IRRIGATION INFRASTRUCTURE REHABILITATION IN ALBERTA; 35 YEARS OF GOVERNMENT/INDUSTRY COOPERATION

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ABSTRACT

Alberta has 1.63 million (661,000 ha) of agricultural irrigation (over 60% of Canada's total) with 1.34 million acres (542,000 ha) in 13 irrigation districts. The districts are privately operated and under the control of the irrigators who pay water rates based on the acres assessed for irrigation. The irrigators elect a Board of Directors to manage the district.

Since 1969, the Government of Alberta's Department of Agriculture, Food and Rural Development (AAFRD) and the irrigation districts have participated in a unique cost shared program to rehabilitate the irrigation water delivery infrastructure, some of which was initially constructed over 100 years ago. Over $630,000,000 (Cdn) has been allocated to cost shared projects within the districts under this program.

In addition to the benefit of grants to the irrigation districts, these programs have allowed Alberta to develop a world-class water distribution system that serves the needs of the irrigation districts as well as municipalities, industries, recreation users and wildlife. Innovative design and construction technologies and products have been developed that are now in common use in Alberta and other areas of the world.

Irrigation districts and contractors have developed methods of rehabilitation that conserve water, improve management and can be constructed in the adverse weather conditions common during Alberta's fall and winter construction periods. Manufacturers developed products to fit the industry, such as large diameter PVC pressure pipe, automated gates and specialized precast concrete structures. Engineers developed unique technologies such as overshot gates, remote control and data collection systems for level control, flow control and canal automation. Some of these products have also found applications in industries other than irrigation.

The assurance of a dependable and efficient water delivery infrastructure has not only benefited the primary producers but also the economy of southern Alberta in particular, and Canada in general, with large agri-business ventures locating new or expanded facilities within the irrigated areas of southern Alberta. Organizations such as Ducks Unlimited reaped the benefits of an assured water supply as they developed areas for wildlife habitat.

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INTRODUCTION

In order to understand irrigation in Alberta, it is important to understand the area, the historical background of irrigation and the evolution of the present legislative, financial and administrative confines under which irrigation districts operate.

Alberta accounts for over 60% of Canada's agricultural irrigation. Irrigated land in Alberta currently totals over 1.63 million acres (661,000 ha) with over 80% of that contained within irrigation districts. This area represents only about 4% of Alberta's cultivated land but is responsible for approximately 20% of the province's gross agricultural production.

Alberta's cultivated soils are generally well suited to agriculture, but unique in that the underlying parent material is glacial till, this being one of the few areas of the world where these soils are irrigated. Topography varies from a rolling terrain in the area near the mountains to relatively flat plains in southeastern Alberta.

The region is classed as semi-arid. Sunshine is one of the more stable climatic features, with southeastern Alberta having the most hours of sunshine in Canada. Although this is one of the drier and hotter areas of Canada, only one crop per season is possible. The crops grown under irrigation are shown in Table 1.

Table 1: Irrigated Crops in Alberta's Irrigation Districts (acres)

Crop	1979 [a]	2004 [b]	Change
Wheat (soft, durum, hard spring, CPS, winter)	220,127	229,130	4.1%
Barley (grain, silage & malt)	199,004	255,004	28.1%
Canola	66,233	114,541	**72.9%**
Other grains & oilseeds	77,770	22,759	-70.7%
Corn (silage, sweet and grain)	22,610	42,380	**87.4%**
Alfalfa & hay (all types for feed)	224,943	318,782	41.7%
Pasture (all types)	86,166	138,263	60.5%
Other forages & silages	7,383	27,258	**269.2%**
Alfalfa & grass seed	6,546	14,346	**119.2%**
Potatoes (including seed)	11,396	41,095	**260.6%**
Sugar Beets	32,474	34,993	7.8%
Peas & beans	25,350	63,033	**148.7%**
Other specialty crops (turf, nursery, mint, market gardens, sunflower, etc.)	3,079	11,715	280.5%
Miscellaneous or unspecified	4,994	17,917	258.8%
Total crops	**988,075**	**1,331,216**	**34.7%**
Summer fallow or non-crop	21,878	8,545	-60.9%

a) Source: Thiessen & Smith, 1981

b) Source: AAFRD Irrigation Branch, "Alberta Irrigation Information", 2004

Alberta has 13 irrigation districts, all in southern Alberta, ranging in size from less than 1,300 acres (500 ha) to over 360,000 acres (146,000 ha). In 2004 there were 1,339,760 acres (542,190 ha) on the assessment rolls. The six largest districts account for over 90% of the total. Each district is independently controlled by the irrigators (farmers) and operates as a quasi-municipal body. The provincial *Irrigation Districts Act* sets the framework under which irrigation districts operate and each district holds a water license issued according to the provincial *Water Act*.

The irrigators elect a Board of Directors who hires staff to operate and maintain the district. The larger districts also maintain an engineering and/or construction department to do design and construction work.

This paper describes how, over the past 35 years, the Government of Alberta, the irrigation districts and private industry (consultants, manufacturers, contractors) have worked together to create world-class water distribution infrastructure for the benefit of all Albertans.

HISTORY

Western Canada has a long history with irrigation. Books by Gilpin (2000), Topham (1982) and Freeman (1994) and papers presented by Thiessen & Smith (1981) and Craig (1987) document that history very well. The historical summary presented here draws extensively on those three documents.

The first irrigation in western Canada was in 1858 out of Humbug Creek in British Columbia. Alberta followed in 1877 with a private scheme from Fish Creek, now in the south part of Calgary. Southern Alberta, because of its harsh climate and sparse vegetation was slow to attract settlers, and it was not until the completion of the transcontinental railroad that much development occurred.

The first major "project" to be developed was in the Raymond/Magrath/Lethbridge area from a diversion on the St. Mary River at Kimball. Between August 1898 and July 1900 approximately 115 miles (185 km) of canal were dug, moving over 1.1 million yd^3 (840,000 m^3) of earth. Prospective settlers were assured that a two-room house could be built for $150, that land was available for $5/acre and that there were employment opportunities with the local coal company. By 1911 about 50,000 acres (20,000 ha) were irrigated.

The Canadian Pacific Railway (CPR) completed Canada's trans-continental railway in 1885 and received a land grant of 25 million acres (10 million ha) for doing so. In 1903 William A. Pearce, Superintendent of Mines for the Dominion Government, convinced the CPR to select the remainder of the land grant earned for railway construction in one large block between Calgary and Medicine Hat. By 1910 the CPR had developed irrigation works in the Western section (east of Calgary) and by 1914 in the Eastern section (surrounding Brooks).

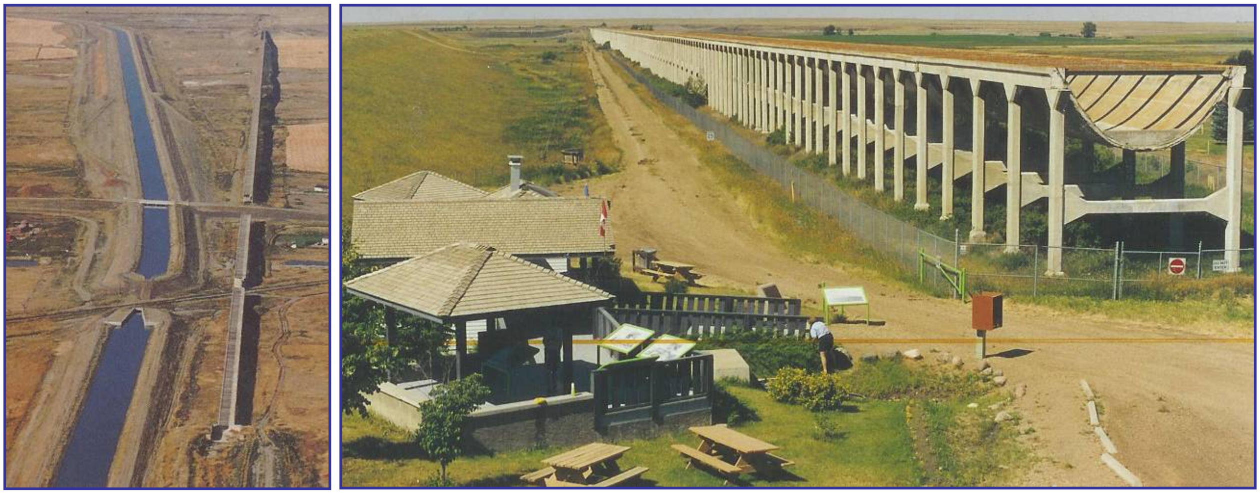

Figure 1: Brooks Aqueducts (Original on the right of each photo. Replacement on the left)

