Town of Coaldale
County of Lethbridge
St Mary River Irrigation District

MALLOY DRAIN MASTER DRAINAGE PLAN

FINAL REPORT

(1755-045-00)

PERMIT TO PRACTICE
MPE ENGINEERING LTD.
PERMIT NUMBER: P 3680
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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Prepared by:

MPE Engineering Ltd.

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EXECUTIVE SUMMARY

1. INTRODUCTION

The area known as the Malloy Drainage Basin is located in and around the Town of Coaldale and covers an area of approximately 21,662 hectares. The area is drained through a complex series of natural and constructed canals and drains with the majority of this water discharging into Stafford Lake Reservoir via the Malloy Drain. The area historically has experienced flooding during significant rainfall and snow melt events, most notably from the events experienced in 2002 and 2005.

These two storm events, plus the recurrent flooding experienced since the area was settled, prompted the County of Lethbridge, Town of Coaldale and the St. Mary River Irrigation District jurisdictions to form a steering committee to investigate alternatives to help alleviate flooding and set design parameters for future development within the Basin. This report is the result of a study conducted by MPE on behalf of the steering committee.

The jurisdictional members of the steering committee represent different sectors of the local population and have different goals and objectives. The varied goals and objectives have been compiled by MPE through interviews and committee meetings. The three jurisdictions realize that the pressures of economic growth and land development will not subside, and guideline improvement strategies must be developed and put in place that deals with stormwater for any future developments.

2. STAKEHOLDER INTERESTS

For several decades, drainage has been a major concern in the Malloy Drainage Basin with several agencies and landowners coming together to resolve issues as they arise. Previous storms, whether they occur from rainfall, or rapid snow melt, have caused significant flooding. There has been past efforts to alleviate flooding in localized areas but a solution to the overall problem has yet to be fully addressed.

The purpose of this section is to express the major interests of the affected stakeholders so that the problem can be sufficiently identified and communicated. Each stakeholder has specific interests regarding legislative laws, jurisdiction, responsibilities, and an overall need to move forward to help resolve all the issues.

The following is a synthesis of each stakeholder's interests and objectives:

Alberta Environment

Alberta Environment (AE) is the regulatory authority for stormwater management in the Province of Alberta and is responsible in the development and enforcement of the Environmental Protection and Enhancement Act and the Water Act.

Their interest in this project is to provide technical expertise in identifying and clarifying the legislative requirements with respect to stormwater management. In addition to its role as a regulator, AE may provide financial assistance through various Provincial grant programs to address study and capital costs. AE has contributed financially in past, through the AMIP Program. However, currently there are no applicable funding programs from AE.

AE works closely with all the stakeholders identified in this study and would have the greatest appreciation overall with respect to the wants and needs of each respective stakeholder.

Alberta Transportation

Alberta Transportation (AT) is responsible for highways and associated bridge infrastructure in the study area. The care of water with respect to highway and bridge infrastructure includes stormwater and irrigation water. The hydrology of the area is an integral factor when designing road drainage systems and bridge structures.

AT, may provide financial assistance through various Provincial grant programs to address capital costs of key structural components. For example, AT administers the Local Roads Bridge Program, supplying local agencies with funding to replace bridge structures approaching the end of their design lifespan.

Pertaining to drainage improvements, AT would consider funding larger capacity structures, should they be warranted, at replacement time.

Town of Coaldale

Like many vibrant smaller urban centres, the Town of Coaldale has significant development pressures due to residential and industrial growth. Many new subdivisions are naturally occurring on the outskirts of Town. The Town, which is situated in the center of the basin, has constructed numerous storm water detention facilities and conveyance pipelines to facilitate the movement of stormwater (the Town contributes approximately 8% of the stormwater within the Malloy Basin) through the Town. This stormwater also eventually ends up in the Malloy Drain System. Over the past several years, the Town of Coaldale has invested a considerable amount of resources into stormwater management and look forward to forming a partnership which will address immediate and long term stormwater management.

The Town receives as much runoff from adjacent rural lands as is generated within its own boundaries, which taxes its stormwater system. Yet at the same time, through its conveyance agreement with SMRID, the Town is obliged to detain all stormwater during a rain event, which results in large stormwater pond requirements. Options to remedy this situation are required.

The Town's primary interests and objectives are:

- Continue to grow and develop in a responsible and sustainable fashion;
- Identify and utilize existing stormwater discharge outlets. This currently occurs at the Cheese Factory Drain, the South Coaldale Drain and the east Coaldale Storm Pond;
- Use and enhance its internal stormwater retention facilities;
- Solidify a long term arrangement with the SMRID for the acceptance and conveyance of stormwater;
- Quantify the amount of stormwater it receives and handles from outside its boundaries;
- Develop storm release (post-event) standards for new development;
- Open to the creation of Regional Drainage Authority or Commission to administrate an overall stormwater plan between the Town of Coaldale, SMRID and the County of Lethbridge.
- Encourage the County of Lethbridge to continue with and enhance control of stormwater flow from its jurisdiction into the Town of Coaldale;

- Encourage the County of Lethbridge to adopt development standards addressing stormwater flows from new developments that may impact inflows into the Town of Coaldale;
- Participate in the implementation of a *Malloy Stormwater Management Plan* which will be shared and communicated to the local landowners and development industry for acceptance and conceptual buy in;
- Fully understand the operational issues with regard to the basin and how it impacts the SMRID and the County of Lethbridge;
- Share and communicate their internal operational procedures during periods of flood response with other stakeholders;
- Comply with all rules and regulations as legislated under the *Environmental Protection and Enhancement Act and Water Act*.
- Pursue all available funding opportunities.

County of Lethbridge

The County of Lethbridge has a particularly strong interest in finding solutions to the drainage problems in the Malloy Basin. Economic growth is occurring along the Highway 3 corridor between Lethbridge and Coaldale and this pressure to develop agricultural land will intensify. In addition, urban residents are moving to country residential subdivisions and are demanding the same level of services that Cities and Towns offer. Drainage from these new developments all eventually ends up in the Malloy Drain System. With the limited capacity of the system, there is virtually no room for additional runoff, and so guidelines must be established that can allow new development without significantly impacting the system.

In addition to mitigating flood damage, the County of Lethbridge is keen on forming a partnership with the Town of Coaldale and the SMRID so that its interests with regards to level of service can improve and continue to facilitate responsible and sustainable development growth in the area.

The County's primary interests and objectives are:

- Respond to property development pressures with a consistent and responsible stormwater plan in the basin area; particularly the Highway 3 corridor between the City of Lethbridge and the Town of Coaldale.

- Eliminate, alleviate or control overland flooding in areas which have experienced repeated events;
- Work to establish mutually accepted run off rates and design storm events and return periods;
- Fully understand the operational issues with regard to the basin and how it impacts the SMRID and the Town of Coaldale;
- Open to the creation of Regional Drain Authority or Commission to administrate an overall stormwater plan between the Town of Coaldale, SMRID and the County of Lethbridge.
- Participate in the implementation of a *Malloy Stormwater Management Plan* which will be shared and communicated to the local landowners and development industry for acceptance and conceptual buy in;
- Open to the creation of a “user fee” system for existing and new development;
- Share and communicate their internal operational procedures during periods of flood response with other stakeholders;
- Comply with all rules and regulations as legislated under the Environmental Protection and Enhancement Act and Water Act.
- Pursue all available funding opportunities;
- To ultimately develop a county-wide Stormwater Master Plan;
- Establish and adopt guidelines that can allow new development without negatively impacting the drainage system.

St. Mary River Irrigation District

The SMRID is the owner of the constructed drains within the Malloy Drainage System, and is a water supplier for agriculture, commercial, municipal and domestic use throughout the Malloy Basin. The drainage system was originally constructed in the early part of the century as part of the Irrigation delivery system. The system drains runoff from a drainage area of 21,662 ha. The drainage system has been utilized by the Town and the County to divert stormwater to Stafford Reservoir.

SMRID is concerned because the Malloy Drainage System was not designed to handle the level of development that has occurred within the basin. The volume of runoff will increase and steps need to be taken limit the amount of water being diverted into the drainage system and limit when this water can be diverted into the drainage system.

The SMRID wants it made clear that they are not a drainage authority. The SMRID is not responsible for the additional runoff that the Malloy System has received from the recent development, and therefore desires full compensation for any capacity upgrades it would make to the infrastructure. The SMRID is also concerned with the quality of water being diverted into Stafford Reservoir. (This report did not deal specifically with water quality.)

The SMRID's primary interests and objectives are:

- Preference is not to handle stormwater flows;
- Partner in the development of a drainage system to control stormwater volume and timing of flows into their system; preferably stored and released *post peak* event;
- Participate in the implementation of a *Malloy Stormwater Management Plan* which will be shared and communicated to the local landowners and development industry for acceptance and conceptual buy in;
- Eliminate, alleviate or control overland flooding in areas which have experienced repeated events;
- Fully understand the operational issues with regard to the basin and how it impacts the Town of Coaldale and the County of Lethbridge;
- Share and communicate their internal operational procedures during periods of flood response with other stakeholders;

Landowners

- Implement a solution to reduce the impact of overland flooding and duration of ponding on their lands.
- Understand each agencies respective roles during flood events;
- Receive clarification and direction for future development of lands;

3. RESULTS OF ANALYSIS

The 2002 storm occurred during the period of June 8th to 10th, 2002. Conditions prior to the storm were recorded as the wettest on record creating saturated soil conditions. During this period a total rainfall of 143 mm was recorded for the Lethbridge area. This storm has been classified as greater than a 1:100 yr storm event.

In 2005 two storm events were experienced, the first event happened in the June and a second event occurred in October which is unusual for this area. Rainfall records show that June 2005 was the wettest month on record, although the flooding and damage was not as wide spread as in 2002.

The study area has been examined in two aspects. Section 3 dealt with a technical analysis of the basin, its hydrology, and infrastructure. Then physical improvements to the system were evaluated. Section 4 discusses issues such as implementation of improvements, administrative bodies, future development, operational guidelines, and flood response planning.

Technical analysis first involved an evaluation of system hydrology. This task study included four major components:

- Identification of each major drainage catchments and major physical drainage constraints.
- Modeling of the individual drainage areas given the existing constraints, natural ponds/depression areas, Town of Coaldale Stormwater Management ponds and the Town's design release rates.
- Conveyance of stormwater flow via Coaldale Lateral, South Coaldale Drain, Upper Malloy Drain/Little East Lateral, Chin2 Lateral, and South Malloy Drain to Stafford Reservoir.
- Model calibration to generate runoff within sub-catchments of the Study Area similar to Associated Engineering Services Limited (AESL, 1979) Study for the 1978 storm.

Several storm scenarios were examined for the purposes of this report, including:

- The recorded events from August, 1978, June, 2002, and June, 2005.
- A continuous model covering the period 1960-1995

- Synthetic rain events based on the Chicago Storm, AB TRANS Runoff Depth Method, and Probable Maximum Flood (PMF)

The "Chicago Storm" event was used as the base storm in the modeling exercises where various scenarios for upgrading the infrastructure were examined. This storm is a common 1:100 year design storm that has been accepted by governing authorities throughout North America as a standard storm in determining instantaneous and total flows from a single-event storm. For the Malloy Basin, the Chicago Storm generates 109.9 mm of precipitation over 24 hours.

The modeling shows that the expected runoff and peak flows far exceed the existing capacity of many portions of the Malloy Drain. The available capacity for runoff of the Malloy Drain downstream of Highway 3 has been estimated at less than 15 m^3/s at some sections, while the modeling shows that a peak of 50 m^3/s could be expected from a 1:100 year storm.

Visually observed flooding areas generally coincided with the locations that the model showed the drain as lacking capacity.

The runoff amounts for different land uses and catchments within the study area are shown below in Table 3.5.

Table 3.5: Existing Catchment Areas Assumed in the Model and Runoff from the 100-Year 24-Hour Event (109.9 mm Rainfall)

	Modeled Areas				Actual Areas		
Area Breakdown	**Rural (ha)**	**Urban & Surrounding (ha) [Note 1]**	**Total Area (ha)**		**Rural (ha)**	**Town (ha) [Note 2]**	**Total Area (ha)**
To Malloy Drain N. of Hwy. 3	3,601	227			3,612	216	3,828
To E. Culverts N. of Hwy. 3	1,004				1,004		
To Hwy. 3 South Ditch	821	361			838.5	343.5	1,182
To Coaldale Lateral	2,986				2,986		
To S. Coaldale Drain	3,715	251			3,727	239	3,966
To Malloy Lake Direct	1,242				1,242		
Sub-Total	***13,369***	***839***			***13,409.5***	***798.5***	***14,208***
To Chin 2 Lateral	**7,454**				**7,454**		**7,454**
TOTAL AREA	**20,823**	**839**	**21,662**		**20,863.5**	**798.5**	***21,662***

	Town Only (ha) [Note 2]	**AT Highways (ha) [Note 3]**	**County Roads (ha) [Note 4]**	**HMQ & SMRID ROW (ha) [Note 5]**	**CPR & AB Rail (ha) [Note 6]**	**Remainder Rural (ha) [County]**	***Total***
Area Breakdown	**770**	**212**	**273**	**230**	**44**	**20,133**	***21,662***
Average Runoff (mm)	**72**	**77**	**78**	**73**	**61**	**30**	***32***
Total Runoff (m^3)	**554,400**	**163,240**	**211,575**	**166,750**	**26,708**	**6,039,900**	***7,162,573***
Runoff Coefficient (%)	**66%**	**70%**	**71%**	**66%**	**55%**	**27%**	**29%**
% of Total Runoff	**7.7%**	**2.3%**	**3.0%**	**2.3%**	**0.4%**	**84.3%**	**100.0%**
Total discharge, m^3	**1,263,000** (Note 7)	**5,899,573**					**7,162,573**
% of Total Discharge	**17.60%**	**82.40%**					**100.00%**

Notes:

1) Urban Area includes Town, SMRID ROW (13.25 ha) within the Town, Highway ROW (15.33 ha) within the Town, plus some immediate rural roads and land assumed as "near urban" fringe. The total urban area assumed in the model is 5 % more than the actual Town area, so modeling is slightly conservative to better account for small pockets of urbanization (acreages) within the rural areas.

2) Town area includes SMRID ROW (13.25 ha) and Highway ROW (15.33 ha) within the Town boundaries. Town area net of these areas is 770 ha.

3) AT Highway ROW area provided courtesy of County of Lethbridge GIS System.

4) County Roads ROW area estimated by MPE for developed county road allowances.

5) HMQ (Her Majesty the Queen) represents Provincial irrigation lands (24.8 ha) and is combined with SMRID irrigation ROW area (205.6 ha); areas courtesy of County of Lethbridge GIS System.

6) CPR ROW area (42.3 ha) and AB Rail ROW area (1.3 ha) are combined; areas courtesy of County of Lethbridge GIS System.

7) Includes runoff from Highway, CPR, and SMRID ROW within Town boundaries; and runoff from contributing upstream rural catchments.

Conclusions from Model – Town Issues

- Catchment into Cottonwood requires significantly more storage than available as confirmed by modeling results. To mitigate flooding potentials in the Cottonwood area, a Pond P17 (see Figure 3.1), and a large Cottonwood Pond (or a rural pond just upstream of Cottonwood Development Lands), are proposed to intercept the rural flows. Current modeling results suggest a pond of about 380,000 m^3 near the vicinity of cottonwood interim Pond (P12). Alternatively, an interceptor drain to carry rural stormwater to Coaldale lateral prior to entering Cottonwood area as a bypass concept has also been proposed (see Figure 3.17).
- The Town's East Storm Pond (P14) under the existing condition scenario with the current pond operating procedure (pump starting and running through the storm event duration) does not spill though comes to very close to spill. If this was operationally changed to pump only after a storm event (zero stormwater release reality), the pond would spill significantly (approximately 404,500 m^3). Under the build-out condition, with the pump running through the storm (current operating procedure), the east pond (P14) would spill ±18,000 m^3 and the Town South Ponds (P10) also require significantly more storage than available (286,740 m^3 = 375,250 m^3 less available volume of 88,510 m^3). There will be also a spill of about 19,000 m^3 from the Jennie Emery Pond (P10D) to the South Coaldale Drain. This is due to assumed additional land use development west of the Town and intensification within the Town.
- To avoid spill primarily in the areas south of Highway 3, both the existing ponds will have to be expanded or new ponds added in the "existing" developed areas, and all new developments and intensification areas must construct their own storm ponds. The existing ponds south of Highway 3 were originally designed on the assumption of 'flow through' ponds that released during storm events, and that the new zero stormwater release policy means the ponds are undersized. This is the biggest impact on the Town's existing ponds south of Hwy 3.
- Pond P5 proposed, immediately west of Range Rd. 20-3, needs to be developed to mitigate flooding in the Town and protect the Evergreen Estates development in the County.
- Prior to significant urban development occurring in the Cottonwood and Evergreen/West Coaldale areas, a more refined hydrologic modeling analysis accompanied by a more detailed ground-proofing is highly recommended to confirm storage required to protect future developments from flooding. Both areas are shown to be seriously deficient of storage based

upon the assumptions in this modeling analysis, and this should be mitigated before the area intensifies further.

- North Coaldale is not as great an issue as the Town North storm ponds are being designed for after storm release. These storm ponds are currently undersized, but upon implementation of all the phases, will be designed to contain the 1:100 year storm volume and with the provision of control gates closed during the storm event.

Conclusions from Model – Rural Issues

- South Malloy Lake is the main flooding area but does not affect large population. However, this location is prime location for a proposed pond to mitigate flooding in the basin.
- North and south rural areas, especially Ponds P2, P3, P4, P5, P6, and P16 locations are naturally flooded rural fields and in some cases (P4, P5 and P6) overtop roads. These areas are prime locations for natural flood easements, land purchase or as a last resort constructed ponds.

Conclusions from Model – Solutions

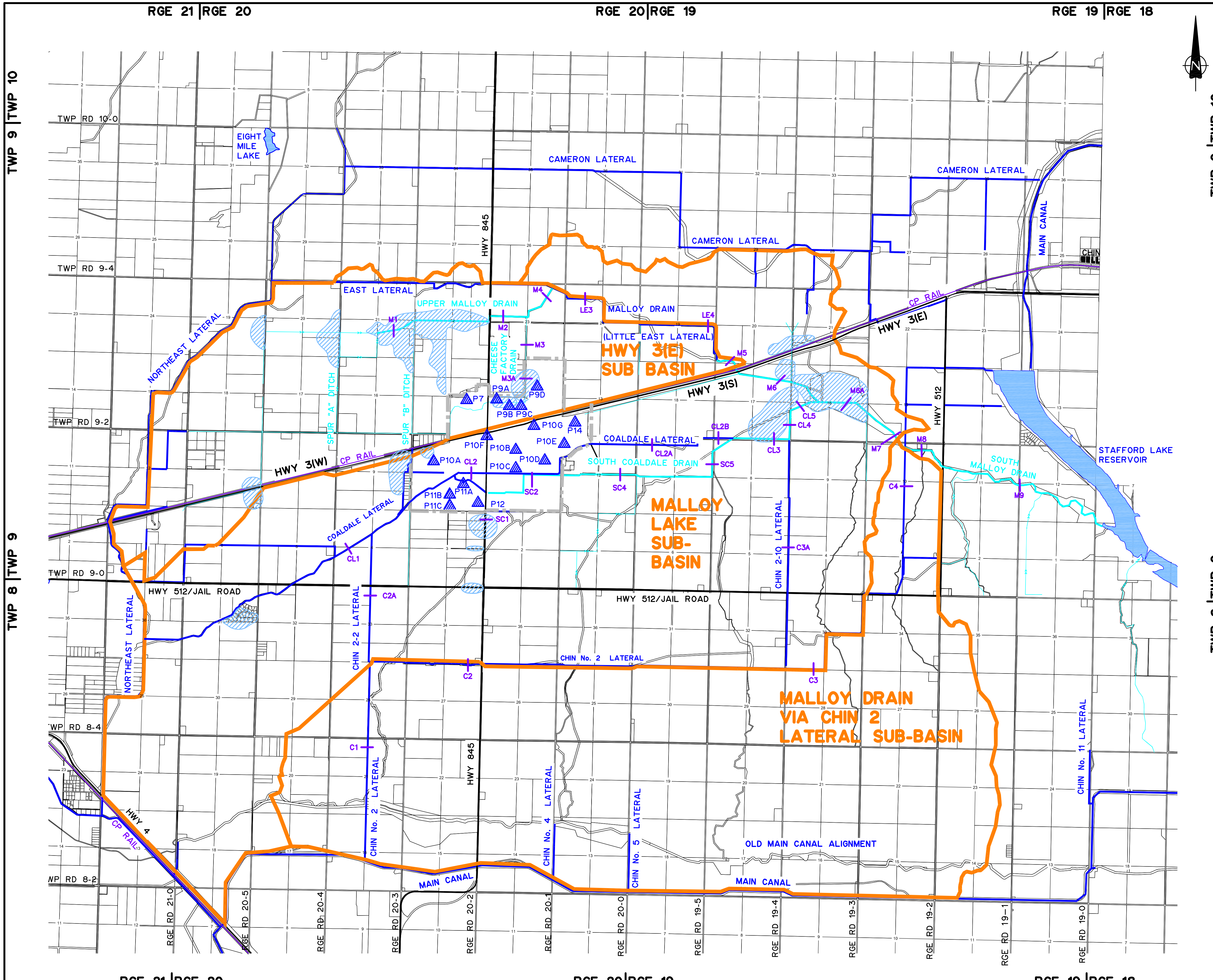
- Not all the existing ponds and natural storage (proposed pond) areas are in the proper place in the basin to attenuate flows during flood events and utilize the existing volume effectively. The possible use of Town’s abandoned reservoirs and lagoon site for future storage should be explored.
- Since the carrying capacity of the Malloy Drain south of Highway 3 is the critical bottleneck in the basin, providing storage upstream of the Malloy Lake at identified locations would mitigate frequent flooding.

Based on the information obtained from the model, four Alternatives were developed and investigated to help deal with the problems being experienced throughout the basin during a Storm Event.

Alternative 1 “Status Quo”

This alternative maintains the status quo. Storm events will happen and flooding will occur. Fields will be inundated and crops damaged. Some County roads will be overtopped, and possibly subject to damage. Claims for flood damage will be submitted to the appropriate agency and dealt with by insurance companies or through the legal system. The advantage of this alternative is that no capital expenditures are incurred. The disadvantage is that the problem never goes away and future generations will have to deal with this problem. Potential problems include further deterioration of infrastructure, exposure to lawsuits for damages, and discouragement of new development in the area. It will be difficult to obtain approval for any new developments because of concerns they would adversely impact landowners already subject to flooding. Future land development, and the associated economic contribution to the area, is hampered unless system improvements can be made.

Cost = flood damages + intangibles



LEGEND

LAND EXPECTED TO EXPERIENCE RECURRENT FLOODING

TOWN BOUNDARY

NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:40, 000 etc) ARE BASED ON 22" x 34" FORMAT DRAWINGS

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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
ALTERNATIVE 1: STATUS QUO

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.15

Alternative 2 "Buy Out Frequently Affected Lands"

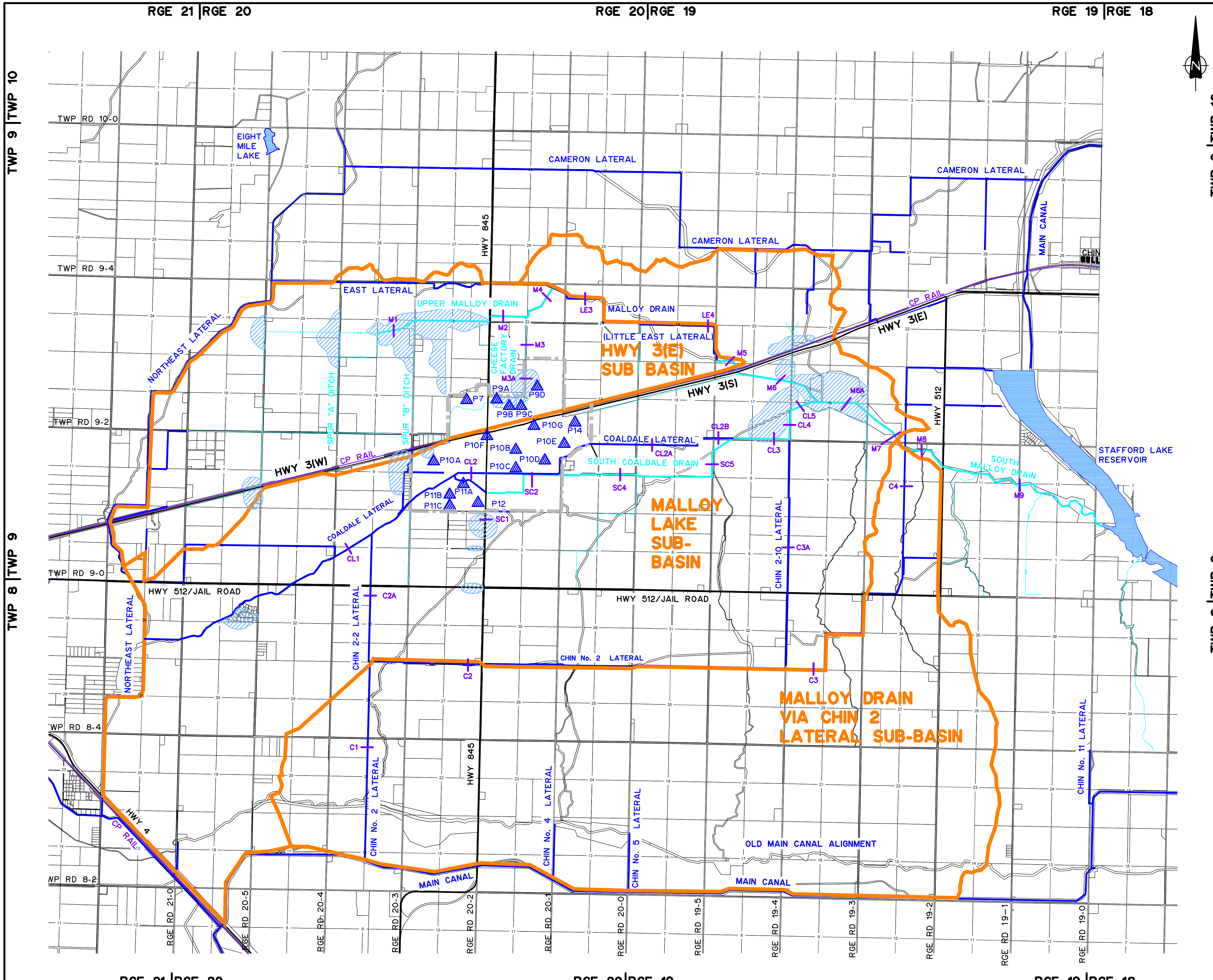
This alternative is similar to Alternative 1, in that no infrastructure improvements are made. However, property damage claims and legal action are largely avoided. This alternative does not address potential damage to roads and drainage works infrastructure. There also would be the same development constraints as in Alternative 1.

Cost = $7,208,000

Alternative 2A "Obtain Flood Easements on Frequently Affected Lands"

Same as above, except that flood-affected lands are covered by a flood easement agreement rather than outright purchase. These agreements may be more difficult to negotiate.

Cost = $1,450,000



LEGEND

FLOOD-AFFECTED LAND TO PURCHASE OR ACQUIRE EASEMENT

TOWN BOUNDARY

NOTE:
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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
ALTERNATIVES 2 AND 2A: PURCHASE FLOOD-AFFECTED LANDS

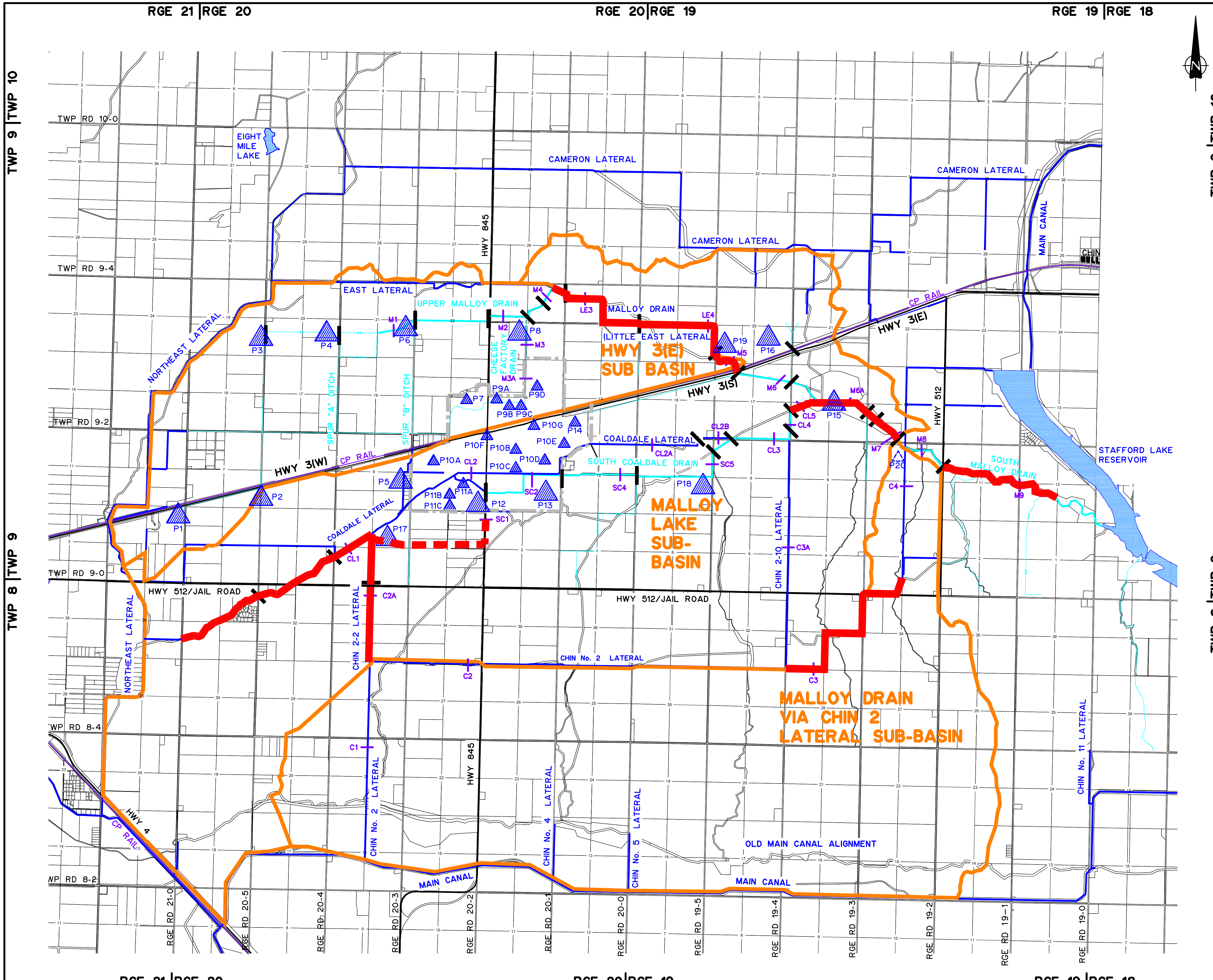
DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.16

Alternative 3 "Combination of Storm Detention Ponds and Enlargement of Existing Drainage Works"

Modeled in Scenarios 1-7, this Alternative allows for the construction of stormwater detention ponds throughout the basin in conjunction with increases in channel capacity. Large amounts of stormwater will be detained until the storm event has passed, and then water will be released slowly into the system as capacity permits.

The most cost-effective of these scenarios (see figure below) is a combination of 623,000 m^3 of new constructed storage and upgrading 26 km of channels to a capacity of 2.0 L/s/ha (1.43 cfs per 100 acres), at a total estimated cost of **$27,250,000**.

