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Central Asia
The Costs of Irrigation Inefficiency in Tajikistan

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CURRENCY EQUIVALENTS

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Currency Unit	-	Somoni (TJS)
TJS 7.88	=	US$1.00
US$1.00	=	TJS 0.13

In this report, "$" and "US$" refer to US dollars.

ABBREVIATIONS

ASCE	-	American Society of Civil Engineering
ADB	-	Asian Development Bank
ALRI	-	Agency for Land Reclamation and Irrigation
BET	-	Beneficial Evapotranspiration
EBRD	-	European Bank for Reconstruction and Development
ET	-	Evapotranspiration (crop water use)
GDP	-	Gross Domestic Product
GIS	-	Geographic Information System
GPS	-	Global Positioning System
I&D	-	Irrigation and Drainage
IFC	-	International Finance Corporation
IID	-	Imperial Irrigation District (California)
ISF	-	Irrigation Service Fee
ITRC	-	Irrigation Training & Research Center
IWRM	-	Integrated Water Resource Management
MEWR	-	Ministry of Energy and Water Resources
METRIC	-	Mapping Evapotranspiration at High Resolution with Internal Calibration
NGO	-	Nongovernmental Organization
MoA	-	Ministry of Agriculture
O&M	-	Operations and Maintenance
PLC	-	Programmable Logic Controller
USAID	-	United States Agency for International Development
VAT	-	Value Added Tax
WB	-	World Bank
WUA	-	Water User Association

WEIGHTS AND MEASURES

CMS	-	Cubic Meters per Second
Ha	-	hectare
kWh	-	kilowatt-hour
m	-	meter
MCM	-	Million cubic meters

DEFINITIONS

Irrigation efficiency	The ratio of effective water use (that is, the water used by the crop) to the water actually applied to the crop
Irrigation productivity	The ratio of crop output (measured in monetary or physical terms, or both) to water either diverted or consumed

Water productivity	The ratio of economic output (measured in monetary terms) to water either diverted or consumed for the purpose of producing the outputs
Effective Irrigation	The ratio of effective water use (that is, the water used by the crop) to the water actually applied to the crop minus the volume of water returned or recycled
Efficiency Losses	The water diverted but not used for evapotranspiration (ET)

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EXECUTIVE SUMMARY

(i) **Background.** The Aral Sea Basin consists of the drainage area of two major rivers, the Amu Darya and the Syr Darya. The rivers originate in the Tien Shan Mountains and the Pamirs, and run through Afghanistan, Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The basin is home to almost 60 million people, and provides irrigation to 11.4 million hectares (Ha). An estimated 116 km^3 is diverted for irrigation, one of the key drivers of economic growth, employment, poverty reduction and food security in the region. At the same time, diversion of water for irrigation of vast agricultural fields has contributed to severe environmental and health problems in the basin.

(ii) As a result of population increases, climate change, and economic development, water resources in Central Asia are increasingly under pressure. At the regional level, annual water availability per person per year, currently 2,500 m^3, is expected by 2030 to reach only 1,700 m^3 per person per year, the internationally recognized level for water stress.

(iii) Despite mounting pressures and increasing water stress, water use in irrigated agriculture is particularly wasteful, with irrigation efficiencies often not more than 30 percent. Improving irrigation efficiency has important regional implications, because large amounts of water could be unlocked for more productive purposes. For example, more efficient use of irrigation water could help increase the water flows into the delta areas of the Aral Sea, and into the Aral Sea itself. Similarly, securing access to drinking water of adequate quality in the downstream parts of the basin requires a more efficient use of water and a reallocation of that water for drinking water purposes.

(iv) But irrigation efficiency is also important from a national perspective. Pumping plays an important role in Central Asia's irrigated agriculture and accounts for significant sunk and operation and maintenance (O&M) costs. For instance, in Uzbekistan, electricity use for Irrigation and Drainage (I&D) pumps accounts for 16 percent of national electricity generation, costing close to US$350 million annually and accounting for 60 percent of the annual budget of the ministry responsible for irrigation. In Tajikistan, over 40 percent of irrigated agriculture relies on pumps – the highest percentage in Central Asia. With more than 20 percent of Central Asia's I&D served by pumps, achieving low irrigation efficiencies comes at a high cost.

(v) **Scope and objectives of the study.** Against this background, a study of irrigation inefficiency in Tajikistan was conducted as the first phase of a larger regional assessment of irrigation inefficiency in Central Asia. This study focuses on Tajikistan in recognition of the interest expressed by national authorities who have articulated concerns about the intensity of energy and water in Tajikistan's economy. Along with its Central Asian neighbors, Tajikistan is highly water- and energy-intensive. The irrigation sector is one of the largest consumers of power in the country. Irrigation efficiency and energy use in the sector are intricately interlinked, and inefficiencies in the use of one resource inevitably have an impact on the other.

(vi) The study focused on causes, costs, and solutions of low irrigation efficiency in Tajikistan's irrigated agriculture. Its main purpose was to raise awareness about the high costs resulting from irrigation inefficiency in Tajikistan.

(vii) A second objective was to develop a methodology for estimating the costs of irrigation inefficiency that might be used when extrapolating the results of the study to other countries in Central Asia.

(viii) **Definition of irrigation inefficiency.** Irrigation inefficiency is defined in this study as the amount of water that is being supplied in excess of beneficial consumptive and evaporative demand. The Mapping Evapotranspiration at High Resolution with Internal Calibration (METRIC) methodology was used to estimate crop evapotranspiration of irrigated crops.

(ix) **Field studies.** In six representative irrigation schemes in the country, field studies were conducted. The methodology that was used in this study involved (i) determining irrigation inefficiency, (ii) determining the costs of pump irrigation, and (iii) determining the costs of irrigation inefficiency. The study identified a range of technical socio-economic and institutional factors contributing to the inefficiency of pump irrigation. They include: limited knowledge and incentives among farmers; extreme sand wear of pumps; problems with poor electric power quality; periodic power outages; deteriorating conditions of the pumping infrastructure; and a network of adjacent irrigation canals.

(x) **Costs of irrigation inefficiency.** The costs of irrigation inefficiency are proportional to the electricity used to pump water. Other fixed costs are not (or less) proportional to inefficiency and were not analyzed in detail. The costs of inefficiency includes electricity costs, direct and indirect price subsidies to agriculture and energy sectors for electricity, and foregone revenues of the Tajikistan national power company, Barqi Tojik, due to bad debts, including cancellation of debts in the irrigation sector. The total cost of pump irrigation to the country was assessed as substantial. In 2013 alone, for instance, the annual cost of pump irrigation in the country was US$31.09 million. The cumulative cost for the period from 2005-13 is even more striking: US$217.89 million or US$95.54 per ha annually. According to FAOSTAT, a statistical report of the Food and Agriculture Organization of the United Nations (FAO), in 2011 an estimated income generated by one hectare of irrigated land was approximately US$95.00, while the cost of pumped irrigation for the same year was US$120.84 per ha (if we consider the losses as a result of electricity subsidies), or US$72.25 per ha (if we don't consider these losses). Because of the high costs of pumped irrigation, maintaining rural livelihoods through public support for irrigation comes at a high real cost to the national budget.

(xi) Cumulative paid and unpaid electricity costs and electricity subsidies from 2005 to 2013 amounted to US$139.48 million, or 69.0 percent of total O&M costs. The costs of irrigation inefficiency at 72 percent was estimated at US$100.43 million from 2005 to 2013. This represents US$11.16 million per year on average, or US$44.11 per irrigated hectare per year.

(xii) The Governments of Afghanistan, the Kyrgyz Republic, Pakistan, and Tajikistan recently signed a power purchase agreement to sell excess summer energy from the Kyrgyz Republic and Tajikistan to Afghanistan and Pakistan. As a result of this power purchase agreement, Tajikistan can now sell excess summer energy to Afghanistan and Pakistan for US$0.05 per kilowatt-hour (kWh) – significantly higher than the 2013 rate of US$0.0041 per kWh and the 2014 rate of US$0.0035 per KWh that the government of Tajikistan charged farmers for pumped irrigation -- and cost recovery is limited. Until recently, summer energy surpluses and comparably minimal water demands of other sectors reduced the opportunity costs of summer energy (and of the efforts to improve efficiency in the summer) to close to zero. The competing and more profitable use of summer energy is thus expected to provide an incentive to the Government of Tajikistan to pursue irrigation efficiency.

(xiii) In view of this development, the analysis examined the cost implications of improved pump irrigation efficiency under three different scenarios. The scenarios are based on different mixes of investments in irrigation efficiency and use of saved water for irrigation expansion or electricity generation. In Scenario 1, estimates are made of the efficiency improvements and energy savings that will be gained as a result of training of Water User Associations (WUA) and Agency for Land Reclamation and Irrigation (ALRI) staff. No physical investments will be made in this scenario, and water savings will be used for irrigation expansion. In Scenario 2, an assumption is made that in addition to the training under scenario 1, physical investments will be made in irrigation infrastructure to improve efficiency, and savings will be used to expand irrigation. In Scenario 3, an assumption is made that water savings as a result of efficiency improvements will be used to generate electricity that will be sold to Afghanistan and Pakistan for institutional strengthening. Instead of using water savings gained from efficiency improvements for irrigation expansion, these savings will be used to generate electricity.

(xiv) The results of the analysis of these three scenarios suggests that the highest reduction in costs to the country at 62 percent will be achieved mainly through the release of saved power to the export market (that is, 57 percent from exported energy and 5 percent from increased collection of irrigation service fees and power fees). In other words, the cost of pump irrigation to the country cannot be meaningfully reduced when the saved energy is used to expand irrigation coverage that is using energy at a subsidized rate. If the government follows the pump irrigation cost reduction model proposed under Scenario 3, the earnings from the power exports could then be used to support the population whose livelihoods depend on pump irrigation.

I. INTRODUCTION

A. Background

1. The Aral Sea Basin consists of the drainage area of two major rivers, the Amu Darya and the Syr Darya. The rivers originate in the Tien Shan Mountains and the Pamirs, and run through Afghanistan, Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. The basin is home to almost 60 million people, and provides irrigation to 11.4 million hectares. An estimated 116 km3 is diverted for irrigation, one of the key drivers of economic growth, employment, poverty reduction, and food security in the region. At the same time, diversion of water for irrigation of vast agricultural fields has contributed to severe environmental and health problems in the basin.

2. Water resources in Central Asia are increasingly under pressure. For example, in Uzbekistan, average annual water availability per year and per person is already close to 1,700 m^3, which is the threshold for water stress. At the regional level, annual water availability per person, currently 2,500 m^3, is expected to reach this stress level by 2030. In addition, abundance and shortage have important seasonal, geographic, and economic dimensions because downstream countries are highly dependent on upstream countries for obtaining essential water for irrigation. Hydropower resources are concentrated in the Kyrgyz Republic and Tajikistan, while thermal energy resources are concentrated in Uzbekistan, Turkmenistan, and Kazakhstan.

3. Despite emerging water stress, water continues to be used in a particularly wasteful manner. Irrigation efficiency in the region is estimated at about 30 percent (that is, only 30 percent of the water that is withdrawn from the rivers for a specific irrigated area actually reaches the roots of plants), and average annual abstraction for irrigation is well over 15,000 m^3 per hectare. Low irrigation efficiency and high water losses are associated with the fact that much of Central Asia's hydraulic assets were developed from the 1960s to the1980s and are now aging as a result of deferred maintenance. But policies, institutions, and human capacities also play a role in providing an environment that is less favorable for using water efficiently. For instance, the use of mandatory production quotas in some countries in Central Asia, and the hands-on involvement of local authorities in water management to make sure the quotas are being met, often lead to chaotic water management schemes that result in high operational losses.

4. Improving irrigation efficiency has important regional implications because large amounts of water could be unlocked for more productive purposes by other sectors or in other locations in the basin. For example, more efficient use of irrigation water could help increase the water flows into the delta areas of the Aral Sea, and into the Aral Sea itself. Similarly, securing access to drinking water of adequate quality in the downstream parts of the basin requires a more efficient use of water and a reallocation of that water for drinking water purposes.

5. But irrigation efficiency is also important from a national perspective. Pumping plays an important role in Central Asia's irrigated agriculture and accounts for significant sunk and operations and maintenance (O&M) costs. For instance, in Uzbekistan, electricity use for irrigation and drainage (I&D) pumps accounts for 16 percent of national electricity generation, costing close to US$350 million annually, and accounting for 60 percent of the annual budget of the ministry responsible for irrigation. With more than 20 percent of Central Asia's I&D served by pumps, achieving low irrigation efficiencies comes at a high cost in the national budgets.

6. As a result of inefficient use of irrigation water, all Central Asian countries score high in global rankings that compare the water use per person and per unit of Gross Domestic Product (GDP). Central Asian countries are among the most water-intensive economies in the world. Aside from the environmental consequences of desertification and salinization, water scarcity is becoming a binding constraint to growth in irrigated agriculture. A more efficient use of water would reduce the costs of inefficient use and increase the returns in terms of agricultural production, productivity, and income.

7. Helping Central Asia countries improve irrigation efficiency would thus provide an important contribution to reducing public expenditures and increasing incomes. Determining the high costs of inefficiency would be the first step, a step that this study sets out to do.

8. The study focuses on Tajikistan in recognition of the interest expressed by national authorities who have articulated concerns about the intensity of energy and water in Tajikistan's economy. Like its Central Asian neighbors, Tajikistan is highly water- and energy-intensive. Ninety percent of water withdrawals in the country is allocated to irrigation, with 44 percent of the area that was originally equipped for irrigation being reliant on pumps. The irrigation sector accounts for a significant proportion of the total national electricity bill, and is also one of the largest consumers of power in the country. Irrigation efficiency and energy use in the sector are intricately interlinked, and inefficiencies in the use of one resource inevitably have an impact on the other. (See Appendix D for a Background Note on the relationship between energy and irrigation in Tajikistan.)

B. Scope and Methodology of the Study

9. The study is the first phase of a larger, regional assessment of irrigation inefficiency in Central Asia aimed at sensitizing irrigation practitioners in the region about the high costs – and therefore the importance – of irrigation inefficiency. Against this background, a study was conducted investigate the costs, causes, and mitigation measures of low irrigation efficiencies found in Tajikistan's irrigated agriculture. (See Appendix B for a description of the terms of reference for the study.) The study was designed as a pilot analysis to both identify key issues associated with assessing irrigation inefficiency, and to extrapolate the results to other countries in the region. Raising awareness that irrigation inefficiency comes at a high cost at the national level (in addition to the high costs of inefficient resource allocation more broadly at the basin level) was the main purpose of this report. A second objective was to develop a methodology for estimating the costs of irrigation inefficiency that will be used when extrapolating the results of the study to other countries in Central Asia

10. The study identifies key determinants of irrigation inefficiency in Tajikistan and proposes generic solutions targeting improvements in these areas. The report is structured along the following pillars: (i) determining irrigation inefficiency in the context of Tajikistan; (ii) determining the variable costs of the irrigation sector, in particular related to the performance of pump irrigation; (iii) determining the cost of irrigation inefficiency for the economy; and (iv) proposing aggregate solutions for addressing irrigation efficiency at the national level.

11. Field work associated with the study was conducted in June 2013, and data were obtained for six representative pumping schemes. Visits were also made to two pump repair shops. Initial and subsequent information gathering was facilitated by Sulton Rahimzoda, First Deputy

Minister of Energy and Water Resources. (See Appendix B for a list of key visits during the information gathering process.) Crop water use in the six scheme areas was estimated for May and June of 2013 using the Mapping Evapotranspiration at High Resolution with Internal Calibration (METRIC) process, which is a computational procedure that uses data from local weather stations and from remotely sensed Landsat satellite images to estimate water used by crops. Appendix A contains a detailed description of the METRIC process used in the study.

12. There is no accurate information available (locally or nationally) on scheme details such as area per crop, pump flow rates, distribution of water throughout the schemes, and power consumption per pump station. The six selected schemes were: (i) KNS, Zafarabod District; (ii) KojabokirgonProject, Bobojon Gafurov District; (iii) Makhram, Kanibadam District; (iv) Faizobodkala, Panj District; (v) Garouti, Jillikul District; and (vi) Urtabuz, Farkhor District. A detailed description of the selected schemes is provided in Appendix C.

C. Definition of Irrigation Efficiency

13. For the purpose of the study, irrigation efficiency is defined as the share of the withdrawn water that is used beneficially, as follows:

$$Irrigation\ Efficiency = \frac{Volume\ of\ Beneficial\ Evapotranspiration}{Volume\ of\ Pumped\ Water} \times 100$$

14. Much discussion has been devoted to determining what exactly is considered beneficial. For instance, leaching to reduce salinity in the root zone of soils, as practiced widely in Central Asia, can be argued to be a beneficial use of water. Similarly, leakage from canals is sometimes used by downstream farmers for irrigation of crops and should therefore not always be considered a loss. This study will only consider beneficial evapotranspiration (ET) as a beneficial use.

15. Irrigation efficiency consists of two connected subsystems, as follows:

- *Conveyance efficiency (water delivery efficiency)* is the ratio between beneficial evapotranspiration (BET) at the last field and water withdrawal from the offtake. BET refers to water evaporated and transpired by plants. For the purpose of this study, all other water use is considered a loss. The major losses fall into three categories:
    a. Seepage and spill losses between the canals and the fields
    b. Spill and seepage from canals and pipelines
    c. Operational spill, such as those associated with management of pump cascades, daytime-only irrigation, escape flows, and so forth.

- *Field irrigation efficiency (water application efficiency)* is the ratio between BET and the amount of water supplied to a field. It includes all losses to the scheme at the field level. The major losses are related to:
    a. Field characteristics, including levelness, length and gradient of furrows, length of fields
    b. Soil characteristics, including depth of soil profile, porosity, existence of plough pan, and so forth
    c. Field application techniques (furrow/basin/sprinkler/drip, and so forth).

16. Improving irrigation efficiency is not a purely technical matter, but includes a wide array of social, policy, institutional, and agronomic measures that need to be addressed. Some of them are focused on on-farm measures, such as providing full information to farmers and WUAs about water delivery, and ensuring a reliable and predictable supply to farmers, educating them about crop water requirements and specific crop irrigation schedules, and offering reliable weather forecast services to farmers for better planning and management of water supply. Other measures are aimed at creating incentives for farmers to adopt water-saving technologies and to improve water management practices. Enforcement and oversight to ensure that delivery schedules are respected are also important to ensure higher efficiencies.

17. However, no amount of capacity and incentives can accomplish high efficiencies if schemes are designed and operated in a manner that is too complex. For example, a long crested weir and orifice turnout combination will help provide a fairly constant turnout discharge. Canals that require full supply to command the fields may lose the dead storage through infiltration and evaporation at times when the canal does not operate. Agronomy can have an impact on efficiency because of crop choice. For example, rice uses much more water than other crops. Improving efficiency therefore requires a comprehensive effort to address all these issues in a consistent manner.

18. **Scheme efficiency vs. river basin efficiency.** Among irrigation practitioners, it is commonplace to downplay the importance of irrigation scheme efficiency as compared to overall river basin efficiency. One argument is that the only water loss to a basin is through evapotranspiration, and that infiltration and percolation losses within irrigation schemes will find their way back to the river basin through groundwater or surface runoff. The same applies to drainage flows, and many irrigation experts therefore speak about “effective efficiency” that does not consider these return flows as losses in view of their re-use downstream. In fact, while scheme efficiency can be low, overall basin efficiency can actually be very high as a result of repeated re-use of irrigation water. While this argument is technically correct to some extent (if we discount the evaporation losses that are often associated with wasteful water use, and if we ignore the water quality losses when drainage water percolates through salinized soil profiles), the present study considers percolation as a loss because it increases the pumping costs of a scheme. For the same reason, return flows are considered a loss because they add to the pumping costs, and the report therefore adopts a very “restrictive” definition of irrigation efficiency.

19. **Irrigation efficiency vs. irrigation productivity.** Expanding the scope of the study from irrigation efficiency to irrigation productivity (or even further to water productivity) would dilute the main message of the study significantly. We reach this conclusion notwithstanding two issues: one is that the costs of low water productivity to the national economy as a result of inadequate agricultural and water sector policies[1] are likely to be much higher than the costs of pumping; and the second is that it is recognized that water productivity (that is, the ratio of crop output (measured in monetary or physical terms, or both, to water either diverted or consumed) as opposed to water use efficiency (that is, how much of the water abstracted actually reaches the plants) could be the more important policy consideration,

[1] See Appendix E for an analysis of the agricultural and water sector reforms that are under implementation in Tajikistan

20. The costs of irrigation particularly include operation and maintenance expenditures, such as staff salaries, fuel for machinery, electricity for pumps, and depreciation of assets. Most of these costs depend to a limited extent on the efficiency of water supply, and cannot be reduced by improving irrigation efficiency. For example, inefficient water use does not necessarily increase staff salaries, nor does it increase capital investment costs. The only costs that have a strong correlation with inefficiency are the costs of pumping, including both the costs of fuel, and the costs of maintenance and depreciation. The study therefore focuses on the pumping costs as a proxy for the costs of inefficiency. This is justified because other fixed costs associated with irrigation inefficiency are comparatively independent of the magnitude of the inefficiency, and they cannot be reduced by improving efficiency. The fixed costs are therefore neglected in this study.

21. **Determine irrigation inefficiency.** In the study, six pilot schemes were examined that were located in a diverse set of environments to determine each scheme's inefficiency, that is, the amount of water being supplied in excess of beneficial consumptive or evaporative demand. Evaporative demand was calculated by using the METRIC analysis for a two-month period (May and June) in 2013. Irrigation supplies were obtained by analyzing pumping records of the six pilot schemes. Rainfall was not taken into account, since precipitation was negligible during the study period.

22. **Determine the costs of pump irrigation.** Information about the extent of the area that was originally developed for pump irrigation in Tajikistan is readily available. The study analyzed public expenditures for irrigated agriculture, including pumping costs, maintenance costs, and capital development costs.

23. Public subsidies were taken into consideration, including price discounts for electricity and debt cancellation. The costs of pump irrigation were then divided into fixed and variable costs. Only variable operating costs (for instance, electricity costs) were considered; maintenance costs and capital expenditure costs were not included in the calculation of the costs of irrigation inefficiency. Export prices for saved energy were used to quantify the value of the savings.

24. **Determine the costs of irrigation inefficiency.** The cost of inefficiency was computed as a product of the variable cost of pump irrigation and irrigation inefficiency.

25. The methodology adopted in this study to calculate water use is standard for modern projects in the western United States, because the use of the Irrigation Training & Research Center (ITRC) METRIC process simplifies data collection and reduces assumptions regarding crop water usage. In the context of Tajikistan, where availability of reliable information is a major constraint, the METRIC procedure was the only realistic approach to estimating crop ET of irrigated crops, for the following reasons:

- There was no need to rely on inexact data of crop types. Rather, METRIC only requires a knowledge of whether an area has field crops or tree and vine crops.
- There was no need to rely on inexact data of cropped acreage. This is often a major weakness using standard procedures, because reported areas may be quite different from actual areas. Errors with standard procedures include poor reporting, uncertainty about planting and harvesting dates, and differences between the gross area and the net area.

- There was no need to know the details of irrigation scheduling, including when irrigation water was applied to individual fields, the irrigation method, and soil characteristics.
- METRIC automatically compensates for non-uniform growth (and therefore non-uniform ET) within a field. Standard crop water usage estimates often ignore this reality, and therefore the crop ET is usually over-estimated.
- Internal project recirculation of water was automatically taken into account because the boundaries of the computations were set at the borders of the project.

26. **Limitations of the study.** The study revealed that the methodology was able to generate fairly accurate estimates of the costs of inefficiency, as confirmed by cross-checking the data against a number of indicators. Nevertheless, the following limitations have to be acknowledged, in view of potential expansion of the methodology to other Central Asian countries or other specific irrigation schemes. It should be noted that studies in other Central Asian countries are expected to be able to take advantage of better data availability, in particular with respect to supply of water to project areas:

- *Data availability.* The two major data weaknesses for the computation of irrigation efficiency are the following:
    - Lack of good local weather data: This is a limitation for any method of ET computation.
    - Uncertainty regarding the gross volumes of water applied to the project: Pump flow rates were not tested, but instead were de-rated from new design flow rates based on observations of pump discharges and pump impeller conditions. The estimated volumes also depend upon data on the hours of pump operation, which were obtained from hand-written notes in field books at each pumping plant.
- *Selection bias.* The study analyzed six "representative" pumping schemes, covering 28 percent of the pump-irrigated area in Tajikistan. Because the schemes were located in a diverse set of environments, and were considered to incorporate average conditions, the study can work on the assumption that the results of the study can be extrapolated. However, there may be a bias in the selection of the irrigation schemes themselves, which could result in the results being considered less reliable.
- *Omitted variable bias.* Only the costs of electricity in determining the variable costs were considered. As the report mentions, other costs may to some extent also be a function of the volume delivered. The costs therefore under-estimate the real costs of irrigation inefficiency.
- *Measurement bias.* As a result of data limitations, only two months were used to calculate the seasonal irrigation inefficiency. However, inefficiency may not be a fixed variable throughout the irrigation season, and extrapolating from two months of data might be inaccurate. For example, pre-season clean-up of canals will improve efficiency at the beginning of the season, but these effects will wear off. It is believed that, despite the weaknesses, the adopted methodology provides a reasonably accurate estimate of efficiency because the estimated efficiency is fully consistent with other estimates of irrigation efficiency in Tajikistan.

