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CASE STUDY

AGRICULTURAL/URBAN/ENVIRONMENTAL WATER SHARING IN THE WESTERN UNITED STATES: CAN ENGINEERS ENGAGE SOCIAL SCIENCE FOR SUCCESSFUL SOLUTIONS?†

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ABSTRACT

Throughout the world, demand exceeds supply when it comes to water for agriculture, urban needs and a healthy environment. In the western United States water is being permanently transferred from agriculture, putting food security and the viability of rural communities at risk. The authors of this paper are separately and jointly involved in projects and studies to determine how water might be shared between agricultural, urban, and environmental sectors in ways that effectively stretch supplies, with benefits to all.

Engineering solutions will be necessary. But legal and institutional changes and alternative approaches to achieve economic and other social benefits, must be addressed as well. Stakeholders from all sectors must be fully engaged at all levels.

The authors present a water-sharing model under development in the South Platte River Basin of Colorado in the western United States. They discuss the convening in 2010 of western United States water leaders from agricultural, urban, and environmental sectors to develop recommendations for western governors for overcoming obstacles to multi-sector water sharing. The authors draw from examples provided by international academics and practitioners to show that our greatest challenge in this water balance puzzle is not technological but sociological.

KEY WORDS: Multi-sector water sharing; stakeholder collaboration; social and economic factors in water management

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RÉSUMÉ

Partout dans le monde, la demande est de plus en plus perçue comme supérieure à l'offre quand on examine le besoin d'eau douce pour l'agriculture, pour les besoins urbains et pour maintenir un environnement sain. Cela n'est nulle part plus évident que dans l'ouest des États-Unis, où la tendance est à définitivement réallouer l'eau pour l'agriculture, au risque de mettre en péril la sécurité alimentaire et la viabilité des communautés rurales. Les auteurs de cet article sont séparément ou conjointement impliqués dans des projets et des études visant à déterminer comment l'eau peut être partagée entre l'agriculture, la ville, et l'environnement de manière à étirer efficacement les allocations, au bénéfice de tous.

Des solutions d'ingénierie telles que l'emploi d'outils de mesure de haute technologie, des techniques d'irrigation à haut rendement et l'adoption de régimes de gestion innovants seront nécessaires. Mais les changements juridiques et institutionnels, les approches alternatives pour atteindre des bénéfices économiques et autres avantages sociaux, et la gestion du paradoxe des droits d'eau privés vs eau pour le bien public doivent être considérés pour que ces solutions techniques soient acceptées. Les intervenants de tous les secteurs doivent être pleinement impliqués à tous les niveaux.

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† Agricole / urbain / urbain / environnemental: le partage des eaux dans l'ouest des États-Unis: les ingénieurs peuvent-ils s'engager dans les sciences sociales pour trouver des solutions efficaces.

Les auteurs présentent un modèle de partage de l'eau en cours de développement dans le sud du bassin de la Platte River (Colorado) pour montrer comment les ingénieurs tentent d'intégrer les considérations en sciences sociales dans leur formulation technologique pour atteindre le succès.

Ils discutent de la convocation en 2010 des dirigeants des états de l'ouest des USA des secteurs, rural, urbain et environnemental pour élaborer des recommandations pour les gouverneurs de l'ouest sur la façon dont les obstacles au partage de l'eau multisectorielle pourraient être surmontés. Les agriculteurs, les urbains et les écologistes envisagent-ils de nouvelles façons d'aborder la collaboration de leurs réalités pour répondre aux besoins multiples? Vont-ils risquer une perte afin d'augmenter les chances de gain global?

Les auteurs s'appuient sur des exemples fournis par des universitaires et des praticiens internationaux pour montrer que notre plus grand défi dans le puzzle de l'équilibre de l'eau n'est pas technologique, mais sociologique.

