A REVIEW OF GENETIC ALGORITHM TECHNOLOGY FOR IRRIGATION WATER ORDERING SYSTEMS

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Institute For Sustainable Irrigated Agriculture, Tatura, Victoria

National Program *for*
Irrigation Research and Development

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EXECUTIVE SUMMARY/FINDINGS

This review was commissioned by the National Program for Irrigation Research and Development, Land and Water Australia. With respect to the terms of reference, the principal findings of the review according are:

1. Detail the current state of research into the use of GA technology

Application of GA technology to irrigation water order scheduling

Current knowledge concerning the potential use of GA technology in optimising irrigation water order scheduling is limited to research findings from Project UAD14. These findings indicated that GA technology is capable of scheduling 350 - 400 irrigation water orders to achieve desired outcomes. The technology is suitable for batch-processing orders to generate initial schedule plans.

Further investigation needs to be carried out before full commercialisation can be considered seriously. This should include evaluation of both the technical and operational aspects of the technology, and an evaluation of its benefits and costs. This research was proposed in the Project UAD16 submission, but a more detailed research plan regarding evaluation of the benefits and costs is necessary, especially in relation to water savings.

Other applications of GA technology to water delivery systems

The University of Adelaide group has been enormously successful in its commercialisation of GA technology for pipeline networks design and pump operation optimisation. Their clients include a number of water authorities in Australia and overseas.

A more recent innovation in the application of GA technology has been in leak detection and the calibration of pipe internal roughness in water distribution systems using data collected from the pipeline systems under transient flow conditions.

2. Analyse the future applicability of GA for commercial scale water ordering systems

Although further evaluation of the GA technology is necessary before commercialisation, research findings from Project UAD14 indicated that the technology is potentially applicable to commercial scale water ordering systems.

Although interest among water authorities in Australia in investing in or adopting GA technology is currently low (see Point 3), this situation may change over the next five to ten years. For example, water authorities who have inefficient or no ordering and scheduling systems will come under increasing pressure to improve their system performance and distribute water resources more efficiently. New property developments will strain the capacity of some systems to meet irrigation demands. Changes in industry types may also increase demand for more reliable water delivery. Water authorities will be under greater pressure to improve their customer service, while maintaining cost effectiveness.

On the other hand, it may be more appropriate for some authorities to make strategic and targeted investment in increasing their system capacity including removing system capacity constraints. Advances in automatic technology of channel water regulation have the potential to make water delivery systems more flexible in meeting customer demands.

3. Quantify the likely demand from industry for such a product

Results from a survey of 16 major water authorities in Australia suggest that the industry demand for GA technology is low at present.

Of the 13 water authorities who responded to the survey, 11 have predominantly gravity driven systems, and two pressurised pipeline systems. Only four water authorities surveyed expressed any interest in the technology. Among these, only Goulburn-Murray Water indicated that they might consider buying a finished product with demonstrated, proven benefits.

Nine water authorities indicated that they had no interest in the technology. A number of these indicated that they had no need for any sophisticated water order scheduling systems because their supply of water to individual irrigators is continuous (not on-and-off) during the irrigation season. The two water authorities with pressurised pipeline systems considered their current water order and scheduling system very effective and the GA technology developed to date better suited to gravity driven systems.

As outlined in Point 2, it is likely that there will be increased pressure for more water authorities to adopt some form of advanced order scheduling system in the next five to ten years. Even so, any significant increase in demand from industry for the GA technology would be dependent on the availability of a proven commercial product offering demonstrable benefits. However, development of such a product is unlikely without water authorities first making significant investment in the technology. Thus, there is the “chicken-and-egg” problem.

4. Provide details on expected industry cash/in-kind contributions to further development

Of all the water authorities surveyed, only Goulburn-Murray Water expressed a willingness to make an in-kind contribution ($20,000 per year for two to three years) to complete the evaluation of GA technology.

None of the water authorities surveyed were interested in participating in commercial development of GA technology. The main reason given is that they did not see such activity as their core business. Water authorities considered it more appropriate for commercial software developers (such as Rubicon Systems) to undertake this development. However, as mentioned earlier, this is unlikely given the current low demand for such a product by water authorities.

