AN INFRASTRUCTURE MANAGEMENT SYSTEM FOR ENHANCED IRRIGATION DISTRICT PLANNING

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ABSTRACT

The common issues of population and economic growth pressures and aging infrastructure, across the province of Alberta, indicated the need for some enhanced level of reinvestment in that infrastructure. The government-sponsored Capital Planning Initiative (CPI) was implemented as an on-going process improving the level and type of information provided to decision-makers, specifically related to a diverse inventory of all infrastructure that had a government-funding component associated with it. As a result of annual capital works funding provided to Alberta's 13 irrigation districts by the Government of Alberta, their works could be eligible for on-going and enhanced CPI funding.

In order to provide appropriate and effective information to the CPI process, an Irrigation District Infrastructure Management System (IDIMS) was developed. It not only provided a means to quantify the cost of aging irrigation infrastructure and its current condition, it also assisted irrigation districts in qualifying and quantifying the state of their works for their continual re-construction planning. A web-based interactive software package known as the *Irrigation District Web-based Infrastructure Management System (I.D.WIMS)* was developed and implemented, now providing a common reference for consistent evaluations on the need for and extent of capital re-investment from one district to another.

INTRODUCTION AND BACKGROUND

Infrastructure and Alberta's Capital Planning Initiative

The entire infrastructure that the Government of Alberta has some form of financial obligation or commitment to totals approximately $95 billion (CDN). This includes "owned" infrastructure such as highways, government offices and water management headworks, as well as "supported" infrastructure (those works owned by other agencies or municipal authorities but for which the Alberta Government does provide on-going capital funding support). The latter includes such facilities as schools, hospitals, rural roadways and irrigation district infrastructure. Recognizing that sustainable infrastructure is critical to Alberta's

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ability to continue its strong economic development, the Government initiated a process to evaluate the condition and use of that infrastructure that it had some responsibility for and to derive a current replacement cost and projected life for those works. Therefore, a system to satisfy those objectives, with respect to irrigation district infrastructure, was developed in a partnership between the Irrigation Branch of Alberta's Department of Agriculture, Food and Rural Development (AAFRD) and the organized irrigation districts within the province.

Irrigation In Alberta

There are 13 organized autonomous irrigation districts in Alberta, collectively supplying water to approximately 1.325 million acres (536,000 ha) of assessed irrigation land in the southern region of the province. In addition, there are approximately 285,000 acres (115,000 ha) of land irrigated across the province through what are referred to as privately licensed and individual water user-developed irrigation projects. Irrigation districts are particularly characterized by their extensive infrastructure and their operation under provincial legislation known as the *Irrigation Districts Act.*

Each of the districts has its own somewhat unique history of development, but, in general, they have been in existence for nearly one hundred years or more. As a result, aging infrastructure has been an issue that has been on the forefront of both irrigation district and government agendas for some time. In the first half of the 20th century, conveyance works were all constructed as unlined open earth channels, many difficult to maintain and much of it plagued with extensive seepage problems. By the beginning of the 21st century, the nearly 7,700 kilometers of water delivery works had been significantly up-graded to a point where nearly 30 percent of that length had been replaced with buried pipelines and an additional 25% rehabilitated as open channels lined for seepage control.

Irrigation Rehabilitation Program. The Alberta Government recognized, many years ago, that the irrigation water management infrastructure in southern Alberta did more than just convey water to irrigation farmers. It not only supported a diversified irrigated agriculture and value-adding industry that promoted regional development, it also conveyed water for municipal purposes to many rural communities, for various industrial uses, for other agricultural purposes (e.g. intensive livestock operations), as well as for recreation and wildlife habitat enhancements.