II. DETERMINING IRRIGATION INEFFICIENCY

A. Tajikistan's Pumped Irrigation Sector

27. Tajikistan has approximately 953,000 ha of agricultural arable land, of which 79 percent is irrigated. (Table 2.1). Today, less than 500,000 ha of arable lands receive irrigation water, primarily due to deteriorated conditions of irrigation infrastructure. Pump irrigation is designed to serve around 383,000 ha. However, the actual mix between pumped and gravity irrigation is unknown.[2] Out of approximately 36 large, 450 inter-farm, and 1,807 on-farm pumps, only 21 large, 286 inter-farm and 900 on-farm pumps are presently operational. Design areas of the presently operational pumping infrastructure is estimated at around 280,850 ha. However, water does not reach an estimated 27,500 ha within the command area.

Table 2.1: Agricultural Arable Land in Tajikistan

Location	Rainfed arable land, ha	Irrigable arable land, ha	Irrigated arable land, ha	Irrigable arable land under pump irrigation, ha	Irrigated arable land under pump irrigation, ha	Shares of pump irrigated arable land in total irrigated arable land, %
Sugd	61,905	287,266	171,113	162,760	145,760	85%
Khatlon	95,688	338,087	230,359	102,911	93,911	41%
RRS	45,451	106,079	63,425	15,085	13,585	21%
Badakhshan	741	18,224	8,125	92	92	1%
National	**203,785**	**749,656**	**473,022**	**280,850**	**253,348**	**54%**

Source: ALRI 2015

28. As Table 2.2 shows, approximately 208,000 ha (or 75 percent) of the land is served by non-cascade pumping infrastructure. The remaining areas are served by cascade pumps which pump water up to 300 meters high. The country's pumping infrastructure is complex in design and is technically aging. Some pressure pipelines, for instance, have been in operation for over fifty years and are characterized by water leakages. In addition to the poor technical conditions of the infrastructure, power supply is also unreliable, especially in the springtime, leading to significant losses of crop yield and additional maintenance costs to repair the power outage-related technical faults.

Table 2.2. Pump Irrigation Areas by Height of Water Lifting

Location	Pump irrigation areas by height of water pumping, ha					Total, ha
	Up to 100m	100 – 150m	150-200m	200- 250m	250- 300m	
Sughd	109,051	24,415	26,040	1,627	1,627	162,760
Khatlon	90,562	11,320	1,029	-	-	102,911
RRS	7,995	2,112	3,922	754	302	15,085
Badakhshan	92	-	-	-	-	92
National	207,700	37,847	30,991	2,381	1,929	280,850

Source: ALRI 2015

[2] WB Report 72293-TJ

29. Deterioration has been more rapid on pumped schemes than on gravity schemes. This is also explained by a lack of adequate technical and financial support that was made available from Moscow during the years when Tajikistan was part of the Soviet Union. Furthermore, the former centralized governance style was more conducive to soliciting voluntary cooperation and contributions from farmers.

B. Institutions

30. The Agency for Land Reclamation and Irrigation (ALRI), recently established to replace the former Ministry of Melioration and Water Resources, is a key agency responsible for the operation of approximately 400 pump stations, which collectively have approximately 1,500 pumps, but where less than half of the pumps are functional. Small farmer-owned pumps (the quantity is unknown but is estimated at approximately 2,000) are extensively used in some areas – often lifting water from scheme canals to adjacent lands. There are also approximately 1,800 irrigation and drainage wells that pump groundwater, thereby lowering the water table.

31. The “Water Users Association” Law was adopted on November 8, 2006, and laid a foundation for establishment, operation, and management of WUAs as “non-commercial organizations providing services for operation and maintenance of irrigation systems for the benefit of water users”.[3] Development of WUAs has been supported by the key development partners in the country. However, WUAs are still facing legal, management, operational, and budget constraints in their evolution into strong and socially representative organizations. Poor conditions in the inherited infrastructure creates bottleneck in WUA development because improvement of on-farm irrigation service delivery is associated with relatively large initial investments in rehabilitation of the network. Another challenge faced by WUAs is that they are dependent on irrigation authorities rather than having a partnership-based relationship with them, and WUAs are in many cases just perceived as agents of irrigation agencies in collecting irrigation fees. Low technical and managerial capacity, as well as limited financial resources, also diminish the chances of WUAs succeeding.

32. The largest initiative to expand WUA capacity development is currently channeled through the support of the World Bank and the United States Agency for International Development (USAID), which have jointly assisted the Tajikistan government in establishing and strengthening one hundred WUAs in southern Khatlon Oblast. Areas with well-functioning WUAs have reported better irrigation service delivery. However, success of WUAs is largely dependent on the overall condition of the irrigation infrastructure in the area. As observed during the field visits, the WUAs located in the areas with gravity irrigation or the ones set-up after rehabilitation of the irrigation network (including pumps) are likely to demonstrate better performance. In the areas, where WUAs are active, the organizations prove to be efficient both in assisting collecting irrigation fee collection rates (operating as an agent for water services) and promoting rights of water users for equitable access to irrigation water.[4] They were also able to establish a basic system of “checks and balances” in the irrigation sector.

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[3] Republic of Tajikistan. "“Water Users Association” Law of the Republic of Tajikistan # 387 ." Dushanbe, November 26, 2006.

[4] Examples of the WUA Kavsari Kandi Kuhan in Kanibadam district and Obi hayot in J. Rumi district.

C. Determining Irrigation Efficiency in the Six Study Schemes

33. **Comparison of the selected pumped schemes.** In all schemes visited, the technical conditions of pumps, motors, and peripheral hardware largely contributed to irrigation inefficiency. There are many engineering technical details, but the two main problems appeared to be extreme sand wear of pumps and poor electric power quality including periodic outages. Technical solutions exist for all of the problems that were identified. Water distribution is a challenge of both hardware and management; management changes are difficult, but pump and electricity problems can be solved with infusions of money – if done properly.

34. Appendix C provides detailed information for each scheme, as well as a sketch of key facilities. Table 2.3 provides a comparison of key data for each selected scheme.

Table 2.3: Key characteristics of the Six Selected Pumped Schemes

	KNS[5]	**Kojabokirgon**	**Makhram**[6]	**Fayzobodkala**	**Garouti**	**Urtabuz**
Original design hectares	?	14,136	4266	2502	9742	6144
Actual irrigated hectares	17,188	13,420	3169	2247	8030	3248
Number of original pumps	19	39	8	18	44	30
Number of operational pumps	8	21	5	13	32	14
Design flow into scheme, CMS	21	48	12	10	18	13
Actual flow into scheme, CMS	15.6	21	6.5	4.7	7.7	2.3
Silt load in water	Low	Very Low	Very Low	Very High	High	Very High
Electric Power						
Reliability/quality of electric power	Excellent	Poor	Good	?	?	?
Volume Pumped (Ha-m)						
May 2013	2591	3898	*1030*	659	909	711
June 2013	2342	4085	*667*	648	2272	887
Million kWh Used						
May 2013	27.8	24.9	*3.4*	4.6	5.2	2.0
June 2013	25.9	23.0	*2.2*	4.7	5.5	3.6
Pumping Plant Efficiency, %	57[7]	53	47	22	37	Very low
kWh/m^3	1.09	.60	*.33*	.71	.34	.35
Irrigation Performance						
Average Crop Coefficient (unstressed mature crop ≈ 0.9 - 1.15)						
May 2013	.24	.28	.38	.40	.37	.43
June 2013	.20	.44	.32	.37	.30	.37
ET - Crop Evapotranspiration (Ha-m)						
May 2013	672	614	197	138	458	215
June 2013	741	1271	214	181	522	258
Irrigation Efficiency, %						
May 2013	26	16	19	21	50	30
June 2013	32	31	32	28	23	29

35. A summary of the information presented in Table 2.3 suggests the following:

[5] kWh for KNS are from 2012, not from 2013
[6] Makhram monthly data for kWh and hours pumped was very inconsistent
[7] The Pumping Plant Efficiency for KNS used pumped volumes from 2013 and power from 2012; this likely caused an over-estimation of efficiency.

- Approximately 40 percent of the pumps do not function.
- The flow rates of the functioning pumps are lower than the design flow rates.
- The actual irrigated areas are significantly less than the design acreage.
- There are major differences between schemes in terms of the availability of good quality power.
- The three schemes in the northern region have had relatively clean water due to uptake of water from the Kayrakkum reservoir. However, there are huge silt loads in the water in schemes that do not receive water directly from a reservoir.
- The pumping plant efficiencies in the schemes with clean water are higher than those with dirty water. None are excellent.
- The scheme irrigation efficiencies are low (in the 30 percent range).

36. **Evapotranspiration (ET) Estimates.** Appendix A provides a description of the process that was used to estimate crop evapotranspiration in each of the six selected schemes. The methodology has been used in a variety of schemes in the United States and Mexico. It provides a more accurate estimate of crop ET than can be obtained with assumptions of specific crop acreages, irrigation management, pests, soil fertility, planting and harvest dates, and so forth. In any case, none of that detailed information is readily available in Tajikistan.

37. Despite constraints regarding data availability, estimates are believed to be reasonable because of the following factors:

- Crop consumptive use (ET) could be estimated quite accurately from satellite images and the METRIC methodology for May and June of 2013. Although there were uncertainties about exact scheme boundaries, the areas used for the analysis matched the areas provided by each scheme.
- Discussions and observations at the pumping plants and repair facility provided the basis for estimates of likely pump flow rates. The flow rate per pump is found in both the “Irrigation Efficiency” and “Pumping Plant Efficiency” computations.
- The electric consumption (kWh) numbers appeared reasonable if multi-month totals were used so that errors for individual months are averaged.
- “Excellent” pumping plant efficiencies rarely exceed 70 percent. Because the Pumping Plant Efficiency estimates in this report only used elevation changes for the total dynamic head (friction and minor losses are relatively small and were ignored because there were uncertainties in even the elevation changes), an “excellent” Pumping Plant Efficiency would likely be computed as between 65-70 percent. That sets an upper boundary on potential Pumping Plant Efficiency values. However, the lack of good maintenance facilities, the fact that many of the pumps are old, the lack of excellent bearing and impeller balancing, and other factors would likely lower that value for pumps even in the best of conditions.
- The computed values of Pumping Plant Efficiency and Irrigation Efficiency vary inversely with errors in the estimate of volumes (cubic meters) pumped. If the pumped volume is over-estimated, the computed Pumping Plant Efficiency rises, and the computed Irrigation Efficiency drops. These two values therefore serve as reality checks against each other, because likely ranges are known from field estimates and various data.

38. Because of uncertainties related to estimates of the volume pumped, the computations were simplified and did not account for stored rainfall or leaching requirements. "Field Irrigation Efficiency" values will be higher than the values in Table 2.3, because the computed inefficiencies include conveyance losses and spills that occur before the water reaches the fields.

D. Key Factors Contributing to Irrigation Inefficiency

39. Several factors, ranging from institutional, socio-economic, and technical, contribute to the deteriorating status of irrigation inefficiency in Tajikistan. Observations made during field visits would identify more details on the specific infrastructure conditions that are exacerbating the efficiency of the irrigation sector.

40. **Sedimentation.** There is a need for good sediment ponds upstream of the first pumping plants. High sediment (sand) loads, one of the major causes of low pumping plant efficiencies, result in high maintenance expenses, and also require schemes to perform frequent canal cleaning.

41. **Pump Station Pipelines.** The large pipelines between the pumps and canals are steel, and can be quite long. Numerous leaks were observed. It is easy to replace a pipeline, requiring only a monetary investment. It was noted that for just one scheme (Garouti), pipe replacement represented about 50 percent of the requested investment (other items were motors, pumps, valves, and electrical panels). The pipe cost was about TJS 41 million (US$5.2 million). It does not appear that efforts have been made to explore options for pipe lining to increase the life of existing pipes. No active or passive cathodic protection systems were observed on the steel pipes, although such systems are commonly used to minimize pipeline corrosion.

42. **On-Farm Pipelines.** Pipelines providing water control between the canals and groups of farmer fields were observed in a variety of schemes. These pipelines were often located on the territories serviced by WUAs. Pipelines are an excellent tool, and if designed and maintained properly, can greatly enhance farm irrigation management. There are many variations of pipeline (and associated hardware) designs, each with specific benefits and disadvantages.

43. **Dilapidated Canals.** Many of the pipelines have fallen into disrepair. As a result, water supply to the fields is unreliable and inflexible, yields are reduced, farmer income and motivation are low, and maintenance of pipelines falls off. Operators currently need spillage to avoid under-supplying the downstream pumps in cascades. As much as 1 m^3 per pump station was observed. This represents a substantial energy loss, and also causes additional wear on pumps.

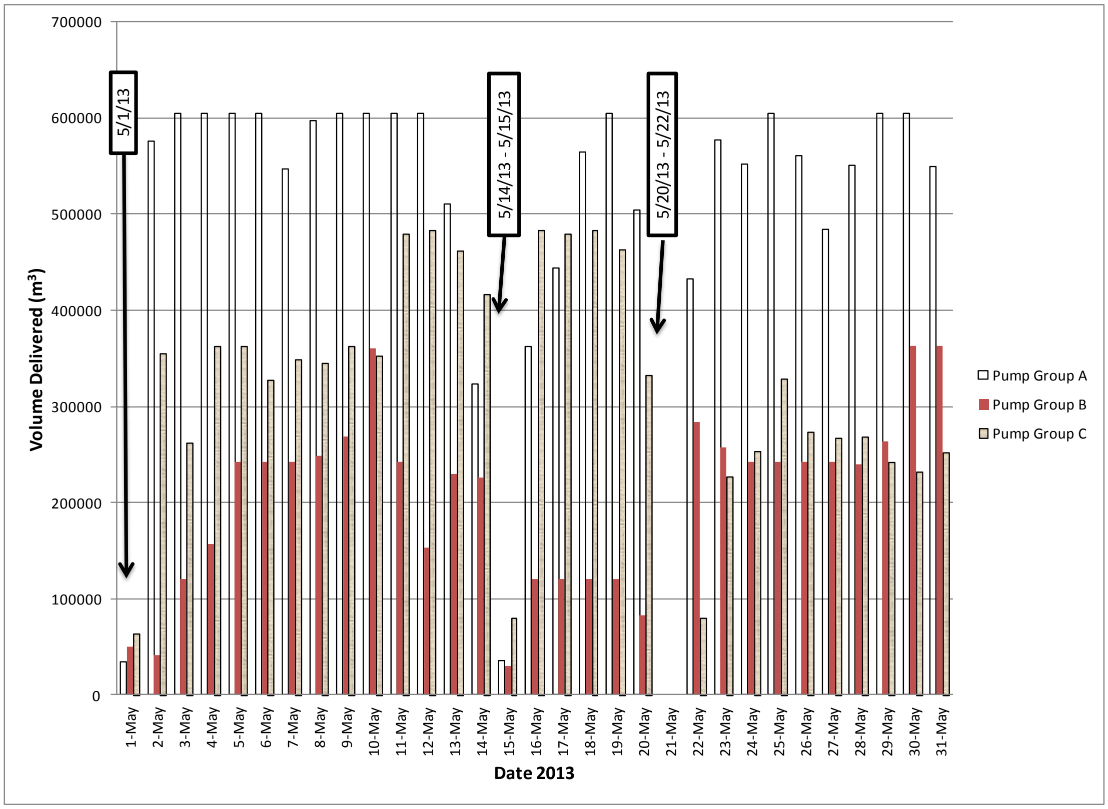
44. **Water Level and Flow Control in Canals.** The WUAs and farmers often do not have equipment to control water flow in the canals. Basic irrigation structures, such as outlet gates, are not in place, which leads to unpredictable water flows and increased water losses in the system during the periods of water abundance.

45. **Electric Power Quality**. The poor power quality that is provided to many of the pumping plants in Tajikistan causes pump motors to shut down automatically. Unless the pumping plants are located near a major electrical transmission line, voltage fluctuations and complete power outages are not uncommon, and may occur 10 or 20 times each year. The interruptions result from limitations in the size, age, condition, and reliability of the electrical

transmission and distribution assets. They create severe operation problems to both pump station operators and farmers. The problems are worse for farmers, who then face unexpected interruptions in their water supply, which poses significant constraints in particular on production of higher value crops for markets.

46. Figure 2.1 illustrates the on/off nature of the first pumping station in the Kojabokirgon scheme. The days with little or no pumping are days when electricity outages occurred.

Figure 2.1. Volumes Pumped per Day at the Kojabokirgon Pumping Plant 1



Source: Author

III. DETERMINING THE COST OF PUMP IRRIGATION

47. The analysis uses the official data of ALRI and its district level agencies. There are two limitations with this data that may affect the accuracy of the results of the analysis. The first limitation relates to the accuracy of ALRI data on O&M of pumping infrastructure. Specifically, the financial reporting system of ALRI does not keep separate the expenditures on gravity and pump irrigation and on drainage systems. In addition, no accurate data exists on investments in rehabilitation and modernization of pumping infrastructure. The second limitation relates to the completeness of the data. ALRI is responsible for O&M of large and interim pumping infrastructure for which data is available. As described earlier in Section II, there are an additional 2,000 farmer-owned and maintained field-level pumps that lift water from off-farm canals to farm fields. Information is not available on how many of these on-farm pumps are functional and what the pumping costs for these functional pumps. According to ALRI, nearly all field-level pumps are unused either due to their poor technical conditions or to unaffordability of power costs.

48. **Public expenditures.** Irrigation – either pumped or by gravity supply – is crucial for the livelihoods of the rural population. However, it comes at a high cost to the country. Annual expenses for irrigation were reported to be TJS 87 million (US$11.0 million[8]), not including special construction projects funded by international financiers. Approximately TJS 31 million are provided by the government for operating expenses, 41 million TJS are received from farmers, and TJS 15 million are provided by the government for capital projects.

49. Expenditures (not adjusted for inflation) on irrigation O&M fell from US$88.0/ha in 1990 to US$14.3/ha in 2003. The requirements just for O&M were estimated in 2004 by ADB at US$21-28/ha for gravity systems and US$60-150/ha in pumped systems. Using the present irrigated area of 515,000 ha and annual expenditures of US$23 million (including US$4.7 million unpaid electrical bills), the current average cost for all irrigation expenses (including O&M) are approximately US$45/ha.

50. **Water Charges**. Farmers are charged TJS 17.7 per 1,000 m^3 of water (TJS 15.5 plus 18 percent Value Added Tax (VAT), regardless of whether the water is pumped or gravity fed. If the six projects are “typical”, the average electricity charge to ALRI is approximately TJS 14 per 1,000 m^3 pumped. If one considers the administrative costs, the farmer charges would be barely enough to cover the average electricity cost in pumped projects. No money remains for any other costs (pump repair, salaries, canal maintenance, upgrading, transportation, and so forth).

51. The collection rate from farmers is approximately 70 percent in the north, and an estimated 50 to 60 percent in the remainder of the country, which implies that farmer payments are insufficient to pay for electricity costs. The approximately TJS 41 million collected from farmers represents about 48 percent of the total budget of ALRI.

52. **Electricity Consumption**. Table 3.1 provides national electricity data related to irrigation.

[8] 100 diram (*дирам)* = TJS 1 = 1 Somoni (*сомонӣ)* = US$0.13.

Table 3.1: Monthly Electric Power Statistics. (Generated and required values are 4-5 year averages.)

Month	Million kWh per month			ALRI consumption of electricity, as a % of National Requirements	TJS/kWh	Million TJS per month for irrigation power
	ALRI only	**National Generated**	**National Required**			
Jan	15.4	1332	1469	1	0.057	0.878
Feb	17.7	936	1144	2	0.057	1.009
March	10.4	804	1237	1	0.057	0.593
April	86.2	1025	1300	7	0.0188	1.621
May	236.5	1587	1521	16	0.0188	4.446
June	289.8	1736	1549	19	0.0188	5.448
July	334.3	1939	1633	20	0.0188	6.285
August	309.6	1909	1619	19	0.0188	5.820
Sept.	165.4	1836	1408	12	0.0188	3.110
Oct	53.8	1001	1310	4	0.057	3.067
Nov	34.2	1012	1352	3	0.057	1.949
Dec	21.3	1071	1467	1	0.057	1.214
Totals:	**1575**	**16188**	**17009**	**9**	**Annual:**	**35.4**
						US$4,036,488

Source: Author

53. The costs and values assigned to electricity consumption vary by usage and time of year.

- The current price of electricity charged to the public is TJS 0.12/kWh (US$.015/kWh).
- ALRI is charged a reduced rate during the irrigation season of TJS 0.0188/kWh (US$.002/kWh).
- In the six projects examined for this report, the weighted average usage of power was 0.64 kWh/m^3 pumped, with a range of 1.09 - 0.33 kWh/m^3, depending on the scheme.
- The average power usage is about 9,210 kWh/ha.
- At an annual weighted average cost of TJS 0.0225/kWh, the annual energy cost to ALRI is TJS 207/ha of irrigated land supplied by pumps.
- Assuming that the six selected schemes represent the other national pumped schemes, the volume pumped nationwide is approximately 2,461 million cubic meters (MCM), or 246,000 ha-m, or about 14,500 m^3/ha. (This number is only provided to give a sense of magnitude.)
- Table 3.2 below shows that the average power consumption per hectare in May and June for the six "typical" schemes that were examined in this study is almost identical to the national average.

Table 3.2: Average Power Consumption per Hectare

	Nation	Six schemes visited
Million kWh for pumping during May and June	526	133
Hectares irrigated with pumped supply	170,000	47,300
kWh/ha for those 2 months	**3100**	**2900**

54. **Operation and Maintenance of Pumping Stations** (excluding the cost of electricity). It appeared (but was not verified with numbers) that just keeping the pump stations operational was one of the largest scheme expenditures, and was likely much greater than the cost of electricity. Total costs include:

- Spare parts
- People to maintain the equipment at the stations
- The pump maintenance shops
- Transportation to and from the maintenance shops
- Management time

55. Detailed cost estimates would require a comprehensive inventory of the existing pumps and their conditions. The costs for pump station pump replacement, valve replacement, motor reconditioning, and maintenance facilities would likely total approximately US$350 million (TJS 2,758 million). This does not include the costs for rehabilitating drainage or well pumps.

IV. THE FINANCIAL COST OF INEFFICIENCIES IN PUMPED IRRIGATION SCHEMES

56. This section examines the real financial cost of pump irrigation to the country, including direct and indirect price subsidies, debts of the Agency for Land Reclamation and Irrigation (ALRI) to the Tajikistan national power company, Barqi Tajik, and debts of water users for irrigation water delivery which, if paid, could be invested in operation and maintenance (O&M) of pumping infrastructure. Concerns about the costs of irrigation inefficiency has recently gained in importance since the recent signing of a power purchase agreement between Afghanistan, the Kyrgyz Republic, Pakistan, and Tajikistan for the supply of summer energy. Energy use in Tajikistan during summer, previously not recognized as a concern because of the excess energy availability in summer, has been propelled on the national agenda because energy wastage now results in high opportunity costs.

A. Public Support to Pumped Irrigation

57. The government supports pump irrigation through direct and indirect subsidies in both agriculture and energy sectors.

58. **Direct irrigation sector subsidies**. As shown in Figure 4.1, the direct subsidies to ALRI's pump irrigation budget are large, and the amount of subsidies has been steadily increasing since 2005. In 2013, the government's contributions to ALRI's pump irrigation budget of US$14.31 million consisted of a one-time direct subsidy of US$2.72 million for the O&M of the infrastructure and US$7.17 million from state budget funds for ALRI.