Cost = $27,250,000



LEGEND

- CONSTRUCTED DETENTION POND
- UPGRADED CHANNEL
- NEW CHANNEL
- UPGRADED CULVERT
- TOWN BOUNDARY

NOTE:
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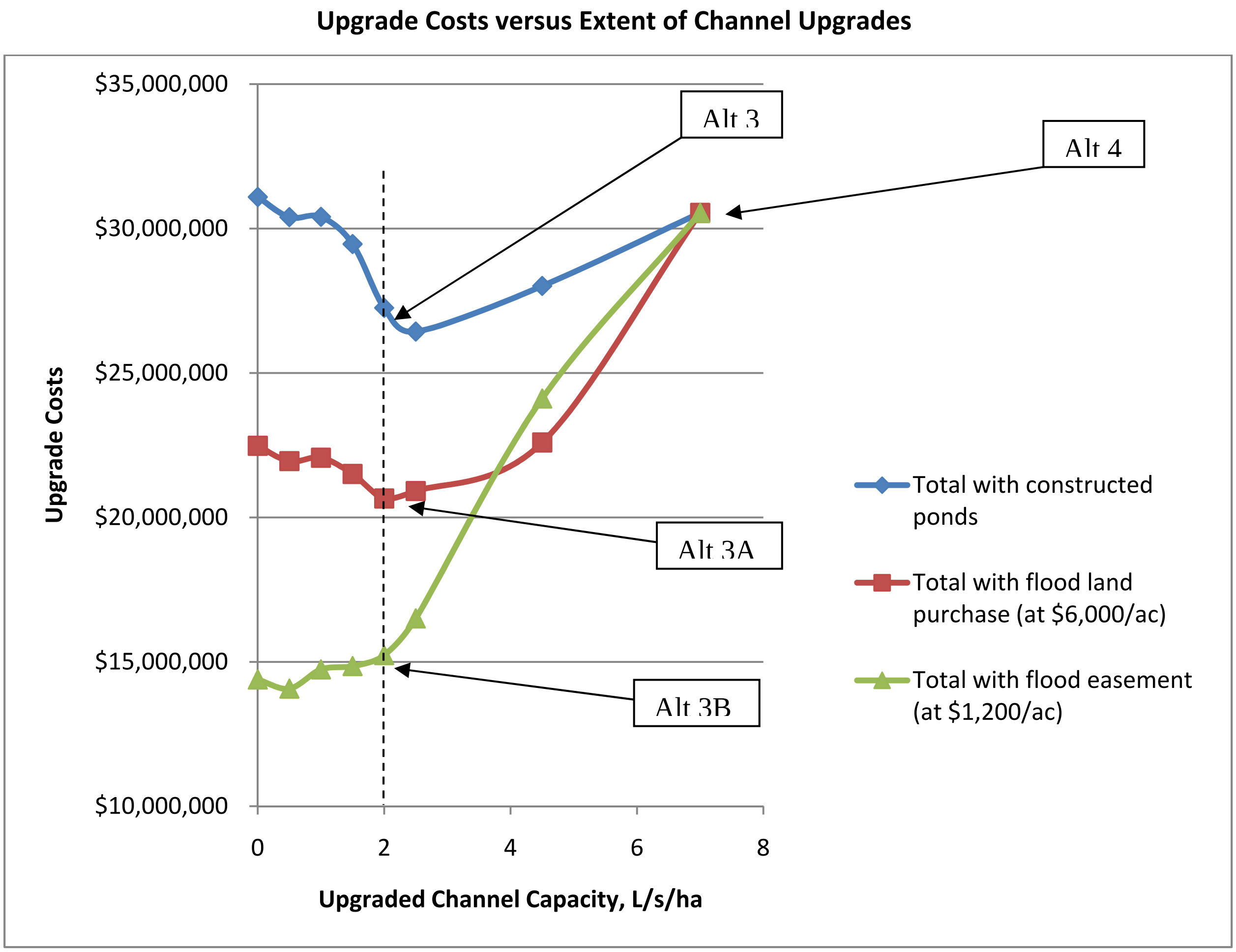
COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 5: CONSTRUCT COMBINATION CHANNEL UPGRADES AND DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.13



Alternative 3A

Purchasing land for natural ponding sites is about 50% of the cost of actually constructing storage at those sites, and where applicable would reduce the costs for this Alternative by $6,500,000.

Cost = $20,700,000

Alternative 3B

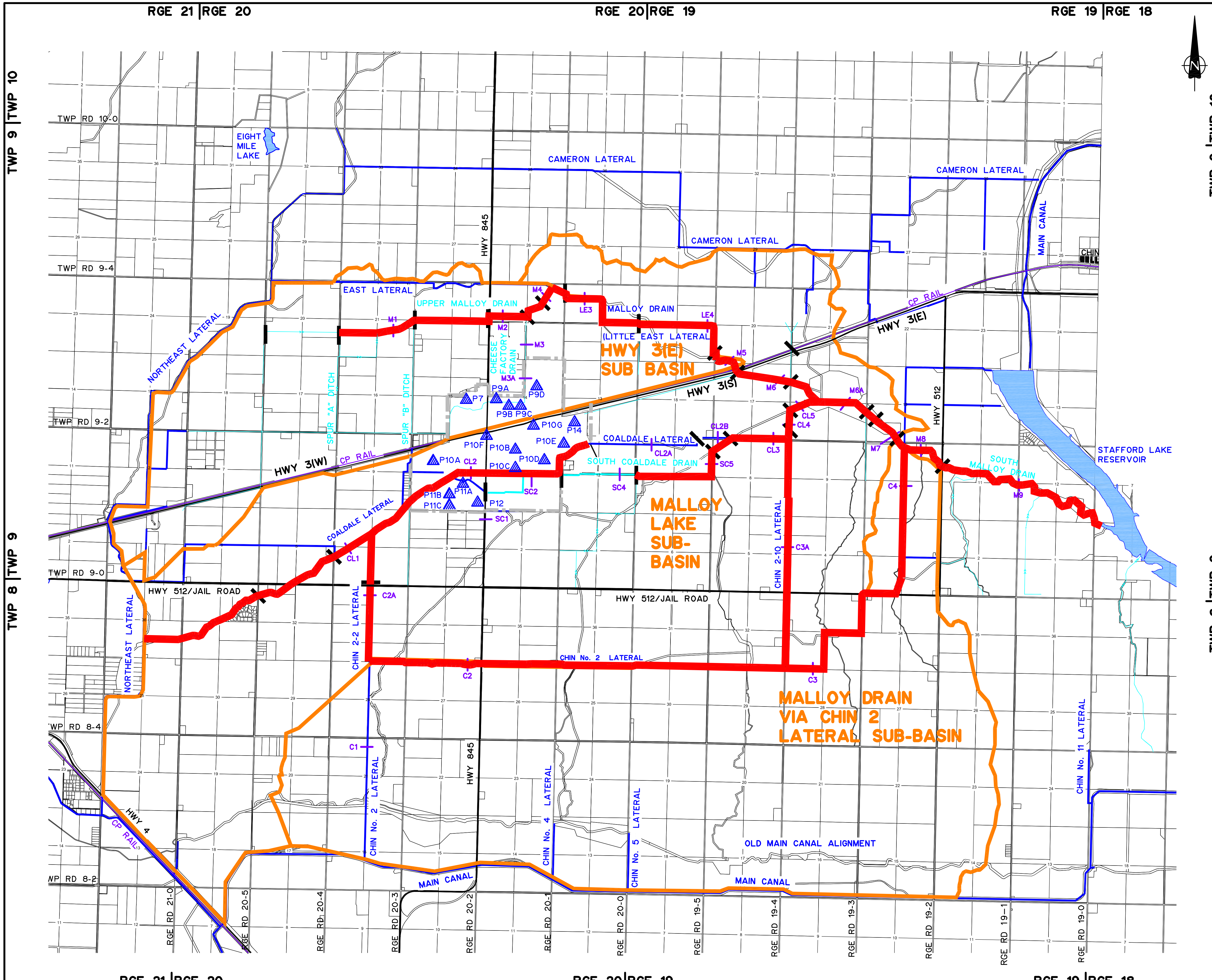
Acquisition of flood easements (whereby land ownership is unchanged) is about 15% of the cost of the constructed pond cost, and where applicable would reduce the total of this Alternative by $12,000,000. This does not include periodic payments (at a pre-agreed rate structure) when damages occur after flood event.

Cost = $15,200,000

Alternative 4 "Fully Expand the Malloy Drain"

The modeling (Scenario 8) shows that over 100 m^3/s can be experienced at the downstream end of the Malloy Drain, if the channels upstream are expanded to convey all the runoff. The size of drain required to handle this flow rate is very large and expensive to build and maintain. The estimated cost to construct a drain of this size is estimated at **$30,500,000**.

Cost = $30,500,000



LEGEND

- CONSTRUCTED DETENTION POND
- UPGRADED CHANNEL
- UPGRADED CULVERT
- TOWN BOUNDARY

NOTE:
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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 8: FULL CHANNEL UPGRADES AND NO NEW DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.14

Additionally, two alternatives were developed to deal with specific constraints with Town infrastructure.

Alternative 5 "Interception of Rural Inflow at Town Edge"

An estimated 54% of the Town's outflow (682,000 m^3 is the outflow from the 100-year storm event) is from runoff entering the Town from catchments outside of Town boundaries. This external runoff has impact on the Town's operation with respect to required storage and control of the storm effluent quality. A proposed concept to intercept the external runoff into new drains constructed along the Town's perimeter was examined.

Estimated costs to construct the interceptor drains are:

- North interceptor: $3,000,000
- South interceptor: $3,500,000

These costs are for channel construction only, and not including costs for accommodating existing roads and other infrastructure, which could easily double or triple the total cost.

Alternative 6 "Dedicated Outlet for Coaldale Stormwater to the Oldman River"

This alternative examined the possibility of diverting storm water from the Town of Coaldale north 14 km to the Oldman River via pipeline. The benefits of this alternative are reduced loading on the Malloy Drain, and potentially lower downstream infrastructure upgrade costs. To be practical, this alternative requires that runoff from upstream rural catchments be excluded from the pumped flow, through the construction of interceptor drains as in Alternative 5 above, or construction of storage ponds to collect the upstream rural runoff. The cost of the pipeline and pumping system (excluding the costs to interconnect all the Town's stormwater to a single pumping site), is estimated at **$2,800,000 to $5,300,000**, depending on the size of pipeline chosen, and the rate with which the Town would want to empty its storage ponds. Including the interconnections in Town, and the prerequisite Alternative 5, total cost is in the order of **$10,000,000 to $14,000,000**.

Cost/Benefit of Upgrades To Malloy Infrastructure

The following statistics were obtained courtesy of the Insurance Bureau of Canada (IBC), and the Alberta Emergency Management Agency (AEMA, which administers disaster recovery funding).

From IBC:

- $300,000 in insurance claims for June 6-8, **and** June 17-19 flood events, Alberta-wide.

From AEMA:

- Disaster Recovery funding for the June, 2005 event as follows:

Table 3.22: Disaster Recovery Funding

	Lethbridge County	Town of Coaldale	SMRID
Individuals	$230,718	$166,770	-
Municipality/Agency	$112,299	$27,827	$502,222

The AEMA figures were used to determine a very rough assessment of averted physical damages (i.e. benefits) resulting from upgrades to the Malloy drainage system. (The IBC information was considered too general to be applicable.) The following factors were considered:

- For the purposes of this analysis, the 2005 storm and the 1:100-year Chicago storm are roughly equivalent in severity and damage potential. Thus the AEMA values need only be adjusted for the size of the affected land base.
- Malloy Basin is 7.6% (21,662 ha/284,000 ha) of the size of Lethbridge County.
- Applicable damages within Malloy Basin of County

  = 7.6% x ($230,718+$112,299) = **$26,000**
- Town of Coaldale values do not require adjustment,

  = $194,600.
- Malloy Basin infrastructure is 3.5% (70 km/2000 km) of the length of the total SMRID infrastructure. Applicable damages within Malloy Basin of SMRID

  = 3.5% x $505,222 = **$17,600**

Therefore, total flood damages costs, extrapolated to 100 yr event, within Malloy Basin

=$26,000 + $194,600 + $17,600 = **$238,000**

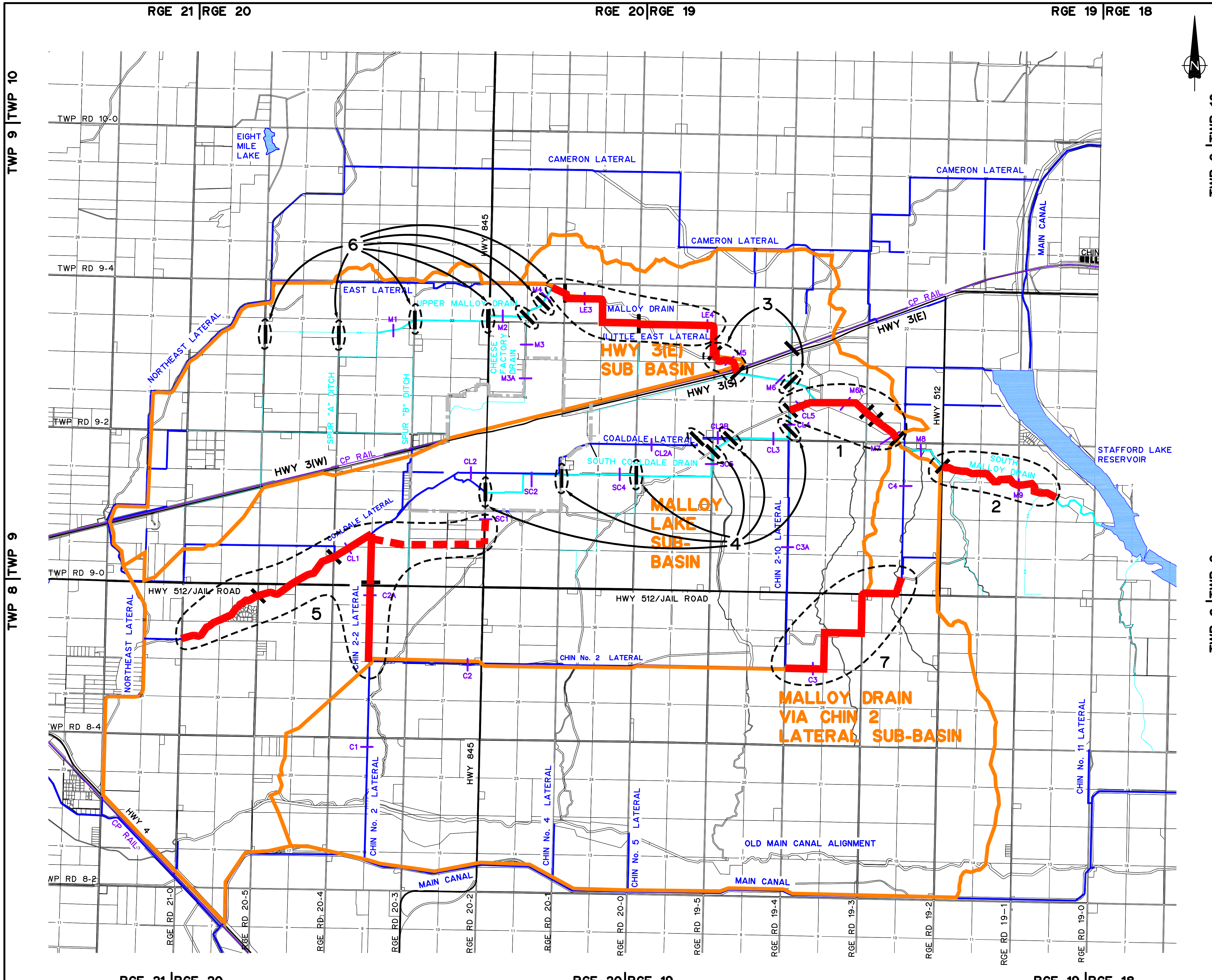
The $238,000 figure represents only defined, claimed damages to public and private property. As discussed previously, there are also potentially significant intangible costs to maintaining status quo, such as restricted development. Table 3.23 below displays a cost/benefit comparison of selected alternatives.

Table 3.23: Comparison of Upgrade Costs versus Expected and Averted Damages

Channel/Pond Upgrade Alternatives	Estimated Flooded Area	Upgrades Cost	Damages, $	Averted Damages, $	Intangible Costs
Alternative 1: Status Quo	487 ha	$0	$238,000 (from above)	$0	Economic impact of restricted development
Alternatives 3, 3A, 3B: Combination upgrade of ponds and channel (Scenario 5)	0 ha	$15M-$27M	$0	$238,000/event	
Partial Alternative 3: Upgrade channels to 2.0 L/s/ha, but no new storage; allow reduced flooding	363 ha	$4.8M	$177,000 (363/487 x $238,000)	$61,000/event	Economic impact of restricted development

Phased Implementation of Capital Upgrades

As the extent of the proposed upgrades is too large to be constructed or funded as a single project, a phased implementation of Alternative 3 (upgrades to channels to 2.0 L/s/ha, plus new storage) is proposed. The total upgrade program is portioned into six phases, as shown in Figures 3.18 and 3.19.



LEGEND

- UPGRADED CHANNEL
- NEW CHANNEL
- UPGRADED CULVERT
- PHASE
- TOWN BOUNDARY

NOTE:
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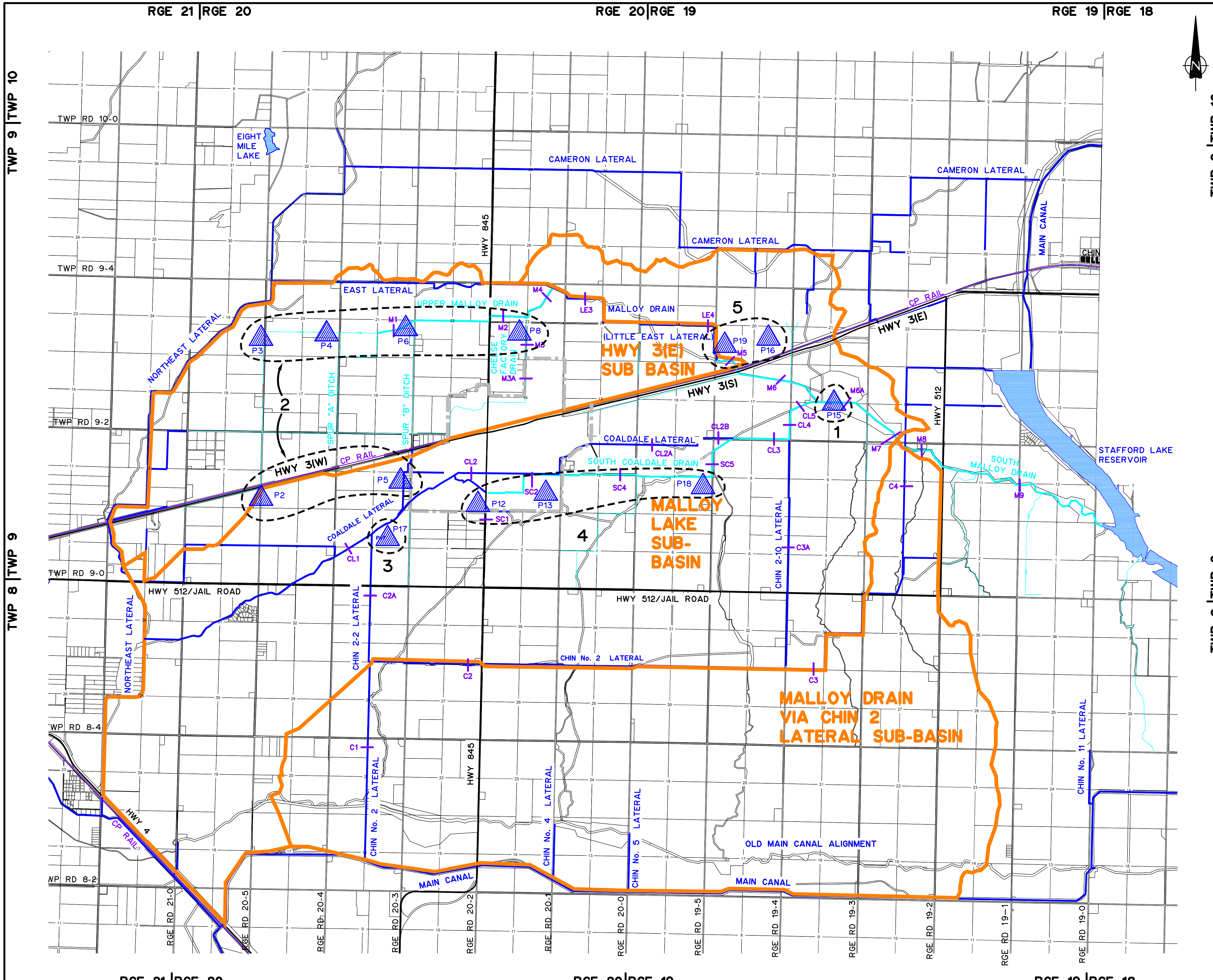
MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PHASES OF PROPOSED CHANNEL AND CULVERT UPGRADES

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.18



LEGEND

- ▲ PROPOSED CONSTRUCTED DETENTION POND
- - - - PHASE
- TOWN BOUNDARY

NOTE:
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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PHASES OF PROPOSED CONSTRUCTED DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.19

Funding for capital improvements may come from various sources:

- Federal or provincial grants
- Off-site levies to developers
- Surcharges to new and existing users
- Existing tax base
- Debenture or other borrowing mechanisms
- Contributions from Ducks Unlimited, or similar agencies, to developing natural ponds

These funding avenues should be pursued further.

4. DEVELOPMENT STANDARDS

Until upgrades to the system can be implemented, future developments will have to provide storage for 100% of their runoff during a storm event, and discharge no more than 0.4 L/s/ha after the storm (upon approval by SMRID), in order to not impact the system. Once the system is upgraded throughout the basin to a capacity of 2 L/s/ha, as suggested above, developments can discharge during a storm at the system capacity (2 L/s/ha). The storage requirements will thereby be reduced. Stormwater Best Management Practices will still apply.

5. RECOMMENDATIONS

1. Initiate the adoption and Implementation of this Master Drainage plan. Three possible administrative models discussed in this report could alleviate the difficulty with implementing a drainage plan over a catchment basin with multiple jurisdictions involved, and should be evaluated further.
   - Drainage Commission
   - Utility
   - Ad-Hoc Drainage Committee

2. Given limited resources, the Master Drainage Plan and the recommended improvements may not be fully implemented for a few years. Considering the strong pressure for development in the area, some interim policies are appropriate.

- For small development proposals, defined as residential developments of no more than three residences, source control BMPs should be incorporated to maintain the peak flows and runoff volumes at or below current pre-development levels.
- For "major" developments (those greater than three residences)
  - Zero discharge allowed during storm event. Release to be allowed only after a storm event and upon approval by Drainage authority (i.e. entire runoff volume to be stored on-site during the storm.)
  - Maximum allowable post-event discharge rate equivalent to 0.4 L/s/ha.
  - Major developments should include the upstream contributing areas within their stormwater management plans.

3. A *Comprehensive Capital Plan* should be developed to provide a "roadmap" for implementing capital improvements. The measures presented in Alternative 3, at a cost of **$27,000,000**, should be considered as part of the Comprehensive Capital Plan. Further analysis and decision-making will be required in the following areas and incorporated into the Plan.
   - The number and locations of required storage ponds should be addressed on a site-specific basis.
   - The scheduling of channel upgrades needs to be in a logical manner, in conjunction with the provision of new storage ponds, or in designated natural storage areas, and in consideration of any impact on downstream areas.
   - Decide on which sites might be pursued for the option of purchasing land or flood easement rights.
   - Come to an agreement, through committee, on allocation of costs not covered by provincial grants that might be acquired.
   - Develop and implement an off-site levy or similar means of cost recovery be implemented to provide an equitable sharing of the costs of regional facilities amongst benefiting areas.

4. Once capital improvements have been made, guidelines for future developments, in keeping with the Master Drainage Plan, should include:
   - Establish 2.0 L/s/ha release rates from developments for both during a storm event, and post-event. Possibly consider different targets for small and large developments.

- Stormwater Plan prepared by a qualified professional to meet local jurisdiction and AENV requirements.
- Stormwater facilities to be within a Public Utility Lot.
- Excess capacity to be built into facilities to accommodate outside areas.
- Policies adopted to encourage new developments to implement source control best management practices (BMPs), low impact strategies (LID's), and policies to promote long-term monitoring of the effectiveness of those BMP's and LID strategies.

5. A *Storm Response Plan* should be prepared to identify the procedures and initial points of contact that the Town, County, and SMRID can follow in response to drainage concerns and associated damage or risk due to imminent flooding during a storm event.
    - A prioritized *Emergency Pumping Plan* be developed and adopted to address existing drainage concerns, based on a priority rating system and potential risk to property.
    - Develop policies to provide guidelines for the acceptance of emergency pumped, gravity-released, or hauled stormwater from developments.

ACKNOWLEDGEMENTS

MPE would like to express its gratitude to the Steering Committee members for their guidance during preparation of this Master Drainage Plan, and their dedication to addressing this issue:

ALBERTA ENVIRONMENT

Kathleen Murphy, Water Approvals Team Leader

ALBERTA TRANSPORTATION

Ron Smith, P.Eng., Bridge Engineer, Bridges - Lethbridge

TOWN OF COALDALE

Kim Craig, Mayor
Roy Ermter, Director of Operations

COUNTY OF LETHBRIDGE

Morris Zeinstra, Committee Chairman
Michel Savard, Director of Municipal Services
Donna Irwin, Recording Secretary

SMRID

Jim Csabay, Chairman
Jan Tamminga, Operations Manager

We would also like to express thanks to other officials and staff of the Town of Coaldale, County of Lethbridge, and SMRID, for their attendance at meetings and/or taking the time to meet MPE staff and provide their perspectives on the subject.

Leo Ludwig and Don Wentz – Town of Coaldale
Tom Crooks, Ron Renwick – SMRID
John Wilms, Jim Graham, Scott Tollestrup, and Duane Charlesworth – County of Lethbridge

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FIGURES

APPENDICES

1.0 INTRODUCTION

The area known as the Malloy Drainage Basin is located in and around the Town of Coaldale and covers an area of approximately 21,662 hectares. The area is drained through a complex series of natural and constructed canals and drains with the majority of this water discharging into Stafford Reservoir via the Malloy Drain. The area historically has experienced flooding during significant rainfall and snow melt events, most notably from the events experienced in 2002 and 2005.

The 2002 storm occurred during the period of June 8^{th} to 10^{th}, 2002. Conditions prior to the storm were recorded as the wettest on record creating saturated soil conditions. During this period a total rainfall of 143 mm was recorded for the Lethbridge area. This storm has been classified as greater than a 1:100 yr storm event.

In 2005 two storm events were experienced, the first event happened in the June and a second event occurred in October which is unusual for this area. Rainfall records show that June 2005 was the wettest month on record, although the flooding and damage was not as wide spread.

These two storm events, plus the recurrent flooding experienced since the area was settled, prompted the County of Lethbridge, Town of Coaldale and the St. Mary River Irrigation District jurisdictions to form a steering committee to investigate alternatives to help alleviate flooding and set design parameters for future development within the Basin. This report is the result of a study conducted by MPE on behalf of the steering committee.

2.0 BACKGROUND

2.1 Study Area

It is important to recognize the unique characteristics of the Study Area in the Malloy Drain Drainage Basin Plan (MDDBP). This area can present a number of challenges from the perspective of managing drainage issues by three agencies with quite different mandates, namely County of Lethbridge (County), Town of Coaldale (Town) and the St. Mary River Irrigation District (SMRID) as these agencies attempt to investigate alternatives to help alleviate flooding and set design parameters for future development within the Basin.

The Study Area is illustrated on Figure 2.1. It encompasses 21,662 ha land, including rural agricultural lands mostly within the County, the Town of Coaldale, and some country residential subdivisions within the County. The terrain is relatively flat with a significant number of natural low-lying areas with limited culvert, canal, and channel (storm drain) capacities.

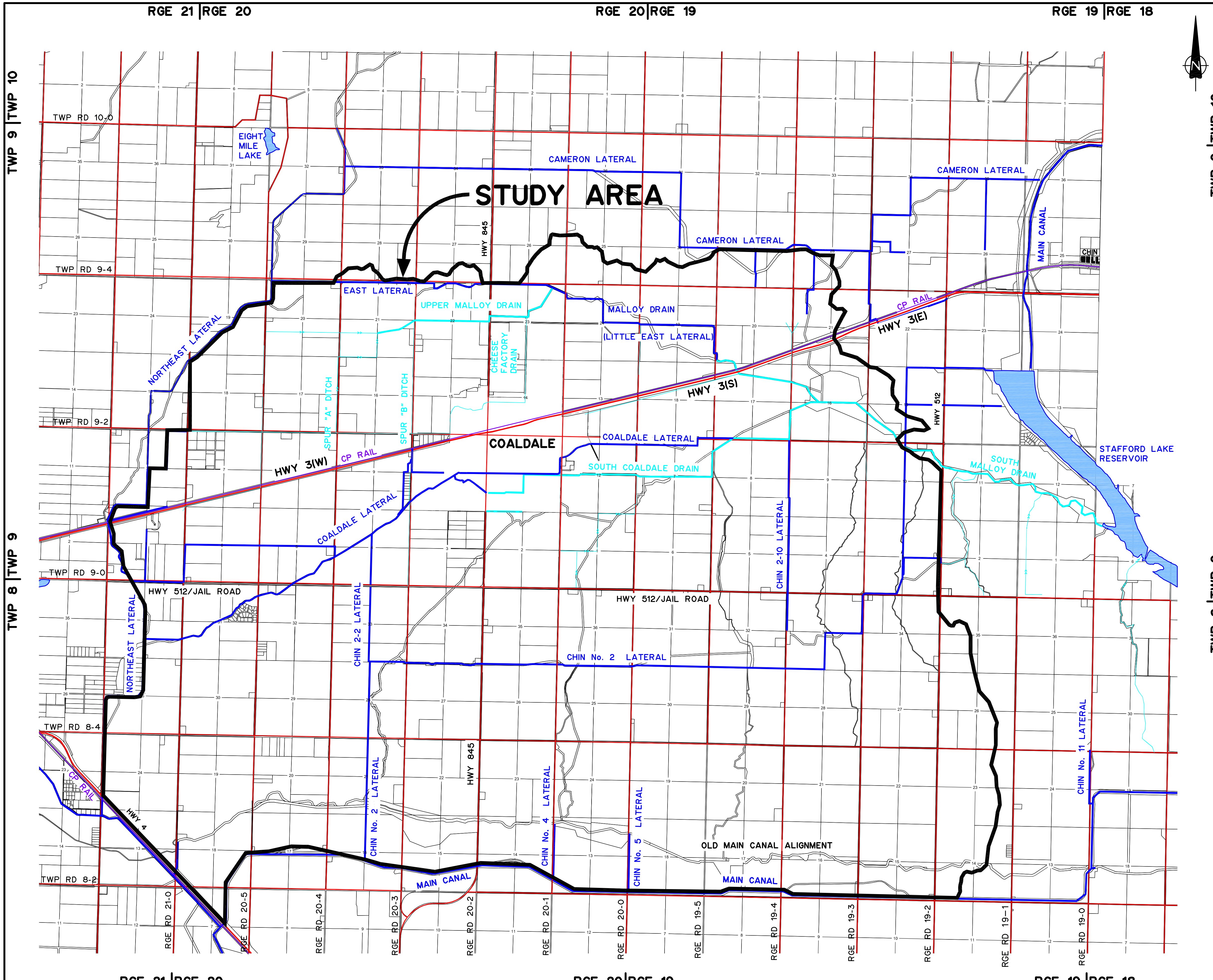
2.2 Nature of Problem

The nature of the problem is a matter of perspective and recent history. Prior to European settlement in the late 1800's, the subject study area topography was an undisturbed natural ecosystem which allowed for stormwater to naturally flow, attenuate, pond and infiltrate in an unaltered state.

The following summation attempts to review the affect on the area drainage with respect to the different agencies and their roles throughout the "development years". This summation is a perspective gained from a collection of field experiences and observations, and provides content for stakeholder introspect and discussion.

Railway Development:

The construction of the Canadian Pacific Railway opened up Western Canada to immigration and the development of primary based industries such as mining and agriculture. The Federal Government facilitated and encouraged the development of the railway and rural roads to serve the growing population and economy.



LEGEND

STUDY AREA BOUNDARY

NOTE:
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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
STUDY AREA

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	2.1

Railway construction requires the rail structure to be elevated above natural topography (earthen berm) which can attenuate high flows and create ponding upstream of the embankment. As a man made structure, the CPR Railway intercepts and attenuates flows within the Malloy Basin.

SMRID Irrigation and Agriculture:

Early irrigation techniques employed flood irrigation which required ditching and leveling to assist with water control. Over time, irrigation methods became more sophisticated (pumps and sprinklers) and integration into an overall water control network which included ditching, small canals, road ditches and natural channels.

