to avoid delays and cost overruns in major construction projects: the government of Andhra Pradesh is taking such steps through the Jalayagnam program (see appendix G, attachment 2), which seeks to increase the efficiency of government-financed construction.

A combination of problems rendered the project unviable, yet the appraisal considered the possibility of cost overruns, delayed benefits, limited diversification, and a shortfall in yield gains. Nonetheless, the appraisal concluded that the project was robust enough to risk. This is because it adopted the standard approach to sensitivity analysis employed in Bank appraisals—of varying one assumption at a time. The possibility that bad things may be combined was not considered.[31] Using the SAR's own figures, if all the adverse shocks considered did occur—which they did, and more severely than assumed in the SAR's sensitivity analysis—then the ERR for the whole project falls from 24 percent to just 3 percent.[32]

The sorts of problems encountered are far from unusual in irrigation projects. The simple step of calculating the ERR for a situation that combined all the risks would have cast serious doubt on the viability of the investment. This was not done, as Bank procedures are far removed from best practice (box 4.1).

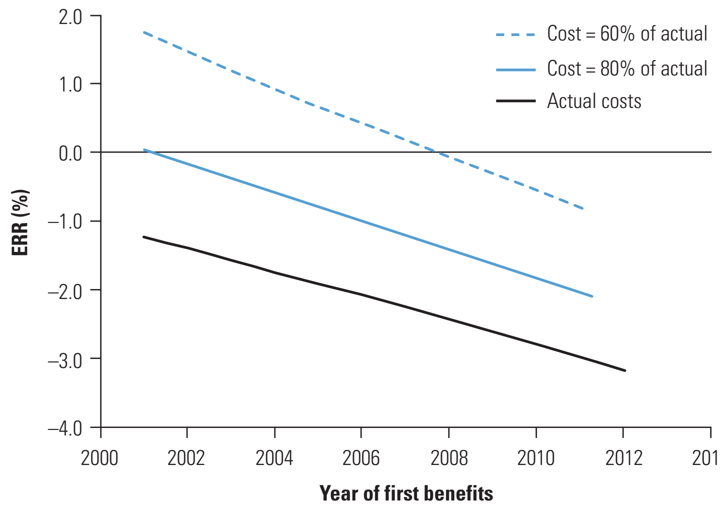
The problem was exacerbated by some of the unrealistic assumptions made at appraisal, a problem highlighted in IEG's recent irrigation sector review (IEG 2006b). Ex post returns were generally found to be lower than those at appraisal because of overestimation of cropped area, expected yields, and output prices (IEG 2002).

Resolving the Irrigation Paradox

The irrigation paradox is well illustrated by this study. The investments in the two schemes supported by AP II and AP III have yielded a low ERR. At the same time, the investments have yielded very high private rates of return to beneficiary households. The increments in net farm income and employment have indeed contributed to poverty reduction. The smoothing of income made possible by irrigation has helped prevent households from moving in and out of poverty because of the vagaries of weather.

The paradox is also readily understood. Farmers reap the majority of the benefits but bear very few of the costs. In effect, then, the projects are an income transfer from state coffers (including World Bank grant and loan funds) to farmers, supplemented by subsidies to electricity supply, extension workers, and so on. Given that the overall financial and economic returns are negligible, shifting all costs to farmers would remove the poverty-reduction impact of irrigation; indeed, poverty would be increased. The paradox can only be resolved by transforming unviable investments into viable ones. A number of steps will help achieve this.

Figure 4.9: Investments in SRBC Had No Chance of Providing an Acceptable Rate of Return



The figure shows the ERR for SRBC varying two factors: (1) the extent of cost overruns is different for each of the three curves, and (2) the date of first benefits becomes later, moving from left to right. Even under the most optimistic scenario the ERR is still less than 3 percent.

Source: World Bank database.

Box 4.1: Improving the Quality of Sensitivity Analysis in Bank Appraisals

World Bank appraisal reports conduct deterministic sensitivity analyses, varying just one assumption at a time. Several changes of increasing complexity could be made to this approach to improve the quality of appraisal. The simplest change would be to assume the worst for each assumption considered in the analysis. The ERR is truly robust if it remains acceptable in the face of such analysis. If not, then a more elaborate approach is needed.

The second change would be to assign probabilities to the possible outcomes. Once that is done, an expected rate of return can be calculated in a straightforward manner, if it is assumed that the various risks are independent of one another. If they are not independent, then the correct approach and best practice for sensitivity analysis is to specify the joint distributions and use Monte Carlo simulations to plot the distribution of the ERR.

Sources: White 2004; Belli and others 2002.

First, appraisal methods have to undertake a more rigorous assessment of risks to screen out potentially unviable investments. Second, the planning about construction time and costs, including problems in land acquisition, needs to be realistic, and the planning needs to take steps to tackle the problems that plague these areas. Third, the assessment needs to be realistic about yield and diversification benefits. If it is believed that these really can be achieved with good quality extension services, then coordination is required (perhaps through WUAs) to ensure that farmers receive the information.

If these steps can be undertaken, then investments may be identified that yield a suitable ERR and that will yield sufficient income to farmers so they can meet O&M costs. But the subsidy element of the capital cost will remain. So the question needs to be asked: Is this the best use of resources?

The paradox can only be resolved by transforming unviable investments into viable ones.

Chapter 5

Building a brick main canal in India. Photo by Curt Carnemark, courtesy of World Bank Photo Library.

Summary and Lessons Learned

Two points need be borne in mind when reviewing the findings of this study and drawing lessons from them. First, the projects were "old-style" irrigation projects of the sort the Bank is not currently financing in India. Despite this, the government of Andhra Pradesh is keen to see an expansion of the area covered by major irrigation schemes and has launched a substantial program of new construction. The Bank's new guidelines for investment lending in India show that some of the lessons from the experience of projects such as AP II and AP III have been learned. Second, the reform process establishing WUAs and defining their roles in practice is likely to be a long-term one.

Findings on the Six Evaluation Questions

Did investments in irrigated agriculture increase production in Andhra Pradesh?

Yes. Access to irrigation increases both yields and cropping intensity. Cropping intensity is increased through the extension of growing into additional seasons. It also reduces interyear income fluctuations caused by variations in rainfall.

However, the expected diversification into higher-value crops has not occurred. In fact, irrigated farmers are less diversified, as they grow more paddy than farmers whose land is not irrigated, resulting in excessive water use in the head reaches.

What are the impacts of PIM on incomes and poverty alleviation, and who benefits?

Gaining access to irrigation raises net farm income by about 60 percent. Indirect benefits come as well, from additional wage employment. These indirect benefits are about one-quarter of the value of the direct benefits.

The top wealth quartile captures the largest portion of the direct benefits and so enjoys the largest absolute increase in income. But additional employment income is mostly captured by the second quartile, which experiences the largest percentage income growth. The poorest quartile gains the least absolute benefit but still enjoys income growth of about 20 percent.

Although the largest absolute gain goes to those who are better off, irrigation results in little change in the Gini coefficient. The poverty-reduction impact is sensitive to the poverty line. Using an upper poverty line, irrigation induces a one-off 25 percent reduction in the poverty headcount. There will be a larger dynamic impact, as irrigation helps smooth productivity and income over time, breaking the circle of negative income and debt that can undermine asset accumulation.

Do investments in irrigation yield a satisfactory economic return?

In principle, yes; in this case, no. The ex post rate of return is only 2 percent. The low level results from cost overruns, construction delays, and discrepancies between realized income increases and those expected at appraisal.

Two factors are not allowed for in this analysis, one positive, one negative. First, the ERR calculation assumes a steady benefit stream. In fact, irrigation smoothes production income compared with the "without project" scenario. But the benefits are only sustained if the canal system is maintained. Large-scale irrigation will only be economical if construction costs can be constrained and benefits sustained. The Bank's new guidelines prioritize increasing the efficiency of irrigation departments, which this study confirms to be a necessary starting point for profitable investments.

Was the Bank's support for canal irrigation relevant and appropriate?

In principle, yes. In practice, however, the answer is twofold: no for the SRBC component and yes for rehabilitation of SRSP. Irrigation has proven potential to increase agricultural production and reduce poverty. Andhra Pradesh has unrealized irrigation potential, so helping meet this potential appears entirely consistent with a poverty-reduction strategy—provided, of course, the project delivers an acceptable ERR. SRBC failed to do this, but other aspects of design were inappropriate as well.

Excessive faith has been placed in WUAs as a means of solving problems of both equity in water distribution and sustainability. But WUAs lack mechanisms to enforce equitable distribution, even if they should wish to do so. The physical design of the system lacked the means for monitoring and enforcing proper water usage (that is, software reform cannot work if the hardware is missing), and alternative pricing schemes have not been explored. Increasing the role of WUAs may improve sustainability, though the evidence shows that provision for financing O&M matters more than which bodies are responsible for the works. It remains possible, of course, that other investments may have been even more relevant and appropriate.

Do WUAs facilitate greater participation of the poor and of disadvantaged groups in water management and access to irrigation?

No. The poorest are excluded from WUAs because they are mostly landless. About half of cultivators in canal and tank irrigation schemes report that they are members of their local WUA. The better off are more likely to be members, partly as irrigated land is more likely to belong to the better off than land in general. Higher castes dominate the leadership of most WUAs. Among members, the better off are more likely to feel they have influence over water management. WUAs and distributary committees have not provided an effective mechanism for resolving intercommunity disputes, so the pattern of excessive water use by farmers in the head reaches continues, depriving tail-enders, who are usually poorer, of water. This might have been addressed by the project committees, but the irrigation bureaucracy has blocked their creation.

Are WUAs an effective means of providing sustainable O&M?

It is too early to say. The positive experience with rehabilitation to date is due to the availability of external funds (from the Bank's APERP) to finance these works. Some of the signs for future sustainability are not promising: nonpayment or underpayment of water fees is widespread; most WUA members do not feel that O&M is their responsibility; and the amount of money available to WUAs for O&M is too small, even if they were to receive their full allocation.

On Selecting Irrigation Investments

The first lessons regard selection of irrigation investment. More judicious selection would avoid those projects most likely to have negative returns.

Many previous "lessons learned" still remain to be learned. The gap between ERR at appraisal and that found in this study is large. This has been a consistent finding in IEG reviews of irrigation projects. The reasons given here are the same as the reasons found before: underestimation of costs and overestimation of benefits. Specifically—

- ***Construction delays undermine the economic viability of investments.*** Serious delays that postpone the realization of benefits, such as those experienced during these projects, reduce the rate of return to the investment. For large-scale irrigation projects to appear economically attractive, they must be able to be constructed on time or in a manner that allows benefits to be phased in at an earlier stage. The government of Andhra Pradesh is taking steps to remedy these problems in the latest phase of irrigation expansion.

- ***Unrealistic appraisal estimates increase the likelihood of financing poor investments.*** The SAR predicted gains from increased yields and crop diversification that are far from those that have been realized; the SAR made the investment appear far more attractive than it actually was. The Bank's new guidelines for irrigation seek to strengthen appraisal procedures, which should directly address this issue.
- ***The method of risk assessment used in appraisals understates the actual risk that the project may not be viable.*** Appraisal reports consider risks one at a time, not considering the possibility that more than one of the assumptions in the analysis may not be realized. Risk assessment methods that look more rigorously at possible states of the world will result in more realistic assessments of project viability.
- ***Analyses need to value all benefits and costs.*** Existing studies (including this one) neglect some important benefits. The main ones are increased groundwater levels and smoothing consumption. All costs should be valued as well, including realistic full resettlement costs, adverse environmental impacts (which are most likely long term), and negative effects on those deprived of water by irrigation elsewhere. The Bank's new guidelines explicitly recognize the importance of including all costs and benefits in the appraisal analysis.

On Participatory Irrigation Management

The lessons regarding PIM are generally applicable to most forms of participatory (community-based) development.

- ***Bottom-up development needs support from the top.*** The initial burst of WUA activity reflected strong support from the state government. Once the government changed, there was less support for the program, so it lacked the central direction needed to bring about change in the bureaucracy and to support WUAs as a pro-poor institution at the grassroots level.
- ***PIM may alleviate the problems of large-scale irrigation schemes, but it cannot eliminate them.*** Several of the problems encountered in these projects, such as construction delays and weakness of extension services, will not be solved by the introduction of WUAs. Moreover, WUAs are not realizing a potential benefit, as funds for O&M are insufficient.
- ***PIM is not intrinsically pro-poor.*** Farmers benefiting from irrigation are among the less poor, and the better-off farmers are most likely to participate in WUAs. Hence, WUAs are more likely to reinforce existing social patterns than to change them.
- ***WUAs have limited means to effectively resolve water allocation disputes.***

On the Impact of Irrigation

Finally, there are lessons on the design of irrigation projects.

- ***Irrigation raises output through higher yields and cropping intensity and stabilizes production, all of which contribute to poverty reduction. But irrigation investments constitute a sizeable subsidy to farmers who are not among the poorest or even the poor.***
- ***The direct income benefits to farmers from irrigation provide the potential for full recovery of the recurrent costs of the services provided.*** Current water charges are a tiny fraction of the net increment in income that irrigation makes possible. Increasing these charges is necessary for sustainability of the system.
- ***Incentive structures, including water pricing policy, encourage water wastage.***

Appendixes


Workers in a rice field. Photo by Thomas Sennett, courtesy of World Bank Photo Library.

APPENDIX A: SAMPLE SELECTION OF IEG IRRIGATION SURVEY

The Independent Evaluation Group (IEG) study design required the sample to be split into three groups: villages receiving canal irrigation since before the first-round survey in June 2005 (Group 1); villages receiving canal irrigation for the first time in the two agricultural seasons prior to the second-round survey, that is, between rounds one and two of the survey (Group 2); and villages not receiving canal irrigation yet, but scheduled to receive it in the near future (Group 3) (table A.1).

The rationale for this design is as follows. Comparing the treatment group (Group 2) with the second control group (untreated; Group 3) will allow for a standard double-difference estimation of project effect. The control was selected from villages scheduled to receive irrigation in line with a "pipeline approach," that is, the assumption that those selected for participation but not yet treated are more likely to share characteristics with the treatment group than would a randomly selected control sample. However, there is a concern that farmers take time to adapt their farming to the availability of irrigation. Control 1 (Group 1) provides a group that has received at least two treatments (years of irrigation), allowing single-difference estimates with the untreated group.

AP II and AP III financed work in two command areas, Srisailam Right Branch Canal (SRBC) and the Sriramasager Project (SRSP). The study originally intended to select the sample from an area served by the new SRBC canal. However, at the time of the first round of the survey, a year after Andhra Pradesh III (AP III) had closed, very little water had been released (irrigating 7,800 hectares [ha] of a planned 65,000 ha) in the SRBC command, because the micro-network was at best 20 percent complete. Completion of the network was estimated for 2008 (now expected for 2007), so the prospects of a much larger irrigated area by the time of the 2006 second round were bleak. The sample was therefore restricted to the SRSP command, where the main canal and several distributaries are being extended.

Specifically, the study focused on areas irrigated by SRSP between kilometer (km) 234 and km 284. This area falls entirely within Warangal district. Farmers on these distributaries are at various stages of receiving water: Some had received water by the time of the first round; some were to get it by the second round, and some at some point later. These characteristics fit with the desired three-group sample design. Hence, the sample design consisted of three groups of six villages each: (a) Control 1—water released for the first time in *kharif* 2003, (b) Project (treatment group): water released in *kharif* 2005, and (c) Control 2: no water released yet.

In this range, other than distributary canal 31 (DC 31), the new canal construction work is *not* funded by the Bank. Moreover, DC 31 is not suitable for inclusion in the sample, as all works were completed prior to *kharif* 2003; that is, all villages on the canal are in Group 1. However, Bank-funded rehabilitation of the main SRSP canal is what has made water releases south of km 234 possible (see chapter 2). Hence, the sample selection is

Table A.1: Scheme for Survey Coverage

	Round 1	Round 2
Group 1 (Control 1)	■	■
Group 2 (treatment)		■
Group 3 (Control 2)		

Note: Shading indicates that the group has been exposed to irrigation.

Table A.2: Distribution of Villages by Reach

	Head	Middle	Tail	Unclassified	Total
Number					
Control 1	55	29	5	4	93
Project	26	71	30	5	132
Control 2	3	1	15	0	19
Percent					
Control 1	59	31	5	4	100
Project	20	54	23	4	100
Control 2	16	5	79	0	100

Source: Calculated from Andhra Pradesh census data, 2000.

justified on three grounds. First, reaching the areas served has been made possible by Bank-funded activities, even if the Bank has not directly financed the canal extensions. Second, the impact of irrigation in the areas may reasonably be expected to be similar to those in areas which *were* financed by the Bank. Third, a major focus of this study is the economic justification for investing in further new irrigation works in the state.

Because access to irrigation is determined by topology, this analogy to a pipeline approach appears promising. However, it is known that access to water differs between the head and tail reaches,[1] and evidence from the pilot confirmed the prevalence of water theft/inefficient usage in upper reaches. Unfortunately for the evaluation design, the coverage of the canal system is being extended mainly by developing the tail reaches of the longer distributaries (the longest being DC 38 at 80 km in length). Hence, as shown in table A.2, potential treatment and control sample villages are not evenly spread across the various reaches. Control 1 villages are concentrated in the head reaches and Control 2 villages in the tails. The exceptions come because there are some short canals (DC 40 and 41 at around 10 km in length each), which can be counted as "all head."

Table A.3: Socioeconomic Characteristics of Project and Potential Control Villages (group averages)

	Control 1	Project	Control 2
Literacy (%)	48.3	45.4	39.1
Male literacy (%)	61.0	57.5	48.9
Female literacy (%)	35.0	33.2	29.0
No. of educational institutions	1.00	1.00	0.94
No. of medical institutions	1.10	1.08	0.94
Drinking water	1.00	1.00	0.94
Pucca road	0.74	0.65	0.88
Distance to Warangal (km)	37.1	60.1	84.3
Percent scheduled castes	14.2	15.9	10.9
Percent scheduled tribes	19.1	21.6	35.8
Percent of land cultivated	21.8	19.4	16.0
Percent agriculture laborers	24.7	26.9	30.5
Sex ratio (women/1,000 men)	961	974	912

Source: Calculated from Andhra Pradesh census 2000.

Moreover, other characteristics, which are very likely correlated with project outcomes, also vary systematically between project areas and the potential controls. Broadly speaking, Control 1 villages are most developed and Control 2 least so, with the treatment group falling in the middle; see the various indicators in table A.3. Control 2 also has a much higher share of scheduled tribes, some villages being close to 100 percent scheduled tribe communities.

The initial sample design was to stratify by reach and select even numbers for each group from head and tail (leaving out the middle reach), although the sample size was small for Control 2, especially for head reaches.[2] However, this procedure did not eliminate the systematic differences between the three groups, so the validity of the comparison could be called into question.

Hence, a matching procedure based on propensity score matching was adopted. A probit regression was estimated using census data of "the propensity to be irrigated"; that is, villages in the treatment group were given a value of one for the dependent variable. Irrigation status for each village was taken from a list provided by the Irrigation Department in Warangal district. The regressors were the variables shown in table A.3. A population-weighted random sample of 12 project villages was then drawn, and the nearest neighbor village (based on propensity score) from the other two groups identified. The 12 were reduced to 8 to avoid duplicate matches from Control 2 (but even so only 7 villages were picked from this group). Inspection of the actual values of the socioeconomic characteristics was used to remove the less typical villages, resulting in a sample of 18, 6 in each group. This procedure considerably reduced intergroup variation in socioeconomic characteristics, and where it remained, it did not follow the systematic pattern shown in table A.3.

Unfortunately, the sample selected was problematic; field visits revealed that Irrigation Department data on irrigation status of each village were not reliable. To rectify this situation, a list was made of three to four possible matches for each of the two controls, again using the closest match based on the propensity scores. The actual situation in these villages was verified in the field, and thus the final sample selected. But even then villages that were due to receive water between the surveys (that is, to be in the project group) turned out not to receive water.

Table A.4: Characteristics of Selected Villages

	Group		
	No irrigation	New irrigation	Irrigation
Literacy (%)	39	47	42
Male literacy (%)	50	58	54
Female literacy (%)	28	35	31
No. of educational institutions	1.00	1.00	1.00
No. of medical institutions	1.00	1.00	1.00
Drinking water	1.00	1.00	1.00
Pucca road	0.89	0.17	0.17
Distance to Warangal (km)	71	36	44
Percent scheduled castes	12	19	15
Percent scheduled tribes	37	15	29
Percent of land cultivated	19	17	25
Percent agriculture laborers	30	29	24
Sex ratio (women/men)	967	968	977

Source: Calculated from Andhra Pradesh census data, 2000.

There are two possible ways to handle this situation. The first is to include the tail-end villages in the treatment group, which would give an impact measure of the "intention to treat." The second approach is to recategorize the tail enders into the "no water" group (Control 1), so the impact estimate is that for "treatment of the treated." But since tail-end villages are unlike other villages, this latter approach reintroduces systematic differences into the pre-existing characteristics of the sample villages, as clearly shown in table A.4. However (as argued at greater length in appendix C), we know the direction of bias. Tail-end villages have less access to markets, less well-educated populations, and are less visited by extension workers, so we would expect the impact of irrigation to be less than in the head reaches. Hence, using impact estimates based on the head reaches produces an upward bias in those estimates. In addition, the treatment of the treated impact estimate of course exceeds that from intention to treat. Nonetheless, it is the treatment of the treated estimate for the higher reaches that is used here, because—despite the upward bias in impact (that is, we have an upper bound estimate)—the rate of return to the project is low.