Figure 4.1. ALRI, Pump Irrigation Budget, US$, millions

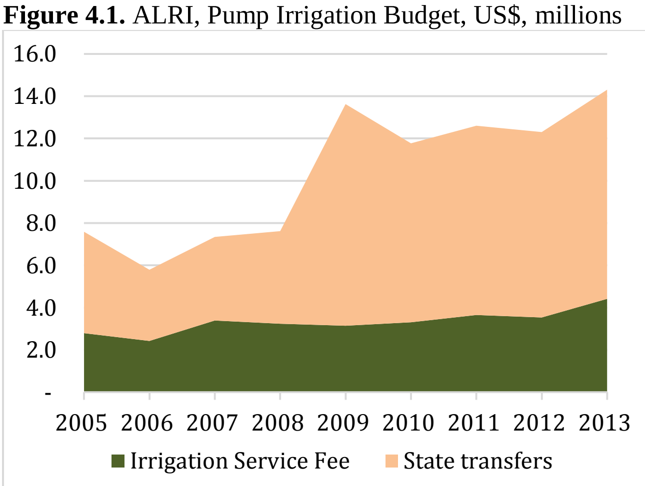
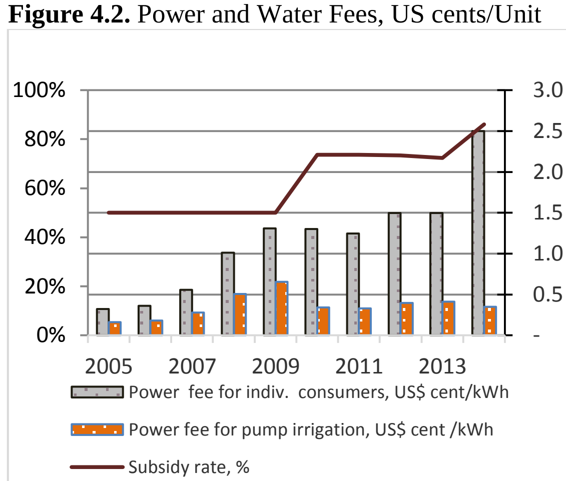


Figure 4.2. Power and Water Fees, US cents/Unit



Source: ALRI, 2015

59. **Power Subsidies.** The government's support also comes in the form of power price subsidies. With the exception of 2007 and 2008, the government set the power tariff for pump irrigation at discounted rates. As shown in Figure 4.2, since 2010, discounts have been very substantial at approximately 70 percent. Furthermore, while the discounted tariff in 2010 was set for the period of May 1 to September 30, in 2011 the subsidized season was extended starting from April 1 to September 30.

60. **Debt Cancellation.** Another government support for pump irrigation is in the form of cancellation of water user debts to ALRI for irrigation service fee (ISF) consumption, and funds owed by ALRI to Barqi Tajik for power consumption. As shown in Table 4.1, the government cancelled these debts twice since 2005: US$5.1 million in 2009 and US$48.2 million in 2014.

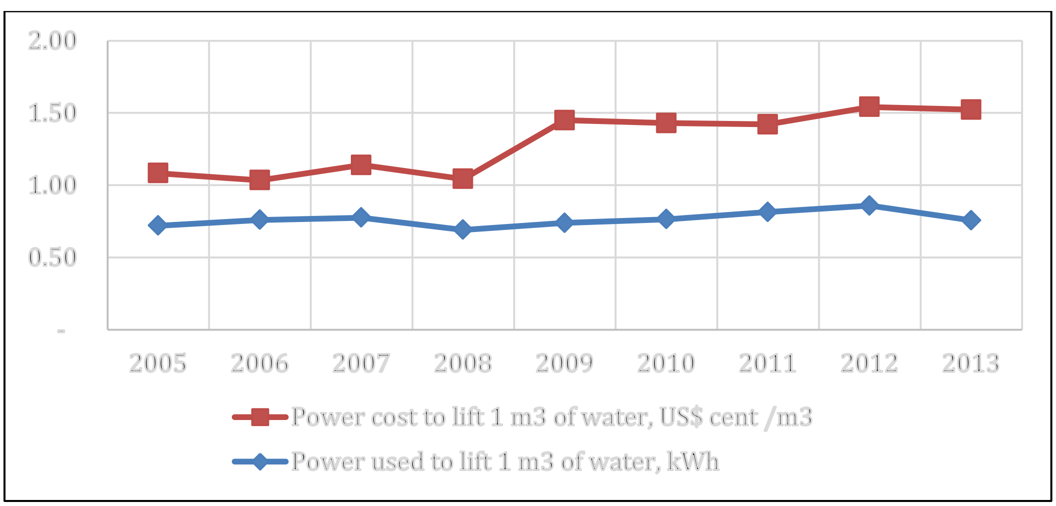
Table 4.1. Pump Irrigation: Financial and Technical Characteristics

Years	Actual irrigated area, ha	Actual volume of lifted water, million m^3	Irrigation Service Fee, million US$		Power fee, million US$			O&M budget (excl. power)		Capital investments, million US$
			charged	paid	charged	paid	debt cancelled	planned	actual	
2005	258,848	2,090	8.59	2.80	3.23	2.11		7.29	4.74	0.74
2006	258,848	2,105	8.08	2.43	3.33	0.25		7.03	4.57	0.97
2007	258,848	2,018	9.71	3.39	4.80	1.08		7.58	4.93	1.34
2008	256,848	2,169	16.59	3.24	15.13	0.44		8.54	5.55	1.63
2009	256,348	1,918	14.61	3.15	15.73	5.54	5.06	9.03	5.87	2.21
2010	256,348	1,769	12.98	3.31	6.45	1.26		12.02	7.81	2.69
2011	255,348	2,079	8.53	3.66	7.18	1.34		12.94	8.41	2.86
2012	252,348	1,802	8.17	3.54	7.36	0.68		13.46	8.75	2.88
2013	253,348	1,869	8.13	4.42	6.38	1.85		14.70	9.55	2.91
2014*							48.18			
Total		**17,818**	**95.39**	**29.93**	**69.62**	**14.55**		**92.58**	**60.18**	**18.23**

Note: at the time of the preparation of the current analysis, data only till April 2014 was available

61. **Cost recovery of pump irrigation is very low.** As presented in Table 4.1, the respective average collection rates for ISF and power fees for the period 2005-13 were 31 percent and 21 percent. Consequently, the actual O&M budget for pump irrigation for the same period did not exceed 65 percent of the planned budget of US$92.58 million. Inadequate O&M and limited capital investments resulting from these poor technical conditions of the pumping infrastructure perhaps explains the increased power consumption to lift 1 m^3 of water since 2005 (Figure 4.3).

Figure 4.3. Power Consumption Per 1 m^3 of Lifted Water



Source: Author

B. Total Cost of Pump Irrigation to the Public Sector

62. **Total cost of pump irrigation.** The costs of pump irrigation to the country, which includes both the costs of pump irrigation to ALRI and losses to the energy sector, are presented in Table 4.1. The pump irrigation cost to ALRI, which is shown in column 5, includes the actual amount paid by ALRI to Barqi Tajik for consumed power at the subsidized rate, and for O&M budget and capital investments. Since 2005, the pump irrigation cost to ALRI increased from US$7.59 million to US$14.31 million. As Figure 4.1 shows, the bulk of the ALRI budget comes from the state budget. The pump irrigation cost to the energy sector is considerably higher. Cumulative losses to Barqi Tajik in the form of debts written-off for unpaid power fees and forgone revenues due to the subsidized power tariff from 2005 to 2013 are estimated at US$281.98 million. This amount is 112 percent higher than the pump irrigation costs to ALRI of US$92.96 million.

63. The total cost of pump irrigation to the country is substantial. In 2013 alone, the annual cost of pump irrigation to the country was US$31.09 million. The cumulative cost for the period from 2005 to 2013 is estimated at US$217.89 million or US$95.54 per hectare per year (the sum of columns 5 and 8 in Table 4.2), assuming that the irrigated area is 253,348 ha. According to FAOSTAT, an estimated income generated by one hectare of irrigated land was approximately US$95.00 in 2011. The cost of pumped irrigation for the same year was US$120.84 per ha.

Table 4.2. Cost of Pumped Irrigation to the Economy

Years	Actual cost to ALRI				Costs to energy sector			**Total cost of pump irrigation to the country, million US$** (5+8)
	Power fee paid, million US$	Actual O&M (excl power), million US$	Capital investments, million US$	Total, million US$ (2+3+4)	Losses due to power fee subsidy, million US$	Unpaid power fee, million US$	Total, million US$ (6+7)	
1	2	3	4	5	6	7	8	9
2005	2.11	4.74	0.74	7.59	1.93	1.13	3.06	10.65
2006	0.25	4.57	0.97	5.79	2.32	3.08	5.40	11.19
2007	1.08	4.93	1.34	7.35	3.49	3.72	7.21	14.56
2008	0.44	5.55	1.63	7.62	6.06	14.70	20.75	28.37
2009	5.54	5.87	2.21	13.63	7.43	10.19	17.62	31.25
2010	1.26	7.81	2.69	11.77	10.36	5.19	15.55	27.32
2011	1.34	8.41	2.86	12.60	12.41	5.85	18.25	30.86
2012	0.68	8.75	2.88	12.30	13.62	6.68	20.30	32.60
2013	1.85	9.55	2.91	14.31	12.25	4.54	16.78	31.09
Total	**14.55**	**60.18**	**18.23**	**92.96**	**69.86**	**55.07**	**124.93**	**217.89**

Source: Author

64. Paid and unpaid electricity costs and price subsidies from 2005 to 2013 represented US$139.48 million (the sum of columns 2, 6 and 7 in Table 4.2), or 69.0 percent of total O&M costs. The costs of irrigation inefficiency at 72 percent is estimated at US$100.43 million between 2005 and 2013. This represents US$11.16 million per year on average, or US$44.04 per hectare per year.

C. Opportunity Cost of Electricity

65. **Signing of the CASA-1000 agreement.** Until recently, summer energy surpluses reduced the opportunity costs of summer energy (and the efforts to increase efficiency in summer) to close to zero. The Governments of Afghanistan, the Kyrgyz Republic, Pakistan, and Tajikistan recently signed a power purchase agreement to sell excess summer energy from the Kyrgyz Republic and Tajikistan to Afghanistan and Pakistan. According to the recently signed agreement, the Kyrgyz Republic and Tajikistan receive US$0.05 per kWh – significantly higher than the 2013 rate of US$0.0041 per kWh and the 2014 rate of US$0.0035 per KWh that the government of Tajikistan charged farmers for pumped irrigation.

66. The signing of the power purchase agreement is a potential game changer, as summer energy surpluses in Tajikistan can now be sold to Afghanistan and Pakistan for US$0.05 per kWh. The subsidized fee for irrigation pumping is US$0.0035c per kWh, and cost recovery is limited. More efficient irrigation and the related reductions in energy use will help Tajikistan sell these energy savings to Afghanistan and Pakistan, while reducing the costs of irrigation. The competing and more profitable use of summer energy is expected to provide an incentive to the Government of Tajikistan to pursue irrigation efficiency.

67. In view of this development, the analysis examined the cost implication of improved pump irrigation efficiency under three different scenarios. Technical and financial results of the examined interventions under these scenarios are summarized in Table 4.3.

68. The scenarios are based on different mixes of investments in irrigation efficiency and uses of the saved water for irrigation expansion or electricity generation. They investigate the implications of using water savings for irrigation and electricity generation. In Scenario 1, estimates are made of the efficiency improvements and energy savings that will be gained as a result of training of WUA and ALRI staff. No physical investments will be made in this scenario, and water savings will be used for irrigation expansion. In Scenario 2, an assumption is made that, in addition to the training under scenario 1, physical investments will be made in irrigation infrastructure to improve efficiency, and savings will be used to expand irrigation. In Scenario 3, an assumption is made that water savings as a result of efficiency improvements will be used to generate electricity that will be sold to Afghanistan and Pakistan for institutional strengthening. Instead of using water savings gained from efficiency improvements for irrigation expansion, these savings will be used to generate electricity. Details about the three scenarios, the assumptions underlying each of them, and their implications for irrigated areas, electricity generation, and cost savings are presented below.

69. **Scenario 1: Institutional improvements in performance of water agencies, and to increase irrigated areas to use the saved irrigation water.** The assumption in Scenario 1 is that the current pump irrigation efficiency at 30 percent will be increased to 35 percent through improved institutional capacity of the water agencies (WUAs and ALRI) resulting in more efficient water distribution planning and O&M planning and implementation. The costs of these "soft" investments are based on actual project investments in Central Asia. The current volume of lifted water is projected to remain unchanged. Improvements in irrigation water delivery service is projected to lead to increases in the following: (i) irrigated lands within the command areas from 253,400 ha to 266,070 ha (a 5 percent increase); (ii) ISF collection from 53 percent to

60 percent; and (iii) power fee collection rate from 29 percent to 55 percent.[9] The improved irrigation water delivery service is expected to increase water and power fee collections by US$2.23 million. This cost recovery amount is expected to be deducted from the current state transfers to pump irrigation. As a result the current pump irrigation cost to the country would be reduced from US$31.09 million to US$28.86 million (or 7 percent reduction). This translates into a reduction of the pump irrigation cost per ha from US$122.7 to US$111.5, and an increase of the cost recovery rate from 20 percent to 29 percent. No incremental investments are projected under this scenario.

70. **Scenario 2: Institutional and technical investments to improve irrigation efficiency to expand irrigation water delivery to command areas.** The assumption in this scenario is that, in addition to the institutional improvements previously discussed, investments will be made in on- and off-farm physical infrastructure to increase the current pump irrigation efficiency from 30 percent to 45 percent. Based on unit prices recorded in a recent and ongoing irrigation infrastructure rehabilitation project in the country and also in the Kyrgyz Republic, the required investments are estimated at US$350.00 per ha. The investments would allow the pumping stations to increase the volume of pumped water from 1,869 million m^3 to 2,090 million m,^{3} thereby making it possible to irrigate the entire command areas, that is, 280,850 ha (a 27 percent increase). The technical life of rehabilitated infrastructure is assumed to be 25 years and the annual maintenance costs are assumed to halve following the rehabilitation. Improved technical and institutional water delivery capacities of water agencies are expected to lead to increases in irrigation service fee collection rates from 54 percent to 85 percent and power fee collection rates from 29 percent to 65 percent. As a result, additionally collected ISF and power fees at US$5.63 million would reduce the current pump irrigation cost to the country from US$31.09 million to US$24.68 million or by 21 percent. The reduction is even higher when costs per hectare are considered. For instance, the current cost per ha of US$122.7 would be reduced to US$87.9 or a 48 percent reduction.

71. **Scenario 3: Institutional investments to improve irrigation efficiency and release of energy savings for export.** Scenario 2 is similar to Scenario 1 except for one assumption. In Scenario 1, an assumption is made that the current volume of lifted water at 1,869 million m^3 will remain the same and that with the improved water delivery service the volume of water will irrigate an additional 5,500 ha. In contrast, in Scenario 3 an assumption is made that the currently irrigated area at 253,400 ha will remain unchanged, and that with the improved water delivery service only 1,602 million m^3 of water will be required to irrigate these areas. A 15 percent reduction in the volume of lifted water would release 15 percent of the currently consumed power of 202,000 kWh to the market to be sold at the export tariff at US$0.05 per kWh. The ISF and power fee collection rates, like in Scenario 1, are assumed to increase from 54 percent to 60 percent and from 29 percent to 55 percent respectively. These changes are expected to generate an additional US$1.62 million from increased collection of ISF and power fees and US$15.11 million from the marketing of the released power for export. The current pump irrigation cost to the country would be reduced from US$31.09 million to US$11.70 million or by 62 percent. The earnings from power exports account for 57 percent of the cost reduction, while increased collection of water and power fees would contribute the remaining 5 percent. In this scenario, the

[9] These assumptions are plausible as the respective fee collection rates for water and power were approximately 60 percent in 2014 and 65 percent in 2005.

cost of pump irrigation per hectare would be reduced from US$122.7 to US$46.2, or by 67 percent.

Table 4.3. Summary of Technical and Financial Results under Scenarios 1, 2 and 3

Description	**Current scenario:**	**Future Scenario 1:**	**Future Scenario 2:**	**Future Scenario 3:**
Interventions		institutional only	institutional and technical	institutional only
Incremental investments		none	yes (US$350 per ha)	none
Expected technical results				
Irrigation efficiency rate, %	30%	35%	45%	35%
ISF collection rate, %	54%	60%	85%	60%
Power collection rate from irrigation sector, %	29%	55%	65%	55%
Power collection rate from ind. consumers, %	80%			80%
Expected financial results				
Incremental ISF collection, US$ million		0.57	3.24	0.46
Incremental power fee collection, US$ million		1.66	2.39	1.16
Value of released power, US$ million				15.11
Total cost of pump irrigation, US$ million	**31.09**	**28.86**	**24.68**	**11.70**
Cost savings, %		**7%**	**21%**	**62%**
Total cost of pump irrigation per ha, US$	**122.71**	**111.50**	**87.89**	**46.17**

Source: Author

V. ISSUES ASSOCIATED WITH IRRIGATION EFFICIENCY

72. This section provides a discussion of a number of issues that are associated with irrigation efficiency. They either determine or are determined by the success of efforts to improve irrigation efficiency. They are presented without prioritization but with the recognition that integrated solutions need to be pursued. Predictability and reliability of the irrigation supply are the key operational terms.

A. Existing Priorities of Pump Managers

73. Resource allocation in the six schemes appears to focus on pump maintenance and sediment removal. With little budget, scheme personnel must struggle to overcome issues involving these two items. Very little personnel time, energy, resources, or innovation remain to solve the huge problems associated with not being able to provide flexible, reliable, and equitable water distribution down to the fields. Scheme proposals currently focus on immediate problems faced by scheme personnel, for instance obtaining funds for replacement pumps and pipelines.

74. ALRI should spread its resources and efforts in a more balanced manner, including water movement and management between the rivers and the individual fields. Until the quality of water distribution service to fields can be improved, strong WUAs are unlikely to develop.

B. The High Cost of Power Outages

75. The pump operators in most schemes continually struggle with pumping outages that are associated with the loss of electricity or low power quality. When the pumps shut down, the pipelines sometimes empty out. Check valves may not exist or may not work properly. When the electricity becomes available, it can be difficult to prime pumps. However, the operators have learned to take advantage of the shutoff times to repair pump bearings and perform other maintenance. Not once during the field visits was anything mentioned about the impact of these outages on irrigation performance, water conservation, and the strength of water user associations.

76. This problem of outages is huge. It takes hours to fill up pipelines and canals when they are empty. When the power goes off, all of the pipelines and canals begin to empty out. Deliveries to farmers begin to dwindle and eventually stop – all without any advance notice. The distribution channels that convey water to individual fields become dry. Farmers who are irrigating suddenly do not have water. At that point, any organized schedules of farmer irrigations or flow measurement programs are worthless. This problem repeats itself weekly, and in some cases, more often.

77. Once the pumps are restarted, it takes many hours to re-establish flows. Furthermore, almost all the field irrigation is gravity (surface) irrigation with furrows or border strips. Water may have advanced halfway across a field when the water disappears. Farmers need to re-irrigate the first half of a field just to get the water to the position it was in when the water disappeared.

78. In summary, when water levels are uncontrollable and unpredictable, farmers and scheme authorities who manage canals understand that it is often fruitless to develop good irrigation

schedules or to invest in good flow measurement and control measures. Farmer leaders recognize that if they try to form an organization that requires dependable water, it will fail. Hence, there is no motivation by responsible farmers to take the lead in a losing endeavor. This is especially true if the primary function of the water user association is to collect money to give to scheme authorities. Good water control in schemes is therefore a precondition for strong WUAs, high irrigation efficiencies, and high crop yields.

79. Unreliable supplies could be addressed by installing buffer reservoirs downstream of each pumping plant discharge point. These buffer reservoirs fill up while the pumps operate, and are automatically drained by gravity when power outages occur.

80. Such reservoirs are found in California for a different purpose, but with the same end result. In California, some irrigation districts do not pump between noon and 6 p.m. because the electricity rates are high during those hours. Buffer reservoirs allow them to pump 18 hours a day, but deliver consistent flow rates to canals 24 hours a day.

81. Operators at the pumping plants appear to have a good idea of the time of the day when the power quality deteriorates. Having a predictable time could provide a new model for daily pump operation. Each pumping plant could depend upon scheduled off times for pump maintenance.

82. Each reservoir would only have sufficient capacity to serve the area immediately downstream of it. Its capacity would be determined by the average historic down time of the pumps. One concern is that reservoirs often act as silt traps. Because of the high silt loads, this would be especially important in Khatlon. Maintenance equipment and procedures are available and must be included in the investment.

83. An additional and significant benefit could be that the inlet and outlet control of the reservoirs could be designed so that the pump flows do not need to exactly match the required flow rates in a canal. If the gravity discharge is automatically regulated to maintain a constant desired flow rate, then if the reservoir empties or fills up, a pump can be turned on or off.

C. Irrigation Schemes and Water User Associations

84. Other countries have found themselves in somewhat similar situations regarding irrigation schemes to what Tajikistan now faces. It is not uncommon for central governments to discover that for one reason or another they have not been able to maintain (much less modernize) existing irrigation schemes.

85. Irrigation schemes fall into a vicious downward spiral of degradation, followed by rehabilitation, followed by even worse degradation. In Tajikistan, this is most obvious in the case of pumping plants where pumps are constantly being rebuilt, and 40 to 50 percent of the pumps and motors no longer operate at all.

86. The observations below regarding the United States might assist the future direction of the Tajikistan government as it is relates to irrigation. These observations are related to the

gradual evolution of successful irrigation schemes. (See Appendix F for a more detailed analysis of a comparison with the United States.)

- In most countries, water and electricity for irrigation have historically been greatly subsidized in federal (national) pumped irrigation schemes.
- For irrigation schemes that were constructed by the United States government, the farmers had to pay back the construction costs over a period of 40 to 50 years. However, there was a very favorable, low interest rate.
- The justification for subsidies was that the countries would benefit from political and economic stability that irrigation schemes would bring in. The subsidies also recognized the significant "multiplier" benefits that irrigation schemes would bring to the local and national economies.
- In the United States, as field irrigation practices have improved, as water user organizations have become more sophisticated, and as crop yields have increased, the farmers have been able to pay for the complete costs of irrigation.

87. In national irrigation schemes outside of the United States, WUAs have generally been formed by the government if they did not previously exist. Global experience suggests that the WUAs must be large enough to be sustainable (usually at least 5,000 ha each) and must not exist primarily to collect money for the government. Although thousands of water user associations have been formed in the world over the past three decades, the vast majority have failed because of a lack of ownership.

88. In many of the pumped schemes, the crop yields are so low, and the water control from the main and lateral canals is so poor, that it is unlikely that WUAs will be socially or financially able to support large irrigation schemes in the near future. A long-term improvement program to provide manageable water will need to succeed before farmer support on sustainable levels can be achieved.

VI. PRIORITIES FOR ACTION

A. Impacts of various irrigation interventions on total O&M costs and crop yields

89. This section analyzes and proposes a number of priority actions to improve the performance and efficiency of irrigated agriculture in Tajikistan. At the same time the section intends to show that not all interventions to increase irrigation efficiency automatically lead to a reduction in electricity use, and therefore to a reduction of the operational expenses, for reasons outlined below.

- Less area is irrigated now – or more area is actually under-irrigated – than was originally intended for each scheme. It thus seems logical that if there is less conveyance loss, then more area could be irrigated, or less area could be under-irrigated. The net effect is no savings in power.

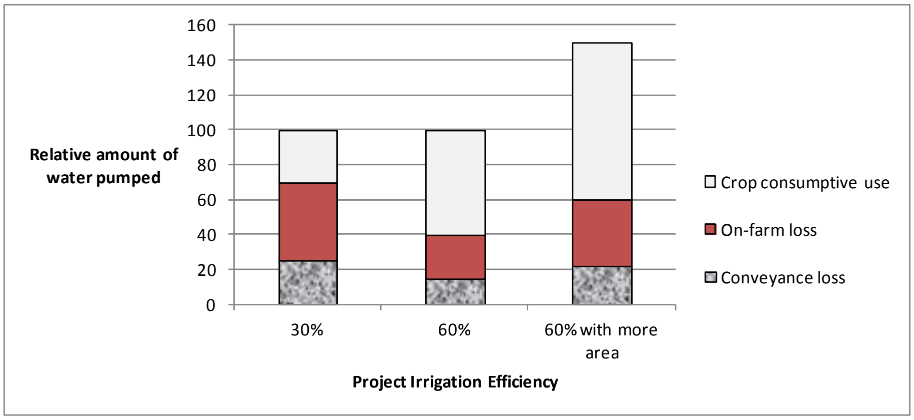
- The immediate consequence of poor irrigation management and poor distribution uniformity of water across fields is very poor crop yields. This means:
    a. If there is very weak and non-uniform crop growth, the evapotranspiration (ET) is much lower than it could be. This is clear from the satellite images.
    b. Because the predominant irrigation method is surface irrigation, farmers must wet the entire field even if the growth is spotty. A certain volume of water is required to simply wet the field during irrigation, regardless of how healthy the plants are. Farmers cannot use less water for irrigation simply because the actual average field ET is lower than what it should be. The amount of water infiltrated is a function of the soil, not of the crop.

