COMPARISON OF PIPED AND OPEN CHANNEL DISTRIBUTION OF IRRIGATION WATER SUPPLIES

Contents

Annex 1: Generic Information Derived from the Case Studies

Appendices:

COMPARISON OF PIPED AND OPEN CHANNEL DISTRIBUTION OF IRRIGATION WATER SUPPLIES.

SUSTAINABLE FARMING FUND and THE RITSO SOCIETY

Extension to Project SFF 05-117: Irrigation Scheme Sustainability Code

SUMMARY REPORT

1.0 Background

In many of the large water enhancement schemes under investigation in New Zealand, it is possible to distribute water from the source of supply to user points by utilizing gravity head. The options for gravity distribution are open channel or large diameter pipes. In some existing schemes built some 50 years ago, options for replacing existing open channels with pipes are being investigated.

The reasons for contemplating piping rather than open channels are many and complex, and site specific. Communities faced with an assessment of the merits/demerits of the choice have identified the need for a systematic methodology that would allow informed choices to be made

This development of a methodology to address this situation was incorporated in the Sustainable Farming Fund supported project (SFF 05-117) whose main objective was the development of an Irrigation Code of Practice. It became clear that the work needed to develop a robust methodology for pipes and open channel comparison was in excess of the resources of SFF 05-117, and an application to extend the scope of the original project was developed and subsequently approved.

The agreed extension of project SFF 05-177 deals with the development of a generic methodology to allow a robust comparison of open channel and piped distribution systems for large scale irrigation schemes, in the NZ context, hereafter called the Project.

Milestone 1a of the Project was a report of an international literature search for investigations of the pros and cons of open channel and piped systems for large scale irrigation flows. The report on the literature search is included as Appendix 1.

Milestone 2a relates to a detailed case study of options in the context of the proposed Central Plains Water Scheme (CPW), and Milestone 2b was to investigate the conversion of three existing distribution channels in the Ashburton Lyndhurst Irrigation Scheme (ALIS) to a piped system. The detailed technical analyses of these two case studies are included as Appendixes 2, 3 and 4.

The general issues and suggestions regarding estimation of capital costs are dealt with in Appendix 5, which also applies these suggestions to the capital cost estimates for each of the open channel and piped options in the case studies.

The rationale behind the case study investigations was that the conduct of the work would surface important generic issues applicable to other circumstances where the options are an issue, and inform the development of the generic methodology, which is the main objective of the project. The generic technical aspects of the Project are included as Appendix 7 – Technical Issues Related Piped and Open Channel Systems. The suggested approach to economic cost comparisons and the Case Study economic results are contained in Appendix 6. These appendixes will be useful for others investigating the piped/open channel options in different circumstances, as will the detailed case studies where the use of the general approaches are illustrated by way of examples.

An important part of the project was to investigate the position of the rural communities involved in the case studies to the social, environmental and cultural issues involved – Milestone 4a. This investigation is detailed in Appendix 8.

An unedited version of the draft final report was reviewed at a meeting held at MAF Policy offices in Christchurch on 13 June 2007. The report of this meeting is included as Appendix 9, and the main suggestions have been included in this final report.

This Summary Report includes the major findings of all the detailed work reported in the appendixes. Annex 1 to the Summary Report draws some general conclusions from the work. It is intended for the general reader, and where findings are presented, they are referenced to the relevant sections of the detailed appendixes.

2.0 The Case Studies – General Features

2.1 Objectives of Case Studies

The objectives of CPW investigation of the piped/open channel distribution options were to allow a robust comparison of capital costs, annual costs for operation and maintenance, costs of energy for on farm pumping, estimates of the value of water savings and different easement and land footprint needs, and to identify any non-quantifiable attributes of each option that should be considered in the assessment of the worth of both options. An associated objective was to identify key issues that needed to be incorporated in a generic methodology. The ALIS case study objectives were to assess the merits/demerits of changing an existing open channel supply race system to a piped supply.

2.2 Design Criteria

It was decided at the start that the comparison of options should be based on designs that delivered, as far as possible, the same level of service delivery for each option. As a consequence, the main design criteria used for the CPW case study included:

- On-demand availability for all water users
- The same number of delivery point nodes (305)
- Peak Rate of supply at farm delivery point equivalent to 0.6 l/s/ha
- Annual water use 625 mm
- Minimum supply pressure at full demand 5 m

For the ALIS case study, the design criteria for the piped supply were:

- On-demand availability for all water users
- The same number of farms serviced (27)
- Peak Rate of supply at farm delivery point equivalent to 0.49 l/s/ha
- Annual water use 625 mm
- Minimum supply pressure 42 m at all times

2.3 Distribution Layouts

Central Plains. The CPW study area of 36,000 ha is 56% of the total scheme area of 64,000 ha. This relatively large sample size was selected to capture the range of topographic variability that exists across the full area, and to ensure that the findings could be reasonably applicable for the full area. The layout of the proposed CPW open channel distribution system is shown on Figure 1