APPENDIX B: REGRESSION RESULTS

This chapter reports the full regressions for the results discussed in chapters 3 and 4. Estimation procedures are listed in the title of each table. All data for these regressions are from the IEG survey.

Table B.1: Determinants of WUA Membership, 2006 (probit regression)

	Cultivating households only	All households
	Coefficient (t-stat)	Coefficient (t-stat)
Caste (ref = scheduled caste)		
Scheduled tribes	–0.60**	–0.33
	(–2.17)	(–1.31)
Other backward caste	–0.43**	–0.31
	(–1.79)	(–1.49)
Other caste	–0.70**	–0.56*
	(–2.02)	(–1.70)
Wealth (ref = 1st, poorest quartile)		
2	0.98**	1.02***
	(2.57)	(3.12)
3	1.16**	1.23***
	(2.95)	(3.70)
4	1.95***	1.96***
	(5.01)	(5.70)
Land (acres)	0.01	0.04
	(0.21)	(1.22)
Education (ref = none)		
Primary	0.25	0.18
	(1.25)	(1.06)
Secondary or higher	0.35	0.21
	(1.42)	(0.91)
Intercept	–1.62***	–1.90
	(–3.94)	(–5.49)

Notes: The regression includes village dummies that are not shown. Estimation drops the three villages in which there are no WUA members. These village dummies are the identifying variables for the selection equation for the two stage estimates reported in table B.2; t statistics in parentheses.

*Significant at 10 percent.

**Significant at 5 percent.

***Significant at 1 percent.

Table B.2: Determinants of Participation in WUA Activities, 2006 (probit and ordered probit, adjusted for selection into WUA membership)

	Attended WUA meeting	Regularly attend WUA meeting	Taken part in O&M	Take part in WUA decision making	Feel influence water management	Voted for WUA president	Voted for TC chair
Wealth quartile (ref category = 1)							
2	0.57	0.14	4.71	4.33	4.66	0.21	0.10
	–1.36	–0.32	(.)	(.)	(.)	–0.61	–0.29
3	0.321	0.27	4.39	4.02	3.67	0.35	0.34
	–0.79	–0.68	(13.06)***	(12.16)***	(7.56)***	–0.96	–0.95
4	0.67	0.55	4.30	3.82	3.97	0.36	0.43
	–1.63	–1.26	(14.76)***	(10.07)***	(11.59)***	–0.94	–1.16
Education level (ref category = none)							
Primary	0.53	0.69	0.36	0.46	0.18	–0.057	0.02
	(2.62)***	(2.70)***	–1.58	(1.78)*	–0.62	–0.29	–0.10
Secondary or higher	0.40	0.32	–0.32	–0.29	–0.88	0.08	0.13
	–1.47	–0.96	–0.84	–0.79	(1.88)*	–0.33	–0.52
Caste (ref category = scheduled caste)							
Scheduled tribe	–0.52	–0.36	0.65	0.18	–0.21	–0.13	–0.11
	–1.55	–0.89	–1.41	–0.29	–0.34	–0.49	–0.45
Other backward caste	–0.53	–0.56	0.86	0.16	0.46	–0.13	–0.08
	(2.05)**	–1.64	(2.35)**	–0.34	–1.12	–0.51	–0.34
Other caste	–0.69	–0.26	0.83	0.64	0.29	–0.03	0.01
	(1.69)*	–0.57	–1.64	–1.06	–0.43	–0.08	–0.02
Land (acres)	–0.003	0.01	–0.01	0.01	0.01	–0.002	–0.01
	–0.14	–0.33	–0.49	–0.27	–0.4	–0.07	–0.18
Lambda	–5.343	–3.409	–5.118	–3.975	–3.838	–6.564	–6.104
	(5.90)***	(3.63)***	(5.41)***	(3.75)***	(3.87)***	(7.59)***	(7.32)***
Constant	1.787	0.177	–3.414	–3.811	–3.88	3.124	2.733
	(2.23)**	–0.22	(5.35)***	(4.40)***	(4.95)***	(4.13)***	(3.80)***
Observations	566	566	566	566	566	566	566

Note: Sample is WUA members only. Absolute value of t statistics in parentheses. WUA = water user association.

* Significant at 10 percent.

** Significant at 5 percent.

*** Significant at 1 percent.

Table B.3: Determinants of Perception that Water Is Fairly Distributed within Village (probit using 2006 data)

	(1)	(2)
Wealth quartile (ref = 1)		
Quartile 2	–0.10	–0.11
Quartile 3	0.10	0.01
Quartile 4	0.14	0.01
Education level (ref = none)		
Primary	0.07	0.09
Secondary or higher	–0.26	–0.22
Land (ref = landless)		
Marginal	0.96***	0.97***
Small	1.09***	1.14***
Large	1.22***	1.25***
WUA		
Household member	0.76***	0.80***
Village membership rate	–0.48	–1.38**
Irrigation characteristics		
Proportion household land irrigated	0.84*	. .
Number of waterings of irrigated plots	0.07***	. .
Village water adequacy	. .	0.98
Intercept	–2.63***	–2.88***
Number of observations	896	896

Note: . . = negligible.
*Significant at 10 percent.
**Significant at 5 percent.
***Significant at 1 percent.

Table B.4: Dependent Variable: Value of Total Farm Output

	Coefficient	t-stat
Log of land (ha)	0.57	13.25***
Log of capital (service value)	0.02	1.89*
Log of draught animals (value)	0.02	2.03**
Log of male days own labor	0.07	2.29**
Log of female days own labor	0.04	3.30***
Log of female days hired labor	0.10	3.10***
Log of male days hired labor	0.05	1.79*
Log of fertilizer (expenditure)	0.09	3.15***
Log of seeds (expenditure)	–0.02	–1.07
Log of pesticides (expenditure)	–0.01	–0.63
Log of other inputs (expenditure)	0.00	–0.05
Rabi season (dummy)	0.13	2.17**
Summer season (dummy)	0.03	0.34
Permanent crops (dummy)	0.13	1.00
Log of age of head of household	0.06	0.60
Log of education of head of household	0.11	2.53***
Share of canal-irrigated land	0.04	0.25
Share of tank-irrigated land	0.43	3.60***
Share of tubewell-irrigated land	0.30	2.45***
Share of borewell-irrigated land	0.29	2.65***
Crop shock (dummy)	–0.19	–2.84***
Log of distance from market (km)	–0.01	–0.46
Constant	7.66	17.53***
Observations	506.00	
R-square	0.68	

Note: Value in rupees; ha = hectares.
***Significant at 1 percent.
**Significant at 5 percent.
*Significant at 10 percent.

Table B.5: Dependent Variable: Production per Hectare

	Coefficient	t-stat
Log of land (ha)	–0.30	–8.98***
Log of capital (service value)	0.02	2.44**
Log of labor (days)	0.13	3.45***
Log of all inputs (expenditure)	0.15	4.52***
Log of age of head of household	–2.22	–1.57
Log of age of head of household squared	0.31	1.63*
Log of education of head of household	0.11	3.64***
Red sandy soil (dummy)	0.11	1.89*
Black soil (dummy)	0.18	3.28***
Chaudu soil (dummy)	0.18	3.12***
Irrigation sources (number)	–0.17	–2.66**
Rabi season crop (dummy)	–0.32	–5.72***
Summer season crop (dummy)	–0.44	–4.77***
Crop shock (dummy)	–0.13	–2.94***
Rice crop	1.12	7.55***
Maize crop	0.66	4.24***
Groundnut crop	0.24	1.50
Cotton crop	0.44	3.39***
Chilies crop	0.14	0.57
Turmeric crop	0.69	4.74***
Pulses crop	–0.31	–2.09**
Canal-irrigated field (dummy)	–0.50	–2.44**
Tank-irrigated field (dummy)	0.29	2.92***
Groundwater-irrigated field (dummy)	0.00	0.02
Canal x rice	0.64	2.92***
Canal x maize	1.09	2.81**
Canal x groundnut	0.52	1.33
Canal x chilies	0.67	1.90*
Canal x turmeric	1.04	2.31**
Groundwater x rice	0.15	1.71*
Groundwater x chilies	0.45	2.11**
Constant	8.95	3.36***
Observations	1,113.00	
R-square	0.45	

Note: Production measured in kilograms; ha = hectares.
***Significant at 1 percent.
**Significant at 5 percent.
*Significant at 10 percent.

Table B.6: Dependent Variable: Value of Fertilizer Expenditure

	Coefficient	t-stat
Land (ha)	94.43	1.39
Canal-irrigated land (ha)	660.11	3.60***
Tank-irrigated land (ha)	692.34	4.65***
Tubewell-irrigated land (ha)	399.42	3.29***
Borewell-irrigated land (ha)	435.32	3.41***
Pumpset (dummy)	180.75	0.43
Rabi season (dummy)	–299.47	–1.76*
Summer season (dummy)	355.22	1.39
Red sandy soil (dummy)	186.99	2.66***
Black soil (dummy)	232.92	3.34***
Chaudu soil (dummy)	280.62	3.38***
Extension (dummy)	–181.51	–0.21
Female-headed household	–1,784.16	–2.11**
Age of head of household	4.49	0.29
Education of head of household	22.17	0.18
Cultivators in household (number)	315.56	1.92*
Laborers in household (number)	–345.65	–2.39**
Off-farm nonagricultural workers (number)	–722.60	–2.29**
Scheduled tribe	–1,550.92	–1.84*
Scheduled caste	–1,600.94	–2.16**
Other backward caste	–1,037.31	–1.51
Wealth index	2457.82	1.32
Draught animals (number)	144.72	0.81
Sheep (number)	47.32	0.44
Goats (number)	71.92	1.07
Distance to fertilizer shop (km)	–33.19	–1.11
Share of maize land	–1,950.32	–1.40
Share of groundnut land	1,828.03	1.33
Share of cotton land	617.52	1.05
Share of chilies land	3,526.50	2.90***
Share of turmeric land	3,569.64	2.86***
Share of pulses land	–83.87	–0.08
Share of other crops	1,616.61	0.79
Male wage (village)	–19.73	–0.22
Constant (village)	6,841.99	1.07
Observations	491.00	
R-square	0.56	

Note: Village level price variables for major crops were included but not shown as insignificant; ha = hectares.
***Significant at 1 percent.
**Significant at 5 percent.
*Significant at 10 percent.

Table B.7: Dependent Variable: Value All Inputs Expenditure

	Coefficient	t-stat
Land (ha)	43.29	0.30
Canal-irrigated land (ha)	2,080.30	5.63***
Tank-irrigated land (ha)	1,833.91	6.24***
Tubewell-irrigated land (ha)	2,086.32	8.64***
Borewell-irrigated land (ha)	1,674.16	6.71***
Pumpset (dummy)	–74.25	–0.08
Rabi season (dummy)	–1463.38	–4.46***
Summer season (dummy)	–485.95	–0.89
Red sandy soil (dummy)	422.87	2.84***
Black soil (dummy)	530.38	3.57***
Chaudu soil (dummy)	848.73	4.78***
Extension (dummy)	2,163.85	1.17
Female-headed household	–3,443.59	–1.95**
Age of head of household	24.19	0.73
Education of head of household	–94.22	–0.35
Cultivators in household (number)	–86.85	–0.25
Laborers in household (number)	–302.06	–0.98
Off-farm nonagricultural workers (number)	–1,437.84	–2.20**
Scheduled tribe	326.18	0.19
Scheduled caste	–305.26	–0.20
Other backward caste	1,166.22	0.82
Wealth index	8,714.84	2.21**
Draught animals (number)	–267.84	–0.70
Sheep (number)	722.09	3.07***
Goats (number)	10.67	0.07
Distance to fertilizer shop (km)	–44.89	–0.71
Share of maize land	–271.01	–0.09
Share of groundnut land	4,623.78	1.55
Share of cotton land	2,468.32	1.99**
Share of chilies land	9,236.46	3.52***
Share of turmeric land	5,975.32	2.20**
Share of pulses land	801.12	0.36
Share of other crops	6,347.78	1.44
Rice price (village)	–5.14	–0.70
Maize price (village)	–4.58	–1.28
Groundnut price (village)	0.71	0.40
Cotton price (village)	6.57	0.84
Chilies price (village)	1.16	1.14
Turmeric price (village)	–0.46	–0.54
Pulses price (village)	–1.09	–1.01
Other prices (village)	0.40	0.57
Male wage (village)	55.17	0.28
Constant (village)	–1,0748.02	–0.83
Observations	514	
R-square	0.60	

Note: Value in rupees.
***Significant at 1 percent.
**Significant at 5 percent.

Table B.8: Total Household Labor Demand (days)

	Coefficient	t-stat
Land cropped	–0.40	–0.06
Canal-irrigated land	58.10	3.42***
Tank-irrigated land	51.02	6.32***
Tubewell-irrigated land	86.34	8.40***
Borewell-irrigated land	40.07	3.63***
Share of maize land	–10.93	–0.07
Share of groundnut land	21.12	0.13
Share of cotton land	100.20	1.50
Share of chilies land	120.60	0.92
Share of turmeric land	–12.27	–0.09
Share of pulses land	–17.92	–0.13
Share of other crops	557.04	2.36**
Share of red sandy soil	–172.12	–2.63***
Share of black soil	–12.59	–0.22
Share of *chaudu* soil	–85.87	–1.49
Draught animals (number)	48.78	2.56***
Goats (number)	–5.96	–0.79
Education of head of household	–16.52	–1.14
Female-headed household	–137.53	–1.35
Age of head of household	2.13	0.90
Female children (number)	–14.37	–0.61
Male adults (number)	11.35	0.40
Female adults (number)	101.85	2.92***
Elderly male (number)	–35.25	–0.51
Elderly female (number)	–44.65	–0.68
Scheduled tribe	105.56	1.16
Scheduled caste	66.65	0.83
Other backward caste	84.02	1.18
Wealth index	412.22	2.14**
Male wage (village)	–3.87	–0.31
Constant	3.50	0.01
Observations	471	
R-square	0.52	

***Significant at 1 percent.
**Significant at 5 percent.

Table B.9: Dependent Variable: Demand for Own Household Labor (days)

	Coefficient	t-stat
Land cropped	5.66	1.82*
Canal-irrigated land	5.24	0.66
Tank-irrigated land	–4.44	–1.17
Tubewell-irrigated land	1.37	0.29
Borewell-irrigated land	–0.78	–0.15
Share of maize land	43.28	0.59
Share of groundnut land	111.81	1.44
Share of cotton land	34.71	1.09
Share of chilies land	102.92	1.67*
Share of turmeric land	35.54	0.56
Share of pulses land	–42.55	–0.63
Share of other crops	–14.72	–0.13
Share of red sandy soil	–148.50	–4.82***
Share of black soil	–20.49	–0.75
Share of *chaudu* soil	–95.51	–3.51***
Draught animals (number)	27.37	3.06***
Goats (number)	–3.62	–1.03
Education of head of household	–12.46	–1.84
Female headed household	–17.35	–0.35
Age of head of household	0.57	0.51
Female children (number)	1.11	0.10
Male adults (number)	33.60	2.52**
Female adults (number)	87.59	5.33***
Elderly male (number)	69.30	2.11**
Elderly female (number)	–38.46	–1.24
Scheduled tribe	86.04	2.00**
Scheduled caste	80.59	2.12**
Other backward caste	93.99	2.82**
Wealth index	61.59	0.68
Male wage (village)	–11.61	–1.95
Constant	438.61	2.05
Observations	464	
R-square	0.33	

***Significant at 1 percent.
**Significant at 5 percent.
*Significant at 10 percent.

Table B.10: Dependent Variable: Hired Labor Demand (days) (Tobit)

	Coefficient	t-stat
Land cropped	–6.29	–0.95
Canal-irrigated land	52.67	3.15***
Tank-irrigated land	55.44	6.90***
Tubewell-irrigated land	85.03	8.35***
Borewell-irrigated land	41.15	3.73***
Share of maize land	–71.53	–0.41
Share of groundnut land	–92.73	–0.56
Share of cotton land	64.23	0.94
Share of chilies land	8.25	0.06
Share of turmeric land	–58.17	–0.43
Share of pulses land	32.24	0.20
Share of other crops	569.70	2.44**
Share of red sandy soil	–39.39	–0.59
Share of black soil	4.09	0.07
Share of *chaudu* soil	5.08	0.09
Draught animals (number)	21.64	1.12
Goats (number)	–2.52	–0.31
Education of head of household	–5.69	–0.39
Female headed household	–112.38	–1.12
Age of head of household	1.56	0.66
Female children (number)	–12.63	–0.53
Male adults (number)	–21.82	–0.76
Female adults (number)	18.75	0.51
Elderly male (number)	–101.37	–1.45
Elderly female (number)	–8.52	–0.13
Scheduled tribe	42.35	0.45
Scheduled caste	–14.08	–0.17
Other backward caste	–10.16	–0.14
Wealth index	358.65	1.83*
Male wage (village)	10.31	0.80
Constant	–521.68	–1.12
Observations	435	
R-square	0.48	

***Significant at 1 percent.
**Significant at 5 percent.
*Significant at 10 percent.

APPENDIX C: SINGLE- AND DOUBLE-DIFFERENCE IMPACT ESTIMATES

Single-Difference Estimates from Secondary Sources

Single-difference estimates of the impact of irrigation on crop production are available by comparing irrigated and rain-fed plots in comparable areas. Geographic proximity is taken to ensure comparability. Such estimates are the most common method of estimating the impact of irrigation. Single difference estimates are reported here from the economic analysis for the AP III Implementation Completion Report (ICR), IEG's own reestimation following the ICR methodology, the AP III Baseline Survey, and the IEG survey data.

The SRSP command covers three districts: Karimnagar, Nizamabad, and Warangal. To estimate production impacts in SRSP, the ICR for AP III used data for Karimnagar district, comparing data from the 16 *mandals* that fall entirely within the SRSP command with the 22 *mandals* located outside the SRSP command area and that do not have any significant surface irrigation sources. The SRBC command falls within Kurnool district, from which data were used for the five *mandals* accounting for 90 percent of the command area. Because no irrigation water had been received at the time this report was prepared, these data are the "without project" scenario. The "with project" data are assessed based on ICR mission's field visits and discussions. The SRBC estimates used in the ICR are therefore speculative rather than being based on firm data.

Table C.1 summarizes the results from the ICR's analysis regarding yields, and table C.2 those for cropping patterns and intensity. The years used for the analysis are not stated.

Tables C.3 and C.4 present IEG's own calculations of the same analysis on an annual basis for the years 2002–03 to 2004–05 regarding cropping patterns and intensity. The data show the fall-off in production in the last year, the last year of the drought in which no water was released in the SRSP command. This year can be seen as a natural experiment, the fall in yields (table C.5) partly capturing an "after versus before" irrigation effect (but also showing the impact of general water shortage in unirrigated areas).

The IEG results differ somewhat from those in the ICR. The command area cropping intensity is similar, but lower in the noncommand comparison group *mandals*. In the IEG data the absolute share of paddy is lower in both treatment and comparison groups and the difference smaller. But the paddy remains more common in irrigated areas than unirrigated, especially in the *kharif* season (paddy has quite a high share of noncommand area *rabi* production because *rabi* production is necessarily irrigated). Finally, the reported yields in the ICR are higher than those in the more recent data, though the "natural experiment" of no SRSP releases in the last year gives very similar yield impact estimates to those from the SRSP baseline, which are reported next.

The second set of single-difference estimates is from the AP III baseline report for SRSP. The yields for the command area are based on crop-cutting experiments carried out by the Agriculture Department, and those for noncommand areas in the three districts are based on the data from the Directorate of Economics and Statistics. Where these estimates are not available, SRSP estimates are compared with the state-level estimates. Table C.6 reports the yield estimates obtained in this manner.

A final set of single difference estimates comes from the IEG survey data, taking the comparison of

(text continues on page 71)

Table C.1: Single Difference Yield Estimates (kg 000/ha)

	SRSP		SRBC		Percent increase	
	WOP	WP	WOP	WP	SRSP	SRBC
Paddy (*kharif*)	4.0	4.6	4.5	5.1	15.0	13.3
Paddy (*rabi*)	4.3	5.1	4.0	5.4	18.6	35.0
Maize (*kharif*)	3.3	3.9	n.a.	n.a.	18.2	n.a.
Maize (*rabi*)	4.0	5.0	n.a.	n.a.	25.0	n.a.
Cotton (*kharif*)	1.0	1.5	1.0	1.5	50.0	50.0
Chilies (*kharif*)	n.a.	1.5	n.a.	1.5	n.a.	n.a.
Chilies (*rabi*)	n.a.	1.5	n.a.	1.5	n.a.	n.a.
Groundnut (*kharif*)	n.a.	n.a.	1.0	2.0	n.a.	100.0
Groundnut (*rabi*)	1.1	1.7	1.5	2.5	54.5	66.7
Groundnut (*kharif*)	n.a.	n.a.	1.0	2.0	n.a.	100.0
Sunflower (*kharif*)	n.a.	n.a.	0.6	1.2	n.a.	100.0
Sunflower (*rabi*)	n.a.	n.a.	1.0	2.0	n.a.	100.0
Sorghum (*kharif*)	n.a.	n.a.	1.0	2.0	n.a.	100.0
Sorghum (*rabi*)	n.a.	n.a.	1.5	2.5	n.a.	66.7
Chickpea (*rabi*)	n.a.	n.a.	1.0	2.0	n.a.	100.0

Source: Economic and financial analysis working paper for AP III ICR.
Note: WOP = without project; WP = with project; n.a. = not applicable.