Therefore, in 1969, the provincial government initiated a capital works funding program that would, on an annual basis, provide cost-shared funds to the irrigation districts to assist them in rehabilitating their respective works in a sustainable fashion. Today, this program, currently known as the Irrigation Rehabilitation Program (IRP), provides a minimum of $19 million (CDN) per year to the 13 districts, to be matched, on a 75:25 cost-shared basis, with $6.33

million (CDN) of irrigation district funding. (Total IRP funding = approximately $19/ac/annum.) It is critical, then, to be able to assess the current state of this infrastructure, qualifying and quantifying the condition of the un-rehabilitated as well as the rehabilitated, particularly after an investment toward the latter of some $700 million (CDN) over the last three decades or so.

INFRASTRUCTURE INVENTORY

In order to adequately develop the required Irrigation District Infrastructure Management System (IDIMS), providing a comprehensive assessment of the current state of the irrigation district works, it was necessary to first develop some system of component identification. Fortunately, a major study to evaluate the opportunities for future irrigation growth in Alberta (Irrigation Water Management Study Committee 2002) was just concluding when this infrastructure evaluation initiative was implemented. As a major component of the water management study, a complete inventory of all irrigation district infrastructure was developed within a GIS application. This was required in support of the detailed water management modeling carried out through the Irrigation Demand Model (IDM) (USCID/EWRI 2002). Now, each year, in consort with the irrigation districts, this spatial and attribute database is up-dated to reflect current configurations and components. This system, referred to as the Irrigation District Infrastructure Information System (IDIIS), contains a wide variety of descriptors concerning three basic groups of infrastructure types, namely:

1) Conveyance works – 7,640 kilometers of open channels and pipelines, made up of more than 10,000 reaches (line segments), delivering irrigation water to more than 13,000 farm turnouts.
2) Drainage works – 282 kilometers of constructed and 3,887 kilometers of natural open channel and pipeline drains, made up of approximately 2,500 reaches (line segments), collecting unused or returned system water from the irrigated areas.
3) Major structures – 163 uniquely identifiable structures such as dams, reservoir headgates, pump lift stations, main canal drop and check structures, and the like.

Some of the principal infrastructure descriptor attributes that are attached to each line segment (reach) are:

- Segment or structure no.
- Land location
- Type of material
- Capacity
- Type of works
- Pipe diameter
- Length
- Purpose of works
- Type of construction

Figure 1 is a graphical representation of the identification and classification of typical works, as stored within the IDIIS GIS shape files, uniquely identifying each canal or pipeline segment, the type of construction, turnout structure locations, etc. A segment is defined as a continuous length of linework that has exactly the same attribute data attached to it.