One of the most significant irrigation structures in North America was built in the Eastern section during that time. The Brooks aqueduct was perhaps the greatest challenge faced by the CPR engineers. Built across a two mile wide, 60-foot deep (3.2 km wide, 18 m deep) valley, this reinforced concrete barrel flume, interrupted in its middle by an inverted siphon to accommodate the railway line, was beset by problems from the beginning. It was later described by R.T. White, former Eastern Irrigation District (EID) General Manager as ".... an engineer's dream and an operator's nightmare". In 1979 the concrete aqueduct was replaced by a canal, constructed in a huge earth fill built across the valley (Figure 1).

Another significant irrigation structure was built in the Western section during that time. In 1904 construction began on a diversion weir across the Bow River in what is now Calgary.

Figure 2: Bow River Diversion (Glenbow Museum Photo)

It has been said that, at the time, this diversion was the second largest in the world, second only to a diversion on the Nile River in Egypt. Work progressed on this diversion weir and the main canal (Figure 2) for what is now the Western Irrigation District and in 1905 Reservoir #1 (Chestermere Lake) was filled with water for the first time.

Figure 3: Irrigation Construction in the Early 1900's (Glenbow Museum Photo)

In his 1994 book documenting the history of the Western Irrigation District George Freeman stated:

> *"It is of interest to consider this situation in today's terms. With modern equipment we would have quite a problem accomplishing what had been done with horses and fresnos. At one time during the peak of the irrigation construction there were 450 men and 400 teams of horses employed on contract work while a further 300 men and 60 teams of horses were working on operation and maintenance of the ditches. With modern bureaucracy, we would still be staggering through the mountains of paperwork which would have developed and, in that time, we would not have moved a shovelful of earth. It must be remembered, however, that there were no obstacles other than the topography to interfere with the construction and it was possible to proceed across the terrain under the direction of the contours only, without interference from man-made impediments or government bureaucracy."*

Starting with the formation of the Taber Irrigation District in 1915 and the Lethbridge Northern Irrigation District in 1919, farmer owned organizations were the dominant force for the next three decades.

Following World War II, the era of government involvement in irrigation development began. In 1935, the federal government formed the Prairie Farm Rehabilitation Administration (PFRA) and it assumed a dominant role. From 1948 to 1972 the PFRA built eight large dams (Shady, 1989) including the St. Mary Dam, creating the first major on-stream irrigation storage reservoir.

The role of the provincial governments in water management is significant in Canada. In 1930, Canada turned over all interests in natural resources to the provinces. This included water, forests, coal, oil and natural gas. Therefore, responsibility for water resources falls on the provinces, not the federal government. The federal government retained jurisdiction for matters of navigation, fisheries and international treaties governing watersheds. In Alberta, ownership of the oil and natural gas reserves has had significant financial benefit.

With the provinces having the responsibility for water, they are very active in irrigation. On the Canadian prairies (Alberta, Saskatchewan and Manitoba) much of the natural water in the rivers begins as snowfall on the east slopes of the Rocky Mountains and flows easterly to Hudson's Bay. The Prairie Province Water Board, formed in 1948, insures that each province gets its fair share of the water available. By agreement, 50% of the water available in one province (e.g. Alberta) must be allowed to flow to the neighboring province (e.g. Saskatchewan).

IRRIGATION REHABILITATION PROGRAM DEVELOPMENT

Up to the late 1960's, irrigation development had gone through three phases: Company, Irrigation District and Government. The Prairie Farm Rehabilitation Agency (Agriculture and Agri-Food Canada) participated to a large extent in irrigation rehabilitation in Alberta until 1973.

This paper concentrates on the newest "fourth stage". The self-managed irrigation districts, governed by Provincial legislation, operate and maintain irrigation works and rehabilitate these works, with Alberta Agriculture, Food and Rural Development (AAFRD) providing the major share of rehabilitation funding.

Alberta Environment (AENV) owns and operates many multi-purpose water resource projects (head works, dams, reservoirs and canals). These head works also provide water to the irrigation districts that own and operate the downstream infrastructure. The Alberta government, on behalf of AENV, has constructed many major provincially owned and operated works as well as some irrigation district owned main canals and storage reservoirs. The last major AENV projects completed were Oldman River Dam and the St. Mary Dam spillway replacement. The province is currently invested millions of dollars annually in the rehabilitation of the Carseland-Bow River Headworks system, another key AENV owned and operated system.

Figure 4: Old Wooden Control Structure

In the late 1960's, the province and the irrigation districts started to rebuild the irrigation distribution systems owned by the districts under cost sharing agreements. The need for a rehabilitation program with a major contribution from a senior level of government was clearly demonstrated by the deteriorated condition of irrigation works, partly due to inadequate or lack of maintenance.

Many canals were eroded while others had siltation or weed and tree growth, which restricted the flow carrying capacity. It was estimated that up to 10% of the total irrigated area was affected by salinity due to seepage from canals. Wooden drop and check structures were badly deteriorated (Figure 4) and there were periods of interrupted water delivery due to failure of some portion of the distribution system. The irrigated acreage had increased significantly which created capacity problems in many areas.

A 1967 federal Agriculture Rehabilitation and Development Act (ARDA) study showed that the benefits of irrigation accrued 14% to the irrigation farmer, 41 % to the surrounding municipality and the province (Alberta) and 45% to the country (Canada) as a whole (Freeman, 1994). Based on this study and, with Alberta assuming the governments' role, the first cost shared Irrigation Capital Works (ICW) Program was based on an 86% contribution by Alberta. The districts (farmers) provided the other 14% from their general revenues. A unique aspect of the program was that it was to fund rehabilitation of both large and small projects in all 13 districts.

In the first year, AAFRD allocated $584,000 to the districts. The money was distributed among the districts on the basis of acres on the assessment rolls. AAFRD engineers provided the engineering for all projects in the early years. In the years following the program continued in various forms for 5-year increments. A later economic study (AIPA, 1984) suggested an 85/15% ratio and was instrumental in convincing the government to continue the cost-shared program. Methods of allocating the funds among districts varied over the years. The annual grants have varied from under a million to $30 million (Figure 5).