90. Figure 6.1 below depicts three different irrigation scenarios. They can be described as follows:

- ***30 percent Irrigation Efficiency.*** The left-hand bar indicates the approximate condition today. About 30 percent of the pumped water is used for crop evapotranspiration (consumptive use).
- ***60 percent Irrigation Efficiency.*** The center bar indicates what is likely to be achieved with the use of modernization and the right incentives. The same amount of water will be pumped, but a higher percentage will be used for crop evapotranspiration because of improved water delivery service and on-farm improvements. This particular graphic assumes a 70 percent on-farm efficiency. There is no electricity saving as a result of improving irrigation efficiency.
- ***60 percent Irrigation Efficiency with More Area.*** The right-hand bar indicates what would happen if more pumps become functional and there is improved water delivery service and improvements in on-farm irrigation. More area could be irrigated, and yield would increase by about 50 percent if approximately 50 percent more water was pumped. The electrical power cost would increase by 50 percent unless pumping plant efficiency improved.

91. Therefore, if the irrigation practices were more reliable and predictable, the yields should improve considerably. This in turn would increase the ET in each field, which would then cause an increase in irrigation efficiency with the same volume of applied water. As discussed before, there would be no power savings.

Figure 6.1. Water Destinations with Various Scenarios



92. One aspect of "timing" may result in savings in power. There often no good correlation between pump operation and irrigation water demand at the end of the summer. This might be one area that is relatively easy to improve without better hardware, because it mainly requires increased communications and motivation. Although better scheduling of pumping hours at the end of the summer is a good idea, in order for it to work there need to be more consistent and transparent computations and communications with farmer groups. These are not likely to be strong until progress is first made in solving some fundamental main system issues and problems.

E. Indicators for Scheme Performance Evaluation

93. Making progress with irrigation modernization and improvement of irrigation efficiency moves slowly. There are pre-conditions for improving yields, so investments of many years are needed before farmers increase yields and are willing to pay more for high-quality service delivery. The impacts of modernization that gradually makes irrigation water delivery more dependable and flexible cannot be immediately measured. The impact of improving pumping plant efficiencies, on the other hand, can be measured immediately. Nevertheless, performance indicators at all levels can be used to document progress.

94. Recommended performance indicators are:
- Change in pumping plant efficiencies
- Change in frequency of pump repair
- Change in the quality of water delivery service that is provided by scheme personnel to group turnouts (as measured by user satisfaction surveys)
- Change in irrigated areas covered by good quality irrigation services
- Change in yields on fields that receive immediate intervention such as gated pipe, land leveling, or targeted phosphorus fertilizer application
- Changes in the amounts of water fees collected
- Changes in the rates of water fee collection
- Changes in meaningful information management

Table 6.1: Comparison of the Impacts of Various Irrigation Interventions on Energy and Crop Yields

Action	Type of Energy Reduction		Crop Yield		Serious Drawbacks
	Reduction of Gross Energy (kWh)?	(Reduction of energy)/(cubic meters pumped)?	Will the action increase total yield in the scheme?	Will the action increase yield/field?	
Install dependable pumps with excellent repair facilities	No. More pumps will operate more hours.	Yes. A "dependable" pump would require that it has less wear, is of better materials, has less friction, and maintains its high efficiency for a longer duration.	Yes. More water will be available and likely more hectares will be irrigated or less hectares under-irrigated.	Yes. More water will be available and likely more hectares will be irrigated or less under-irrigated.	None, except initial cost.
Improve pump efficiency	No, if the efficient pumps are used for more hours. Yes, if the same volume of water is pumped.	Yes	Yes. More water will be available and likely more hectares will be irrigated or less under-irrigated.	Yes. More water will be available and likely fewer hectares will be under-irrigated.	None, except initial cost.
Install buffer reservoirs at the heads of canal laterals	No. More kW would be used during off-peak hours to compensate for the lack of pumping during hours of peak electrical load requirements.	Yes. Less water would drain inefficiently from the canals and field distribution system during each shutoff of pumps.	Yes. Water will be available with much higher dependability, allowing farmers to improve irrigation.	Yes. Water will be available with much higher dependability, allowing farmers to improve irrigation.	None, except the need for consistent maintenance. This is a very high priority item.
Replace all pumps and motors	No. Currently only about half of the pumps operate, for less than 100 percent of the time. Therefore, total replacement would consume more kWh because more water would be pumped.	Likely only temporarily, if the core causes of pump wear are not addressed and if the pumps are simply replaced. New designs and materials are needed.	Yes. More water will be available and likely more hectares will be irrigated or less under-irrigated. For an individual field the water will not start/stop unpredictably.	Yes. More water will be available and likely fewer hectares will be under-irrigated.	Unwise use of funds, because all of the original pumps are not being used.
Replace leaky pump discharge pipes	Yes. A higher percentage of pumped water would be delivered.	Yes. A higher percentage of pumped water would be delivered.	Yes. More water will be available and likely more hectares will be irrigated or less under-irrigated.	Yes. More water will be available and likely fewer hectares will be under-irrigated.	Very expensive. In the Garouti scheme, pump discharge pipe replacement accounted for about 50 percent of total rehabilitation costs. Alternative solutions are needed.
Reduce/eliminate regulation spill upstream of pumping stations	Yes. Often water is pumped up several lifts and is then spilled for control purposes	Yes. A higher percentage of pumped water would be delivered.	Yes. More water will be available and likely more hectares will be irrigated or less under-irrigated.	Yes. More water will be available and fewer hectares will be under-irrigated.	None.
Reduce seepage and spillage from canals and canalettes	No. If there is less seepage and spillage, there will be more water application to fields. Less water will not be pumped	Yes. A higher percentage of pumped water would be delivered.	Yes. More water will be available and likely more hectares will be irrigated or less under-irrigated.	Yes. More water will be available and less hectares will be under-irrigated.	If this was done with complete replacement of canals, it would be an unwise investment. Volumes of seepage and causes need to be explored better.

Action	Type of Energy Reduction		Crop Yield		Serious Drawbacks
	Reduction of Gross Energy (kWh)?	(Reduction of energy)/(cubic meters pumped)?	Will the action increase total yield in the scheme?	Will the action increase yield/field?	
Improve on-farm irrigation scheduling – making water available more frequently	No. Farmers would irrigate more frequently. For surface irrigation, more irrigations result in more infiltration. Unless there was a dramatic shift in management, this would happen.	No	No. There would be less water available for some hectares, although some hectares would be better irrigated.	Maybe. It would depend upon the soil and crop type and the existing irrigation schedule.	This is a wasted effort if water is not delivered with a high degree of dependability, if farmers are not accountable for volumes of water used, and if those volumes are not measured accurately.
Improve the distribution uniformity of water application along individual furrows	No. Less water might be applied per field, but other fields need the water.	No	Yes. Farmers will likely use less water or apply what they use more efficiently. Any conserved water would irrigate more land.	Yes. Farmers will likely use less water or apply what they use more efficiently.	This must be approached slowly in very simple terms with solutions that work. Lessons must be learned.
Improve the control of water into individual furrows	No. Less water might be applied per field, but other fields need the water.	No. Less water might be applied per field, but other fields need the water.	Yes. Farmers will likely use less water or apply what they use more efficiently. Any conserved water would irrigate more land.	Yes. Farmers will likely use less water or apply what they use more efficiently.	This must be approached slowly in very simple terms with solutions that work. Lessons must be learned.

Priority #1: Breaking the Vicious Cycle

95. Breaking the vicious cycle in irrigation management of inadequate resources, poor quality of service delivery, and low incomes requires a long-term approach. Revenues will not increase and costs will not go down overnight. Because the Government of Tajikistan plans to continue to provide to farmers livelihood services in irrigation schemes that depend on pumping, continued public support in paying for the expenses of these schemes will be required. However, at the same time, efforts need to be made to increase incomes and cost recovery, while reducing costs.

96. Breaking the vicious cycle needs to start by improving the quality of service delivery. International experience has provided ample evidence (especially in municipal water supply) that increasing service fees without improving the quality of service delivery is not successful. The following series of actions and development of plans should be considered priority:

1. Develop a plan for strengthening WUAs. Scheme managers must keep in mind that until water is available to a WUA in a flexible and reliable manner, WUAs are unlikely to succeed. This will require a re-definition of how the WUAs work with the canal operators (including some form of performance measurement), how funds are transferred (with most of the funds remaining at the local level and directly linked to performance), and what responsibilities are required of both parties (scheme managers and WUAs) for success.

2. Increase crop yields. This should include some independent on-farm improvements such as gated pipe, land leveling, and appropriate phosphate fertilization on cut areas. This plan should also contain metrics to evaluate the success and failures of the program. Pilot implementation should provide reasonable information of costs, problems, and benefits.

3. Implement modernization steps. This should involve developing confidence, expertise, data on true costs, and benefits related to the modernization of the main water distribution systems for several schemes. In addition, this must be done for complete schemes, not just a few demonstration areas. Different approaches can be used in different scheme areas, but the intent is to implement modernization in complete schemes. This is necessary to learn how to integrate tasks and responsibilities that are currently primarily performed as individual, disconnected efforts. In order to address the priority objective to provide a more reliable and more flexible water supply to the schemes, the following two action plans should be considered:

    a. Identify one or two pumping schemes, such as KNS, that have few pumping problems. Place a major emphasis on quickly (within 3 to 4 years) modernizing the hardware and operations of the main and lateral canals through improved water level and flow control, flow measurement, improved communication with WUAs, electronic record keeping, mobility of staff, and improved daily scheduling of flow rates. Verify pump flow rates and develop procedures to properly operate the pumping plants to pump the correct flows on an hourly basis. Work with WUAs from the outset. Scheme employees must be trained and equipped to replace and repair all of the hardware (for instance, gates).

b. Consider employing a private operator to improve management of the pumping station and who will operate the pumps on the basis of key performance indicators. Doing so would incentivize the operator to provide reliable and flexible water supplies to WUAs.

4. Once the main and lateral canal operations are operating reasonably well, focus on making essential infrastructure improvements downstream of the canals and strengthening the WUAs. ALRI must be immersed in the complete integrated effort – from the pump stations to the final efforts with the WUAs. The lessons learned from these schemes (both positive and negative), and the gaining of knowledge of true costs and the efforts required, will be essential for planning future modernization programs. These schemes should also serve as training grounds for ALRI staff and engineers. As other schemes are modernized in the future, these schemes will serve as examples. The following action plan should be considered:

   a. Locate two schemes that have extreme problems with power outages. Install buffer reservoirs downstream of each of the pumping plant discharges with proper inlet and outlet controls. Then follow the same procedures as recommended above for the two pumping schemes.

5. Before modernizing the schemes mentioned above, develop the performance indicators. It is especially important to use the ITRC-based Rapid Appraisal Process that was developed for the World Bank (WB) to identify proper interventions necessary for canal modernization. Careful thought must be given to the training of the persons who will develop the performance indicators. The people who ultimately do the field work should be employees of ALRI because a bigger objective is to develop the domestic expertise to understand modernization. Simply contracting the work out will not develop this necessary expertise.

6. Address the issue of future corrosion to the pump discharge pipelines. The cost to replace all the pipelines is very high. Eventually the pipes will need to be replaced, but less expensive options such as cathodic protection and sleeving and lining of pipes should be examined, tested, and implemented on a pilot scale.

7. Develop a national plan, and begin to implement that plan, to reduce expenses related to operating the pumping plants. This involves a combination of improving pumping plant efficiencies to reduce the energy costs, and also reducing the costs associated with constantly rebuilding and servicing pumps. This should be a national plan. When donors offer assistance for individual schemes, their assistance should fall within the national plan. If this is not done, Tajikistan will eventually have a wide mix of incompatible hardware, parts, training, and maintenance requirements. The key elements of this plan are:

   a. **Sand/silt settling basins.** Sand and silt wear are the major cause of low pump efficiencies and large maintenance costs. There should be a plan to systematically equip pumping plants with good settling basins, including the proper equipment to frequently clean the basins, and the means to dispose of the sand and silt. The maintenance equipment and basin designs should be standardized.

   b. **Pump Specifications.** Definition of pump specifications and rules for the selection and installation of new pumps. Many of the existing pumps are so worn out that eventually they will need to be replaced. There needs to be a plan to replace them properly. A plan might consist of:

i. Development of an inventory of each of the approximately 800 functioning pumps. This will include, for each pump:
    1. Measured flows. This requires the purchase of portable transit-time external flow meters.
    2. Measured discharge pressures
    3. Measured input kW. This could require special equipment, or during the winter one pump at a time could be operated, and the kW to the plant can be measured to determine this value.
    4. Computed pumping plant efficiency
    5. Pump hardware and orientation (diameters, valves, and so forth)

ii. Definition of the characteristics required for "typical" pumping plants, including:
    1. A high bowl/impeller efficiency at the required flow rate and pressure
    2. Net positive suction heads
    3. Impeller materials that are resistant to wear, such as Ni-Al-Bronze or Aluminum-Bronze 954 Alloy
    4. A mix of large and small pumps, so that flow rates can be more carefully matched to the demand
    5. A required number of "spare" pumps and motors available to turn on if other pumps must be taken off-line for servicing

iii. Definition of the requirements for proper pump and motor maintenance. This will include the required training, transportation, shop equipment, and spare parts, both at each individual pumping plant, and at regional pump and motor maintenance facilities. Emphasis must be placed on what specific equipment is needed to rebuild pump impellers of different materials, how to ensure quality control, and how to dynamically balance repaired impellers.

c. **Pump Supplier.** Once the needs are reasonably well defined, ALRI should embark on a search for a single pump supplier that can supply the specified training, service, and equipment at a reasonable price. It is essential that the final decision not be made solely on price, but also heavily weigh the importance of proven quality.

d. **Maintenance Facilities.** Once the pump supplier is identified, it is essential that excellent maintenance facilities be established, and that personnel are trained before the pumps are purchased. There is typically a rush to purchase pumps, but without insufficient thought being given to the eventual maintenance of them.

Priority #2: Monitor Performance and Progress

98 The following are further actions that should be implemented as part of efforts to monitor the performance and progress of the schemes:

1. Develop good, simple Geographic Information System (GIS) maps of all the schemes. Consolidate the scattered efforts that are currently underway. Take care that the expenses for

this effort do not get too large because these efforts can become very expensive if they are not properly controlled.

2. Develop a better understanding of the “multiplier” economic impact of irrigated agriculture on Tajikistan’s financial health. This will be very important when seeking increased financial support.

3. Define what records and data are important for both evaluation and operation of the schemes. Standardize formats and computations. Equip offices to electronically enter, manipulate, and transfer this information.

4. Evaluate the lessons learned from all the steps described under Priority #1.

5. Reassess financial and human needs for expanding the limited work outlined under Priority #1. Reestablish priorities, and seek funding.

6. Implement the lessons learned as rapidly as possible.

7. Continue quantifying performance indicators, to assess the success of various interventions.

VII. CONCLUSIONS

1. Pumping plays an important role in Central Asia's irrigated agriculture and accounts for significant sunk and O&M costs. As a result of the inefficient use of irrigation water, Central Asian countries are among the most water-intensive economies in the world and increasingly face the challenge of addressing the proportionally low contribution of water to economic development, employment, and poverty reduction.

2. This study focused on the costs of irrigation inefficiency to the Tajik economy. The Tajik irrigation sector is one of the largest consumers of power in the country. Hence, irrigation efficiency and energy use in the sector are intricately interlinked, and inefficiencies in the use of one resource inevitably have an effect on the other.

3. This study examined the implications of improved pump irrigation efficiency in Tajikistan. Field work was conducted in June 2013, and data were obtained for six representative pumping schemes. Crop water use in the six scheme areas was estimated for May and June of 2013 using the METRIC process (see Appendix A).

4. The study found that the average weighted irrigation efficiency across the six schemes that were part of the study was close to 28 percent, with some of the schemes performing at an efficiency that was as low as 16 percent (Kojabokirgon). The highest measured efficiency was 50 percent in the Garouti irrigation scheme.

5. It was found that the following factors contribute significantly to irrigation inefficiency:

- High sediment (sand) loads is one of the major causes of low pumping plant efficiencies that result in high maintenance expenses, and also require schemes to perform frequent canal cleaning.
- Pump station and on-farm pipelines between the pumps and canals are steel, and contain numerous leaks.
- There are dilapidated canals that result in water supply to the fields being unreliable and inflexible. Operational losses are required to avoid under-supplying the downstream pumps in cascades.
- Water level and flow control in canals are not in place, which leads to unpredicted water flows and increased water losses in the system during the periods of water abundance.
- Low electric power quality causes pump motors to shut down automatically, creating severe operational problems for both pump station operators and farmers.

6. It was found that the total overall costs of pump irrigation (including O&M, electricity costs and capital investments) for the period from 2005 to 2013 was US$218 million, or US$94 per hectare. Paid and unpaid electricity costs and subsidies for the same period represented US$139.48 million, or 69.0 percent of total O&M costs. The costs of irrigation inefficiency at 72 percent was estimated at US$100.43 million between 2005 and 2013. This represents US$11.16 million per year on average, or US$44.11 per irrigated hectare per year.

7. The Governments of Afghanistan, the Kyrgyz Republic, Pakistan, and Tajikistan recently signed a power purchase agreement to sell excess summer energy from the Kyrgyz Republic and Tajikistan to Afghanistan and Pakistan.

8. As a result of this power purchase agreement, Tajikistan can now sell excess summer energy to Afghanistan and Pakistan for US$0.05 per kWh – significantly higher than the 2013 rate of US$0.0041 per kWh and the 2014 rate of US$0.0035 per KWh that the government of Tajikistan is charging farmers for pumped irrigation, and cost recovery is limited. The competing and more profitable use of summer energy is thus expected to provide an incentive to the Government of Tajikistan to take measures to improve irrigation efficiency.

9. In view of these facts, the analysis examined the cost implication of improved pump irrigation efficiency under three different scenarios. The outcome of this scenario analysis suggests that the highest reduction in costs to the country at 62 percent will be achieved mainly through the release of saved power to the export market (that is, 57 percent from exported energy and 5 percent from increased collection of irrigation service fees and power fees). In other words, the cost of pump irrigation to the country cannot be meaningfully reduced when the saved energy is used to expand irrigation coverage using energy at a subsidized rate. If the Government follows the pump irrigation cost-reduction model proposed under Scenario 3, the earnings from the power export could then be used to support the population whose livelihoods depend on pump irrigation. Investing in energy savings in irrigated agriculture becomes an attractive proposition if these savings are sold to Afghanistan and Pakistan.

APPENDIXES

APPENDIX A. METRIC ANALYSIS

A crop consumptive use (evapotranspiration) analysis was conducted for six projects in Tajikistan for a two-month period (May and June) during 2013. The analysis coincided with gathering pumping records from the pump stations supplying these irrigation projects. Remotely sensed data (satellite images) were used to compute the actual evapotranspiration from fields at the time the images were taken, using the Cal Poly ITRC[10] METRIC process. The monthly evapotranspiration was estimated by computing a pixel by pixel crop coefficient for each image and averaging that over the estimated pumping plant service area in each project. The monthly grass reference evapotranspiration (*ETo*) is then multiplied by the average *Kc* to estimate the total monthly actual crop evapotranspiration (*ETc*).

$$ETc = Kc \times ETo$$

More details on the procedure are included below.

CAL POLY ITRC METRIC Model

The Mapping Evapotranspiration at High Resolution with Internal Calibration (METRIC) process is based on a surface energy balance. It depends upon both accurate and frequent Landsat satellite thermal images (available only once per 16 days and less frequently if clouds are covering the area) and an understanding of the cropping systems within a region. The METRIC procedures have gradually evolved from research in the United States and other countries and have the objective of being able to directly estimate actual *ETc* over large areas with limited data availability (such as irrigation method, or irrigation practices). The image processing can be relatively fast, but the collection of significant background data (besides the satellite images) that are necessary for each image is time-consuming. Proper use of METRIC also requires expert input and interpretation on the part of those who run the program.

Landsat 8 image pixel resolution is 30 meters by 30 meters. Inputs into the ITRC METRIC model include:

- Landsat imagery
- Weather station data (hourly and daily data)
- Digital elevation data
- Spreadsheet calculated values
- Tabulated constants

The general monthly *ETc* computational procedure includes the following inputs:

- ITRC METRIC was used to compute the *ETc* the instant the satellite image is taken.
- The hourly grass reference evapotranspiration (*ETo*) at the time the image is taken was used to compute a *Kc* value for that image date (*Kc* = *ETc*/*ETo*) for each pixel in the image.

[10] Irrigation Training and Research Center (ITRC). California Polytechnic State University (Cal Poly). San Luis Obispo, California USA 93407-0730. www.itrc.org cburt@calpoly.edu

- For this project, the *Kc* from each image was averaged by the service area for each pumping plant to get a Service Area *Kc*. If there were multiple images taken in a month, the Service Area *Kc* from each image data was averaged.
- Monthly *ETo* compiled from daily *ETo* data was multiplied by the monthly service area *Kc* to estimate the monthly Service Area *ETc* (the volume of water consumed through evapotranspiration).

Satellite Images

Landsat 8 images available from the United States Geological Survey (USGS) on sixteen-day intervals were used in the ITRC METRIC process for the six projects examined. The six project locations are scattered throughout the nation of Tajikistan. This required multiple Landsat images to be processed for each image date. The Landsat 8 images that encompassed the areas of interest were located in Path 153, Rows 32 and 34, and in Path 154, Rows 32 and 34, for a total of four different Landsat images. Three image dates (from May through the beginning of July) were examined for each of the images, resulting in a total of 12 Landsat images processed for this project. Figures A.1 through A.4 show close-up views of the areas of interest for this project from the Landsat 8 images.

Figure A.1. KNS Area with Infrared Image in the Background

Figure A.2. Kojabokirgon and Makhram Areas with Infrared Image in the Background

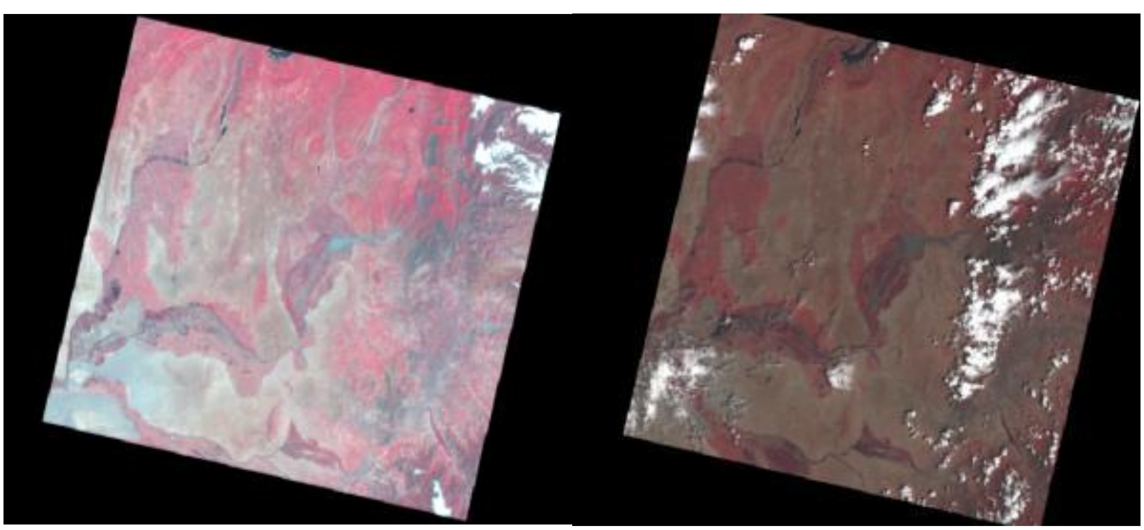
o

Figure A.3. Garouti Area with Infrared Image in the Background

Figure A.4. Fayzobodkala and Urtabuz Areas with Infrared Image in the Background

In order to obtain reliable results from the modeling process, daily images need to be free of cloud coverage in the area of interest. Figure A.5 shows a comparison between a usable and an unusable image for ITRC METRIC modeling.

Figure A.5. Usable Landsat Image (Left Image) and an Unusable Landsat Image (Right Image)



All available cloud-free images were used for the modeling process as seen in Table A.1. A total of 12 images were processed using ITRC METRIC.

