REPAIR/REPLACEMENT OPTIONS FOR

CONCRETE LINED IRRIGATION CHANNELS

GUIDELINES FOR PIPELINE REPLACEMENT

1 Overview

Pipeline replacement differs from the other repair/replacement options discussed previously in that all previous options have maintained the status quo, ie. an open channel system of delivering water. Pipeline replacement on the other hand allows the water system operator to offer a pressurised water reticulation system to users with its inherent benefit of increased operating head at the farm gate.

Conventional open channel water delivery systems generally constrain the user to employ flood or furrow irrigation methods which depending on soil type, farm slope or crop type can lead to problems of over watering, water logging and rising groundwater levels. With increased operating head offered by pipeline replacement, more irrigation methods are available to the user such as spray or trickle irrigation. This allows the user more flexibility in tailoring an irrigation regime that suits the user's particular needs. This not only results in increased crop yields but also encourages the efficient usage of water by users.

Increased water efficiency in delivery and in on-farm application methods is another major reason for choosing pipeline replacement as a viable repair/replacement option. Most irrigation areas along Eastern Australia are in a mature state of development with the prospect for additional water storage infrastructure within these areas becoming increasingly difficult due to economic, social and environmental pressures. At the same time there are increasing demands from emerging markets to gain access to additional water allocation. In this climate one way for an irrigation area manager to free up additional water allocations is through increased water efficiency. Pipeline replacement although not the total solution to improving water efficiency, nevertheless has an important role to play.

2 Issues to be Considered

Pipeline replacement compared to other repair/replacement options is generally one of the most expensive with a high up front capital cost. For pipeline replacement to be a cost-effective strategy the decision needs to be based on addressing multiple issues not just narrowly focused on a single issue. It is highly unlikely that pipeline replacement would be adopted solely for alleviating channel leakage problems for instance. The advantage of pipeline replacement over other repair/replacement strategies is that it offers the water system operator the ability to address issues that may have been peripheral to the initial reason for deciding on the replacement (ie. channel leaking).

The issues that need to be addressed before considering pipeline replacement as the optimum repair/replacement option fall into the following broad categories: -

- Amount of Channel Leakage (or degree of deterioration)
- Capacity of Channel
- Off Line /On Line Construction
- Improved Distribution Efficiency
- Farming Practices
- Environmental Issues

2.1 Amount of Channel Leakage (degree of deterioration)

Pipeline replacement is relatively expensive compared to other repair/replacement options with a high up front capital cost. As a consequence generally concrete lined channels that are near to the end of their economic lives (ie. exhibiting major sinkholes or undermining of lining) are more appropriate candidates for replacement than concrete lined channels with lesser deterioration. Concrete lined channels that have minor holes or minor joint deflections between the bays can generally be patched or joints sealed at a cheaper cost than pipe replacement. Concrete lined channels for which the underlying foundation is still competent (ie. no cavities or fines washed out) can also be rehabilitated cost-effectively via geomembranes / liners rather than via pipeline replacement.

As mentioned previously there may be other reasons why pipeline replacement may be adopted in situations where on pure repair issues there are cheaper alternatives (ie. improved water efficiency, improved level of service, reduced O&M costs). In these situations the benefits of these other factors needs to be quantified so that an overall cost of pipe replacement can be compared against alternative repair/replacement options.

2.2 Capacity of Channel

It is generally accepted that the cheapest way to distribute water is via a trapezoidal shaped open channel. This cost advantage becomes even more pronounced the larger the flow rate (ie. the larger the channel) that is being delivered. Another limitation to pipeline replacement is that most flexible pipe products are only manufactured in Australia to diameters less than one metre and with some regional factories manufacturing flexible pipe to diameters of less than 650 mm. Freight costs then become significant if larger diameters are required. Although concrete pipe is available in diameters in excess of one metre, it is usually cheaper to re-line large capacity channels than to replace with large diameter concrete pipe.