Table C.2: Single-Difference Cropping Pattern (share of cropped area) and Intensity

	SRSP		SRBC	
	WOP	WP	WOP	WP
Cropping patterns				
Kharif				
Paddy	42	70	2	4
Sorghum	0	0	5	4
Sunflower	0	0	5	15
Maize	6	9	0	0
Groundnut	0	0	2	22
Cotton	12	20	15	5
Chilies	0	1	0	5
Rain-fed crops	40	0	0	0
Total	100	100	29	55
Rabi				
Paddy	21	32	2	1
Sunflower	0	0	6	25
Sorghum	0	0	25	0
Chickpea	0	0	40	35
Maize	5	7	0	0
Groundnut	5	6	1	29
Chilies	0	1	0	5
Total	31	46	74	95
Cropping intensity	130	145	103	150

Source: Economic and financial analysis working paper for AP III ICR.
Note: WOP = without project; WP = with project.

Table C.3: Single-Difference Estimate of Cropping Intensity (ratio of gross cropped area to net area sown)

	2002–03	2003–04	2004–05	Average
Command *mandals*	141	151	134	142
Noncommand *mandals*	119	123	116	119
Single difference	22	28	18	23

Table C.4: Crop Shares of Cropped Area, by Season

	2002–03		2003–04		2004–05		
	Kharif	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***	**Total**
Command area							
Paddy	52	53	46	54	29	21	44
Groundnut	0	11	0	10	0	23	4
Cotton	17	0	19	0	35	0	16
Chilies	3	0	4	0	3	0	2
Turmeric	3	0	3	0	5	0	3
Total	100	100	100	100	100	100	100
Memo items							
Total (000 ha)	117	49	119	63	93	31	472
Total as % 2002–03	100	41	102	53	79	27	
Noncommand area							
Paddy	32	38	17	29	13	25	21
Groundnut	2	16	1	12	1	18	3
Cotton	18	0	14	0	39	0	20
Chilies	3	3	2	4	3	0	3
Turmeric	0	0	0	0	0	0	0
	100	100	100	100	100	100	100
Memo items							
Total (000 ha)	88	17	117	26	119	17	384
Total as % 2002–03	100	19	133	30	135	20	

Source: Directorate of Economics and Statistics.
Note: ha = hectares.

Table C.5: Karimnagar District Average Yields (kg/ha), 2000–01 through 2004–05

	2000–01		2001–02		2002–03		2003–04		2004–05	
	Kharif	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***
Rice	3.1	3.1	3.0	3.5	2.6	3.2	3.2	3.2	2.3	2.8
Jowar	0.7	1.0	1.0	1.1	1.0	0.8	0.9	0.9	0.9	1.0
Maize	3.2	4.0	3.5	5.0	3.1	4.4	3.9	4.7	2.3	3.5
Groundnut	0.6	1.9	0.6	2.0	0.5	1.6	0.5	2.1	0.9	1.0
Chilies	2.2	2.3	1.9	2.8	1.4	2.5	1.7	3.3	1.4	3.0
Cotton	0.4		0.2		0.3		0.4		0.2	

Source: Directorate of Economics and Statistics.

Table C.6: Single-Difference Yield Estimates, SRSP (kg 000/ha)

	Kharif			*Rabi*		
	CADA	Non-CADA	% difference	CADA	Non-CADA	% difference
Paddy						
1990–2000	3.1	2.4	27	3.4	2.5	38
1998–99	3.1	2.7	13	3.5	2.9	22
1997–98	2.6	1.9	36	2.9	2.5	18
1996–97	3.0	2.6	14	3.3	2.8	18
1995–96	2.2	2.2	0	2.8	2.6	5
1994–95	2.7	2.5	8	2.9	2.4	21
Maize						
1990–2000	3.8	3.3	15	4.2	3.7	13
1998–99	3.7	3.3	11	5.2	3.6	46
1997–98	2.6	1.9	36	3.6	2.7	36
1996–97	3.0	2.6	14	4.8	3.8	26
1995–96	2.2	2.2	0	3.8	3.1	25
1994–95	2.7	2.5	8	3.6	3.2	14
Groundnut						
1990–2000	n.a.	n.a.	n.a.	1.6	1.2	35
1998–99	n.a.	n.a.	n.a.	1.5	1.5	1
1997–98	n.a.	n.a.	n.a.	1.1	0.9	17
1996–97	n.a.	n.a.	n.a.	1.7	1.5	13
1995–96	n.a.	n.a.	n.a.	1.4	1.0	46
1994–95	n.a.	n.a.	n.a.	1.6	1.1	43

Single-Difference Yield Estimates, SRSP (kg 000/ha)

	Turmeric			Chilies			Cotton		
	SRSP	State	Percent difference	SRSP	State	Percent difference	SRSP	State	Percent difference
1994–95							0.31	0.29	9
1995–96	4.8	4.9	–2	1.6	1.8	–13.0	0.34	0.26	31
1996–97	5.0	4.2	19	2.3	2.2	5.0	0.36	0.32	14
1997–98	5.8	5.7	2	1.6	2.0	–22.0	0.23	0.25	–6
1998–99	5.5	5.6	–2	2.1	2.4	–13.0	0.35	0.20	75
1990–2000	4.2	4.7	–10	1.8	1.8	0	0.34	0.26	30

Source: AFC (Hyderabad) AP III baseline survey.

Note: CADA = Command Area Development Authority, which includes but is greater than the irrigated area; ha = hectares; kg = kilogram; n.a. = not applicable.

Table C.7: Plot-Level Single-Difference Estimates from 2006 Survey Data

	Level			Single difference				Tubewell or borehole
				Kg/ha		Percent		
	Unirrigated	Canal	Tank	Canal	Tank	Canal	Tank	
Paddy *(kharif)*	3.7	3.0	5.6	–0.7	1.9	–19	51	4.6
Paddy *(rabi)*	1.2	4.9	3.0	3.7	1.8	308	150	2.5
Cotton	1.2	1.2	2.0	0.0	0.8	0	67	1.2
Chilies	0.5	0.7	0.8	0.2	0.3	40	60	1.0

Source: IEG survey.
Note: ha = hectares; kg = kilogram.

yields from irrigated plots and unirrigated ones using the 2006 data. These data were collected only in Warangal district. In this presentation (table C.7), "unirrigated" excludes plots irrigated from groundwater by either tubewells or boreholes. The impact is largest for paddy in *rabi,* given the very low reported yield in the unirrigated plots.

There are three sources of bias in the single-difference estimates. First, it is assumed that the "pre-irrigation" values of the indicators were the same in the treatment and controls. However, the irrigated areas tend to be more developed than the unirrigated, having more education, better access to markets, and a lower share of short-term consultants. Hence, these areas may be expected to have higher yields even in the absence of irrigation, so the single-difference estimate has an upward bias.

Second, the estimates assume that irrigated areas are entirely irrigated and unirrigated areas entirely not irrigated. In fact, not all the irrigated area will use canal waters. For this reason, the single-difference estimate underestimates the impact of irrigation. Third, the comparison area will include plots (probably the majority) using groundwater irrigation. Bringing surface irrigation will either replace one source with another or allow conjunctive use of irrigation waters—the impact of either of these being less than that of moving from rain-fed to irrigated farming. Thus, the single-difference estimate is an overestimate of the likely actual impact of canal irrigation being introduced. In summary, two of the biases are upward (an overestimate) and one is downward (an underestimate). (There is also the upward bias from using the treatment of treated effect; see appendix A).

By making some assumptions it is possible to correct the biases. The second bias is most straightforward, because the additional information required is the share of the area that is irrigated in the treatment districts. Data from the baseline survey put this between 60 and 70 percent; the lower figure is taken here, which gives the larger increase in yields. Assuming that yields in the unirrigated part of the treatment group are the same as those for the comparison group, then, for example, the 15 percent increase in *kharif* paddy yields becomes 25 percent. Dealing with the other two sources of bias requires further assumptions: (1) that the social and economic advantages give a pre-intervention yield differential of 20 percent and (2) that the benefit of going from groundwater irrigation to having access to surface irrigation is 60 percent of the benefit of going from rain-fed to surface irrigation, and that this adjustment applies to 50 percent of irrigated plots (the other 50 percent going from rain-fed to canal irrigation).

These assumptions are applied in table C.8. The unadjusted estimate is the average of the ICR estimate and the baseline survey estimate (calculated as an average across all available years). The lower estimate comes from correcting the sources of upward bias and the upper estimate from correcting that for downward bias. The point estimate

Table C.8: Single-Difference Yield Impact Estimates after Adjusting for Sources of Bias (percent increase in yield)

	Unadjusted		Adjusted					
			Kharif			Rabi		
	Kharif	Rabi	Lower estimate	Point estimate	Upper estimate	Lower estimate	Point estimate	Upper estimate
Paddy	16	19	8	17	27	9	20	32
Maize	16	26	8	17	27	12	28	43
Cotton	38	n.a.	18	41	63	n.a.	n.a.	n.a.
Groundnut	n.a.	50	n.a.	n.a.	n.a.	24	53	83

Note: n.a. = not applicable.

results from applying all three corrections at once, these adjusted point estimates being slightly higher than the unadjusted estimates. Considering the upper and lower estimates, the wide range in these figures is not surprising. What is most striking is that for the most important crop—paddy—the largest estimate of the increased yield is still less than one-third, and it may be less than 10 percent. These increases are considerably less than those used at appraisal.

There are two further means to attempt to remove the biases in the single difference estimate. The first is to ensure a valid match, that is, ensure that pre-intervention conditions were the same and trends similar other than the presence of the intervention. The second is to use double differencing to remove the pre-intervention difference.

Controlling for pre-intervention differences can be done in two ways. The first is to consider control at the community level, which was done using the method of propensity score matching described in appendix A. As explained in that appendix, the 18 villages were placed in three groups: no canal irrigation, new canal irrigation between the two surveys, and existing canal irrigation at the time of the first round. The tables show the single difference (changes between the two rounds) for these groups. The no-irrigation category includes tail-end villages intended to receive irrigation that have not actually received it. This approach in principle ensures that communities have common characteristics with regard to education, caste composition, and market access, all of which may affect agricultural productivity. However, as seen in appendix A, making the match proved somewhat difficult, given the fact that villages to be irrigated *are* rather different from those already receiving irrigation. The single-difference village-level estimates are given by the figures in the 2006 column headed "Single difference" in table C.9, which compares 2006 yields in villages newly connected to the canal system with those without such access in either year.

Table C.9: Community-Level Yields by Project Irrigation Status (kg 000/ha)

	2005			2006			Single difference	Change (matched plots)		
	None	New	Existing	None	New	Existing		None	New	Existing
Paddy *(kharif)*	2.9	2.5	1.9	3.2	4.9	3.0	1.7	1.2	0.6	1.5
Paddy *(rabi)*	1.7	1.9	0.7	2.5	4.6	3.7	2.1	–0.7	0.6	1.8
Cotton	0.8	0.8	0.7	1.2	1.8	1.3	0.6	0.1	0.7	0.4
Chilies	0.6	0.4	0.1	1.0	2.0	2.0	1.0	0.5	2.0	0.1

Source: IEG survey.
Note: ha = hectares; kg = kilogram.

Table C.10: Single Difference Paddy Yields by Soil Type, 2006 (kg 000/ha)

	Canal and tank	Groundwater	None	Single difference	
				kg/ha	Percent
All soils					
Kharif	5.1	3.6	4.6	1.5	29
Rabi	3.5	3.0	2.0	0.5	14
Red sandy soils					
Kharif	6.5	3.6	n.a.	2.9	45
Rabi	2.8	2.6	n.a.	0.2	7
Red soils					
Kharif	5.5	3.0	n.a.	2.5	45
Rabi	3.3	2.0	n.a.	1.3	39
Black *choudu*					
Kharif	4.6	4.1	n.a.	0.5	11
Rabi	4.5	3.4	n.a.	1.1	24

Note: ha = hectare; kg = kilogram; n.a. = not applicable.

The community-level data can also be used for before versus after for newly irrigated plots or communities. The average for all plots can be used, or the sample can be restricted to those growing that crop in both 2005 and 2006, thus controlling for ecological conditions (such as soil type). This is the figure shown in the last three columns of table C.9, headed "Change (matched plots)." This "before versus after" approach gives absolute yield increases of 0.7 tons/ha (both seasons), 0.6 tons/ha for cotton, and 2 tons/ha for chilies; in percentage terms these figures are 24 and 32 percent for paddy in the *kharif* and *rabi* seasons, respectively. They are much higher for cotton (88 percent) and chilies (500 percent), though the latter figure is based on too few observations to be a useful estimate. Before versus after estimates are overestimates if there is a general rising trend in yields in nontreatment areas. Table C.9 shows this clearly was the case, so these single differences are upper estimates (and broadly consistent with the upper estimates shown in table C.8, calculated by adjusting for the bias in the treatment-comparison group single-difference data discussed above).

The match can also be improved by controlling for soil type. Sample sizes are too small to do this for any crop other than paddy, and the comparison has to be for canal and tank irrigation versus groundwater irrigation. The results, shown in table C.10, give estimates of increased yields ranging from 11 to 45 percent.

Measuring Impact Using Double Differences

The double-difference impact estimate is the difference in the change in the indicator of interest between the treatment (project) and untreated (comparison) areas, or, equivalently, the change in the difference.

Using the first definition, the single difference is the before versus after comparison of the indicator in the project area. Before versus after does not yield a reliable measure of impact because other factors will have influenced the outcome during the intervention. This bias is removed by the double difference, which compares the change in the project area with the change in the comparison area, where the comparison area has been subject to the same trends, with the important exception of the intervention being absent.

Using the second definition, the single difference is the estimate reported in the previous section, that is, the postintervention difference between the values of the indicator in the treatment and comparison areas. This approach can be subject to bias if the preintervention values of the indicator were not the same. Hence, the double difference takes this into account by comparing changes between project and comparison groups rather than levels.

The potential problem with double-difference estimates is the presence of selection bias if beneficiaries are selected conditional on variables that are correlated with the indicator under examination. If these selection variables are observable, then this bias can be removed by including them as conditioning variables in the analysis, either using a regression approach or matching observations based on these characteristics. If selection is on unobservables, then the bias cannot be removed, although various approaches might still be used to deduce impact by producing upper or lower estimates if reasonable assumptions might be made to calculate the magnitude of the bias, as was done for the single-difference estimates above.

Approach to double-difference estimates in this study

As described in appendix A, matching for this study was done at the community level. The double-difference estimates are constructed using panel data from the IEG survey at the level of the plot, the household, or the community. Table C.11 summarizes the data. The discussion of yields uses the plot and community-level panels.

The first (or single difference) of the double-difference estimates can be made in two ways. The first means of calculating single difference is to use the 2006 data to compare treatment and control areas, such as reported in the first section of this appendix. At the plot level this approach is the source of the figures in the column headed "Single difference" in table C.7 and discussed above. The community-level results were shown in table C.9. The alternative single difference is the before versus after, also discussed above.

As described above, the double difference is the change in the differences, or difference in the changes. The approach can be biased if the treatment group differs systematically from the control with respect to variables that are also correlated with the outcome. But the bias can be removed by controlling for the selection variables, which this study does in the selection of the communities to be included in the control group. Fixed effects regressions are also used for some outcomes.

But there is a further complication in making double-difference estimates for agricultural vari-

Table C.11: Classifications According to Irrigation Status

Irrigation status	Plot	Household	Community
None	Plot does not receive canal or tank irrigation water	No plots cultivated by the household receive canal or tank irrigation water	Community either not connected to SRPS system, or tail-end village officially connected but not receiving water
New	Plot received canal or tank irrigation water for first time in *kharif* 2005	At least one plot cultivated by the household received canal or tank irrigation water for first time in *kharif* 2005	Community received water for first time in *kharif* 2005
Existing	Plot received canal or tank irrigation water prior to *kharif* 2005	At least one plot owned by the household received canal or tank irrigation water prior to *kharif* 2005	Community received water prior to *kharif* 2005

ables, which are subject to annual variations because of weather conditions. Harvests may be broadly classified as poor, normal, or good, reflecting bad, average, or good years, respectively. Hence, the year-to-year comparison may cover any one of nine possible combinations (bad-bad, bad-good, and so forth).

This creates two problems. First, the impact of irrigation differs between bad and good years; it is expected to be more in bad years, as large-scale irrigation ensures water supply, which is less available to those depending on groundwater sources. By contrast, in a good year water is plentiful, so canal access matters less. (These observations need to be further caveated by season: they apply to the *kharif* season, in the survey areas *rabi* crops, and summer crops are irrigation dependent). So observations are needed across different types of year to average the effect. The second problem is that 2005 was not a bad year but a disastrous one, in which no water was officially released in the SRSP command. Hence the "already irrigated" sample did not receive water that year (though a small number do claim to have done so).

Double-difference estimates

Yield

Yield estimates were calculated at the plot level, with plots matched by both plot and season. Hence, only those plots having the same crop, during the same season, in consecutive surveys are used in the analysis. The project group is identified in two ways: those plots using a new irrigation source in 2006 (calculated separately for canal, tank, tube, and borehole) and those plots using a new irrigation source in 2006 that did not have access to irrigation in 2005. The comparison group for the first treatment group consists of those plots with no change in irrigation source between 2005 and 2006. The comparison group for the second treatment group comprises plots with no irrigation in both 2005 and 2006.

These calculations are made for the four major crop categories: paddy, cotton, chilies, and turmeric. The results are shown in table C.12. In some cases, the sample size of the panel is too small, so the difference reported is that between the unmatched group means. In other cases, the sample size is too small for any estimates to be made. Hence, although Control 2 is more appropriate, Control 1 has to be used. Table C.13 reports the double-difference estimates of cropping intensity. The impact of canal irrigation is toward the upper end of those reported above, though the impact of tanks is lower and, as explained elsewhere, tank irrigation picks up some of the effect of canal water.

Table C.12: Double Difference Estimates of Impact on Yield (kg 000/ha)

	Single difference		Double difference	
	Control 1	Control 2	Control 1	Control 2
Paddy				
New canal	1.3	1.4	0.7	1.0
New tank	1.4	1.7	0.7	1.4
New bore	1.0	1.7	0.3	1.8
New tube	1.4	1.6	0.7	1.3
None	0.7	0.3	n.a	n.a
Cotton				
New canal	0.7[a]	. .	0.7	. .
New tank	0.6	1.0	0.6	0.7
New bore	0.4	0.7	0.4	0.4
New tube	0.5[a]	1.0	0.5	0.7
None	0.2	0.2	n.a	n.a
Chilies				
New canal	0.4[a]	. .	0.2	. .
New tank	0.7[a]	. .	0.4	. .
New bore	0.6[a]	0.7[a]	0.4	0.0
New tube	1.4[a]	1.7[a]	1.2	0.9
None	0.2	0.7[a]	0.0	0.0
Turmeric				
New canal	. .	. .	. .	. .
New tank	1.6[a]	. .	1.0	. .
New bore	1.2[a]	. .	0.6	. .
New tube	1.2	. .	0.7	. .
None	0.6	. .	0	. .

Source: IEG survey.
Note: . . = not calculated owing to small sample size.
a. Based on difference in simple (unmatched) group means (because of small panel sample size).

Table C.13: Double-Difference Impact on Cropping Intensity

	Control 1	Control 2
New canal	41	. .
New tank	14	21
New bore	13	4
New tube	11	16
None	0	0

Note: . . = not calculated.

The impact estimates are calculated as follows: (1) paddy—simple average of canal and tank double difference using Control 2; (2) cotton—simple average of tank double difference using Control 2, and twice the Control 1 estimate for canal, on the grounds that the Control 2 estimates are approximately twice those of Control 1; and (3) turmeric and cotton—simple average of canal and tank double difference using Control 1. The choices for making the estimates err on the side of overestimating the benefits. But as noted in the main text, estimated impact is on average only half that expected at appraisal.

It should be mentioned that the yield impact estimates in I&CADD's project completion report (I&CADD 2004) are higher, averaging around 100 percent for paddy in Karimnagar and Warangal districts; the season is not stated by the date of data collection (March–May), which suggests it may be *rabi* when the impact is higher. However, the data in that report are suspect because they also discuss impact in the SRBC command,

Table C.14: Double-Difference Estimates of Household-Level Employment Effects

		Domestic labor (days)	Employment		
			Kharif (days)	Rabi (days)	Total
Single difference					
New canal	Control 1	–107	55	74	113
	Control 2	. .	. .	91	. .
New tank	Control 1	–508	43	106	145
	Control 2	–887	45	86	126
New tubewell	Control 1	166	40	28	196
	Control 2	311	38	34	82
New borehole	Control 1	–827	20	30	75
	Control 2	–640	10	42	89
None	Control 1	–216	24	30	44
	Control 2	140	5	19	31
Double difference					
New canal	Control 1	109	31	44	69
	Control 2	. .	. .	. .	. .
New tank	Control 1	–292	19	76	101
	Control 2	–1027	40	67	95
New tubewell	Control 1	382	16	–2	152
	Control 2	171	33	15	51
New borehole	Control 1	–611	–4	0	31
	Control 2	–780	5	23	58

Note: . . = not calculated.

despite the fact that no water had been released there at the time the report was written. In the case of paddy yields, the completion report cites a 53 percent increase in "project villages" in SRBC. There was no irrigation there, so this increase can be combined with the 100 percent increase in SRSP to give a double-difference yield impact estimate of approximately 50 percent, which is more consistent with the estimates used in this study.