The earliest irrigation canals followed the natural terrain where the drainage course was structurally enhanced to a channel-like structure to assist with irrigation delivery and irrigation drainage outflow. These initial canals followed the natural drainage patterns as this was the easiest and least expensive method of delivering water.

The evolution and development of irrigation was primarily driven by the landowners who wanted greater control of water and access to land situated in natural lows and drainage courses. With continued advances in farming and irrigation techniques, present day farmers *expect* and *aspire* to maintain total control over the application of irrigation water. Over time, smaller canals structures were removed from the natural drainage courses and relocated to the perimeter of land parcels. Here, the canal structures met and joined with road drainage systems, creating an intensified drainage system network.

With advances in pipeline technology, the SMRID has constructed buried pipelines to more efficiently deliver significant irrigation flows currently served by smaller canals. The removal of these smaller canals from the land base has an <u>immediate and significant effect</u> on the land's drainage characteristics. Landowner's seek to "reclaim" the land occupied by the former canal structure allowing fewer restrictions to cultivation and the implementation of pivot irrigation systems. During storm events, a reclaimed area does not have the previous capacity, or control, resulting in altered flows to other drainage systems or road ditch networks.

All canals, because of their nature, intercept and accumulate stormwater as it naturally flows from the land base. Stormwater which may have ponded, or run to another area to pond, has been rerouted and re-intensified through the irrigation canal systems.

The SMRID canal infrastructure currently accepts stormwater flows. These canal systems are not designed to carry stormwater volumes resulting in severe capacity issues during high flow storm events.

Provincial Road Development – Alberta Transportation

Initial road development occurred within the Dominion Lands Survey System which provided for land ownership and definition of public right-of-way. Provincial highways were then developed to meet and grow with the developing communities and industries.

The earliest roads were constructed by elevate-and-grade methods which closely followed the existing topography. During storm events, water would slightly attenuate and then pass through low level culverts, or overtop the road during high flow events. With increased traffic volumes and advances in transport vehicles, roads evolved to larger and more sophisticated structures.

Roads are designed primarily to carry traffic loads, vehicle configurations and traffic movements in a safe and economical fashion. An important design consideration in the development of roads is the care of water. Road elevation, ditch grading, and use of culverts are methods implemented to mitigate water damage to a road structure and are part of sound engineering practices.

Because the road top elevation is designed to be above natural ground, it serves as an embankment and does attenuate certain stormwater flows. Ditch grading and culverts are designed to control and direct water through the road right of way where it can proceed on to its natural drainage course. Provincial road and bridge structures have design limits and are constructed to established standards. Design flows are normally determined from one of three techniques:

- Physical capacity of channel
- Historic records analysis
- Basin runoff potential

These techniques do not rely on a single design storm for establishing required capacity.

County of Lethbridge Road Development:

In the rural areas, local roads initially had limited effect on drainage patterns as many were constructed to the *elevate-and-grade* standard. Through the years, the County of Lethbridge has initiated improvements through its road network which has had a significant effect to the local drainage. Roads were elevated above the natural sod lines, ditches were graded to flow water along the road right of way, and in some locations centreline culverts were installed to allow for passage of water through the road along its natural drainage course.

Over the years, landowners have influenced decisions with respect to road and drainage development. Landowner right-of-way negotiations (required for road widening) have resulted in major alterations in the natural flow of stormwater. A natural draw which previously flowed across a field is now directed to the County ditch where it is re-routed through the road network ditch system.

Rural road development dealt with drainage on a per project basis which meant it was localized to the project parameters with little or no appreciation of the overall basin or downstream impacts. Often, when it was realized that drainage patterns had been changed, measures to alleviate with further ditching and drainage structures were employed.

With the advanced farming techniques of today and the primary use of pivot irrigation systems, residences and operations are routinely located in the corners of a quarter section bordering the road system. This places these developments in areas where stormwater is being directed through the road ditch network system. During high flow events, the intersections can be severely impacted by the volume of flow.

Landowners expect the County to accept and control drainage in the rural areas. The County is limited to what it can do within the restrictions of the road right-of-way.

Town of Coaldale:

The Town of Coaldale is geographically situated to receive stormwater from the surrounding area resulting in ponding of its low lying areas. This accumulation of water was initially capitalized upon as it provided a source of water to local industries and to the community.

For several years Coaldale has experienced flooding caused by its urban development and the influx of storm runoff from the surrounding land base. The Town has directed significant resources in the development of stormwater infrastructure that deals with internally created flows as well as the incoming flow generated outside of its boundaries.

Certain areas within the Town limits are natural depressions where stormwater runoff accumulates. Most of Coaldale does not have natural topographical relief (drainage) and relies on stormwater discharge to constructed drains.

2.2.1 Previous Studies

There have been two studies specific to the Malloy Basin in recent history. In 1979 Associated Engineering Services Ltd. prepared the, *Coaldale Flood Control Study* for Alberta Environment Planning Division, on behalf of the Town of Coaldale. This study examined the hydrology of the entire Malloy Basin.

In 2003, MPE prepared the *Malloy Drain Study*, jointly for the Town, County, and SMRID. This report dealt with only the Lower Malloy Drain south of Highway #3.

2.2.2 Stakeholder Interests

For several decades, drainage has been a major concern in the Malloy Drainage Basin with several agencies and landowners coming together to resolve issues as they arise. Previous storms, whether they occur from rainfall, or rapid snow melt, have caused significant flooding. There have been past efforts to alleviate flooding in localized areas but a solution to the overall problem has yet to be fully addressed.

The purpose of this section is to express the major interests of the effected stakeholders so that the problem can be sufficiently identified and communicated. Each stakeholder has specific interests regarding legislative laws, jurisdiction, responsibilities, and an overall need to move forward to help resolve all the issues.

The needs and interests of each stakeholder are complicated and sufficiently intricate which can present a problem when attempting to find a global and comprehensive solution. In any resolution process, it is imperative that each stakeholder fully understands the global problem and how it impacts their regional partners. Each stakeholder needs to understand:

- How the drainage problem affects each stakeholder;
- The roles and responsibilities of each stakeholder;
- Current measures undertaken, or future planning to mitigate drainage issues under the auspices of each jurisdiction;
- How will implemented measures and concentrated efforts come together in one cohesive and well managed plan regarding drainage in the Malloy Basin.

The following is a synthesis of each stakeholder's interest based on interviews by Neil Powell and George Romao of MPE with senior representatives of each jurisdiction in September 2009:

Alberta Environment

Alberta Environment (AE) is the regulatory authority for stormwater management in the Province of Alberta and is responsible in the development and enforcement of the *Environmental Protection and Enhancement Act* and the *Water Act*.

Their interest in this project is to provide technical expertise in identifying and clarifying the legislative requirements with respect to stormwater management. In addition to its role as a regulator, AE may provide financial assistance through various Provincial grant programs to address study and capital costs. AE has contributed financially in past, through the AMIP Program. However, currently there are no applicable funding programs from AE.

AE works closely with all the stakeholders identified in this study and would have the greatest appreciation overall with respect to the wants and needs of each respective stakeholder.

Alberta Transportation

Alberta Transportation (AT) is responsible for highways and associated bridge infrastructure in the study area. The care of water with respect to highway and bridge infrastructure includes stormwater and irrigation water. The hydrology of the area is an integral factor when designing road drainage systems and bridge structures.

AT, may provide financial assistance through various provincial grant programs to address capital costs of key structural components. For example, AT administers the Local Roads Bridge Program, supplying local agencies with funding to replace bridge structures approaching the end of their design lifespan. Pertaining to drainage improvements, AT would consider funding larger capacity structures, should they be warranted, at replacement time.

Town of Coaldale:

Like many vibrant smaller urban centres, the Town of Coaldale has significant development pressures due to residential and industrial growth. Over the past several years, the Town of Coaldale has invested a considerable amount of resources into stormwater management and look forward to forming a partnership which will address immediate and long term stormwater management.

The Town's primary interests are:

- Continue to grow and develop in a responsible and sustainable fashion;
- Identify and utilize existing stormwater discharge outlets. This currently occurs at the Cheese Factory drain, the South Coaldale Drain and the East Coaldale Storm Pond;
- Use and enhance its internal stormwater retention facilities;
- Solidify a long term arrangement with the SMRID for the acceptance and conveyance of stormwater;
- Quantify the amount of stormwater it receives and handles from outside its boundaries;
- Develop storm release (post-event) standards for new development;
- Open to the creation of Regional Drainage Authority or Commission to administrate an overall stormwater plan between the Town of Coaldale, SMRID and the County of Lethbridge.

- Encourage the County of Lethbridge to continue with and enhance control of stormwater flow from its jurisdiction into the Town of Coaldale;
- Encourage the County of Lethbridge to adopt development standards addressing stormwater flows from new developments that may impact inflows into the Town of Coaldale;
- Participate in the implementation of a *Malloy Stormwater Management Plan* which will be shared and communicated to the local landowners and development industry for acceptance and conceptual buy in;
- Fully understand the operational issues with regard to the basin and how it impacts the SMRID and the County of Lethbridge;
- Share and communicate their internal operational procedures during periods of flood response with other stakeholders;
- Comply with all rules and regulations as legislated under the *Environmental Protection and Enhancement Act and Water Act*.
- Pursue all available funding opportunities.

County of Lethbridge

The County of Lethbridge has a particularly strong interest in finding solutions to the drainage problems in the Malloy Basin. In addition to mitigating flood damage, the County of Lethbridge is keen on forming a partnership with the Town of Coaldale and the SMRID so that its interests with regards to level of service can improve and continue to facilitate responsible and sustainable development growth in the area.

The County's primary interests are:

- Respond to property development pressures with a consistent and responsible stormwater plan in the basin area; particularly the Highway 3 corridor between the City of Lethbridge and the Town of Coaldale;
- Eliminate, alleviate or control overland flooding in areas which have experienced repeated events;
- Work to establish mutually accepted run off rates and design storm events and return periods;
- Fully understand the operational issues with regard to the basin and how it impacts the SMRID and the Town of Coaldale;

- Open to the creation of Regional Drain Authority or Commission to administrate an overall stormwater plan between the Town of Coaldale, SMRID and the County of Lethbridge;
- Participate in the implementation of a *Malloy Stormwater Management Plan* which will be shared and communicated to the local landowners and development industry for acceptance and conceptual buy in;
- Open to the creation of a “user fee” system for existing and new development;
- Share and communicate their internal operational procedures during periods of flood response with other stakeholders;
- Comply with all rules and regulations as legislated under the Environmental Protection and Enhancement Act and Water Act;
- Pursue all available funding opportunities;
- To ultimately develop a county-wide Stormwater Master Plan;
- Establish and adopt guidelines that can allow new development without negatively impacting the drainage system.

SMRID

The Saint Mary River Irrigation District is a water supplier for agriculture, commercial, municipal and domestic use throughout the Malloy Basin. The SMRID wants it made clear that they are not a drainage authority and have no accommodation built into their water delivery systems to handle stormwater flows.

The SMRID’s primary interests are:

- Preference is <u>not</u> to handle stormwater flows;
- Partner in the development of a drainage system to control stormwater volume and timing of flows into their system; preferably stored and released *post peak* event;
- Participate in the implementation of a *Malloy Stormwater Management Plan* which will be shared and communicated to the local landowners and development industry for acceptance and conceptual buy in;
- Eliminate, alleviate or control overland flooding in areas which have experienced repeated events;
- Fully understand the operational issues with regard to the basin and how it impacts the Town of Coaldale and the County of Lethbridge;

- Share and communicate their internal operational procedures during periods of flood response with other stakeholders.

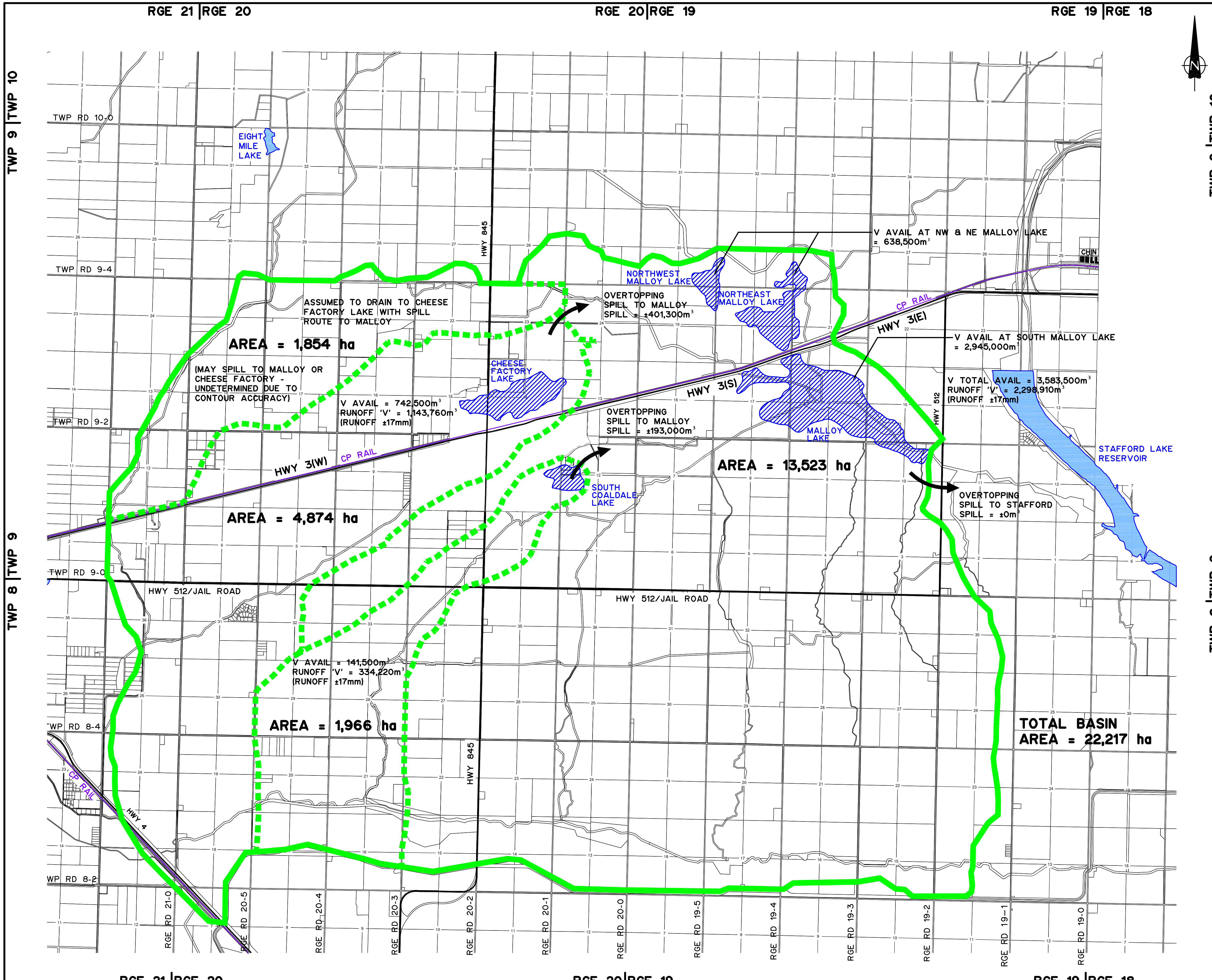
Landowners

- Implement a solution to reduce the impact of overland flooding and duration of ponding on their lands.
- Understand each agencies respective roles during flood events.
- Receive clarification and direction for future development of lands.

2.3 Development History

Prior to settlement in the area, natural drainage collected in three lake sites as shown in Figure 2.2. Development began to occur with dryland farming, and then around the turn of the century, the first irrigation canal was brought into the area. However, extensive irrigation infrastructure was not constructed until the 1940's.

Irrigated farming remains the main land use outside of the Town. Population growth in both the Town and County has been steady but moderate (1-2% per year) However, in more recent years, development within the County, particularly industrial development along the Highway 3 corridor, has intensified.



LEGEND

BASIN BOUNDARY

SUB-CATCHMENT BOUNDARY

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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PRE-DEVELOPMENT CATCHMENTS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	2.2

2.4 Existing Stormwater Management Systems and Infrastructure

Existing drainage infrastructure falls into the following broad categories:

- Irrigation canals and drains owned by SMRID
- Field drains owned by individual landowners
- Ditches on County and provincial roads
- Runoff collection and storage within the Town of Coaldale
- Local collection and storage at various industrial parks and residential acreages throughout the County

A brief description of the major systems follows. See Figure 2.3 for reference.

2.4.1 Alberta Transportation

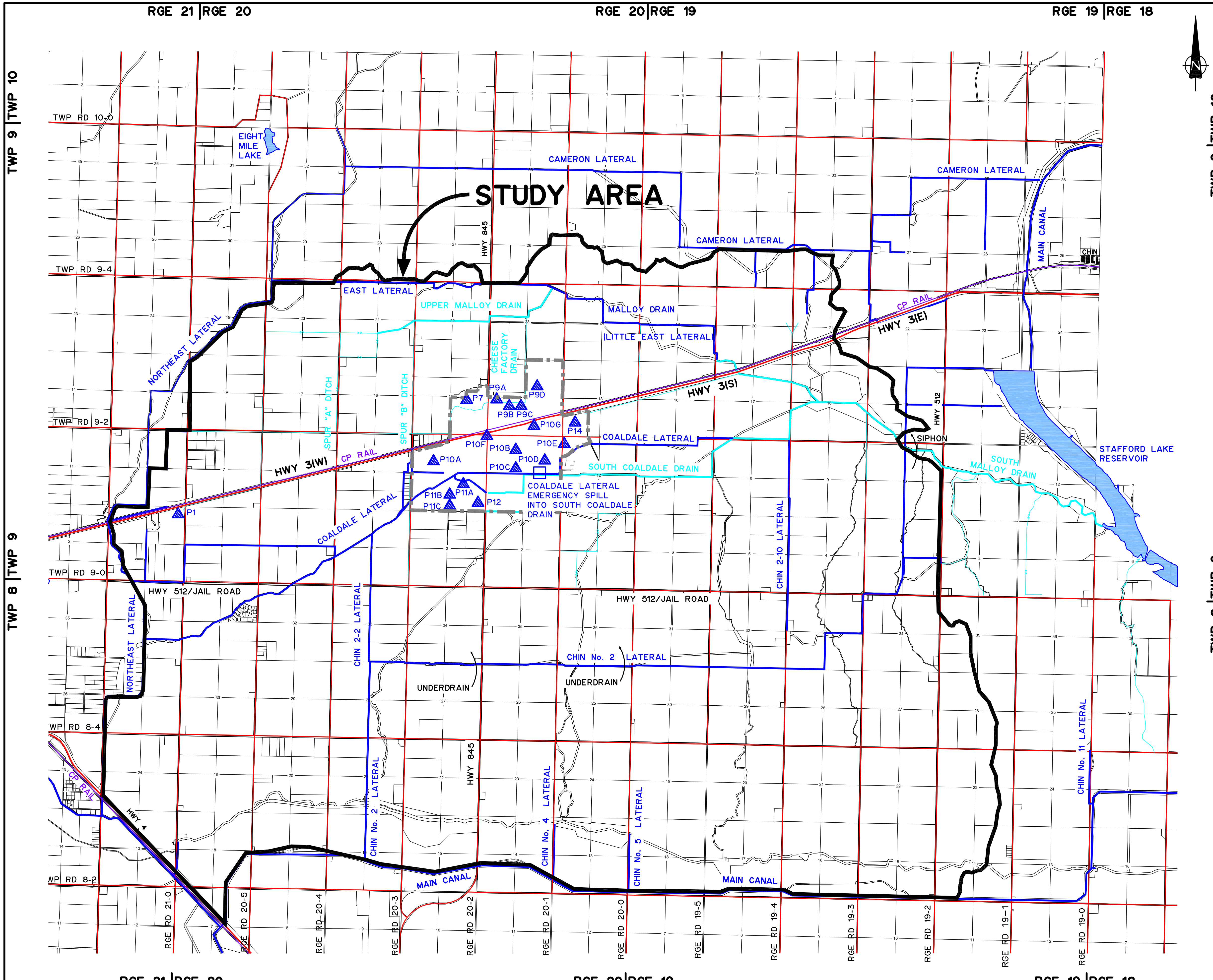
Alberta Transportation administers Highway #3 and Secondary Highways #512 and #845 through the Crown, who owns the lands. Drainage ditches capture runoff from the roads, and in some cases, from adjacent areas. Most of this runoff in the Malloy Basin ends up eventually in the Malloy Drain south of Highway 3. The total area of Alberta Transportation highways is approximately 212 ha within the study area.

2.4.2 Lethbridge County

Lethbridge County administers the network of paved and gravel Township and Range Roads, and their associated ditch systems. Road allowances are owned by the Crown. Without question the ditch systems receive runoff from more than just the roads. However, except at key locations, County infrastructure has not been modeled as discrete conveyance channels or runoff catchments, but has been accounted for by adjusting the catchment parameters (CN number) of the larger rural catchment areas.

2.4.3 SMRID

SMRID owns both canals and drainage channels (approximately 70 km in total) within the basin. There is some overlap of these duties, as low-lying canals receive runoff from adjacent land, and some drainage



LEGEND

- CONSTRUCTED STORAGE POND
- EMERGENCY SPILL STRUCTURE
- CANALS
- DRAINS
- ROADS
- TOWN BOUNDARY

EXISTING CONSTRUCTED STORAGE PONDS

POND #	POND NAME	VOLUME
P1	BROXBURN	25,637m^3
P7	BIRDS OF PREY	128,300m^3
P9A*	STATION GROUND 'A'	16,979m^3
P9B*	STATION GROUND 'B'	22,116m^3
P9C*	STATION GROUND 'C'	14,504m^3
P9D*	N.E. INDUSTRIAL	72,840m^3
P10A*	WATERFRONT	25,500m^3
P10B*	R.I. BAKER	10,887m^3
P10C*	ST. JOSEPH	6,231m^3
P10D	JENNY EMERY	4,700m^3
P10E*	EAST VIEW	33,700m^3
P10F*	WELCOME	712m^3
P10G*	MCCAINS	5,976m^3
P11A*	COTTONWOOD 1	8,040m^3
P11B*	COTTONWOOD 2	3,800m^3
P11C*	COTTONWOOD 3	8,900m^3
P12	COTTONWOOD INTERIM (#4)	32,400m^3
P14	EAST POND	148,902m^3
TOTAL		570,124m^3

* NOTE: PONDS LUMPED IN MODEL INTO MAJOR PONDS P9, P10, P11 (SEE FIGURE 3.1)

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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
EXISTING INFRASTRUCTURE

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	2.3

channels have been equipped with check structures in order to utilize the drainage water for irrigation. SMRID also owns the receiving body for the Malloy Basin drainage, which is Stafford Lake. Stafford Lake has an operating capacity of 3,050 dam^3 (2,500 ac ft) in its normal operating band, with a change in level of 1.6 m. The SMRID Main Canal enters Chin Reservoir. Stafford Lake is fed directly from the Chin Reservoir outlet structure. The flow rates from Chin Reservoir into Stafford Lake, and out of Stafford Lake are controlled automatically to meet water demands and maintain a constant level in Stafford Lake. Stafford Lake outlet control gates have a maximum capacity of 73 m^3/s.

2.4.4 Town of Coaldale

The majority of the Town land is served by urban storm water collection systems. The Town owns 12 storm ponds from which outflow can be regulated. In addition to these ponds, there are three privately owned ponds for developments within the Town. The total storage capacity of these ponds is approximately 544,500 m^3.

Table 2.1: Town of Coaldale Storage Ponds – Current and Future Capacity

Pond #	Name	Sub-Ponds	Total Volume m^3 Existing	Future
P7	Birds of Prey	N/A	**128,300**	**128,300**
P9	NE Town Ponds (Lumped)	NE Industrial Phase 1 Interim Pond (South)	72,840	N/A
		NE Industrial Phase 2 Ultimate Pond includes Phase 1		161,150
		Station Grounds Pond A	16,979	16,979
		Station Grounds Pond B	22,116	22,116
		Station Grounds Pond C	14,504	14,504
	SUB-TOTAL P9		**126,439**	**214,749**
P10	Town Ponds (Lumped)	RI Baker School Pond	10,887	10,887
		St Joseph School Pond	6,231	6,231
		Eastview Pond	33,700	33,700
		Water Front Pond	25,500	31,000
		Welcome Pond	712	712
		McCain Pond	5,976	5,976
	SUB-TOTAL P10		**83,015**	**88,515**
P10D	Jennie Emery Pond		**4,700**	**4,700**
P11	Cottonwood	Pond # 1	8,040	8,040
		Pond # 2	3,800	3,800
		Pond # 3	8,900	8,900
	SUB-TOTAL P11		**20,740**	**20,740**
P12	Future Cottonwood	Interim Detention Area	**32,400** Note 1	N/A
		Future Pond # 4 & # 5		43,900
	SUB-TOTAL Cottonwood Ponds (P11,P12)			**64,640**
P14	Town East Pond		**148,902** Note 2	**148,902**
		TOTAL TOWN ONLY	**544,496**	**649,806**

Notes:

1. *Estimated interim volume of 32,400 m^3 was provided by Cottonwood Developer's Consultant (Martin Geomatic Consultants). Interim storage is eliminated after ponds 4 and 5 are built.*
2. *East Pond - Max volume defined at elevation where property damage would occur (flood residences)*

The Town also has an abandoned raw water reservoir, having a total volume of 475,000 m^3. Approximately 130,000 m^3 of this could be made accessible for gravity diversion to/from the South Coaldale Drain. Also from a potential perspective, the Town owns a sanitary lagoon just north of Town limits. There has been discussion about the potential for the Town waste water lagoons to be replaced by a regional waste water system, at sometime in the future. The lagoons could then be retired from service and could be used as storm water storage ponds. This location has been identified as storage P8 site in the model. However, for the purposes of this report it is assumed that the lagoons would not be available for storage in the foreseeable future, and a new pond would be constructed nearby. Both of these facilities are currently not receiving stormwater flows, but represent an opportunity for development into future stormwater storage sites.

In addition to runoff from within its borders, the Town also receives and conveys a roughly equal amount of runoff from adjacent rural catchments (quantities are discussed later in Section 3). The Town has three major discharge points. Approximately 22% of the runoff is discharged into the Cheese Factory Drain, and from there into the Upper Malloy Drain. The majority of runoff from the south half of the Town is discharged from its East Pond into a Town ditch along Highway 3, and then into the Lower Malloy Drain. (A very small area of the Town drains into the Coaldale Lateral. The remainder of runoff from South Coaldale is directed into the South Coaldale Drain and then into the Malloy Drain.)

2.5 Current Study: Scope and Approach

2.5.1 Study Scope

The primary objectives outlined in the project proposal were:

- Review drainage basin rainfall data used to determine peak hourly runoff flows for the drainage basin;
- Review the standard roadway drainage ditch used by the County of Lethbridge;
- Review existing drainage systems and identify future drainage system requirements to accommodate development within the County and within the Town of Coaldale;
- Identify the impacts that future development will have on the SMRID and their existing drainage and irrigation systems;

- Identify and prioritize capital projects needed in the drainage system and prepare budget level costing for these improvements. These capital projects may include detention facilities, enlargement of existing drainage canals, or construction of new drainage works;
- Identify possible sources of Provincial or Federal funding to assist in the construction of these capital projects;

Although this report does not specifically deal with a “quantitative” analysis of water quality, the implicit expectation is that any new facilities or developments will follow AENV guidelines and BMP/LID technologies where appropriate. These facilities will improve runoff water quality by implementing forebays and wet ponds to enhance sediment removal. BMP’s can reduce runoff volumes and thereby improve quality. BMP’s can include features such as thicker top soil, rain gardens (infiltration), bioswales and similar techniques.

In a meeting held on November 20, 2009 to review report content, the objectives were reviewed and additional desired outcomes of the study were solicited. In no particular order, the objectives stated included:

- A clear definition of the study area and its boundaries.
- Guidelines for allowable discharges from new developments.
- Suggested methods for collecting funding for capital upgrades, including government grants and developer contributions.
- No recommendations on the allocation of costs amongst the three primary stakeholders (Town, County, and SMRID) at this time.
- Include costs on various alternatives. Even those that are seemingly uneconomic should be presented for comparison.
- Explore both capital improvements and operational strategies (e.g. a Drainage Management Plan).
- An initial cost-benefit analysis of recommended improvements versus expected damages.
- Suggestions for administrative models for basin drainage management.
- A summary section with parts which could easily be used to create publications for distribution to landowners, developers, and the public in general.

2.5.2 Approach

The study area has been examined in two aspects. Section 3 deals with a technical analysis of the basin, its hydrology, and infrastructure. Then physical improvements to the system are evaluated. Section 4 discusses issues such implementation of improvements, administrative bodies, future development, operational guidelines, and flood response planning.

3.0 ANALYSIS

The major bottlenecks on the overall system are:

- Lower Malloy Drain (South of Hwy 3), especially the channel and culverts within the 3.9 km reach immediately upstream of Highway 512.
- Culverts along Lower Malloy Drain and the South Coaldale drain.
- Coaldale Lateral especially through Coaldale and west of Town.

3.1 Methodology and Analytical Approach

The basic approach taken in this study includes four major components:

- Identification of each major drainage catchment and physical drainage constraints.
- Modeling of the individual drainage areas given the existing constraints, natural ponds/depression areas, and Town of Coaldale Stormwater Management pond volume and allowable release rates.
- Conveyance of storm flow via Coaldale Lateral, South Coaldale Drain, Upper Malloy Drain, Little East Lateral, Chin2 Lateral, and South Malloy Drain to Stafford Reservoir.
- Model calibration to generate runoff within sub-catchments of the Study Area similar to Associated Engineering Services Limited (AESL) Study of 1979 for the 1978 storm.

The physical drainage constraints have been identified based upon site visits and survey of major selected culverts/bridges (size, invert elevation, length) irrigation check structures, and pivot crossing structures. The individual sub-catchments within the Malloy Drain Drainage Basin (MDDB) were delineated using the topographic map with 0.5 m contour interval (pre-irrigation) provided by the St Mary River Irrigation District (SMRID) and legal base lines.

The major drainage areas within the MDDB and constraints are discussed in more detail in the following sections.

3.2 Available Storage

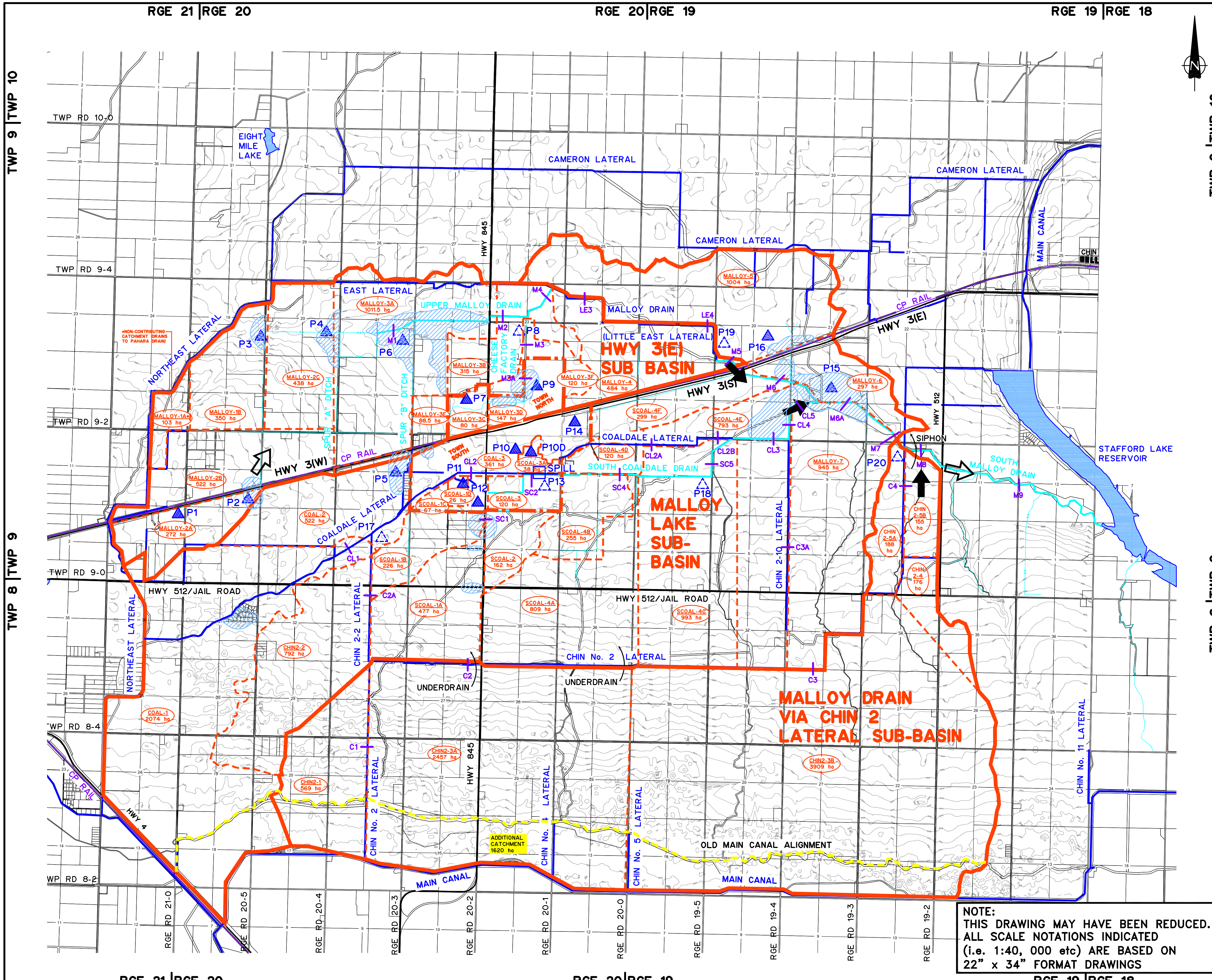
The limits of the natural ponding areas on Figure 3.1 are estimated by contour information, as well as interviews with local responders to past storm events (2002 and 2005), particularly the former Director of Municipal Services at the County of Lethbridge, Mr. Neil Powell. The existing available storage within the basin is summarized in Table 3.1. Further details on available storage on individual ponds and natural ponding areas will be discussed in Section 3.5.1.