Thus given the increasing cost disadvantage with larger flow rates and the limitation of flexible pipe sizes, pipe replacement is generally viable only for lateral (or feeder) channels that serve individual farms. For the larger channels (ie. main or distributor channels) it is generally more cost effective to re-line the channel than to replace with a pipeline. The experience in the Burdekin River Irrigation Area in North Queensland has been that it is generally cost effective to replace channels with pipelines where the design capacities required are less than 500 l/s (43 Ml/day) and served areas less than 500 hectares.

2.3 Off Line /On Line Construction

Generally most lateral channels are being utilised to deliver water to irrigators twelve months of the year. This means that any pipeline replacement needs to ensure continued supply to irrigators during construction. Ideally it would be desirable to construct the pipeline off line so that the existing channel could still supply irrigators whilst construction was taking place. In the first instance it needs to be determined whether the existing channel reserve or easement is physically wide enough to accommodate a pipeline together with the existing channel. This assessment would need to take into account pipe stockpiles, spoil areas, construction equipment and access tracks. In cases where space is limited, consideration needs to be given whether a separate new alignment can be found. Additional land resumption costs associated with a new alignment might be justified where bends can be removed, pipeline access crossings reduced or power may available for purposes of metering or on-farm irrigation.

Where a new alignment is not feasible and insufficient space available for a pipeline to be placed next to the existing channel, it will be necessary to construct the pipeline on line. Whilst most lateral channels are utilised year round, in many irrigation areas along Eastern Australia, the channel system is shutdown during the winter months of June-July for maintenance purposes. This shutdown period offers the ideal opportunity to construct the pipeline on line. The obvious location to place the new pipeline is in the bed of the existing channel. However a number of factors make this proposition less attractive. They include :-

- Occurrence of rough edges where one section of the lining has dropped relative to the other. This can lead to the formation of point loads on the pipeline.

- Unknown foundation conditions. Even where the concrete lining appears to be in reasonable condition there may be unseen cavities beneath the lining or areas of variable soil properties which when subjected to pipe loadings may settle and induce stresses within the pipeline. This would seem incompatible with the assumed design life of at least 50 years for the pipeline that was used in the economic evaluation for choosing pipeline replacement over alternative repair/replacement options.

- Unreinforced nature of the concrete lining. Most concrete lined lateral channels consist of unreinforced concrete less than 50 mm thick. The use of unreinforced concrete as the foundation base for a pipeline is not desirable given that the lining has no shear strength and relies totally on the competency of the underlying foundation for its strength. Thus any differential settlement that occurs after installation of a pipeline within an existing channel will give rise to movement of the lining and possible formation of point loads.

- Cover requirements. Generally the diameter of the pipeline required to deliver the flow rate is close to the depth of the existing channel. Once a bedding layer is placed in the bed of the existing channel, the top of the pipe is close to natural surface. This necessitates the formation of a mound over the pipeline to ensure adequate cover. This may be undesirable where access is required across the pipeline (eg. where one farmer owns adjacent lots either side of the channel).

The provision of a mound over the pipeline to ensure adequate cover would also require the importation of additional spoil material which might not be available nearby. This would add to cost of construction.

On balance of the above factors it is not desirable to construct a pipeline on line by placing in the bed of the existing channel. If it is required to construct a pipeline on line, then it is preferable to remove the concrete lining first before placing the pipeline. The advantage of removing the lining entirely is that the foundation material can be inspected and assessed following removal of the lining and where necessary additional material imported should the insitu material prove unsuitable.

2.4 Improved Distribution Efficiency

A concrete lined open channel distribution system at best has a distribution efficiency of 90%. An open channel system of water distribution tends to be manually intensive in terms of regulating flows with its series of check structures. It is not uncommon for there to be uncontrolled releases through overflows ending up in watercourses and drains should irrigators stop watering and flow entering the lateral adjusted. Distribution efficiency can drop to 80% and in some bad cases as low as 70% should the concrete lining deteriorate badly leading to high seepage losses and water physically flowing out of the system at concrete structures that have been undermined. Conversion of a concrete lined open channel system to a fully piped system can improve the distribution efficiency by between 10-20% by eliminating evaporation, seepage and uncontrolled releases out of the system. For a lateral serving an area of 300 hectares this can represent an annual water saving of 350 megalitres (based on an allocation of 8 Ml/ha).