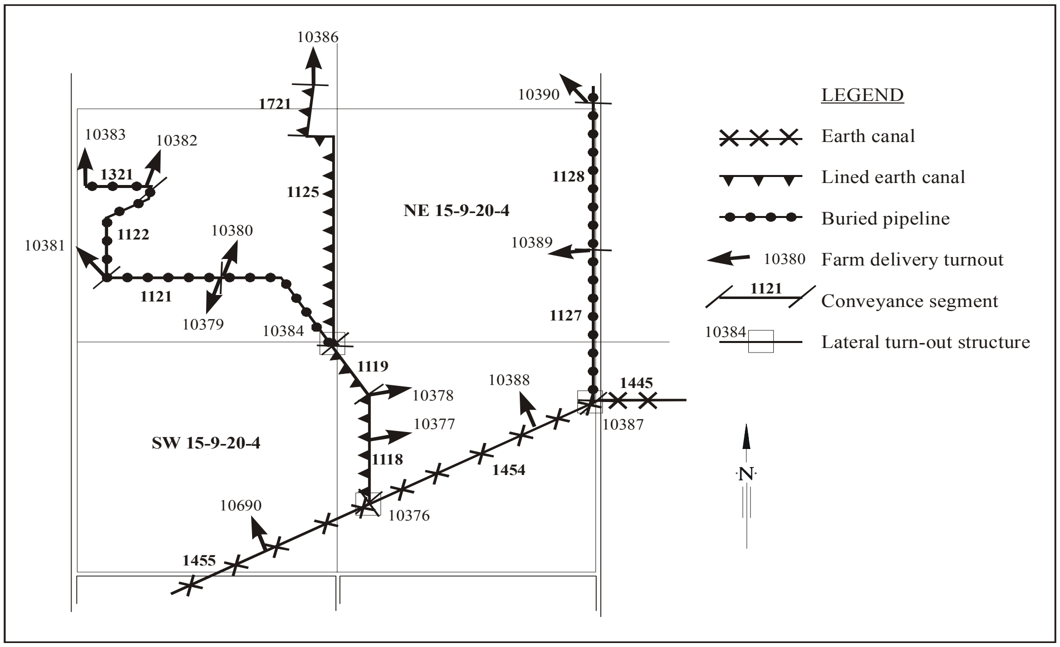

Figure 1. The IDIIS spatial linework and attribute information assignments.

Replacement Cost

In addition to quantifying and qualifying the physical inventory of the existing infrastructure, the other major undertaking required the development of a current replacement cost for each type of works and construction-type identified. This was critical in addressing future capital planning requirements. The technical committee, made up of AAFRD and irrigation district staff that were appointed to develop and implement the IDIMS program, derived current replacement costs that are up-dated each year. Based on numerous works rehabilitation contracts that had been completed in the previous year or two and the experiences of the various irrigation districts, overall average construction costs for all districts, per unit length of works, were agreed upon. These were tabulated by type of construction and by flow capacity. Table 1 summarizes the costs initially applied in the first year of the project (2001). Each year thereafter, these values have been adjusted based upon the annual construction cost index, reflecting inflation through the prior year.

Although, for example, the types of construction of open channel conveyance works were divided into five different groupings, it was agreed that all replacement channels would be assumed to be armored, whether they were

Table 1. Typical unit replacement costs for conveyance works.

CAPACITY of WORKS (cms)	REPLACEMENT COSTS by TYPE OF CONVEYANCE WORKS				
	Earth Canal* ($/m)	**Lined Canal** ($/m)**	**Armored Canal ($/m)**	**Lined & Armored Canal ($/m)**	**Concrete Canal** ($/m)**
55.0 - 100.0	500	800	500	800	n/a
30.0 - 54.99	400	700	400	700	n/a
15.0 - 29.99	300	500	300	500	n/a
6.0 – 14.99	225	380	225	380	380
3.5 - 5.99	175	335	175	335	335
1.5 - 3.49	150	300	150	300	300
< 1.5 ***	$1,000/ac	$1,000/ac	$1,000/ac	$1,000/ac	$1,000/ac

* Replacement costs assume future replacement channels will be armoured.
** Replacement costs assume future replacement lined channels will be armoured.
*** Replacement costs assume future works replacement will all be developed with a variety of pipeline systems.

lined or unlined. It was also assumed, for cost determination purposes, that all existing open channels with a current design capacity of 50 cubic feet per second (1.5 cms) or less, would, at the time of replacement in the future, be replaced with a buried pipeline. On this basis, as illustrated in Table 1, respective replacement costs were assigned.

One of the exceptions to the above concept regarded the costing of pipelines. Due to variable topography conditions, it was recognized that pipeline costs could vary significantly from project to project and from one district to another. Again, after sampling numerous recently constructed pipeline projects, it was generally agreed, the first time that replacement costs were derived, that pipeline costs averaged approximately $1,000 per acre served. Nonetheless, in order to effectively cost out each unique segment of pipeline identified within the IDIIS, there needed to be some correlation of cost with the attribute of the *flow capacity* of the works. Therefore, twenty or so recent pipeline installation projects were assessed for their project costs and as proportionally distributed according to their various flow capacities. This resulted in about 85 different flow rate and cost relationships. Through regressional analysis of these data points, a representative cost equation was derived, as presented as Equation 1.