Employment

Double-difference employment effects were calculated using the household panel by averaging across the various irrigation categories (as used for yields above). These results (table C.14) show that adoption of canal or tank irrigation increases employment throughout the year between 80 and 100 days. The fixed-effects regression (table C.15) gives the same result.

The community-level panel can be used to consider employment from the employee rather than the employer perspective. The data show that a new canal gives an increase in household agricultural employment of about 80 days more than that with no irrigation (table C.16). The community-level analysis also shows wage effects. Wages, especially for women, rose across the district in 2006, by most in areas with new canal irrigation (table C.16).

Summary of SRSP Estimates

Table C.17 summarizes the various estimates of the impact of irrigation on paddy yields. These results are expressed in percentage terms, but it should be remembered that it is the absolute increase that matters for the rate of return analysis, because it is the absolute increase in net farm income that constitutes the core of the project benefits (especially for paddy, which has the largest crop share). The "without project" value assumed in the staff appraisal report (SAR) (3.2 tons/ha) is toward the upper end of those observed in the district—indeed at levels only recently attained in the SRSP command itself (figure C.1). Table C.18 provides a summary of estimates for cropping intensity.

Table C.15: Fixed-Effects Regression of Employment Effects

	Kharif	*Rabi*	Total
Canal	33.8	27.1	60.9
	–1.0	–1.1	–1.3
Tank	–22.6	–41.3	–64.0
	–1.1	(2.76)***	(2.28)**
Tubewell	1.6	22.5	24.2
	–0.1	–1.4	–0.8
Borehole	24.3	48.0	72.4
	–1.3	(3.56)***	(2.86)***
Canal* area	–2.0	4.8	2.8
	–0.6	(2.03)**	–0.6
Tank* area	14.3	24.1	38.4
	(4.73)***	(10.77)***	(9.17)***
Borehole* area	–1.2	–11.8	–13.0
	–0.4	(5.41)***	(3.17)***
Tubewell* area	1.6	–9.4	–7.9
	–0.5	(4.26)***	(1.90)*
Constant	78.8	18.1	96.8
	(6.68)***	(2.08)**	(5.94)***
Observations	916	916	916
R-squared	0.32	0.09	0.43
Marginal effect at mean area			
Canal	20	61	81
Tank	37	60	97
Tubewell	11	–37	–26
Borehole	9	–21	–12

Note: Absolute value of t statistics in parentheses.
*Significant at 10 percent.
**Significant at 5 percent.
***Significant at 1 percent.

Table C.16: Change in Employment (days/household/year) and Wages (Rs/day)

	Change in employment	Change in wages	
		Female	Male
None	33	2.1*	0.2
New	114*	3.3*	–1.9
Existing	42*	1.8	2.9*

Source: IEG survey.
*Significant at 5 percent.

Srisalam Right Bank Canal

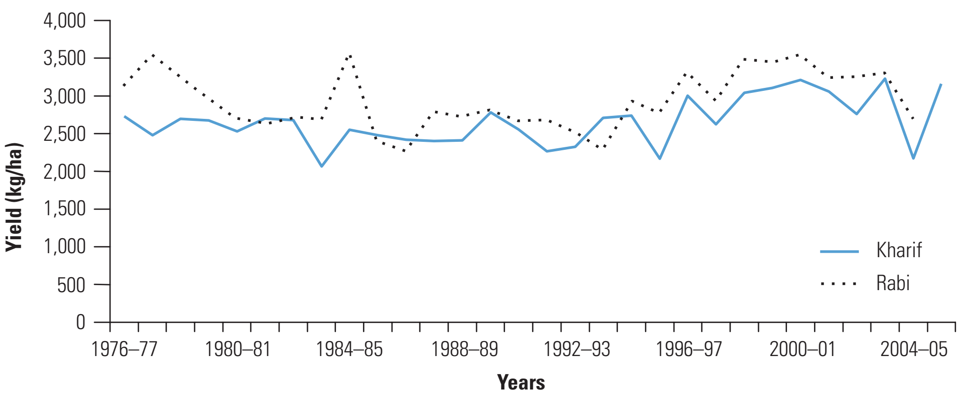
Because the SRBC command has not yet received irrigation, there are no ex post data available for impact analysis. The approach adopted here is that appraisal estimates are overly optimistic, so that lower percentage increases are assumed. Table C.19 shows the appraisal and ICR estimates, together with those used in this study. The initial yields used are usually the lower of the estimates from the two sources. In the case of paddy, the lower of the two estimates (from the SAR) is still the highest level achieved in Kurnool district in the last 15 years; the average from 1989–90 to 2003–04 has been 2.6 tons/ha, peaking at 3.2 tons/ha in 2000–01 (data from the Directory of Economics and Satistics, Andhra Pradesh).

Table C.17: Summary of Impact on Rice Yields (percentage increase)

		Kharif		***Rabi***	
		Single difference	**Double difference**	**Single difference**	**Double difference**
ICR		15	n.a.	19	n.a.
IEG	*Mandal*-level	63	n.a.	37	n.a.
	"Natural experiment"	63	14	34	66
	Community level	53	84	84	135
	Community level (matched plots)	29	–24	14	n.a.
	Plot-level	32	24	46	33
AFC (SRSP baseline)	16	n.a.	20	n.a.	
Adjusted single difference	17	n.a.	20	n.a.	
Memo: assumed in SAR	69	n.a.	69	n.a.	

Notes: ICE = Implementation Completion Report; n.a. = not applicable; SAR = Staff Appraisal Report.

Figure C.1: Yields in the SRSP Command Area



Source: I&CADD and Directorate of Economics and Statistics.

Table C.18: Estimates of Impact on Cropping Intensity

		Single difference	Double difference
ICR		15	n.a.
IEG	*Mandal* level	23	n.a.
	"Natural experiment"	17	10
	Plot level	14	21

Note: n.a. = not applicable.

Table C.19: SRBC Yield Impact Estimates

	SAR		ICR		This study		Percentage change		
	WOP	WP	WOP	WO	WOP	WP	SAR	ICR	This study
Kharif									
Paddy	3.2	5.4	4.5	5.1	3.2	3.8	69	13	20
Cotton	1.1	2.5	1.0	1.5	1	1.5	127	50	50
Sorghum	1.2	2.5	1.0	2.0	1	1.6	108	100	60
Sunflower	0.6	1	0.6	1.2	0.5	0.8	67	100	67
Groundnut	1	2.2	1.0	2.0	1	1.6	120	100	60
Chilies	0.9	2.5	n.a	1.5	0.8	1.6	178	n.a.	60
Rabi									
Paddy	n.a.	n.a.	4.0	5.5	3.6	5.0	n.a.	38	40
Groundnut	1.0	2.5	1.5	2.5	1.0	1.7	150	67	67
Sorghum	1.2	3	1.5	n.a.	1.2	2.0	150	n.a	67
Sunflower	0.6	2	1.0	1.8	0.6	1.1	233	80	80
Chickpea	0.6	1.5	1.0	2.0	0.6	1.1	150	100	80

Source: IEG data.
Notes: n.a. = not applicable; SAR = Staff Appraisal Report; WOP = without project; WP = with project.

Table D.1: Irrigation Spending and Potential Created in Andhra Pradesh

	Amount spent (million Rs.)			Irrigation potential created (million ha)		
	Major and medium	Minor	Total	Major and medium	Minor	Total
Preplan period 1951	—	—	—	1.33	1.37	2.70
First plan (1951–56)	375	35	410	0.08	0.03	0.10
Second plan (1956–61)	574	44	618	0.18	0.02	0.20
Third Plan (1961–66)	915	186	1,101	0.37	0.05	0.42
Three annual plans (1966–69)	609	108	717	0.08	0.04	0.12
Fourth plan (1969–74)	1,187	182	1,369	0.19	0.06	0.25
Fifth plan (1974–78)	2,691	388	3,079	0.21	0.09	0.31
Two annual plans (1978–80)	2,577	238	2,815	0.15	0.06	0.21
Sixth plan (1980–85)	7,296	411	7,707	0.31	0.08	0.39
Seventh plan (1985–90)	13,064	1,314	14,378	0.09	0.07	0.16
Annual plan (1990–91)	2,828	478	3,305	0.01	0.01	0.02
Annual plan (1991–92)	3,339	486	3,825	0.01	0.01	0.02
Eighth plan (1992–97)	22,653	1,869	24,522	0.04	0.04	0.08
Ninth plan (1997–2002)	50,272	7,757	58,029	0.58	0.03	116,058.61
Tenth plan (2002–07)	91,538	16,072	107,610	n.a.	n.a.	0.94

Note: n.a. = not applicable; — = not available.

Table D.2: SRSP: Actual Area Irrigated as a Percentage of Planned Area Irrigated

	1995–96	1996–97	1997–98	1998–99	1999–2000
Above Lower Manair Dam					
Kharif					
Head	129	94	140	87	85
Middle	55	74	78	49	85
End	45	40	68	88	88
Rabi					
Head	55	76	. .	51	42
Middle	52	57	. .	66	n.a.
End	50	52	. .	67	99
Below Lower Manair Dam					
Kharif					
Head	25	44	59	66	73
Middle	42	38	55	113	110
End	50	51	53	97	89
Rabi					
Head	26	41	. .	55	94
Middle	45	44	. .	98	112
End	40	42	. .	76	n.a
Simple average	51	54	75	76	88

Source: AFC SRSP baseline survey, pp. 127–29.
Note: . . = no water released this season; n.a. = not applicable.

Table D.3: Area under Different Irrigation Sources as Percent of Total Area

	2005	2006
Canal	4.6	5.2
Tank	7.8	20.5
Tube	44.8	50.5
Bore	27.0	26.5
None	23.6	11.3

Source: IEG survey.
Note: Sums to more than 100, as some plots have multiple sources.

Table D.4: WUA Membership by Socioeconomic Characteristics (% households with WUA member), 2006

		% households with member	
	Category	All households	Cultivating households only
Landowning	Landless	0.0	0.0
	Marginal	18.4	18.4
	Small	12.2	12.2
	Large	28.2	28.2
Education	None	8.4	13.7
	Primary	20.7	30.1
	Higher than primary	15.6	24.7
Caste	Scheduled caste	13.3	28.5
	Scheduled tribe	5.0	6.7
	Backward caste	13.2	21.8
	Other caste	20.5	28.0
Wealth	1	0.8	2.0
	2	7.6	11.4
	3	9.3	13.7
	4	28.0	37.0

Source: IEG survey.

Table D.5: Gini Coefficients for Land Ownership by Irrigation Source

	Canal and tank	Tubewell and borehole	All land
2005	0.57	0.40	0.35
2006	0.45	0.39	0.34

Source: IEG survey.

Table D.6: Share of Irrigated Land Owned by Wealth Quartile

	Canal	Tank	Tubewell	Borehole	All land
2005					
1	4	10	7	7	8
2	5	10	23	14	19
3	23	9	28	24	26
4	69	71	43	54	47
2006					
1	13	6	4	7	8
2	14	16	16	22	22
3	43	12	17	27	24
4	31	65	63	44	47
Total	100	100	100	100	100

Source: IEG survey.

Table D.7: Involvement in WUA Activities by Wealth Quartile (percent), 2006

Quartile	Member	Regularly attend meetings	Take part in O&M	Take part in decision making	Influence water management
1	0.8	0.2	0.0	0.0	0.0
2	7.6	1.1	3.6	1.7	3.1
3	9.3	1.8	3.2	1.3	0.6
4	28.0	11.0	11.1	4.7	4.4

Source: IEG survey.

Table D.8: Actual and Expected Crop Yields (kg 000/ha)

		Staff appraisal report		
Crop	Handbook of statistics (2003–04)	Without project	With project	IEG survey
Paddy	2.2	3.2	5.4	3.8
Cotton	2.4	1.1	2.5	1.9
Chilies	n.a.	0.9	2.5	1.6
Turmeric	n.a.	3.2	4.0	2.0

Sources: Handbook of Statistics Warangal District 2003–04; AP III ICR, appendix 10.
Note: ha = hectare; kg = kilogram; n.a. = not applicable.

Table D.9: Crops Shares in Crop Income (percent)

	Rice	Cotton	Maize	Chilies	Turmeric	Groundnut	% exclusive rice producers
2005							
Irrigation source							
Canal	61.7	24.7	0.5	6.8	2.1	2.7	42.1
Tank	61.2	16.8	6.1	2.2	2.9	0.8	48.1
Bore	37.9	36.5	2.9	8.5	5.3	2.7	17.4
Tube	42.1	36.2	0.9	6.3	4.2	3.1	20.0
None	32.1	32.6	1.7	6.5	3.5	1.2	22.0
Number of sources							
0	32.1	32.6	1.7	4.5	0.7	1.2	22.0
1	41.2	35.0	2.2	7.3	4.3	2.7	22.3
2	49.2	27.4	4.9	6.0	6.0	2.4	22.9
Total	39.4	33.8	2.3	6.5	3.5	2.2	22.4
2006							
Irrigation source							
Canal	59.0	15.4	4.2	10.3	7.5	2.8	32.3
Tank	59.7	25.4	2.0	3.5	4.3	1.9	38.8
Borehole	44.5	30.2	2.0	8.0	6.7	2.2	17.4
Tubewell	42.4	28.9	2.8	8.4	8.0	5.5	18.5
None	43.6	34.2	4.8	1.0	1.0	2.2	20.0
Number of sources							
0	43.6	34.2	4.8	1.0	1.0	2.2	20.0
1	48.6	27.7	2.4	7.4	5.0	3.0	23.7
2	47.8	27.1	2.3	7.2	11.1	2.7	21.5
Total	48.1	28.3	2.5	6.8	5.5	2.9	

Source: IEG survey.
Note: Income is sales + imputed value of own consumption.

Table D.10: Sources of Information on Agriculture-Related Matters

	Received information (percentage of cultivating households)	Source from which received information (as a percent of those who received information)			
		Friends and family	Extension worker	Training	Community worker
2005					
Use of fertilizer	7.7*	7.8	2.2	13.2*	74.7
Seeds	7.0*	8.5*	0.0	5.2	84.0
Pest management	0.9*	39.7	0.0	22.5	18.9
Soil conservation	1.0*	84.0*	0.0	16.0	0.0
Agricultural marketing	0.2	100.0	0.0	0.0	0.0
Irrigation methods	0.3	0.0	0.0	0.0	0.0
O&M of canals	0.0	n.a.	n.a.	n.a.	n.a.
Water management	0.2	100.0	0.0	0.0	0.0
2006					
Use of fertilizer	6.7*	50.4*	0.0	16.5	26.3
Seeds	3.4*	39.3*	0.0	32.0*	18.2
Pest management	1.5*	0.0	0.0	75.1*	0.0
Soil conservation	0.3	0.0	0.0	0.0	0.0
Agricultural marketing	4.1*	64.7*	0.0	6.2	18.7
Irrigation methods	0.4	0.0	0.0	100.0	0.0
O&M of canals	0.0	n.a.	n.a.	n.a.	n.a.
Water management	0.0	n.a.	n.a.	n.a.	n.a.

Source: IEG survey.
Note: n.a. = cannot be calculated as 0 positive responses to screening question; O&M = operations and maintenance.
*Significant at 5 percent.

Table D.11: Gross and Net Cropped Area (hectares), 2005 and 2006

	Cultivated area (net cropped area)	Gross cropped area	Cropping intensity
2005	1,610	2,414	150
2006	1,760	2,738	156
Percent increase	9.4	13.4	3.7

Source: IEG survey.

Table D.12: Cropping Intensity by Irrigation Source and Number of Sources

	2005	2006
Irrigation source		
Canal	202	199
Tank	148	151
Tube	159	168
Bore	143	169
None	139	90
Total	150	156
Number of sources		
0	139	90
1	150	161
2	180	182

Source: IEG survey.

Table D.13: Average Crop Prices, 2005 and 2006 (Rs per quintal)

	2005		2006	
	Mean	Median	Mean	Median
Rice	718	672	605	581
Maize	929	643	511	500
Groundnut	1,063	977	1,420	1,447
Cotton	1,692	1,714	1,797	1,798
Chilies	1,430	1,441	2,272	2,129
Turmeric	1,011	606	1,605	1,550
Pulses	1,448	1,136	1,632	1,683
Jowar	2,000	2,000	900	900

Source: IEG survey.

Table D.14: Means of Water Transfer to Field by Irrigation Source, 2006

	Canal	Tank	Bore	Tube
Free intake	74	80	18	8
Manual pump	0	1	3	4
Electric pump	26	19	78	87
Other	0	0	1	1

Source: IEG survey.

Table D.15: Agricultural Employment (average days per household)

	Outside employment			Own farm	
Year	All households	Cultivating households	Noncultivating households	All households	Cultivating households
2005	155	57	306	221	336
2006	223	157	313	190	317

Source: IEG survey.

Table D.16: Average Employment of Outside Labor by Season (days)

Season	2005	2006
Kharif	98	145
Rabi	2	46
Total	99	191

Source: IEG survey.

Table D.17: Agricultural Employment by Gender (days)

	2005	2006	Change
Kharif			
Female	63	101	38
Male	37	34	–2
Rabi			
Female	1	91	90
Male	1	54	54
Total			
Female	64	199	135
Male	38	114	76
Percent female in total	63	64	64

Source: IEG survey.
Notes: Total is taken as total of subsample means. Differences caused by rounding.

Table D.18: Agricultural Employment by Wealth and Landholding (average days per household), 2005

Quartile	All households	Cultivating households	Landholding	All households	Cultivating households
1	278	88	Landless	306	n.a.
2	123	50	Small	79	79
3	159	70	Marginal	22	22
4	62	41	Large	21	21

Source: IEG survey.
Note: n.a. = not applicable.

Table D.19: Employment of Domestic Labor by Wealth and Landholding (average days per household), 2005

Quartile	All households	Cultivating households	Landholding	All households	Cultivating households
1	134	290	Landless	n.a.	n.a.
2	227	308	Small	273	273
3	239	348	Marginal	400	400
4	282	364	Large	461	461

Source: IEG survey.
Note: n.a. = not applicable.

Table D.20: Agricultural Employment by Wealth and Landholding (average days per household), 2006

Quartile	All households	Cultivating households	Landholding	All households	Cultivating households
1	294	209	Landless	316	n.a.
2	234	182	Marginal	223	210
3	239	168	Small	135	128
4	132	108	Large	66	65

Source: IEG survey.
Note: n.a. = not applicable.

Table D.21: Employment of Domestic Labor by Wealth and Landholding (average days per household), 2006

Quartile	All households	Cultivators only	Landholding	All households	Cultivators only
1	82	265	Landless	0	n.a.
2	171	269	Marginal	244	265
3	223	338	Small	355	361
4	273	357	Large	383	390

Source: IEG survey.
Note: n.a. = not applicable.

Table D.22: Agricultural Employment by Wealth and Land Ownership, 2005

	Workers as percentage of those age 16–65		Days worked as percent of available days	
	Outside employment	Own farm	Outside employment	Own farm
Wealth quartile				
1	50	29	21	9
2	23	55	10	15
3	25	47	10	15
4	11	52	4	18
Landholding				
None	57	n.a.	23	n.a.
Marginal	10	67	5	19
Small	3	80	1	23
Large	7	72	2	27
All	27	45	11	14

Source: IEG survey.
Note: n.a. = not applicable.

Table D.23: Agricultural Employment by Wealth and Land Ownership, 2006

	Days worked as percent of available days		Days worked as percent of available days	
	Outside employment	Own farm	Outside employment	Own farm
Wealth quartile				
1	73	23	24	7
2	59	41	18	12
3	53	49	17	15
4	29	46	9	19
Landholding				
None	68	n.a.	25	n.a.
Marginal	55	59	15	18
Small	38	70	9	24
Large	20	65	6	27
All	53	40	17	14

Source: IEG survey.
Note: n.a. = not applicable.

Table D.24: Agricultural Day Wage (Rs/day)

	2005		2006	
	Female	Male	Female	Male
Mean	24.95	48.09	27.50	70.72
Median	25	50	30	50

Source: IEG survey.
Note: n.a. = not applicable.

Table D.25: Distribution of Wages by Year by Sex (Rs/day)

	Female		Male	
	2005	2006	2005	2006
<=20[a]	44	13	1	0
25	28	45	0	1
30	26	41	7	16
35	0	0	1	0
40	1	0	3	9
45	0	0	3	0
50	0	1	74	63
55	0	0	2	0
60	0	0	10	4
65	0	0	0	0
70	0	0	0	7

Source: IEG survey.

a. There is just one female observation below 20 in both years.

Table D.26: Socioeconomic Characteristics by Reach on Distributary Canal

Reach	Adult literacy	Scheduled caste (%)	Scheduled tribe (%)	Pucca road (%)	Distance to Warangal (km)
Head	48.1	15.7	20.1	67	39.1
Middle	45.6	14.1	24.3	74	53.0
Tail	43.6	15.7	18.8	65	76.4

Source: Calculated from Andhra Pradesh census.

APPENDIX E: THE FARM MODEL, RATE OF RETURN ANALYSIS, AND DISTRIBUTIONAL IMPACTS

The farm model, based on that in the SAR, shows farm income without project (WOP) and with irrigation (with project, WP) for a typical hectare. Farm models are estimated separately for SRBC and SRSP. The basis for the yield increases and crop shares is explained in appendix C. Farm inputs are assumed to increase with irrigation, though not by as much as assumed in the SAR. These increases in inputs as a result of irrigation are confirmed by the multivariate analyses (tables B.6–B.10). The smaller increase than that expected at appraisal can be linked to the reduced delivery of extension services. Lower inputs are one reason that actual yields are lower than those anticipated at appraisal.