Another associated issue that needs to be addressed when considering pipeline replacement is metering. Most concrete lined lateral channel systems utilise Dethridge Wheels for metering water delivered to farms. The problem with Dethridge Wheel meters is that they can be physically manipulated. Dethridge Wheel meters can be ‘drowned out’ so that they do not rotate and hence they under read the amount of water being delivered.

Generally if the concrete lined channel is being considered for repair/replacement then it is likely that the Dethridge Wheel meters (or at least the associated concrete work) are also of need of repair/replacement. Pipeline replacement thus offers the opportunity to replace the Dethridge Wheel meters with more accurate, tamper proof meters. Generally pipeline replacement offers increased head at the meter offtake so that PA (propeller actuated) meters can be used. Where head loss is critical or weeds are a problem, then 'magflo' meters (magnetic flow meters) can be used instead. Magnetic flow meters are extremely accurate over a wide flow range and having no moving parts, essentially maintenance free. Magnetic flow meters can be obtained in either mains powered or solar powered versions.

2.5 Farming Practices

Concrete lined channel distribution systems as with all open channel systems are low head systems (operating head at the meter offtake in the order of 0.5 m). Therefore unless the farmer invests in additional expensive pumping plant, the only way the farmer can irrigate his farm is via flood or furrow irrigation. Flood irrigation whilst excellent in some cases is not appropriate in all cases. Flood irrigation in wrong situations can lead to topsoil erosion, over watering and water logging. Not only does this result in wasted water and lead to a raising of the water table; it can also result in reduced crop yields due to inappropriate application rates.

Pipeline replacement if used in conjunction with a re-lift pumped system can offer irrigators sufficient head at the farm gate to enable the use of trickle, drip or spray irrigation methods. These methods may be more appropriate for certain crop types and soil types. The cost of such a combined re-lift/ pipeline replacement option may be greater than a pipeline replacement option, which is purely gravity fed, depending on the available slope and required capacity. Any such additional cost could be warranted if irrigators are prepared to pay for the increased head or if the environmental costs of water logging were significant.

2.6 Environmental Issues

Excessive leakage from a badly deteriorated concrete lined channel in conjunction with uncontrolled releases and inappropriate irrigation methods can lead to water logging and consequent raising of the water table. This can lead to salinity problems and render surrounding lands unproductive and infertile. Uncontrolled discharges into natural watercourses and wetlands may alter the natural cycle and lead to changes in vegetation. Pipeline replacement can effectively eliminate most uncontrolled releases into the environment.

3 Pipe Materials

Pipe materials consist of two general classes; rigid pipes and flexible pipes. They are discussed in more detail below. The services of a professional engineer should always be engaged to determine appropriate pipe type, size, pressure and load class to suit each individual situation.

3.1 Rigid Pipes

3.1.1 Reinforced Concrete (RC)

There are many reinforced concrete pipe products including drainage and pressure pipe. This section focuses on pressure pipe.

Manufacturers

- CSR Humes Pty Ltd
- Rocla Industries Ltd

Standard Lengths/Diameters

Reinforced concrete pipe is available in lengths up to 2.44m. Reinforced concrete pipe is generally available in diameters from 300 mm to 2100 mm, with diameters up to 3600 mm available for special orders.

Jointing

Reinforced concrete pressure pipe is jointed using rubber ring joints (RRJ).

Load/Pressure Class

Reinforced concrete pressure pipe comes in a range of load classes and pressure heads. Reinforced concrete pressure pipe for pipeline replacement should be a minimum of Class 2 and possibly Class 3 depending on the traffic loadings to which the pipeline will be subjected. For a gravity fed pipeline replacement option, the pipe to be used should have a minimum test pressure of 90 - 150 kPa. For a pumped pipeline replacement option, the pipe may have a test pressure of up to 500 kPa.

Pro-Cons

Reinforced concrete pressure pipes are limited in that they only come in short pipe lengths (2.44 m) making installation take longer. It can also be quite heavy for the larger diameters making handling more difficult.