MOTS CLÉS: multiple usages de l'eau; collaboration entre les acteurs; facteurs sociaux et économiques de la gestion de l'eau

INTRODUCTION

The Special Session of the 21st International Congress on Irrigation and Drainage was titled 'Modernization of Agricultural Water Management Schemes.' The organizers asked for papers to address strategies by which irrigation institutions could 'link their central task of providing irrigation services' to the necessity of integrating the demands for water for agricultural production with the demands of other users, including urban and environmental. They sought strategies being used whereby delivery systems and on-farm management systems are being managed in ways that incorporate 'informed decisions on the use and reuse of agricultural water.' In addition to papers considering such technological aspects as modernizing infrastructure and automation of irrigation systems for better operation, the session organizers asked for papers considering such aspects as institutional modalities; financial, legal and policy implications; and environmental issues.

The authors of this paper attempt to combine their engineering and social science experiences and perspectives to address many of these issues in one paper. To accomplish their intent, their paper consists of three distinct sections. First is a review of international perspectives on the need to better incorporate the social sciences with technological sciences and to meaningfully involve diverse stakeholders in order to optimize use of water to meet growing global needs. Second is a description of a water-sharing model under development in the South Platte River Basin of Colorado in the western United States to show how engineers are attempting to incorporate social science considerations into their technological formula to achieve success. Third, they will discuss the 2010 convening of western US water leaders from agricultural, urban, and environmental sectors in an attempt to override polarized interests and remove obstacles to multi-sector water sharing.

INTERNATIONAL PERSPECTIVES

Juan Carlos Alurralde—Bolivia

In 1998, the Bolivian government proposed legislation that allowed for the privatization of water and provided a private, foreign-owned company with a concession to sell water. Social groups mobilized in protest, paralyzing the country, destabilizing the government and causing a political crisis. Bolivia's 'Water War' hit the front pages of newspapers worldwide. The government was forced to break the contract with the private company and set up a special council to draft a water management law based on public input (International Development Research Centre, 2006).

Bolivian water engineer Juan Carlos Alurralde became actively involved in the council. He proposed a research project to use a water simulation model developed by the Danish Hydraulic Institute to build a computerized replica of Bolivian water systems, to simulate how effective various approaches to allocating water rights would be—information critical to developing a new water law. The model would be fed with existing cartographical information and data on water, precipitation, and climate, while GIS and lot-by-lot fieldwork and surveys would be used to map water rights. The International Development Research Centre provided US$270 000 to support the research project, which ran from 2002 to 2005 (International Development Research Centre, 2006).

Alurralde was convinced that dialogue based on solid research could help point to a fair and efficient model for water management that everyone could accept. But if social groups did not trust the research, there was a risk that they would reject the findings. So, the researchers decided to include social groups that had protested against the water law in the research process—by inviting them to participate in the research design, asking them to help gather data, and regularly communicating and explaining their findings. In effect, the researchers would be using both technical and social science in their approach. Members of irrigators' groups and farmers were among those participating in the research. Ultimately it was found that the government's privatization approach would lead to more inefficient use of water and cause larger differences in water availability between communities, actually resulting in water deficits in many cases. Subsequently, the government of Bolivia enacted a water rights law that gained widespread acceptance—a successful example of combining high-tech science with grassroots dialogue.

Dipak Gyawali—Mexico City World Water Forum

Dipak Gyawali, an engineer/political economist from Nepal, spoke at the 2006 World Water Forum in Mexico City about a European Commission study investigating 67 research projects relative to the EU's Integrated Water Resource Management Goals. Gyawali said that all 67 research projects—mostly hard technology research—could be boiled down to three major findings. The first finding was that 'research must constructively engage stakeholders in all phases—from design to interpretation.' (Gyawali, 2006). He said we must constructively engage all stakeholders by incorporating what each brings to the table, not just tolerating them.

The second finding was that 'researchers must find better ways to communicate the results of their research to those who are in positions to make policy.' Gyawali said researchers have to figure out appropriate ways to communicate research, including the need to understand and deal with distinct mindsets stakeholders use to filter data. The third finding was that 'the most critical need for research is not for more technical solutions, but for socio-political solutions to water problems.' Gyawali proposes that we need research integrating water law, economics, human mindsets and behaviour, and that we should conduct such research as confidently as we address hydrology and hydraulics.

In his book *Water, Technology and Society*, Gyawali (2003) argues that we need to move from a technocratic approach to take full account of the social and political context of our water challenges. He shows that both analytical comprehension and effective policy action require a holistic conceptualization of the interface between water, technology, and social context.