The farm budget is for a typical hectare, with the net income calculated as a weighted average of net income from each crop (the weights being the share in gross cropped area), the total multiplied by cropping intensity. The resulting net farm incomes with and without the project are shown in table E.1. In the case of SRSP, the IEG estimate lies between those from the SAR and the ICR. But the estimated increase in net farm income in the SRBC command is less than half that calculated by the other two reports. As explained at various points in this report, there is no irrigation yet in the SRBC command. Hence, the ICR relied on "informed judgments" of the sort used in the SAR, presumably explaining the similar estimate. But the figure seems somewhat optimistic, being based on yield increases larger than those observed elsewhere and a diversification into high-value crops, which has not occurred in other places (see appendix B).[1]

The benefits stream in the rate of return analysis is net farm income (valued at economic rather than financial prices, though only the latter are shown here) multiplied by the irrigated area. Given problems in reaching tail-enders and evidence of overestimation of irrigated area by I&CCAD, it is assumed that the irrigated area reaches 80 percent of that stated in the SAR and ICR. This figure may prove optimistic for SRBC, where the Bank has questioned the adequacy of the water supply. The results (table E.2) show the low return to these investments. Estimates are shown, including all investment costs for both AP II and AP III, which is the relevant figure for this report. Economic rates of return (ERRs) calculated using only the AP III investment costs are also shown. Further notes on the calculations will be found in the tables beginning on page 97.

Poverty and Distributional Impact

Benefits per hectare of irrigation

The income benefits are the increment in farm income and wage income to agricultural employees (payment to domestic labor is already included in

Table E.1: Net Farm Income (financial prices) With and Without Project (Rs/ha)

	SAR		ICR		IEG estimates		Percentage increase		
	WOP	WP	WOP	WP	WOP	WP	SAR	ICR	IEG
SRBC	7,469	3,4356	4,894	24,089	5,970	15,526	360	392	160
SRSP	9,796	22,792	8,842	14,965	7,524	16,070	133	69	114

Note: ha = hectare; ICR = Implementation Completion Report; Rs = rupees; SAR = Staff Appraisal Report; WOP = without project; WP = with project.

Table E.2: Estimates of the Economic Rate of Return

	SAR			IEG	
	All costs	Excluding AP II	ICR	All costs	Excluding AP II
SRBC	9	14	12	–2	0
SRSP	31	34	16	5	11
Whole project	19	24	15	2	6

Note: SAR = Staff Appraisal Report.

net farm income; see table E.3). The increase in employment income can be further broken down into higher wages (benefiting all employees) and increased employment. The additional employment is given by the labor demand in the farm model; canal irrigation draws on additional external labor rather than household labor (a result shown in both the double-difference and regression estimates). The distribution of this gain across quartiles is based on the respective share of each quartile in the incremental employment from 2005 to 2006 (table E.4). The benefit from higher wages accrues to all those in employment and is thus distributed across the quartiles according to their share in 2006 employment. The whole of the wage increase is being attributed to irrigation, which is an overestimation, but these benefits are relatively small, so this does not distort the overall picture.

Table E.3: Summary of Farm Model Results (average/ha)

	SRBC		SRSP	
	WOP	WP	WOP	WP
Rs per hectare				
Revenue	10,043	23,748	14,558	26,957
Costs	4,072	8,222	7,034	10,886
Net farm income	5,970	15,526	7,524	16,070
Wages	1,646	3,622	3,316	5,397
Days hired labor	88	188	177	280
Percentage increase				
Revenue		136		85
Costs		102		55
Net farm income		160		114
Wages		120		63
Days hired labor		114		59

Notes: ha = hectare; Rs = rupees; WOP = without project; WP = with project.

The allocation of net farm income is less straightforward, as average and marginal shares of irrigated land show a less clear pattern, although it is clear that the bottom quartile has little and the top quartile has the majority (table D.6). The current distribution of farm income for the model is the observed 2006 distribution, and the incremental income share based on each quartile's share of canal and tank irrigated land in 2006. The distribution of benefits from a hectare of irrigation as a result of these calculations is shown in figure E.1.

Community-level poverty model

To calculate how benefits are distributed across households at the community level, a model was constructed using the 2006 survey data as the baseline. The following assumptions were applied to the data:

Net farm income increases by Rs 8,800 (a weighted average in the incremental net incomes for SRBC and SRSP from the farm models) for each hectare of land the household owns that will become irrigated. The proportion of land irrigated is a function of income (one-fifth for the bottom quartile, one-quarter for the second, one-third for the third, and one-half for the top quartile).

The income of all households from agricultural wages increased by 2.5 percent.

The gain from additional employment is calculated as a percentage increase in agricultural labor income, where the increase is proportionate to each quartile's share in the marginal increase in employment (table E.4), with an adjustment factor to capture the share attributable to irrigation (the adjustment factor brings the gains into line with those from the calculations reported above).

The resulting income gains by quartile are shown in figure E.2, which has a similar overall pattern to figure E.1, the main difference being the smaller benefit to the bottom quartile and larger benefit to the top quartile. The model presentation breaks down the wage and employment effects separately. These two sets of results *need not* be the same, as the former shows the distribution of incremental benefits from irrigating 1 ha of land, whereas the latter captures the effects of a community getting access to irrigation, allowing for differential access to that irrigation.

Poverty impact

The simulation across the data set allows estimation of poverty levels with and without irrigation. Because the bottom quartile receives the least benefits, the poverty impact is very sensitive to the poverty line chosen (table E.5 and figure E.2). The impact is also not that great because of the finding that the bottom quartile does not benefit from the marginal increase in employment. Relaxing that assumption and allocating the employment benefit according to average rather than marginal shares shows a slightly greater poverty impact than for the lower poverty line (scenario 2).[2]

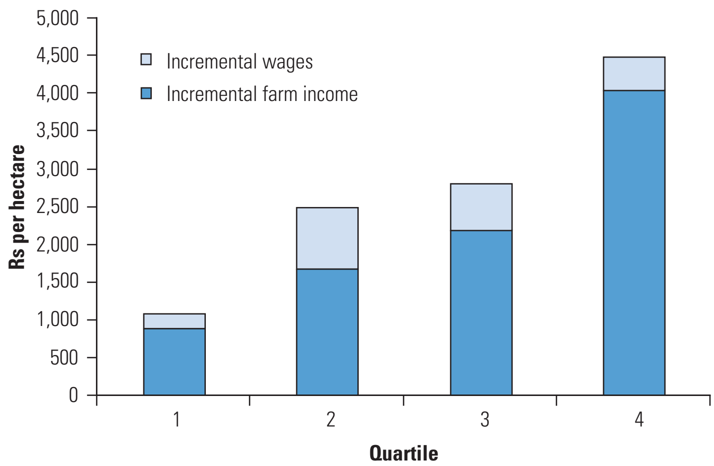
The same data are used to calculate the Gini coefficients. These coefficients appear high because of the large number of negative incomes (which are set to zero for the calculation). Despite the largest absolute benefit going to the top quartile, the Gini is unaffected because relative income growth is greatest among the second quartile—or the lowest quartile, if they were to have a larger share in the employment benefits (table E.6).

Table E.4: Derivation of Share of Employment

Quartile	Days of agricultural employment 2005	Days of agricultural employment 2006	Change	Share of change
1	278	294	16	0.06
2	123	234	111	0.40
3	159	239	80	0.29
4	62	132	70	0.25

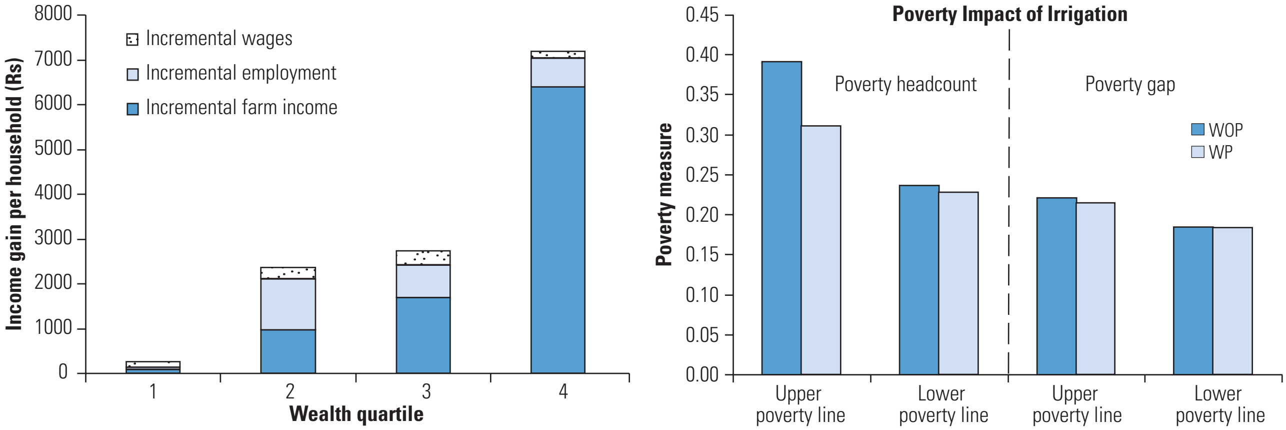
Source: IEG survey.

Figure E.1: Distribution of Benefits from 1 Hectare of Irrigation



Source: IEG survey.
Note: Rs = rupees.

Figure E.2: Distribution Benefits Across All Households by Wealth Quartile



Note: Units of measure are poverty headcount and poverty gap. Rs = rupees; WOP = base case (no irrigation); WP = with project (irrigation).

Table E.5: Poverty and Inequality Measures

	Upper poverty line			Lower poverty line		
Measure	**WOP**	**WP**	**WP scenario 2**	**WOP**	**WP**	**WP scenario 2**
Poverty headcount	0.39	0.29	0.31	0.24	0.21	0.20
Poverty gap	0.22	0.21	0.21	0.18	0.18	0.18

Source: IEG survey.

Table E.6: Quartile Income Shares and Income Growth

		Income shares		Percentage change	
Quartile	**Base case**	**Simulation 1**	**Simulation 2**	**Simulation 1**	**Simulation 2**
1	4.4	4.1	4.3	8.6	17.5
2	13.5	14.0	13.7	15.5	12.6
3	21.9	21.9	22.0	10.7	11.0
4	60.2	60.0	60.0	10.3	9.9

SRBC: Per Hectare Financial Budget: Without Project—*Kharif* and Two-Season Crops

	Paddy	Soybean	Sorghum	Sun-flower	Seed bandi	Vege-tables	Ground-nut	Cotton	Cotton seeds	Chilies	Sugar-cane	Turmeric	Mulberry	Existing mango	New mango
Yield (tonnes/ha)	3.2	0.8	1.0	0.5	0.5	7.0	1.0	1.0	0.8	0.8	80.0	1.5	4.5	4.0	8.0
Price	4,000	8,000	3,500	10,750	15,000	2,200	10,500	18,500	110,000	15,000	550	15,000	8,500	5,000	5,000
Value	12,800	6,400	3,500	5,375	7,500	15,400	10,500	18,500	82,500	12,000	44,000	22,500	38,250	20,000	40,000
Byproducts															
Yield (t/ha)	1.6	0.0	2.0	0.0	0.0	0.0	1.0	0.0	0.5	0.0	0.0	0.0		0.0	
Price	300		120				300		20,400						
Value	480		240				300		10,200						
Total gross value	13,280	6,400	3,740	5,375	7,500	15,400	10,800	18,500	92,700	12,000	44,000	22,500	38,250	20,000	40,000
Inputs															
Seeds (kg/ha)	40	75	8	10	15	0.8	90	13	3	4	8,000	3	1,250	0	10
Price (/kg)	6.9	10	5	15	30	150	20	25	200	200	0.6	1,000	0.25	0	10
Value	276	750	40	150	450	120	1,800	325	600	800	4,800	3,000	3,12.5	0	100
Urea (kg/ha)	100	30	60	50	10	40	100	25	40	50	75	100	300	25	150
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	400	120	240	200	40	160	400	100	160	200	300	400	1,200	100	600
DAP (kg/ha)	100	30	60	50	10	40	100	25	25	50	75	100	150	35	50
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5		8.5	8.5	8.5	8.5	8.5	8.5
Value	850	255	510	425	85	340	850	212.5		425	637.5	850	1,275	297.5	425
MOP (kg/ha)	0	15	0	0	0	35	0	0	0	50	35	75	150	0	150
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	0	75	0	0	0	175	0	0	0	250	175	375	750	0	750
Manure (t/ha)	2	1	0	0	0	4	2	0	2	3	6	10	4	0	0
Price (/t)	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Value	280	140	0	0	0	560	280	0	280	420	840	1,400	560	0	0
Chemicals (kg/ha)	2.5	0	0	0	1	4	1	0	0	5	0	1	0	1	3
Price (/kg)	252	252	252	252	252	252	252	252	252	252	252	252	252	216	216
Value	630	0	0	0	252	1,008	252	0	0	1,260	0	252		216	648
Labor (md/ha)	170	85	53	74	96	315	84	74	800	220	364	645	346	75	85
Price/md	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Labor costs (50%)	3,188	1,594	994	1,388	1,800	5,906	1,575	1,388	15,000	4,125	6,825	12,094	6,488	1,406	1,594
Price/day	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	838	536	402	402	369	938	436	402	670	804	1,273	804	268	67	268
Total costs	6,461	3,470	2,186	2,565	2,996	9,207	5,593	2,427	16,710	8,284	14,851	19,175	10,853	2,087	4,385
Net production value	6,819	2,930	1,554	2,811	4,505	6,193	5,208	16,073	75,990	3,716	29,150	3,325	27,397	17,913	35,615

SRBC: Per Hectare Financial Budget: Without Project—*Rabi* Season

	Rabi Sunflower	Sorghum	Sunflower seed	Sorghum seeds	Vegetables	Groundnut	Coriander	Chickpea	Castor	Tobacco
Yield (t/ha)	0.6	1.2	0.6	1.0	7.0	1.0	0.4	0.6	0.9	1.1
Price	10,750	3,500	30,000	7,500	2,200	10,500	13,000	9,350	10,000	13,000
Value	6,450	4,200	18,000	7,500	15,400	10,500	5,200	5,610	9,000	14,300
Byproducts										
Yield (t/ha)	0.0	2.4	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Price		120	10,750			300				
Value		288	5,375			300				
Total gross value	6,450	4,488	23,375	7,500	15,400	10,800	5,200	5,610	9,000	14,300
Inputs										
Seeds (kg/ha)	10	8	10	12	0.8	90	12	50	5	0.5
Price (/kg)	15	5	45	40	150	20	15	15	45	130
Value	150	40	450	480	120	1,800	180	750	225	65
Urea (kg/ha)	50	60	60	120	40	100	10	30	50	100
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	200	240	240	480	160	400	40	120	200	400
DAP (kg/ha)	50	50	120	150	40	100	10	30	60	120
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Value	425	425	1,020	1,275	340	850	85	255	510	1,020
MOP (kg/ha)	0	35	0	35	35	0	0	0	0	0
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	0	175	0	175	175	0	0	0	0	0
Manure (t/ha)	0	0	3	0	4	2	0	1	3	1.5
Price (/t)	140	140	140	140	140	140	140	140	140	140
Value	0	0	420	0	560	280	0	140	420	210
Chemicals (kg/ha)	0	0	2	0	4	1	25	2	3	1
Price (/kg)	252	252	252	252	252	252	4	252	252	252
Value	0	0	504	0	1,008	252	100	504	756	252
Labor (md/ha)	74	53	90	90	315	84	36	34	92	166
Price/md	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Labor costs (50%)	1,388	994	1,688	1,688	5,906	1,575	675	638	1,725	3,113
Total animal days (adj)	12	12	14	16	28	13	10	13	18	18
Price/day	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	402	402	469	536	938	436	335	436	603	603
Total costs	2,565	2,276	4,791	4,634	9,207	5,593	1,415	2,842	4,439	5,663
Net production value	3,886	2,212	18,585	2,867	6,193	5,208	3,785	2,768	4,561	8,638

SRBC: Per Hectare Financial Budget: With Project—*Kharif* and Two-Season Crops

	Paddy	Soybean	Sorghum	Sun-flower	Seed bandi	Vege-tables	Ground-nut	Cotton	Cotton seeds	Chilies	Sugar-cane	Turmeric	Mulberry	Existing mango	New mango
Yield (t/ha)	5.4	1.5	2.5	1.6	0.8	12.0	1.6	1.5	1.2	1.6	100.0	2.0	5.0	4.5	8.0
Price	4,000	8,000	3,500	10,750	15,000	2,200	10,500	18,500	110,000	15,000	550	15,000	8,500	5.000	5.000
Value	21,600	12,000	8,750	17,200	12,000	26,400	16,800	27,750	132,000	24,000	55,000	30,000	42,500	22.500	40.000
Byproducts															
Yield (t/ha)	2.7	0.0	5.0	0.0	0.0	0.0	1.0	0.0	0.8	0.0	0.0	0.0		0.0	
Price	300		120				300		20,400						
Value	810		600				300		16,320						
Total gross value	22,410	12,000	9,350	17,200	12,000	26,400	17,100	27,750	148,320	24,000	55,000	30,000	42,500	22.500	40.000
Inputs															
Seeds (kg/ha)	40	75	12	10	15	0.8	90	3	3	4	8,000	3	1250	0	10
Price (/kg)	6.9	10	5	15	30	150	20	25	200	200	0.6	1,000	0.25	0	10
Value	276	750	60	150	450	120	1,800	75	600	800	4,800	3,000	312.5	0	100
Urea (kg/ha)	100	75	100	70	30	200	60	90	100	200	275	175	250	60	125
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	400	300	400	280	120	800	240	360	400	800	1,100	700	1,000	240	500
DAP (kg/ha)	150	60	50	80	20	120	150	150	250	100	100	150	150	35	50
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5		8.5	8.5	8.5	8.5	8.5	8.5
Value	1,275	510	425	680	170	1,020	1,275	1275		850	850	1,275	1,275	297.5	425
MOP (kg/ha)	0	35	40	0	15	100	0	200	300	100	50	100	150	0	150
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	0	175	200	0	75	500	0	1,000	1,500	500	250	500	750	0	750
Manure (t/ha)	3	2	2	2	2	6	3	3	4	6	8	15	5	0	0
Price (/t)	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Value	420	280	280	280	280	840	420	420	560	840	1,120	2,100	700	0	0
Chemicals (kg/ha)	3	0.5	0	1.5	2	5	1.5	5	10	7.5	0	2	0	1	3
Price (/kg)	252	252	252	252	252	252	252	252	252	252	252	252	252	216	216
Value	756	126	0	378	504	1260	378	1,260	2,520	1,890	0	504		216	648
Labor (md/ha)	200	100	90	80	110	380	100	225	1,240	300	420	680	330	50	60
Price/md	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5
Labor costs (50%)	3,850	1,925	1,733	1,540	2,118	7,315	1,925	4,331	23,870	5,775	8,085	13,090	6,353	963	1,155
Total animal days (adj)	25	16	14	13	11	30	16	20	28	36	40	29	8	2	8
Price/day	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	838	536	469	436	369	1,005	536	670	938	1,206	1,340	972	268	67	268
Total costs	7,815	4,602	3,567	3,744	4,085	12,860	6,574	9,391	30,388	12,661	17,545	22,141	10,658	1,783	3846
Net production value	14,596	7,398	5,784	13,457	7,915	13,540	10,526	18,359	117,932	11,339	37,455	7,860	31,842	20,717	36,154

SRBC: Per Hectare Financial Budget: With Project—*Rabi* Season

	Rabi Sunflower	Sorghum	Sunflower seed	Sorghum seeds	Vegetables	Groundnut	Coriander	Chickpea	Castor	Tobacco
Yield (t/ha)	1.1	2.0	1.0	1.0	12.0	1.7	0.5	0.8	0.9	1.1
Price	10,750	3,500	30,000	7,500	2,200	10,500	13,000	9,350	10,000	13,000
Value	11,825	7,000	30,000	7,500	26,400	17,850	6,500	7,480	9,000	14,300
Byproducts										
Yield (t/ha)	0.0	4.0	0.5	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Price		120	10,750			300				
Value		480	5,375			510				
Total gross value	11,825	7,480	35,375	7,500	26,400	18,360	6,500	7,480	9,000	143,00
Inputs										
Seeds (kg/ha)	10	12	10	12	0.8	90	20	50	5	0.5
Price (/kg)	15	5	45	40	150	20	15	15	45	130
Value	150	60	450	480	120	1,800	300	750	225	65
Urea (kg/ha)	80	90	150	120	220	100	30	40	50	100
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	320	360	600	480	880	400	120	160	200	400
DAP (kg/ha)	100	120	120	150	25	50	10	30	60	120
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Value	850	1,020	1,020	1,275	212.5	425	85	255	510	1,020
MOP (kg/ha)	0	40	50	80	100	0	0	0	0	0
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	0	200	250	400	500	0	0	0	0	0
Manure (t/ha)	2	2	3	3	6	3	0	2	3	1.5
Price (/t)	140	140	140	140	140	140	140	140	140	140
Value	280	280	420	420	840	420	0	280	420	210
Chemicals (kg/ha)	1.5	0	2	0	7	1	25	3	3	1
Price (/kg)	252	252	252	252	252	252	4	252	252	252
Value	378	0	504	0	1,764	252	100	756	756	252
Labor (md/ha)	90	70	90	80	380	105	40	40	92	166
Price/md	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5
Labor costs (50%)	1,733	1,348	1,733	1,540	7,315	2,021	770	770	1,771	3,196
Total animal days (adj)	13	14	14	16	34	18	10	13	18	18
Price/day	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	436	469	469	536	1139	603	335	436	603	603
Total costs	4,146	3,737	5,446	5,131	12,771	5,921	1,710	3,407	4,485	5,746
Net production value	7,679	3,744	29,930	2,369	13,630	12,439	4,790	4,074	4,515	8,555