The advantage of reinforced concrete pipe is that no special welding equipment is required (as with the case of polyethylene) to join the pipes. Reinforced concrete pipe being a rigid pipe depends less on bed and haunch compaction for its inherent strength compared to flexible pipe. This means that levels of compaction required is less than what is required for flexible pipe. In normal trench conditions it is not necessary to extend the haunch zone to above the top of the pipe as is the case with flexible pipe. This saves on sand and installation time.

History of Use

Reinforced concrete pipe has been used successfully in Australia for more than eighty-five years following the development of the centrifugal method of pipe manufacture by Walter Hume in 1910.

3.2 Flexible Pipes

There are numerous flexible pipe materials available including polyvinyl chloride (PVC), glass reinforced plastic, ductile iron, steel etc. This section has focussed solely on flexible pipe materials which have diameter ranges capable of handling the entire length of the pipeline replacement. The typical pipe diameters required for the pipeline replacement of most concrete lined lateral channels is in the order of 375 - 800 mm. For this reason PVC pressure pipe was not covered in the following sections since it cannot cover all diameters (ie. another pipe product would need to be used in conjunction with PVC). Ductile Iron and steel pipe materials are not covered since most pipeline replacement projects are low head in nature and thus the expense of ductile iron and steel is not justified.

3.2.1 Medium Density Polyethylene (MDPE) - Solid Wall

Manufacturers

- Iplex Pipelines Australia Pty Ltd
- Vinidex Tubemaker Pty Ltd
- Industrial Pipe Supplies (IPS) Pty Ltd

Standard Lengths/Diameters

MDPE solid wall pipe is available in lengths of 20-22 m for pipe diameters up to 630 mm. For pipe diameters greater than 630 mm the standard length is 12 m. MDPE solid wall pipe is available in Australia in diameters from 16 mm to 1000 mm.

Jointing

MDPE solid wall pipe comes with plain ends and can be jointed using five methods :-

1. electrofusion couplers for diameters up to 315 mm.
2. 'victaulic' couplers (using shouldered ends).
3. other mechanical couplers (ie. 'straub' coupler).
4. flanged joint (using stub flange and backing plate).
5. butt fusion welding.

The last method is by far the most common.

Load/Pressure Class

The pipe suitable for pipeline replacement is manufactured from a PE 80B black medium density polyethylene material (as specified in AS/NZS 4131). MDPE solid wall pipe is available in Australia in pressure classes from PN 3.2 to PN 16. MDPE solid wall pipe used for pipeline replacement should have a minimum pressure class of PN 3.2. This pressure class is suitable for most gravity fed pipeline replacement projects. Pumped pipeline replacement projects will generally require MDPE solid wall pipe with a pressure class of PN 4 or greater.

Pro-Cons

The advantages of MDPE solid wall pipe include :-

- relatively light (560 mm OD PN 4 pipe weighs approximately 30 kg/m).
- comes in long pipe lengths (up to 22 m).
- can be welded in 'strings' of pipe of hundreds of metres long outside of the trench and then dragged into position by an excavator.
- pipeline is one continuous chain if butt fusion welding is used.
- depending on size, offtakes and tappings into the pipeline can be post installed via socket fusion welding or electrofusion saddles. Mechanical clamping tees can be used for the larger offtakes. This allows the flexibility for moving the location of offtakes and tappings during construction.

All these advantages means that laying rates of 150 metres or more per day can be achieved depending on pipe diameter.

The disadvantages of MDPE solid wall pipe include :-

- required specialised equipment and trained operator for carrying out of butt fusion welding and extrusion welding.
- require strict control on haunch compaction to ensure strength of pipe product.
- require adequate room outside of trench to allow for welding of pipe strings.

History of Use

Polyethylene pipe in its various forms has been used in Europe and the United States since about 1945. Limited production began in Australia in the mid 1950s, mainly with small diameters for industrial and agricultural applications. Up until recently most polyethylene pipe used in Australia has been high density polyethylene (HDPE) however now days the range of polyethylene pipe products is more varied to suit individual applications and not restricted solely to HDPE.