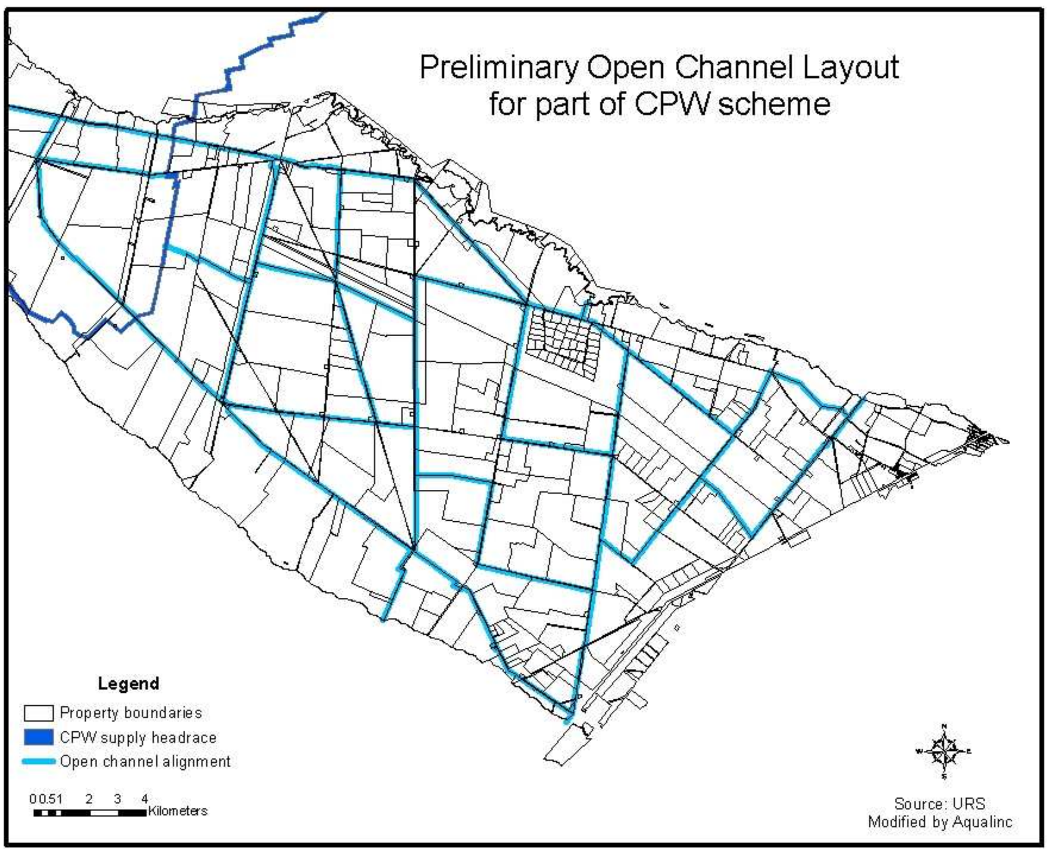

Figure 1: Preliminary open channel layout for part of CPW scheme

This layout is that adopted by the CPW consultants for the purpose of land designation and has been negotiated with the landholders to minimize disruption to farm operations. The discharges in each section of the channel system are shown, as provided by the CPW consultants. It will be noted that additional short pipe extensions had to be provided to supply each farm outlet and make the system comparable to the piped delivery system. In general terms, main supply channels follow roads, with the channel formation located within the property boundary of adjacent farmland.

The layout adopted for the proposed CPW piped distribution system is shown on Figure 2. This layout was chosen as optimum from a range of layouts investigated. It will be noted that the layout does not necessarily follow roads and delivery points are comparable to the open channel layout.