Colorado Trout Unlimited—Jeopardized Stream Segments Research

At a meeting of water leaders in Colorado, Melinda Kassen, a water attorney then representing Trout Unlimited, a major US environmental organization, encountered resistance to proposed research. The research would map stream segments in the state in order to identify which were optimal to preserve or restore. Knowing that economic resources prevent restoration or preservation of all the state's jeopardized streams, the organization favoured identifying which should receive prime attention—to gain the most benefit at the least cost. Resistance to the research was not based on scientific concerns, but sociological ones. Water leaders from other sectors pointed out that identifying stream segments in jeopardy would be very sensitive politically because of private property issues.

This interchange brings up important questions of how scientists can move forward with research to determine best use of water resources given a highly politicized and polarized milieu. Should it be up to environmental organizations to conduct such research or should all sectors unite to explore these issues, recognizing that saving some water for the fish is important to all of us, whether it is because we want the fun of catching the fish, we want to keep fishermen coming to the state for the tourism economy, or because we think healthy fish is an indicator of a healthy environment we all require to thrive? In leaving such research to environmental groups to perform and fund, are we setting up an 'us versus them' scenario? How do we move beyond polarized positions to confront uncomfortable water allocation conflicts?

Klamath Basin, Oregon, United States

Stephen Snyder (2003), a New Mexico attorney and mediator, participated in a study conducted by the Natural Resources Law Centre at the University of Colorado in which he investigated what could be learned from those involved in trying to mediate water use conflicts between fishermen, farmers, and loggers in the Klamath Basin of Oregon. Scientific facts have a role in resolving such conflicts, Snyder (2003) concedes, but like Gyawali and Alurralde, he points out that research must involve all the stakeholders if the findings are to be accepted. 'If the negotiations involve contentious technical and scientific issues, a joint fact-finding process should be established for investigating these issues.' In joint fact finding an investigation of an issue is performed by a neutral expert or panel of experts chosen by a group of stakeholders. Snyder (2003) says that joint fact finding can lead to shareholders actually 'participating in an interactive dialogue with the neutral experts so as to enhance their understanding of the complexities involved in addressing problems to which there are no clear answers.' He finds that participants in joint fact finding 'often find themselves revising their original assumptions and preconceived notions about what must be done to resolve the problem. They find they are able to favourably consider negotiating proposals they would never have entertained had there been no joint fact-finding process,' (Snyder, 2003).

Snyder (2003) quotes one of the participants involved in the Klamath Basin mediation: 'Policy differences, not scientific disputes, are what are at stake in a water allocation negotiation, and no scientific panel can make credible judgments about policy issues. In a negotiation, all stakeholders must be involved both in formulating the questions asked and directing the investigation of independent experts.' He says

'Many debates over science are in fact debates over values. Pretending that uncertainty does not exist, or that there are scientific answers to questions that are in reality questions of values does nothing to further resolution of difficult issues.'

Patrick Field, William Ruckelshaus, Peter Senge

Patrick Field from the MIT-Harvard Consensus Building Institute refers to the need for 'process technology' to resolve conflict over natural resources such as water. He suggests that process technology must catch up with hard technology. We know how to engineer technological processes to solve our water problems, he says, but we need to concentrate more on the process for engaging stakeholders if we are going to be successful in solving water conflict (Snyder, 2003).

William Ruckelshaus, the first director of the US Environmental Protection Agency (EPA), says adaptive management is just as applicable to social experiments as biological ones. We don't have to get it right the first time, he says. We can learn from our mistakes and keep on experimenting. He warns that we have to break through the shallow façade of rhetoric and reach to the heart of the issue. 'Only when people are united despite their differences by hard-earned trust, does the astounding political power of collaboration become effective, (Snyder, 2003).