3.2.2 Glass Reinforced Plastic (GRP)

Manufacturer

- Iplex Pipelines Australia Pty Ltd

Standard Lengths/Diameters

GRP pipe is available in a standard length of 6 m. GRP is available in Australia in diameters from 300 mm to 1200 mm.

Jointing

GRP pipes are jointed using a coupling (collars or sleeves) which has an internal synthetic rubber seal running the full width of the coupling.

Load/Pressure Class

GRP pipe used for pipeline replacement should have a minimum stiffness of SN 5000. To prevent undue damage to the pipes (especially if transported long distances) a minimum stiffness of SN 10000 is advisable. GRP pipe is available in Australia in pressure classes from PN 4 to PN 25. GRP pipe used for pipeline replacement should have a minimum pressure class of PN 4. This pressure class is suitable for most gravity fed pipeline replacement projects. Pumped pipeline replacement projects will generally require GRP pipe with a pressure class greater than PN 4.

Pro-Cons

The advantages of GRP pipe include:-
- standard length of 6m and weight less than RC pipe making handling and installation easier.
- do not require specialised equipment for jointing of pipe.

The disadvantages of GRP pipe include:-
- require specific fittings for bends, offtakes and tappings.
- being a flexible pipe it is still critical to obtain high haunch compaction to ensure pipe adequacy.

History of Use

GRP pipes have been in use in Europe since the mid 1950s. Production in Australia commenced in the late 1980s.

3.2.3 High Density Polyethylene (HDPE) - Profiled Wall

Manufacturers

- Iplex Pipelines Australia Pty Ltd

Standard Lengths/Diameters

HDPE profiled wall pipe is available in a standard length of 6 m. HDPE profiled wall pipe is available in Australia in diameters from 375 mm to 3000 mm.

Jointing

HDPE profiled wall pipe is generally manufactured with spigot and socket ends for use with rubber ring joints. It can however be manufactured with plain ends to allow for butt fusion welding as per MDPE solid wall pipe (refer to Section 3.2.1 previously). HDPE profile wall pipe can also be jointed with a bolted flange connection.

Load/Pressure Class

HDPE profiled wall pipe suitable for pipeline replacement is manufactured from a PE 80C black high density polyethylene material (as specified in AS/NZS 4131). HDPE profiled wall pipe is available in Australia in a variety of profiles to suit various soil and traffic loading situations. The profile required for pipeline replacement varies with diameter but generally a profile that gives a minimum stiffness of SN 5000 should be adequate.

HDPE profiled wall pipe with rubber ring joints is suitable generally for pipeline replacement where the maximum static head is approximately 6 metres. For heads greater than this a fully welded or flanged jointed system would be required.

Pro-Cons

The advantages of HDPE profiled wall pipe include:-
- standard length of 6m makes handling and installation easier.
- do not require specialised equipment for jointing of pipe if pressures are less than 6 metres.
- is amenable to be jointed in a variety of ways (ie. RRJ, welded or flanged connection).
- small offtakes and connections can be field welded into pipeline as per MDPE.
- can use a wide range of fittings especially given its choice in jointing methods.

The disadvantages of HDPE profiled wall pipe include:-

- Maximum static head of 6 metres for rubber ring jointed pipe. Would require fully welded or flanged connection for higher operating heads. This would substantially increase installation costs given its relatively short pipe length of 6m.
- being a flexible pipe it is still critical to obtain high haunch compaction to ensure pipe adequacy.

History of Use

HDPE profiled wall pipe is a relatively new pipe product developed in Europe in the 1960s. Has been used in Australia since the 1980s. Being mainly a non-pressure pipe it has mainly been used for stormwater and sewerage projects.

3.3 Relative Cost

The relative cost of replacing a concrete lined channel with a pipeline compared to re-lining with concrete can vary greatly depending on channel capacity and available fall (or slope). Generally it is more attractive to retain an open channel system where the available bed slope is flat (< 1 in 4000) and where the channel design capacity required is large (ie. ≥ 500 l/s). This is as expected given the superior hydraulic performance of a trapezoidal section compared to a circular pipe section. As a guide the up front capital cost of replacing a concrete lined channel (0.5m bed width, 1.5H:1V batters and a bed slope of 1 in 3000) with a pipeline ranges from 1.1 – 2.4 times the cost of re-lining the channel with concrete depending on the pipe product chosen.