Table A.1. Chosen Image Dates for ITRC METRIC Process

Image Dates Selected for ITRC METRIC Process			
KNS	**Makhram and Kojabokirgon**	**Garouti**	**Fayzobodkala and Urtabuz**
5/5/2013	5/14/2013	5/5/2013	5/14/2013
6/6/2013	6/15/2013	6/6/2013	6/15/2013
6/22/2013	7/1/2013	6/22/2013	7/1/2013

Weather Data

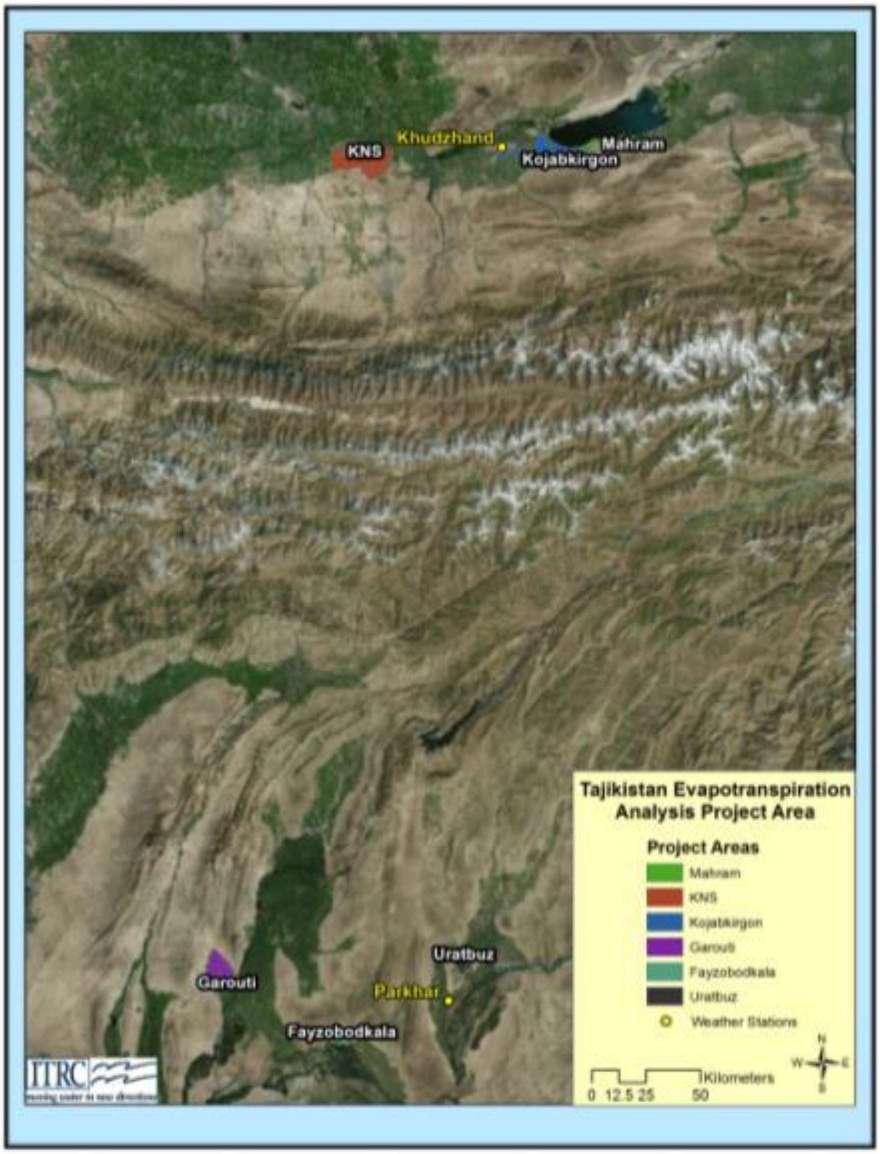
Daily and hourly weather data for the project time frame were collected from Weather Underground.[11] This website collects and stores data from weather stations throughout the world. Two weather station sites were selected: one in the northern region of Tajikistan at Khudzhand Airport, and one in the south (Parkhar Airport). Figure A.6 shows the location of these weather stations in relation to the project areas examined.

Weather data collected from each station included hourly and daily information from May through July of 2013. Weather data parameters available were air temperature, relative humidity, dew point temperature, wind speed, and precipitation. Weather data needs to be estimated near the time that the image is taken (approximately 10-11 a.m.). Specifically, hourly grass reference evapotranspiration (*ETo*) is required by the ITRC METRIC model to compute the grass reference-based crop coefficient on a pixel-by-pixel basis throughout the image. Daily *ETo* is summed up for each month and multiplied by the pumping plant service area *Kc* to estimate the monthly *ETc*. Monthly ASCE Standardized PM ETo computed from weather data obtained from two weather stations in 2013 is shown in Table A.2

ETo is computed based on the American Society of Civil Engineering (ASCE) 2005 Standardized Penman Monteith (PM) equation for a grass reference crop. The PM equation requires input on solar radiation, which was not measured at the weather stations in this study. Instead, the solar radiation was estimated based on a corrected maximum clear sky solar radiation (*Rso*). *Rso* can be computed directly based on latitude, elevation, and day of year. *Rso* assume clear skies, which is never the case. Clouds and haze will influence the true solar radiation reaching the earth's surface. Therefore, corrections were made to the daily data as will be discussed.

[11] www.wunderground.com

Figure A.6. Location of the Projects and Weather Stations for this Project



Hourly *ETo*

As previously mentioned, the hourly *ETo* is needed to estimate the *ETo* at the time the image is taken. It was assumed that since there were no clouds covering the area of interest in any of the processed images, the *Rso* was equal to the *Rs* at this instant; therefore, no correction was made to the hourly data. The hourly data collected at each weather station, and the computed *Rso* data, were used to compute the ASCE 2005 Standardized *ETo* using a program called REF-ET developed by Richard Allen from the University of Idaho.[12]

[12] http://extension.uidaho.edu/kimberly/tag/reference-evapotranspiration/

Daily *ETo*

The daily *ETo* was used to compute the monthly *ETo*, which was multiplied by the monthly Service Area *Kc*. From day to day, the solar radiation reaching the earth's surface is impacted by cloud cover and haze. A correction for the clear sky solar radiation (*Rso*) was made based on the estimated monthly percent of sunshine at each weather station location. The percent of sunshine was obtained from the FAO AQUASTAT website[13] on a monthly basis. The daily *Rso* data was reduced by the monthly percent of sunshine to correct *Rso* to *Rs*.

The daily data collected at each weather station and the corrected *Rs* data was then used to compute the daily ASCE 2005 Standardized *ETo* using REF-ET. The daily *ETo* was summed up for May and June 2013 to obtain the monthly *ETo*.

ETo and individual weather data were used within the ITRC METRIC process to compute inputs into the software. ITRC METRIC computed the instantaneous *ETc* for every pixel within the Landsat image at the instant the image was taken. Knowing the *ETo* at that instant from the local weather station, a crop coefficient (*Kc*) can be computed (*Kc* = *ETc/ETo*). It has been shown that this instantaneous *Kc* at the time of image acquisition (approximately 11 a.m.) was a very good representation of the *Kc* for that entire day.

Table A.2. 2013 Monthly ASCE Standardized PM ETo Computed from Weather Data Obtained from the Two Weather Stations

	Monthly ETo	
	Khudzhand	Parkhar
Month	mm/month	mm/month
April	101	89
May	164	153
June	214	215
July	223	209
August	194	172

Elevation Data

A Digital Elevation Model (DEM) obtained from DIVA-GIS was used to adjust the model outputs based on the surface elevation through the area of interest. The DEM used had a pixel resolution of 90 m.

METRIC Kc Results

Figures A.7 through A.9 consist of example *Kc* results from three different image dates and their ranges of *Kc* values (Urtabuz). At the end of this appendix, Figure A.10 contains 16 panels showing all *Kc* images and a reference Landsat 8 image for each of the project sites. The lighter the pixel color, such as yellow, the lower the *Kc* value. Conversely, the darker the pixel color, such as blue, the higher the *Kc* value.

[13] http://www.fao.org/nr/water/aquastat/quickWMS/climcropwebx.htm

Figure A.7. Urtabuz ITRC METRIC *Kc* Results for May 14, 2013

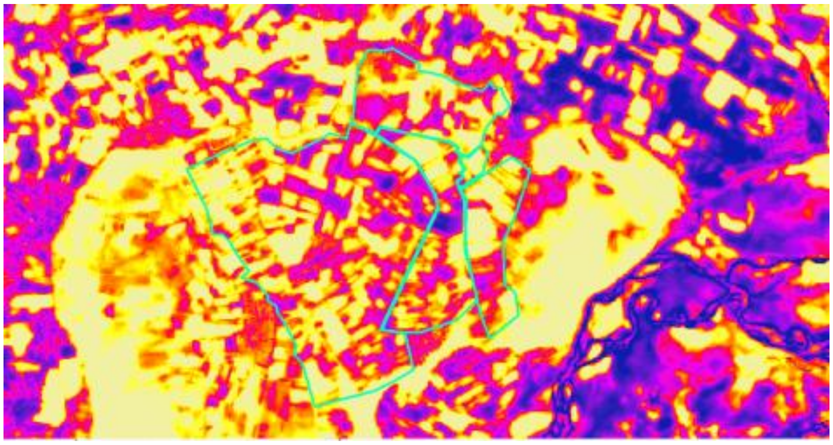


Figure A.8. Urtabuz ITRC METRIC *Kc* Results for June 16, 2013

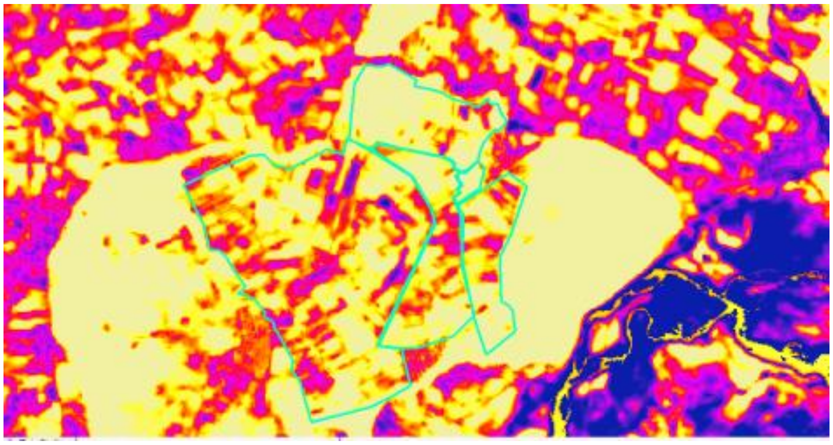
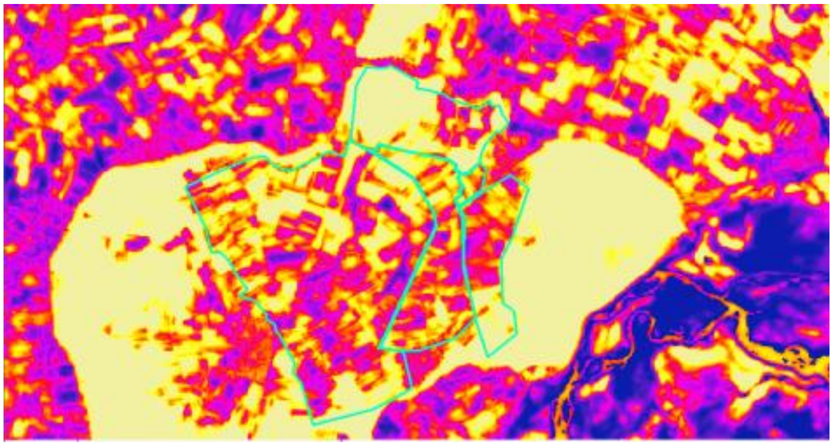


Figure A.9. Urtabuz ITRC METRIC *Kc* Results for July 1, 2013



Volume of ETc by Project

Using ArcGIS, the *Kc* values from each image processed were averaged by the estimated service areas. Since each pixel within the image is the same size, the Service Area Average *Kc* accounts for cropped areas and fallow areas equally. Higher fallowed areas or areas with poor crop cover would have a lower *Kc* value than crops with full canopy cover that are well irrigated.

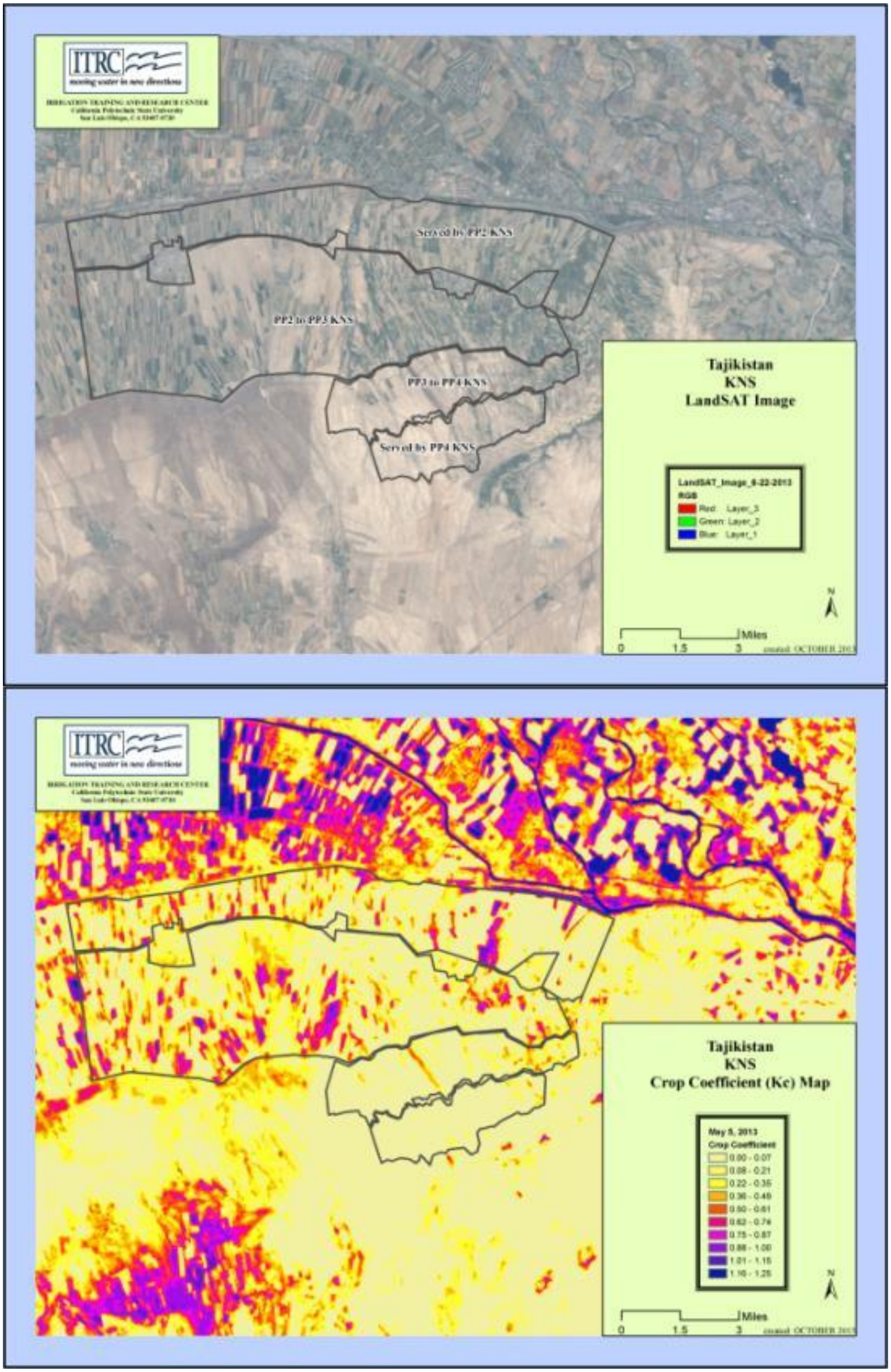
As shown in Table A.3 below, the following image dates corresponding to Service Area *Kc* values were averaged to estimate the monthly Service Area *Kc*:

Images processed on May 5, May 14 and June 6 = May *Kc*
Images processed on June 15, 22 and July 1 = June *Kc*

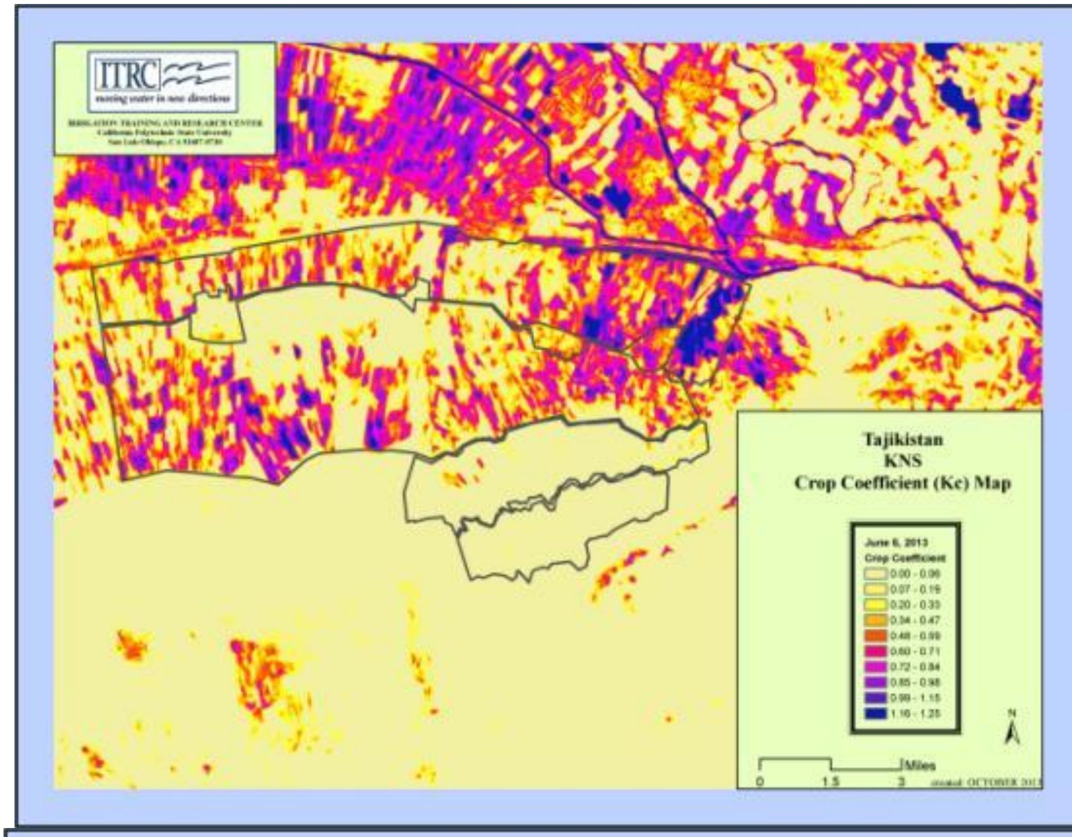
Table A.3. Estimated Monthly Evapotranspiration (Consumptive Use) within Six Tajikistan Irrigation Projects (May and June, 2013)

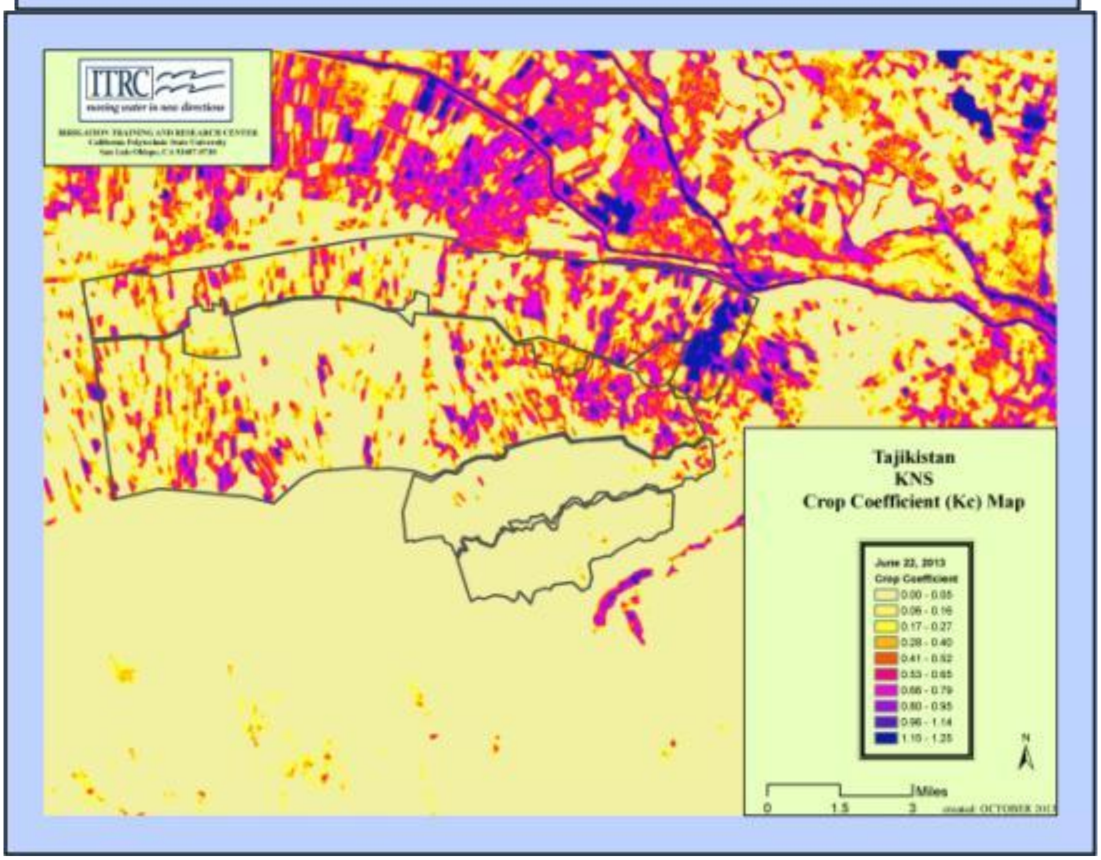
Project	Average Kc		ETo, mm/mo		Ha	ETc, Ha-m/month	
	May-13	Jun-13	May-13	Jun-13		May-13	Jun-13
KNS	0.24	0.20	164	214	17,188	672	741
Kojabokirgon	0.28	0.44	164	214	13,420	614	1,271
Makhram	0.38	0.32	164	214	3,169	197	214
Fayzobodkala	0.40	0.37	153	215	2,247	138	181
Garouti	0.37	0.30	153	215	8,030	458	522
Urtabuz	0.43	0.37	153	215	3,248	215	258