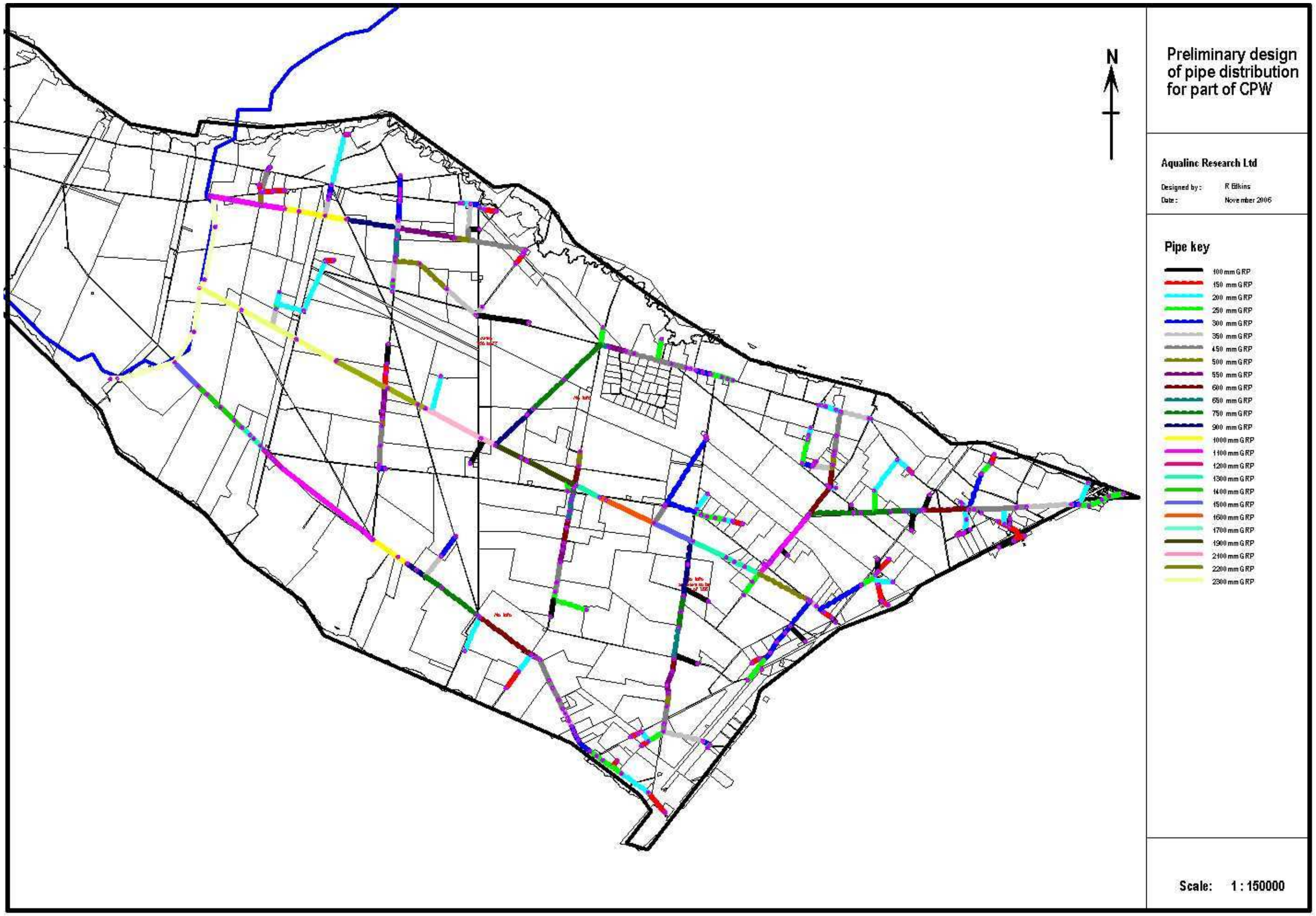

Figure 2: CPW - proposed pipe layout

ALIS. The area covered by the ALIS case study (4,084 ha) is shown on Figure 3. The existing lateral races – Laterals 1, 2 and 3 are shown as well as the chosen alternative piped system.

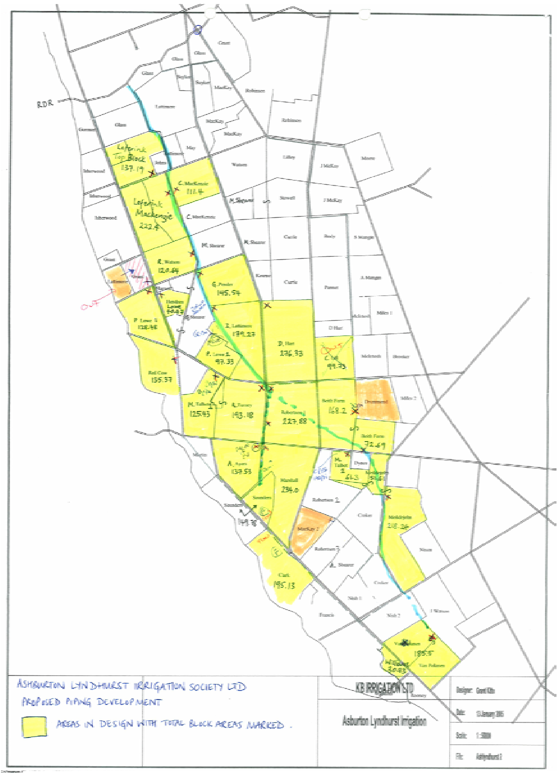

Figure 3: Part of ALIS Scheme

2.4 Capital Costs

Capital costs are based on estimation of physical quantities, material costs and unit rates. Unit rates and material costs for items shown on the costing tables in Appendixes 2, 3 and 4. These are based on recent tenders and as-built costs for completed projects with similar items. The hydraulic design and estimates of work quantities and associated capital costs have been subjected to independent peer review by Beca Engineering Consultants, which generally confirmed the reasonableness of the rates used.

2.5 Operations and Maintenance Costs

The estimation of operational costs includes the fixed and variable costs of the establishment needed to operate each scheme, based on experience with established open channel and piped schemes in NZ. Maintenance costs for each option are based on costs collated for similar open channel schemes and assumptions about the maintenance needs of the CPW scheme, benchmarked to other piped schemes.

2.6 Energy Costs

Central Plains The design of both options assumes that on-farm pumping will be needed using variable speed pumping installations for the piped option and fixed duty pumps for the open channel option. The pipe scheme design has considered the trade off between the incremental capital costs of providing higher pressures at farm boundaries by reducing friction losses versus on-farm energy costs. Figure 2 shows a design based on delivering a minimum pressure of 5 m at farm turnouts under the piped system – in the CPW scheme assumptions, this is the most cost effective solution. Energy costs with the piped system will vary depending on farm location. Figure 4 shows the variation in supply pressures across the study area that indicates that the design minimum of 5 m is exceeded for a large number of turnouts for a good deal of the time in an average season. Energy costs for the open channel option assumes pumping from ground level. Estimates of average annual energy costs for each option are based on the average water requirements derived from a 30 year climatic sequence. Details are given in Appendix 2.