5. Recommend an appropriate way forward and the future role (if any) for the NPIRD

The NPIRD Project Brief for this review stated that: *" ... further investment should be contingent upon the private sector (including Rural Water Authorities) demonstrating confidence in the technology by committing resources to on-going development."*

The initial investment made by NPIRD in Project UAD14 was worthwhile. However, the survey results from this review (bearing in mind the NPIRD Project Brief) suggest that further investment in this technology by the NPIRD cannot be justified.

Of the water authorities surveyed, only Goulburn-Murray Water was willing to make a small in-kind contribution to further evaluate the GA technology. However, Goulburn-Murray Water was unwilling to invest in any commercial development activities.

It is suggested that the NPIRD can still play a useful role in communicating the findings of Project UAD14 and this review.

6. Consider the public versus private benefit issue as it relates to any future project

Potential public benefits from this technology would accrue from improved environmental management – including lower diversions and reduced volumes of degraded quality return water. Other potential benefits, such as reducing labour cost and improved customer service, are more a private benefit for the private and semi-private service providers. The potential for such public and private benefits is yet to be demonstrated.

NPIRD's projects need to demonstrate a 'national' benefit, not just benefits for one or two individual water authorities. Because of the limited interests in the technology by water authorities, it would be difficult to justify any further spending on the development of the technology by NPIRD.

Additional objective: Increase awareness throughout Australia of NPIRD investment in GA technologies to date

This review has increased the awareness of NPIRD investment in GA technologies through its survey of 16 major water authorities across Australia. A detailed discussion paper on the development of the technology, along with a survey form, was sent to these water authorities, with a follow-up telephone survey. Awareness was also generated through the inclusion of the senior managers of four large water authorities in the review steering committee. In addition, an ANCID article and an ARRIP form concerning the GA technology were widely distributed.

1. REVIEW BACKGROUND

1.1 The National Program for Irrigation Research and Development (NPIRD)

The National Program for Irrigation Research and Development (NPIRD) is one of 18 programs delivered under the umbrella of the then Land and Water Resources Research and Development Corporation (LWRRDC), now called Land and Water Australia (LWA). The Program has operated since 1993 and was established as a partnership between LWA and the irrigation industry to address issues related to the sustainability of irrigated agriculture.

NPIRD's mission is to provide leadership for national irrigation research and development and facilitate the adoption of technology that improves natural resource sustainability and the economic viability of irrigation regions.

The new Program Plan for Phase 3 of NPIRD provides the framework for research and development investment over the three-year period ending June 2002. Issues, objectives and activities identified in this Plan have been developed following wide consultation with current and potential partners, state-based natural resource management agencies, irrigation industry groups and research institutions. The Plan takes a holistic approach to irrigation research and development, whilst recognising that each irrigation region has its own unique characteristics.

In Phase 3, NPIRD will focus on five key areas:

(a) Water use efficiency;
(b) Environmental impacts of, and effects on, irrigation;
(c) Socio-economic and policy issues;
(d) Irrigation knowledge and its use; and
(e) Benchmarking, monitoring and feedback.

1.2. This review

In Phase 2 of the NPIRD an investment was made into the preliminary testing and incorporation of genetic algorithm technology (GA) for optimisation of advance water ordering in open channel irrigation networks (project reference UAD14).

UAD14 managed to successfully incorporate the technology into ordering systems on a pilot scale. However, the use of GA in full-scale commercial systems is as yet unproven. Also, quantification of the benefits and costs are still somewhat unclear. Notwithstanding these concerns, there appears to be sufficient confidence in the industry to suggest that the technology has almost reached the point of commercialisation.

A subsequent funding application was submitted to NPIRD Phase 3 to continue development of GA technology (Project referenced UAD16). The Committee was in the difficult position of having to decide how much additional public expenditure should go into something for which significant private interests may accrue. Without some additional public support, there is doubt as to whether the technology will be picked up. However, the Committee felt that further investment should be contingent upon the private sector (including Rural Water Authorities) demonstrating confidence in the technology by committing resources to on-going development.