Figure A.10. Crop Coefficient Images for Each of the Project Sites

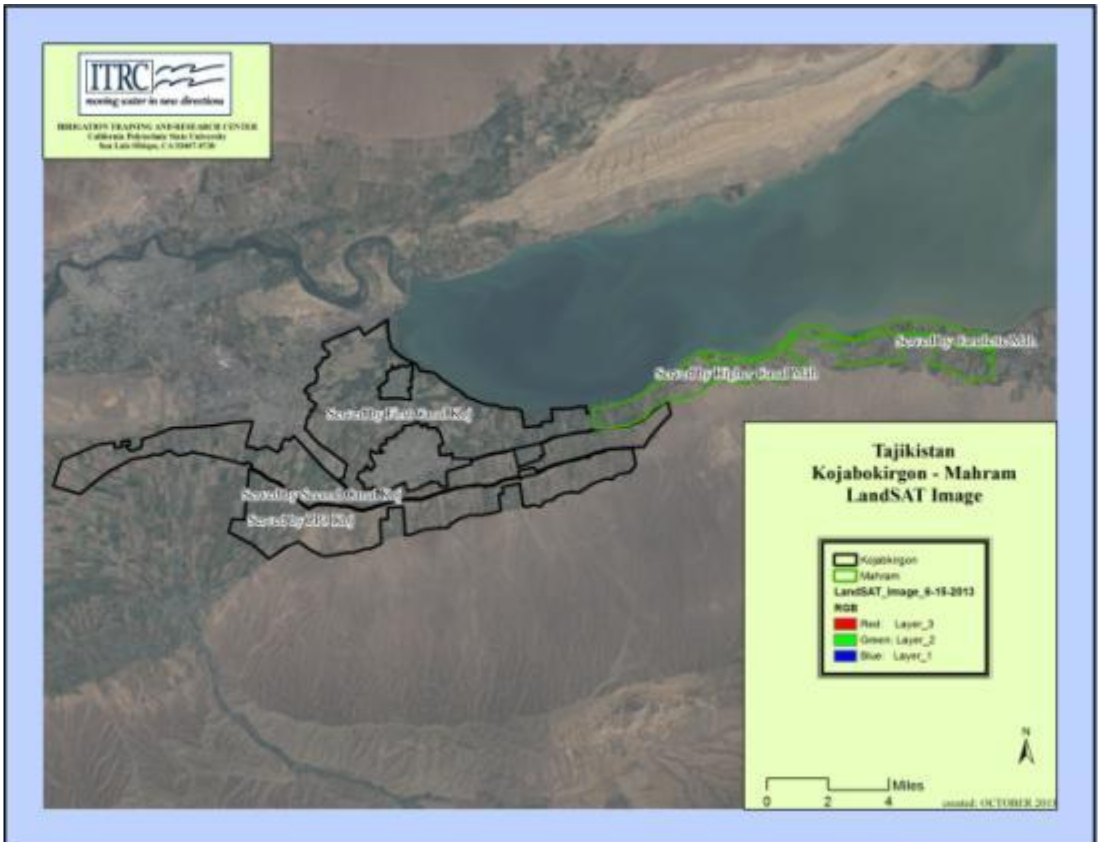


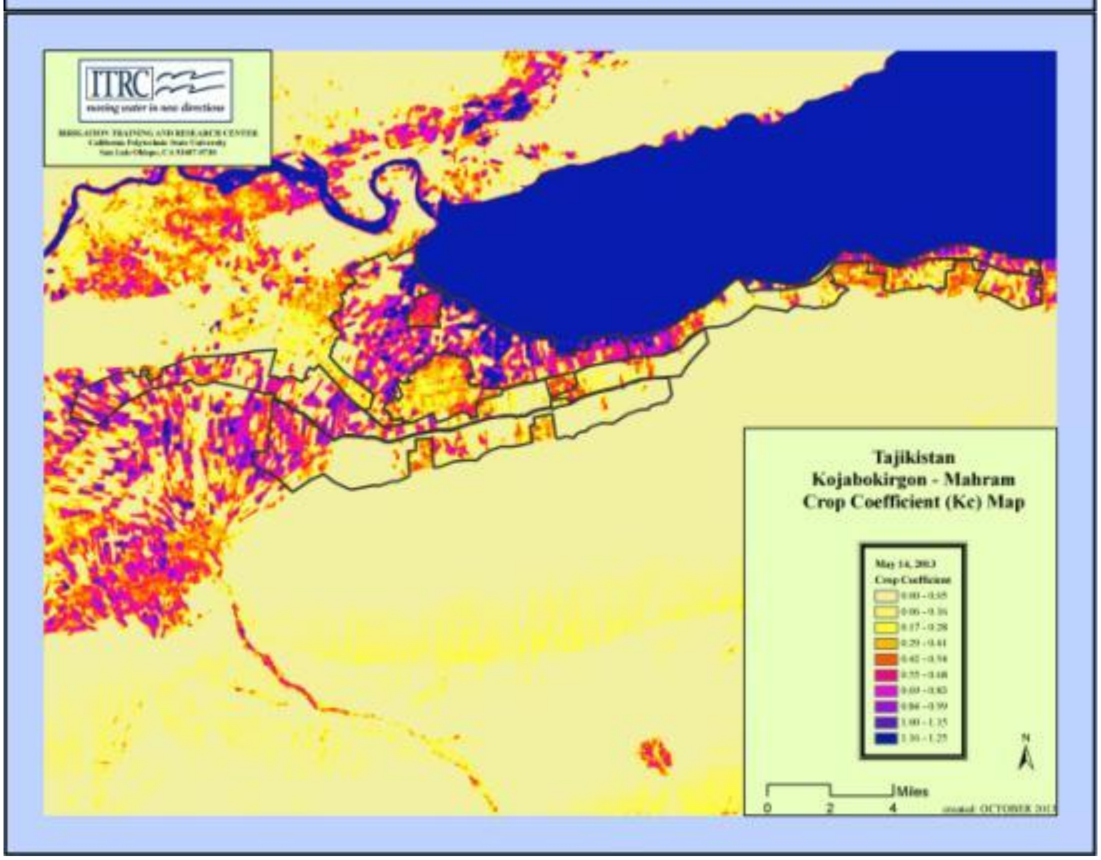
Appendix A

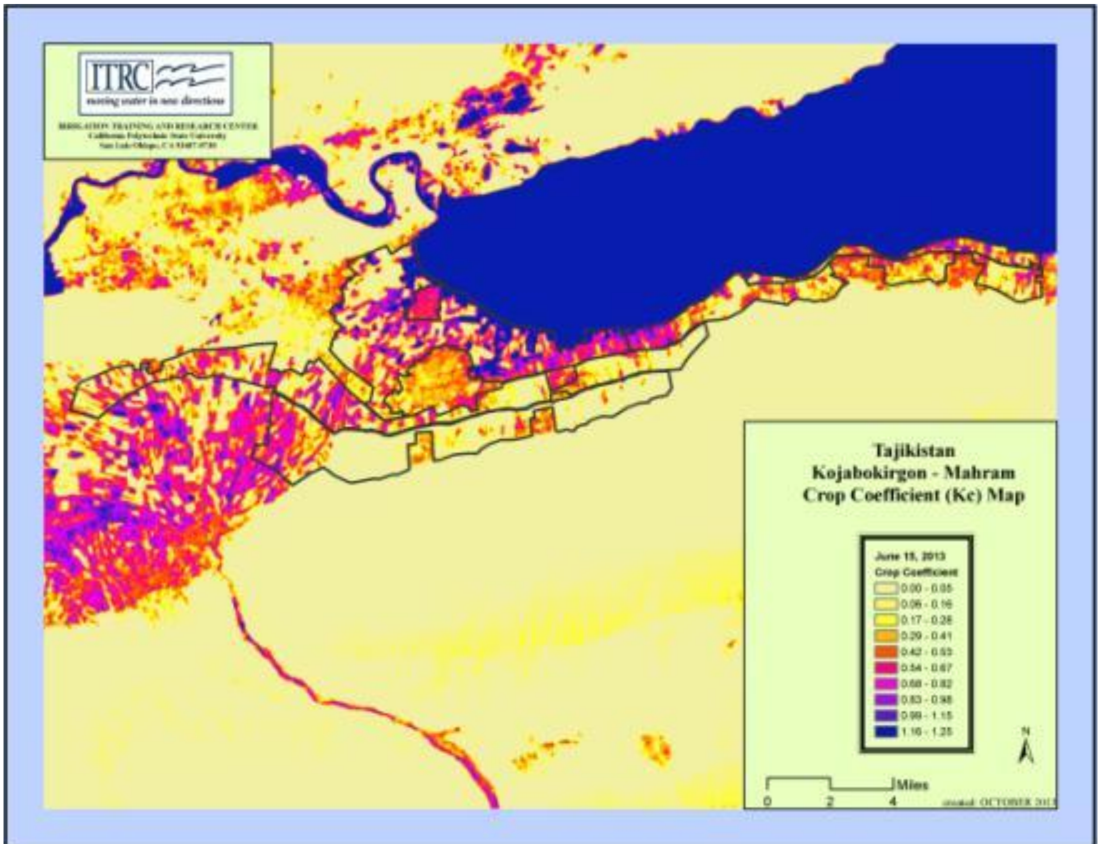

ITRC
Tajikistan
KNS
Crop Coefficient (Kc) Map
June 6, 2013
Crop Coefficient
0.00 - 0.06
0.07 - 0.19
0.20 - 0.33
0.34 - 0.47
0.48 - 0.59
0.60 - 0.71
0.72 - 0.84
0.85 - 0.98
0.99 - 1.15
1.16 - 1.25
N
Miles
0
1.5
3

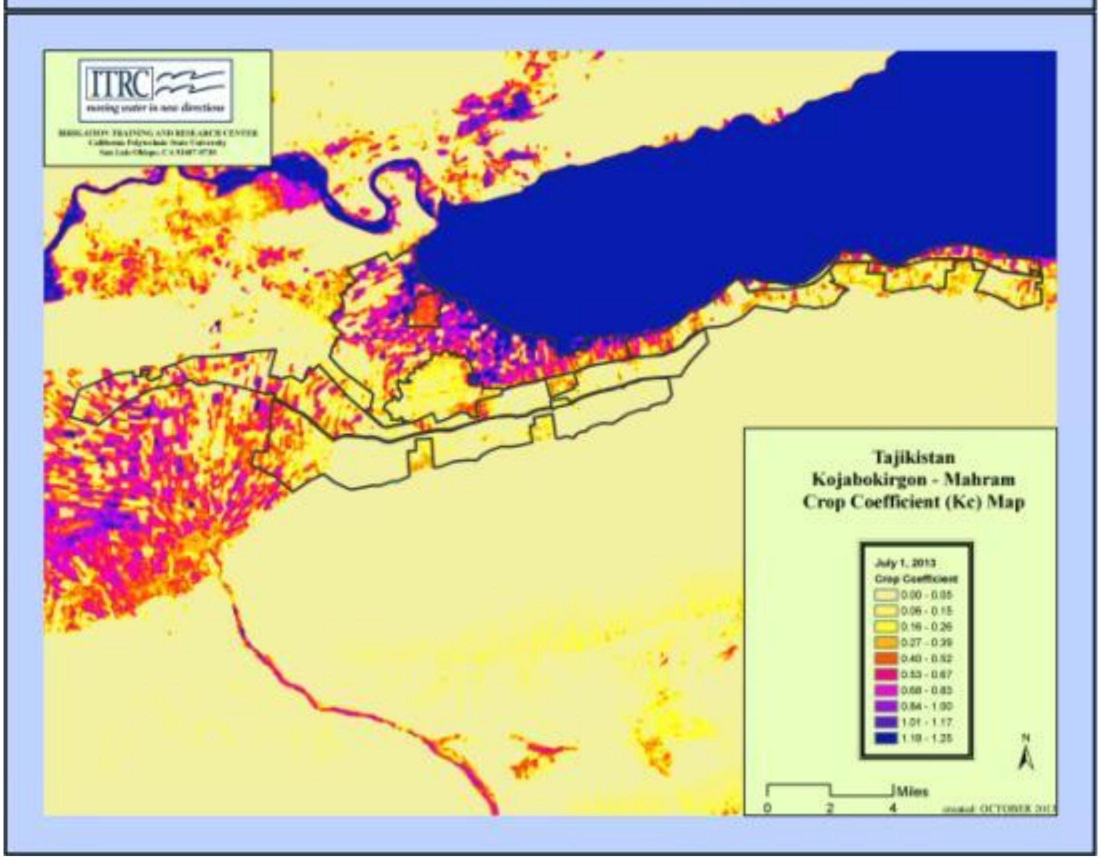

ITRC
Tajikistan
KNS
Crop Coefficient (Kc) Map
June 22, 2013
Crop Coefficient
0.00 - 0.05
0.06 - 0.16
0.17 - 0.27
0.28 - 0.40
0.41 - 0.52
0.53 - 0.65
0.66 - 0.79
0.80 - 0.95
0.96 - 1.14
1.15 - 1.25
N
Miles
0
1.5
3

Appendix A

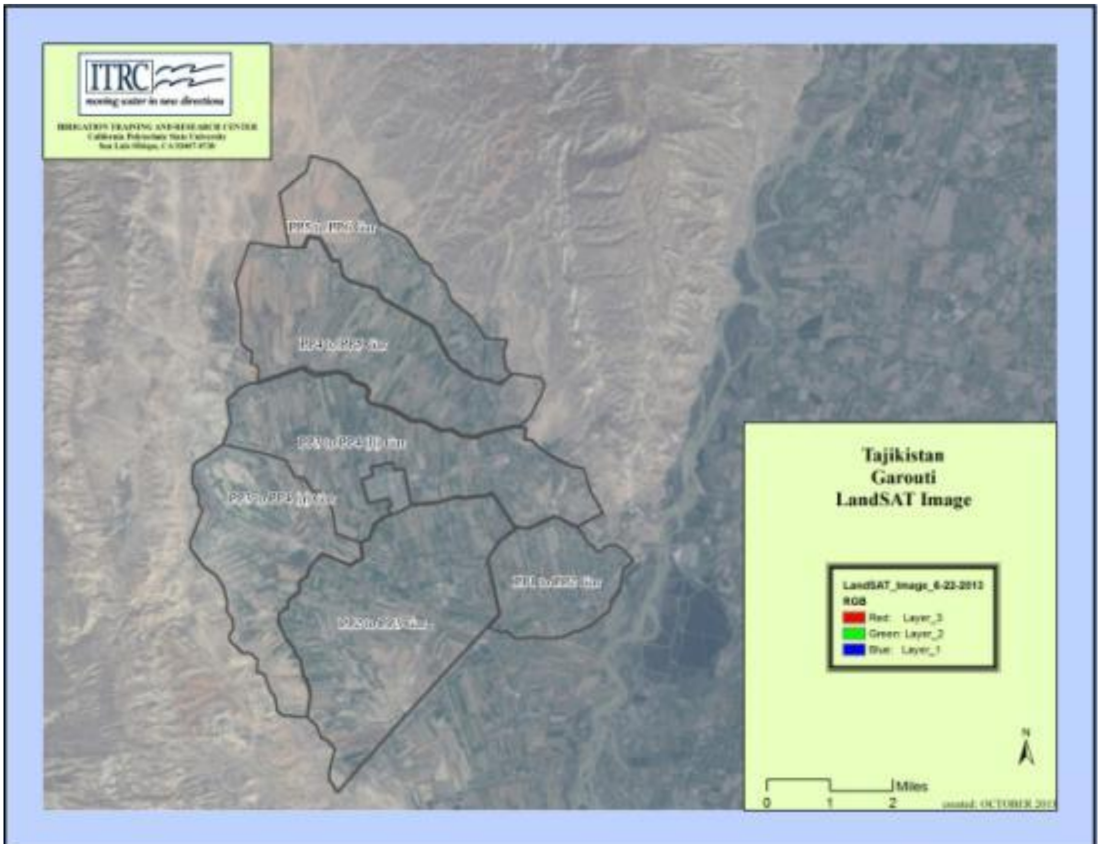

ITRC
moving water in new directions
Tajikistan
Kojabokirgon - Mahram
LandSAT Image
Kojabokirgon
Mahram
LandSAT_Image_6-15-2013
RGB
Red: Layer_3
Green: Layer_2
Blue: Layer_1
N
Miles
0
2
4

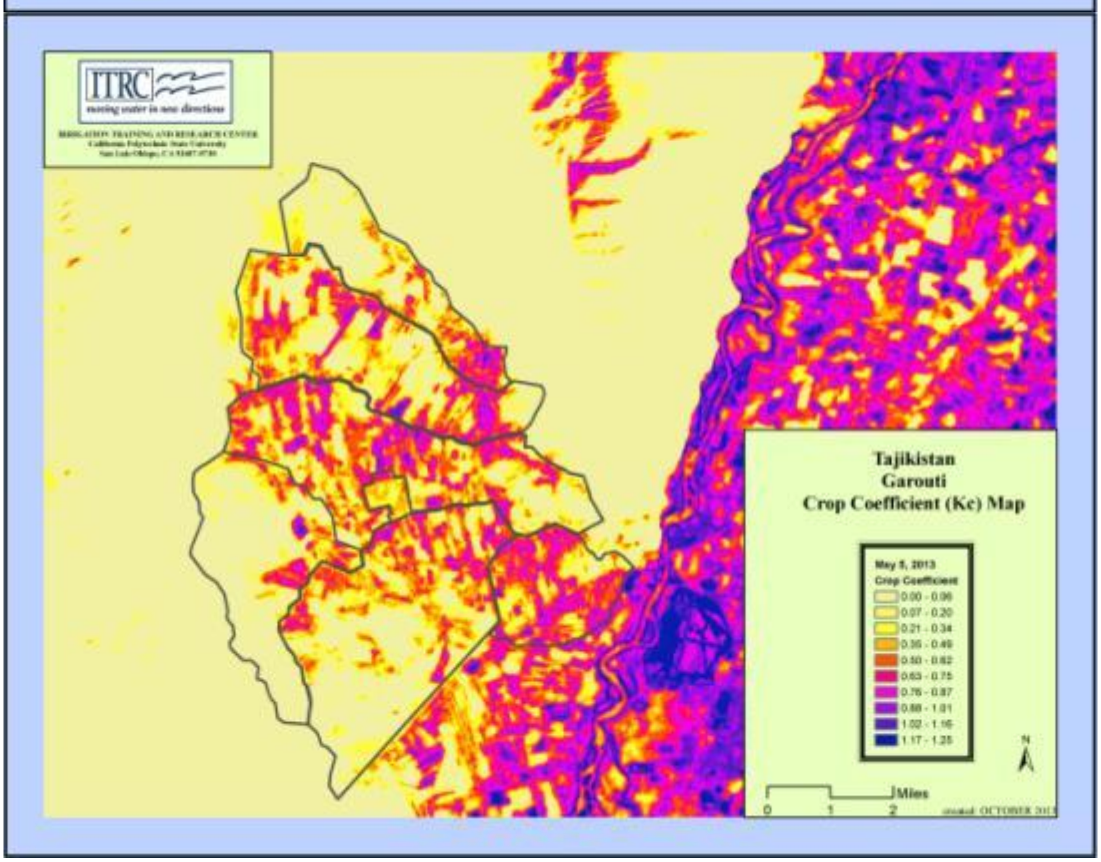

ITRC
moving water in new directions
Tajikistan
Kojabokirgon - Mahram
Crop Coefficient (Kc) Map
N
Miles
0
2
4

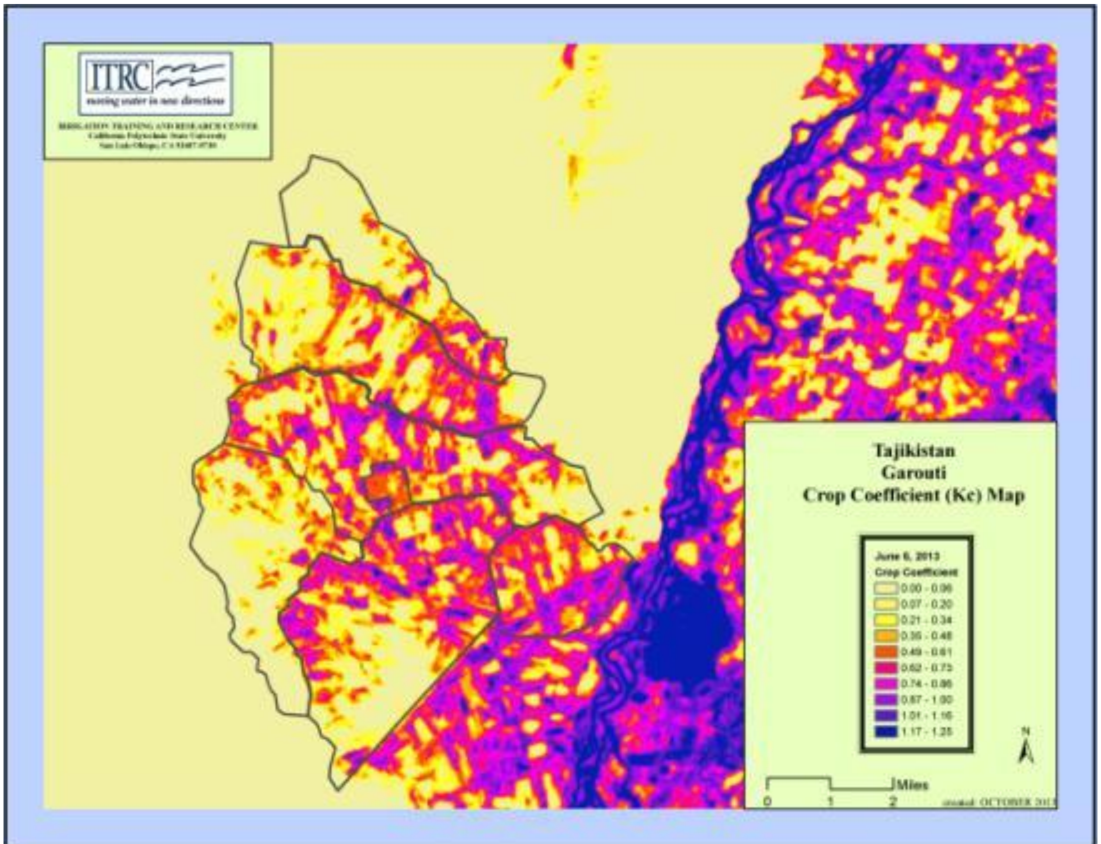

ITRC
Tajikistan
Kojabokirgon - Mahram
Crop Coefficient (Kc) Map
June 15, 2013
Crop Coefficient
0.00 - 0.05
0.06 - 0.16
0.17 - 0.28
0.29 - 0.41
0.42 - 0.53
0.54 - 0.67
0.68 - 0.82
0.83 - 0.98
0.99 - 1.15
1.16 - 1.25
N
Miles
0 2 4

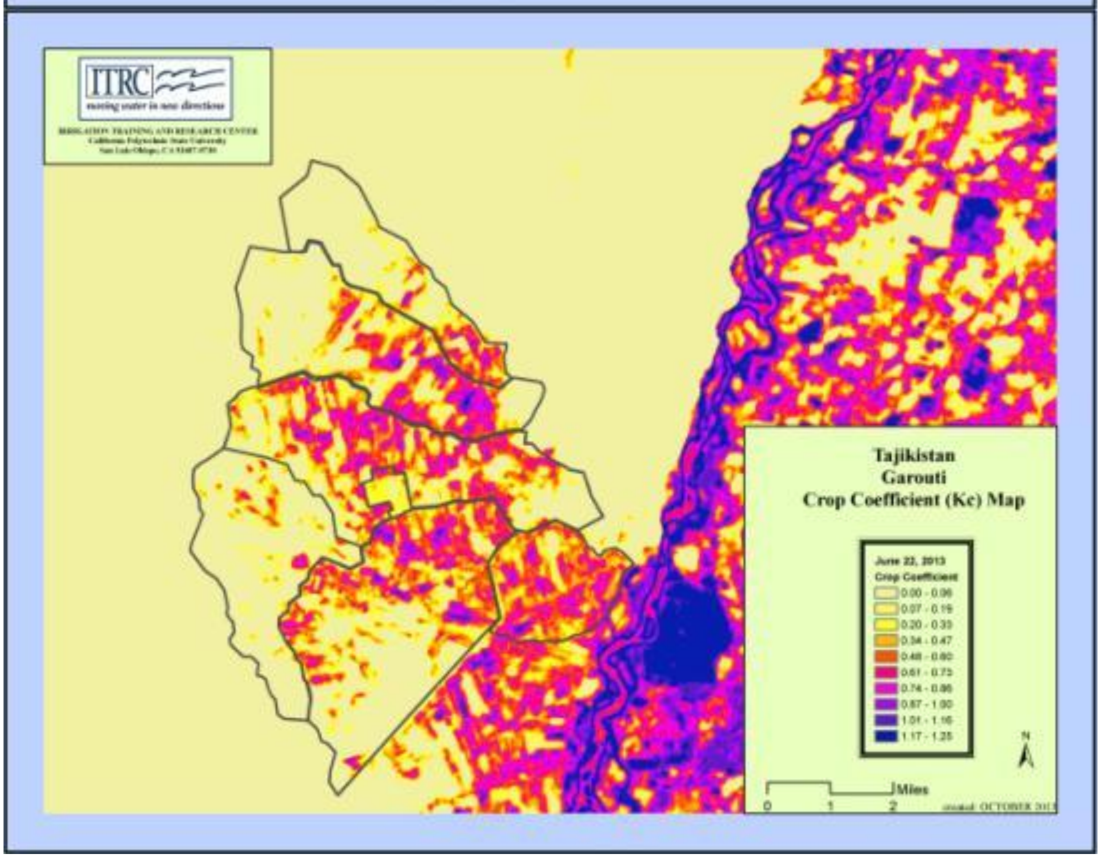

ITRC
Tajikistan
Kojabokirgon - Mahram
Crop Coefficient (Kc) Map
July 1, 2013
Crop Coefficient
0.00 - 0.05
0.06 - 0.15
0.16 - 0.26
0.27 - 0.39
0.40 - 0.52
0.53 - 0.67
0.68 - 0.83
0.84 - 1.00
1.01 - 1.17
1.18 - 1.25
N
Miles
0 2 4

Appendix A


ITRC
Tajikistan
Garouti
LandSAT Image
LandSAT_Image_6-22-2013
RGB
Red: Layer_3
Green: Layer_2
Blue: Layer_1
N
Miles
0
1
2