SRBC: Per Hectare Financial Budget: Without Project

	Kharif crops			Two season						*Rabi* crops			
	Paddy	**Maize**	**Pulses**	**Groundnut**	**Cotton**	**Chilies**	**Turmeric**	**Existing mango**	**Sunflower**	**Paddy**	**Maize**	**Groundnut**	**Pulses**
Yield (t/ha)	3.0	2.0	0.6	0.6	0.8	0.8	2.5	4.0	0.6	3.0	2.2	1.0	0.6
Price	4,000	3,800	10,500	10,500	18,500	15,000	15,000	5,000	10,750	4,000	3,800	10,500	10,500
Value	12,000	7,600	6,300	6,300	14,800	12,000	37,500	20,000	6,450	12,000	8,360	10,500	6,300
Byproducts													
Yield (t/ha)	1.5	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.5	2.2	1.0	0.0
Price	300	80		300						300	80	300	
Value	450	160		300						450	176	300	
Total gross value	12,450	7,760	6,300	6,600	14,800	12,000	37,500	20,000	6,450	12,450	8,536	10,800	6,300
Inputs													
Seeds (kg/ha)	40	20	20	90	13	4	3	0	10	40	20	90	20
Price (/kg)	6.9	10	10	20	25	200	1000	0	15	6.9	10	20	10
Value	276	200	200	1800	325	800	3000	0	150	276	200	1,800	200
Urea (kg/ha)	150	120	10	40	30	100	150	25	50	150	120	40	30
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	600	480	40	160	120	400	600	100	200	600	480	160	120
DAP (kg/ha)	100	50	50	100	25	50	100	35	50	100	50	100	50
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Value	850	425	425	850	212.5	425	850	297.5	425	850	425	850	425
MOP (kg/ha)	0	30	0	0	0	50	75	0	0	0	30	0	0
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	0	150	0	0	0	250	375	0	0	0	150	0	0
Manure (t/ha)	2	3	0	2	0	3	10	0	0	2	3	2	0
Price (/t)	140	140	140	140	140	140	140	140	140	140	140	140	140
Value	280	420	0	280	0	420	1400	0	0	280	420	280	0
Chemicals (kg/ha)	2.5	2	0	1	0	5	1	1	0	2.5	2	1	0
Price (/kg)	252	252	252	252	252	252	252	216	252	252	252	252	252
Value	630	504	0	252	0	1260	252	216	0	630	504	252	0
Labor (md/ha)	170	98	78	103	84	245	645	75	78	180	98	103	57
Price/md	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Labor costs (50%)	3,188	1,838	1,463	1,931	1,575	4,594	12,094	1,406	1,463	3,375	1,838	1,931	1,069
Total animal days (adj)	25	18	10	13	12	24	24	2	12	25	18	13	10
Price/day	50	50	50	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	838	603	335	436	402	804	804	67	402	838	603	436	335
Total costs	6,661	4,620	2,463	5,709	2,635	8,953	19,375	2,087	2,640	6,849	4,620	5,709	2,149
Net production value	5,789	3,141	3,838	891	12,166	3,047	18,125	17,913	3,811	5,602	3,917	5,091	4,151

SRBC: Per Hectare Financial Budget: With Project—*Kharif* and Two-Season Crops

	Paddy	Maize	Sunflower	Pulses	Vegetables	Groundnut	Cotton	Chilies	Turmeric	Existing mango	Soybean
Yield (t/ha)	4.2	2.2	1	0.9	12.0	1.2	1.6	1.6	3.5	4.5	0.5
Price	4,000	3,800	10,750	10,500	2,200	10,500	18,500	15,000	15,000	5,000	8,000
Value	16,800	8,360	10,750	9,450	26,400	12,600	29,600	24,000	52,500	22,500	4,000
Byproducts											
Yield (t/ha)	2.1	2.2		0.0		1.0	0.0	0.0	0.0	0.0	
Price	300	80				300					
Value	630	176				300					
Total gross value	17,430	8536	10,750	9,450	26,400	12,900	29,600	24,000	52,500	22,500	4,000
Inputs											
Seeds (kg/ha)	40	20	10	20	0.8	90	3	4	3	0	75
Price (/kg)	6.9	20	15	10	150	20	25	200	1,000	0	10
Value	276	400	150	200	120	1,800	75	800	3,000	0	750
Urea (kg/ha)	200	160	50	35	150	70	90	200	175	35	75
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	800	640	200	140	600	280	360	800	700	140	300
DAP (kg/ha)	125	65	70	65	100	125	100	75	125	40	75
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Value	1,062.5	552.5	595	552.5	850	1,062.5	850	637.5	1,062.5	340	637.5
MOP (kg/ha)	0	60	60	0	70	0	0	75	90	0	0
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	0	300	300	0	350	0	0	375	450	0	0
Manure (t/ha)	2	3	3	0	0	2	0	3	10	0	0
Price (/t)	140	140	140	140	140	140	140	140	140	140	140
Value	280	420	420	0	0	280	0	420	1,400	0	0
Chemicals (kg/ha)	3.5	3	1	0.5	4	1	5	7	1.5	1.5	0.5
Price (/kg)	252	252	252	252	252	252	252	252	252	216	252
Value	882	756	252	126	1,008	252	1,260	1764	378	324	126
Labor (md/ha)	205	110	88	65	300	110	180	245	710	75	80
Price/md	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5
Labor costs (50%)	3,946	2,118	1,694	1,251	5,775	2,118	3,465	4,716	13,668	1,444	1,540
Total animal days (adj)	25	18	16	10	25	15	18	30	26	2	10
Price/day	50	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	838	603	536	335	838	503	603	1,005	871	67	335
Total costs	8,084	5,789	4,147	2,605	9,541	6,295	6,613	10,518	21,529	2,315	3,689
Net production value	9,346	2,747	6,603	6,845	16,860	6,606	22,987	13,482	30,971	20,185	312

SRBC: Per Hectare Financial Budget: With Project—*Rabi* Season

	Chilies	Turmeric	Existing mango	Sunflower	Paddy	Maize	Vegetables	Groundnut	Pulses	Soybean
Yield (t/ha)	1.6	3.5	4.5	1.5	4.2	3.2	12.0	1.8	1.0	0.5
Price	15,000	15,000	5,000	10,750	4,000	3,800	2,200	10,500	10,500	8,000
Value	24,000	52,500	22,500	16,125	16,800	12,160	26,400	18,900	10,500	4,000
Byproducts										
Yield (t/ha)	0.0	0.0	0.0	0.0	2.1	3.2		1.8	0.0	
Price					300	80		300		
Value					630	256		540		
Total gross value	24,000	52,500	22,500	16,125	17,430	12,416	26,400	19,440	10,500	4,000
Inputs										
Seeds (kg/ha)	4	3	0	10	40	20	0.8	90	20	75
Price (/kg)	200	1,000	0	15	6.9	10	150	20	10	10
Value	800	3,000	0	150	276	200	120	1800	200	750
Urea (kg/ha)	200	175	35	50	200	60	150	70	35	75
Price (/kg)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Value	800	700	140	200	800	240	600	280	140	300
DAP (kg/ha)	75	125	40	50	125	65	100	125	65	75
Price (/kg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Value	637.5	1,062.5	340	425	1,062.5	552.5	850	1,062.5	552.5	637.5
MOP (kg/ha)	75	90	0	0	0	60	70	0	20	0
Price (/kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Value	375	450	0	0	0	300	350	0	100	0
Manure (t/ha)	3	10	0	0	2	3	3	2	0	0
Price (/t)	140	140	140	140	140	140	140	140	140	140
Value	420	1,400	0	0	280	420	420	280	0	0
Chemicals (kg/ha)	7	1.5	1.5	1	3.5	3	4	1	0.5	0.5
Price (/kg)	252	252	216	252	252	252	252	252	252	252
Value	1,764	378	324	252	882	756	1,008	252	126	126
Labor (md/ha)	245	710	75	90	205	122	250	110	65	80
Price/md	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5
Labor costs (50%)	4,716	13,668	1,444	1,733	3,946	2,349	4,813	2,118	1,251	1,540
Total animal days (adj)	30	26	2	13	18	20	25	16	16	10
Price/day	50	50	50	50	50	50	50	50	50	50
Animal costs (67%)	1,005	871	67	436	603	670	838	536	536	335
Total costs	10,518	21,529	2,315	3,195	7,850	5,487	8,998	6,328	2,906	3,689
Net production value	13,482	30,971	20,185	12,930	9,580	6,929	17,402	13,112	7,594	312

SRBC Economic Rate of Return (Rs)

Year	Investment costs	Addtitional O&M	Total costs	Incremental benefit	Net benefit
1989	284	0	284	0	–284
1990	347	0	347	0	–347
1991	294	0	294	0	–294
1992	1,005	0	1,005	0	–1,005
1993	918	0	918	0	–918
1994	2,354	0	2,354	0	–2,354
1995	2,843	0	2,843	0	–2,843
1996	768	0	768	0	–768
1997	787	0	787	0	–787
1998	578	0	578	0	–578
1999	714	0	714	0	–714
2000	1,148	0	1,148	0	–1,148
2001	1,287	0	1,287	0	–1,287
2002	1,348	0	1,348	0	–1,348
2003	867	0	867	0	–867
2004	827	5	832	74	–758
2005	0	5	5	74	69
2006	0	16	16	263	247
2007	0	23	23	368	346
2008	0	33	33	547	514
2009	0	33	33	547	514
2010	0	33	33	547	514
2011	0	33	33	547	514
2012	0	33	33	547	514
2013	0	33	33	547	514
2014	0	33	33	547	514
2015	0	33	33	547	514
2016	0	33	33	547	514
2017	0	33	33	547	514
2018	0	33	33	547	514
2019	0	33	33	547	514
2020	0	33	33	547	514
2021	0	33	33	547	514
2022	0	33	33	547	514
2023	0	33	33	547	514
2024	0	33	33	547	514
2025	0	33	33	547	514
2026	0	33	33	547	514
2027	0	33	33	547	514
2028	0	33	33	547	514

Note: ERR = –2 percent. Rs = rupees.

SRSP Economic Rate of Return (Rs)

Year	Investment costs	Addtitional O&M	Total costs	Incremental benefit	Net benefit
1989	3,581	0	3,581	0	–3,581
1990	431	0	431	0	–431
1991	380	0	380	0	–380
1992	633	0	633	0	–633
1993	694	0	694	0	–694
1994	890	0	890	0	–890
1995	1,245	0	1,245	0	–1,245
1996	728	16	744	216	–528
1997	1,643	16	1,660	216	–1,443
1998	1,209	49	1,257	649	–609
1999	1,456	65	1,522	865	–657
2000	1,863	81	1,944	1,081	–863
2001	2,623	90	2,713	1,189	–1,524
2002	1,156	98	1,254	1,297	43
2003	2,027	106	2,133	1,405	–728
2004	1,549	114	1,664	1,514	–150
2005	0	122	122	1,622	1,499
2006	0	130	130	1,730	1,599
2007	0	130	130	1,730	1,599
2008	0	130	130	1,730	1,599
2009	0	130	130	1,730	1,599
2010	0	130	130	1,730	1,599
2011	0	130	130	1,730	1,599
2012	0	130	130	1,730	1,599
2013	0	130	130	1,730	1,599
2014	0	130	130	1,730	1,599
2015	0	130	130	1,730	1,599
2016	0	130	130	1,730	1,599
2017	0	130	130	1,730	1,599
2018	0	130	130	1,730	1,599
2019	0	130	130	1,730	1,599
2020	0	130	130	1,730	1,599
2021	0	130	130	1,730	1,599
2022	0	130	130	1,730	1,599
2023	0	130	130	1,730	1,599
2024	0	130	130	1,730	1,599
2025	0	130	130	1,730	1,599
2026	0	130	130	1,730	1,599
2027	0	130	130	1,730	1,599
2028	0	130	130	1,730	1,599

Note: ERR = 5 percent. Rs = rupees.

Combined SRBC and SRSP Economic Rate of Return (Rs)

Year	Investment costs	Addtitional O&M	Total costs	Incremental benefit	Net benefit
1989	3,865	0	3,865	0	–3,865
1990	778	0	7,78	0	–778
1991	675	0	675	0	–675
1992	1,639	0	1,639	0	–1,639
1993	1,612	0	1,612	0	–1,612
1994	3,245	0	3,245	0	–3,245
1995	4,088	0	4,088	0	–4,088
1996	1,496	16	1,512	216	–1,296
1997	2,430	16	2,447	216	–2,230
1998	1,786	49	1,835	649	–1,187
1999	2,170	65	2,236	865	–1,371
2000	3,011	81	3,092	1,081	–2,011
2001	3,910	90	4,000	1,189	–2,811
2002	2,504	98	2,602	1,297	–1,304
2003	2,895	106	3,001	1,405	–1,595
2004	2,377	119	2,495	1,587	–908
2005	0	127	127	1,695	1,569
2006	0	146	146	1,993	1,847
2007	0	153	153	2,098	1,945
2008	0	164	164	2,277	2,113
2009	0	164	164	2,277	2,113
2010	0	164	164	2,277	2,113
2011	0	164	164	2,277	2,113
2012	0	164	164	2,277	2,113
2013	0	164	164	2,277	2,113
2014	0	164	164	2,277	2,113
2015	0	164	164	2,277	2,113
2016	0	164	164	2,277	2,113
2017	0	164	164	2,277	2,113
2018	0	164	164	2,277	2,113
2019	0	164	164	2,277	2,113
2020	0	164	164	2,277	2,113
2021	0	164	164	2,277	2,113
2022	0	164	164	2,277	2,113
2023	0	164	164	2,277	2,113
2024	0	164	164	2,277	2,113
2025	0	164	164	2,277	2,113
2026	0	164	164	2,277	2,113
2027	0	164	164	2,277	2,113
2028	0	164	164	2,277	2,113

Note: ERR = 2 percent. Costs are investment costs, excluding dam safety, O&M, and land costs. All prices converted to 2006 prices, using wholesale price index deflator where necessary. Incremental benefit is net farm income from farm model (valued at economic prices) times newly irrigated area. Standard conversion factor is 0.92. Rs = rupees.

APPENDIX F: VILLAGE PROFILES

Appendix F: Village Profiles

Village	Water availability	Canal condition	Reach	WUA member (% all households)		Irrigation source (% of all plots)			
						2005		2006	
				2005	2006	Canal	Tank	Canal	Tank
Uyyalawada	No water	Canal not completed because of land dispute; heavy siltation	Tail	0	2	1.6	0.0	0.0	1.5
Vennaram	Received water once only in 2004	Canal not completed	Tail	12	4	4.1	0.0	4.0	0.0
Lingagiri	No water	Not yet constructed	n.a.	2	0	0.0	9.6	0.0	23.6
Pragthisingaram	No water	Not yet constructed	n.a.	2	14	0.0	10.3	5.0	62.5
Narsapur	Water since *rabi* 2006	n.a.	n.a.	2	20	0.0	11.4	13.6	44.1
Ingurthy	Water since 2005; most goes to tanks	Good	Head	10	14	17.1	2.4	11.1	8.9
Komatipalli	Water since 2005, goes to tanks preventing flow to two villages downstream	Main distributary clogged, tertiary good	Middle	18	10	2.9	1.4	7.0	8.5
Upparagudem	Received water once only in 2004	Canal completed by heavily silted	Middle	0	12	0.0	18.9	2.6	15.4
Kampalle	Received water once only in 2004. Water taken by farmers upstream	Heavily silted	Tail	0	8	0.0	0.0	0.0	13.0
Nallabelli	Water since *rabi* 2006	n.a.	n.a.	10	28	2.4	14.3	4.0	44.0
Rajanpalli	No water	Not yet constructed	n.a.	12	18	5.6	9.3	0.0	12.7
Malaya	Water since 2003, flows to tanks	Main distributary good, tertiaries clogged	Middle	0	4	6.3	4.2	5.6	9.3
Mahadesapuram	Received water once only in 2004	Heavily silted	Head	0	0	0.0	2.0	0.0	1.9
Thopanpally	Water since 2003, goes to tanks preventing flow to three villages downstream	Good	Head	12	14	11.9	2.4	17.8	6.7
Deekshakunta	Water since 2005, flows to tank	Good	Middle	13	19	2.2	13.0	3.7	22.2
Peddakorpolu	No water, diverted upstream to other villages	Distributary unusable	Tail	10	0	0.0	11.5	0.0	12.3
Chinnakondapak	Water not released because farmers want to release to tanks to which ID opposed	n.a.	n.a.	0	20	0.0	26.8	0.0	30.4
Muchimpala	Canal	Good	Middle	10	12	0.0	8.6	12.8	25.6

Note: n.a. = not applicable.

APPENDIX G: COMMENTS FROM GOVERNMENT OF ANDHRA PRADESH

I. Introduction[1]

Irrigation is definitely a powerful force for poverty reduction. The expansion in the irrigation sector and adoption of new techniques of agriculture (Green Revolution) has resulted in an increase of per capita grain production, which clearly shows that the reason behind it is irrigation. Hence, irrigation cannot be concluded as a paradox, and it is the basic requirement for the sustenance of mankind. Any developmental activity has got its diversified impact, and a balanced view has to be taken when an assessment is being taken. Investments made toward irrigation infrastructure are mainly one time, but the benefits (direct/indirect) are long term. The emphasis on new construction, rehabilitation of systems, and quality of work is altogether different from the schemes planned especially to eradicate poverty.

It is agreed that the findings of the IEG study are important and definitely provide altogether different perceptions, but to draw conclusions on the entire irrigation development portfolio is inappropriate and not justifiable. The irrigation infrastructure creation as an effective mechanism for fostering growth and economic upliftment in the project areas is proved beyond doubt across the globe. Moreover, the methodology of assessing the impact, the sample size, and the sample chosen by IEG has significant differences, and therefore, the findings are misleading.

It is very much understandable that the two projects taken up are of different nature; that is, one is basically a rehabilitation of an existing system (SRSP) and the other one is set to complete a new irrigation system for bringing new areas under irrigation. Thus, special issues concerned with these two projects and circumstances considered by the Bank for assisting are overlooked by the study, and the report is made exclusive of these facts. It may not be out of context to mention that IEG has prejudged the issues and extrapolated/generalized the small sample survey results across the irrigation investments.

However, the project-specific status with remarks and participatory irrigation management efforts taken up by the state are highlighted below so that the objective assessment of the AP II and AP III projects is brought out in a more focused manner.

II. Performance of SRBC and SRSP Projects

SRBC project

Salient features of SRBC and the present progress of the project:

- The SRBC scheme was formulated to irrigate 190,000 acres by utilizing 19 TMC of Krishna water from the foreshore of Srisailam Dam to benefit the chronic drought-prone areas in Nandyal, Banaganapalli, and Koilakuntla taluks of Kurnool district and Jammalamadugu taluk of Kadapa district.
- The SRBC scheme was cleared by the planning commission in 1981.
- After completion of preliminaries, the works from km 0–km 10 of SRBC were commenced in 1984.
- Because of paucity of funds and to aid in the speedy execution of the project, part of the scheme was posed for World Bank assistance in 1984.

- 37 percent of the works were completed by the time AP II was closed in 1994.
- The balance of the works of the project (except Gorakallu balancing Reservoir, Owk second stage, and main canal beyond 141.00 to 199.00 under SRBC scheme) was taken up with World Bank assistance under a separate project—AP III.
- Under AP II and AP III, all infrastructure to create irrigation potential to an extent of 1,53,936 acres under 16 blocks was completed except a micro-network.

Status of the Project: As of March 2004, Rs. 988.52 Crores had been spent, and the main canal and distribution system were completed; as of December 2006, 1,192.46 Crores had been spent and water supplied through field channels to an extent of 88,121 acres.

Works in Progress in SRBC: Sri Narasimharaya Sagar Project—

1. Excavation of field channels:

   (a) From Block I to X by Ayacutdar Committees/water user associations (WUAs)
   (b) From Block XI to XIV by Contracting agency
   (c) Phase II works of Owk Reservoir Complex.

2. SRBC from km 141 to km 199, including distributaries XVII to XXI and micro-network.

Present Scenario: Expenditure particulars under World Bank aid

Andhra Pradesh II irrigation project—333 Crores (approximately)
AP III irrigation project—845 Crores (approximately)

(a) Micro-network under XV and XVI blocks were completed.
(b) Micro-network under I to X blocks are being executed under CADWM program.
(c) Micro-network under XI to XIV are being executed by contracting agency.
(d) Irrigation potential created up to 2006 under I to XVI blocks is 153,936 acres and ayacut brought under irrigation is 87,895 acres by constructing field channels.
(e) Since 2004, until water is supplied through the SRBC system to an ayacut of 30,000 A/c to 130,000 A/c as per the ayacut development, as shown below (includes without field channels also):

2004–30,000 A/c
2005–50,000 A/c
2006–130,000 A/c
} against 160,000 A/c

(f) Hence the benefits are now reaching the beneficiaries. Moreover, the WUAs were recently elected and have been functioning since November 2006.
(g) The sample survey for SRBC will reveal a different picture if taken up now as it is programmed to release water for entire ayacut of 160,000 A/c during *kharif* 2007.
(h) Furthermore, the CWC is conducting monitoring every year and communicating its observations and the same are being complied.