Table 3.1 Existing Storage

Location	Existing & Interim Storage Volume[1], m^3
County of Lethbridge	
• Constructed	25,637
• Natural and flood areas	2,821,564 [2]
Sub-Total	**2,847,201**
Town of Coaldale	
• Constructed	544,496
TOTAL	**3,391,697**

Notes:

1. Currently available storage volume at spill elevation.
2. Estimated from contour maps. Used for modeling purposes only.



NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED.
ALL SCALE NOTATIONS INDICATED
(i.e. 1:40, 000 etc) ARE BASED ON
22" x 34" FORMAT DRAWINGS

PONDS/STORAGE AREAS

POND #	POND NAME	TYPE	SUB-BASIN
P1	BROXBURN B.P.	C	HWY 3(E)
P2	HWY 3(W)	N,F	HWY 3(E)
P3	UPPER MALLOY RURAL	N,F	HWY 3(E)
P4	UPPER MALLOY RURAL	N,F	HWY 3(E)
P5	WEST TOWN	N,F	MALLOY LK.
P6	UPPER MALLOY RURAL	N,F	HWY 3(E)
P7	BIRDS OF PREY	C	HWY 3(E)
P8	LAGOON SITE (FUT)	F	HWY 3(E)
P9	NE TOWN (LUMPED)	C,N,F	HWY 3(E)
P10	TOWN (LUMPED)	C	MALLOY LK.
P11	COTTONWOOD	C	MALLOY LK.
P12	INTERIM COTTONWOOD	I,F	MALLOY LK.
P13	RAW RES. (FUT)	F	MALLOY LK.
P14	TOWN E. POND	C	MALLOY LK.
P15	MALLOY LAKE	N,F	MALLOY LK.
P16	NE MALLOY LAKE	N,F	MALLOY LK.
P17	POTENTIAL COALDALE LATERAL POND	F	MALLOY LK.
P18	POTENTIAL S. COALDALE DRAIN POND	F	MALLOY LK.
P19	POTENTIAL HWY 3 NORTH POND	F	HWY 3(E)
P20	MALLOY LAKE S.E.	F	MALLOY LK. VIA CHIN 2

POND TYPE:
C – EX. CONSTRUCTED
I – EX. INTERIM
N – EX. NATURAL
F – FUTURE CONSTRUCTED OR DESIGNATED

SUB-BASIN	AREA (ha)
HWY 3(E)	3828 ha
MALLOY LK.	10,380 ha
CHIN 2	7,454 ha
TOTAL	21,662 ha

LEGEND

- CATCHMENT NAME AREA
- SUB-BASIN BOUNDARY
- CATCHMENT BOUNDARY
- MALLOY/SOUTH COALDALE/ CHEESE FACTORY DRAIN
- LATERAL & MAIN CANALS
- TOWN BOUNDARY
- REACH CROSS-SECTION 'M4'
- CONSTRUCTED STORAGE POND
- NATURAL STORAGE POND
- FUTURE STORAGE POND
- MAJOR FLOW POINTS
- FLOODING AREAS
- FLOW DIRECTION

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
DRAINAGE BASIN CATCHMENTS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2009	FIGURE	3.1

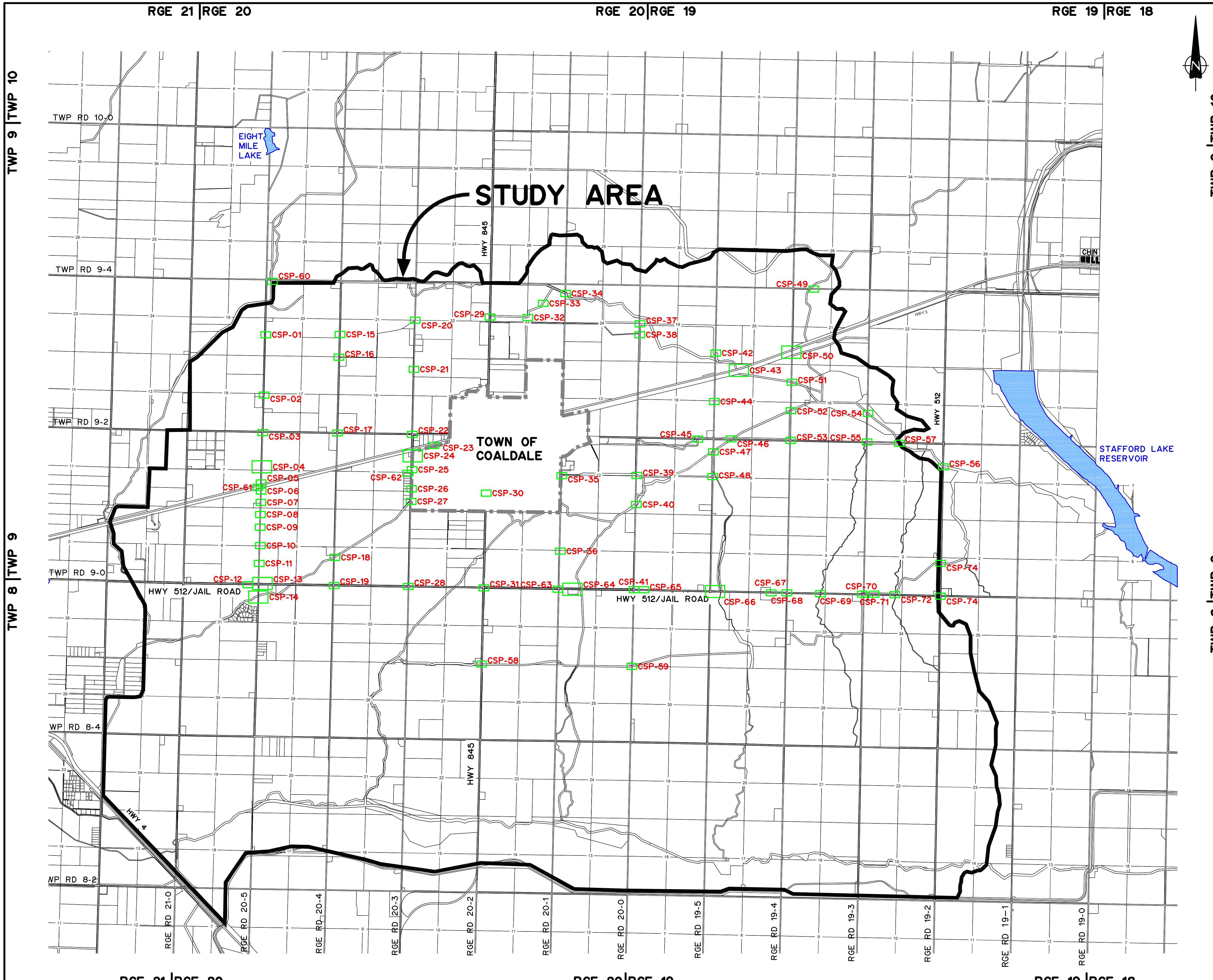
3.3 Drainage Areas and Constraints

The Malloy Drain Drainage Basin (MDDB) has been estimated to be 21,662 ha, and is designated as the Study Area. This total basin area has been divided into three sub-basins, namely Highway 3(E), Malloy Lake, and Malloy Drain via Chin2 Lateral sub-basins (see Figure 3.1). Figure 3.2 illustrates the MPE surveyed culverts (both under canals and across roads and highways) and bridges and their identification numbers (CSP # 01 to CSP # 74) within the entire MDDB.

The Highway 3(E) sub-basin (3,828 ha) covers the basin area north of Highway 3 including 227 ha in the Town of Coaldale catchment. About 80 ha of Town's sub-catchment drains via the Birds of Prey Storm Pond (Pond 7) whereas about 147 ha of Town's sub-catchment drains via Town North Lumped Ponds (Pond 9). Both the catchments drain to Cheese Factory Drain and ultimately to Upper Malloy Drain. The North Lumped Ponds consist of four individual ponds, of which three are privately owned by Station Grounds Inc. Highway 3(E) sub-basin also receives some drainage (272 ha) from south of the Highway 3.

The Malloy Lake sub-basin (10,380 ha) includes drainage from areas west of the Town of Coaldale and south of Highway 3, Town of Coaldale and surrounding lands (612 ha), and lands northwest of Chin2 Sub-lateral and north of Chin2 Lateral canals. In addition, Malloy Lake sub-basin includes a large depressional catchment designated as MALLOY-5 (1,004 ha) which drains to south Malloy Drain via cross culverts at Highway 3 and road ditch along Range Road 19-4. Coaldale Lateral canal, which begins approximately 400 m west of Range Road 21-0 and 1.2 km south of the Highway 3 at the southwest boundary of the Study Area, is the major conveyance for irrigation water until it reaches the Town of Coaldale east boundary. Because of capacity constraints, only about 120 ha of catchment area (SCOAL-4D) is assumed to drain to this lateral. Whereas, the remaining catchments (6,832 ha) on the Malloy Lake sub-basin assumed to drain via South Coaldale Drain and ultimately join to South Malloy Drain.

The Malloy Drain via Chin2 Lateral sub-basin (7,454 ha) receives drainage from lands east and south of Chin2 Lateral canal and discharges to South Malloy Drain upstream of Highway 512 intersection. At its intersection with the Malloy Drain, a portion of the flow in Chin2 Lateral passes under the drain via a siphon pipe, and carries on directly to Stafford Lake. This sub-basin, drains downstream of the so called "South Malloy Lake" (flood prone area since 1963) and has not been identified to be a problematic area in terms of drainage conveyance but likely contributes to back-flooding on the Malloy Drain.



LEGEND

CSP-# CULVERT(S) LOCATION SITE (SURVEYED)

TOWN BOUNDARY

TWP 9 | TWP 10

TWP 8 | TWP 9

NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:40, 000 etc) ARE BASED ON 22" x 34" FORMAT DRAWINGS

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
CULVERT INDEX MAP

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2009	FIGURE	3.2

Numerous drainage constraints have been identified within the study area and major ones include:

- Culvert capacities at local county roads, rail road crossings, access roads, Highway 845 and Highway 3;
- Channel capacities along the Malloy Drain, Cheese Factory Drain, and South Coaldale Drain;
- Channel capacities along the Little East Lateral, Coaldale Lateral, and Chin2 Lateral canals, and
- Constructed berms and fences at various locations within the basin.

The following sub-section provides overview of catchment descriptions under each major sub-basin.

3.3.1 Highway 3(E) Sub-Basin

Figure 3.1 illustrates the three Major Drainage Areas within the Highway 3(E) sub-basin. Drainage areas are generally defined by the conveyance channel, road network(s), and pond systems. Each will be discussed in more detail in the following section.

Drainage Area: Upper Malloy Catchments

Upper Malloy sub-catchments include: MALLOY-1A*, MALLOY-1B, MALLOY-2A, MALLOY-2B, MALLOY-2C, MALLOY-3A and MALLOY-3B. Characteristics of each sub-catchment are summarized below.

MALLOY-1A*

This sub-catchment (103 ha) as shown on Figure 3.1 originates approximately 350 m west of Range Road 21-0 around the intersection of Township Road 9-2 with approximate catchment boundary along Northeast Lateral canal. This sub-catchment drains north via Pahara Drain and is not part of the study area as it does not contribute to the Malloy Drain.

MALLOY-1B

This sub-catchment is primarily a rural catchment with an average slope of 0.6 %, bounded by Range Road 20-5 to the east, Northeast Lateral to the north, Township Road 9-2 to the south, and Range Road 21-0 to the west. Drainage from this sub-catchment is via a 500 mm CSP culvert across Range Road 20-5 (CSP # 01) towards the east along a small ditch/channel (the Upper Malloy Drain). Historically, flooding was observed around the upstream end of CSP # 01 and the approximate extent of flooding is shown on

Figure 3.1 as Pond P3. However, no major spills across Range Road 20-5 were observed during past storm events.

MALLOY-2A

This sub-catchment is primarily rural and some newly developing urban developments. It has an average slope of 0.4 % and is bounded by Range Road 20-5 and natural ridge to the east and southeast, Highway 3 to the north, natural ridges and Jail Road to the south, and Northeast Lateral to the west. This sub-catchment drains north across Highway 3 and the Railway Alignment. Broxburn Business Park is one of the developments within the County of Lethbridge in this sub-catchment. It has a constructed storm pond (P1). Drainage from this sub-catchment is via a 600 mm CSP culvert across Highway 3 and a 450 mm CSP (CSP # 5) across the Railway north of Highway 3 on the west side of RR 20-5 flowing north along a small ditch. Historically, flooding was observed on the north and south side of the intersection of Highway 3 and Range Road 20-5, shown as the flooding extents on Figure 3.1.

MALLOY-2B

This sub-catchment is primarily a rural catchment with an average slope of 0.5 %, bounded by Range Road 20-4 to the east, Highway 3 to the south, Township Road 9-2 to the north, and Northeast Lateral and the MALLOY-1A boundary to the west. This sub-catchment drains east along the Township Road 9-2 ditch, then flows north along the RR 20-4 ditch and eventually joining the MALLOY-3A sub-catchment. The culverts along the road ditch vary between 500 mm (CSP # 03) and 900 mm (CSP # 17). Historically, flooding was observed around the intersection of Highway 3 and Range Road 20-5 on the southeast side of this sub-catchment.

MALLOY-2C

This sub-catchment is primarily a rural catchment, bounded by Range Road 20-4 to the east, East Lateral canal to the north, Township Road 9-2 to the south, and Range Road 20-5 to the west. Drainage from this sub-catchment is via a 600 mm CSP culvert across Range Road 20-4 (CSP # 15) towards the east along a small ditch/channel (the Upper Malloy Drain). Historically, flooding was observed around the upstream end of CSP # 15 and the approximate extent of flooding is shown on Figure 3.1 as Pond P4. Some spill across RR 20-4 near the CSP location was observed during past storm events.

MALLOY-3A

This sub-catchment is primarily a rural catchment with an average slope between 0.2 and 0.3 %, bounded by Range Road 20-3 to the east, about 100 meters south of Highway 3 to the south, Township Road 9-4 and Little East Lateral to the north, a height of land (berm) east of Range Road 20-2, and Range Road 20-4 to the west. This sub-catchment drains north northeast and then east, via the Malloy Drain. Drainage from this sub-catchment is via a 1200 mm CSP culvert across Range Road 20-3 (CSP # 20) towards the east along the Upper Malloy Drain. Historically, significant flooding was observed on the west and east side of Range Road 20-3. Spill across Range Road 20-3 from west to east was also observed. Extent of flooding had been quite significant around P6 area due to constructed berms and fence along spurs “A” and “B”. Both spur ditches were recommended in the AESL 1979 study.

MALLOY-3B

This sub-catchment is primarily a rural catchment with an average slope between 0.2 and 0.3 %, bounded by Range Road 20-1 and natural ridges to the southeast, Highway 3 to the southwest, the Town of Coaldale boundary to the south, Township Road 9-4 and Little East Lateral to the north, a height of land few hundred meters east of Range Road 20-2, and Range Road 20-3 to the southwest. This sub-catchment drains northeast via trap lows and depressional areas, ultimately joining the Malloy Drain. Drainage from this sub-catchment is via CSP # 32 and CSP # 33 towards the east northeast along the Upper Malloy Drain. This sub-catchment receives drainage from Town’s Birds of Prey Storm Pond and Cheese Factory Lake areas via the Cheese Factory Drain.

Drainage Area: Birds of Prey Storm Pond & Cheese Factory Lake Catchments

The Birds of Prey Storm Pond and Cheese Factory Lake sub-catchments include: MALLOY-3C and MALLOY-3D (both within the Town), and MALLOY-3E and MALLOY-3F (both rural areas outside of the Town). Characteristics of each sub-catchment are summarized below.

MALLOY-3C

This sub-catchment is within the Town and is primarily from a residential sub-division (Garden Grove), a mobile home park development and the Birds of Prey Ponds (West Pond & East Pond; Pond P7 in Figure 3.1). This sub-catchment is considered fully developed within the Town of Coaldale. The outlet of the Birds of Prey Pond is closed during rain storm event and the control gate is opened to release stormwater slowly during off-peak periods due to capacity limitations downstream, primarily the Cheese Factory Drain and Malloy Drain.

MALLOY-3D

This sub-catchment is within the Town and primarily consists of residential sub-division (Station Grounds Development) and the Northeast Industrial developments. Historically, this sub-catchment has been a flood-prone area within what was known as the "Cheese Factory Lake", given capacity constraints on the Cheese Factory Drain and existing trap lows. A number of small stormwater ponds are combined for modeling purposes into the Town North Lumped Ponds (P9). These have been designed to contain the 1:100 year storm runoff volume with a 'post-storm' release. The control gate across the Cheese Factory Drain is closed during storm events and is opened to release stormwater slowly during the off-peak periods. This helps offset the capacity limitations in the downstream ditch and Cheese Factory Drain.

MALLOY-3E

This sub-catchment is primarily a rural catchment with an average slope between 0.1 and 0.2 %. It drains east to the Town of Coaldale Birds of Prey Pond catchment. This sub-catchment is bounded by Range Road 20-3 to the west, the Town boundary to the east, Highway 3 to the south, and a natural drainage divide to the north. Drainage is primarily from west to east, entering the Town boundary where it joins a culvert and ditch system. This system eventually enters the Water-Wildlife Preserve, known as the Birds of Prey Pond (Pond P7).

MALLOY-3F

This sub-catchment is primarily a rural area located east of the Town boundary adjacent to Range Road 20-1. It drains from east to west. Runoff from this sub-catchment collects along the east side of the Range Road 20-1 in a trapped low area. During the largest storm events, the trapped low area can fill to capacity and potentially spill over Range Road 20-1 into the west ditch and eventually into the MALLOY-3D sub-catchment.

Drainage Area: Little East Lateral & Highway 3 North Catchment

MALLOY-4

MALLOY- 4 is the only sub-catchment within the Little East Lateral and Highway 3 (E) North Catchment. This sub-catchment is primarily a rural catchment with an average slope between 0.1 and 0.2 %, bounded by Range Road 19-5 to the east, Highway 3 to the south, Little East Lateral and Malloy Drain to the north and northeast, and MALLOY-3F and MALLOY-3B boundaries to the west. This sub-catchment drains north northeast and into the Malloy Drain. Drainage from this sub-catchment is via CSP # 37 and CSP # 38 towards the east along the Malloy Drain prior to crossing Highway 3.

3.3.2 Malloy Lake Sub-Basin

Figure 3.1 illustrates the three Major Drainage Areas within Malloy Lake sub-basin south of Highway 3. Drainage areas are generally defined by the conveyance channel, road network(s), and pond systems. Each will be discussed in more detail in the following section.

Drainage Area: Town West, Town, Highway 3 North, and Highway 3 Ditch Catchments

Town West, Town, Highway 3 North, and Highway 3 Ditch sub-catchments include: COAL-2, COAL-3, MALLOY-5, and SCOAL-4F respectively. Characteristics of each sub-catchment are summarized below.

COAL-2

This sub-catchment is primarily a rural catchment with an average slope less than 0.1 %. It drains to the Town of Coaldale from the west, immediately south of Highway 3. This sub-catchment is bounded by Range Road 20-5 and a natural drainage divide to the west, the Town boundary and Range Road 20-3 to the east, a drainage ditch and Coaldale Lateral to the south southwest, and Highway 3 to the north. Drainage from this sub-catchment is via a 500 mm CSP culvert across Range Road 20-3 (CSP # 24) flowing east into the Town's Waterfront Storm Pond catchment. Historically, flooding was observed around the upstream end of CSP # 24. The approximate extent of flooding is shown on Figure 3.1 as Pond P5. Spill across Range Road 20-3 was observed during past storm events.

COAL-3

This sub-catchment is primarily a residential development within the Town of Coaldale. This sub-catchment is serviced by numerous ponds combined for modeling purpose into the Town South Lumped Ponds (Pond P10: Waterfront Pond, Welcome Pond, McCains Pond, St. Joseph Pond, R.I. Baker Pond, and Eastview Pond). These ultimately drain into the Town's East Pond (Pond P14). Minor storm drainage from this sub-catchment is via a storm sewer line with pipe sizes varying from 900 mm to 1650 mm from the west of Town into the East Pond (P14). East Pond (P14) outflow is pumped at a rate of 1.85 m^3/s to the Highway 3 ditch, which ultimately drains into the South Malloy Drain, immediately south of Highway 3.

SCOAL-4F

This is primarily a rural sub-catchment with an average slope between 0.1 and 0.2 %, bounded by Highway 3 to the north, the Town boundary to the west, a natural drainage divide to the south, and South Malloy Drain to the east. Drainage from this sub-catchment flows north to northeast. It combines with the P14 outflow and drains via the Highway 3 ditch to South Malloy Drain, immediately south of Highway 3.

MALLOY-5

This sub-catchment is primarily a rural catchment with an average slope less than 0.1 %, bounded by approximately height of land between Range Road 19- 4 and 19-3 to the east, Highway 3 to the south, Little East Lateral and Malloy Drain to the southwest, and the Cameron Lateral Canal and height of land to the north and west. This sub-catchment contains significant depressional areas designated as the "Northeast Malloy Lake" and "Northwest Malloy Lake". It drains south across Highway 3 and ultimately joins to the South Malloy Drain via a road ditch along Range Road 19-4. Drainage from this sub-catchment is via CSP # 50 south along the South Malloy Drain into "Malloy Lake". Due to large accumulations of flood water in the depressional areas, pumping of storm water during flood events has been observed from this sub-catchment. The approximate extent of flooding within this sub-catchment is shown on Figure 3.1.

Drainage Area: Coaldale Lateral Catchments

Although some fairly large catchments west of the Town, such as COAL-1 and CHIN2-2 likely drain into the Coaldale Lateral, the Lateral's freeboard capacity is inadequate to contain peak flows from these areas. As such, the flows are assumed to spill into the South Coaldale Drain, and are modeled accordingly. There is an emergency spillway structure to accommodate the spill from the Coaldale Lateral to the South Coaldale Drain; a few metres west of the 11th Street Storm Pump Station (see Figure 3.1).

SCOAL-4D

This is the only sub-catchment assumed to drain directly into the Coaldale Lateral, east of the Town boundary. It has an average slope less than 0.1 % and is bounded by the Town Boundary and Range Road 20-1 to the west, South Coaldale Drain to the south, a height of land about 150 metres east of Range Road 20-0 to the east, and a natural divide to the north. This is primarily an undeveloped sub-catchment adjoining to the Town.

Drainage Area: South Coaldale Drain and Malloy Lake Catchments

South Coaldale Drain sub-catchments assumed include: COAL-1, CHIN2-2, SCOAL-1A, SCOAL-1B, SCOAL-1C, SCOAL-1D, SCOAL-3, SCOAL-3A (Jennie Emery sub-catchment), SCOAL-4A, SCOAL-4B, SCOAL-4C, and SCOAL-4E. MALLOY-6 and MALLOY-7 are the sub-catchments that directly drain into the South Malloy Drain. As explained in the previous section, some of the upslope areas (COAL-1 and CHIN2-2) actually drain into the Coaldale Lateral, but in reality will spill into the South Coaldale Drain. Characteristics of each sub-catchment are summarized below.

COAL-1

This sub-catchment is primarily a rural catchment with an average slope between 0.5 and 0.6 %, bounded by the CHIN2-2 sub-catchment to the east, Highway 4 sub-basin boundary to the south, Northeast Lateral to the west and a canal to the north. This sub-catchment drains northeast into the Coaldale Lateral, but due to capacity constraints in the Coaldale Lateral, surface runoff from major storm events is assumed to spill into the SCOAL-1B sub-catchment and ultimately into the South Coaldale Drain via the Cottonwood Development Lands (SCOAL-1C) within the Town.

CHIN2-2

This sub-catchment is primarily a rural catchment with an average slope between 0.5 and 0.6 %. It is bounded by Chin2-2 Lateral to the east, the Chin2 Lateral to the southeast, and a height of land to the south, west and northwest. This sub-catchment is assumed to drain northeast into the SCOAL-1B sub-catchment and ultimately into the South Coaldale Drain via the Cottonwood Development Lands (SCOAL-1C) within the Town. Surface runoff from this sub-catchment in major storm events is assumed to spill from Chin2-2 Lateral, due to capacity constraints in the Chin2-2 Lateral.

SCOAL-1A

This sub-catchment is primarily a rural catchment with an average slope between 0.6 and 0.7 %. It is bounded by Range Road 20-2 (Highway 845) to the east, Chin2 Lateral to the south, a height of land to the north and northeast, and Chin2-2 Lateral to the west. This sub-catchment drains northeast into the SCOAL-1B sub-catchment and ultimately into the South Coaldale Drain via the Cottonwood Development Lands (SCOAL-1C) within the Town. Drainage from this sub-catchment is via a road ditch along Highway 845 towards the north.

SCOAL-1B

This sub-catchment is primarily a rural catchment with an average slope between 0.4 and 0.5 %. It is bounded by Range Road 20-2 (Highway 845) to the east, a drainage divide to the south and southeast, the Town boundary to the north, and a height of land to the west and southwest. This sub-catchment drains northeast into the South Coaldale Drain via the Cottonwood Development Lands (SCOAL-1C) within the Town.

SCOAL-1C

This sub-catchment includes the undeveloped portion of the Cottonwood Estates plus the Land "O" Lakes Development (some residential area and Golf course) within the Town. This sub-catchment is bounded by Coaldale Lateral to the north and northwest, Range Road 20-2 (Highway 845) to the east, and the Town boundary to the south. This sub-catchment consists of Golf Course ponds and an interim stormwater detention pond (Pond P12 in Figure 3.1) that outlets into the South Coaldale Drain via a 900 mm cross culvert (CSP # 30) on Highway 845. Although small portion of the Land "O" Lakes area north of the Coaldale Lateral likely drains into the Coaldale Lateral, for modeling purposes based on the available contours, all of the area north of the Coaldale Lateral area are assumed to drain into the existing Town catchments eventually draining to the Town's East Pond (P14). Although Land "O" Lakes primarily drains to the Coaldale Lateral, it is assumed to contribute to the South Coaldale Drain during major storm events. This has been adopted in the model, and is considered reasonable given the capacity limitations within the Coaldale Lateral.

SCOAL-1D

This sub-catchment includes the existing Cottonwood Estates Residential Development within the Town. This sub-catchment is serviced by a few small storm ponds (Ponds 1, 2, & 3 lumped into Pond P11). The catchment drains into catchment SCOAL-1C, which outlets into the South Coaldale Drain. This sub-catchment is bounded by the Coaldale Lateral to the north and northwest and the Cottonwood Estates Development boundary to the west, south, and east. This sub-catchment drains into the SCOAL-1C sub-catchment.

SCOAL-2

This sub-catchment is primarily a rural catchment with average slope between 2.5 and 3 %. This sub-catchment is bounded by the Town boundary to the north, Range Road 20-2 (Highway 845) to the west, Jail Road to the South and a natural drainage divide to the east. This sub-catchment drains north northeast to the SCOAL-3 sub-catchment in the Town.

SCOAL-3

This sub-catchment includes a partially developed area of the Town with average slope between 0.2 and 0.3 %. Two abandoned raw water reservoir cells exist within this sub-catchment (Potential Pond P13 in Figure 3.1). South of the existing reservoir cells, a new privately owned development (Seasons) is being planned with a storm pond (P13A) to service the development. This sub-catchment is bounded by the Town boundary to the east and south, Range Road 20-2 (Highway 845) to the west, and the Coaldale Lateral to the north. The South Coaldale Drain passes through the middle of this sub-catchment and drainage is north northeast via the South Coaldale Drain.

SCOAL-3A

This sub-catchment is serviced by the Town's Jennie Emery Storm Pond (P10D) around the School site. The outflow from the Jennie Emery Storm Pond discharges into the South Coaldale Drain via 11th Street Storm Pump Station and culverts. Three culverts underneath the Coaldale Lateral discharge the stormflow from this sub-catchment into the South Coaldale Drain. Emergency spill from this sub-catchment is conveyed via the emergency spillway structure, located a few metres west of the 11th Street Storm Pump Station, into the South Coaldale Drain.

SCOAL-4A

This sub-catchment is primarily a rural catchment with an average slope between 0.65 and 0.75 %. It is bounded by Range Road 20-0 to the east, South Coaldale Drain Lateral to the north, Chin2 Lateral to the south, Highway 845 to the west, and a drainage divide to the northwest. This sub-catchment drains north northeast into the South Coaldale Drain Lateral and eventually toward the South Coaldale Drain main channel.

SCOAL-4B

This sub-catchment is primarily a rural catchment with an average slope between 0.1 and 0.2 %. It is bounded by Range Road 20-0 to the east, Chin2 Lateral to the south, a South Coaldale Drain Lateral to the north northeast, and Range Road 20-2 to the west, and a drainage divide to the northwest. This sub-catchment drains north northeast into the South Coaldale Drain main channel via the South Coaldale Drain Lateral.

SCOAL-4C

This sub-catchment is primarily a rural catchment with an average slope between 0.4 and 0.5 %. It is bounded by a natural drainage divide to the east, Chin2 Lateral to the south, Coaldale Lateral to the north, and Range Road 20-0 to the west. This sub-catchment drains north northeast into the South Coaldale Drain.

SCOAL-4E

This sub-catchment is primarily a rural catchment with an average slope between 0.3 and 0.4 %. It is bounded by Range Road 19-4 and Chin2-10 Lateral to the east, Chin2 Lateral to the south, a drainage divide to the north, the South Malloy Drain and Coaldale Lateral/South Coaldale Drain to the northeast, and a drainage divide to the west. This sub-catchment drains north northeast via the Coaldale Lateral and South Coaldale Drain into the South Malloy Drain. Approximately 10 to 30 % of this sub-catchment was inundated in 2002 and 2005 as illustrated by the flooding extent area on Figure 3.1. Due to channel and culvert capacity constraints downstream along the South Coaldale Drain, flooding was especially prominent in the western portions of "Malloy Lake" within this sub-catchment.

MALLOY-6

This sub-catchment is primarily a rural catchment with an average slope less than 0.05 %. It is bounded by a drainage divide to the east and northeast, Highway 3 to the north, and South Malloy Drain to the south and southwest. This sub-catchment is mostly dominated by a large depressional area known as "Malloy Lake" and drainage is to the south southeast along the South Malloy Drain across Range Road 19-3, which is especially problematic. Drainage from this sub-catchment is via CSP # 54 along the South Malloy Drain. Historic flooding occurred in this sub-catchment due to limited channel and culvert capacities downstream along the South Malloy Drain.