ALIS. The design of the ALIS piped system results in zero cost for energy, and account has been taken of the energy costs involved in some pumping from the open channel system.

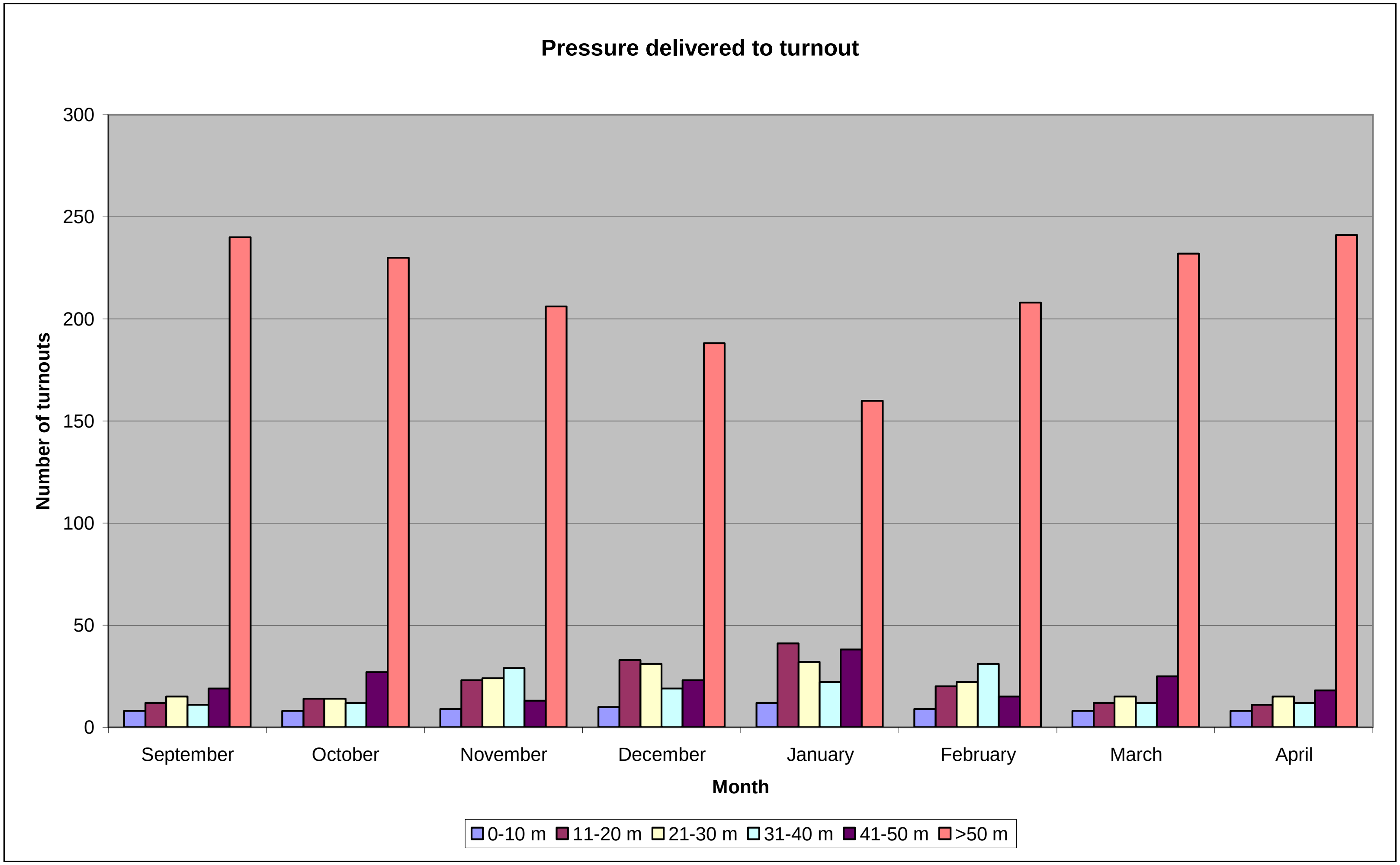

Figure 4: Turnout pressure for different flow demands, for turnouts located lower within the scheme

2.7 Benefits from Distribution Efficiency Differences

CPW and ALIS. Losses from the piped distribution system will be minimal – no seepage or operational losses have been assumed. Based on CPW consultant estimates, the losses from the open channel system from these two causes have been estimated at 20%. Measured losses in Laterals 1, 2 and 3 of ALIS case study area are 20%.

The cost/benefit accommodation of these differences has been assessed by assuming that saved water has a market value and can be sold after scheme commissioning, as explained in more detail in Section 3 this report.

3.0 Economic Cost Comparisons of Pipe and Open Channel in Case Studies

The technical analyses and cost estimates of the detailed case studies are given in Appendixes 2, 3, 4 and 5; and the economic cost comparisons of the case studies are based on the generic methodology in Appendix 6.

The economic cost comparison between pipe and open-channel options follows the generic methodology, with the common assumptions applicable to each case study summarised below:

- All prices are in constant 2006 dollars;
- The analysis period adopted is 30 years;
- Base capital costs are "best estimates" and include commissioning costs but exclude physical contingencies[1];
- The options are compared in discounted cash flow framework over this period with real discount rates of 6, 8 and 10 percent; and
- Real electricity prices are assumed to rise by 1 percent annually over the next 10 years.