The following recommendations were made for UAD16 in light of the above comments:

(a) That the project be split into two phases.
(b) Phase 1 should include a short review that brings together the current state of the research and scopes future applicability of genetic algorithms for water ordering systems. The Committee allocated $10,000 to Phase 1, which is to be conducted in collaboration with staff from Goulburn-Murray Water. Target audience would be irrigation utilities throughout Australia. The report would also need to identify future research requirements (if any) and preparedness of utilities to contribute to research funding.
(c) Funding of Phase 2 will be subject to outcomes of Phase 1. The NPIRD Management Committee has set aside up to $50,000 for possible future investment subject to these outcomes.

This review will complete Phase 1.

2. REVIEW OBJECTIVES AND APPROACH

2.1 Review objectives

The objectives of this Review (DAV37) were to prepare a scoping report that

(a) details the current state of research into the use of GA technology;
(b) analyses the future applicability of GA for commercial scale water ordering systems;
(c) quantifies the likely demand from industry for such a product;
(d) provides details on expected industry cash / in-kind contributions to further development;
(e) recommends an appropriate way forward and the future role (if any) for the NPIRD;
(f) considers the public versus private benefit issue as it relates to any future project.

A further and important objective is to increase awareness throughout Australia of NPIRD investment in GA technologies to date.

2.2 Review approach

The review was conducted by four consultants:

- Dr Q.J. Wang (Principal Scientist Soil and Water, Agriculture Victoria, DNRE, Tatura),
- Mr Clive Luscombe (Manager System Control Centre, Goulburn-Murray Water),
- Dr Hugh Turral (Senior Research Fellow, University of Melbourne), and
- Mr Daryl McKenzie (Water Systems Planner, Goulburn-Murray Water).

Review findings were presented to the Steering Committee. The final conclusions and recommendations were made collectively by the review consultants and the Steering Committee members.

The Review consultants undertook the following activities according to the project agreement:

(a) Establishing a Steering Committee;
(b) Reviewing UAD14 findings and the UAD16 proposal;
(c) Reviewing other literature on the use of GA technology for delivery systems (not exclusively rural water distribution);
(d) Holding discussions with Goulburn-Murray Water staff on GA technology.;
(e) Holding a workshop in Melbourne with key stakeholder groups, including Goulburn-Murray Water, Rubicon Systems, University of Adelaide and other steering committee members;

(f) Preparing and distributing a discussion paper and survey for water utilities throughout Australia. These were sent to 16 major water authorities throughout Australia;
(g) Conducting a phone survey to follow-up the written survey. Of the 16 water authorities, 13 responded to our survey;
(h) Collating survey results and preparation of a report on findings. A summary of the survey results is given in Tables 1 to 3 (Pages 16 and 17);
(i) Convening a meeting of the steering group to review findings from the desktop review and survey.
(j) Preparing a final report for submission to LWA, including:
   a. desktop review results;
   b. discussion paper;
   c. collated survey results and findings;
   d. steering committee meeting minutes;
   e. consultants' recommendations (response to each objective).

3. TECHNICAL BACKGROUND

3.1 Project UAD14

Project UAD 14 ("An Evaluation of the Applicability of Genetic Algorithm Technology to Flow Management of Open-Channel Gravity Systems") was funded by NPIRD. The project was carried by the Department of Civil and Environmental Engineering, University of Adelaide, with in-kind contribution from the Goulburn-Murray Water and Rubicon Systems Australia. It was a three-year project from 1996 to 1999.

The following is a summary from the UAD14 final project report:

"*The research carried out in Project UAD14 examined the use of genetic algorithm (GA) optimisation to identify water delivery schedules that achieve the best possible outcomes for a set of objectives, while satisfying a set of constraints. Results were obtained initially for an idealised system of five irrigators on a channel spur, in which the GA technique efficiently identified the known optimal schedule for the simple irrigation order optimisation problem.*

Actual ordering regimes corresponding to irrigation season periods operated in the past by an actual water authority were then used to generate results of more general interest. These real-world trials were carried out in the Department of Civil and Environmental Engineering at the University of Adelaide (the University) in conjunction with Goulburn-Murray Water (GMW) and Rubicon Systems Australia Pty Ltd (Rubicon). They used GMW's Tatura, Victoria, area historical field data and Rubicon's Irrigation Planning Module (IPM) ordering and management software. The University's GA software was integrated with Rubicon's IPM software by two groups co-developing an appropriate application programming interface (API) between the two otherwise independently developed software layers.