MALLOY-7

This sub-catchment is primarily a rural catchment with an average slope between 0.4 and 0.5 %. It is bounded by a drainage divide and Chin2 Lateral to the east and southeast, South Malloy Drain to the north, and Range Road 19-4 to the west. Approximately 10 to 20 % of this sub-catchment contains depressional area known as "Malloy Lake". Drainage south to southeast along the South Malloy Drain across Range Road 19-3 is especially problematic. Runoff from this sub-catchment flows north into the South Malloy Drain. Historic flooding occurred in the northern portion of this sub-catchment due to limited channel and culvert capacities downstream along the South Malloy Drain. Portions of this sub-catchment plus sub-catchments SCOAL-4E and MALLOY-6, make up the "Malloy Lake".

3.3.3 Malloy Drain via Chin2 Lateral Sub-basin

Figure 3.1 illustrates the Major Drainage Areas within the Malloy Drain via Chin2 Lateral sub-basin. Drainage areas are generally defined by the conveyance channel, road network(s), general topography, and pond systems. Each will be discussed in more detail in the following section.

Drainage Area: Chin2 Lateral Catchments

Chin2 Lateral sub-catchments include: CHIN2-1, CHIN2-3A, CHIN2-3B, CHIN2-4, CHIN2-5A, and CHIN2-5B. Characteristics of each sub-catchment are summarized below. Significantly large sub-catchments (> 2,000 ha) exist within this sub-basin but no significant flooding problems were reported within this sub-basin, except at the confluence of the South Malloy Drain.

CHIN2-1

This sub-catchment is primarily a rural catchment with an average slope between 0.7 and 0.8 %. It is bounded by a drainage divide to the west and northwest, the SMRID Main Canal to the south, and Chin2 Lateral to the east. This sub-catchment drains north into Chin2 Lateral and then flows east via the Chin2 Lateral canal system.

CHIN2-3A

This sub-catchment is primarily a rural catchment with an average slope between 1 and 1.1 %. It is bounded by Chin2 Lateral to the west, the SMRID Main Canal to the south, Chin2 Lateral to the north and Range Road 20-0 to the east. This sub-catchment drains north northeast and then flows east via Chin2 Lateral canal system. A small portion of this area, likely drains via an existing underdrain beneath the Chin2 Lateral, but for modeling purposes, the entire flow is assumed into the Chin2 Lateral.

CHIN2-3B

This sub-catchment is primarily a rural catchment with an average slope between 0.6 and 0.7 %. It is bounded by Chin No. 5 Lateral and Range Road 20-0 to the west, the SMRID Main Canal to the south, Chin2 Lateral and Jail Road to the north northeast and a drainage divide to the east. This sub-catchment is the largest (3,909 ha) among all the sub-catchments within the study area. This sub-catchment drains north northeast into the Chin2 Lateral canal system, and eventually into the South Malloy Drain.

CHIN2-4, CHIN2-5A, and CHIN2-5B

These three sub-catchments are small in size and all drain via the Chin2 Lateral canal system north into the South Malloy Drain, upstream of Highway 512/Range Road 19-2. Average slope of these sub-catchments varies between 0.2 and 0.6 %. All the upstream CHIN2 sub-catchments drain via these three sub-catchments through the Chin2 Lateral canal system channel into Stafford Lake and Malloy Drain.

3.4 Hydrologic Modeling

It has been recognized that the challenges in the Malloy Drain Drainage Basin are primarily drainage related. The natural topography of the entire basin is relatively flat with no natural outlets. Only constructed drains and irrigation canals provide varying degree of drainage conveyance but have limited capacity with constraints due to various hydraulic structures (culverts, irrigation check structures, under drains) and limited channel capacity along the drainage path.

Hydrologic modeling has been carried out to reflect the basin characteristics and conveyance capacity in terms of peak flow generation given various storm events that have occurred in the region or are likely to occur. Hydrographs are routed through constructed ponds, natural depression areas (proposed ponds), and only along certain sections of channels/drains/canals if the modeled flows can be contained in the given channel sections. In case of irrigation canals, only freeboard capacity of the canal is used for channel routing as the canal is assumed to be carrying irrigation flows when the storm occurs. The following sections provide brief overview of storm events and modeling analysis.

3.4.1 Rainfall Records and Storm Events

For the Lethbridge Airport, the 1:100 year *Intense Stormwater Event* represents approximately 102 to 110 mm of rainfall with rainfall intensity varying between 150 to 250 mm/hr within a 24 hour period. Other discrete storm events such as the June 2002 event that occurred in and around Lethbridge are also significant in terms of widespread flooding in the region.

Comparatively, the *High Rainfall Drainage Event* represented by the June 2005 event does not approach the intensity as in *Intense Stormwater Event*; however, the daily rainfall was still quite high varying between 49 and 89 mm respectively at the Lethbridge Research Centre and Lethbridge Airport stations.

The *Intense Stormwater Event* storms generally produce higher peak flows for a short duration of time (e.g., 1 hour or less) in comparison to *High Rainfall Drainage Event* storms. *High Rainfall Drainage Event* storms on the other hand last longer and produce more runoff due to saturated ground conditions, and generally require more storage than the *Intense Stormwater Event* storms.

The Ontario Climate Centre can provide hourly precipitation data for any specific station in Canada. The June 2005 hourly rainfall data for Lethbridge Airport station from the Ontario Climate Centre included some suspect values. Upon comparison, the Government of Alberta's Climate Mapper contour data indicated between 257 and 316 mm of precipitation with an average of 287 mm for June 2005 in the Lethbridge region. Therefore, the hourly rainfall data provided by Ontario Climate Centre was adjusted to a June 2005 rainfall total of 287 mm for modeling purpose (see Figure 3.5).

The closest weather station to the Study Area is the Lethbridge Research Centre in Lethbridge, with a recorded rainfall of 254 mm for June 2005, and a maximum daily of 49 mm (see Figure 3.6). It is evident from Figure 3.6 that the June 2005 rainfall total represents over two times that of the 1:100-year return period, 24 hour event total rainfall from the Chicago Storm. Comparison of June 2005 data for Lethbridge Airport (Figure 3.5) and Lethbridge Research Station (Figure 3.6) revealed that event occurrences match quite well with some variations in daily storm totals.

Historic monthly precipitation data available for the Lethbridge Airport from Environment Canada climate records were obtained and plotted in Figure 3.7. As shown in Figure 3.7, the highest monthly precipitation occurred in 1951, 1963, 1965, 1978, 1993, 2002, and 2005. Monthly rainfall data at the Lethbridge Airport shows that over the past 70 years of record, the June 2005 event gave the highest monthly precipitation at 272 mm. As shown in Figure 3.7, it is only one of two months on record with precipitation over 250 mm, the last being 251 mm recorded in June 2002.

The SMRID provided some unofficial records (anecdotal) of rainfall that occurred during June 1995 and September 2005 as recorded by landowners within the Malloy Basin. These records show localized events with much higher intensity than the Lethbridge Research Station or Lethbridge Airport, but those data may not represent the wider basin. The techniques for recording the rainfall are also unknown. Since the 1:100 year rainfall event selected for this study (109.9 mm in 24 hours) is more intense than the June 6, 1995 event rainfall information locally obtained, we have adopted the “official rainfall information” obtained from the City of Lethbridge. The Chicago Storm is a design storm distribution widely used by practicing drainage engineers in the USA and Canada. This distribution was originally proposed by Keifer and Chu in 1957. While developing this storm distribution pattern, they preserved the maximum volume of water falling within a specified duration, the average amount of rainfall before the peak intensity, and the relative time of the peak intensity. To preserve these characteristics, Keifer and Chu (1957) developed the Chicago Storm from empirical Intensity Duration Frequency (IDF) relationships. By using the IDF relationships, they made procedures and concepts familiar to engineers and simple to obtain and therefore, the Chicago Storm has become widely accepted for use in Engineering Practice (Greenland Engineering, 1997).

The following storm events have been analyzed as part of the storm modeling in the basin. Source weather station, and date for each is shown in Table 3.2.

Table 3.2: Storm Events, Weather Station, and Data Source

Intense/ Discrete Storm Event	Weather Station	Data Source
Aug 22, 1978 storm: 89 mm in 24 hours	Lethbridge Airport & Lethbridge Research Station	AESL, 1979
June 6, 1995 storm: 67 mm in 24 hours	Lethbridge Research Station	Agri Food Canada
June 8-10, 2002: 175 mm in 72 hours	Lethbridge Airport	Environment Canada
June 8-10, 2002: 143 mm in 72 hours	Lethbridge Research Station	Agri Food Canada
1:100 year Chicago Storm: 102.5 mm in 24 hours	Lethbridge Airport	West Lethbridge Storm Study (MPE, 1989)
1:100 year Chicago Storm: 105.5 mm in 24 hours	Lethbridge Airport	Environment Canada IDF for 1960-1994
1:100 year Chicago Storm: 109.9 mm in 24 hours (ADOPTED DESIGN STORM)	**Lethbridge Airport**	**City of Lethbridge (Stantec, 2000)**
High Rainfall Drainage Event	**Weather Station**	**Data Source**
June 1-30, 2005: 287 mm in 30 days	Lethbridge Airport	Environment Canada
June 1-30, 2005: 254 mm in 30 days	Lethbridge Research Station	Agri Food Canada
Historic Continuous Event	**Weather Station**	**Data Source**
Continuous Hourly Rainfall 1960-1995: 8,550 mm	Lethbridge Airport	Environment Canada

As part of the Underground Infrastructure Master Plan (UIMP) study for the City of Lethbridge, an analysis was undertaken to investigate the best representative storm for the City. From the analysis, it was determined that the traditional Chicago Storm distribution was representative of the type of rainfall events experienced in the City. In order to provide a common design standard and criteria for the future, the UIMP Study Team developed Lethbridge specific Intensity-Duration-Frequency (IDF) constants from a least squares solution of the raw rainfall data for the Standard Chicago Distribution storm equation (Stantec, 2000). Following the UIMP study, City of Lethbridge endorsed the IDF constants for the 1:5 and 1:100 year storms as part of their design standards for developments within the City. The City of Lethbridge endorsed IDF constants (Stantec, 2000) superceded the previous IDF parameters for Lethbridge and surrounding region and are thus considered to be the most representative single event design storm for this study (i.e., An *Intense Stormwater Event*).

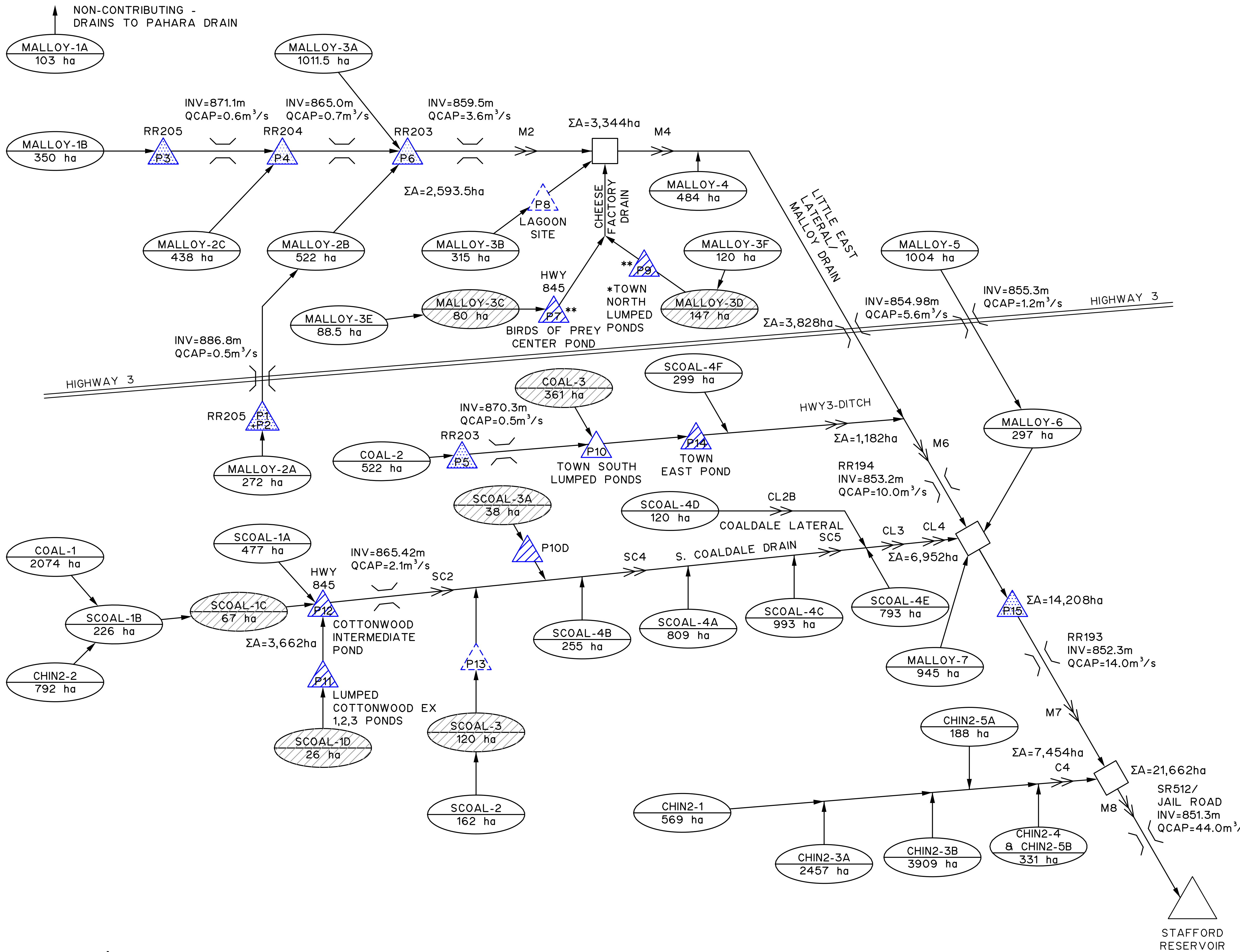
The 1:100 year *Intense Stormwater Event* provides a basis for the design of stormwater facilities, similar to that adopted in the past for a number of developments in the Lethbridge and Coaldale area, and similar to that recommended by Alberta Environment (AENV) in the design of conveyance works and storage facilities. The *High Rainfall Drainage Event* provides a basis for the broader and longer-duration rainfall event, especially evident in June 2005.

For the purposes of this study and the design of facilities, the City of Lethbridge 1:100 year Chicago Storm is adopted (109.9 mm in 24 hours). This is considered a reasonable design event storm accepted by AENV, familiar to designers, and resulting in reasonable sizing of facilities.

3.4.2 Stormwater Model

Both the *Intense (Discrete) Stormwater Event* and the *High Rainfall Drainage Event* are modeled using the SWMHYMO Version 4.02 computer model. SWMHYMO modeling has been used in rural and urban catchments in Canada with varying catchment sizes and is the most often used hydrologic modeling software in Master Drainage Plan (MDP) studies. A SWMHYMO modeling schematic for the study area is shown in Figure 3.3.

In addition to modeling the intense, discrete, and high rainfall drainage storm events, it is recommended in most MDP studies to run the continuous modeling using historic rainfall data (30 years or more). As a comparison for detailed design within any particular sub-catchment area, it is recommended to run the



* ADD 18,000m³ VOLUME REQUIREMENT FOR 100 YEAR EVENT TO ACCOUNT FOR POTENTIAL FLOW FROM SOUTH TOWN AREA

** ASSUMES BIRDS OF PREY STORM POND OUTLET AND TOWN NORTH POND OUTLET CLOSED

LEGEND

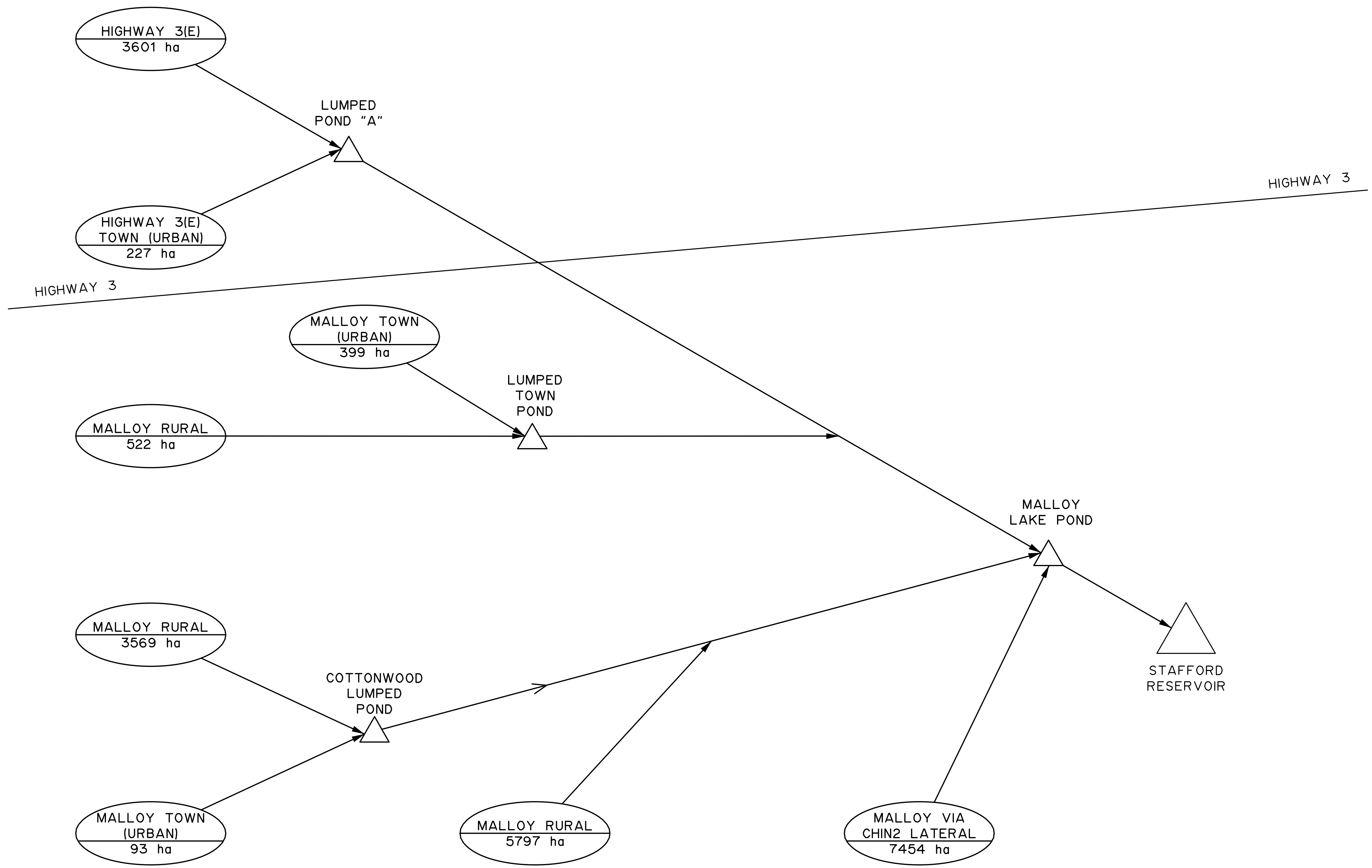
MALLOY-6 297 ha	CATCHMENT NAME AREA (ha)
→	FLOW DIRECTION
M6	CHANNEL REACH AND CROSS SECTION REFERENCE
)(	CULVERT
	CONSTRUCTED STORAGE POND
	NATURAL STORAGE POND
	FUTURE STORAGE POND
	CRITICAL FLOW JUNCTION
MALLOY-3C 80 ha	TOWN CATCHMENTS

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SWMHYMO MODELLING SKETCH

DESIGNED	KP	CHECKED	
DRAWN	JH	JOB	1755-045-00
SCALE	NTS	SHEET	
DATE	JANUARY, 2010	FIGURE 3.3	



LEGEND

MALLOY-6 / 296 ha	CATCHMENT NAME / AREA (ha)
⟶	FLOW DIRECTION
△	STORAGE POND

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
QHM MODELLING SKETCH

DESIGNED	KP	CHECKED	
DRAWN	JH	JOB	1755-045-00
SCALE	NTS	SHEET	
DATE	DECEMBER 2009	FIGURE 3.4	

continuous model in addition to other design storm scenarios (intense and discrete events), and adopt the most conservative storage result as stated in the Alberta Environment Stormwater Management Guidelines (AENV, 1999). A longer duration continuous model, QHM Version 3.1, using the available hourly data from the Lethbridge Airport during the period from 1960 to 1995 is modeled for the study area. A QHM modeling sketch with lumped catchments and ponds for the study area is shown in Figure 3.4.

Figure 3.5: June 2005 Daily Precipitation Data – Lethbridge Airport

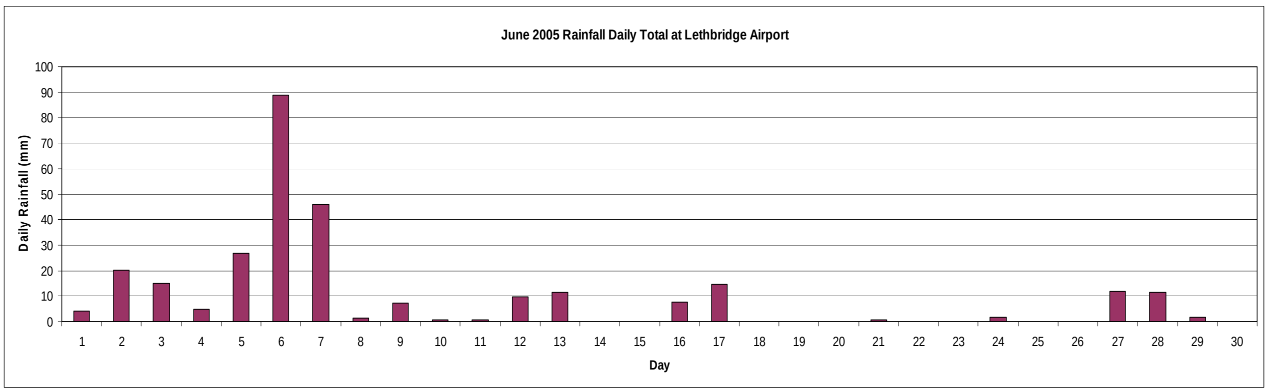


Figure 3.6: June 2005 Daily Precipitation Data – Lethbridge Research Centre

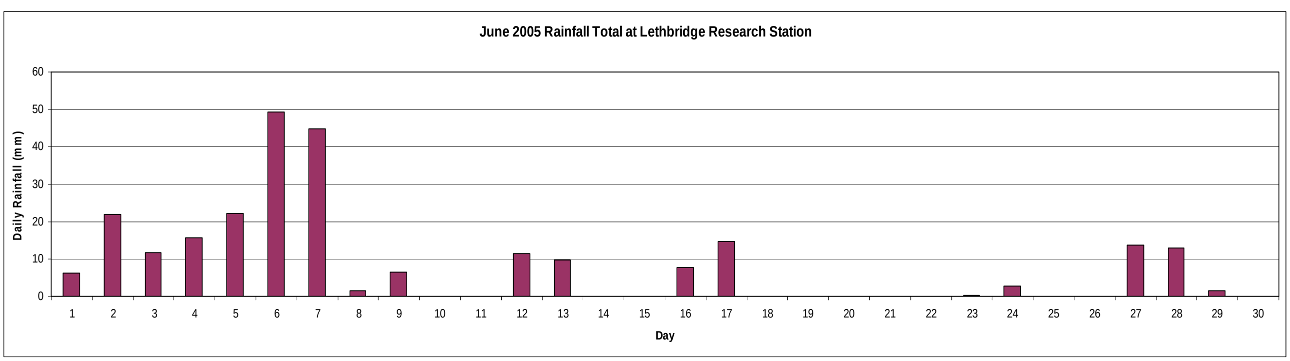
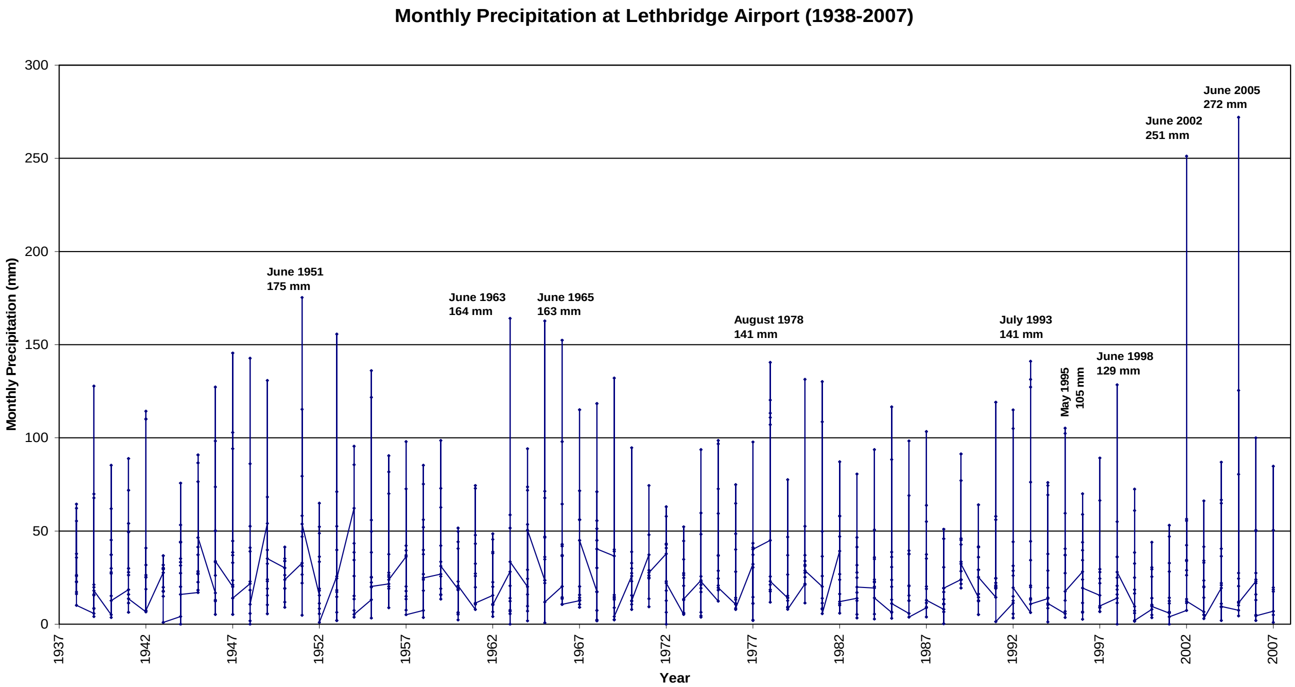


Figure 3.7: Monthly Precipitation at Lethbridge Airport (1938-2007)



3.4.3 Event Model Calibration

Associated Engineering Services Ltd (AESL) completed *The Coaldale Flood Control Study* (AESL, 1979), hereinafter referred as "*AESL Study*" for the Malloy Drain Basin in 1979. This study used August 22, 1978 rain storm in addition to 1978 spring snowmelt storm in their storm modeling of the basin using the HYMO model. According to AESL study, 89 mm of rain fell over 24 hours in and around Coaldale area. Based on this rainfall event, AESL study constructed a design rainfall hyetograph.

Since SWMHYMO is the product of HYMO based models, use of SWMHYMO model for this study was considered appropriate to compare results with the AESL study and other urban drainage modeling results completed around Coaldale area. Based on the rainfall hyetograph for the 1978 storm from AESL study (89 mm in 24 hours), a mass curve was constructed and used in the current storm modeling for the existing condition. The current model was calibrated to give similar order of magnitude results as the 1979 AESL model.

AESL study had identified a number of pockets within the Malloy Basin as areas of no runoff and low runoff based on natural depressions, flat topography, and no definite outlet. While calibrating the

SWMHYMO model for the Malloy Basin with the AESL study, some of the modeling parameters were adjusted to match the peak flows and runoff depths as closely as possible from most of the sub-catchments. In order to match with the AESL results, initial abstraction (IA) values for various sub-catchments were adjusted to varying values between 3.4 mm to 50 mm with majority of rural catchments having an IA value of 30 mm. IA value of 3.4 mm was used for rural catchments adjoining to the Town of Coaldale (as used in the past studies, for consistency), and IA value of 40-50 mm was used for large sub-catchments with significant depressional storage areas. The initial abstraction (IA) is generally the amount of rainfall that fills up the depressions storage such as small trapped lows, valleys or ponds before overland runoff begins. This amount is eventually lost via infiltration and evaporation.

In addition to IA, another sensitive parameter in model calibration was the runoff curve number (CN). The CN method was originally developed by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture for estimating runoff from ungauged agricultural watersheds. The method was subsequently applied to other watersheds in urban drainage problems. CN is a nonlinear transformation of a watershed storage parameter and relates total runoff to total rainfall for a wide variety of land uses for four hydrologic soil groups and three antecedent moisture conditions (AENV, 1999). The depth of runoff is computed by an equation using the total depth of rainfall for a given storm event and the estimated CN value for the given catchment.

AESL used the CN values between 69 to 70 for rural areas with a CN of 70 for majority of rural catchments and 75 to 85 for urban areas. MPE adopted a CN value of 70 in most rural sub-catchments and 72 to 79 in the near urban and urban catchments, respectively, to be consistent with previous storm modeling in the Town of Coaldale. Selection of CN value was based on the existing land use and dominant soil types within the study area as much as possible and being consistent with the previous hydrologic modeling projects in the basin. The model calibration parameters are shown in Table 3.3.

After calibrating the SWMHYMO model for the 1978 storm, other *intense*, *discrete*, and *high rainfall drainage events* as shown in Table 3.2 were run. Preliminary modeling runs indicated that the *high rainfall drainage event* of June 2005 simulations required the maximum amount of storage in the basin. Therefore, the outflow-storage curves for the natural storage areas (proposed ponds) were created to contain June 2005 storm event without any spill downstream in the drainage system. Under typical conditions, the allowable outflows from the proposed ponds are based on the existing culvert size at the immediate downstream road, however, to contain high drainage event storms, weir flow on the roads were added in the outflow-storage curves resulting into significantly higher outflows than allowable flows. The allowable outflows from the Town of Coaldale ponds were based on the existing design discharge of the constructed and interim ponds, and the East Pond Pump Station.

Table 3.3: SWMHYMO Model Calibration Parameters

Parameter	Value	Notes
Total Rainfall	89 mm	August 22, 1978 event—AESL, 1979
Total Runoff	20 mm	Overall runoff in the basin
CN	70-75	Rural Catchments
CN	78-79	Urban Catchments
Impervious Initial Abstraction	1.7 mm	Estimated depressional storage
Antecedent Moisture Condition	II	AMC II assumed moist prior to storm
Parameters Adjusted for Calibration:		
Pervious Initial Abstraction (Rural Agricultural)	30-50 mm	Estimated to match AESL runoff in majority of rural catchments
Pervious Initial Abstraction (Urban or near urban)	3.4 mm	Estimated to match parameters for storm modeling catchments adjoining to the Town of Coaldale

3.5 Comparison of Storm Events

All the model simulation results for the existing condition using different storm events are presented in Table 3.4 below. In addition to SWMHYMO and QHM modeling results, peakflow estimation for bridge culverts design in Alberta using the Runoff Depth method of Alberta Transportation (AT, 2006) and Probable Maximum Flood (PMF) estimation for Prairie Rivers (PFRA, 2009) are shown in Table 3.4 as a comparison.