As a result, for any given segment of pipeline (or future pipeline) of a specified length, the replacement cost value of that pipeline segment could be calculated.

$$C_R = 50 + (240 \text{ x } Q) + (80 \text{ x } Q^{0.5}) \quad (1)$$

where: C_R = Replacement cost for a pipeline for a given capacity ($/meter);
Q = Rated capacity of the pipeline segment (cubic meters per second).

Similar replacement cost tables and replacement cost equations were derived for constructed and natural drainage works to arrive at a full replacement value of those types of works. For the major structures, an engineering consultant was contracted to derive the current replacement values of each individual structure, applying a consistent costing protocol across all districts.

PHYSICAL STATE OF THE INFRASTRUCTURE

Under the Capital Planning Initiative, all infrastructure was to be evaluated according to three different classification parameters.

1) *Condition* - The overall physical state of a given component of works, relative to its original design and construction, rated as either *"Good", "Fair"* or *"Poor"*.

2) *Functional Adequacy* - Qualifies works as to whether or not a specific segment or component:
   - Has sufficient capacity to meet anticipated demand;
   - Provides an appropriate or realistic level of service to water users;
   - Can be maintained with reasonable access and at reasonable cost;
   - Provides for efficient operations and water use; and
   - Minimizes parcel severance or interference to field farming operations.

   Irrigation works are classified as to their *functional adequacy* by assigning a simple rating of ***Yes*** (adequate) or ***No*** (not adequate).

3) *Utilization* - Quantifies infrastructure as to the extent it is used, relative to its designed purpose. Currently, for irrigation district works, a single overall utilization value for all infrastructure components within an individual district is assigned. It is derived as a ratio of *annual actual irrigated area to assessed irrigation area* for that respective district. This qualifier is now being considered for a more in-depth quantification by deriving more specific utilization values for individual works components.

Condition of Works

For each type of infrastructure, specific criteria were established to rate the physical condition of each component of those works. For open channels, a point rating system was devised that would consider four different physical factors and assign a point value to each given line segment (reach). The better the condition of a channel, the higher the point rating that was assigned. Open channels were evaluated according to the following criteria.

- <u>Bank Condition</u> – Cross-section as affected by erosion, slumpage or livestock damage. (Maximum – 6 pts.)
- <u>Control Structures</u> – Integrity of structure(s) and effectiveness at controlling and regulating flows. (Maximum – 6 pts.)
- <u>Seepage</u> – Impact of water loss. (Maximum – 6 pts.)
- <u>Potential for Failure</u> – Washout potential, scored highest for lowest level of risk. (Maximum – 6 pts.)

Overall points rating:	Good	-	18 to 24 points
	Fair	-	11 to 17 points
	Poor	-	4 to 10 points

Similar rating systems were applied for pipeline conveyance works as well as for both open channel and pipeline drainage works. A more unique set of assessment criteria was developed for those works classed as *major structures*, because of their greater diversity and stand-alone functions.

COLLECTING AND COMPILING THE DATA

In collaboration with the 13 irrigation districts, AAFRD established the common spatial and attribute databases that everyone would work from, while the irrigation districts took care of carrying-out the actual condition evaluations and submission of their findings. It was understood by all parties that the assessments being performed would be carried out in an objective fashion, recognizing the significant investments that the Alberta Government had already committed to in rehabilitating the irrigation works through the past 30 years or more.

A Common Interface for Data Entry and Reporting

AAFRD had a stand-alone software package developed that would allow for easy entry of condition and functional adequacy evaluation data corresponding for each unique reach of conveyance or drainage works, or for each major structure identified within the IDIIS shape files. Further, for easier exchange of required or desired information, the software application was developed as a web-based system, referred to as the *Irrigation District Web-based Infrastructure Management System (I.D. WIMS).*

I.D. WIMS was set-up to have all of the relevant GIS shape file and attribute data hosted on a single common server, accessible to all parties via the Internet. Figure 2 illustrates how all 13 irrigation districts became connected for the compilation of this information. It is important to note that each irrigation district could only access data attributable to their respective works and similarly only input data that were relevant to the database representing their respective district. This applied to both data input and reporting output.