Peter Senge is well known in the United States for his work on a conflict resolution approach known as Appreciative Inquiry. He has lectured extensively throughout the world, translating the abstract ideas of systems theory into tools for better understanding of economic and organizational change. Applying Senge's thinking to the issue of water allocation challenges brings up the question of whether we require a paradigm shift in the way we approach such challenges. Senge says, 'we are stuck in patterns where solutions are arrived at through the process of downloading, or taking an existing framework and applying it to the situation at hand, (Senge, 2005). He talks about a perspective on leadership and social change based on slowing down to ponder a problem so that we can 'illuminate the blind spot.' He suggests we need to create a deep awareness of the problem as a whole, not just its parts. In the arena of water allocation, that could be interpreted as our needing to look not only at the technological fixes, but the economic, legal, sociological, environmental and even spiritual aspects. He challenges us to retreat and reflect, to go to an 'inner place of stillness, then listen and make sense of it, (Senge, 2005).

SOUTH PLATTE RIVER BASIN WATER-SHARING MODEL

Engineers and water scientists are working with economists, water attorneys, and social scientists to develop a model for water sharing in the South Platte River Basin of Colorado in the western United States (Figure 1), with the intent that the model can be used in other places where agriculture is under pressure to give up water for urban and environmental needs.

A Colorado study researching water supply availability and needs for each of Colorado's river basins, projects that water supply in the South Platte Basin will be significantly short of demand by 2030.To meet a forecasted 65% population growth, an additional 500 million m^3 (400 000 acre feet) of water will be needed. The prevalent presumption is that the additional 500 million m^3 will likely come from transfers of water from irrigated agriculture to municipal and industrial uses (Colorado Water Conservation Board, Camp Dresser & McKee, 2004).

This population growth and water demand dynamic is playing out throughout Colorado and elsewhere in the western United States in the form of municipal acquisition of whole farms—along with the water—through outright willing-seller, willing-buyer purchases. The transferable portion of the water right is often 100% removed from the farm and the use of the water is most often changed to municipal use. The farm is dried up into perpetuity. This process of permanent dry up is often referred to as 'buy and dry.'

Concerned about the negative effects of buy and dry on agriculture, rural communities, and even the environment, the state of Colorado has funded research into alternatives to permanent transfer of water from agriculture. These methods allow farmers to share water to which they have rights in ways that prevent permanent sale of the water. Such methods include interruptible water supply agreements, rotational fallowing, water banking and reduced consumptive use through changed irrigation and farming practices.

Given western water law, transferable water from agriculture is typically limited to the portion of the water a

Figure 1. South Platte River Basin, Colorado, Western United States. This figure is available in colour online at wileyonlinelibrary.com/journal/ird

farmer's crop historically consumes via evapotranspiration, not the full amount the farmer has rights to divert. This portion used directly by the crop is referred to as 'consumptive use' (CU) and does not include 'return flows'—water diverted that must return to the system for use by others. For example, after diversion into an earthen canal, the diverted flow immediately begins to diminish because of conveyance losses, the most notable of which is seepage. Seepage can be quite significant especially over the full length of the canal and is likely the single highest source of loss in earthen canals. Most seepage returns to the river as subsurface flows. Farmers desiring to 'conserve' water by reducing such seepage are typically not allowed to do so because that would affect supplies anticipated by downstream users. Most definitely, a farmer is not allowed to conserve that water and put it to additional use, for instance for expanding crop acreage. Farmers are not allowed to transfer such return flow water for use by others such as municipalities.

However, consumptive use water, that portion of the diverted water that is fully consumed by the crop, can theoretically be transferred for other uses, such as municipal or environmental. Once an estimated or a fully decreed consumptive use is known for a given water right, it opens up the potential to consider options for how the CU might be utilized or allocated differently in the future. The consumptive use could be allocated to a new use priority or some balance between old and new priorities. The consumptive use can now be viewed more rationally as an on-farm CU water budget with potential alternative uses. A new use of the CU might be to portion off some of this 'set aside' CU to a municipal or environmental water user for suitable monetary consideration.

The model described here is being developed to assist farmers in evaluating alternative irrigation or cropping practices to determine if they would want to consider changed practices in the future in return for an additional revenue stream to maintain or improve profitability of the overall farm operation. One such changed practice is that of rotational fallowing, a situation whereby a farmer chooses to allow some segment of his or her farm to lay fallow for a period of time so that the consumptive use water formerly used becomes available for temporary transfer for some other use, such as municipal. Lease of the water from the fallowed ground can be thought of as an additional crop-water.