This generic framework is then applied to each case study as follows.

3.1 Central Plains Case Study

The sub-area adopted in this case study is described in Section 2c, and covers a gross command area of 36,000 ha. The specific assumptions applicable to the economic analysis of this case study are as follows:

- Implementation extends over 5 years, with the first 2 years devoted to resource consenting and initial preparatory work, and the subsequent 3 years to civil work;
- Commissioning costs add 3 percent to capital costs and are spread over years 5 of the implementation period and into Year 6, the first year of operation;

[1] Physical contingencies would need to be included as part of detailed project costings.

- Resource consenting expenditure for the open channel option occurs over years 1 and 2 of the analysis period, and involves an investment of 5 percent of base capital costs spread equally over the 2 years– the piped option involves an expenditure of 85 percent of this amount;
- Legal costs for the open channel network are assumed at 4 percent of base capital costs, equally spread over Years 1 and 2 – expenditure for the piped system is at 40 percent of this amount;
- There are no additional infrastructure costs (such as upgrades to the electricity network) associated with either option;
- The open-channel system will require the canal footprint to be purchased;
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs.
- The open channel network assumes the purchase of 280 ha of land for the canal footprint, and another 22 ha of land for other minor works, or a total of 302 ha. The pipe scheme assumes 164 ha of land for land easement, with no land purchase;
- The compensation price for land purchase is $15,000/ha.
- Operational costs for both systems are $16/ha;
- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 305 pumps are replaced at year 15. With the pipe system, 57 turnouts do not require pumps. Of the remaining 248 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha.; and
- Water “savings” with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a “value” of $4,600/ha and is “sold” in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 1.

Table 1: Central Plains - Open Channel vs Pipe

	Present Value Cost ($ millions)
Open Channel System	
6% discount rate	162
8% discount rate	132
10% discount rate	110
Piped Distribution System	
6% discount rate	118
8% discount rate	102
10% discount rate	90

This analysis indicates that the piped distribution system holds promise to be a cheaper option than the open-channel system, when evaluated over a 30 year analysis period. Although the piped system is about twice as expensive in terms of base capital costs ($123 million vs. $64 million), the lower operations costs with the piped system because of the pressurised water delivery reducing on-farm pumping costs, together with the value of the water savings generated from the piped system, result in a lower-cost alternative when viewed over the longer term.

In terms of sensitivity analysis, this result is robust across all three discount rates. In addition, sensitivity testing indicates that:

- Should there be no real increase in the price of electricity over the analysis period, there is negligible change to the results because the "value" of these savings do not start to occur until after Year 6 and then only escalate at 1 percent annually for 4 years;
- Should the value of the water "savings" be negligible, then the two options become comparable in present value cost terms at the higher discount rates (8 and 10 percent);
- Should capex costs increase by 20 percent, the piped option still remains the preferred option in terms of the present value of comparative costs; and
- If pump operating costs increase by 20 percent, there is only a small change to the results, and the comparison remains similar.

3.2 ALIS Case Study

The sub-area adopted in this case study is described in Appendix 4, and covers a gross command area of 4,083 ha and supplies water to 3,200 ha. The specific assumptions applicable to the economic analysis of this case study are as follows:

- Implementation extends over 4 years, with the first year devoted to resource consenting and initial preparatory work, the subsequent year to preparatory work followed by two years of civil work (Years 3 and 4);
- Commissioning costs add 3 percent to capital costs and are spread over years 4 of the implementation period and into Year 5, the first year of operation;
- Resource consenting expenditure for the piped system occurs in year 1 of the analysis period, and involves an investment of 2 percent of base capital costs;
- Legal costs for the piped network are assumed at 1 percent of base capital costs, equally spread over Years 1 and 2;
- There are no additional infrastructure costs (such as upgrades to the electricity network);
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs;
- The pipe scheme assumes a network layout involving land easement, with no land purchase;
- The piped system will "release" for sale that area of land which currently forms the footprint of the open-channel network– it is assumed that 30 ha of this land will be sold in Year 5 at $15,000/ha.;
- Operational costs for both systems are $16/ha (in other words, no operational costs savings are assumed);

- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 27 pumps are replaced at year 15. With the pipe system, 8 turnouts do not require pumps. Of the remaining 19 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha (in other words, the pipe system has a maintenance cost saving of $3/ha.); and
- Water "savings" with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a "value" of $4,600/ha and is "sold" in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 2.

Table 2: ALIS - Replacing Open Channel with Pipe Reticulation

	Present Value Cost ($ millions)
Piped Reticulation System	
6% discount rate	4.5
8% discount rate	5.0
10% discount rate	5.3

This analysis indicates that the piped distribution system is likely to be more expensive than the open-channel system it replaces when evaluated over a 30 year analysis period. The capital costs of the piped system are such that they cannot be offset by the savings in operations costs (reduced on-farm pumping costs), together with the value of the water savings generated from the piped system.

In terms of sensitivity analysis, this result is robust across all three discount rates. Using the 8 percent discount rate as a comparative benchmark, the base case PV of cost for retrofitting is $5M. If capex is reduced by 20 percent, this falls to $2.9M and if capex falls by 40 percent, the PV of cost falls to $0.8M, leading to the conclusion that the result is most sensitive to capex. If water sales revenue increase by 20 percent, the PV of cost in the base case falls from $5M to $4.7M. In the case where opex cost savings are increased by 20 percent, the PV of the cost falls to $4.5M.