Table 3.4: Storm Summary and Existing Condition Model Results

Storm Event	Rainfall	Duration	Peak Flows @ Malloy Lake	Storage Used	Runoff
1978 (Aug. 22)	89 mm	24 hours	35.4 to 48.8 m^3/s	2.5 Million m^3	20 mm (22%)
1995 (June 6)	67 mm	24 hours	17.8 to 13.9 m^3/s	1.3 Million m^3	9 mm (13%)
Chicago 24-Hour 100-Year (Leth West, 1989)	102.5 mm	24 hours	39.7 to 62.2 m^3/s	2.9 Million m^3	28 mm (27%)
Chicago 24-Hour 100-Year (AES- IDF, 1960-1994)	105.5 mm	24 hours	48.5 to 74.8 m^3/s	3.1 Million m^3	29 mm (28%)
Chicago 24-Hour 100-Year (City of Lethbridge IDF) (ADOPTED)	**109.9 mm**	**24 hours**	**52.9 to 87.7 m^3/s**	**3.3 Million m^3**	**32 mm (29%)**
2002 (June 8-10)-Env Can	175 mm	72 hours	51.2 to 83.4 m^3/s	4.6 Million m^3	81 mm (46%)
2002 (June 8-10)-Res Cen	143 mm	72 hours	57.8 to 92.9 m^3/s	3.9 Million m^3	56 mm (39%)
2005 (June 1-30)-Env Can	286.9 mm	30 days	> 80 m^3/s	6.5 Million m^3	167 mm (58%)
2005 (June 1-30)-Res Cen	254 mm	30 days	> 80 m^3/s	5.7 Million m^3	137 mm (54%)
QHM Continuous (1960-1995)	8,549.8 mm	35 years	53.3 to 62.5 m^3/s	5.4 Million m^3	1,042 mm (12 %)
AT Runoff Depth Method (AT, 2006)			34.5 to 52.6 m^3/s		35 mm
PMF Method (PFRA, 2009)			350 to 400 m^3/s	46 Million m^3	209 to 211 mm

3.6 Modeling Results

All results in this section are based on the Chicago 24-hour, 100-year storm event using the City of Lethbridge IDF curves.

3.6.1 Runoff Volumes and Available Storage

The runoff volume is the amount of precipitation that does not infiltrate into the ground, and is not trapped by natural terrain features. Water collecting against a road is considered runoff. The model was run for three land use conditions: existing, pre-development, and ultimate build-out. The runoff volume and available storage under three land use condition scenarios are discussed below.

3.6.1.1 Existing Conditions

The existing conditions scenario takes into account the various land uses, such as urban development, irrigated land, and non-irrigated rural land.

The runoff amounts for different land uses and catchments within the study area are shown below in Table 3.5.

Table 3.5: Existing Catchment Areas Assumed in the Model and Runoff from the 100-Year 24-Hour Event (109.9 mm Rainfall)

	Modeled Areas				Actual Areas		
Area Breakdown	**Rural (ha)**	**Urban & Surrounding (ha) [Note 1]**	**Total Area (ha)**		**Rural (ha)**	**Town (ha) [Note 2]**	**Total Area (ha)**
To Malloy Drain N. of Hwy. 3	3,601	227			3,612	216	3,828
To E. Culverts N. of Hwy. 3	1,004				1,004		
To Hwy. 3 South Ditch	821	361			838.5	343.5	1,182
To Coaldale Lateral	2,986				2,986		
To S. Coaldale Drain	3,715	251			3,727	239	3,966
To Malloy Lake Direct	1,242				1,242		
Sub-Total	***13,369***	***839***			***13,409.5***	***798.5***	***14,208***
To Chin 2 Lateral	**7,454**				**7,454**		**7,454**
TOTAL AREA	**20,823**	**839**	**21,662**		**20,863.5**	**798.5**	***21,662***

	Town Only (ha) [Note 2]	AT Highways (ha) [Note 3]	County Roads (ha) [Note 4]	HMQ & SMRID ROW (ha) [Note 5]	CPR & AB Rail (ha) [Note 6]	Remainder Rural (ha) [County]	*Total*
Area Breakdown	**770**	**212**	**273**	**230**	**44**	**20,133**	***21,662***
Average Runoff (mm)	**72**	**77**	**78**	**73**	**61**	**30**	***32***
Total Runoff (m^3)	**554,400**	**163,240**	**211,575**	**166,750**	**26,708**	**6,039,900**	***7,162,573***
Runoff Coefficient (%)	**66%**	**70%**	**71%**	**66%**	**55%**	**27%**	**29%**
% of Total Runoff	**7.7%**	**2.3%**	**3.0%**	**2.3%**	**0.4%**	**84.3%**	**100.0%**
Total discharge, m^3	**1,263,000** (Note 7)	**5,899,573**					**7,162,573**
% of Total Discharge	**17.60%**	**82.40%**					**100.00%**

Notes:

1) Urban Area includes Town, SMRID ROW (13.25 ha) within the Town, Highway ROW (15.33 ha) within the Town, plus some immediate rural roads and land assumed as "near urban" fringe. The total urban area assumed in the model is 5 % more than the actual Town area, so modeling is slightly conservative to better account for small pockets of urbanization (acreages) within the rural areas.

2) Town area includes SMRID ROW (13.25 ha) and Highway ROW (15.33 ha) within the Town boundaries. Town area net of these areas is 770 ha.

3) AT Highway ROW area provided courtesy of County of Lethbridge GIS System.

4) County Roads ROW area estimated by MPE for developed county road allowances.

5) HMQ (Her Majesty the Queen) represents Provincial irrigation lands (24.8 ha) and is combined with SMRID irrigation ROW area (205.6 ha); areas courtesy of County of Lethbridge GIS System.

6) CPR ROW area (42.3 ha) and AB Rail ROW area (1.3 ha) are combined; areas courtesy of County of Lethbridge GIS System.

7) Includes runoff from Highway, CPR, and SMRID ROW within Town boundaries; and runoff from contributing upstream rural catchments.

Typical runoff generated from **rural areas** showed the following characteristics:

- Is in the order of 20 to 34 mm (18% to 31% of total rainfall) from a 109.9 mm 100-Year 24-hour event.
- Some smaller and steeper areas runoff is 53 to 55 mm (48 to 50%).
- Average runoff is 30 mm equating to a runoff coefficient of 27%.
- Peak flows generally vary from 4 to 19 L/s/ha, but in some catchments higher, with smallest catchment peaking at 39 L/s/ha.
- Peak flows depend on length of basin, depressional storage, and steepness. Length and depression reduce peak flows, whereas, steepness increases the magnitude of the peak.

Typical runoff generated from **urban areas** showed the following characteristics:

- Is in the order of 80 to 86 mm (73% to 78% of total rainfall) from a 109.9 mm 100-year 24-hour event.
- Some undeveloped (still 'rural') areas have lower runoff.
- Average runoff is 72 mm equating to a runoff coefficient of 66%.
- Peak flows vary from 78 to 90 L/s/ha in typical developed urban areas.
- Peak flows run very high for very short time (< one hour).

Under the existing condition scenario, the amount of storage used in the constructed and natural (proposed) ponds is summarized in Table 3.6 below. *Zero stormwater release* means that there is no release during a storm event, with gradual release after ±24 hours following commencement of the storm (or once the properly sized storm ponds are full).

Table 3.6: Storage Available at Spill Elevation and Volume Used under Existing Condition from 1:100 Year 24-Hour Storm Event (109.9 mm Rainfall)

Pond#	Pond Name	Constructed Storage at Spill (m^3)	Natural Storage at Spill	Storage Used (m^3) [Note 1]	Unused (+) /Deficit (-) (m^3)
P1	County Broxburn B.P.	25,637	N/A	--	N/A
P2	Rural-Hwy 3 West	N/A	N/S	--	N/A
P1+P2				69,280	
P3	Rural-Upper Malloy	N/A	N/S	83,980	N/A
P4	Rural-Upper Malloy	N/A	N/S	144,900	N/A
P5	Rural-West of Town	N/A	N/S	181,200	N/A
P6	Rural-Upper Malloy	N/A	N/S	427,600	N/A
P7	Town Birds of Prey	128,300	N/A	116,100	12,200 (+)
P9	Town North Lumped	126,439	N/A	126,400	56,135 (spill)
P10	Town South Lumped	83,015	N/A	83,015	0
P10D	Town Jennie Emery	4,700	N/A	4,700	18,880 (spill)
P11	Town Cottonwood (1,2,3) Lumped	20,740	N/A	11,500	9,190 (+)
P12	Town Cottonwood Interim	32,400	N/A	410,400	378,000 (-)
P14	Town East	148,902	N/A	148,100	802 (+)
P15	Rural-South Malloy Lake	N/A	N/S	1,239,000 [Note 2]	N/A
P16	Rural-NE Malloy Lake	N/A	N/S	200,500	N/A
Total (m^3)		570,100		**3,246,730**	

Notes: N/S = Natural Storage based on contour information; N/A = Not Applicable

1) Assumes the following allowable release rates for the constructed ponds obtained from various storm reports, design drawings and documents include: P1 = 0.54 m^3/s (1:5 yr pre-dev); P7 and P9 = 0 or near 0 (Control Gate); P10 = 0.46 m^3/s (using inlet control device from Eastview to East Pond); P10D = 0.16 m^3/s; P11 = 0.7 m^3/s to P12; P12 = 1 m^3/s via Hwy 845 900 mm CSP; P14 = 1.85 m^3/s to Hwy 3 ditch via pumping. Storage requirements increase if zero release policy is implemented.
2) Storage values for P15 (Rural-South Malloy Lake) assume that the CHIN2 catchments with a drainage area of 7,454 ha are routed through P15, which is conservative. If CHIN2 catchments are not routed through P15, then the volume at P15 decreases by approximately 234,000 m^3.

In the modeling analysis, a conservative assumption was made in terms of catchments draining to the South Malloy Lake Pond (P15). Particularly, the CHIN2 catchments with a total drainage area of 7,454 ha were routed through P15. Due to restricted channel and culvert capacities near Highway 512, this assumption was considered conservative and reasonable.

Review of the values for storage used listed in Table 3.6 indicates that catchments into the Cottonwood Pond (P12) require significantly more storage than available (378,000 m^3 = 410,400 m^3 less available volume of 32,400 m^3). This deficit is due to the large contributing rural catchment area (> 3,000 ha), currently assumed to be draining through P12. The impact of this contributing catchment area should be analyzed in more detail to better determine the storage and possibly local interceptor ditches that will be required prior to further development of the Cottonwood area. The level of detail required for this analysis is beyond the scope of this study.

Two other areas where more pond storage required include: Pond P5 because it is adjacent to an urban area, namely Evergreen Estates and Pond P15, the “South Malloy Lake”, which has by far the largest storage requirements. These three areas in the basin are very critical locations during the flood events as confirmed in the modeling results and past flood history.

Based on the modeling results shown on Table 3.6, there is a shortage of about 2.7 million m^3 storage in the whole basin between the required storage and what is currently constructed. This shortage is manifested as uncontrolled flooding of rural lands.

Within the Town of Coaldale, the model predicts that Jennie Emery Pond (10D) will spill approximately 19,000 m^3 to the South Coaldale Drain, and the Town North Ponds (P9) will collectively spill approximately 56,000 m^3. The Town North Ponds are already planned for expansion that will eliminate this deficit. However, Jennie Emery Pond is not. Regarding other areas in the Town, no other storage shortfalls currently exist. However, this is the situation only if the Town can continue to release stormwater from its East Pond (P14) at 1.85 m^3/s during a storm, as has been modeled here. If a zero *stormwater release policy* is applied in the south part of the Town, similar to the north part of the Town, about 404,500 m^3 of additional constructed storage will be required, either upstream of or at the Town’s East Pond (P14).

3.6.1.2. Pre-development Conditions

A pre-development condition represents the terrain before any development occurred on the land. Runoff volumes are typically lower, as was the case in this model run shown in Table 3.7. Total runoff in the basin was between 52% and 63% of what it is today. The 1978 and 2002 storm events are also shown for comparison. These events illustrate that runoff increases dramatically with the intensity of the storm. Although the 2002 storm total was less than twice the precipitation of the 1:100 year 24-Hour Chicago Storm, it generated 3 times the runoff.

Table 3.7: Pre-Development Runoff

Storm	Runoff (% Coefficient)
100-Year 24-Hour Chicago Storm (109.9mm)	17 mm (16%)
1978 Storm (89mm)	10 mm (11%)
2002 Storm (175mm)	51 mm (29%)

3.6.1.3. Build-out Conditions

The build-out condition scenario assumes some new development within the County (mostly in the urban fringe areas) and some intensification within the Town. Based upon 2 to 3 % population growth over the next 20 to 25 years, the added urban areas represent the approximate area that will intensify from a rural (little impervious area) to an urban (more impervious area). For the modeling purposes only, this scenario has been set-up with the following assumptions.

- Two quarter sections in the County of Lethbridge have been considered to undergo development. These include: COAL-2 sub-catchment immediately west of the Town boundary, and MALLOY-2A sub-catchment around the existing Broxburn Business Park.
- Within and around the Town of Coaldale,
  - the Station Grounds and Northeast Industrial Area sub-catchment MALLOY-3D will be intensified,
  - the Cottonwood Development Lands sub-catchment SCOAL-1C will be intensified,
  - the Seasons Development and other areas within sub-catchment SCOAL-3 will be developed,
  - a quarter section within the sub-catchment SCOAL-4F, immediately east of Town's East Pond (P14) is considered under new development for the modeling purpose only. The actual development may occur at other locations.

The following table (Table 3.8) provides the summary of sub-catchments, landuse, and development intensity under the existing and future build-out condition scenarios.

Table 3.8: Existing and Build-out Condition Summary (Urban and Surrounding Town of Coaldale)

Modeled Catchments	Area (ha) [Note 1]	Existing Condition		Build-out Condition	
		Landuse	Development Intensity	Landuse	Development Intensity
COAL-3	361	Res/Com	Fully	Res/Com	Fully
MALLOY-3C	80	Res	Fully	Res	Fully
SCOAL-1D	26	Res	Fully	Res	Fully
SCOAL-3A	38	Res	Fully	Res	Fully
SCOAL-4F2 [Note 2]	65	Rural	Rural	Res	Fully
MALLOY-3D	147	Res/Com/Ind	Partially	Res/Com/Ind	Fully
SCOAL-1C	67	Rural	Rural	Res	Fully
SCOAL-3	120	Res	Partially	Res	Fully
TOTAL	904				

Notes: Res = Residential; Res/Com = Residential/Commercial; Res/Com/Ind = Residential/Commercial/Industrial

1) Area is based on total modeled urban area of 904 ha under the build-out scenario.
2) SCOAL-4F2 is adjacent land east of the Town Boundary, south of Highway 3 (SE 13-9-20-W4M) and is the portion of SCOAL-4F that is assumed to be converted to urban development in the Build-out scenario.

The area and runoff amounts under the existing and the future build-out condition scenarios are shown in Table 3.9 below.

Table 3.9: Existing and Build-out Condition Area and Runoff Summary

Items	Town of Coaldale		County of Lethbridge	
	Existing	Build-out	Existing	Build-out
Area (ha) [Note 1, 2]	798.5	863.5	130 ha Rural	130
Impervious Area (ha) [Note 1, 2]	257.5	366	Near 0 (130 ha Rural)	45.5
% Imperviousness (Overall)	32	42	0	35
Runoff (mm)	72	84	30	79
Runoff Coefficient (%)	66	76	27	72
Runoff Volume (m^3)	574,920	725,340	39,000	102,960

Notes:

1) Area prorated for Town only based on 839 ha modeled under the existing condition.
2) Area prorated for Town only based on 904 ha modeled under the build-out condition.

Under the build-out condition scenario, the amount of storage used in the constructed and natural (proposed) ponds is summarized in Table 3.10 below. Two additional storage ponds, near the Coaldale waste water lagoon (P8) and the abandoned raw water reservoir site (P13), are assumed to take some of Town's stormwater volume under the build-out condition.

Table 3.10: Storage Available at Spill Elevation and Volume Used under Build-out Condition from 1:100 Year 24-Hour Strom Event (109.9 mm Rainfall)

Pond#	Pond Name	Constructed Storage at Spill (m^3) [Note 1]	Natural Storage at Spill	Storage Used (m^3)	Unused (+) /Deficit (-) (m^3)
P1	County Broxburn B.P.	25,637	N/A	--	N/A
P2	Rural-Hwy 3 West	N/A	N/S	--	N/A
P1+P2				96,090	
P3	Rural-Upper Malloy	N/A	N/S	83,980	N/A
P4	Rural-Upper Malloy	N/A	N/S	144,900	N/A
P5	Rural-West of Town	N/A	N/S	183,300	N/A
P6	Rural-Upper Malloy	N/A	N/S	432,200	N/A
P7	Town Birds of Prey	128,267	N/A	116,100	12,167 (+)
P8	Rural-Town Lagoon Site	N/A	N/S	104,900	N/A
P9	Town North Lumped	214,749	N/A	191,100	23,649 (+)
P10	Town South Lumped	88,510	N/A	375,250	286,740 (-)
P10D	Town Jennie Emery	4,700	N/A	4,700	Note 4
P11	Town Cottonwood (1,2,3) Lumped	20,740	N/A	11,550	9,190 (+)
P12	Town Cottonwood Future Ponds 4, 5	43,900	N/A	412,900	369,000 (-)
P13	Town-Reservoir	130,000 [Note 3]	N/A	127,700	N/A
P14	Town East	148,902	N/A	148,902	Note 5
P15	Rural-South Malloy Lake	N/A	N/S	1,229,000 [Note 2]	N/A
P16	Rural-NE Malloy Lake	N/A	N/S	200,500	N/A
Total (m^3)		**805,405**		**3,396,262**	

Notes: N/S = Natural Storage based on contour information; N/A = Not Applicable

1) Assumes the following allowable release rates for the constructed ponds obtained from various storm reports, design drawings and documents include: P1 = 0.54 m^3/s (1:5 yr pre-dev); P7 and P9 = 0 or near 0 (Control Gate); P10 = 0.46 m^3/s (using inlet control device from Eastview to East Pond); P10D = 0.16 m^3/s; P11 = 0.7 m^3/s to P12; P12 = 1 m^3/s via Hwy 845 900 mm CSP; P14 = 1.85 m^3/s to Hwy 3 ditch via pumping. Storage requirements increase if zero release policy is implemented.
2) Storage values for P15 (Rural-South Malloy Lake) assume that the CHIN2 catchments with a drainage area of 7,454 ha are routed through P15, which is conservative.
3) The existing raw water reservoir has a total volume of 475,000 m^3, of which approximately 130,000 m^3 could be filled via gravity from the South Coaldale Drain.
4) Model predicts spillage of 19,000 m^3
5) Model predicts spillage of 20,000 m^3.

Review of the values for storage used (Table 3.10) indicates that there will be a shortage of 2.6 million m^3 of storage within the whole basin between required storage and what is currently or planned to be constructed. This shortage is manifested as uncontrolled flooding of rural areas.

Similar to the existing condition, catchments into the Cottonwood Pond (P12) require significantly more storage than available (369,000 m^3 = 412,900 m^3 less available volume of 43,900 m^3). This deficit is due to the large rural area (> 3,000 ha), assumed to be draining through P12, and intensification of Cottonwood development lands.

Town South Ponds (P10) also require significantly more storage than available (286,740 m^3 = 375,250 m^3 less available volume of 88,510 m^3). The model also predicts that during a 1:100 year storm, there will be a spill of about 19,000 m^3 from the Jennie Emery Pond (P10D) to the South Coaldale Drain and a spill of about 20,000 m^3 from the Town's East Pond (P14), unless these two ponds are expanded. This increase in required pond volume is due to development growth west of the Town (in the County) and intensification within the Town. To avoid spill, and consequent flooding downstream, new ponds within the new development areas are required, and new or expanded ponds within the existing areas may also be required.

Town pond spill values assume a 'flow through' release assumption that allows release during a storm, as the ponds were originally designed. However, the new *zero stormwater release policy*, currently specified in the Town's recent conveyance agreement with the SMRID, will significantly increase the pond volumes required, particularly in the Town south of Highway 3, by an additional 500,000 to 550,000 m^3 over the values presented here.

3.6.1.4 Conclusions from Model

- Catchment into Cottonwood requires significantly more storage than available as confirmed by modeling results. To mitigate flooding potentials in the Cottonwood area, a Pond P17 (see Figure 3.1), and a large Cottonwood Pond (or a rural pond just upstream of Cottonwood Development Lands), are proposed to intercept the rural flows. Current modeling results suggest a pond of about 380,000 m^3 near the vicinity of cottonwood interim Pond (P12). Alternatively, an interceptor drain to carry rural stormwater to Coaldale Lateral prior to entering Cottonwood area as a bypass concept has also been proposed (see Figure 3.17).
- The Town's East Storm Pond (P14) under the existing condition scenario with the current pond operating procedure (pump starting and running through the storm event duration) does not spill though comes to very close to spill. If this was operationally changed to pump only after a storm event (zero stormwater release reality), the pond would spill significantly (approximately 404,500 m^3). Under the build-out condition, with the pump running through the storm (current operating procedure), the east pond (P14) would spill ±18,000 m^3 and the Town South Ponds (P10) also require significantly more storage than available (286,740 m^3 = 375,250 m^3 less available volume of 88,510 m^3). There will be also a spill of about 19,000 m^3 from the Jennie Emery Pond (P10D) to the South Coaldale Drain. This is due to assumed additional land use development west of the Town and intensification within the Town.
- To avoid spill primarily in the areas south of Highway 3, both the existing ponds will have to be expanded or new ponds added in the "existing" developed areas, and all new developments and intensification areas must construct their own storm ponds. The existing ponds south of Highway 3 were originally designed on the assumption of 'flow through' ponds that released during storm events, and that the new zero stormwater release policy means the ponds are undersized. This is the biggest impact on the Town's existing ponds south of Hwy 3.
- Pond P5 proposed, immediately west of Range Road 20-3, needs to be developed to mitigate flooding in the Town and protect the Evergreen Estates development in the County.
- Prior to significant urban development occurring in the Cottonwood and Evergreen/West Coaldale areas, a more refined hydrologic modeling analysis accompanied by a more detailed

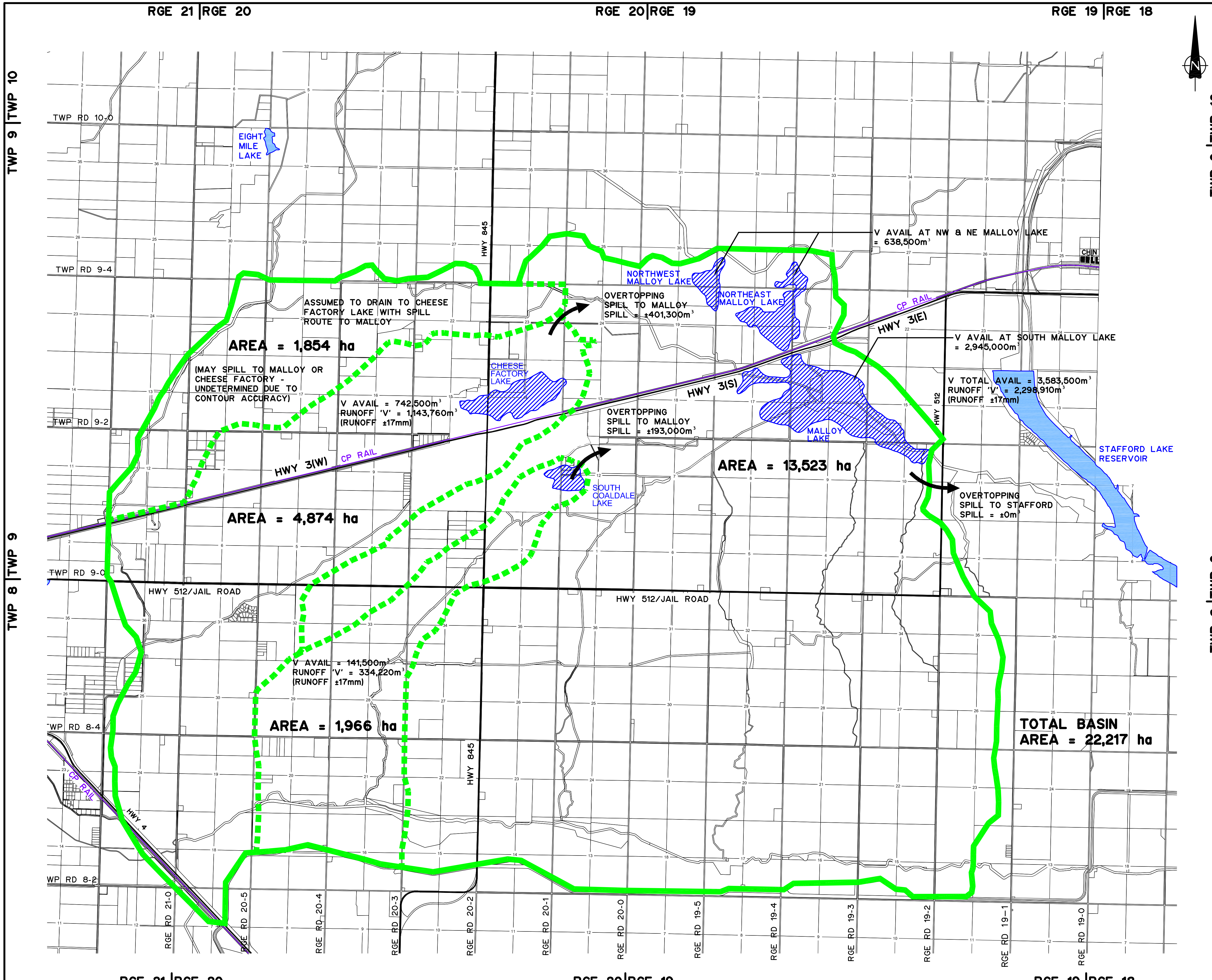
ground-proofing is highly recommended to confirm storage required to protect future developments from flooding. Both areas are shown to be seriously deficient of storage based upon the assumptions in this modeling analysis, and this should be mitigated before the area intensifies further.

- North Coaldale is not as great an issue as the Town North storm ponds are being designed for after storm release. These storm ponds are currently undersized, but upon implementation of all the phases, will be designed to contain the 1:100 year storm volume and with the provision of control gates closed during the storm event.
- South Malloy Lake is the main flooding area but does not affect large population. However, this location is prime location for a proposed pond to mitigate flooding in the basin.
- North and south rural areas, especially Ponds P2, P3, P4, P5, P6, and P16 locations are naturally flooded rural fields and in some cases (P4, P5 and P6) overtop roads. These areas are prime locations for natural flood easements, land purchase or as a last resort constructed ponds.
- Not all the existing ponds and natural storage (proposed pond) areas are in the proper place in the basin to attenuate flows during flood events and utilize the existing volume effectively. The possible use of Town's abandoned reservoirs and lagoon site for future storage should be explored.
- Since the carrying capacity of the Malloy Drain south of Highway 3 is the critical bottleneck in the basin, providing storage upstream of the Malloy Lake at identified locations would mitigate frequent flooding.

3.6.2 Basin Hydraulics

3.6.2.1 Pre-development Conditions

Development of the Malloy Drain and South Coaldale Drains has changed the way the runoff collects. Originally in pre-development times, with no natural outlets, three natural lakes formed, as shown on Figure 3.8. In present times, the volume and area of Malloy and Cheese Factory Lakes are much smaller than experienced in pre-development times, and the South Coaldale Lake no longer forms. Additionally, during pre-development the lakes remained longer, reducing only with evaporation, infiltration, and evapo-transpiration. The estimated sizes of the lakes forming during pre-development conditions, after a 100-year storm, are shown in Table 3.11.



NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:40, 000 etc) ARE BASED ON 22" x 34" FORMAT DRAWINGS

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PRE-DEVELOPMENT CATCHMENTS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:4,0000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.8

Table 3.11: Pre-Development Volume of Malloy and Cheese Factory Lakes with No Outlet (Pre-Drain)

South Coaldale Lake	Cheese Factory Lake	Malloy Lake
334,220 m3 (271 ac ft)	1,143,760 m3 (928 ac ft)	2,298,900 m3 (1,864 ac ft)

3.6.2.2 Existing Conditions

Existing infrastructure has reduced the occurrence of the major 'lakes' by providing a 'drain'. Drains and in some cases canals, have intercepted runoff and increased the speed of transfer from upstream to downstream catchment areas. Constructed storage areas such as the ponds at the Birds of Prey Centre have reduced the volume of water collecting in these lakes. From a flooding perspective, the area is better off with the drains than without. However, large storm events can overwhelm the drainage system and result in flooding where the runoff flows exceed the capacity of the channels.

In order to evaluate the drainage system, the hydraulic capacities of the channels and culverts were estimated. Channels were partitioned into reaches where cross section was approximately uniform. These are listed in Table 3.12. Using channel geometry and Manning's formula for uniform flow in channels, the corresponding capacities were calculated. The culverts in these reaches were identified and their flow capacities calculated based on the diameter, length, and estimated water depth in channel. An average culvert capacity was applied to each reach.

Capacities of both the channels and the culverts for the selected reaches are shown in Table 3.13. Capacities are expressed as both total capacity and unit capacity.

Total capacity is merely the hydraulic capacity of the channel or culvert. Unit capacity refers to the amount of runoff, over and above the base flow if any, that the infrastructure can handle on a unit area basis. It is expressed in L/s/ha to allow comparison between sub-basins regardless of their area. A value of 1.0 L/s/ha is equal to 1.43 cfs per 100 acres.

The reaches within the study basin are shown on Figure 3.9, and have been colour-coded by their unit flow capacities. The colour coding provides a rough guide of their capacities relative to the size of the catchment area from which they receive runoff. For a given storm event size, infrastructure throughout the basin should be able to accommodate roughly the same unit runoff. Any components of the drainage infrastructure with lower unit capacities than the rest of the system would be bottlenecks. The difference between unit channel/culvert capacity and the estimated unit runoff flows creates flooding that must be made up by storage.

It should be pointed out that a special consideration has been made for the Coaldale Lateral reaches labeled as CL2, CL2A and CL2B. From hydraulic modeling and observed flooding sites (near P5 and P12) it appears that portions of the Coaldale Lateral could be overwhelmed from the runoff received from sub-basins COAL-1, SCOAL-1B, and CIN2-2, and the channel overtops during a storm. Much of this excess will flow into the South Coaldale Drain. The South Coaldale Drain has much larger capacity and would not require as significant of upgrades to handle the transfer of runoff from these sub-basins, whereas the Coaldale Lateral would require costly upsizing. It has therefore been assumed that the transfer of runoff from the Coaldale Lateral to South Coaldale Drain would be “built” into the system by constructing a diversion spillway and channel. As outlined previously in this report, model scenarios incorporate this assumption.

Table 3.12: Channel Dimensions and Estimated Capacities

X-section #	Bottom Width, m	Side Slope	Total Depth, m	Slope, m/m	Full Capacity (m^3/s)	Base Flow (m^3/s)	Runoff Capacity (m^3/s)
Chin							
C1	3.66	2.0	1.85	0.0005	13.3	6.1	7.2
C2	4.33	2.0	2.07	0.00037	12.1	5.3	6.8
C3	3.5	2.0	1.79	0.0004	8.2	3.2	5.0
C4(Note 2)	1.22	1.5	1.32	0.007	21.6	4.4	17.2
C2a	0.61	1.5	0.76	0.00136	2.0	0.6	1.4
C3a	1	3.0	1	0.002	3.6	0.3	3.3
Coaldale							
CL1 (Note 1)	1.83	1.5	1.16	0.0005	2.2	0.9	1.3
CL2 (Note 1)	1.83	1.5	1.22	0.00045	2.3	0.8	1.5
CL2A	1.5	3.0	1.4	0.00045	4.3	1.2	3.1
CL2B	1.2	3.0	1.4	0.00045	4.0	1.1	2.9
CL3	9	3.0	2.2	0.0009	40.8	1.1	39.7
CL4	12.5	3.0	2	0.0009	43.5	1.1	42.4
CL5	1.8	1.5	1.2	0.00113	3.6	1.0	2.7
Upper Malloy							
M1	2.1	1.6	1.6	0.0004	4.0	0.0	4.0
M2	2.3	3.0	1.8	0.0004	8.0	0.0	8.0
M3	2.5	2.0	1	0.00038	1.9	0.0	1.9
M3A	2.5	2.0	1	0.0015	3.7	0.0	3.7
M4	1.5	1.6	2.5	0.0015	17.7	0.0	17.7
Little East							
LE1	2.3	2.0	1.6	0.0005	5.4	2.0	3.3
LE2	2.3	2.0	1.6	0.0005	5.4	2.0	3.3
LE3/4	2.3	2.0	2	0.00036	7.4	2.9	4.4
Lower Malloy							
M5	1	1.6	1.8	0.0013	6.7	2.9	3.8
M6	1	2.0	2.25	0.001	12.8	2.9	9.9
M6A	1	2.0	2.25	0.001	12.8	3.9	8.8
M7	0.5	2.0	2.5	0.0004	9.3	4.1	5.2
M8	4.6	3.0	2.2	0.0008	25.6	4.2	21.4
M9	2.6	3.0	2.5	0.0014	35.3	4.2	31.2
South Coaldale Drain							
SC1	0.91	2.0	2.5	0.001	16.2	0.0	16.2
SC2	0.91	2.0	2.2	0.002	16.7	0.0	16.7
SC4	18	3.0	3	0.0007	109.5	0.0	109.5
SC5	3.5	3.0	2.2	0.0007	21.0	0.0	21.0

Notes:

1. There is an additional 0.6m of freeboard in CL1 and CL2 from the average height of natural ground above "banks", based on record profile drawings. This applies to most, but not all, of these two reaches. With localized bank lifts, the runoff capacity would increase from approx. 1.4 cms to 4.4 cms.