It is evident therefore that the selection of a pipeline replacement option is generally based on savings in operation and maintenance costs or other factors (eg. automation, increased operating head, etc) given that the upfront capital cost of relining the existing channel with concrete is cheaper than pipeline replacement.

4 Installation Considerations

There are a number of aspects with a pipeline replacement project which need to be considered. They include :-

- Space Requirements for Welding of Polyethylene Pipe
- Off Line Construction - Trenching Adjacent to Channel
- Decommissioning of Channel Following Construction

4.1 Space Requirements for Welding of Polyethylene Pipe

As mentioned in Section 3.2.1 previously, butt fusion welding is generally the preferred jointing method for pipes larger than 280 mm. The butt fusion welding process involves laying out the pipe to be welded in a line running along the top of the trench. For welding pipes up to 500 mm in diameter, the welding machine is relatively compact and sits on a wheeled buggy so that it can simply be moved to the next joint once the weld has been completed. For pipes greater than 500 mm, the welding machine is more bulky and tends to be fixed in position. The welding process therefore involves bringing the pipe to the welding machine. This is usually done by a 20 tonne excavator and sling. Therefore the minimum width required to carry out the welding operation is approximately 4 m allowing for the width of the excavator and the welding machine. For narrow reserves (eg. 10m wide) this will pose a problem of locating both the trench and the welding area on the same side of the concrete lined channel, especially if the existing channel is located centrally within the reserve. One option would be to dig the trench on one side of the channel and carry out the welding on the other side. This would mean that the welded string would have to be dragged over the channel which would still be in operation during construction. This method would be hazardous and precarious given that it is likely that the string would have to be dragged over channel structures. A preferred option would be to negotiate with the farmer for use of a strip of land adjacent to the channel temporarily whilst construction is in progress for purposes of welding the pipe. Some compensation costs may be involved if crops need to be cleared.

4.2 Off Line Construction - Trenching Adjacent to Channel

The construction of the pipeline adjacent to a concrete lined channel whilst still in operation poses the problem of water seepage into the trench. This could give rise to pipes floating and or trench collapse. The fact that the concrete lined channel is being replaced probably means that the lining has badly deteriorated and it is likely that significant seepage/leakage will be occurring. In this instance a number of methods can be employed to safeguard construction.

These methods include :-

1. Dig the trench as far as practicable from the channel. Wherever possible a minimum offset of 1.8 m from the edge of the channel to the pipe centreline should be maintained.

2. Do not leave any section of trench left open overnight (or over the weekend). Ensure that only sufficient trench to allow for the amount of pipe laying, sanding and backfilling that would occur in one day is dug.

3. If open trench is to be left overnight then sumps are constructed in the trench and small suction pumps employed to ensure that the trench stays de-watered.

4.3 Decommissioning of Channel Following Construction

Following construction of the pipeline the redundant concrete lined channel will remain. It is not recommended that the open channel be left uncovered due to the safety issue of physical injury to people, livestock and machinery by falling into the uncovered channel. Public health issues are also likely to arise from the ponding of stagnant water. It is recommended that the concrete lined channel be backfilled with soil and levelled off. All old concrete structures (eg. check structures) should be demolished and removed.

5 Summary and Recommendations

The decision to be made on pipe replacement is not one of choosing the right pipe material as all pipe materials if properly designed and constructed will give a similar level of performance and standard. Indeed pipe contracts are so keenly contested that it is likely that the price for various pipe products will vary from project to project. Therefore the pipe product to be chosen will be based on the lowest whole of life cost submitted by tenderers for that project.

The decision on whether to proceed with pipeline replacement is rather one of assessing economically the benefits of pipeline replacement (which are independent of pipe material) versus the continued costs of maintaining the status quo - ie. an open channel distribution system.

6 References

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Further Information

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