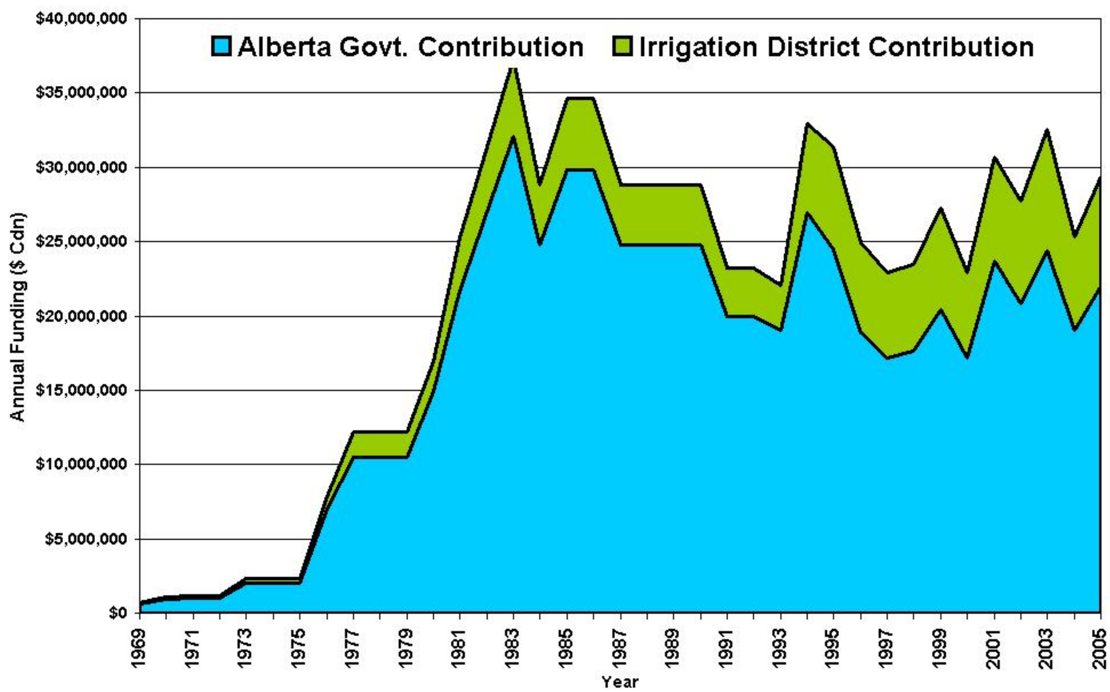

Figure 5: Historical Levels of Irrigation District Rehabilitation Funding

Prior to 1995 rehabilitation programs were for five-year intervals with no assurance that they would be renewed. This made long range planning difficult for some districts. In 1995 a new era of irrigation rehabilitation began. After public consultation by a legislative committee, the provincial government adopted the current Irrigation Rehabilitation Program (IRP). The program became long range in nature with the cost sharing changed to 75/25%, similar to other Alberta government cost shared infrastructure programs. One senior government official is said to have made the comparison that funding this infrastructure is like funding highway construction, since these canals and pipelines deliver water to our communities, just like highways deliver other commodities.

The present level of funding is $22 million annually. The available base funding is distributed among the 13 irrigation districts based on the number of acres they serve and the amount of infrastructure (replacement value) they own and operate. In some years, special capital funding is provided to individual districts for special projects, which address critical and/or unique issues.

Funds are dispersed according to Irrigation Rehabilitation Financing Agreements entered into annually by each district and the Alberta government. Engineering is now done by private consulting engineers or by irrigation district engineering staff according to standards developed by the industry (Alberta Agriculture, 1991).

Annual Rolling Three-Year Plans are prepared by each irrigation district and submitted for approval to the Irrigation Council. In those plans the districts provide detailed information on the projects they plan to start during the upcoming construction year, and those “New Year One” projects are reviewed and approved for funding by the Irrigation Council. The Irrigation Council is a body appointed by the Minister of AAFRD and is currently made up of five public members (generally farmers with irrigation district experience) and one representative each from AAFRD and AENV. Once approved, the new projects may proceed with design and construction by private contractors or the district.

TECHNICAL EVOLUTION AND INNOVATION

Figure 6: Centre Pivot System on Canola

Before one considers the improvements made within the irrigation districts, it must be acknowledged that in Alberta, as in many other parts of the world, the irrigation farmer himself has adopted many technical innovations. Mechanization replaced labor, with sprinkler irrigation now used on 83% of the area within the districts (up from 70% in 1999). Center pivots account for over 61 % (up from 40% in 1999) of the irrigation in the districts. More land is irrigated with less water and less land is damaged due to over irrigation or salinity.

The irrigation district’s responsibility for water supply ends at the farm turnout. No funds from the government are used for the operation and maintenance of the districts and these grants are not given to individual farmers. Cost shared funds are only used to rehabilitate the water delivery infrastructure within the districts.

Early district rehabilitation projects consisted mainly of rebuilding the canal banks or opening up the canal cross-section by cleaning and replacing critical control structures. Few projects included seepage control, gravel armour slope protection or pipelines because of the cost. With no guarantee of funding beyond the five-year intervals, efforts were often concentrated at fixing the worst spots here and there, rather than rehabilitating complete laterals in a planned fashion.

As the rehabilitation program matured into a long-term program, and after most of the large capacity problems were handled, the standards used for rehabilitation design and construction (Alberta Agriculture, 1991) were improved. Control structures were upgraded, many with electrically operated gates, some automated. Pipeline systems were introduced. These improvements were an attempt to make the projects last 50 years and improve water and land use efficiencies and, where possible, align canals along legal boundaries.

Membrane Lined Canals

Originally, little was done to control seepage from canals. The build up of saline soil and waterlogged conditions adjacent to canals prompted the development of seepage control methods.

The first attempts at linings involved polyethylene (PE) membranes but extensive damage resulted from the loss of cover due to erosion, livestock, external hydrostatic pressures and by mechanical equipment during installation and maintenance. Weeds established themselves on the liner cover and maintenance costs related to aquatic and canal bank weed control were not reduced.

Experience has shown that, where membrane linings are needed, they must be protected by non-erosive cover materials. Modern reinforced PE or a poly-vinyl chloride (PVC) liners use gravel armour slope protection for erosion control.

Numerous methods of installing liners have been used. The two most common are:

1) The canal is over-excavated, and the liner is installed and covered with gravel (Figure 7). This method has proven to work very well where the canal banks are good and where gravel is readily available.

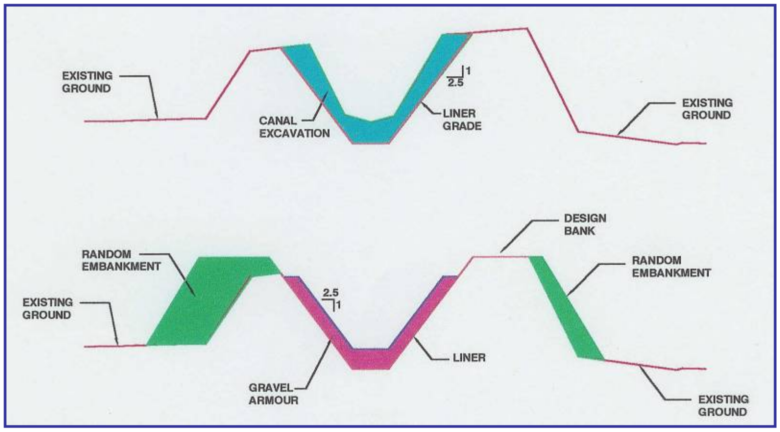

Figure 7: Gravel Armour Placed Directly Over the Liner

2) The canal is over-excavated using this material to rebuild the outside half of the canal banks. The liner is then installed and a compacted clay fill material placed on the liner with dozers and compactors. The canal side slopes have gravel armour slope protection placed on them (Figure 8). This method is preferred but costly if the banks are in good condition. If the existing banks are in poor condition, this method can be cost effective.

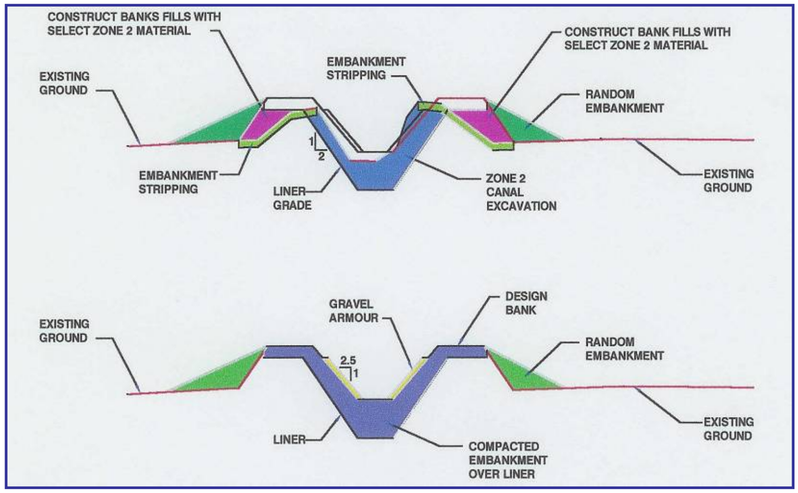

Figure 8: Gravel Armour Over Compacted Fill Over Liner

Other exposed liners have been tried including synthetic rubber, prefabricated asphalt or aluminum sheeting and fiberglass-reinforced polyester. Spray-on asphalt and sulphur have also been tried on an experimental basis. Tests have shown that, for a variety of reasons, these materials are not a practical method of seepage control.