A successful run of the optimization model indicates the projected net return associated with the crops to be grown, along with crop yields, the practices to be adopted, and the anticipated unit prices. This modelled net return can then be contrasted with the historic net return from the farming operation. The model utilizes farmer-user inputs for the simulated farming operation to mathematically optimize future farming operations against a quantified or presumed consumptive use water budget for the farm. The farm simulation input is easy to use by simple point and click entry of boundaries over the top of aerial imagery to outline the farm itself and existing or proposed fields, then inputs such as planned 'willing to grow' crops and practices are added. When finished, the farmer has a precise computer-generated map of the farm that becomes the basis for planning and running scenarios.

A future low-risk revenue stream may be brought into the farm's revenue forecast by virtue of the lease of a proportional amount of water to a municipal, industrial, or environmental user. Optimization algorithms are used to evaluate a farmer-considered package of changed practices which may include deficit irrigation, new crops, dryland crops, permanent or rotational fallowing of fields, and crop rotations. Some farmers will also consider upgraded irrigation systems as an aspect of implementing these practices. The farmer-driven optimization may include any or all of these changed practices as well as continued full irrigation of crops. To evaluate and compare multiple practices as a cohesive package and in the context of the option to lease water is new.

The simulation and optimization model output assists in comparing historic practices and net returns with future practices and net returns which would include a revenue stream associated with a lease or sale of a proportion of the farmer's CU water. The actual comparison between alternatives is accomplished by evaluating the change in net returns between historic practices and modelled future practices. The model utilizes crop water production functions, some of which are very newly researched and reported, to forecast crop yields based on changed irrigation practices.

The model allows a farmer to view his or her CU water differently than in the past. Namely, the CU can be viewed within a farm water budget and evaluated for future uses. Might the farmer wish to part off a portion of the CU, under contract, to a higher economic value driven by non-agricultural interests? The optimization of future net returns, based on adoption of a package of changed farming practices, allows for a comparative analysis. Multiple runs of the model can provide understanding of the potential and, in effect, a useful sensitivity analysis.

The model allows for iteration with new cropping and management regimes, where field-based water and crop data can be fed instantly into computers and stored in databases. Annual water supply forecasts can be coupled with cropping plans, all to help farmers decide how best to use their water and to allow cities and industrial users easy entry to a water market where farmers can sell the use of a cubic metre (acre-foot) of water almost as easily as they can sell a tonne (bushel) of corn.

Farmers operating under a senior surface irrigation right within a ditch system may wish to work together as a new cooperative group, or as a subset of shareholders, wishing to implement this technology. This affords a larger block of CU water, and a larger block will be more attractive to the leasing entity. The ditch company or the cooperative would become the managing entity. The resulting implemented system would include supervisory control and data acquisition (SCADA) hardware, software, and instrumentation suitable for farm management objectives, ditch company management objectives, and state engineer operational reporting requirements.

Some farmers will not consider using this technology because their operations are profitable and sustainable in today's agricultural economy. Others are farming in a marginal financial sense. An operational change using these technologies might help increase profits, allow for, or support irrigation system improvements, and otherwise help those farmers stay in business and continue providing significant regional economic benefits. The fact that new measuring systems—computer-controlled irrigation gates, networks of stream gauges, soil moisture sensors, and remote data-gathering devices—have become affordable enough to allow farmers and irrigation companies to use them, greatly increases feasibility for farmers to utilize this model.

Figure 2 shows the geographic information system (GIS) style field data entry screen. The farmer does not need to know GIS program or input features in order to input field data into the system. Data entry is facilitated by using intuitive point and click tools. Field boundaries can be input, colour coded, named, and resultant acreage returned.

Figure 3 shows the reported results of the optimization run and indicates the projected net return given the farmer inputs.