2. There is a 1.55 m^3/s-capacity siphon on Chin2 Lateral (Reach C4) under the Malloy Drain. Flow rates in excess of 1.55 m^3/s enter the Malloy Drain via a spill structure.

Table 3.13: Channels and Culverts: Total and Unit – Area Capacities

Reach	Catchment Area, ha	Channel Runoff Capacity		Culverts In Reach	Culvert Capacity	
		Total, m^3/s	Unit-Area, L/s/ha	ID #'s	Total, m^3/s	Unit-Area, L/s/ha
Chin						
C1	568	7.2	12.7			
C2	3025	6.8	2.3			
C3	6933	5.0	0.7			
C4	7452	17.2	2.3			
C2a	792	1.4	1.8	19	1.8	1.5
C3a	736	3.3	4.5			
Coaldale						
CL1	2104	1.3	0.6	14,18,27	7	2.9
CL2	30	1.5	50.0	4 x no ID		
CL2A	120	3.1	25.7	4 x no ID		
CL2B	120	2.9	24.3	45	3.6	20.8
CL3	6479	39.7	6.1	-		
CL4	7215	42.4	5.9	52,52A	7	0.8
CL5	7215	2.7	0.4	-		
Upper Malloy						
M1	788	4.0	5.1	1,15	0.65	0.8
M2	2598	8.0	3.1	20,29	4.1	1.6
M3	238	1.9	7.9			
M3A	238	3.7	15.6			
M4	3366	17.7	5.3	32,33	6.7	2.0
Little East						
LE1	632	3.3	5.3	-		
LE2	632	3.3	5.3	-		
LE3/4	3850	4.4	1.2	34,37	7.5	1.2
Lower Malloy						
M5	3850	3.8	1.0	42,43	5.6	0.7
M6	5000	9.9	2.5	51	10	0.8
M6A	13265	8.8	0.8	-		
M7	13265	5.2	0.4	54,54A	14	0.7
M8	21662	21.4	2.3	56	44	0.9
M9	21662	31.2	1.4			
South Coaldale Drain						
SC1	703	16.2	23.0			
SC2	3662	16.7	4.6	30,35	2.6	0.7
SC4	3943	109.5	27.8	39	4	1.0
SC5	4936	21.0	4.2	47	6.6	1.3

To put the unit capacities in perspective of storm event return periods, they can be expressed as follows:

Table 3.14: Reach Capacities by Storm Event Size

Typical Peak Flow Unit Capacities, L/s/ha (rural catchment unless otherwise noted)	Equivalent Storm Size, Year Frequency
0.5-1	1:5
2-3	1:20
3-4	1:25
4-8	1:50
25	>1:100
12-30 (urban catchments)	1:5

As a broad-brush generalization, the channel capacities in the basin are typically sized to accommodate the 1:20 to 1:50 year return period events, although notably, some of the Lower Malloy channel has only a 1:5 year capacity. Culverts are typically sized from less than the 1:20-year capacity.

Additional comments on the determination and assessment of the unit capacities follows below:

- Full channel capacity is taken to be at flow to top of bank. In the case of a canal, the operational base flow in the irrigation canals has been considered. Full design flow has been assumed, and is subtracted from the total capacity of the canal, leaving a “freeboard capacity” available for runoff flow.
- Most drains are assumed to have no pre-storm base flow. That is, the full channel cross section is available for runoff.
- However, drains downstream of canals are assumed to carry the canal design flow as a pre-storm base flow. This base flow is subtracted from total capacity.
- Canal base flow is assumed to be at design flow during a storm. In other words, it has been conservatively assumed that there is not enough time to shut off irrigation flows in the canals during a storm event.

- Capacities of culverts at key locations have also been calculated. However, these capacities are dependent on tailwater depth in the channel downstream of the culvert, which has been estimated. An accurate determination of all culverts in the system is beyond the scope of this study, so only a sample of the major culverts has been included.
- Not all culvert capacities have been determined. For example: culverts in road ditches have not been considered; Chin Canal has several culverts, but they have not been assessed, as no flooding issues along it were noted.
- Culvert and channel capacities can be more accurately assessed as part of future upgrades along specific reaches in the study area.
- In some reaches the channel is the limiting factor, while other reaches are limited by culvert capacity.
- As mentioned in Section 3.5.1.1, a 100-year storm typically generates 4 to 19 L/s/ha (rural) and up to 90 L/s/ha in urban areas.
- Some catchment areas require higher unit capacities than others. For example, the Cheese Factory drain has a relatively large unit capacity of greater than 10 L/s/ha, but it serves an urban catchment with high runoff rates. Thus although this reach shows as "green", suggesting suitable capacity, a detailed subcatchment analysis could very well show it to be undersized. In addition, receiving channels downstream have lower unit capacities, and create bottlenecks that can be a cause of backup in the Cheese Factory Drain.
- The drains do have limited capacity, and represent 'bottlenecks' in areas where their unit capacities are significantly less than the unit runoff rates from any given storm event.
- Portions of the Lower Malloy system can only accommodate from less than 0.5 L/s/ha to about 1.5 L/s. This is the major bottleneck on the entire system.
- In the upper reaches and along the South Coaldale Drain, there is higher unit capacity, often 2.5 to 10 L/s/ha, due to the large cross sections. However, the South Coaldale Drain is still restricted by culvert capacity.

3.7 Upgrade Scenarios

Eight model scenarios were run, representing varying degrees of channel upgrades and storage development. The model identified the amount of storage volume required to satisfy the channel constraints in each scenario. Locations where the storage would occur were assigned to the model, and the model determined the amount of storage required at each site. Generally, the greater the channel upgrades, the less storage required, and vice-versa. Site locations are shown on Figure 3.9.

3.7.1 Drain Upgrades

For the purposes of the study, the upgrades were grouped by the extent of capacity upgrade. Scenarios 1 and 8 represent the extreme cases of:

- no channel upgrades, and
- upgrades sufficient to convey peak flows without new storage, respectively.

Intermediate scenarios 2-7 represented upgrade of channels and culverts, where required, to unit capacities of 0.5-4.45L/s/ha as follows:

Table 3.15: Modeled Scenarios

Scenario	Minimum Channel Unit Capacity (L/s/ha)
1	No channel upgrades
2	0.5
3	1.0
4	1.5
5	2.0
6	2.5
7	4.5
8	7.0

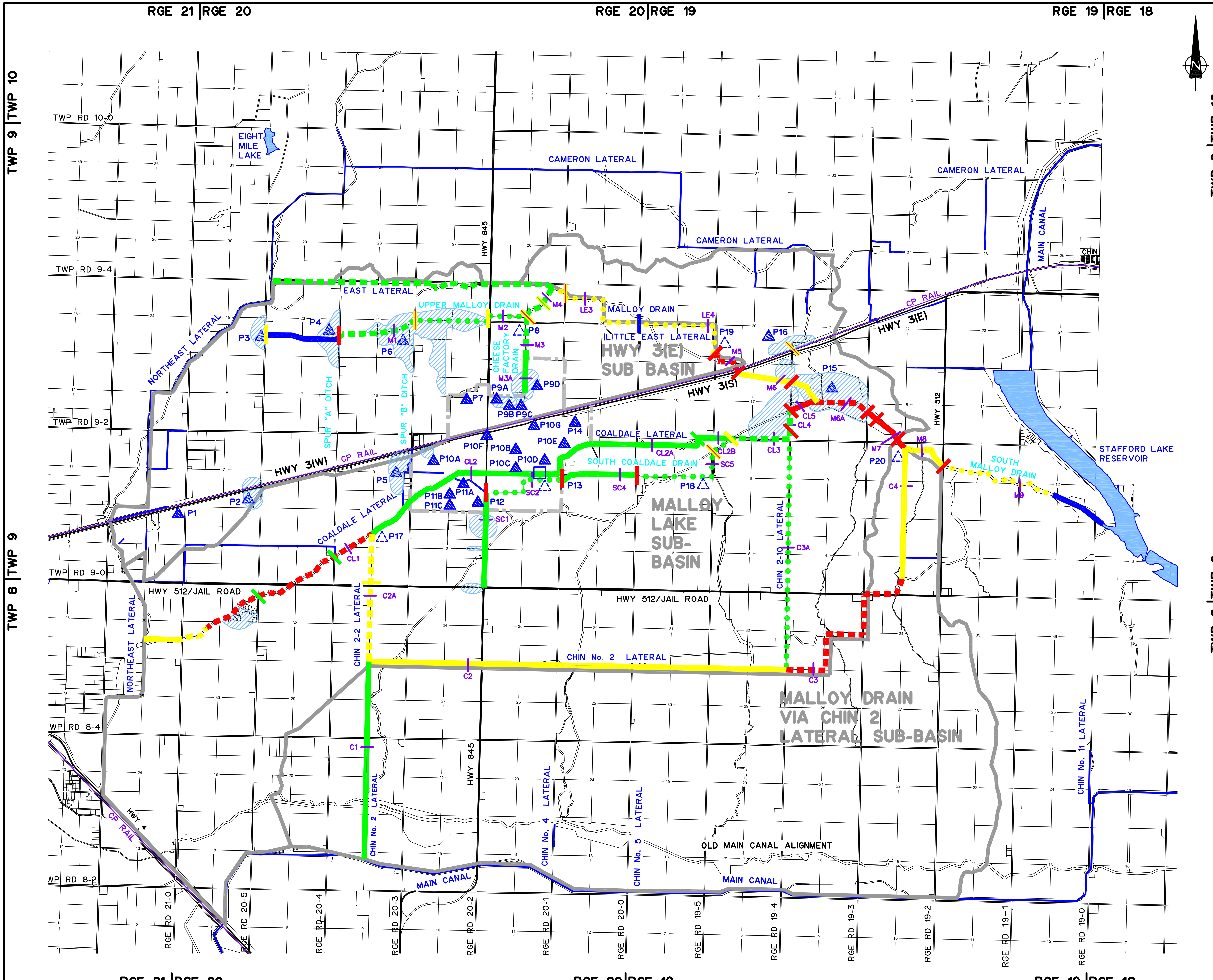
The upgrades assumed are shown in Table 3.16 below.

Table 3.16: Drain Upgrades for Model Scenarios

Channel Upgrades			Culvert Upgrades		
Reach	**Scenarios**	**Length Upgraded, m**	**Scenarios**	**Culverts Replaced, ID#**	**Location**
Chin					
C1	-		-		
C2	6-8	8500	-		
C3	3-8	2500	-		
C4	6-8	2000	-		
C2a	5-8	2200	5-8	19	Hwy #512
C3a	8	5400			
Coaldale					
CL1	3-8	5000	8	18,27	Between RR 203,204
CL2, CL2A, CL2B	-		-		
CL3	8	1100	-		
CL4	8	500	3-8	52,52A	Twp Rd 9-2 & RR 19-4
CL5	2-8	400	-		
Upper Malloy					
M1	8	900	3-8	1,15	RR's 205, 204
M2	8	2500	5-8	20,29	RR's 203, 202
M3, M3A	-		-		
M4	8	600	6-8	32,33	N of Cheese Factory Drain
Little East					
LE1,/2	-		-		
LE3/4	4-8	4100	4-8	34,37	RR's 201, 200
Lower Malloy					
M5	4-8	500	3-8	42,43	RR 195, CPR &Hwy #3
M6	8	1600	4-8	51	RR 194
M6A	3-8	1000			
M7	2-8	1000	3-8	54,54A	RR 193, and pivot crossing just downstream
M8	6-8	1000	4-8	56	RR 192
M9	4-8	3000	-		
South Coaldale Drain					
SC1	3-8	2400(Note 1)	-		
SC2	-		3-8	30,35	RR's 202, 201
SC4	-		4-8	39	RR 200
SC5	8	2600	4-8	47	RR 195

Notes

1. *West extension of South Coaldale Drain to convey proposed spill diversion from Coaldale Lateral.*



LEGEND

CHANNEL CAPACITY (L/S/ha)
- <0.5
- >0.5-1.0
- >1.0-1.5
- >1.5-2.0
- >2.0-2.5
- >2.5-5.0
- >5.0-10.0
- >10.0
- TO BE DETERMINED

CULVERT CAPACITY (L/S/ha)
- 1.0 OR LESS
- >1.0-1.5
- >1.5-2.0
- >2.0-2.5
- >2.5
- TO BE DETERMINED

- REACH CROSS-SECTION "SC4"
- CONSTRUCTED STORAGE POND
- NATURAL STORAGE POND (MODELLED)
- FUTURE STORAGE POND
- FLOOD AFFECTED AREAS
- TOWN BOUNDARY

NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:40,000 etc) ARE BASED ON 22" x 34" FORMAT DRAWINGS

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
CHANNEL AND CULVERT CAPACITY CONSTRAINTS MAP

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.9

3.7.2 Storage Requirements

With the upgrade scenarios listed above, the model was run for each scenario to determine the required storage. The storage volumes are shown in Table 3.17 below. These volumes include existing storage ponds in their totals.

Table 3.17: Comparison of Upgrade Options for 100-Year 24-Hour Design Storm

	Upstream Channel Design	Required Channel Upgrade Length	Lower Malloy Design Flow Range (Note 1)	Lower Malloy Lake Storage (P15 + P20) (Note 2)	Total Storage Required in Basin (Notes 3,4)
No Channel Upgrade - Most Storage Needed.	Existing: Scenario 1	-	6 to 21 m^3/s	1,800,000 m^3 (ac ft)	5,250,000 m^3 (4,257 ac ft) (24 mm)
Minimal Channel Upgrade - Reduced Storage Needed.	0.5 L/s/ha Scenario 2	1.4 km	7 to 22.55 m^3/s	1,763,000 m^3 (1,471 ac ft)	5,121,000 m^3 (4,152 ac ft) (24mm)
Further Increase Upper Channels	1.0 L/s/ha Scenario 3	9.9 km	14 to 26 m^3/s	1,795,000 m^3 (1,468 ac ft)	4,734,000 m^3 (3,838 ac ft) (22 mm)
Further Increase Upper Channels	1.5 L/s/ha Scenario 4	15.4 km	21 to 33 m^3/s	1,735,000 m^3 (1,419 ac ft)	4,301,000 m^3 (3,487 ac ft) (20 mm)
Further Increase Upper Channels	2.0 L/s/ha Scenario 5	17.6 km	28 to 44 m^3/s	1,377,000 m^3 (1,127 ac ft)	3,612,000 m^3 (2,929 ac ft) (17 mm)
Further Increase Upper Channels – Less Storage Needed	2.5 L/s/ha Scenario 6	26.1 km	36 to 54 m^3/s	1,096,000 m^3 (896 ac ft)	3,044,000 m^3 (2,468 ac ft) (14 mm)
Further Increase Upper Channels – Less Storage Needed	4.5 L/s/ha Scenario 7	36.4 km	64 to 97 m^3/s	292,000 m^3 (238 ac ft)	1,474,000 m^3 (1,195 ac ft) (7 mm)
Further Increase Upper Channels – No New Storage Needed (Note 5)	~7 L/s/ha Scenario 8	41.3 km	105 to160 m^3/s	-	-

Notes:

1. *The Lower Malloy Design Flow is over 14,208 ha to 21,662 ha contributing area, plus a 4 m3/s irrigation flow allowance. Current Capacity on the Lower Malloy downstream of the South Coaldale Drain is approximately 11.1 m^3/s up to Chin2, then increases to 25 m^3/s up to Hwy 512.*
2. *For 2.0 and 2.5 L/s/ha scenarios, Lower Malloy Lake volume also includes P18.*
3. *Current 'constructed' storage available in the system is 817,459 m^3, which includes Broxburn Pond, Birds of Prey, North Coaldale & Station Grounds, South Town Ponds, Cottonwood Permanent & Interim Pond.*
4. *Proposed volumes assume pumps used. If a piped outlet operating by gravity, ponds may need to be marginally larger to account for low outlet flows when pond levels are low. Pond outlet flows don't maximize until there is significant depth in pond.*
5. *However, some localized and short term ponding may still occur.*

It should be noted that with the exceptions of Scenarios 6-8, the required total storage is greater than occurs in the existing system model (=3,300,000 m^3, see 100-year, 109 mm, Chicago Storm, Table 3.4). This is because under current conditions and infrastructure, very high peak flows are occurring where roads are overtopped or deliberately breached. This breaching means less storage is used. To prevent roads from breaching, more storage is required. In the upgraded model scenarios, road overtopping has been assumed to be unacceptable, and additional storage is provided to prevent it.

3.7.3 Cost Estimates

3.7.3.1 Channels

To determine order-of magnitude costs to upgrading channels, the following methods and assumptions are used.

- **Base unit price of $250/m**, for large (>25cms capacity) canals, with an average excavation quantity of 10 m^3/m. The $250/m valve is based on recent canal tenders, excluding costs of structures or armour. (Drains are normally built with unarmoured side slopes.) An allowance of 30% has been added to the unit prices to account for associated costs not included in the canal tenders.
- For each reach, the required increase in total capacity was calculated, and from this, an increase in cross-sectional area was estimated.

An adjustment factor to unit cost based on relative size of the canal is applied. The linear cost per metre to upgrade is assumed proportional to the amount of excavation required to increase its size. For example, on Reach M7, downstream of Malloy Lake:

	Scenario 3, 1.0 L/s/ha		Scenario 6, 2.5 L/s/ha	
Existing Capacity, m^3/s	Required Capacity	Unit Cost, $/m	Required Capacity	Unit Cost, $/m
9.3	17.2	$202	37.0	$626

Based on these unit costs, estimated costs to upgrade channel capacity as follows:

Table 3.18: Channel Upgrade Costs

Scenarios (see Table 3.15 for scenario description)								
Reach	**Length, m**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Chin								
C1	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -
C2	8500	$ -	$ -	$ -	$ -	$ 157,867	$ 1,875,783	$ 3,549,783
C3	2500	$ -	$ 184,085	$ 488,581	$ 748,947	$ 1,029,908	$ 1,996,352	$ 2,972,253
C4	2000	$ -	$ -	$ -	$ -	$ 13,669	$ 146,042	$ 290,369
C2a	2200	$ -	$ -	$ -	$ 6,338	$ 19,627	$ -	$ 135,551
C3a	5400	$ -	$ -	$ -	$ -	$ -	$ 42,120	$ 360,056
Coaldale								
CL1	5000	$ -	$ 171,527	$ 390,055	$ 593,029	$ 791,945	$ 1,258,137	$ 1,258,137
CL2/2A/2B		$ -	$ -	$ -	$ -	$ -	$ -	$ -
CL3	1100	$ -	$ -	$ -	$ -	$ -	$ -	$ 348,996
CL4	500	$ -	$ -	$ -	$ -	$ -	$ -	$ 136,883
CL5		$ 11,362	$ 50,362	$ 82,819	$ 114,019	$ 142,402	$ 248,040	$ 398,188
Upper Malloy								
M1	900	$ -	$ -	$ -	$ -	$ -	$ -	$ 147,786
M2	2500	$ -	$ -	$ -	$ -	$ -	$ 1,277,183	$ 1,277,183
M3/3A		$ -	$ -	$ -	$ -	$ -	$ -	$ -
M4	600	$ -	$ -	$ -	$ -	$ -	$ -	$ 76,267
Little East								
LE1/2	-					-		
LE3/4	4100	$ -	$ -	$ 226,135	$ 549,864	$ 809,324	$ 1,904,164	$ 3,148,428
Lower Malloy								
M5	500	$ -	$ -	$ 23,833	$ 47,223	$ 69,558	$ 145,279	$ 238,057
M6	1600	$ -	$ -	$ -	$ -	$ -	$ 314,442	$ 1,060,618
M6A	1000	$ -	$ 46,124	$ 174,558	$ 297,324	$ 409,910	$ 779,866	$ 1,448,323
M7	1000	$ 55,234	$ 262,584	$ 454,204	$ 640,640	$ 814,385	$ 1,412,840	$ 2,346,094
M8	1000	$ -	$ -	$ -	$ -	$ 597,868	$ 1,296,990	$ 1,407,069
M9	3000	$ -	$ -	$ 76,333	$ 600,901	$ 1,128,821	$ 2,908,217	$ 5,244,231
South Coaldale Drain								
SC1	-		$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000
SC2/4	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SC5	2600	$ -	$ -	$ -	$ -	$ -	$ -	$ 335,667

Note: Scenario 1 has no channel upgrades and is therefore not included.

3.7.3.2 Culverts

Unit costs, from AB Trans Unit Price Average Report for supply and install, as follows:

400 mm dia.	$165/m
600 mm dia.	$193/m
900 mm dia.	$350/m
1050 mm dia.	$441/m
1200 mm dia.	$570/m

Extrapolated costs for larger diameters as follows:

1500 mm dia	$825/m
2000 mm dia	$1100/m
2400 mm dia	$1319/m
3000 mm dia	$1649/m
2400 x 4000 arch	$1759/m

An additional 50% was added to these figures to cover associated costs not included in the tender item. Based on these unit costs, and culvert replacements as listed in Table 3.16 above, the culvert upgrade costs are as follows:

Table 3.19: Culvert Upgrade Costs

	Scenario (see Table 3.15 for scenario description)						
Reach	**2**	**3**	**4**	**5**	**6**	**7**	**8**
CL1						$769,500	$769,500
CL4		$99,000	$99,000	$148,500	$148,500	$297,000	$445,500
LE3		$-	$74,250	$99,000	$117,000	$157,000	$157,500
M1		$31,500	$31,500	$31,500	$39,690	$99,000	$99,000
M2		$-	$-	$74,250	$74,250	$118,700	$148,500
M4		$-	$-	$-	$99,000	$148,500	$157,500
M5		$296,820	$296,820	$296,820	$296,820	$297,000	$315,000
M6		$-	$58,500	$74,250	$74,250	$148,500	$222,750
M7		$148,500	$157,500	$157,500	$157,500	$315,000	$472,500
M8		$-	$157,500	$157,500	$157,500	$236,250	$236,250
C2A		$-	$-	$19,845	$19,845	$25,650	$37,125
SC2		$51,300	$74,250	$74,250	$99,000	$148,500	$148,500
SC4		$-	$37,125	$37,125	$49,500	$74,250	$74,250
SC5		$-	$37,125	$49,500	$49,500	$78,750	$78,750
Total		$627,120	$1,023,570	$1,220,040	$1,382,355	$2,914,000	3,362,625

Note: Scenario 1 has no channel upgrades and is therefore not included.

3.7.3.3 Constructed Storage Site Costs

Cost estimates have been developed for construction of storage in the volumes presented earlier in Table 3.16. For an order of magnitude cost, construction costs are assumed to comprise of excavation and a pumping facility. Unit prices for large canal earth works projects have been around \$3.50/ m^3 recently, and have been assumed for this estimate. A fixed allowance has been used for the majority of pumping facilities. Land acquisition costs for storage sites have been included, at a purchase price of \$14,826/ha (\$6,000/acre).

Ponds P15 and P20 (Malloy Lake) appeared separately in the hydrology model (different catchment areas) but were assumed to combine into a single storage site.

In these estimates the cost to construct the Cottonwood Interim Pond site (P12) into an established pond has been included.

There has been discussion about the potential for the Town waste water lagoons to be replaced by a regional waste water system, at sometime in the future. The lagoons could then be retired from service and could be used as storm water storage ponds. This location has been identified as storage P8 site in the model. However, for the purposes of this report it is assumed that the lagoons would not be available for storage in the foreseeable future, and a new pond would be constructed nearby.

A special case exists for P13, which is the abandoned raw water reservoir for the Town of Coaldale. With relatively minor modification, high flow levels in the South Coaldale Drain could be diverted into it, and a regulated post-storm discharge could occur by gravity. An estimated 130,000 m^3 could be stored in this manner. With additional excavation and pumping facilities provided, another 500,000 m^3 could be added to its capacity. Based on our results, the required storage at site P13 is less than 130,000 m^3 for all scenarios; so no excavation costs are carried at this time. The option remains to transfer additional runoff from other areas and further upgrade the reservoir (i.e. excavation and pumps), but this is not considered at this time in the costs.

The projected pond construction costs are shown in Table 3.20 below.

Table 3.20: Estimated Storage Site Construction Costs

	Scenario (see table 3.15 for scenario description)						
Pond Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**
P1 & P2 (m^3)	99,381	95,140	75,503	61,394	50,840	41,898	15,167
$	$ 750,854	$ 725,104	$ 606,137	$ 520,126	$ 456,024	$ 400,949	$ -
P3 (m^3)	107,134	104,613	92,487	81,302	71,356	63,658	41,394
$	$ 849,950	$ 835,833	$ 767,927	$ 705,291	$ 649,594	$ 606,485	$ 481,806
P4 (m^3)	131,334	127,610	111,219	96,772	83,160	70,954	35,791
$	$ 1,051,470	$ 1,028,616	$ 929,826	$ 842,923	$ 759,696	$ 686,342	$ 472,430
P5 (m^3)	175,062	175,062	175,062	175,062	175,062	175,062	175,062
$	$ 1,315,347	$ 1,315,347	$ 1,315,347	$ 1,315,347	$ 1,315,347	$ 1,315,347	$ 1,315,347
P6 (m^3)	445,347	430,471	362,988	300,270	243,547	193,423	54,111
$	$ 2,990,943	$ 2,901,638	$ 2,495,733	$ 2,118,512	$ 1,777,863	$ 1,475,169	$ 634,022
P8 (m^3)	96,850	94,039	81,281	69,839	59,349	50,100	22,517
$	$ 843,360	$ 825,618	$ 749,174	$ 679,098	$ 615,354	$ 559,560	$ 391,095
P12 (m^3)	231,765	225,529	196,659	170,627	147,306	127,076	66,298
$	$ 1,656,884	$ 1,618,962	$ 1,445,290	$ 1,288,511	$ 1,147,914	$ 1,025,626	$ 658,269
P13 (m^3)	92,937	91,023	81,791	73,084	65,313	59,212	41,567
$	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000
P15 (m^3)	815,898	779,713	626,231	496,070	376,429	275,373	11,920
P20 (m^3)	983,301	983,301	1,169,226	1,239,442	1,002,200	820,921	279,751
$	$11,305,514	$11,088,878	$11,283,559	$10,923,867	$ 8,786,322	$ 7,095,246	$ -
P16 (m^3)	220,269	209,243	160,095	118,583	83,265	53,421	0
$	$ 1,587,506	$ 1,520,761	$ 1,224,532	$ 974,065	$ 760,284	$ 580,158	$ 250,000
P17 (m^3)	552,145	528,156	418,037	324,577	241,895	171,897	9,822
$	$ 3,582,012	$ 3,437,674	$ 2,776,007	$ 2,214,631	$ 1,717,612	$ 1,295,623	$ 313,003
P18 (m^3)	616,596	599,041	524,834	453,557	386,769	329,313	145,906
$	$ 3,968,938	$ 3,863,630	$ 3,418,070	$ 2,989,919	$ 2,588,906	$ 2,243,153	$ 1,139,074
P19 (m^3)	113,002	108,936	90,007	73,483	59,010	46,135	11,300
$	$ 940,811	$ 916,042	$ 802,039	$ 701,505	$ 613,456	$ 535,356	$ 322,280
TOTAL	**$31,093,590**	**$30,328,102**	**$28,063,642**	**$25,523,797**	**$21,438,373**	**$18,069,014**	**$8,494,683**

Note: Scenario 8 has no constructed storage, and is not shown in the table above.

As an alternative to constructing ponds, the costs to purchase sites and develop natural ponds (i.e. designated flooding areas) with minimal construction were examined. This was performed for sites P1, 2, 3, 4, 5, 6, 15, 16, and 20. Costs assumed were $14,826/ha ($6,000/acre) for land purchase, plus $100,000-$400,000 for a regulated outlet structure.

A second, similar alternative would be to acquire flooding easements for the affected lands at these same sites. In this way the land could continue to be owned and used by the existing landowner, with agreed-upon damages paid after a flooding event. Up-front costs assumed were $2,965/ha ($1,200/acre) for land easement acquisition, plus $100,000-$400,000 for a regulated outlet structure.

The determined land purchase costs run roughly 55% of the cost for excavated ponds. The determined easement costs run roughly 15% of the cost for excavated ponds. The costs for these alternatives are included in the combined costs in Table 3.21 below.

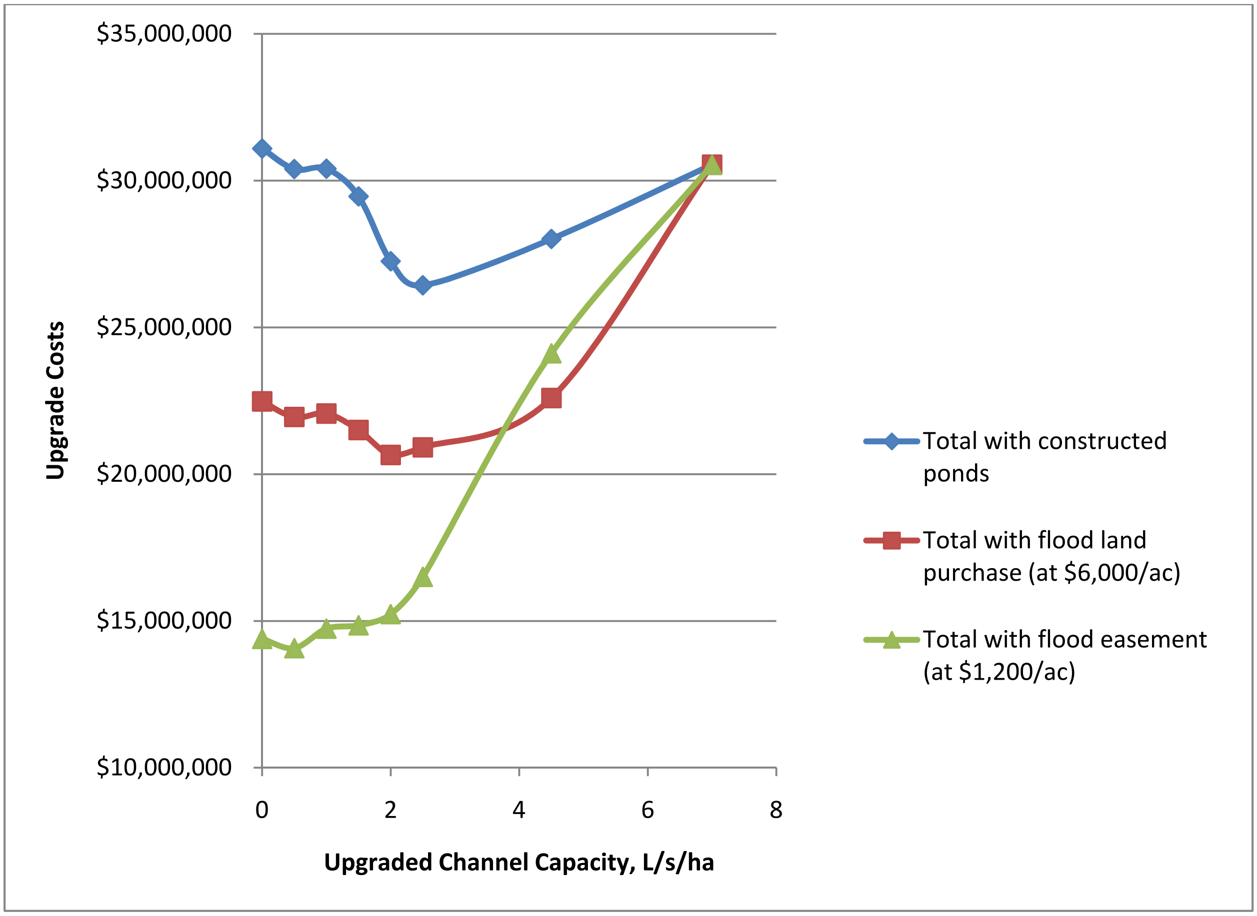
3.7.3.4 Combined Costs

Dollar values from Tables 3.17, 3.18, and 3.19 have been combined below for an aggregate cost to achieve each Scenario.