Results have shown great promise in the ability of GA techniques to determine irrigation order schedules that provide good first approximations suitable for investigation. The intention is that these schedules will be reviewed and finalised by
GMW irrigation planners, and then implemented by Tatura network field operators."

3.2 Proposed Project UAD16

Following the completion of Project UAD14, the University of Adelaide group submitted to NPIRD a new research proposal (UAD16) "Optimising Water Distribution Efficiency using Genetic Algorithms" to further develop the GA technology.

The objectives of the proposed Project UAD16 are:

(a) Demonstrate, through application of GA optimisation to a real system, improvements in channel operation, system planning, and customer service.
(b) Compare, using Goulburn-Murray Water's (GMW) performance measures, irrigation schedules optimised by the GA and those proposed by planners:
   - for extended periods in the past, as documented in GMW records; and
   - for irrigation periods "in real time", in parallel with GMW planners.
(c) Quantify water distribution efficiency gains achieved by applying GA optimisation to scheduling in GMW's open-channel gravity irrigation system.

The proposed project is of two-year duration, funded by NPIRD with an in-kind contribution by Goulburn-Murray Water and Rubicon.

3.3 The GA Technology for Irrigation Order Scheduling – What Is It About?

Optimisation

A typical mathematical optimisation problem involves three elements: a set of decision parameters (variables), an objective function, and a set of constraints. Optimisation employs a procedure to search for an optimum combination of unknown parameters that will give a minimum or maximum value of the objective function value whilst satisfying the set constraints.

The crudest optimisation procedure is to evaluate all possible parameter combinations and pick the optimum one. However, for many optimisation problems, the number of enumerations will be too large to find the optimum solution in a reasonable timeframe. Thus, numerous optimisation techniques have been devised to speed up the search for an optimum solution or its approximation.

There may be multiple objectives/outcomes that need to be considered in an optimisation problem. The most common treatment is to consider all of these outcomes and in some fashion construct a single objective function that represents an overall outcome.

With some optimisation problems and techniques, it is necessary to use a "penalty function" to move the solution away from one that violates constraints, and build it into the objective function.

Genetic Algorithms (GA)

The GA technique can be considered as an optimisation tool that can approximately identify an optimum solution reasonably quickly. The GA technique is one of the more efficient techniques to handle the "harder-to-optimise" problems, especially those involving large numbers of unknowns. Irrigation water order scheduling is one such problem, because of the huge number of possible schedule plans and the complicated way that irrigation systems would respond to different schedule plans. It should be pointed out that, in general, GA optimisation still requires a large number of evaluations of solutions.

Genetic algorithms are one of the more recently developed optimisation techniques. They are based on an analogy of the biological processes of "survival of the fittest" and adaptation. Genetic algorithms search among a population of points (solutions) simultaneously, work with a coding of the variable set and use probabilistic transition rules.

A population of *m* points (solutions) is chosen initially at random in the solution space. The objective function values are calculated at all points and compared. From these *m* points, two points are selected randomly, giving better points higher chances of success. The two selected points are subsequently used to generate a new point in a certain random manner with occasionally added random disturbance. This is repeated until *m* new points are generated. The generated population of points are expected to be more concentrated in the vicinity of optima than the original points. The new population of points can be used again to generate another one and so on, yielding points more and more concentrated in the vicinity of the optima.

A GA optimisation run can be terminated when it has reached a specified number of evaluations of solutions or satisfied some kind of convergence criterion. The best solution found in any GA run cannot be guaranteed to be the absolute optimum solution, but when tested properly for a particular optimisation problem, may be considered to be a good approximation to the optimum solution.

Irrigation Order Scheduling

Irrigation order scheduling is carried out in arranged demand systems where customers place irrigation orders. Water authority staff then release water to ensure it is efficiently distributed to customers. A wide variety of scheduling methods are used throughout Australia.