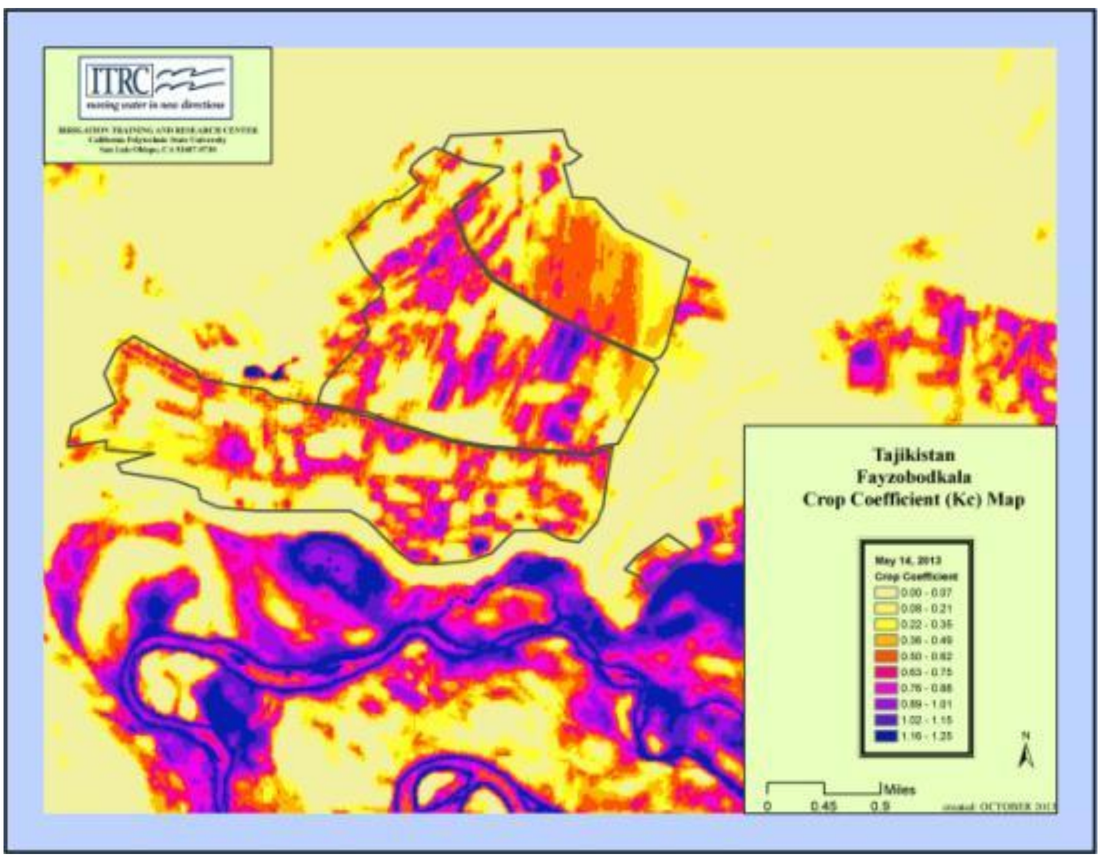

ITRC
Tajikistan
Garouti
Crop Coefficient (Kc) Map
May 5, 2013
Crop Coefficient
0.00 - 0.06
0.07 - 0.20
0.21 - 0.34
0.35 - 0.49
0.50 - 0.62
0.63 - 0.75
0.76 - 0.87
0.88 - 1.01
1.02 - 1.16
1.17 - 1.25
N
Miles
0
1
2


ITRC
moving water in new directions
Tajikistan
Garouti
Crop Coefficient (Kc) Map
June 6, 2013
Crop Coefficient
0.00 - 0.06
0.07 - 0.20
0.21 - 0.34
0.35 - 0.48
0.49 - 0.61
0.62 - 0.73
0.74 - 0.86
0.87 - 1.00
1.01 - 1.16
1.17 - 1.25
N
Miles
0
1
2

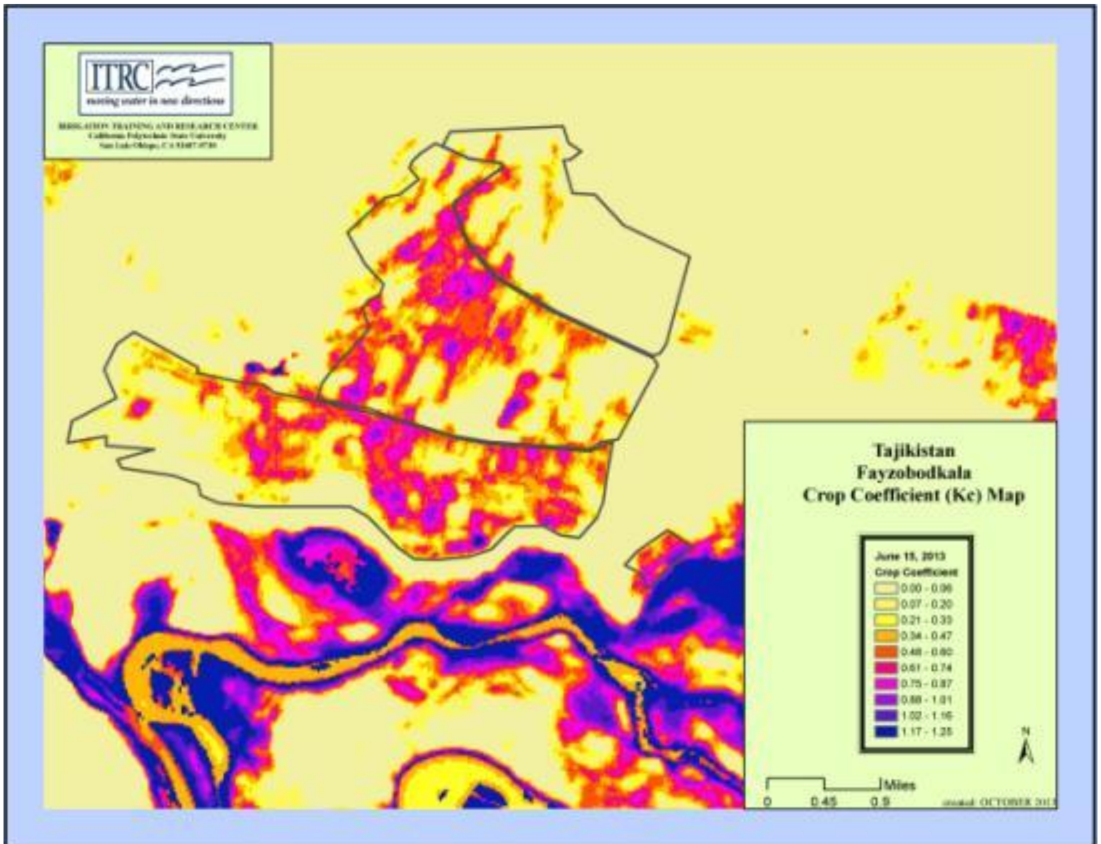

ITRC
moving water in new directions
Tajikistan
Garouti
Crop Coefficient (Kc) Map
June 22, 2013
Crop Coefficient
0.00 - 0.06
0.07 - 0.19
0.20 - 0.33
0.34 - 0.47
0.48 - 0.60
0.61 - 0.73
0.74 - 0.86
0.87 - 1.00
1.01 - 1.16
1.17 - 1.25
N
Miles
0
1
2

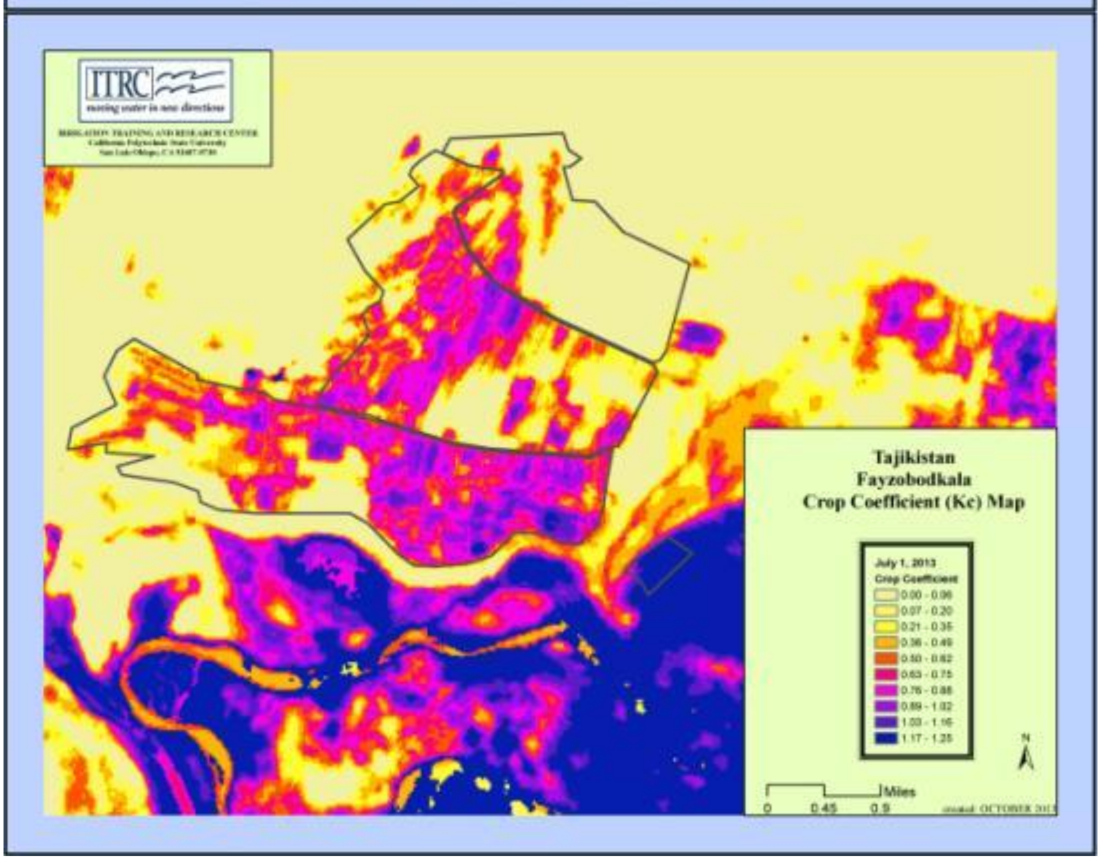
Appendix A


ITRC
moving water in new directions
Tajikistan
Fayzobodkala
LandSAT Image
LandSAT_Image_6-15-2013
RGB
Red: Layer_3
Green: Layer_2
Blue: Layer_1
Miles
0
0.45
0.9


ITRC
moving water in new directions
Tajikistan
Fayzobodkala
Crop Coefficient (Kc) Map
May 14, 2013
Crop Coefficient
0.00 - 0.07
0.08 - 0.21
0.22 - 0.35
0.36 - 0.49
0.50 - 0.62
0.63 - 0.75
0.76 - 0.88
0.89 - 1.01
1.02 - 1.15
1.16 - 1.25
Miles
0
0.45
0.9

Appendix A


ITRC
moving water in new directions
Tajikistan
Fayzobodkala
Crop Coefficient (Kc) Map
June 15, 2013
Crop Coefficient
0.00 - 0.06
0.07 - 0.20
0.21 - 0.33
0.34 - 0.47
0.48 - 0.60
0.61 - 0.74
0.75 - 0.87
0.88 - 1.01
1.02 - 1.16
1.17 - 1.25
N
Miles
0
0.45
0.9
created: OCTOBER 2013


ITRC
moving water in new directions
Tajikistan
Fayzobodkala
Crop Coefficient (Kc) Map
July 1, 2013
Crop Coefficient
0.00 - 0.06
0.07 - 0.20
0.21 - 0.35
0.36 - 0.49
0.50 - 0.62
0.63 - 0.75
0.76 - 0.88
0.89 - 1.02
1.03 - 1.16
1.17 - 1.25
N
Miles
0
0.45
0.9
created: OCTOBER 2013

APPENDIX B. TERMS OF REFERENCE AND IN-COUNTRY VISITS

The terms of reference for this assignment were:

- Determine the immediate costs of irrigation inefficiency, including the energy costs for both irrigation and drainage, and also the costs of additional items that could be quantified, such as those related to pump life span.
- Develop a set of irrigation efficiency indicators that can be used for monitoring progress over time and/or for cross-country comparisons and benchmarking. The indicators should be relevant for other Central Asian countries to ensure comparability between data sets.
- Calculate the costs of inefficiency to the national budget.
- Identify expenditures and revenues associated with irrigation and drainage, including: capital expenditures; operations and maintenance (O&M) expenditures; the composition of various expenditures (such as recurrent budget items in the development budget, wage versus non-wage expenditures, and energy versus non-energy related expenses); the main sources of financing the budget; flow of funds; and cost recovery.
- Identify possible measures to reduce the immediate costs of irrigation inefficiency, and for each of these measures, quantify the associated monetary savings as compared to the current situation. The consultant was tasked to present the proposed measures in an attractive graphical manner to facilitate acceptance and adoption on the part of stakeholders.
- Design and implement a stakeholder consultation process for the implementation of the assignment.

The terms of reference included the caveat that there would likely be a scarcity of available data, which would limit the extent of quantitative analysis that could be conducted with reasonable accuracy.

<u>Information Gathering</u>
Visits to various projects throughout the nation in June 2013 were facilitated by First Deputy Minister Rahimov Sulton, of the Ministry of Melioration and Water Resources (now the Ministry of Energy and Water Resources). Engineer Sharofiddinov Husniddin of the ministry made final arrangements and was present during all visits. The excellent assistance of the Ministry of Melioration and Water Resources in all aspects of the information gathering was greatly appreciated.

Key visits during the information gathering process included:
<u>Visits in Dushanbe</u>

- Rahimov Sulton, First Deputy Minister, Ministry of Melioration and Water Resources
- Yatimov Bobojon, Senior Rural Development Officer, World Bank Tajikistan Country Office
- Jelle Beekma, Team Leader, Provision of Technical Assistance to the Government of Tajikistan
- Kamolidinov Anvar, GIZ, Transboundary Water Management in Central Asia
- Mahmoudov Zafar, Communications Manager, Pilot Program for Climate Resilience Secretariat, State Administration for Hydrometeorology
- Aviva Kutnick, Jim Campbell, Nurmatov Mukhiddin, Sayed Ali, USAID office

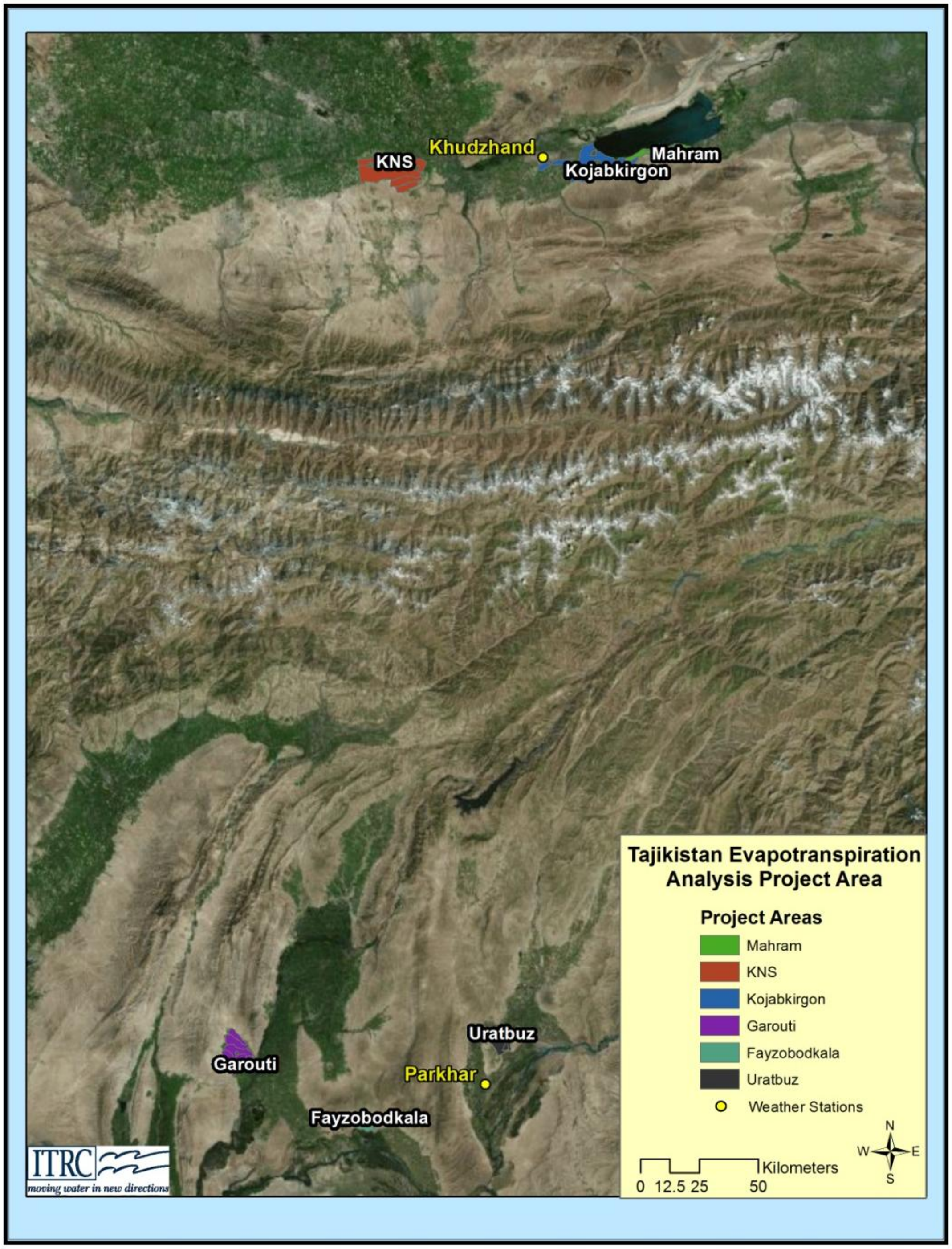
<u>Visits outside of Dushanbe</u>

- Yangi-Choryakkoron (1 pump station), Gisar District
    - Contact person: Nasriddin, Department of Pumped Water Supply, Ministry of Melioration and Water Resources
- Pump repair shop located approximately 50 km southeast of Dushanbe
- Garouty project (5 lifts), Jillikul District
    - Contact person: Odinaev Abrai
- Khatlon Regional office of the Department of Water Resources
    - Contact person: Rahimov Abdugodir, Chief Specialist of pumps
- Vakhsh pump repair shop
    - Contact person: Khushvakhtov Chori, Chief of the repair shop
- Fayzobodkala project, Panj District
    - Contact person: Abdullo Dargaev Abdullo, Head of the Department of Water Resources in Panj District
- Urtabuz cascade project (4 pump stations), Farkhor District
    - Contact persons: Nurullo Khudoidodov Nurullo, Chief of the Regional Department
- Various submersible pump well field sites near Khujand
- Mahram District and Pump Station, Kanibadam Region
    - Contact persons: Yokubov Karimjon, Manager of the pumping station; Aliev Bahromjon, Chief Engineer for the Mahram District; Buzrukov Muhiddin, Electrical Engineer
- Market in Khujand to investigate the availability of sprinklers, PVC pipe, drip equipment
- Boboev Abdunabi, Director of the Sugd Region of Ministry of Melioration and Water Resources, Khujand
- Kojabokirgon pontoon pumping project Bobojon Gafurov District
    - Contact persons: Nzairov Zarifjon, Chief of District Department of Water Resources; Karimov Shavkat, Deputy Chief
- KNS Pump stations (4 lifts), Zafarabod District
    - Contact: Mansurov Ibodullo, Chief of Department in the District; GNS-1 Canal 1, Zafarabod District

APPENDIX C. SELECTED PROJECTS

Eight projects were visited by the consultant, plus one pump repair station. Data were obtained from six of the projects: three in the north and three in the south. The image below in Figure C.1 shows the locations of the six projects.

Figure C.1. Location of Selected Projects in Tajikistan

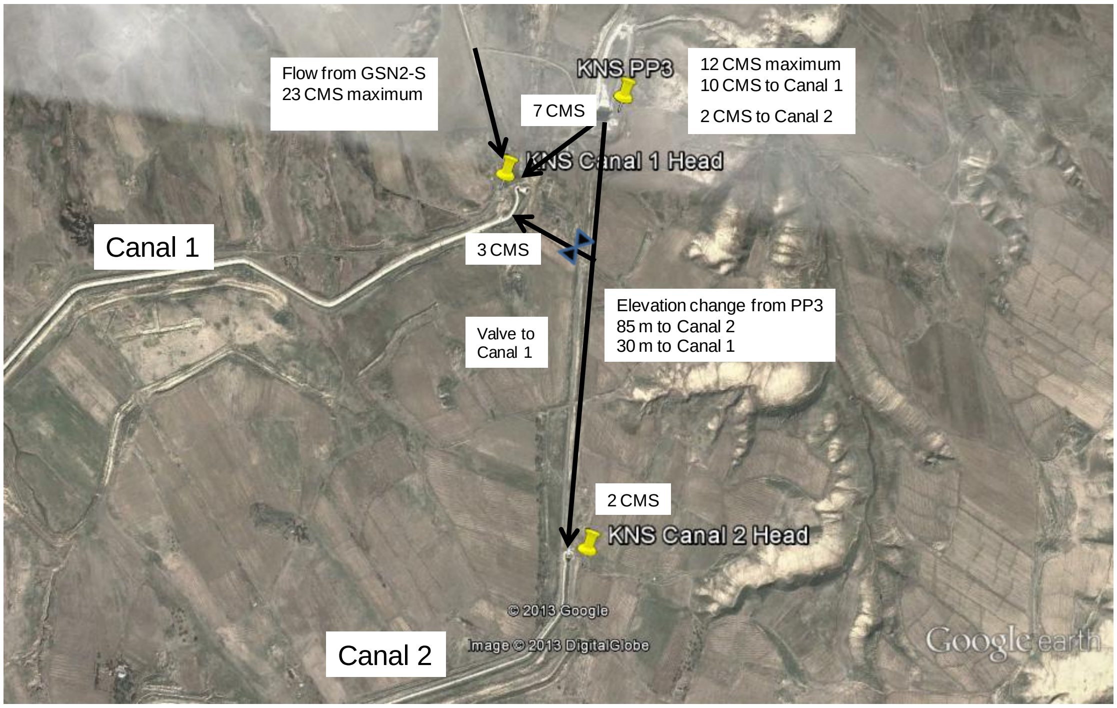


INDIVIDUAL PROJECT LAYOUTS

A sketch of the relative locations of various pumping stations and canals is provided for each project in Figure C.2

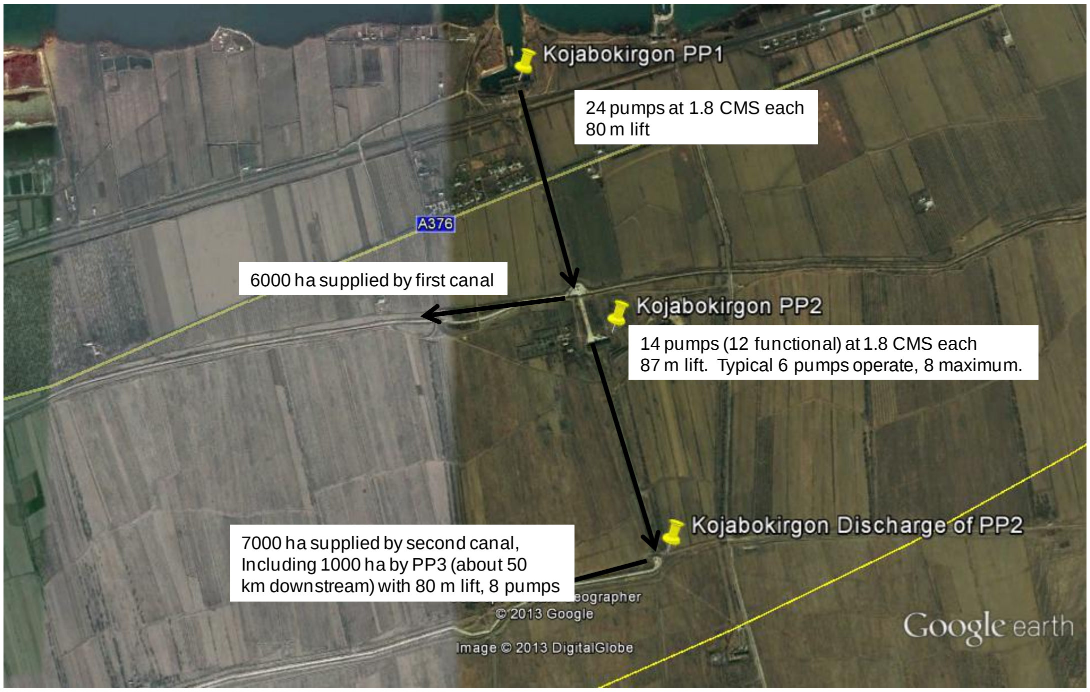
Figure C.2. Location of Pumping Stations and Canals for Each Project