Assessing the risk appetite that developers of a scheme are willing to accept can significantly affect the price paid for construction; operation and maintenance costs; and the replacement period between parts of the scheme infrastructure as it wears out. Risk is not discussed in detail in this report, but an inherent assumption is made that developers will assess it at all levels and for all components of a scheme whether specifically, or by intuition in the decision making process.

To assess the influence of risk and decision making, the ALIS case study was subject to a second phase of pricing to determine if capital cost could be reduced by altering risk assumptions. The focus was to reduce the costs as originally designed. The following lists altered assumptions for assessing the revised costs.

- There is minimal design and a larger portion of 'contractor' design is utilized.
- A small contractor is utilized
- A simple form of contract is used with risk sharing accepted with owners.

- The project is not tendered
- There is a significant portion of the project management undertaken by the scheme developers and the contractor.
- Cheaper pipe materials are utilized, PE in place of FRP.
- Fencing and infilling of the canal for example are not undertaken.

The construction price calculated was approximately $8,500,000m or $2,656/ha. The price was cross checked and confirmed by a contractor. The revised price is approximately 35% lower than that developed in earlier design, and alters the NPV analysis accordingly. If this capex is transferred across to the economic analysis summarised above, the assessed PV of cost for the retrofitting option decreases from $5M in the base case (at a discount rate of 8 percent), to $1.6 M.

3.3 Comparison of Results

It is informative to list some of the reasons why a piped reticulation system is apparently more cost-effective in the Central Plains scenario, whereas retrofitting a piped system into the ALIS may not be as cost effective. In this regard:

- The piped network for the CP scheme involves a base capital cost of around $3,400/ha compared with that for the ALIS at just under $4,100/ha. This is a result of the different layouts (with ALIS being a longer, narrower layout with only some of the properties supplied) and the ALIS design criteria to supply at a minimum head of 42m. Layout, however, appears to have a comparatively dominant impact on scheme cost.
- The CP scheme has higher on-farm pumping operating cost savings for pipe versus open channel than ALIS because: (a) ALIS has a lower system capacity, with less flow being supplied to each property; (b) ALIS has a lower target pressure to be supplied; and (c) ALIS has lower electricity costs.
- The piped network for the CP generates on-farm pump operating cost savings compared with the open channel option of around $160/ha compared with the ALIS of just under $100/ha. The CP figure results from relatively high energy cost values for both options subtracted, whereas the ALIS figure results from a modest energy cost of the limited pumping from races at present, to the piped option where energy costs are zero, because of the high delivery pressures.

3.4 Additional Considerations

It is emphasised that the economic analysis above is only part of the comparative evaluation – other aspects (both perceived benefits and costs, but parameters which cannot be quantified in monetary terms), need to be included in any comprehensive comparison. The extent to which each of these issues will apply, and the weight given to each, will vary with individual circumstances, but the following table lists some of the factors that should be canvassed in any comprehensive comparative evaluation of the options. Individual circumstances may also generate the need for additional matters to be considered which are not listed below.

Table 3: Additional Considerations

System	Additional Potential Comparative Benefits
Open Channel Reticulation	Allows augmentation of lowland streams (although piped schemes can allow direct augmentation)
	Provides additional groundwater resource for potential abstraction
	Provides additional groundwater for dilution of leachates
	Creates potential wildlife habitats
	Provides more equitable on-farm pumping costs across the command
	Provides opportunity to collect and utilise by-wash
	Easier to expand in the future
	Creates opportunity for amenity and recreation benefits on waterways
	Provides for easier implementation through the improved "bankability" which attaches to lower capex.
Piped Reticulation	Reduces potential for water mixing with cultural and bio security implications
	Reduces need for rostered water delivery systems
	Provides pressurized water for fire-fighting
	Reduces access disruption to farm operations from channel bridges, culverts and fences
	Increases land use flexibility without channels dissecting paddocks
	Provides higher water quality at farm turnout
	Reduces need to discharge excess flows after stoppages
	Easier to measure scheme flows
	Reduces issues in health and safety
	Increases scheme security
	Reduces risk of water contaminants
	Less exposure to real price rises in energy costs
	More socially acceptable to wider community
	Reduces visual impacts
	Provides potential potable water supply
	Is perceived to be a more "sustainable" use of resources

Many of these parameters derive from comparisons of both options from social, cultural and/or environmental perspectives, which were issues canvassed during the study through group workshops. The report of this aspect of the investigation is included in Appendix 8, and summarised below.

4.0 Social, Cultural and Environmental Issues

An objective of the project was to gain a better understanding, from rural community people, farmers and stakeholders, of the social, environmental and cultural issues both for and against piped and open channel distribution systems for large-scale water enhancement projects. The approach used was to run two small group workshops at Hororata, in the heart of the Central Plains Water case study area.

Participants of both workshops readily identified pros and cons of both distribution systems, with consistently the same issues expressed at both workshops. The majority of issues presented were either for pipes or against open channels, and were predominantly the antithesis of each other. The results represent a generic position of the attitudes of the rural communities to the choice of options, and these are summarized in Annex 1. They are likely to apply, in general, in other situations.