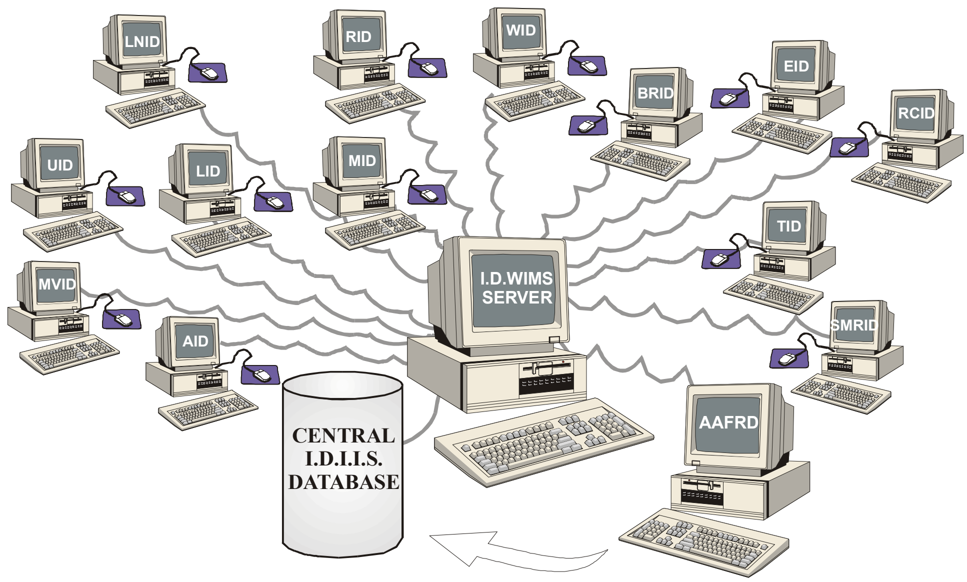

Figure 2. Irrigation district server interface, through *I.D.WIMS* software.

The GIS component of the application was developed using the ESRI MapObjects software components, which provide map-oriented graphical user interface features. Segment and structure data are presented in tabular format for data input and review. The application itself was built as a “desk-top” operating module that only required access to the Internet to download the district-specific server data files and to up-load and synchronize up-dated evaluation information, entered at the local desktop, with the host server database.

<u>Data Entry at the District Level</u>. As the infrastructure component characteristics were already embedded within the attribute databases, districts only needed to (and only authorized to) input condition and functional adequacy assessment data. The structure and security also allowed them to add some optional information such as their own unique works naming conventions and the details of rehabilitation work carried-out themselves, outside of the IRP program. AAFRD staff had “view only” access to the data and therefore could not make any data adjustments unless specifically assigned to do so by a given irrigation district.

<u>Information Reporting at the District Level</u>. Because *I.D.WIMS* was a stand-alone application at the district level, each irrigation district could obtain a variety of district-specific information reports without having to access the web application component, assuming that the data synchronization with the host server was up-to-date. In addition to summarizing the condition of a district’s works, these reports would also quantify a number of other details about the local infrastructure, in both tabular fashion or graphically in the form of thematic maps.

Reports express the information relative to both the extent (e.g. length) of works or the projected replacement cost. Table 2 provides an example of a query report for the Bow River Irrigation District (BRID), available at the local district level.

Table 2. Overall summary of BRID conveyance works by construction type.

Construction Type	Total Length		Total Replacement Cost	
	(km)	% of Total	($M)	% of Total
Open Channel - Earth Only	409.65	39.00%	$81.952	29.22%
Open Channel - Earth & Armored	1.00	0.10%	$ 0.150	0.05%
Open Channel - Concrete Lined	40.18	3.83%	$ 10.495	3.74%
Open Channel - Lined w/ Earth Backfill	164.56	15.67%	$ 46.027	16.41%
Open Channel - Lined w/ Earth Backfill & Armored	210.31	20.02%	$95.445	34.03%
Pipeline - Open or Closed	224.67	21.39%	$46.426	16.55%
Overall Totals	1,050.38	100.00%	$280.496	100.00%

In addition to many other reporting information formats, similar tabulation, as in Table 2, can be obtained and that provide the lengths, replacement costs and proportions of each relative to the *good, fair* and *poor* condition assessments.