Interceptor Drains

Where high groundwater is present, vertical plastic cutoff curtains and tile drains have been effectively used. Open interceptor drains are not practical due to extensive land requirements and high maintenance costs. Interior and/or exterior cutoff walls utilizing plastic lining and gravel chimneys with tile drains are used. On those areas involving high water tables, interceptor drains control seepage to adjacent lands, whether it results from natural flows (high water tables) or canal seepage.

Concrete Lining

Concrete lining was installed in about 180 miles (300 km) of irrigation canals from 1970 to 1988. In Alberta, un-reinforced concrete lining proved unsatisfactory due to extensive cracking which occurred as a result of wet soil conditions in the fall, followed by the cold winter and corresponding frost action (Figure 9). In the late 80's, methods of adding reinforcing to the concrete lining (Figure 10) were developed and these proved effective. However with the advent of larger diameter pressure rated PVC pipe, concrete lining is no longer used in Alberta.

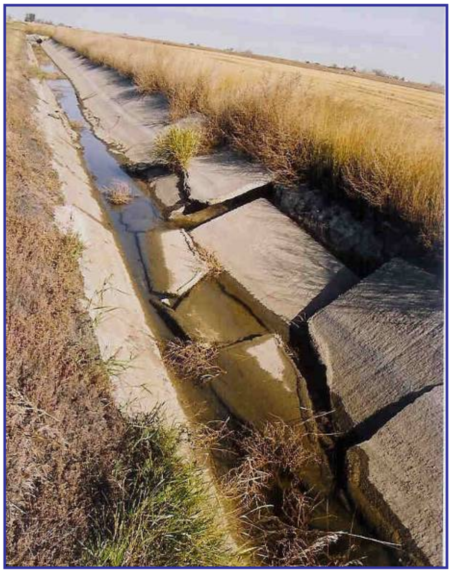

Figure 9: Failed Concrete Lining

Figure 10: Installing Reinforced Concrete Lining

Gravel Armour (Slope Erosion Protection)

Most canals that are rehabilitated today have gravel armour slope protection included, whether or not liners are used. This is expensive ($20-$26/yd^3, $15-$20/m^3) but is likely the best utilization of funds on a project. Figure 11 shows a 20-year-old canal that was only partially armoured. The portion with armour is in excellent shape while the rest is not. Gravel armour at least doubles the life expectancy of a canal.

Numerous studies have been done with gravel armour to determine what side slopes can be used. It was found that 2.5:1 (H:V) to be the optimum; 3:1 was better but only marginally and at a high cost. While 2:1 worked in many cases in small canals, the potential for slope failure on large canals may be too great to be acceptable. Depths of armour vary from 6-8" (150-200 mm) for armour on earth material to 8-12" (200-300 mm) for armour placed directly on membrane liners.

Figure 11: Armoured and Un-armoured Portions of a 20-Year Old Canal

Studies have been done to determine the acceptable gradation of gravel. It has been found that material with too many fines does not work well. Some geotechnical people believe there should be some fines but the districts have found that if the material below 1/4" (6 mm) and above 8" (200 mm) is screened out from a well graded pit run gravel, the armour produced will work very well and is affordable because it can be produced by simply screening the raw product.

CANA Construction[5], a Calgary contractor, designed a large machine for placing membrane liners and gravel armour at the same time in large canals (Figure 12). The machine was effective, but was limited in its application, so now all canal work is done with large backhoes (see Figure 20: Winter Construction).

Figure 12: Canal Liner/Armour Placement Machine

Control Structures

Historically, gates on irrigation structures have been undershot gates. Small flows were controlled with cast iron or fabricated steel gates and large flows were controlled with radial gates. This worked well for flow control structures such as reservoir outlet structures and canal turnouts, but worked poorly for canal check structures where upstream water level control was required. Operators wrestled with the problem of using radial gates as check structures. These have the disadvantage of not passing flood flows easily and thereby there is the danger of overtopping canal banks when flood or surge flows arrive at a structure.

To allow for flood flows, radial gate check structures were often constructed with stop log side bays to assist in level control. This was an improvement in level control but required a much wider structure and created the additional operational problems common with the use of stop logs.

To overcome the limitations of undershot gates for upstream level control two “overshot gates” were developed; the drop leaf gate and the Langemann Gate. These have the advantage of allowing surge or flood flows to pass through the structure without overtopping the canal banks while checking water. They work well for upstream level control, and it is now standard practice to use overshot gates for level control and undershot gates for turnout flow control. This combination has the advantage of maintaining a relatively constant main canal level and delivering relatively constant delivery flow rates to the laterals (and hence the irrigators), regardless of the flow rate in the main canal.

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[5] Note: The use of brand names and company names is for the convenience of the reader and does not imply any endorsement by the authors.

Drop Leaf Gate: The overshot drop leaf gate (a modified crest gate) was first used in Alberta in 1983. It was developed to simplify the control of the upstream water level at check structures. The gate is a flat panel that is hinged on the bottom and a twin cable hoist is used to raise and lower the top edge. Drop leaf gates have been typically fabricated using welded steel (painted or galvanized), but some have been fabricated using aluminum or stainless steel. Typical drop leaf gates (Figure 13) are fabricated using a steel faceplate, wide flange or channel top girder, angle bottom girder and HSS or channel beams. A fabricated hinge with a bronze hinge rod is bolted to the structure sill. Local steel fabricators can easily manufacture drop leaf gates.

Figure 13: Typical Drop Leaf Gates

Figure 14: Large Drop Leaf Gate Hoist

Armtec Water Control Products markets hoists and drop leaf gates. Other suppliers have occasionally supplied hoists, but Armtec have developed a standard line of single and double gearbox hoists.

Cost of the drop leaf gate is affected greatly by the size of the gate hoist (Figure 14). Traditional hoists with large drum-cable ratios (greater than 24:1) are expensive due to the large torque generated by the drum. Standard practice is to use a 12:1 or 16:1 drum-cable ratio. Ratios as small as 10:1 are being used and the first drop leaf gate used an 8:1 drum-cable ratio. A manually operated drop leaf gate and hoist costs approximately $100/ft^2 ($1,100/m^2). The same gate with a 120VAC electric hoist (Rotork actuator) costs approximately $140/ft^2 ($1,500/m^2).

The drop leaf gate has been very successful and most check structures are now constructed with drop leaf gates. Older check structures with radial gates have been retrofitted with drop leaf gates. Initial concerns about silt deposition upstream of the gate, cable corrosion and weed buildup have been shown to be unfounded. At high flows (low gate positions), bed load travels over the gate and does not accumulate. Cable life has been very good. Galvanized cables will last in excess of 20 years. Aquatic weed accumulation on the cables has been a minor problem, but the gate typically passes weeds over the gate rather than accumulating at the gate.

The drop leaf gate has also been utilized for flow measurement. It provides reasonably accurate flow values but needs to be calibrated. The main difficulty is the error induced by cable stretch, top beam deflection, and inaccuracies in the gate position measurement (potentiometer and analog/digital conversion). The discharge co-efficient changes as a function of gate angle but research in Alberta and Arizona has developed calibration equations based on the gate angle.