The Project UAD14 investigation on the use of GA for irrigation order scheduling has been based on the Goulburn-Murray Water system. The following is a brief description of the irrigation scheduling and operation procedure currently employed by Goulburn-Murray Water:

(a) Irrigators lodge orders. Four days' notice is officially required;
(b) A planner produces a schedule. The schedule is for the planning period, i.e., the next four days. The schedule links finishing orders to the next starting orders, thus determining flow requirements within the channel network at given times;
(c) Only the schedule for the next day is made available to irrigators for confirmation of their orders;
(d) A running sheet for the next day is produced for field operators to regulate control structures.

(e) During the implementation of the plan the next day, the planner makes real-time adjustments to take into account of any notified operational changes (deviation from the plan) by irrigators.
(f) The planning process is carried out each day for the planning period (four days ahead) with the main focus being on "Plan day" (being tomorrow in all cases).

Goulburn-Murray Water currently use Irrigation Planning Module (IPM) computer software, developed in conjunction with Rubicon, to assist the planner in scheduling and real-time adjustment.

Using GA for Irrigation Order Scheduling

GA technology can be used for irrigation order scheduling and delivery in the following steps:

(a) Irrigators lodge in orders;
(b) The lodged orders are batch-processed using GA technology to generate an initial schedule plan;
(c) An irrigation planner familarises with the GA plan, fine-tunes and finalises the plan (finalisation is a process which allows customers to confirm start times);
(d) Customers confirm start times.
(e) During the implementation of the plan, the planner makes real-time adjustments to take into account of any operational changes by irrigators. These changes are also updated in the following days GA calculations.
(f) Field operators regulate control structures accordingly using daily running (field) sheets.

4. REVIEW FINDINGS

4.1 Detail the current state of research into the use of GA technology

Application of GA technology to irrigation water order scheduling

Optimisation Objectives and Constraints

Project UAD14 was able to identify a set of significant objectives and important constraints in optimising irrigation order schedules. The objectives that have already been incorporated into the GA optimisation framework are:

(a) Minimise request variations;
(b) Discourage late notice orders;
(c) Disallow channel capacity exceedance;
(d) Minimise channel flow variations;
(e) Minimise control structure regulations;
(f) Satisfy customer service agreements.

A fitness function was constructed for each of the objectives above. The overall fitness of a scheduled plan was a weighted sum of the fitnesses of all the objectives. Note that “fitness function” is GA optimisation terminology equivalent to the use of “objective function” in the general optimisation literature. Planners may change the weightings for different objectives in accordance with any changes in service priorities that may arise.

Other objectives will need to be considered in the future. One that has been identified is the need to ensure customer equity based on inspection of historical data on service delivery to individual customers.

Optimisation Problem Setting

At Goulburn-Murray Water, scheduling is carried out each day for the next four days (planning period). The scheduling on the following day is for the next plan period, and the outcomes from the previous day’s plan become part of this plan, with yesterday’s plan becoming obsolete. It is important to ensure the optimisation strategy really optimises what is intended. This needs to be considered in any future work.

Optimisation Feasibility

The UAD14 optimisation results from an exercise based on data of one historical plan day of the Tatura Network Area indicated that the GA technology was able to arrive at solutions that produce desirable outcomes in terms of constructed objective function values.

The robustness of the results need to be demonstrated by:

(a) having further GA optimisation runs with different random seeds for the exercise above, and
(b) having GA optimisation runs for an extended period of time, not just one day.

Computational Restriction

In the current optimisation setup (order shift at hourly interval, interfaced with Rubicon's irrigation planning module or IPM), batch-processing of 300-400 orders is expected to be the upper limit. The computation time requirement will be prohibitive to process a greater number of orders. There may be room to reduce computation within the IPM, but using a shift interval of greater than one hour will increase the number of orders that can be batch-optimised. However, there may be operational difficulties with this approach. A hierarchical optimisation approach may be considered to combine and optimise area plans at the system level. However, this will be a major research exercise and will require considerable resources.