Technology, however, is not the only issue with reallocating water to protect farms and streams. In Colorado and other western states, water laws make water marketing and leasing, as well as pure conservation, difficult. These laws also sharply limit the ability to move water from one

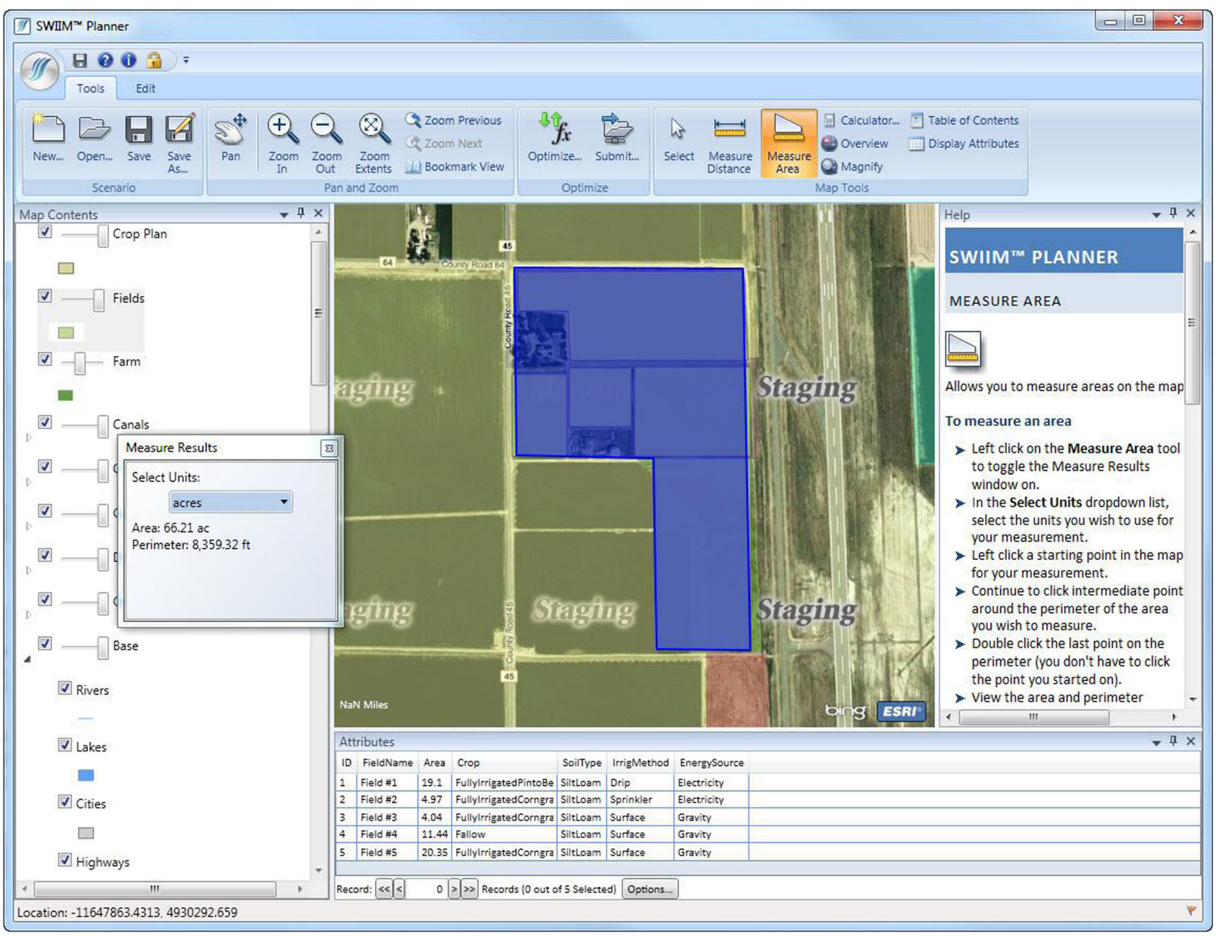

Figure 2. Geographic information system (GIS) style field data entry screen. This figure is available in colour online at wileyonlinelibrary.com/journal/ird