Figure 15: Langemann Gate in an 800 cfs (23 m^3/s) Canal – Upstream & Downstream View

Langemann Gate: The Langemann gate (named after its inventor, a southern Alberta irrigation farmer) is a modification of the drop leaf gate. It was originally developed as a flow control for turnout applications. Whereas the drop leaf gate uses a single hinge with the top edge traveling in an arc as the gate rises, the Langemann gate uses two hinges and the top edge travels in the vertical direction only (Figure 15). This provides better control of the gate height and improves the flow measurement accuracy. It also requires less power as the gate does not have to lift the mass of water that exists on top of a drop leaf gate. Aqua Systems 2000 Inc. has marketed this gate since 1995.

This gate can be configured to operate for upstream level control (with or without automation) but it can also be configured for flow control with a patented flow controller. Since it requires little power to raise the gate, it is ideally suited for solar panel/battery operation. It is also especially well suited for retrofitting into the stop log guides of an existing structure and can replace radial gates in existing structures with minimal need for structural modifications.

Precast Concrete Structures

The IRP has provided Alberta precast concrete firms with the opportunity to develop precast irrigation structures. With construction restricted to late fall, winter and early spring, contractors are required to maximize productivity during adverse weather. Freezing conditions favor rapid construction techniques.

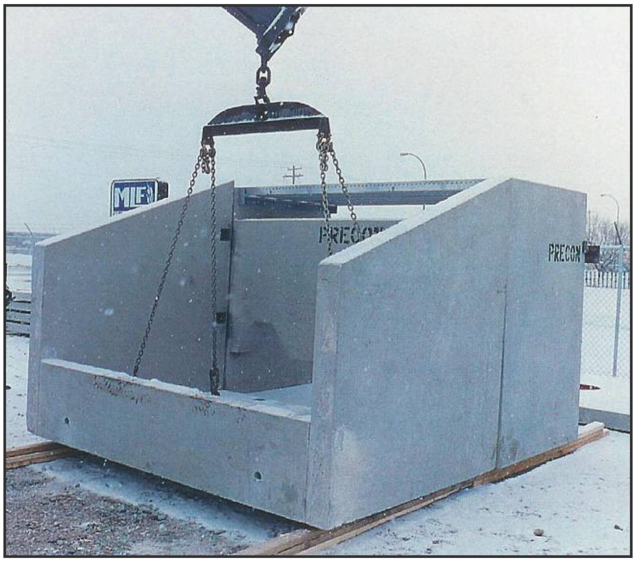

Figure 16: Precast Impact Baffle

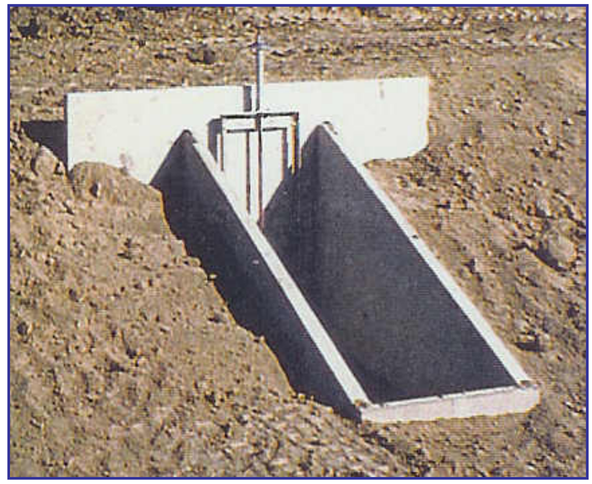

Figure 17: Precast Turnout Structure

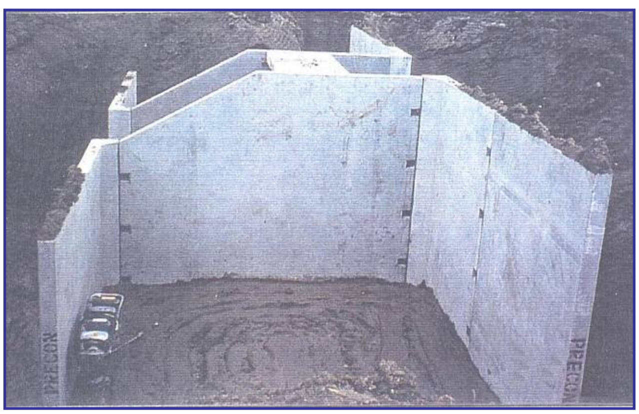

Figure 18: Precast Check/Drop Structure

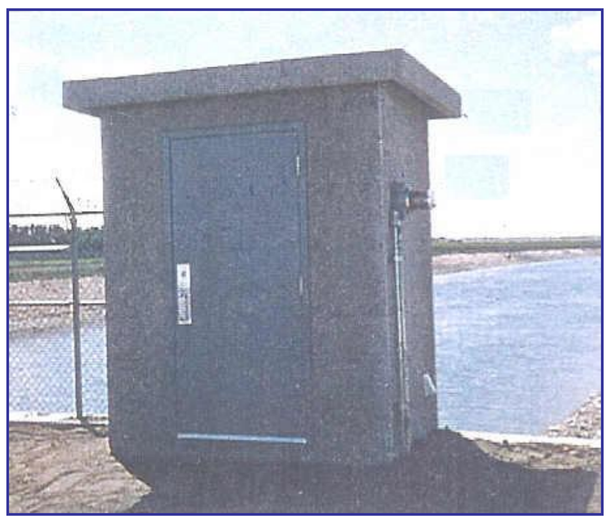

Figure 19: Precast Control Building

Precast concrete is well suited to this type of working environment since the concrete does not have to be poured in freezing weather and most precast structures can be installed and backfilled in one or two days instead of weeks for cast-in-place structures. For smaller structures (<150 cfs, <4.2m^3/s), precast structures are also significantly less expensive than cast-in-place structures.

The major supplier of precast concrete irrigation structures, Precon Precast Products has developed standard control buildings, check structures, check-drop structures, drop structures, impact baffles structures, turnout structures, multi-panel vaults, pipeline inlets, pump stations, and vaults (Figures 16 to 19).

Cold Weather Construction Methods

Cold weather construction in very wet environments and at remote locations can be trying and expensive. Since the canals are in use from May through October, construction generally cannot start until November and must be completed by April. The cold, wet environment in which rehabilitation takes place necessitates both special construction techniques and design considerations.

Figure 20: Winter Canal Construction

Winter construction of reinforced concrete structures requires heated or insulated enclosures. Earth canal construction is often done quickly in small reaches (Figure 20). The canal is over-excavated and work is completed on each short reach within 24 hours so that frozen material is not being worked with.

Pipelines

Pipeline water distribution systems are the logical choice for the smaller supply laterals, particularly where steep topography works to the disadvantage of canals and to the advantage of pipelines. Where steep slopes were the biggest problems in the early years (erosion, numerous drop structures, etc.), those districts with the steep slopes are now the ones best able to use pipelines. In many cases pipelines are even a cheaper alternative. The farmer on the bottom of the ditch who used to have to deal with all of the variations in flows now usually has the highest pressure available at his turnout. Common materials for pipelines include concrete, reinforced concrete, steel cylinder concrete, high-density polyethylene (HDPE) and poly-vinyl chloride (PVC).

Pipelines have become the preferred method of rehabilitation because they reduce operational spills, control seepage, eliminate farm severance and bring more land under production, thereby increasing the production and cash value of farmland.

PE and PVC pipe came on the scene in the early 1980's. Initial problems with excessive deflection in PE pipe resulted from poor backfill methods. However, once proper backfill methods were developed the problems were overcome. Both PE and PVC proved successful for pipelines but the technology of manufacturing PVC pressure pipe in sizes up 48" (1,200 mm) has offered the industry the most economical piping option, when the total cost of materials and installation are considered.

With PVC pipelines being used almost exclusively, the irrigation districts asked PVC manufacturers to make larger PVC pipe available, so that larger canals and canals with flatter grades could be converted to pipe, and the industry responded (see Program Benefits section).