Operational Issues

There are a number of operational issues, some of which arise from the specific nature of the collaboration between Goulburn-Murray Water and Rubicon.

The application of GA technology to water order scheduling is restricted to batch-processing. Not all water authorities currently use batch-processing.

The computer software developed so far interfaces with the IPM system. Only a limited number of water authorities currently use the IPM system. For other systems, it is necessary to develop new software.

Currently the software does not allow a GA optimised plan to be put back to the IPM for visualisation and further analyses.

The software needs to produce sufficient support information to assist planners to easily make real-time adjustments. For example, Goulburn-Murray Water currently uses a system called "order linking" to link up a finishing order with a starting order. An automated system of this kind needs to be built into the software.

Issues Involved in Commercialisation

Costs and benefits are likely to be the main factors for water authorities. There is a need to quantify the likely costs and benefits in any future study. The premise that the use of the GA technology will result in significant water savings, as outlined in the UAD16, needs to be substantiated through well planned data collection, collation, and analysis. The Review consultants believe that the technology will result in some savings in labour for irrigation planning and field operation. The technology has the potential to provide a more equitable service to customers, make irrigation planning more consistent with expected outcomes.

The GA technique needs to be further tested to ascertain its technical robustness when applied to water order scheduling. Applicability of the GA technology to the businesses of individual water authorities and its technical merits compared with systems already in use or other systems potentially available will influence decisions on the adoption of the technology.

For the technology to become operational, investment in the development and testing of operational software and associated procedures is essential. Market size will be important to cost sharing among interested water authorities and whether private companies, such as Rubicon, are willing to make an initial investment.

Any further investment by NPIRD will be contingent upon the private sector (including Rural Water Authorities) demonstrating confidence in the technology by committing resources to on-going development.

Conclusion

Current knowledge of using GA technology to optimise irrigation water order scheduling is limited to research findings from Project UAD14 only. These findings indicate that the GA technology is capable of scheduling a reasonably large number of irrigation water orders to achieve desirable outcomes. The technology is suitable for batch-processing orders to generate initial schedule plans.

Further investigation needs to be carried out before full commercialisation is considered seriously. This should include evaluation of both technical and operational aspects of the technology and evaluation of benefits and costs of the technology. This research has been proposed in Project UAD16 submission, but a more detailed research plan is necessary on how to evaluate benefits and costs, especially those benefits related to water savings.

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Other applications of GA technology to water delivery systems

The University of Adelaide group has been enormously successful in commercialisation of GA technology for pipeline networks design and pump operation optimisation. Their clients include a number of water authorities in Australia and water utilities overseas.

A more recent innovative application of the GA technology is on leak detection and calibration of pipe interval roughness in water distribution systems using data collected from the pipeline systems under transient flow conditions.

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4.2 Analyse the future applicability of GA for commercial scale water ordering systems

Although further evaluation of the GA technology is necessary before any commercialisation, research findings from Project UAD14 indicated that the technology has a potential application to commercial scale water ordering systems.

Although interest among water authorities in Australia in investing in or adopting the GA technology is currently low (see Point 5.3), this situation may change in five to ten year time for the following reasons.

Water authorities who have inefficient or no ordering and scheduling systems will be under great pressure to improve their system performance to distribute water resources more efficiently. New development in some areas mean that the capacity of some systems will be under greater strain to meet irrigation demand. The types of industry are likely to change in some areas, and this may lead to increased demand for highly reliable water delivery. In addition, water authorities will be under greater pressure to improve their customer service, while maintaining cost effectiveness.

On the other hand, it may be more appropriate for some authorities to make strategic and targeted investment in increasing their system capacity including removing system bottlenecks. In addition, advances in automatic technology of channel water regulation have the potential to make the water delivery systems more flexible in meeting water demands.

4.3 Quantify the likely demand from industry for such a product

Results from a survey of 16 major water authorities in Australia suggest that the industry demand for GA technology is low at present.

Of the 13 water authorities who responded to the survey, 11 have predominantly gravity driven systems, and two pressurised pipeline systems. Only four water authorities surveyed expressed any interest in the technology. Among these, only Goulburn-Murray Water indicated that they might consider buying a finished product with demonstrated, proven benefits.