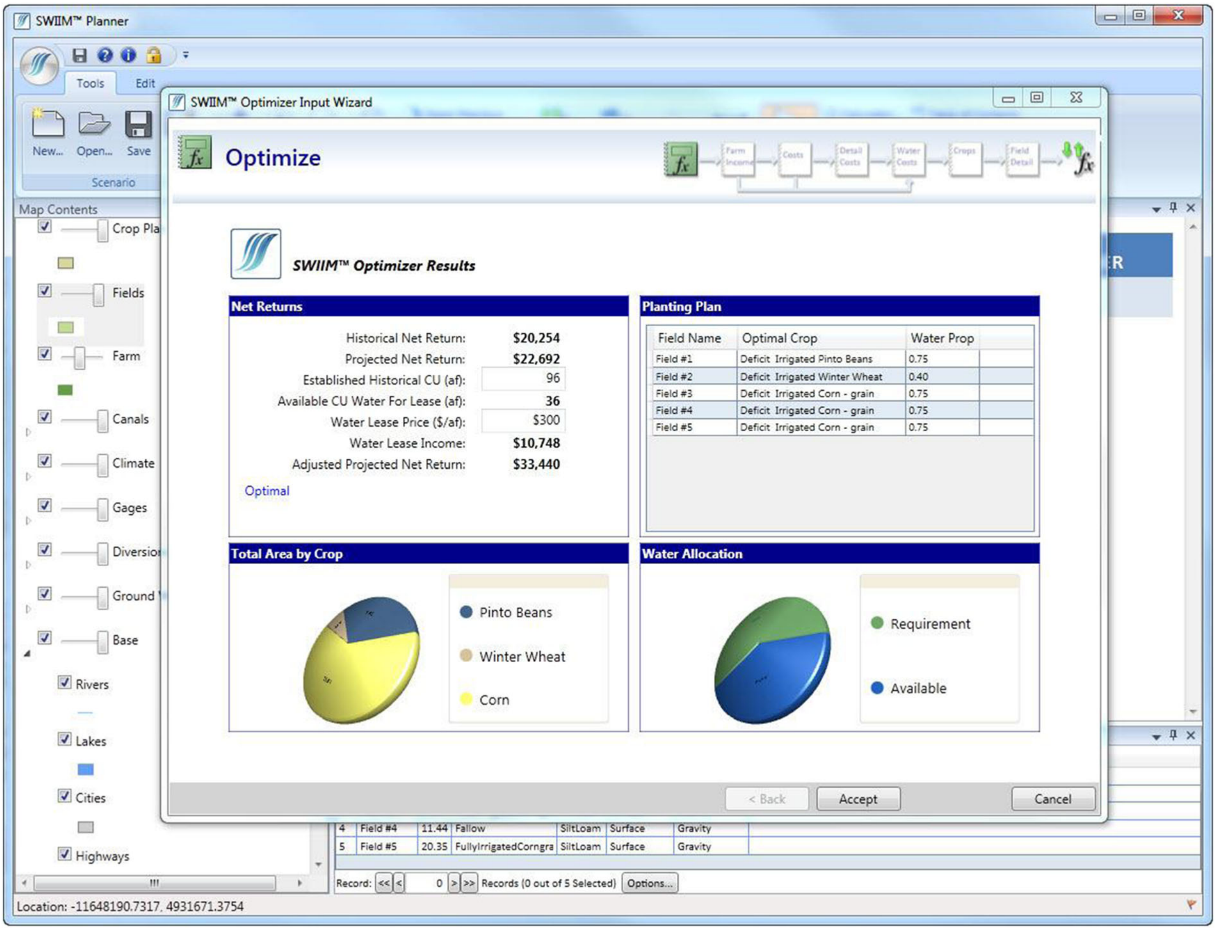

Figure 3. Reported results of the optimization run showing the projected net return given the farmer inputs

use to another quickly. Both usually require expensive engineering studies and years in special water courts, proving that the changes—from farm use to municipal or industrial use—are not harming someone else's water rights.

It is critical, therefore, to combine precise measurement with in-depth, computerized record keeping, powerful databases, and easily accessible water models whose accuracy and data can be verified by regulators and those who want to buy or lease water. The model under development will minimize the amount of time farmers and cities must spend in court to transact sales and leases while creating an efficient system to manage these transactions in the long term. Primary issues and pitfalls to implementing the process and strategies in this model are framed by questions like these:

- can municipal interests view a long-term lease as a viable part of their water portfolio and their projected safe yield at a future date?
- can farmers accept the perceived dramatic changes to their farming operations?
- can the science underpin the strategy sufficiently to satisfy change case objectors and the Colorado Water Court?
- can water be physically transferred based on existing water diversion and delivery infrastructure or is new infrastructure required in some cases?
- do existing state of Colorado statutes support the type of water transfer that is described?