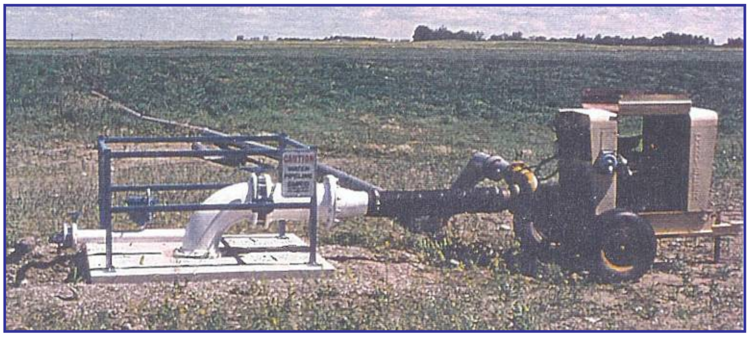

Figure 21: Combination Pump Turnout (right) and Household Turnout (left)

Steel farm turnouts were designed which allowed pumps to be connected directly to the pipeline (Figure 21). The farmer takes advantage of any pressure that is supplied. Some districts levy a surcharge (e.g. 12¢/psi, 1.7¢/kPa) for the pressure supplied to the irrigators.

Figure 22: Centralized Irrigation District Pumping Station

In a few cases, centralized pump stations supply sufficient pressure to operate all the sprinkler systems on a particular lateral (Figure 22).

Some districts use standardized turnout designs (Figure 21), ordered in mass each year to reduce cost. This standardization also has advantages when future maintenance is required. The standard design has a small outlet for household deliveries on all turnouts. This has proven to be a very successful option, as users often want a household delivery at some future date.

The turnouts are often equipped with combination air/vacuum valves and thermally activated valves to prevent frost damage in the spring and fall. Initially epoxy coated steel fittings were used but these corroded. Now cathodic protection (sacrificial anodes) and tape wrap are used on almost all buried steel fittings. Engineers developed design and construction methods to ensure high quality pipelines. These involve pressure tests after construction, use of accurate roughness coefficients for design purposes, settling reservoirs and trash racks at inlet structures.

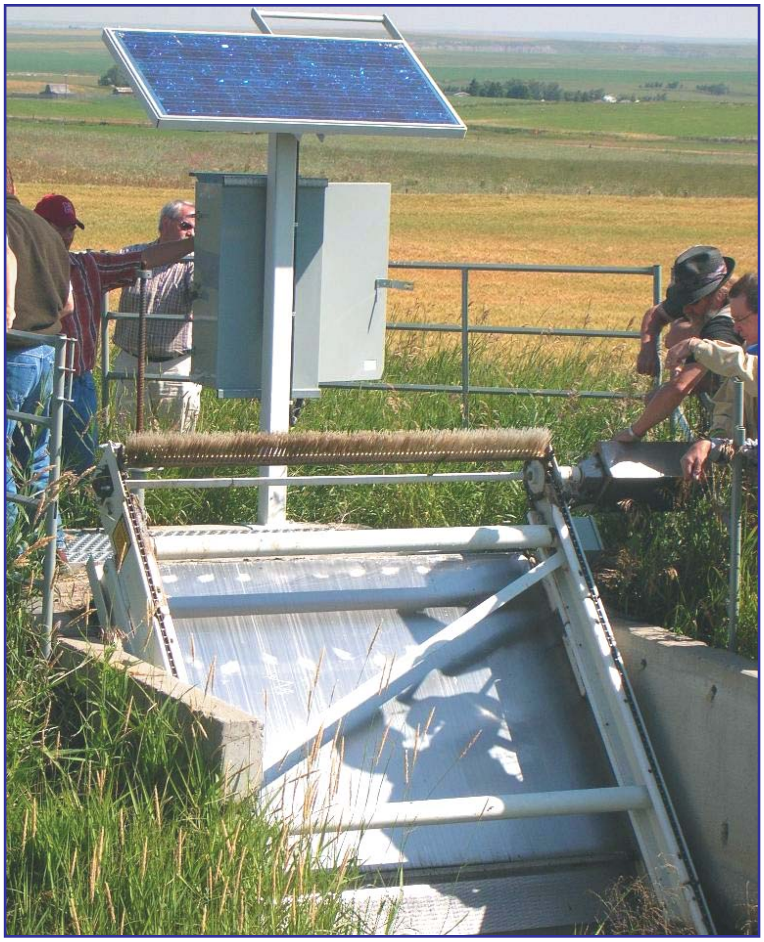

Figure 23: Solar Powered Pipeline Self-cleaning Inlet Screen

Settling reservoirs remove silt and debris before water enters pipelines and are sized according to the particle settling requirements. Trash racks often have automated solar powered weed screens to keep them cleaned off. (Figure 23)

Low head C361 reinforced concrete pipe is used for some irrigation pipelines. This initially proved unsuitable due to problems with bell and spigot joints. Manufacturers developed the R4 joint, which involved reinforcing extending into the bell and spigot. This has proved satisfactory for low-pressure applications.

Pipelines have also been used successfully for spillways. Two types of energy dissipaters are incorporated; one utilizes a hanging baffle concrete structure and the other involves an open-ended vertical steel or concrete riser pipe.

Change in Rehabilitation Methods

Over the years, many types of rehabilitation have been and are being used. Figure 24 shows how buried pipelines have become the rehabilitation method of choice with over 80% of the annual rehabilitation (by length) now done with pipelines.

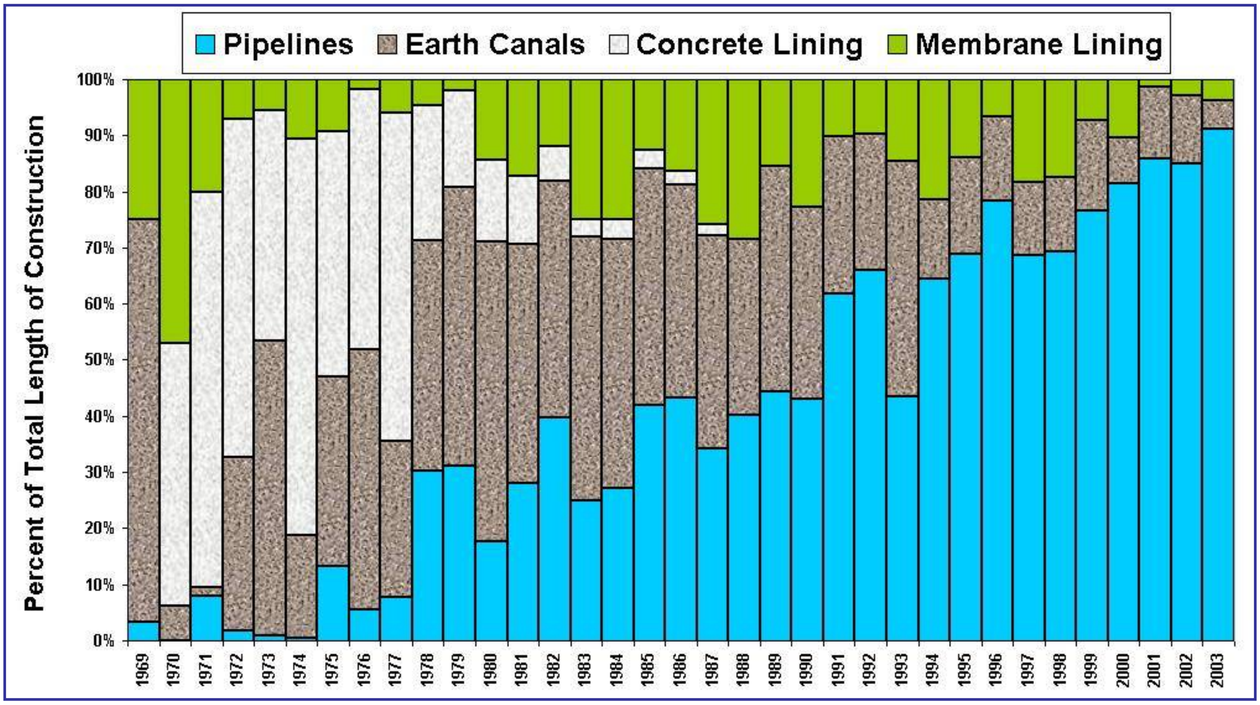

Figure 24: Rehabilitation Methods Used in Alberta

Remote Control and Automation

In this paper "remote monitoring" refers to systems where the conditions at a site (flow, gate position, water level, etc.) can be monitored from a remote location by radio, telephone or other method. "Remote control" is an added level of control and allows an operator to control devices from a remote location. Remote monitoring and remote control systems are both common in irrigation districts.