Pipes Positives:
The main points in support of piped systems includes aspects of land utilization; energy savings; less disruption to current activities; safety; environmental; aesthetics; flexibility; water quality; and community acceptance, consenting ease.
Pipes Negative:
The negative aspects of the piped alternative included: the high upfront cost; higher earthquake risk and possible disruption to farming operations during installation; and where pipes were replacing open channels was the issue of loss of environmental habitat and biodiversity.
Open Channel Positive:
By contrast, benefits for open channels included: lower capital cost; potential recharge of aquifers[2]; potential to generate electricity (which was also identified as a piping opportunity); warmer water and perceived easier future expansion.
Open Channels Negative:
The perceptions about the negative aspects of open channel distribution include: land loss; poor access; poor safety; community disruption during construction; less harmonious community process especially land purchases from unwilling sellers; high cost of land purchase; water loss through leakage and evaporation; poorer water quality and vulnerability to pollution; contamination and sabotage; higher maintenance; no water in winter for community use; and dry channels in winter.

A significant outcome of the workshops was that the majority of the piped distribution benefits could not be classified as just social, cultural or environmental benefits, but did in fact cross several these classifications and in many cases offered economic benefits as well. The overall conclusion was that piped distribution systems were, in general assessment, more sustainable.

5.0 Summary and Conclusions

This investigation of piped and open channel options for large scale irrigation water has as its objective the development of a generic methodology that can be used to capture the main features of each option for decision making purposes.

The study used two case studies to inform the recommendations of the generic methodology: (i) a “greenfields” proposal for a sub-area of the Central Plains Scheme; and (ii) a retrofitting proposal to convert an existing open channel distribution system in the Ashburton Lyndhurst Irrigation Scheme.

[2] The potential positives of a piped system in regard to beneficial recharge were raised at the review meeting – the point being that seepage losses may not be entirely negative in certain situations.

The results of the CPW investigation show that the capital cost of the piped option is roughly double that for a comparable open channel system. Once all of the associated costs and benefits are included, however, it is clear that the NPV of the piped option is considerably more attractive. The implications for the scheme are that: (i) the benefits that make the piped option a more attractive long term option are largely captured by the water users in terms cost savings; (ii) the social and environmental benefits associated with the piped option are of interest to the general public and the communities affected by the scheme development; and (iii) the scheme developers/financiers will need to devise ways of reflecting the benefits of the piped option in developing a financial structure of the development that may support the more expensive piped option.

The economic comparison results of the ALIS retrofitting proposal indicates less benefits to the piped option[3]. The reasons for this result were assessed to be: (i) the low energy cost savings involved, because of the low level of current energy costs; (ii) the relatively larger ratio of piped cost/area served, a function of the layout; and (iii) assumption of less than 100 percent uptake in the initial stages. The attitude of the retrofitting proponents in supporting the proposals was that the change to a gravity piped system would remove the risk and uncertainty perceived of higher future energy costs and the likelihood of full uptake in the future.

In regard to the non-economic issues – social, environmental and cultural - it is clear that rural communities see many long-term benefits in adopting gravity piped distribution technology. The main problem in acting on this attitude was seen to be the higher first cost of the piped option and the financing difficulties that this presents to a sub-section of the beneficiary community in implementing the piped option. The case was made for involvement and support from the wider community to facilitate the implementation of developments that were clearly seen to have long term benefits to the community at large.

A generic approach to the comparison is supported by the material in Appendix 7, which records the general understandings gained during the course of this investigation and the experience of the study team. The main findings that apply to the generic issues are summarized in Annex 1. In addition, a "how to" approach is illustrated in the detailed reports of the two case studies in Appendixes 2, 3, 4 and 5.

[3] This assessment is not as conclusive if a lower cost and less robust design solution is adopted.

Annex 1: Generic Findings Derived from the Case Studies

Experience gained from the detailed case studies has informed the proposed generic approaches reported in Appendix 7 – on technical aspects, and Appendix 6 – on economic cost comparison methodology. The main findings that have migrated to the generic appendixes from the case studies are summarized below:

1 Technical Pipes

As a general comment, the design criteria for the two options should be specifically identified to ensure that the levels of service are comparable

- Optimization of the piped layout is important as there will be a number of combinations of pipe sizes/delivery pressures feasible, each with unique capital and energy costs. The aim should be to select the option with the lowest NPV at the interest rate selected.
- The detail of turnout plumbing is dependent on turnout function, and this needs to be specifically addressed for each situation.
- The protection of the off-farm piped system and on-farm piped systems is a key requirement. It is better to design the off-farm system to cope with the operating pressures, including transients, without the need for pressure regulation within the system; and to protect the on-farm system with pressure control at the turnouts.
- Pressurized pipeline locations are extremely flexible and cause little longer term disruption, and are more acceptable to the community.
- Pipe material, design life and sensitivity to changing hydraulic properties need to be considered.
- Robust comparisons of energy cost differences should take account of the variable seasonal water requirements over a long period, and not be based on peak demands.
- Contour information used in hydraulic design of piped networks needs to be appropriate to the topography.
- Optimization is best done through use of computerized design software, such as Irricad™ .
- When supply points are subject to varying delivery pressure, variable speed pumping units are needed to ensure high pumping efficiencies.
- Pressurized pipe systems have the potential to provide 365 day firefighting facilities. If this is an important issue, looped or interconnected layouts may provide a higher level of security.
- On larger schemes, peak design demand should be set at between 70 and 80% of the theoretical peak demand[4].
- The case study experiences suggest that designing for higher velocities and hence lower delivery pressures is more than offset by increased pumped capital cost, without having to account for decreased energy use – therefore keeping velocities below 3 m/s is an economic plus and also reduces issues with pressure transients.