CONVENING OF WESTERN US WATER LEADERS TO CONSIDER OBSTACLES TO MULTI-SECTOR WATER-SHARING STRATEGIES

In 2010, the Colorado Water Institute at Colorado State University convened representatives from the Nature Conservancy, Family Farm Alliance, Western Urban Water Coalition and two dozen other influential groups to determine if long-held adversarial positions could be set aside and new alliances built in order to remove obstacles to creative water-sharing strategies for mutual benefit. Their work resulted in a report, *Agricultural/Urban/Environmental Water Sharing: Innovative Strategies for the Colorado River Basin and the West*, which was recently presented to the Western States Water Council, the water policy arm of the Western Governors' Association.

The report was a response to a 2008 challenge by the western governors: 'States, working with interested stakeholders, should identify innovative ways to allow water transfers from agricultural to urban uses while avoiding or mitigating damages to agricultural economies and environmental values.' (Smith & Pritchett, 2010). Strategies detailed in the report include:

- farmers and cities in Arizona trading use of surface water and groundwater to the advantage of both;
- ranchers in Oregon paid by environmentalists to forego a third cutting of hay to leave water in the stream for late summer fish flows;
- a ditch company in New Mexico willing to sell shares of water to New Mexico Audubon for bird habitat on the same terms offered to a farmer to grow green chiles;
- a California flood control and water supply project creatively managed to meet multiple goals of restoring groundwater, maintaining instream flows for wild salmon and steelhead, and providing water for cities and farms;
- seven ditch companies cooperating in Colorado in a 'Super Ditch' scheme to pool part of their water through rotational fallowing, for lease to cities, while maintaining agricultural ownership of the water rights.

'While these strategies sound like good common sense, they all face sizable obstacles,' said Reagan Waskom, director of the Colorado Water Institute. If we want to share water for the benefit of all, we need a lot more flexibility, all members of the group agreed.

The group's recommendations to the western governors, developed to provide that flexibility, include:

- design robust processes that give environmental, urban, and agricultural stakeholders opportunities to plan together early on, instead of one-sided 'decide, announce, defend' processes that frequently result in opposition and polarization;
- foster a flexible, river basin-based approach that can lead to cross-jurisdictional sharing of infrastructure, cooperatively timed water deliveries, and strategies to facilitate real-time, on-the-ground, state-of-the-art water management for optimal benefit of cities, farms, and the environment; break down legal, institutional, and other obstacles to water-sharing strategies by developing criteria and thresholds that protect agriculture, the environment and any third parties to water-sharing transactions. And experiment with creative approaches such as 'water resource-sharing zones' that could be set up for trading of water, financial resources, and even locally grown food while encouraging interaction between agricultural, environmental, and urban neighbours;
- expedite the permitting process when programs or projects have broad support of agricultural, urban, and environmental sectors. A governor-championed federal/state pilot review process should be established where a state liaison and a federal designate are appointed to co-facilitate concurrent agency review and permitting without repetitive, costly information exchanges. Permitting is important to protect environmental, economic, and social values, the group agreed, but cumbersome permitting processes often lasting years need an overhaul (Smith & Pritchett, 2010).

Members of the group are promoting their recommendations and instigating dialogue throughout their constituencies.

CONCLUSIONS

Whether in the South Platte Basin of Colorado or elsewhere in the western United States, whether in Bolivia, Nepal, or Mexico City, water supply challenges are expected to increase. How scientists and engineers choose to tackle those challenges will determine whether water conflict is resolved or exacerbated. Technology is an important part of the solution, but drawing on the fields of economics, law, sociology, and other social sciences will be critical going forward. Engaging stakeholders in research and giving them a voice in the development of water policy will greatly increase the chances of success at solving very difficult water challenges. Whether humankind has the capacity to understand the necessity of setting aside personal gain for the benefit of all is yet to be seen, but our survival as a species may very well depend on it.

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