Nine water authorities indicated that they had no interest in the technology. A number of these indicated that they had no need for any sophisticated water order scheduling systems because their supply of water to individual irrigators is continuous (not on-and-off) during the irrigation season. The two water authorities with pressurised pipeline systems considered their current water order and scheduling system very effective and the GA technology developed to date better suited to gravity driven systems.

As outlined in Point 2, it is likely that there will be increased pressure for more water authorities to adopt some form of sophisticated or advanced order scheduling system in the next five to ten years. Even so, any significant increase in demand from industry for GA technology would be dependent on the availability of a proven commercial product offering demonstrable benefits. However, development of such a product is unlikely without water authorities first making significant investment in the technology. Thus, there is the "chicken-and-egg" problem.

Note: with regards to survey results, a small number of "Yes" and "No" responses were re-interpreted in light of the explanatory information provided by respondents. This was done with the approval of the Steering Committee.

Table 1. System Operators by category

System Type	Number Of Responses	Authority
Gravity Driven System	11	Coleambally Irrigation Authority (NSW) First Mildura Irrigation Trust (Vic) Goulburn-Murray Water (Vic) Ord Irrigation (WA) South West Irrigation (WA) Sunraysia RWA (Vic) SunWater Ayr (Qld) SunWater Biloela (Qld) Sunwater Bundaberg (Qld) SunWater Mareeba (Qld) Wimmera Mallee Water (Vic)
Other	2	Central Irrigation Trust (SA) Renmark Irrigation Trust (SA)
No Response	3	Murray Irrigation (NSW) Murrumbidgee Irrigation (NSW) SunWater Mackay (Qld)

Table 2. System Operators interested in GA Technology for Order Scheduling

Authority Name	Do Customers Lodge Orders?	Interest in Technology – Reason	Interested in Investment – Level	Not Interested in Investment – Reason
First Mildura Irrigation Trust (Vic)	Yes	Interested if GA proven and not too expensive.	No response.	No response.
Goulburn-Murray Water (Vic)	Yes	An improvement in planning and scheduling process can provide improved customer service and potential labour and water savings.	$20,000 per year in kind to assist with the completion of the R&D project objectives. Would consider purchase of a commercially developed product with proven benefits.	
Ord Irrigation (WA)	Yes	Future vision is to schedule orders in an attempt to gain greater efficiencies within the delivery system.	No.	Does not know enough about the GA technology to comment. Small irrigation system that is restricted with Government funding.
South-West Irrigation (WA)	Yes	Believe may assist in further developing their batch control system.	No.	No funds available at present. Happy with current system in use.

Table 3. System Operators not interested in GA Technology for Order Scheduling

Authority	Do Customers Lodge Orders?	Not Interested in Technology - Reason
Central Irrigation Trust (SA)	Yes	Current system is simple to use and extremely effective.
Colleambally Irrigation Authority (NSW)	Yes	Believe that GA does not apply to their system and there will be better returns by investing in other areas.
Renmark Irrigation Trust (SA)	Yes	Use same system as CIT. Interest in GA for other purposes.
Sunraysia RWA (Vic)	Yes	GA technology not required for system operations.
SunWater Ayr (Qld)	Yes	Difficult to justify when water is supplied on demand and the distance between control/regulating structures is short. An organisational decision.
SunWater Biloela (Qld)	Yes	Believe does not meet the requirements of a demand-driven system.
SunWater Bundaberg (Qld)	No	Water ordering not required at this time. May be in future.
SunWater Mareeba (Qld)	Yes	Believe not required as order scheduling not used at this time. Demand driven system.
Wimmera Mallee Water (Vic)	Yes	Small enterprise – not cost effective.

4.4 Provide details on expected industry cash / in-kind contributions to further development

Of all the water authorities surveyed, only the Goulburn-Murray Water expressed willingness to make an in-kind contribution of $20,000 per year for two to three years to finish off the evaluation of the GA technology (Table 2, Page 17).