With regard to the sample selection of IEG irrigation survey, it has considered two command areas in SRBC and SRSP. At the time of the first round of the survey, very little water had been released, irrigating 7,800 ha of a planned 65,000 ha in the SRBC command, and the simple reason is that the micro-network was completed to an extent of 20 percent. Completion of the network was estimated for 2008, so IEG has not undertaken the second round of a survey in 2006 in the SRBC command. This is to say that 12 percent of lands were able to be irrigated, and if no system is developed, it could have been simply nil. The deficiency of 8 percent cannot be directly called a shortfall, as the farmers will take sufficient time to develop their lands even after water is made available to them, due to their financial and other constraints. This is quite evident when we observe the development of ayacut in most successful schemes like Godavari Delta, Krishna Delta, and the Nagarjuna Sagar Project. Further, SRBC was a new scheme, whereas SRSP was an extension of existing system under AP II.

The government departments will be strengthened in due time for maintaining efficient management of the irrigation system, so as to redress the weakness in the activities of WUAs.

IEG has come to a conclusion that the project's failure can be attributed to problems both in design and implementation. The rates that were adopted in the estimates are purely based on realistic values and hence only the contractors are able to execute the works with discounts. Further, concluding that government officials at all levels benefited financially from irrigation source, from the study of Robert Wade (1982) in itself is not acceptable to the state and the same cannot be substantiated and the statement is not in good taste.

Sriramasagar project

Salient features of the project: The Sriramasagar project was constructed across the River Godavari to create an irrigation potential of 968,640 acres in four districts: viz., Adilabad, Nizamabad, Karimnagar, and Warangal. Before taking up AP III, 630,000 acres of irrigation potential was created. The area irrigated during 1995–96 was 268,301 acres, against the irrigation potential creation of 630,000 acres.

The third Andhra Pradesh irrigation potential was taken up to complete the irrigation development and scheme rehabilitation works began under second Andhra Pradesh irrigation potential and thus realize the potential for increasing agricultural production and rural income in backward regions of Telangana, covering the districts of Adilabad, Nizamabad, Karimnagar, and Warangal. Rehabilitation and modernization of Kakatiya Canal from 0 km to 234 km and distributory system to stabilize the aycut of 625,000 acres.

District breakdown:

Nizamabad:	11,000 acres
Karimnagar:	543,000 acres
Warangal:	71,000 acres
Total:	625,000 acres

Objectives of AP III:

- Stabilization of 625,000 acres ayacut of Kakatiya Canal up to 234 km
- Dam safety works (SRS Dam, Lower Manair Dam) as recommended by Dam Safety Panel
- Environment Management Plan
- Agricultural support services
- R&R of project-affected persons
- O&M works.

Achievements:
The activities envisaged under AP III are implemented. As a result the carrying capacity of Kakatiya Canal increased from 8,250 cubic feet per second (cusecs) to 9,700 cusecs. Thus the water reached to tail-end areas of all the distributaries, that is, from 0 to 234 km. The area irrigated also increased from 268,301 acres to 796,887 acres (2001–2002).

The following comments are offered on the Report prepared by IEG on impact evaluation of AP II and AP III projects in respect of Sriramasagar Project:

- AP II could not be completed as planned mainly because of delay in finalization of an R&R plan. There was considerable delay in finalizing model bid documents for civil works. The World Bank indicated that it preferred to close AP II instead of extending the project by 2–3 years.
- Appraisal for AP III, which commenced in February 1994 (just prior to closure of AP II in June 1994), took three years.
- AP III became effective in July 1997. The closing date was extended by 18 months and the project was closed in June 2004.
- Even though some problems in procurement were encountered initially, AP III closed on a successful note. IEG has made drastic comments on the functioning of government departments. It is felt desirable not to make an issue of these sorts of comments.
- However, to put the issues in proper perspective the following points are deemed necessary.

  The issue of changing to crops other than paddy defies solution, as seen from past experience. It is better if this issue is not highlighted any longer. During the course of AP III appraisal, it was hinted that supplies from the canal should be restricted to ID crop requirement. The farmers can supplement balance requirement from ground water or restrict their irrigated area.

Without having a first-hand knowledge of problems encountered in implementation of AP II and AP III, making light of the work done achievements is not fair.

Several supervision missions of Bank study teams have visited the project during implementation and appreciated the work being done. The manner in which the benefits of AP III are assessed and quantified may differ from agency to agency.

Verifiable benefits of civil works under AP III:

(a) Enhanced carrying capacity of Kakatiya Canal from 8,250 cusecs to 9,700 cusecs. Records maintained in the department will prove this point.

(b) The distribution system that had deteriorated over a period of time was put back in place. The area irrigated increased over a period of time, with completion of rehabilitation and modernization works. Reports of various supervision missions contain the details.
   (i) Before AP III, the maximum discharge in to the main canal was to 6,000 cusecs versus 8,250 cusecs.
   (ii) After taking up and completion of AP III, the canal discharge was greater than 9,000 cusecs.

(c) The achievements listed in (a) and (b) above were possible with the same quantum of water. The inflows in to the reservoirs and releases over several years can be verified.

(d) Productivity has considerably increased and so has the income of farmers.

(e) Farmers' organizations, which were put in place in 1997 for a 5-year term, functioned fairly well.

However, it has to be put on record that the conclusions of the study do not adequately represent ground reality. The conclusions are not based on project-specific data.

III. General Remarks about Sample Size

The survey consisted of two rounds in June 2005 and March 2006, with limited interrogation of 50 households in each village of the 16 total villages covered and the data collected on income, farm budgets, irrigation, and various aspects of social and political life in the village cannot be formed as a base, especially in the countries like India, which is in developing stages. Thus, the conclusions formulated based on the limited survey with inadvertent public cannot form a base to extrapolate the entire situation and thus the conclusions will not be realistic.

The study, which is a sample one, has revealed certain things. A sample can be called as a viable sample if it satisfies the requirements of certain principles. Further, conclusions made on SRBC based on sample of SRSP are inappropriate.

IV. Participatory Irrigation Management

To improve irrigation performance, the government of Andhra Pradesh took a progressive and innovative step to empower the farmers to manage and operate the irrigation resources through formation of WUAs in 1997. The exclusive Andhra Pradesh Farmers Managed Irrigation Act of 1997 was enacted, which provides the legal support for the functioning of these WUAs.

The objectives of farmers' organizations are carrying O&M of the irrigation system, effective water management, and increased agricultural production. The act emphasized formation of water users' organizations at three levels, namely WUAs, distributory committees (DCs) and project committees for major irrigation projects; two-tier structure (WUA/PC) for medium irrigation projects; and single-tier structures (WUA) for minor irrigation.

The following remarks are made on IEG's observations regarding participatory irrigation management (PIM).

1. The expansion and durability of WUAs has been influenced by external forces.

In 1997, WUAs were constituted for all the irrigation sectors and numbered around 10,000 for involvement of the stakeholders in the management of irrigation systems. DCs were also constituted.

After completion of the WUAs' 5-year tenure, the performance of these bodies is evaluated and thought to bring changes in the set-up of the WUAs for more accountability and more concentration on other statutory requirements, including water management.

It is felt that the WUAs are to be made continuous bodies to have a blend of old and new members for better working of these organizations. To bring the above changes, there was a gap of about one year for conduct of elections to the WUAs.

Elections to all the WUAs in the state were completed and elections for the DCs were also completed in 13 districts and will be completed by the end of April 2007 in the remaining districts. WUAs and DCs are also constituted in the SRBC project during November 2006. Constitution of project committees is also under active consideration of the government.

2. WUA membership is not representative of the population served.

IEG observed that half of the households in 18 villages of Warangal district have access to canal or tank irrigation, but only 18 percent of the all households are members. In this connection, the Act provided membership only for the land holders; that is, land is to be in the name of the person who has voting rights and who is a member of the association. The tenant will get voting rights and be a member of the association if the land holder leases the land. Normally, the land is registered in the name of the head of the family; thus, the households are represented in a smaller percentage.

Representation of the WUAs is mostly by the elite groups; the study conducted by the IEG group is only for a limited area and for all practical purposes the study conducted by ORG (2005) can be taken as reliable study, as the sample taken for the same is 214 WUAs across the state and in all three sectors of irrigation. Backward castes represented around 60 percent of the managing committee of the WUAs. The study also revealed that around 50 percent of the marginal farmers are represented in the managing committee of the WUAs.

Thus, it is not correct that most of the managing committees of WUAs are represented by elite groups. In this connection, it is informed that all the land holders are the voters of the WUA and these are modeled as self-help groups; there are no reservations based on social status. However, in the future, the representation of small and marginal farmers and also other social groups will also increase over and above the present level, as is happening in the other institutions.

Regarding benefits to the poor, the AP II and AP III projects are not exclusively meant for poverty eradication, and in case of irrigation projects, intangible benefits will be more and the same are not emphasized in the IEG study.

A gap ayacut of 10.07 lakhs is bridged during the first three years of implementation of PIM. This will definitely help the poor bring the livelihood opportunities by way of increasing the number of man working days.

3. A positive feature of irrigation development since the 1997 reforms has been rehabilitation of sections of the canal network, so that water now reaches more areas.

After formation of the WUAs and DCs in 1997, massive O&M and MR works were taken in all commands and farmers decided the works should be taken up; they are actively involved in the execution. However, there may be some defects in certain cases; for example, WUA presidents did not take other members into confidence and benefited personally as contractors. This was corrected, making the president's election indirect, which necessarily makes the decisions collective. WUAs are made continuous bodies. The term of 5 years has resulted in complacency, so the term of the president is 2 years to address this problem.

The water rates could not be collected to the expected level due to continuous drought. It can be observed that the water tax collections are around

100 Crores during 1998–99, 1999–2000, and 2000–01 as the season was good. Now O&M is linked to the water tax collections, and the farmers are being informed time and again that more collections will bring sufficient funds for O&M.

It is not correct that the reforms have not broken a vicious circle, as the study is limited to the SRSP Project only, and there are no WUAs in SRBC; thus, the study may not reflect the true picture of PIM. The benefits of the PIM are:

- Sense of ownership
- Dynamic leadership
- Execution of works by WUA
- 10.07 lakh acres gap ayacut bridge
- Increased agricultural production.

As per the ORG study on the performance of the WUAs, around 70 percent WUAs performance is assessed above average in major and minor sectors and 60 percent in medium sector [IEG note: these figures are, in fact 50, 51, and 51 percent, respectively; ORG 2005].

4. The farmers' committee structure (WUAs, DCs, and project committees) is intended to ensure equitable allocation of water, but the structure is incomplete and has limited capacity to do this.

During 1997 elections to the WUAs and DCs were conducted, and they have taken over the charge of O&M and water management. However, project committees could not be formed, as it was felt that the office bearers of the WUAs and DCs get well experienced with the management of the irrigation systems before they take up the responsibility of the project committee, which requires better administrative and management skills.

It is mentioned in the report that breaches of the canal to take water are also common and WUAs seem powerless to act. Indeed, they can act as vehicles for elite capture of these resources. The ORG study (2005) revealed that around 60 percent of the farmers believe that the water supply is more reliable and supply has increased.

Another study conducted by Dr. K.V. Raju (2001) reports that in 50 percent of tail-end WUAs, farmers felt the water has reached their fields with the activities taken up by the WUAs. It is also reported that there is considerable reduction in water conflicts.

As these institutions are new, it cannot be expected that results will be at 100 percent. In the first five years the WUAs and DCs actively involved in the system maintenance. They have also participated in water management. They have prioritized and executed the work. The next step is toward better water management. In this direction steps are being taken by the government through training and capacity building.

5. Are WUAs an effective means to provide sustainable O&M?

The O&M is linked to the water tax collections and FOs. In the major and medium sector, FOs will get 50 percent, and in the minor sector 90 percent of the water tax collections will go toward O&M. In the previous year an amount of Rs 35 Crores was released toward O&M and this year an amount of Rs 60 Crores is earmarked for O&M. This will go up to Rs 150 Crores in the coming years, and O&M works can be taken up in all commands to satisfactory level.

6. Bottom-up development needs support from the top.

The government of Andhra Pradesh is keen to implement PIM in the irrigation sector. As such, elections to all the WUAs have been completed and DCs are also constituted in certain projects; in the remaining projects it will be completed by the end of April 2007. As such, it is not correct that there is a lack of support for WUAs, and government is committed for stakeholders' participation in management of irrigation systems.

7. WUAs have only limited means to resolve water-allocation disputes.

It is not correct to say that WUAs have only limited means to resolve water-allocation disputes per the provisions of the Act. The farmers' organizations have been given powers for settlement of disputes (§§ 26, 27 of the Act).

V. Conclusions

- Based on limited study, conclusions, if any are drawn, will not be considered realistic.
- Visualizing the estimates either low or high is probable in the sense that the features on the ground cannot be foreseen accurately.
- Educating the farmers in a scientific way takes much time. Processes are taking time.
- Farmers will be satisfied with the scientific approaches only if they realize them on the field.
- The success will depend on the availability of water and the timing.
- The output/productivity largely depends on many factors, like monsoons, pest control, other management practices, and so forth.
- The farmers should get loans for their inputs, such as for seeds, pesticides, fertilizers, and so forth.
- Only through sustained campaign and capacity building activities can 100 percent water access can be realized, leading to sustenance of the systems.
- The reform process will continue in the irrigation sector, and the stakeholders will be involved more in coming years for better management of the systems.

Attachment 1: Details of Ayacut Contemplated and Irrigated under SRBC in I to XVI Blocks by March 2007

Sl number	Block number	Contemplated ayacut	Ayacut developed with field channels	Ayacut to be developed with field channels
1	I	16,833.32	7,805	9,028.32
2	II	3,814.81	1,665	2,149.81
3	III	4,745.62	1,410	3,335.62
4	IV	8,869.92	2,090	6,779.92
5	V	4,324.91	1,200	3,124.91
6	VI	4,716.66	2,087	2,629.66
7	VII	13,170.44	7,000	6,170.44
8	VIII	6,333.41	1,500	4,833.41
9	IX	10,812.88	4,600	6,212.88
10	X	24,117.75	8,500	15,617.75
11	XI	4,520.17	3,944	576.17
12	XIA	4,073.11	3,832	241.11
13	XII	2,258.44	1,759	499.44
14	XIIA	5,805.33	4,885	920.33
15	XIII	13,248.68	9,885	3,363.68
16	XIV	9,021.23	8,464	557.23
17	XV	6,165.22	6,165.22	
18	XVI	11,104.31	11,104.31	
Total		**153,936.21**	**87,895.53**	**66,040.68**

Attachment 2: Innovative Measures to Speed Up the System to Ground a Large Number of Projects

Irrigation is the top priority area of Andhra Pradesh. Jalayagnam is a unique venture of the state. The strategy behind successful implementation of various projects that have been identified under Jalayagnam is detailed below.

For any scheme, provision of required funds and their timely release is utmost importance. Budget provided vis-à-vis expenditure incurred since 2004–05 speaks for itself.

Year	Budget provided Rs in Crores	Expenditure incurred Rs in Crores
2004–05	4,200	3,331
2005–06	6,300	6,569
2006–07	10,042	9,109
2007–08	13,014	

All the project works are divided into convenient packages under category I (Rs 150 Crores and above), category II (Rs 50 Crores and above each package), and open category and works are entrusted under an EPC turnkey system. The EPC contractors are expected to do proper planning and execute the works, as per the program. As many as 245 packages have been awarded so far and work is going on as programmed.

About 6.5 lakh acres of land is required to be acquired for all the 35 major and 17 medium projects. So far more than 2 lakhs acres of land have been acquired on consent award method after conducting Gram Sabhas. The district-level committees are delegated with powers to decide the rates up to 50 percent for prevailing rates and the state-level committee with full powers. By this method land acquisition process is speeded up.

Various departments of the government of India are being pursued vigorously for speedy clearances of projects.

Third-party quality control agencies are entrusted with the job of overseeing the quality of construction in all these projects.

An online monitoring system developed by the Center for Good Governance is being used by all the supervising officers right up to the secretaries for review of progress of works.

Monthly review meetings by the Honorable Chief Minister are held.

The irrigation sector requires a lot of improvement. The irrigation efficiency in Andhra Pradesh is only around 35 percent. It needs to be increased to at least 50 percent by tight water management. Though PIM has been in vogue since 1997, the WUAs' performance is not showing the anticipated results in ensuring proper water supplies to tail-end areas of the systems. This is a challenge that the irrigation sector is facing, and every possibility is being explored to have effective water management.

As per the present estimate, an amount of Rs. 72,000 crores is required to complete the ongoing 35 major and 17 medium irrigation projects for creation of additional irrigation potential of 71.17 lakh acres. The expenditure incurred since June 2004 on irrigation projects is Rs 18,000 Crores.

Irrigation potential created in the last few years is given below.

Year	Ayacut in acres
	237,886
	220,491
	692,950

Year	Proposed ayacut in acres
	1,003,630
	1,582,239
	1,099,499

Micro Irrigation: The government issued orders to go for micro irrigation in all lift irrigation schemes, including the Gaaleru Nagari Sujala Sravanthi Scheme. The orders are issued primarily with a view to improve the water use efficiency while bringing additional area under irrigation in certain cases.

IEG Response to Comments

Government comment	IEG response
Irrigation is definitely a powerful force for poverty reduction.	IEG fully agrees with this statement, the report providing new estimates of this impact.
To draw conclusions on the entire irrigation development projects is inappropriate and not justifiable.	The report is specifically an impact evaluation of Bank support under AP II and AP III. Where more general statements are made, they are supported by additional evidence, notably IEG's review *Water Management in Agriculture: Ten Years of World Bank Assistance, 1994–2004* (IEG 2006b).
The methodology of assessing the impact, sample size, and selection of the sample chosen by IEG has significant differences and therefore the findings are misleading. Conclusions made on SRBC based on the sample of SRSP are inappropriate.	The government of Andhra Pradesh's comment appears to assume that IEG's analysis and finding are based solely on the IEG survey. This survey was undertaken to be able to investigate the impact of new irrigation. But a wide range of sources, including government data and the AP III "baseline," are used in the study.
It may not be out of context to mention that IEG has prejudged the issues and extrapolated/generalized the small sample survey results across the irrigation investments.	IEG does not agree with the suggestion that the issues were prejudged. The issue of the sample was discussed in the previous comment.
It is very much understandable that the two projects taken up are of different nature; that is, one is basically a rehabilitation of an existing system (SRSP) and the other one is to complete a new irrigation system for bringing new areas under irrigation. Thus, special issues concerned with these two projects and circumstances considered by the Bank for assisting are overlooked by the study and the report is made exclusive of these facts.	IEG's report does distinguish between SRSP and SRBC, both in terms of outputs and effectiveness. The report is clear that SRSP is rehabilitation and SRBC new construction, and that this is a major reason SRSP has a higher rate of return than SRBC. However, IEG's revisions after receiving the government's comments have made this distinction clearer.
The government departments will be strengthened in due course for maintaining efficient management of the irrigation system, so as to redress weaknesses in the activities of WUAs.	In revising the report, IEG has in several places indicated that the government of Andhra Pradesh has introduced measures to improve the efficiency of construction.
The IEG has made drastic comments on the functioning of government departments. It is felt desirable not to make an issue of this sort of comments.	IEG's comments are substantiated by reference to other studies with similar conclusions. As noted above, attempts by the government of Andhra Pradesh to improve the administration of irrigation are noted in IEG's revised report.
[IEG's] conclusions are not based on project-specific data . . . [so] the conclusions of the study do not adequately represent reality.	Project-specific data are used for SRSP costs and benefits and SRBC costs. Because no water had been delivered to the bulk of the command area of SRBC at the time the study was undertaken, benefits are estimates similar to those in the Bank's Implementation Completion Report (the government's comments of that report did not question these estimates).
Regarding the representation of the WUAs as mostly by the elite groups, the study conducted by the IEG is only for a limited area and for all practical purposes the study conducted by the ORG (2005) can be taken as reliable study, as the sample taken for the same is 214 WUAs across the state and in all three sectors of irrigation.	IEG's conclusions regarding WUA management are not based on its survey, but on a large survey of more than 200 WUAs carried out by cess, and a number of detailed studies. The ORG study is now referred to in the IEG report. The general conclusion is that WUA committees are reasonably representative, but that the president is not, and often runs the WUA with little consultation.

(Table continues on next page)

IEG Response to Comments *(continued)*

Government comment	IEG response
The water rates could not be collected to the expected level because of continuous drought. It can be observed that the water tax collections are around 100 Crores during the periods 1998–99, 1999–2000, and 2000–01, as the season was good.	In the revised report IEG gives the most recently available data on water cess collection, which remains inadequate for O&M.
It is not correct that the reforms have not broken a vicious circle, as the study is limited to the SRSP Project only, and there are no WUAs in SRBC.	As noted above, cess collection remains lower than required, and problems in water availability remain. The revised report gives the date of WUAs being created in SRBC.
It is not correct to say that WUAs have only limited means to resolve water-allocation disputes, per the provisions of the Act. The farmers' organizations have been given powers for settlement of disputes (§§26, 27 of Act).	IEG recognizes these formal powers but maintains that they are inadequate to resolve water disputes, especially those between communities.
It is not correct that there is a lack of support for WUAs, and government is committed to stakeholder participation in management of irrigation systems.	The report has been revised to reflect the commitment of the government to continuing the reform process.