KNS

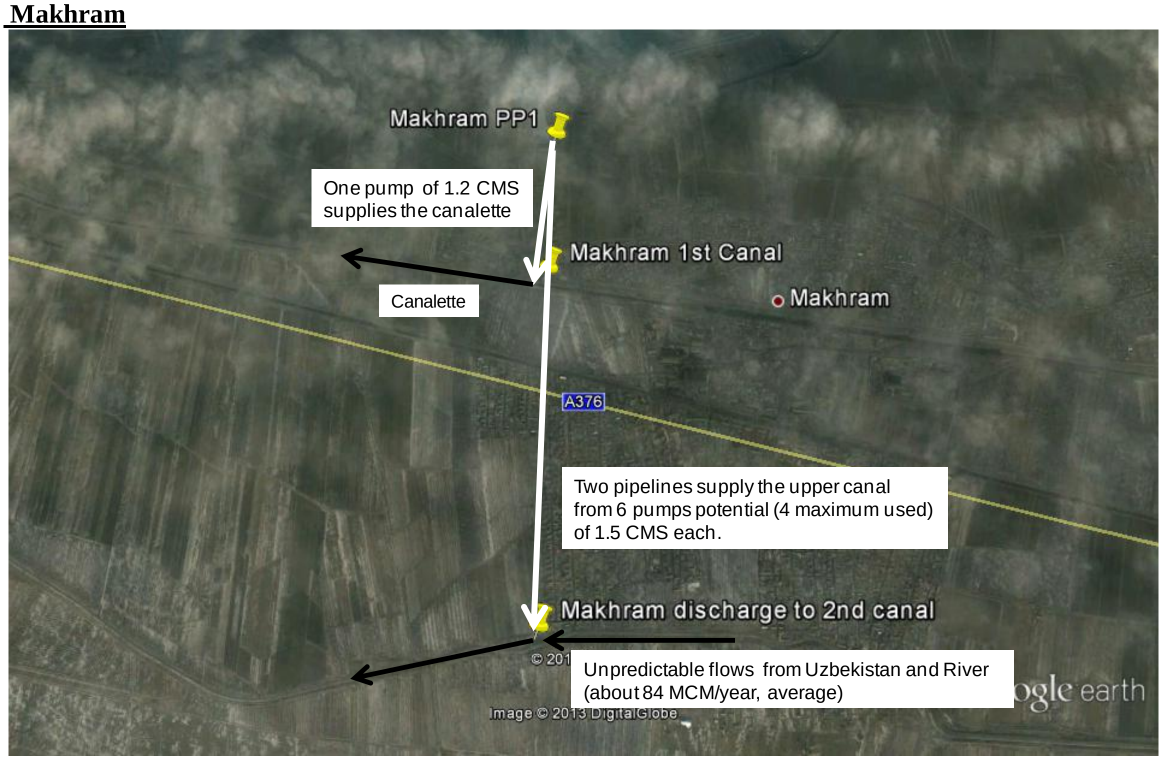


Appendix C

Kojabokirgon

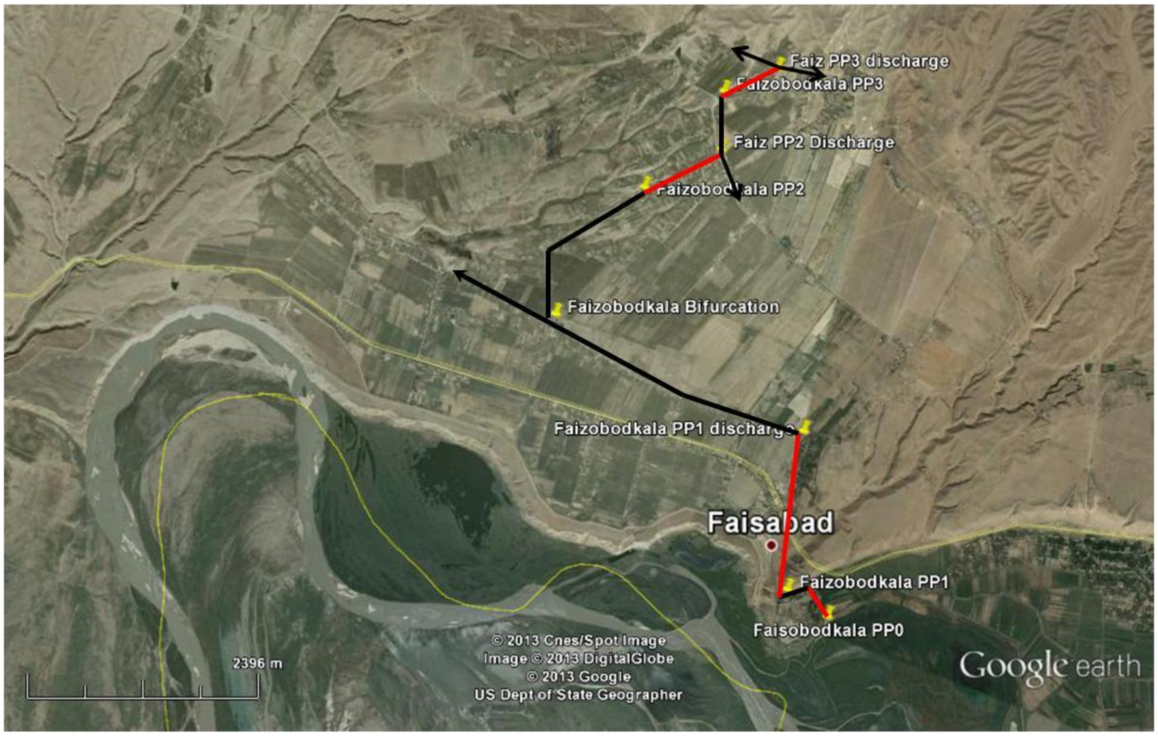


Makhram

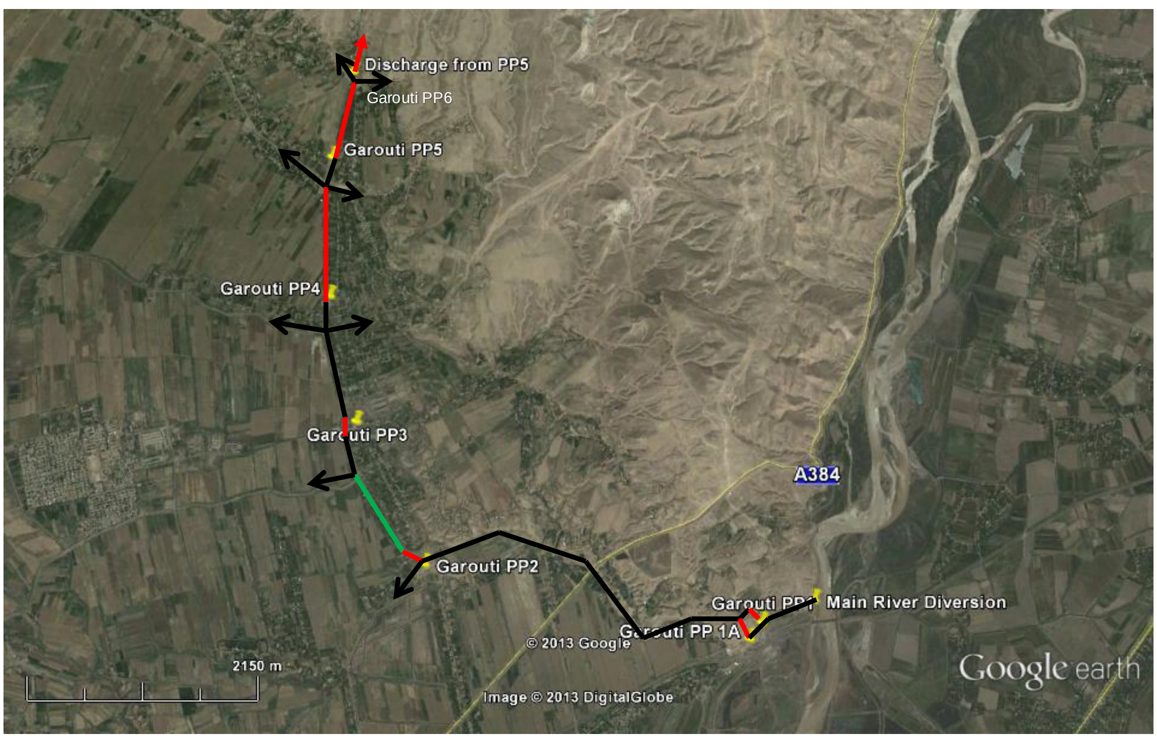


Appendix C

Fayzobodkala



Garouti



Appendix C

Urtabuz

APPENDIX D. ENERGY AND IRRIGATION IN TAJIKISTAN

Background Note

Energy and irrigation are intimately connected in Tajikistan in a number of important ways. In the first place, hydropower resources in the Aral Sea basin are concentrated in the Kyrgyz Republic and Tajikistan, while thermal energy resources are concentrated in Uzbekistan, Turkmenistan and Kazakhstan. Downstream countries are highly dependent on upstream countries for essential water for irrigation. Climate change is expected to exacerbate this dependence.

Secondly, Tajikistan has one of the world's largest potential for further expansion of hydropower. The country is ranked first globally in terms of hydropower reserves per territorial unit. At present, hydropower provides more than 90 percent of the country's energy demand. In addition, the aggregate potential of small hydropower plants in irrigation canals is estimated at 152 million kWh per annum, which constitutes about 10 percent of the current energy consumption in domestic irrigation systems.

Third, energy plays a key role in economic development of Tajikistan. Tajikistan, together with its Central Asian neighbors, is among the most energy- and water-intense countries in the world, with high water and energy consumption per capita and per unit GDP. The share of energy costs in the total volume of the GDP amounts to 60 percent. Energy intensity in Tajikistan is almost twice the world average, and three times higher than in most developed countries, which means that Tajikistan needs two times more energy to produce one unit of GDP then the average country. According to the latest data from different sectors of Tajikistan's economy, the local aluminum producer TALCO accounts for almost half the electricity consumption. Irrigation is the third largest consumer in the country, accounting for a consumption of 19 percent of the total volume of electricity produced, but mostly concentrated in the summer months when electricity is abundant. Irrigated agriculture contributes disproportionally because over 44 percent of the irrigated area relies on pumping, and also because of the limited contribution of irrigated agriculture to GDP.

This important share of irrigation systems in the structure of electric energy consumption in the country demonstrates the importance of reliable and efficient power supply in this sector to ensure national food security. Out of 1.5 million hectares of land in Tajikistan where irrigation is potentially applicable, only 748 thousand hectares of irrigated land have originally been developed for irrigation. At present, it is estimated that only 515,000 hectares are still under operation, out of which an estimated 170,000 hectares (33 percent) rely on pumps. In most facilities, the pumps have exhausted their economic life and the consumption of electricity is excessive.

Low electricity tariffs for pumping stations during the vegetation period (0.3 US cents per k/w/h) are not conducive to energy saving and more efficient use of water and electricity. Thus, reliable energy supply and efficiency of irrigation systems constitute important factors for obtaining sustainable and guaranteed water supply and food security in Tajikistan.

APPENDIX E. AGRICULTURAL, ENERGY AND WATER REFORMS

The Government of Tajikistan is pursuing a number of reforms that each have an impact on the efficiency and productivity of irrigation water use. These reforms are part of Tajikistan's "Strategy for State Administrative Reform" that was launched in March 2006. This appendix provides a summary of these reforms and highlights their impact on irrigation efficiency.

The "Action Plan on Reforming the Agricultural Sector in the Republic of Tajikistan" (Resolution 406 of July 2009) signaled a renewed and stronger commitment to reforms, including changes in several legal acts and institutions. It details specific steps to implement a number of major reforms. Six working groups covering different agricultural policy areas are preparing strategic documents in the following areas:

- Agricultural reform
- Social development in rural areas
- Land reform and in particular establishing a functioning land use right market
- A new mechanism of agricultural finance
- Development of an integrated water resources management system
- Reform of the agricultural administrative system at national, regional and local levels

In all cases, a wide range of stakeholders were actively involved in preparing policy positions including several ministries, state institutions, research organizations, experts from donor and other international organizations. Farmers, nongovernmental organizations (NGO) and women's organizations were also regularly consulted.

Agricultural Sector Reforms

In July 2009, the Government of Tajikistan approved the "Agrarian Reform Program of the Republic of Tajikistan". On 1 August 2012, as part of the Agrarian Reform, the Government of Tajikistan approved the "Agriculture Reform Program" of the Republic of Tajikistan for 2012-20.

The Ministry of Agriculture (MoA) of the Republic of Tajikistan is the central executive authority which is prescribed in the legislation of Tajikistan to carry out development and implementation of the integrated state policy in the sector of agriculture in cooperation with other ministries, agencies, and local executive authorities. As part of its authority, the MoA, at the strategic level, is guiding the efficient use of water in agriculture, such as on irrigated lands and in fishery.

Subsequent to enactment of the Action Plan, the Agriculture Reform Program draft was presented by MoA to the Government and to donors in May 2010. The ministry sent the program draft to other relevant ministries and agencies for comments. So far, positive feedback from most agencies has been provided. Comments and suggestions were also provided by international organizations and experts. After suggestions were discussed and revisions incorporated as appropriate, the program was finalized at the end of 2010.

The agriculture sector reforms are expected to have a positive impact on irrigation productivity because they provide incentives to farmers to grow higher-value crops. As a result, while the volume and the costs of pumping will not necessarily decrease, the value of production per unit of water will improve.

Freedom to Farm

Because of debt write-offs and also the substantial progress in the Land Registration and Cadastral System Project financed by the World Bank, significant gains in establishing a culture of "freedom to farm" have been achieved. There is now much less pressure on farmers to produce cotton. With the national government endorsing the principle of "freedom to farm," local government authorities have less power to exercise pressure over farmers to grow cotton.

Although progress is not rapid enough in some areas, according to the Monitoring Survey of December 2009, approximately 60 percent of farmers felt that they were free to decide when to collect cotton stalks. A sizeable percentage of farmers reported that they had the ability to decide whether or not their cotton crop would be followed by an alternative crop.

Land Use and Ownership Rights

A new land registration law was approved as a critical initial step in the development of a market of land use rights. As noted previously, substantial progress has been made by the Land Registration and Cadastral System Project. In 2009, 5,431 land use certificates were issued while an additional 9,000 have been issued so far this year. The total number of land use certificates that have been issued - including those issued by the State Land Committee - is almost 50,000.

At the end of August 2010 the concept of Tradable Land Use Rights was developed by a USAID project, and it has been presented to key donor agencies for comments. Work is being undertaken on land valuation, which is considered an important issue for land market development. The Asian Development Bank (ADB) is also joining other donors on land-related projects and activities. These reforms are being supported by amendments to the following laws: Law on Dehkan Farms; Law on Mortgages; Law on Registration of Immovable Property and Rights; and Law on Service Cooperatives.

Access to Finance

Government and donors agree on the need to develop a broader base for agricultural lending and to strengthen the overall financial system. The government's response has centered on providing budget-funded credit lines to commercial banks. These amounted to TJS 140 million in 2008, TJS 180 million in 2009, and an estimated TJS 130 million for 2010. Banks were initially required to use most of this credit for cotton, at preferential interest rates. But government has now made this credit available for all types of agricultural products, with no preferential interest rates for cotton. In addition, the government requires that commercial banks use the European Bank for Reconstructiothe systemn and Development's (EBRD) Tajik Agricultural Finance Network (TAFF) loan screening methodology for loans made with budget-funded credit lines.

However, recognizing that government budget lending is not an efficient mechanism, the government has decided to gradually eliminate such lending, and is instead seeking donor support to boost private sector lending for agriculture. EBRD is leading the response to this request through its support for commercial bank lending and the recent acquisition of a minority equity share in the Agro-Invest Bank. The post-harvest credit line for cotton in the restructured Cotton Sector Recovery Project also responds to this need. A trade facilitation program by EBRD and the International Finance Corporation (IFC), and the planned introduction of warehouse receipts by ADB, will further broaden access to rural finance. The mechanisms for trade facilitation and for warehouse receipts are being finalized so implementation may start soon.

Cotton Grading and Regulation

The National Bank of Tajikistan's exports controls have been eliminated, thus removing another layer of government control and intervention. The legislative basis for a modern cotton grading system has also been adopted, but systematic grading has yet to be widely applied in the coming years. It is expected that the ADB-funded Sustainable Cotton Sector Project. Will provide important support for the country-wide implementation of grading.

Non-Cotton Sub-Sector

Non-cotton products produced from household plots, especially staple food commodities such as cereals, meat, milk, vegetables, and potatoes, have recently emerged as a main source of agricultural growth. These commodities are relatively low-cost commodities. They have significant potential to raise the current level of productivity, and can be readily sold in domestic markets. The government recognizes the importance of this non-cotton production and is committed to support it with better irrigation and drainage infrastructure, rural finance services, and better access to inputs.

Water Sector Reforms

The water sector reforms were initiated as part of the “Agriculture Reform Program” for 2012-20. A Presidential Decree of 19 November 2013, #12 “On Improvement of the Management Structure of Executive Authorities of the Republic of Tajikistan” created the legal base for the water sector reforms. According to this decree, the former Ministry of Melioration and Water Resources was abolished and the Ministry of Energy and Water Resources (MEWR) was created. MEWR is charged with water sector policy and regulation, while the responsibility for the operation and maintenance of the irrigation sub-sector was transferred to the newly established Agency for Land Reclamation and Irrigation (ALRI).

The water sector reform aims to lay the foundation for application of Integrated Water Resources Management (IWRM) in Tajikistan based on decentralization and devolution of service delivery activities with responsibilities divided between the ministries, agencies, and (partially) NGO. The proposed reforms are based on common regulatory principles of IWRM and focus on taking into account social, economic, and environmental interests through sustainable and balanced management and development of the water resources.

Implementation of IWRM is expected to facilitate cross-sectoral water transfers in Tajikistan, and to safeguard the interests of vulnerable sectors, such as the use of water for ecological services. As such, the reforms provide an incentive to reduce losses and improve efficiency while also promoting basin water productivity.

Main Stakeholders

MEWR is the central executive authority in the sector of water resources. It carries out functions, in line with Tajikistan legislation, in developing an integrated state policy and implementing normative legal regulations in the areas of management, use, and protection of water resources.

MEWR will fulfill tasks related to development and implementation of national policies, strategies, and programs. It will determine mid-term and long-term goals, will develop, propose, and adopt normative and legislative documents, and will coordinate water-related activities of line ministries and agencies. Furthermore, MEWR will be responsible for planning and implementation of IWRM, regulating relations between different water users, and carrying out other tasks related to management, use, and protection of water resources under its authority.

ALRI is the central executive authority, which carries out land reclamation and irrigation functions, based on Tajikistan legislation in cooperation with other ministries, agencies and local state authorities.

In the water sector, ALRI is charged with land reclamation and irrigation, riverbank protection, and other measures on prevention of mudflows and floods, improvement of ameliorative conditions of irrigated lands, and other tasks within the framework of its assigned responsibilities.

Water User Associations (WUAs) in Tajikistan are the only NGOs specializing in maintenance and operation of irrigation and other water systems at the on-farm level. WUAs are able to join in WUA Federations to bring about more efficient operations. The federations may be created at the level of large canals and other appropriate hydraulic and hydrographic units.

Guiding Principles

<u>Integrated Water Resources Management</u>

The Water Sector Reforms will be implemented on the basis of several guiding principles. A key principle is transitioning to IWRM, which particularly includes improving basin management and separating policy and regulation functions from operational and management tasks, including importantly the operation and maintenance of water services infrastructure. The following principles should be observed in IWRM:

- The environment is recognized as a water user and its needs should not be compromised, because it is difficult to restore deterioration, damage, or even loss of the ecosystem.
- During the definition of priorities for water use, it is necessary to balance requirements of all sub-sectors so that the use of one sub-sector does not jeopardize the use in other sub-sectors.
- In case of emergencies, potable water is the main priority because it is a vital necessity.

Basin Management

Proper planning of water allocation and development of water resources is only possible within the natural flow area of the water resources. Therefore, the river basin is the most appropriate management unit for water resources management. In this regard, the introduction of a basin management approach to water resources management, which is an integral part of IWRM, is considered one of the main principles of water sector reform.

Separation of Policy and Management Functions from Operational Functions

For the purpose of effective implementation of all tasks linked to integrated water resources management, it is necessary to ensure that divisions exist between the constitutional tasks (policy making and legislative), organizational tasks (planning, management, and regulation) and operational tasks (water supply, maintenance service of systems, and rehabilitation).

Current Status of Reforms

Institutional reforms in water sector (with a focus on irrigation) was launched with the issuance of the Presidential Decree of 19 November 2013, #12, according to which political and management functions in the water sector were separated from production and economic functions.

Based on this decree, the Ministry of Energy and Industry was reformed into MEWR, which was assigned policy and regulation functions, while functions of land reclamation and irrigation were assigned to the newly established ALRI.

In accordance with the Resolution of the Government of Tajikistan of 3 March 2014, #149, Open Joint Stock Holding Company Barqi Tojik, the Tajikistan national power company, which had conducted operation and maintenance of hydropower facilities, was detached from the management structure of MEWR.

Thus, MEWR was relieved of the tasks related to production and economy of water resources, including the operation and maintenance of water services facilities, and the ministry is now responsible for policy and management tasks.

Prior to the aforementioned Decree of the President of the Republic of Tajikistan, another critical step was taken on institutional changes. According to the Resolution of the Government of Tajikistan dated 18 May 2012, # 247, the state enterprise "Main Department of Tojikobdehot", which previously was in the management structure of the former Ministry of Land Reclamation and Water Resources, was transferred under the management structure of SUE “Khojagii Manziliu Kommunaly”. Thus, the functions on drinking water supply and sanitation in the country for both urban and rural areas have been brought under the management of a single service organization, which is also in line with the principle of water sector reform.

APPENDIX F. COMPARISON WITH THE UNITED STATES

Water charges are highly variable in successful irrigation schemes. In general, successful schemes invoice farmers depending on the actual expenses for each scheme. In the United States there are some very old irrigation districts with excellent water rights (that is water is “free” at the inlet to the scheme), that do not utilize pumping, and that use earthen canals that charge as low as TJS 17.7 per 1,000 m^3. However, such examples are rare. Typical charges range from 7 to 20 times that amount, with some pumped agricultural water costing as much as TJS 1,060 per 1,000 $m.^3$

For a comparison of budgets, the annual O&M budget for the Imperial Irrigation District (IID) in California is US$143 million. IID has approximately 97 percent gravity flow, all of its irrigated areas are contiguous, and it has approximately 171,000 ha of irrigated land. The quality of water delivery service by IID is very good; IID provides very flexible deliveries to farmers, crop yields are high, and IID employees deliver and measure (within 10 percent accuracy) water to each individual field, for a total of about 4,500 field delivery points. Water deliveries are requested one day in advance of being provided to individual fields; there is no rotation schedule.

ALRI has an annual budget of only 13 percent of the annual budget of IID, but it must manage numerous small schemes with approximately three times the irrigated area. In Tajikistan there are extra high expenses due to pumping. On the other hand, wages in Tajikistan are much lower, and occupational safety rules and standard compliance costs are a fraction of those for IID.

The existence of pumped irrigation schemes is commonplace in some countries. In the United States, examples in California include Banta-Carbona, West Stanislaus, and Patterson Irrigation Districts, plus about 12 large irrigation districts served by the Delta-Mendota Canal and the California Aqueduct. The Columbia Basin Project in the eastern portion of the state of Washington in the United States has 260,000 irrigated ha, with a vertical pump lift of 85 meters (m) to the irrigated area. Many other examples could be provided.

Some differences between Tajikistan schemes and successful schemes in North and South America can be noted. In the Americas:

- Almost all of the collected money stays within the irrigation district, except for water and power purchases.
- The collections do not go first to the province or federal government, with a portion being returned to the individual schemes. Rather, the individual schemes keep all the money that is not paid for power or water.
- The successful schemes charge different rates for water, depending upon the costs within each scheme. Sometimes there are different rates within a single scheme, depending upon the existence of “improvement districts” that farmers in some areas may have voted to fund.
- Delivery of water to the farm, or to no more than 3 or 4 fields, is done by a scheme employee.
- The collection rate is 100 percent in the United States, and close to that in successful South American schemes with strong WUAs.
- The collection of money is a minor part of the activity in strong WUAs. The WUAs are responsible for deciding the budget, the charges for water delivery service, and the improvement schemes that are needed. In other words, they are functioning as local governments that are formed under provincial, state, or national water codes.