[4] The work reported herein was based on meeting 100% of theoretical peak demand.

2 Technical Open Channels

- Canal scheme design is typically unique to the location and flow requirements, and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design.
- In the NZ situation land gradients on irrigated land tend to be steeper than in other places. Open channel distribution systems running downslope will require either (a) provision of head loss structures or (b) protection of the canal prism from high velocities. The choice has important cost and operational implications.
- Modern open channel distribution systems are capable of operating close to on-demand and with low operational losses to bywash spillage, using available downstream control technology. Any valid comparison of piped and open channel systems should require a similar same level of service delivery and performance.
- The criteria adopted for acceptable water losses in open channels are an important consideration for developers and the appropriate Resource Consenting authority. Where seepage targets are set without regard to the available soil types and construction materials canal lining may become prohibitively expensive or possibly unfeasible from a technical viewpoint. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe smaller sub areas of the scheme rather than constructing tertiary canal systems.
- Water management of canal schemes is often more wasteful than pipe schemes. Utilising modern control systems and equipment such as automated gates for a new scheme will provide significantly improved water usages than a manually controlled system.

3 Estimates of Capital Costs

Appendix 5 provides useful guidance for the estimation of capital costs to be used in the economic cost comparison of the pipe and open channel options. Capital cost is a major issue in selecting a preferred option especially for scheme developers and financiers. Some of the major findings from the experience gained in the case studies and other similar projects include:

General

- Suppliers and contractors are often willing to assist with pricing components of projects.
- The accuracy of cost estimation and reliance put on values should be reflective of the level of investigation and design.
- In early stage investigations scheme costs are rarely over-estimated. Often costs are underestimated with hidden costs and requirements only considered at later stages. A number of unexpected costs often become exposed in detailed design.
- Effort to complete several design iterations is recommended to optimise scheme designs as significant savings can be made with clever designs.

Related to Pipes

- Installed costs of large diameter pipes are generally similar. Less expensive pipe types often come with specialized installation systems that increase cost
- Pipe cost may represent up to 60% of total capital cost, so cost estimates are less dependent on specific scheme circumstances.
- Pipe sizes less than 600 mm can often utilize all material types. Above 600 mm the range of materials is more limited including supplier choice.
- For schemes with reasonable topographic variation a significant proportion of total cost will be for bends and anchor blocks.
- The case study spreadsheets were developed for gravity water supply at the intake. Pump schemes may alter pipe designs based on transient effects and the velocity versus friction loss design of the pipe.
- Contractors for pipe scheme construction are limited when compared to canal construction because of the specialist skills required, such as ticketed welding or installation techniques.

Related to Open Channels

- Canal scheme design is typically unique to the location and flow requirements and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design and costs, and hence there is more uncertainty in cost estimates.
- The acceptance criteria for water loss as a risk by developers or set by consents significantly affects canal lining designs and costs if required. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and cost competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe sub areas rather than construct secondary canal networks.

4 Economic Cost Comparison.

The generic approach for economic cost comparisons is provided in Appendix 6, focusing on two situations: (i) a new “greenfields” scheme proposal; and (ii) retrofitting an existing open channel distribution system with pipes. The following items need to be considered in the economic analysis of either situation.

Capital Cost.

Appendix 5 on cost estimation details the itemised capital costs required for estimating open channel and piped reticulation networks. Pre-construction costs will also need to be included, covering such items as feasibility studies through to final design, contract preparation and tendering, liaison with stakeholders, resource consent and building consent costs, legal fees, etc. Aspects of cost often overlooked include costs for:

- easements – different for pipes and open channels
- private disruption to access– may require compensation in open channel situations regardless of culverts and bridges
- land purchase
- additional costs associated disruption/upgrading to public infrastructure – roading, power, water supply

Operational Costs

Each system will also have associated operations (covering system operation and control) and maintenance costs – regular maintenance (say annually), periodic maintenance (say once every five years), and extraordinary maintenance (relating to response to extraordinary events such as major floods, power outages, or earthquakes). Additional items that will need to be addressed for each option include:

- on-farm pumping costs
- water savings and how these are to be valued
- on-farm irrigation management if different levels of service are involved
- improved water quality – reduction in potential for contamination and associated costs
- management of bywash flows
- public safety
- environmental externalities
- increased fire fighting resources.

5 Social, Cultural and Economic Considerations

There is a consistent perception amongst rural communities that piped distribution is a more "sustainable" option than a network of open channels. This perception seems to be based on a mixture of community aspirations and concerns that are difficult to unbundle into social, cultural and environmental categories. It is important that investigations of community views be based on detailed understandings of the technical proposals of possible distribution options. The level of detail of scheme proposals needed to assure this understanding was not available for the case studies, and the results should be treated accordingly.

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