"Automation" refers to devices, which are controlled automatically, without human intervention, according to defined algorithms and make adjustments according to changing conditions. This may occur on-site, or may be controlled by a remote computer or other control system that is in communication with the site. The latter case results in a "remote control, automated site" where the control settings can be changed from the remote location.

Often irrigation district personnel can operate a remote control site (automated or not) from home or from the field using a modem equipped laptop computer.

Automation has been an integral part of irrigation rehabilitation in Alberta and has included pump control, reservoir control, upstream level control, downstream flow control, and

Supervisory Control and Data Acquisition (SCADA). Current trends are towards more central control and automated water ordering systems.

Figure 25: Automated (120VAC) Check/Drop Structure

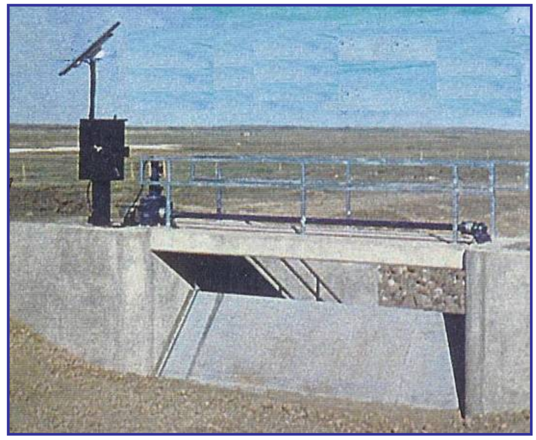

Figure 26: Automated (24VDC Solar) Check/Drop Structure

The first irrigation remote control was implemented in 1980 at an irrigation pump station. Controls consisted of remote access to the site with capability to turn pumps on and off and determine pump status. This was followed in 1982 with reservoir level control at Stafford Reservoir and then rapidly followed with upstream level control automation at drop leaf gate structures.

Early automation efforts utilized simple control algorithms and lookup tables due to hardware limitations. Subsequent efforts, using powerful control hardware, utilized Proportional Control and Proportional Integral Derivative (PID) control loops for better control response.

Considerable effort was spent optimizing the control algorithms to minimize gate movements and still achieve desired control limits. This is particularly important when using the limited energy available at solar powered sites (Figure 26). Best results were obtained where scale models were tested hydraulically to see how well they fit the proposed control algorithms, prior to implementation in the field.

The greatest success has been achieved with the simplest automated sites. All complex installations have suffered from development problems, control algorithm behavior and nuisance alarms. C.M. Burt (2004) documented similar experiences in the U.S.A. and as he stated: "*. . . more than anything else, perhaps the failures were caused by lack of attention to detail. In irrigation automation, the devil is in the details.*"

Programmable logic controllers (PLC's) and personal computers (PC's) are both being used for irrigation control. Gate positions are usually measured using multi-turn potentiometers with 12 bit analog-digital (A-D) converters. A few gates have been installed with optical encoders. Water level is measured with differential pressure transducers or ultrasonic level transmitters. Many districts monitor all return flow and inflow channels using Lakewood data loggers and

Miltronics probes. Even small irrigation districts have made use of this automated data collection technology (Figure 27).

Figure 27: Return Flow Monitoring: Mountain View Irrigation District

Inter-site and central site communication has typically been via telephone lines or radio links where sites are relatively close. SCADA systems have been developed utilizing radio, phone line and Internet data transmission and control. Consideration is now being given to data transmission via satellite. Both real time control and periodic communication connection have been used between sites and central offices. Graphical User Interfaces (GUI's) have been used to simplify information presentation and display site information.

Gate automation usually utilizes fail-safe alarm systems. Several efforts were made to achieve downstream flow control but to date; none have been satisfactory due to control algorithm limitations.

Equipment reliability has been a big issue and the major problem has been power surges due to lightning storms. A present trend is to use solar-cell-recharged 12 or 24 VDC batteries for powering gates and control equipment (Figure 26). This may improve equipment reliability and has the advantage of lower cost at small sites, especially those return flow measurement sites that are at remote locations.

BENEFITS OF THE IRRIGATION REHABILITATION PROGRAM

Farmers

The irrigation farmers benefit greatly. They have a reliable water distribution system that is effective and efficient. More land is in production as pipelines replace canals. As canals are relocated along legal boundaries, larger more effective irrigation and other farm equipment can be used. The amount of land affected by seepage and salinity has been greatly reduced. More land is served with the limited water supply and farmers who have pressurized water available see their annual pumping energy bills reduced. Closed pipelines also give irrigators more flexibility in how the water is delivered to them. This is a key need for modern automated farm irrigation farmers, as documented by C. M. Burt (2004).

Irrigation Districts

Irrigation districts have a system in place that is easier to operate, less expensive to maintain and makes more efficient use of water. Irrigation districts can now serve more acres with the limited amount of water they are allocated. These improvements were made possible, partly as a result of funds provided by the province.

Public at Large

Many communities rely on irrigation districts to supply their municipal water. They benefit from a more reliable water supply. Industry has located in Alberta providing jobs and value added processing. Water based recreational facilities abound in southern Alberta, most of which rely on irrigation water. Fish and wildlife groups have water in areas of the province, which previously had none. The North American Waterfowl Management Program bestows its "Blue Heron Award" on those who make a great contribution to the protection of waterfowl in North America. In Alberta, only four groups have received that award. They are the Western, Eastern, Bow River and St. Mary River Irrigation Districts, a testament to the fact that in addition to delivering water, Alberta's irrigation districts are also faithful stewards of the environment.

Private Industry

The benefits of the IRP extend well beyond the irrigated area of Alberta and many Alberta companies have benefited directly from the IRP. Precast concrete manufacturers, suppliers of raw materials, earth moving and pipeline contractors, consulting engineers and many others have a significant portion of their annual income from irrigation district rehabilitation.

The case of an Alberta manufacturer of PVC pipe could be used as a case study of what the program means to industry.

IPEX Inc. is a manufacturer of, among other things, PVC pressure pipe. IPEX was formed in 1992 with the merger of Scepter Mfg. and the pipe division of Canron. An IPEX vice-president saw opportunities in larger diameter pipe and surveyed Alberta's irrigation districts and responded to a challenge by the Eastern Irrigation District, which was basically "Build it, and we will buy it!" (Swihart, 1997)

As a result the company began making 30" (750 mm) pipe in 1987, 36" (900 mm) pipe in 1989, 42" (1,100 mm) pipe in 1998 and 48" (1,200 mm) pipe in 1999. Irrigation districts in Alberta have utilized all these sizes (Figure 28).

The large diameter pressure pipe, born to serve the irrigation market, now serves a varied market in North America and the world. The manufacturing of this large pipe aids greatly in keeping the plant, which has expanded from 75 to 130 employees, running year round and provides additional security to those employed at the plant. Without the large diameter pipe used by the irrigation districts, some of the employees would be laid off at certain times of the year.

A study prepared for IPEX showed the significant impact irrigation construction in general, and pipeline purchases in particular, has in Canada. For every $1 spent purchasing pipe, Alberta's gross domestic product increased by 82 cents and Alberta's labor income increased by 39 cents. Every million dollars spent on PVC pipe annually supports 12 jobs, half in the Edmonton manufacturing plant and half in associated industries. For every $100 spent on PVC pipe it was estimated that direct and indirect personal taxes paid to the province increased $5 and those personal taxes paid to the federal government increased $9.