APPENDIX H: IMPACT EVALUATION

Impact evaluation seeks to distinguish between what happened with the intervention and what would have happened in the absence of that intervention—that is, with versus without. The without is also called the counterfactual. Establishing a valid counterfactual is usually done using a control group—that is, a group similar to the treatment (beneficiary) group other than it does not have the intervention.

One problem encountered in establishing the counterfactual is that of possible selection bias, whereby there is a systematic bias between treatment and control communities. There are a number of ways around this problem. There are experimental approaches that are either randomized designs or natural experiments. Where these are not possible or applicable, then a quasi-experimental approach can be used, such as regression discontinuity or propensity score matching. Both these approaches are regression based.

If selection is on observables, then regression-based approaches can remove selection bias. If selection is based on time-invariant unobservables, then quasi-experimental approaches can also be used if there are both baseline and endline data (allowing double difference estimates). Only if selection is on time-varying unobservables is it necessary to use experimental approaches to avoid selection bias.

IEG's approach is to stress that impact evaluation should be rigorous *and* relevant. That is, IEG's impact studies apply rigorous approaches but also aim to deliver policy-relevant conclusions. Doing this usually means using a theory-based approach that analyzes the whole results chain for an intervention.

This impact study combines a variety of data sources to examine impact. The survey used a pipeline approach to identify the control communities, and regression analysis for most indicators. Other data sources allow estimates of single, and in some cases, double-difference estimates.

For further information on approaches to impact evaluation, see the two IEG booklets *Impact Evaluation: The Experience of the Independent Evaluation Group of the World Bank* (IEG 2006a) and *Conducting Quality Impact Evaluation under Budget, Time and Data Constraints* (Bamberger 2006).

Recent IEG impact evaluations include: *Agricultural Extension: The Kenya Experience* (2000); *Books, Buildings and Learning Outcomes: An Impact Evaluation of World Bank Support to Basic Education in Ghana* (2004); and *Maintaining Momentum to 2015: An Impact Evaluation of External Support to Maternal and Child Health and Nutrition in Bangladesh* (2005).

Chapter 1

1. Data are from FAOSTATS. For India these figures are 2,070 and 2,470. About 2,000 calories is the minimum daily requirement and is insufficient for those involved in physical labor. Because these are average figures, many people are below this level.

2. Gross cropped area "double counts" land used for multicropping and additional cropping seasons; the latter in particular is often made possible by irrigation.

3. These findings are supported by several different pieces of work, such as the econometric analysis with district data of Datt and Ravallion (1998) and Fan and Hazell (2001). A similar approach using state-level data is Bhattarai and Narayanamoorthy (2003). Recent project-level evidence comes from a study by the International Water Management Institute, which collected data from 26 irrigation systems in six Asian countries (Hussain 2007). For a general overview on irrigation and poverty, see Lipton, Litchfield, and Faurès (2003). For a summary of recent Indian evidence see Malik (2005).

4. For example, average annual lending to irrigation in the period 1994–98 was $610 million, compared with $419 million from 1999 to 2004.

5. It has also been observed that the more rigorous the ex post analysis, the lower the ERR (Berkoff 2002).

6. There are two aspects to excessive water consumption. One is planting crops requiring large quantities of water, notably paddy. The second is applying more water than is strictly necessary.

7. The basic charge was raised from Rs 60/acre to Rs 200/acre, with some variations.

8. The legislation also put in place project committees at the scheme level, but these have not yet been created.

9. WUAs are just one manifestation of *Janmabhoomi*. Many thousands of women's self-help groups were also formed. These are discussed in a separate report on the Andhra Pradesh Rural Livelihoods Program (World Bank 2004b).

10. The government of Andhra Pradesh states that the delay occurred to allow a review of WUA performance and for necessary changes to be instituted.

11. AP II collected no baseline data. AP III collected "baseline" survey data only in 2002, toward the end of the project. This survey data is drawn on in the current study.

12. The terminology here is the evaluation convention of a project or treatment group (that is, those receiving canal irrigation) and an untreated comparison group. The pipeline approach uses as the comparison group those who are scheduled to receive the treatment but who have not yet done so, hence overcoming the problem of selection bias caused by drawing the comparison group from those who will not participate. The bias arises because the determinants of participation may be correlated with project outcomes.

13. In its comments, the government of Andhra Pradesh questions drawing conclusions for the whole project based on a survey carried out in the tail end of SRSP. However, as the text makes clear, IEG's findings are based on a wide variety of data sources.

14. A natural experiment means that a comparison group arises out of a setting without intervention from the evaluator.

15. In project villages, these village-level averages include households without direct access to the irrigation system, but that may have benefited from the recharging of the groundwater through seepage from the canal, tanks filled with canal water, and irrigated plots.

Chapter 2

1. Wade (1982) documents the channels for this rent seeking in detail, and the amounts involved at that time. It continues to be the case that engineers prefer to work in construction rather than O&M.

2. See Vaidyanathan (1999) for a discussion of these issues.

3. Even the ICR, having discussed the problems that prevent water reaching the lower reaches and the fact that these problems have not been addressed, produced ERR estimates assuming the whole command will receive water.

4. The government of Andhra Pradesh piloted the WUA approach in the SRSP command prior to AP III. The expansion of WUAs across the command was, in the words of the appraisal report, to be a "prototype" for public investment schemes elsewhere in the state. However, the "big bang" approach adopted for the creation of WUAs meant that the support through AP III did not serve as a prototype.

5. This figure is for distributaries up to km 234 only. Under SRSP, a further 113,000 ha (funded by the government) have been added, from km 234 to km 284.

6. See also Vaidyanatan 1999 (pp. 59–61) on discrepancies between different data sources regarding irrigated area.

7. Revenue estimates of cropped area are the basis for tax collection, so underreporting produces a rent to be shared between the landowner and revenue official.

8. This problem is not unique to Andhra Pradesh or India. IEG's irrigation sector review reported figures for four projects in East Asia for which the actual cropped area was, on average, 67 percent of that expected at appraisal (IEG 2002, table 3.4).

9. A partial caveat is in order here, because seepage from the canal raises groundwater levels and so facilitates groundwater irrigation (boreholes and tubewells, as well as collection in other water-harvesting structures).

10. The SAR correctly states that the AP II investment costs are sunk costs that are irrelevant to the decision of whether to proceed with AP III. But in evaluating the ex post return to irrigation investments, all costs should be included. Assessing the overall investment based only on the follow-on project would allow a sleight of hand to produce a good rate of return. There is a parallel with the multistate Subernarekha Irrigation Project from the same time as AP II. This project financed initial construction costs, with most of the irrigated area to be established after the project. The appraisal report discounted fears that the later investments may not take place on the grounds that the initial investment costs would by then be sunk costs, so the additional investment would have a very good rate of return! In the event, cost overruns and delays meant that there was no irrigation at all under the project and the Bank decided *not* to finance a follow-on project.

11. In fact, the government's own investment in the scheme began in 1984, though these costs are not shown in this analysis, so the delay is longer and the return lower than shown here.

12. IEG (2002, p. 48–49) cites two other Bank projects in India and one in Nepal where construction delays contributed to a reduction in the ERR by 4 percent.

Chapter 3

1. One of the best known studies of community management of natural resources is Wade's (1988) analysis of irrigation management in Andhra Pradesh.

2. In major schemes, 50 percent is meant to go to the WUA, 20 percent to the distributary committee, and 20 percent to the project committee; in medium schemes the WUA gets 60 percent, and the distributary committee 30 percent; in minor schemes the WUA gets the full 90 percent. The other 10 percent goes to local government.

3. However, most of the discontent was about other aspects of the reforms, such as the increase in the price of subsidized rice and the reduction in power subsidies. There were public protests on these issues and the Communist Party condemned the Chief Minister as being a "daily wage laborer of the World Bank" (Prasad 2004).

4. The preface to an early World Bank review of the Andhra Pradesh experience stated, "The program [is] part of an overall vision for alleviation of poverty being applied in many sectors by Andhra Pradesh's state leaders." More explicitly, the Web site of the International Network on Participatory Irrigation Management says, "PIM can enable the poor to have greater voice in decisions. Conversely, if poor people are excluded and their interests neglected, then irrigation development may disrupt livelihoods and increase inequity. The poor may suffer disproportionately from irrigation performance problems such as water shortage in tail-end areas, and so may also stand to benefit more from performance improvements. Experience shows that participatory irrigation management offers important opportunities to empower the poor in good governance and to provide benefits for the poor."

5. If a landowner does not engage in production himself, then only the tenants are eligible to be members.

6. Few farm households in the sample report no irrigation of any sort on any of their plots. In 2005, there were 40 such households (of 567 cultivating households), none of which was a WUA member.

7. There are various explanations for the lack of political momentum. One is that the Chief Minister's attention became diluted with other concerns, notably new schemes for the Godvari basin. Second, the Secretary who had been instrumental in ushering in the reforms left his post. Third, the new government was suspicious of the new institutions created under the previous Chief Minister and so did not rush to implement the already delayed elections.

8. Bodies such as WUAs have a potentially important role to play when water is scarce, so scarcity might be expected to make the associations more active as farmers try to secure water. But the absence of water altogether means there is nothing to be allocated.

9. The wealth index is constructed from data on ownership of consumer durables, jewelry, and housing quality. It is used rather than income, as it is less affected by endogeneity.

10. The population is divided into four groups: scheduled castes, scheduled tribes, backward castes, and other castes. The first two categories benefit from reservation and other rights written into the constitution. Backward castes were later identified as also being disadvantaged groups requiring special support. The remainder, other castes, are the higher caste groups.

11. It has been argued that this has *not* been the general pattern in India in the past, as there has been a negative correlation between the "irrigation ratio" (the proportion of a household's land that is irrigated) and total landholdings, though that negative correlation has weakened in recent years (Vaidyanathan 1999, p. 85). But larger farmers have a larger absolute area of irrigated land, resulting in a marked inequality: a World Bank study reported that small and marginal farmers accounted for 81 percent of agricultural households at the national level but operate only 45 percent of the irrigated land (World Bank 2003, p. 10).

12. The appraisal report for AP III envisaged that WUAs would also branch into transportation, marketing, and agroprocessing. These things have not happened in any areas covered by this report.

13. This case illustrates one point (that the water flow to the tanks is meant to be limited) but raises another question (why the Irrigation Department has not opposed it elsewhere, raising the specter of political influence and rent-seeking).

14. This is the same figure as that found in another study of WUAs in Andhra Pradesh (Alsop and others 2002).

15. The government of Andhra Pradesh disputes the assertion that WUAs are subject to elite capture, citing the ORG report (2005) as evidence. While it is true that the WAU committees are more representative, the key position of president is not. The lack of consultation by the president is supported by the ORG report.

16. Other measures of socioeconomic status—wealth, education, and an index of political status—are correlated with landholding, so there are problems of multicollinearity undermining their significance. If land is dropped, then wealth and political status become significant. A similar analysis is presented in the paper of Alsop and others (2002), who asked WUA members only. Large landowners, the non-poor, and those who benefited from increased water supply were more likely to respond that the WUA achieved effective management of the irrigation system and better water distribution.

17. The same point is made in Mott MacDonald (2005), drawing on experience from Nepal, the Kyrgyz Republic, as well as Andhra Pradesh. They also emphasize that WUAs lack the technical expertise to manage the canal network.

18. This finding echoes that in Jairath's (2000) review of WUAs, written during the first term of office when there was considerable optimism about the Andhra Pradesh experience: "The tail-end areas of the sample distributaries continue to be deprived of their share of water. There was no effective way of prevailing over the head villages even through the mediation of distributary committees." The World Bank appraisal document for AP III stated that the formation of WUAs would create a lobby against water waste in higher reaches, but this does not seem to have happened.

19. In China, for example, where the benefits of irrigation are more equitably distributed than they are in India, Communist Party officials are active in the water-allocation process. The same author says explicitly that "smooth functioning of the system requires that there be some high authority to enforce rules and resolve conflicts" (Vaidyanathan 1999, p. 27).

20. However, government officials still had to sanction works proposed by the WUA and Reddy and Reddy (2005) state that there was a lot of rent seeking associated with this process, which is to be expected given Wade's analysis (1982).

21. This point is made in each of Mollinga, Doraiswamy, and Engbersen (2001), Alsop and others (2002), and Jairath (2000).

22. According to Wade (1982), contractors play an important role in the system of political and administrative corruption, being responsible for "paying off" so most of the rents raised do not have to pass through the hands of senior politicians. The predominance of contractors among WUA presidents supports suspicions that the situation has not improved since Wade wrote his paper.

23. There is one documented case of farmers in Andhra Pradesh taking it upon themselves to form their own project-level committee and claiming, albeit unsuccessfully, the share of the project committee (Mollinga, Doraiswamy, and Engbersen 2001).

24. On top of the water fee there is meant to be an "own contribution" of 15 percent from WUAs to any works carried out. These contributions are commonly not collected, being estimated at just 5 percent (rather than 15 percent) of expenditures.

Chapter 4

1. This is assuming average farm size of 1.3 ha in SRSP (calculated from IEG survey, the SAR assumed 1.1 ha, but the SRSP baseline gives a higher figure of 1.4 ha), that the irrigation proportion is two-thirds, and that 80 percent of the reported ayacut (area served by the irrigation scheme) actually receives irrigation water.

2. Cropping intensity can also increase with multicropping, that is, growing more than one crop on the same plot at the same time. However, multicropping is more common on rain-fed plots than irrigated ones.

3. See appendix table D.8 for actual and expected yields for major crops.

4. The World Bank's ICR for AP III makes the same observation.

5. "Double-difference" estimates of actual yield increases were calculated using the survey data at both plot and community levels. At the plot level, the first difference is the average change in yields for plots that grew paddy in both 2005 and 2006 but that used canal or tank irrigation only in the latter year. This becomes a double difference by subtracting from this yield increase the yield increase in an "untreated" control area (see appendix C). Two control groups were used. The first control was a panel of plots that had not changed their irrigation source between the two years. The second control comprised plots that were not irrigated during either year (no canal, tank, borehole, or tubewell). In the latter case, the treatment group included those with newly acquired canal or tank irrigation who did not have irrigation in 2005. Although the second double difference is a more satisfactory definition, the sample size becomes small, so the first method has to be used for less common crops. This analysis is complemented by a fixed effects regression of the panel data.

6. The staff of the Agricultural Finance Corporation assisted in the acquisition of these data.

7. The ICR yield increase estimates for paddy are lower than this range.

8. This analysis was also performed controlling for soil type, but the subsample sizes for the unirrigated plots were too small to allow a meaningful comparison.

9. If the comparison group is well chosen, then the treatment and comparison group have the same initial conditions, so that the ex post single difference is equal to the double difference.

10. It might be argued that farmers will take time to realize the full yield potential. However, the yields of newly irrigated farmers are not notably different from those of already irrigated farmers, suggesting that there is little scope for "catch-up."

11. The shortfalls reported here are very similar to those found in a review of four projects in East Asia, with actual yields being 40, 47, 48, and 73 percent of those expected at appraisal (IEG 2002, table 3.3).

12. The benefit stream is net income, that is, revenue minus costs. The percentage change in net income is the percentage change in revenue (–50 percent) times the ratio of revenue to net income, which is taken as 1.5. Hence, the reduction in net income is 75 percent.

13. The appraisal ERRs are those given in the SAR, which *do not* include the AP II sunk costs. According to the SAR, taking these sunk costs into account reduces the overall ERR by just over 5 percent and that for SRSP below Lower Manair Dam by just over 3 percent. Hence, the ERRs with a 50 percent reduction of yields, and allowing for sunk costs, are 9 percent for SRSP below Lower Manair Dam and 3 percent for the whole project.

14. Although those with new access to canal or tank irrigation appear more diversified, this may simply indicate that farmers do not immediately adjust to the less-diversified cropping pattern typical of those who have access to irrigation water for a longer period. Moreover, the double-difference estimates (comparing the change in rice shares between 2005 and 2006 for households that have newly acquired access to canal or tank irrigation) show an increase in rice share of 5–17 percent for those who did not have irrigation previously and of 5–9 percent for those previously using other forms of irrigation.

15. See Jairath 2000 for a discussion of the reasons for rice preference.

16. In Andhra Pradesh the rice price for consumers is guaranteed by the government. If the producer price remains above this consumer price, then the effect of the price reduction is a fiscal saving for government rather than a benefit for consumers.

17. Vaidyanathan's (1999) review of Indian irrigation reports estimates in the range of 20– 30 percent.

18. In the plot-level regression for cropping intensity, none of the irrigation source dummies is significant once the number of sources is included in the regression.

19. Three-quarters of plots with access to canal and tank irrigation acquire the water by flooding, whereas the majority of those with tubewell or borehole irrigation use an electric pump (appendix table D.14).

20. The IWMI study (Hussain 2007) concluded that the multiplier in India was between 1.22 and 3, typically around 2.21, which is higher than, but not inconsistent with, Hazell and Haggblade's (1990) finding that a Rs 100 increase in agricultural incomes increases nonfarm income by Rs 64, that is, a multiplier of 1.64. Bhattarai, Barker, and Narayanamoorthy (2004) suggest an even higher multiplier of 3–4.5.

21. A shadow wage rate of 0.5 has been used in this report (in line with the appraisal and ICR calculations), thus assuming that half the employment is additional or that the alternative employment was only half as productive.

22. Calculated for cultivating households only (see appendix table D.15).

23. This explanation is supported by two findings. First, in 2005 only 16 percent of cultivating households hired out labor for agricultural purposes, but in 2006 nearly two-thirds (64 percent) did so. Second, the fixed effects regression for domestic labor has a negative coefficient on the canal dummy but a positive one on the (canal x area) interactive variable, showing that in larger households canal irrigation increases use of domestic labor (see appendix C for results).

24. Using the constant 2005 price value of farm output, labor productivity was Rs 101 per day's labor in 2005 and 118 in 2006 (the calculation excludes farms with failed crops).

25. The mean wage for women rose from Rs 24.95/day to Rs 27.50/day (and the median from Rs 25 to Rs 30). The mean for men rose from Rs 48.09 to Rs 50.72 (though the median remained unchanged at Rs 50); see appendix table D.24.

26. This increase in outside employment was almost entirely among cultivators: average outside employment rose by 100 days a year for cultivating families, whereas there was no significant change for noncultivating households (appendix table D.15), a finding that mirrors the drop in the use of domestic labor.

27. For example, literacy in head reaches is higher than in tail reaches, though the difference is not great (48.0 versus 43.5 percent—calculated from census data). The main difference is in the distance to Warangal, which is on average twice as far for end-reach villages as for those at distributary heads (appendix table D.26).

28. There is an important caveat that the analysis did not include some benefits. First, it did not allow for the more severe drought-related shocks on rain-fed plots. Second, multiplier effects are not included. Third, the welfare impact of lower food prices is not considered.

29. The benefit inflator is 13 percent (=1/0.88, not 12 percent) because the appropriate base is the share used for canal irrigation. The assumption here is that the benefit per unit of water is the same regardless of end use, which is almost certainly not so, but as good as any other assumption in the absence of data to quantify the benefit from alternative uses.

30. The SRBC main canal is 141 km, which is to irrigate 65,000 ha, which compares to the ayacut of up to 323,000 ha covered by the 234 km of the Kakatiya main canal in SRSP—that is, the irrigated area per km of main canal in SRBC is one-third of that in SRBC.

31. The SAR for AP III did consider just one combination: the two construction-related risks of cost overrun and delayed start.

32. This calculation subtracts from the ERR base case return the decrease caused by allowing for sunk costs (–5.2 percent), a 25 percent reduction in yields

(–2.4 percent), a 20 percent increase in costs (–2.4 percent), a two-year lag in benefits (–5.0 percent), and limited diversification (–5.4 percent).

Appendix A

1. The head reach is the upper 25 percent in length and the tail the bottom 25 percent. Reaches were identified by matching a village list against a list of WUAs, giving villages and minor canals (subdistributary numbers) and using a system map to classify the minors by reach. A small percentage of villages could not be identified (spellings of the same village can vary greatly by the source consulted and even in different rounds of the census) and so are listed as unclassified.

2. A village can be identified by its reach on each of the main, distributary, and minor canals; for example, a village with the position middle, head, tail, would be a village in the middle reach of the main canal, at the head of the distributary and toward the tail of the minor. The reach referred to in the sample design is that in the distributary canal. All sample villages fall within approximately the same reach of the main canal, which is the tail, though this was relatively well served by water in 2005–06, given the good monsoon. The position of the minor also matters, as shown by the fact that we found several instances in which villages at the head of the minor captured all the water.

Appendix E

1. It can be noted in passing that the very high cost per irrigated hectare for SRBC requires substantial yield increases to achieve an acceptable rate of return.

2. The poverty headcount actually falls by less under scenario 2. This is because under scenario 2 the income gain to those in the second quartile is less, so fewer cross the poverty line. Although the income gain for those in the first quartile is more under this scenario, it is insufficient for them to reach the poverty line.

Appendix G

1. Consolidated comments are prepared by IEG on the basis of separate sets of comments submitted to IEG.

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