None of the water authorities surveyed were interested in participating in commercial development, as they did not see this as their core business. It is considered more appropriate for commercial software developers, such as Rubicon, to undertake such development. However, this is unlikely to happen given the current low demand for such a product by water authorities (Tables 2 and 3, Page 17).

Nonetheless, the availability of a finished commercial product will likely attract more water authorities to be interested in the technology.

4.5 Recommend an appropriate way forward and the future role (if any) for the NPIRD

The NPIRD Project Brief for this review stated that

" ... further investment should be contingent upon the private sector (including Rural Water Authorities) demonstrating confidence in the technology by committing resources to on-going development."

The investment made by NPIRD in Project UAD14 was worthwhile for exploring the potential of the GA technology for irrigation water order scheduling. However, following the NPIRD Project Brief for this review, the survey results suggest that any further investment by the NPIRD in this technology cannot be justified either now or in the near future (that is, the next 5 years).

Among all the water authorities surveyed, only Goulburn-Murray Water is willing to make a small in-kind contribution to further evaluate the technology, but is unwilling to invest in any commercial development.

It is suggested that the NPIRD can still play a useful role in communicating the findings of Project UAD14 and this review.

4.6 Consider the public versus private benefit issue as it relates to any future project

The technology may potentially result in savings from an overall reduction in the number of person hours required for scheduling, through a reduced level of manipulation and travel by field operators. Water savings may result that can be directed towards other production or environmental uses. There may also be an opportunity to use the technology to improve customer service.

The following is a qualitative appraisal of potential benefits of adopting the technology based on the information available, interviews of Goulburn-Murray Water staff, and discussions with Steering Committee, University of Adelaide and Rubicon.

Making planning easier

A GA-generated initial plan will save planners' time. However, planners will need to take time to familiarise themselves with the generated plans.

Planners using the GA technology may not be sufficiently familiar with details of the generated plan to allow effective real-time adjustments and interface with customers. This is a major concern expressed by planners. The software needs to be able to provide support information and tools to minimise this problem. This research was planned in the UAD16 proposal.

The GA optimisation can not be used to come up with a solution "instantaneously". Its large computational requirement means that it can only be used to generate initial plans.

The GA technology would assist new planners to become effective quickly, gaining the required level of expertise in a more timely manner. However, planners also expressed fears about the technology's potential to de-skill their work.

Making field operation easier

The use of GA optimisation has potential to reduce the number of channel regulations required. However, operator's travel routes will need to be considered in the optimisation.

Reducing water wastage

It is unclear how a GA generated plan may help in reducing outfalls, as the plan will not be addressing the main cause - deviations by irrigators from their schedule. There appears to be some evidence that channels with less fluctuation are more easily managed and generate fewer outfalls.

There appears to be some opportunity to minimise exceedance of channel design flows, which reduces water wastage (less leakage and spillage), and may prolong infrastructure life.

Better service to customers

A computer optimised plan may be seen as less “emotive” because less input is made by planners directly, with less possibility of favouring certain individuals.

The GA technology will not necessarily deliver a completely equitable service to all customers, as there may be some harder-to-service locations and irrigation regimes. However, it may be possible to build customer service delivery history into GA optimisation to force a more “equitable” outcome.

Conclusion

Potential public benefits from this technology would accrue from improved environmental management – lower diversions, and possibly reduced volumes of degraded quality return water. Other potential benefits such as reducing labour cost and improved customer service are more a private benefit for the private and semi-private service providers. The true potential for such public and private benefits is yet to be demonstrated.

Because of the limited interests in the technology by water authorities, it would be difficult to justify any further spending on the development of the technology by an agency such as the NPIRD, which has a focus on projects that would be of benefit nationwide, not just to one or two water authorities.

4.7 Additional objective: Increase awareness throughout Australia of NPIRD investment in GA technologies to date

This review has increased the awareness of NPIRD investment in GA technologies through the survey of 16 major water authorities throughout Australia. A detailed discussion paper on the development of the technology, along with a survey form, was sent to these water authorities (Appendices 6.5 and 6.6). Awareness was also generated through Review Steering Committee members who are senior managers of four large water authorities. In addition, an ANCID article and an ARRIP form were submitted (Appendices 6.8 and 6.9).

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