IPEX's pipe manufacturing plant is located in Edmonton, over 250 miles (400 km) from the center of irrigation in Alberta. Edmonton is the site of the provincial government where the decisions regarding funding are made and it helps to have this excellent example of the economic impact of irrigation in the city.

Figure 28: Installing Large Diameter PVC Pressure Pipe

Another example of private industry involvement involves two of the North America's largest produces of frozen french fried potatoes. Within a period of months, Lamb Weston (a ConAgra company) and McCain Foods Limited, both announced they were building new french fry processing facilities in southern Alberta. Lamb Weston built its $100 million facility east of Taber and McCain Foods followed with its $94 million facility located between Coaldale and Taber. An example of the spin off benefits of these two plants is demonstrated by a Taber trucking firm purchasing 14 new semi-trailer units and the opening of a new truck-trailer repair business in this town of 8,000 people. In addition, Rogers Sugar Co. has recently invested tens of millions of dollars upgrading its sugar beet processing facilities, also in Taber.

The world class water distribution system, created in part with funds provided by Alberta's IRP, ensures that irrigation farmers will have the water to grow the crops needed by the local food processing facilities and ensures that these facilities will also have a suitable supply of water for use in processing the products.

Well aware of agriculture's contribution to the history of Alberta and its future contribution to the economic well being of the province, Premier Ralph Klein was on hand to officially help turn the sod for the Lamb Weston plant. At the time, he indicated that rather than enticing industry with direct grants, Alberta prefers to market what has commonly been called the "Alberta Advantage". By that we mean Alberta has a skilled, technically trained work force, the infrastructure (including water distribution infrastructure) and affordable energy necessary for industries to compete on the world scale and a tax structure that promotes private enterprise.

The Fraser Institute (established in 1974 as an independent public policy organization in Vancouver, BC) added data on the 10 Canadian provinces to data on 46 states contained in a US study conducted by the Cato Institute to monitor the fiscal performance of those states and provinces. The study focused on fiscally effective government, the general economic climate and assessed the tax and expenditure behavior of those governments in North America. Of the 56 jurisdictions monitored, Alberta finished in first place. Perhaps Alberta's commitment to assisting to provide a reliable and effective water distribution system to the irrigation districts, communities, recreational facilities and wildlife habitat in southern Alberta played a small role in Alberta's placing in that study.

OTHER ALBERTA INITIATIVES

"Water for Life" Strategy

Recognizing the importance of its water resources, Alberta has gone a long way towards developing a comprehensive strategy that will identify short, medium and long-term plans to effectively manage the quantity and quality of the province's water systems and supply.

In Alberta, like most irrigated areas of the world, irrigation is by far the largest consumptive user of water. Therefore the results of this strategy could have a major impact on the irrigation industry.

Water for Life: Alberta's Strategy for Sustainability develops a new water management approach and outline specific strategies and actions to address the province's water issues.

The *Water For Life* strategy is based on three key goals, or outcomes:

- Safe, secure drinking water supply,
- Healthy aquatic ecosystems, and
- Reliable, quality water supplies for a sustainable economy.

The latter outcome is of particular interest to the irrigation industry. In order to achieve that goal, Alberta is inventorying all potential water storage sites that have been studied in the past and using tools included in the *Water Act* to achieve efficient and effective use of water.

Because water is vital to all Albertans, in all areas and communities across the province, the Government of Alberta consulted with Albertans on the challenges and priorities for water management and supply, and sought fresh ideas for responsible solutions to those challenges.

This process is very similar to that suggested by Smith (2004) in a paper presented at the Irrigation Association's Technical Conference that year.

The consultation process had three major components. The first phase was completed in early 2002 when a small, diverse group identified the challenges associated with managing water in the province and several opportunities for improving it. These ideas provided the framework for the second stage of the process, where key stakeholders and all Albertans were invited to respond to the initial directions proposed by the ideas group. The third stage in the process was a Minister's Forum on Water, held in June of 2002. The forum involved 108 invited Albertans and experts.

Working with a panel of experts on water issues, Alberta Environment compiled the ideas and feedback heard through all three levels of the consultation process and developing a series of recommendations and a framework that serve as the provincial water strategy for sustainability.

As part of implementing the Water Strategy, the province has created the Alberta Water Council to advise the government on water management issues. At the basin level, Watershed Planning and Advisory Councils have been created and local Watershed Stewardship Groups are also active making improvements to their local lakes and streams.

Throughout the process the irrigation community has been well represented and, in many ways, been leaders in educating the public as to the value of water and the need to use it as efficiently and effectively as possible. With the improvements made both on-farm and in the irrigation infrastructure, the irrigation industry can show how they are now irrigating far more acres and producing far more crops while, at the same time, taking less water per acre out of the rivers than they did 20 years ago.

More information on "Water for Life – Alberta's Strategy for Sustainability" can be found at:

www.waterforlife.gov.ab.ca

Capital Planning Initiative (CPI)

Another unique Alberta initiative resulted from its decision, beginning in 1997, to develop a provincial wide capital planning strategy. Almost all governments are being subjected to increasing demands for funding for major physical infrastructure (roads, schools, health facilities, colleges & universities, water management infrastructure, etc.). The common issues of aging infrastructure and growth pressures (particularly in Alberta) might suggest the simple solution is simply to spend more money. However funds, in all jurisdictions are limited, so it is imperative that a systematic approach be used to identify the needs and plot a suitable course of action.

The key component of the CPI is to look at all types of infrastructure whether it is government owned (highways and major water resource infrastructure) or government supported (schools, health facilities and irrigation district infrastructure). This was viewed as a much better approach than just targeting the "big ticket" items (e.g. health and education).

All participants in the process were asked to develop an Infrastructure Management System (IMS) for their infrastructure. Again the irrigation districts of Alberta answered the call and, with assistance from AAFRD's Irrigation Branch, they developed and completed a complete IMS which not only catalogued all of the infrastructure owned and operated by the 13 irrigation districts, they also determined the infrastructure replacement cost, condition, utilization and functional adequacy of that infrastructure. The irrigation district IMS database is updated annually. In this way the funding needed to maintain the $2.5 billion worth of infrastructure can be calculated and the needs of irrigation infrastructure (even though it makes up less than 3% of the total infrastructure included in the CPI) is being adequately considered, along with the huge needs of schools, highways and health facilities.

In addition to assisting the irrigation industry in documenting its needs, the CPI process has proven to be a valuable way to shown other Albertans, most of who are not familiar with irrigation, what the value of that infrastructure is and what a large segment of the population it serves in one way or another.

CONCLUSION

This cost shared Irrigation Rehabilitation Program has worked extremely well over the years and provided the irrigation districts with the means to develop world-class infrastructure. Technology developed and used in Alberta has been exported to other areas of North America and the world.

The irrigation districts and Alberta Government have worked together for 35 years to develop that system, but much is still to be done. Some districts still have much of the district to rehabilitate and some work that was done (e.g. un-reinforced concrete lining) needs to be redone as better technology becomes available.

In many different ways the Government of Alberta has recognized the value of irrigation and took on the challenge issued by the irrigation districts. The road has not been easy and with fewer Albertans involved in agriculture all the time (even far less in irrigated agriculture), there were detractors along the way. As Alberta celebrates it centennial in 2005, our faith in irrigation seems to have been justified as we see crop production and processing of produce that is far beyond what our forefathers may have envisioned. The long-range program that is now in place has served us well and will continue to serve Alberta, and all of Canada, into the future.

2005 Alberta Centennial

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RELATED INTERNET SITES

www.agric.gov.ab.ca	AAFRD "Ropin' the Web"
www.waterforlife.gov.ab.ca	Alberta Environment's Water Strategy
www.aipa.org	Alberta Irrigation Projects Association
www.aquasystems.com	Aqua Systems 2000 Inc.
www.armtec.com/watercontrol	Armtec: Water Control Products
www.brid.ab.ca	Bow River Irrigation District
www.eidnet.org/local/aqueduct/	Brooks Aqueduct Official Home Page
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