Information Reporting at the "Server" Level. A wide variety of "roll-up" reports can be generated at the host server level, particularly ones that provide summaries that include all 13 districts and the cumulative totals thereof. Table 3, as one example, provides a final summary tabulation of the condition of all works for all districts. Figure 3 graphically illustrates the proportional distribution of works condition of all irrigation district conveyance works, according to construction type (EC = Earth Canal; EAC = Earth & Armored Canal; LCEB = Lined Canal w/ Earth Backfill; LCEBA = Lined Canal w/ Earth Backfill & Armored; CLC = Concrete-Lined Canal; P = Pipeline) and as measured relative to replacement cost.

Table 3. Summary of the condition of all works for all districts.

Category of Works	Replacement Cost ($M) by Condition Rating			TOTAL Value ($M)
	GOOD	FAIR	POOR	
Conveyance	932.31	790.59	205.65	1,929.55
Drainage	14.07	19.38	9.35	42.79
Major Structures	366.45	202.78	4.26	573.49
TOTAL	**1,312.83**	**1,012.74**	**220.26**	**2,545.83**

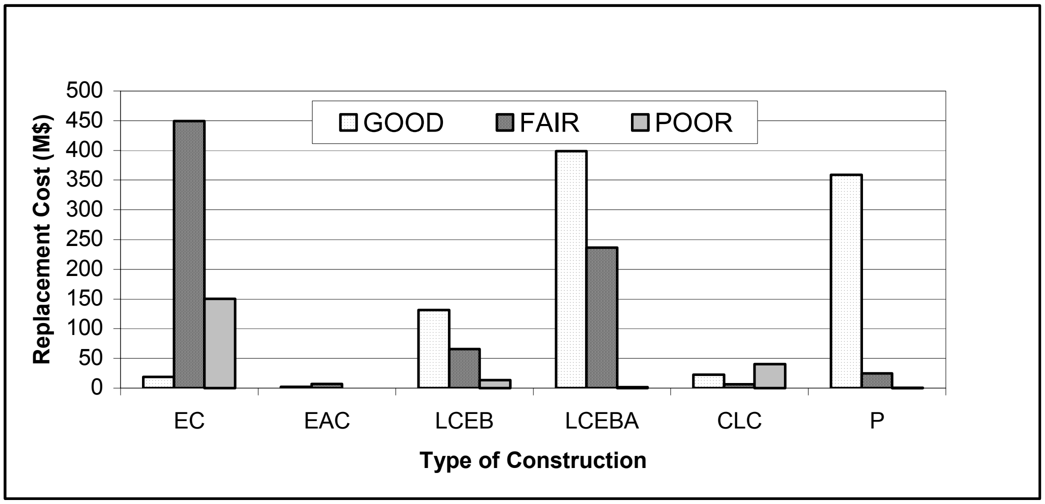

Figure 3. Proportional distribution of all district conveyance works' condition.

CONCLUSION

The IDIMS / I.D.WIMS applications provide an effective means of supporting irrigation infrastructure capital asset management and planning. For example, based on the condition assessment information compiled, it is evident that something in the order of $220 million will need to be invested during the next five to ten years to replace those works currently rated to be in poor condition. Further, during the subsequent 10 to 30 years, reinvestment slightly in excess of $1 billion will be required to rehabilitate those works that are currently rated in fair condition. Similarly, in the 30 to 50-year horizon, a reinvestment of $1.3 billion will be necessary to replace that infrastructure that is currently rated in good condition.

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