Table 3.21: Comparison of Upgrade Options for 100-Year 24-Hour Design Storm

	none	0.5 L/s/ha	1 L/s/ha	1.5 L/s/ha	2 L/s/ha	2.5 L/s/ha	4.5 L/s/ha	~7 L/s/ha
Channel Improvements	$ -	$ 67,000	$ 1,715,000	$ 2,917,000	$ 4,598,000	$ 6,985,000	$ 16,605,000	$ 27,180,000
Culvert Improvements	$ -	$ -	$ 627,000	$ 1,024,000	$ 1,220,000	$ 1,382,000	$ 2,914,000	
Constructed Storage	$ 31,094,000	$ 30,328,000	$ 28,064,000	$ 25,524,000	$ 21,438,000	$ 18,069,000	$ 8,495,000	$ -
Total	**$ 31,094,000**	**$ 30,395,000**	**$ 30,406,000**	**$ 29,465,000**	**$ 27,256,000**	**$ 26,436,000**	**$ 28,014,000**	**$ 30,543,000**
Storage Alternative A								
Flood Land Purchase	$ 11,235,000	$ 10,970,000	$ 10,281,000	$ 9,441,000	$ 7,902,000	$ 6,636,000	$ -	$ -
Total with flood land purchase	**$ 22,478,000**	**$ 21,949,000**	**$ 22,064,000**	**$ 21,506,000**	**$ 20,653,000**	**$ 20,913,000**	**$ 22,593,000**	**$ 30,543,000**
Storage Alternative B								
Flood Easement	$ 3,146,000	$ 3,093,000	$ 2,956,000	$ 2,787,000	$ 2,480,000	$ 2,227,000	$ 1,524,000	
Total with flood easement	**$ 14,389,000**	**$ 14,072,000**	**$ 14,738,000**	**$ 14,852,000**	**$ 15,230,000**	**$ 16,503,000**	**$ 24,117,000**	**$ 30,543,000**

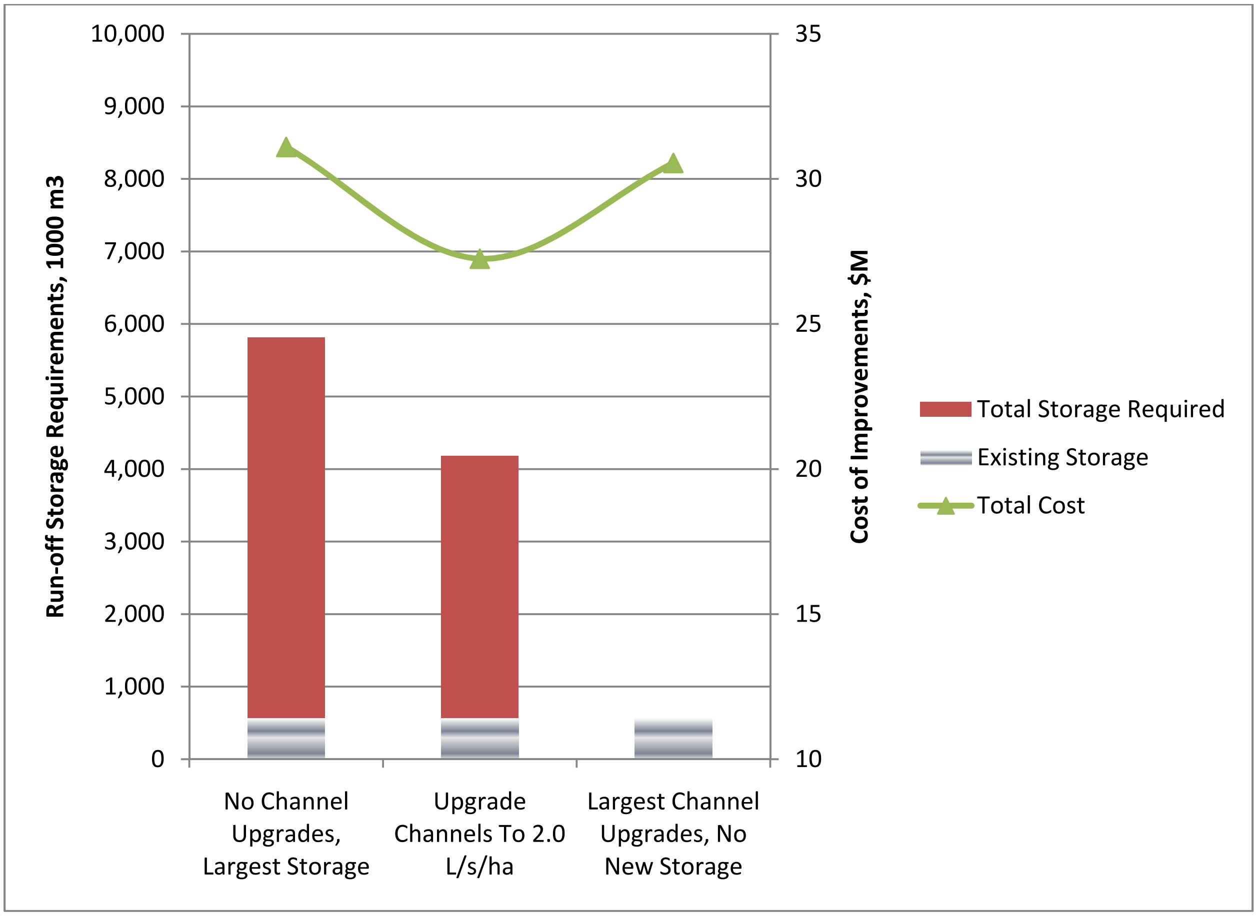
Figure 3.10: Upgrade Costs versus Extent of Channel Upgrades

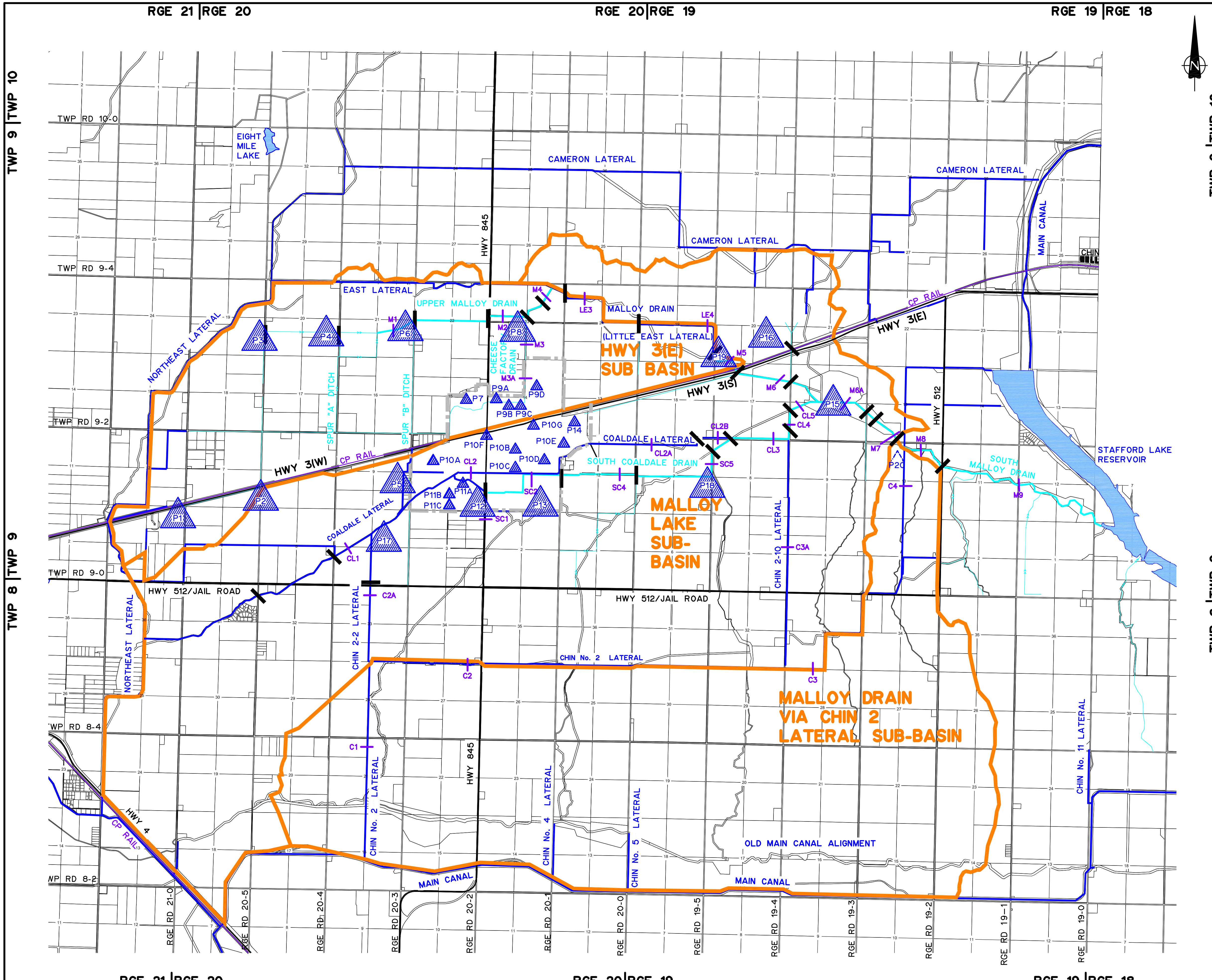


From Figure 3.10 above, the lowest constructed pond cost option appears to be at a scenario 6 (channel upgrades to 2.5 L/s/ha), with the 2.0 L/s/ha option a close second. When a purchase of flood land is considered, the 2.0 L/s/ha scenario is the most cost effective, although the costs are similar to the 2.5 L/s/ha option in this case. When a purchase of flood easements are considered, the 0.5 L/s/ha scenario is by a slight margin the most cost effective, although the costs of the 0.5-2.0 L/s/ha are very similar. As it is unlikely that flood easements could be obtained from all landowners of the selected sites, the 2.0 L/s/ha option is recommended. Where flood easements can be obtained, this will reduce the overall project cost. However, the cost difference from other scenarios is not marked. If there is a compelling reason to select an option emphasizing either more channel capacity or more storage, it should be considered.

Figures 3.11-3.14 provide graphical representations of the recommended option as compared to the two extreme options.

Figure 3.11: Comparison of Upgrade Alternatives





LEGEND

- CONSTRUCTED DETENTION POND
- TOWN BOUNDARY

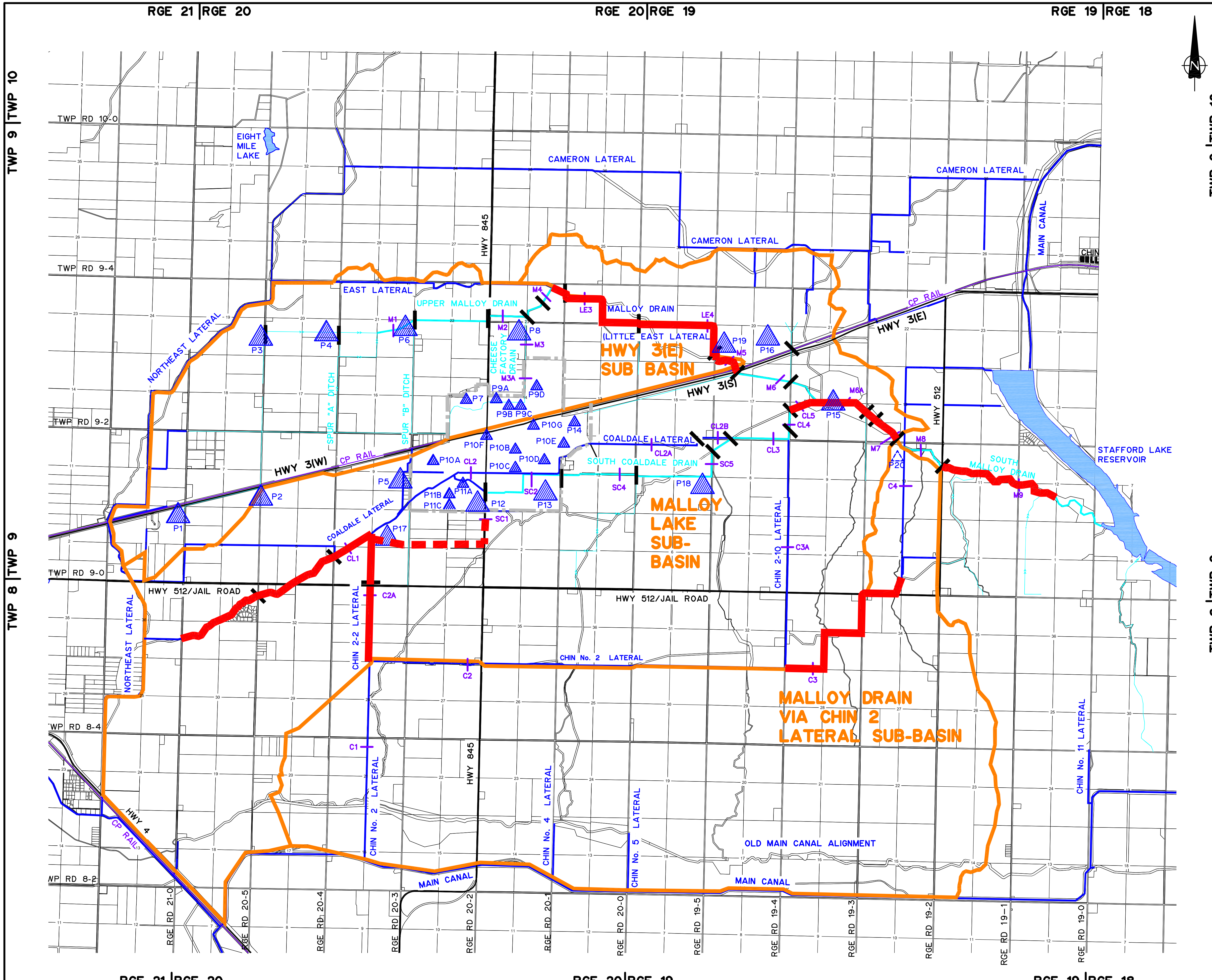
NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:40, 000 etc) ARE BASED ON 22" x 34" FORMAT DRAWINGS

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 1: CONSTRUCT LARGE PONDS, NO CHANNEL UPGRADES

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.12



LEGEND

- CONSTRUCTED DETENTION POND
- UPGRADED CHANNEL
- NEW CHANNEL
- UPGRADED CULVERT
- TOWN BOUNDARY

NOTE:
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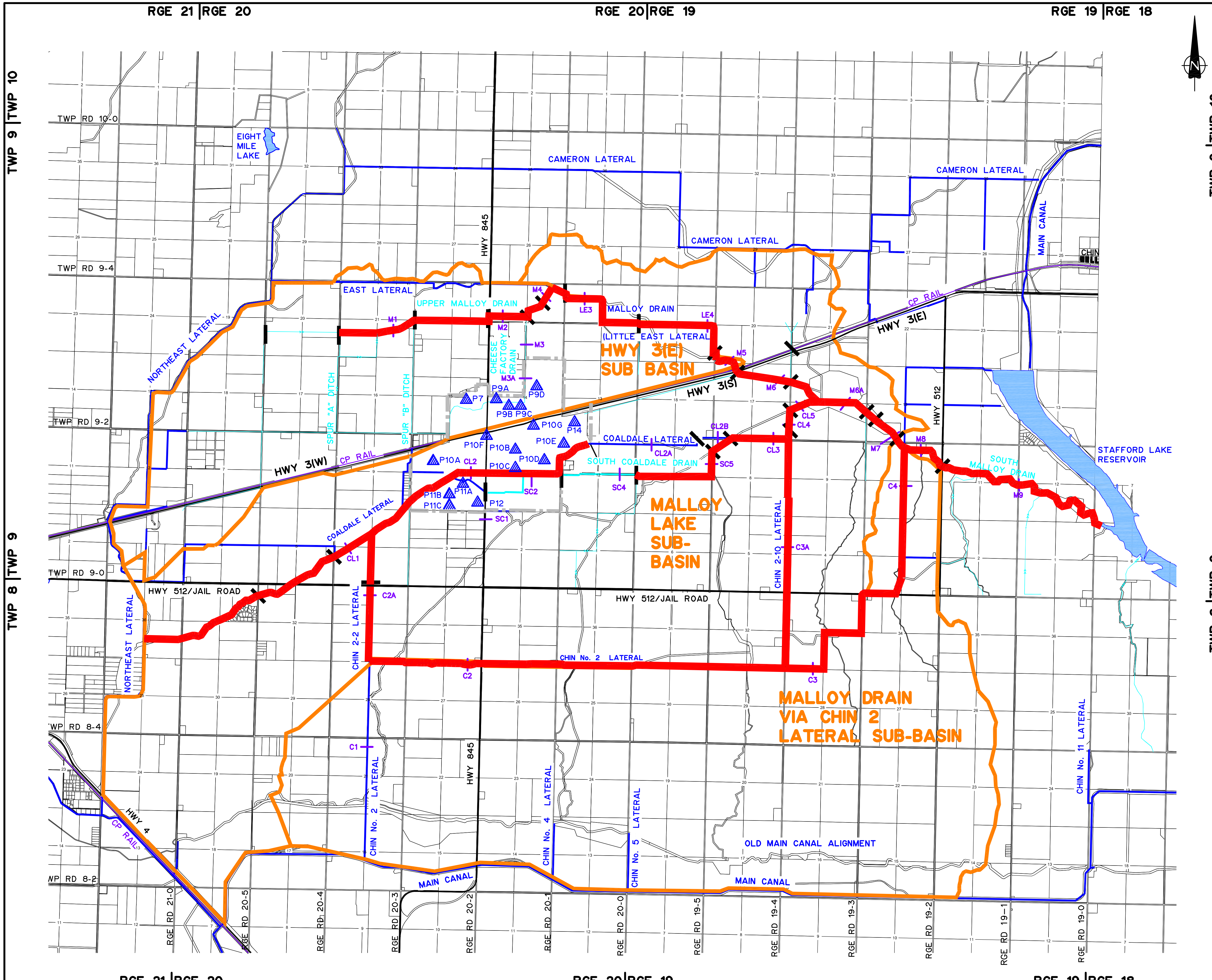
MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 5: CONSTRUCT COMBINATION CHANNEL UPGRADES AND DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.13



LEGEND

- CONSTRUCTED DETENTION POND
- UPGRADED CHANNEL
- UPGRADED CULVERT
- TOWN BOUNDARY

NOTE:
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MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 8: FULL CHANNEL UPGRADES AND NO NEW DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.14

3.8 Assessment of Capital Improvement Alternatives

Based on the information obtained from the model, there appears to be four Alternatives to help deal with the problems being experienced throughout the basin during a Storm Event.

Alternative 1 "Status Quo"

This alternative (Figure 3.15) maintains the status quo. Storm events will happen and flooding will occur. Fields will be inundated and crops damaged. Some county roads will be overtopped, and possibly subject to damage. Claims for flood damage will be submitted to the appropriate agency and dealt with by insurance companies or through the legal system. The advantage of this alternative is that no capital expenditures are incurred. The disadvantage is that the problem never goes away and future generations will have to deal with this problem. Potential problems include further deterioration of infrastructure, exposure to lawsuits for damages, and discouragement of new development in the area. It will be difficult to obtain approval for any new developments because of concerns they would adversely impact landowners already subject to flooding. Future land development, and the associated economic contribution to the area, is hampered unless system improvements can be made.

Cost = flood damages + intangibles

Alternative 2 "Buy Out Frequently Affected Lands"

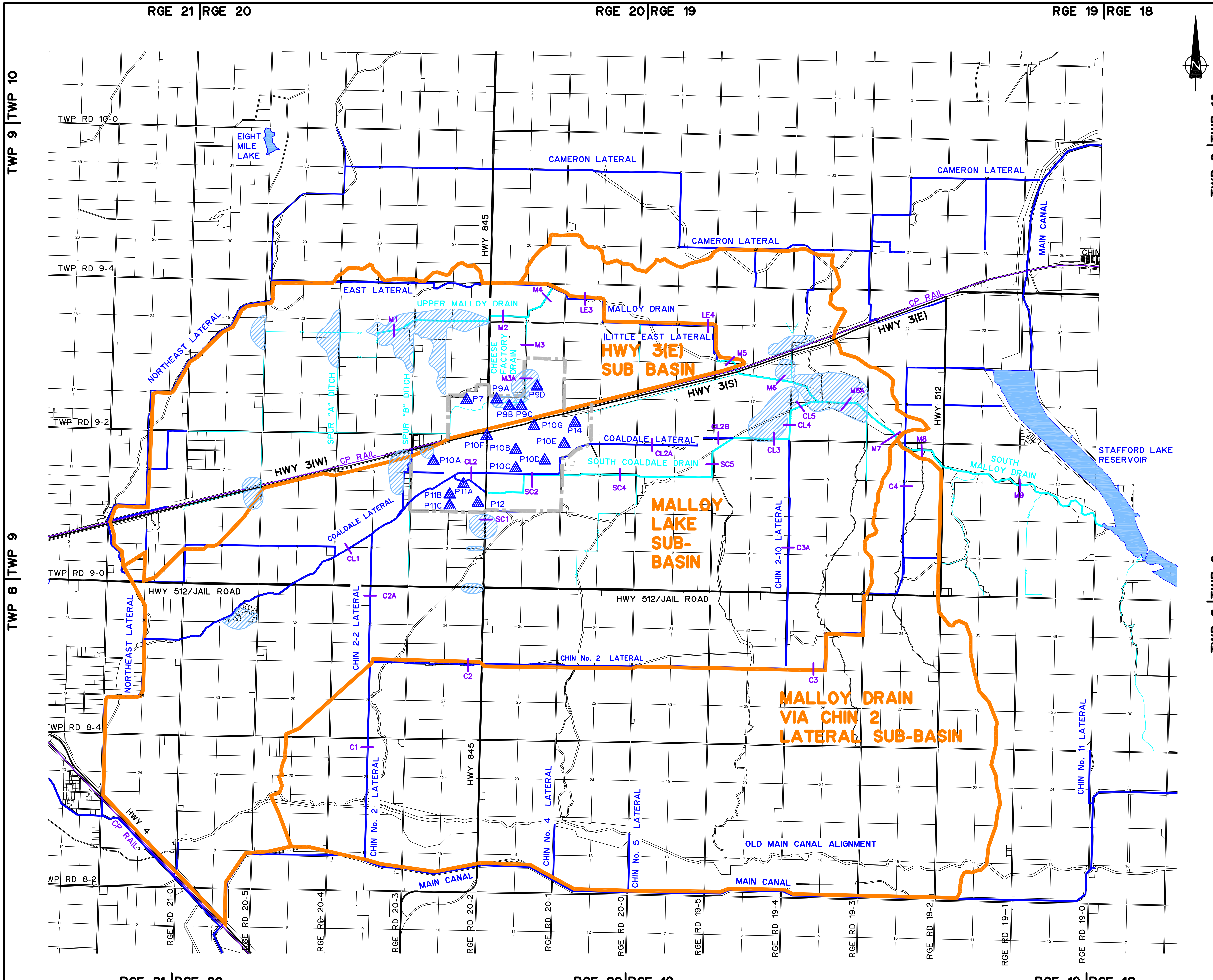
This alternative (Figure 3.16) is similar to Alternative 1, in that no infrastructure improvements are made. However, property damage claims and legal action are largely avoided. This alternative does not address potential damage to roads and drainage works infrastructure. There also would be the same development constraints as in Alternative 1.

Cost = $7,208,000

Alternative 2A "Obtain Flood Easements on Frequently Affected Lands"

Same as above (Figure 3.16), except that flood-affected lands are covered by a flood easement agreement rather than outright purchase. These agreements may be more difficult to negotiate.

Cost = $1,450,000



LEGEND

LAND EXPECTED TO EXPERIENCE RECURRENT FLOODING

TOWN BOUNDARY

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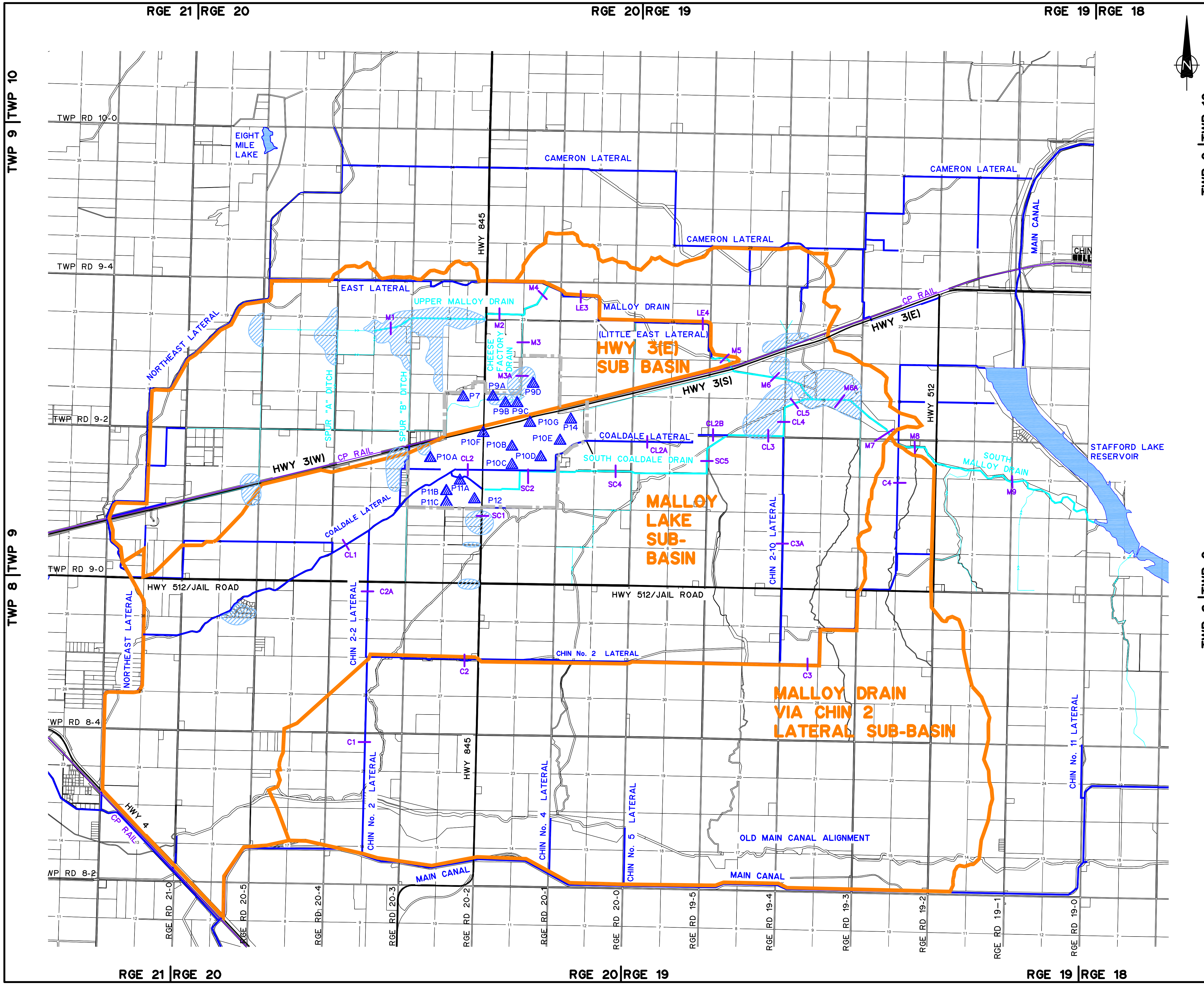
COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
ALTERNATIVE 1: STATUS QUO

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.15



LEGEND

FLOOD-AFFECTED LAND TO PURCHASE OR ACQUIRE EASEMENT

TOWN BOUNDARY

NOTE:
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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
ALTERNATIVES 2 AND 2A: PURCHASE FLOOD-AFFECTED LANDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.16

Alternative 3 "Combination of Storm Detention Ponds and Enlargement of Existing Drainage Works"
Modeled in Scenarios 1-7, this Alternative allows for the construction of stormwater detention ponds throughout the basin in conjunction with increases in channel capacity. Large amounts of stormwater will be detained until the storm event has passed, and then water will be released slowly into the system as capacity permits.

The most cost-effective of these scenarios (see Figures 3.11, 3.13) is a combination of 623,000 m^3 of new constructed storage and upgrading 26 km of channels to a capacity of 2.0 L/s/ha, at a total estimated cost of $27,250,000.

Cost = $27,250,000

Alternative 3A

Purchasing land for natural ponding sites is about 50% of the cost of actually constructing storage at those sites, and where applicable would reduce the costs for this Alternative by $6,500,000.

Cost = $20,700,000

Alternative 3B

Acquisition of flood easements (whereby land ownership is unchanged) is about 15% of the cost of the constructed pond cost, and where applicable would reduce the total of this Alternative by $12,000,000. This does not include periodic payments (at a pre-agreed rate structure) when damages occur after flood event.

Cost = $15,200,000

Alternative 4 "Fully Expand the Malloy Drain"

The modeling (Scenario 8) shows that over 100 m^3/s can be experienced at the downstream end of the Malloy Drain, if the channels upstream are expanded to convey all the runoff. The size of drain required to handle this flow rate is very large and expensive to build and maintain. The estimated cost to construct a drain of this size is estimated at $29,500,000.

Cost = $30,500,000

3.8.1 Storage and Channel Upgrades

Additional comments pertaining to upgrade scenarios follows below:

- Without a more detailed analysis, the sizing and cost estimation for channel upgrades is order of magnitude only that allows a relative comparison of costs between scenarios.
- The feasibility of channel upgrades is reasonably high, since construction would be on existing right-of ways, and would not require significant additional land.
- However, development of pond sites, whether constructed or purchased land, is more contingent on acquiring land for the pond site, which may not always be easy.
- Operationally, upgraded channels may present issues such as reduced capacity over time due to accumulated weed growth. It is also more difficult to provide controlled overflow sites in channels during events larger than the design storm, whereas provision of an emergency spill from a pond is usually feasible.
- Channels, especially one upstream of storage sites can be affected by short intense storms, with higher peak flows than the design storm. Pond storage depends more on the total volume of runoff, not the peak rate, and is not affected by short, intense storms.
- Reduced capacity in the Coaldale Lateral may mean some spilling upstream of the South Coaldale Drain could occur. A diversion channel into the South Coaldale Drain can help.
- Relative to the use of storage, increasing channel capacity has more potential impact on the water levels in Stafford Lake. However, any impacts on Stafford Reservoir look to be quite manageable. Lake Stafford has an area of 437 ha (1136 acres), equating to a storage of 46,000 m^3/cm of level. The entire 100-year runoff from the Malloy Basin, (6,000,000 m3), would raise the Lake level 1.3 m, if no water is discharged from Stafford during the event. From flow charts provided by SMRID, discharge capacity is approximately 73 m^3/s, which is in the same order of magnitude as the peak flow out of Malloy Lake.

3.8.2 Cost Benefit Analysis

The following statistics were obtained courtesy of the Insurance Bureau of Canada (IBC), and the Alberta Emergency Management Agency (AEMA, which administers disaster recovery funding). Agriculture Financial Services Corporation (AFSC), which administers the crop insurance program, was also contacted. However, their records do not differentiate between crop losses due to flood versus pests, drought, hail, etc.

From IBC:

- $300,000 in insurance claims for June 6-8, **and** June 17-19 flood events, Alberta-wide.

From AEMA:

Disaster Recovery funding for the June, 2005 event as follows:

Table 3.22: Disaster Recovery Funding

	Lethbridge County	Town of Coaldale	SMRID
Individuals	$230,718	$166,770	-
Municipality/Agency	$112,299	$27,827	$502,222

The AEMA figures were used to determine a very rough assessment of averted damages (i.e. benefits) resulting from upgrades to the Malloy drainage system. (The IBC information was considered too general to be applicable.) The following factors were considered:

- For the purposes of this analysis, the 2005 storm and the 1:100-year Chicago Storm are roughly equivalent in severity and damage potential. Thus the AEMA values need only be adjusted for the size of the affected land base.
- Malloy Basin is 7.6% (21,662 ha/284,000 ha) of the size of Lethbridge County.
- Applicable damages within Malloy Basin of County

  = 7.6% x ($230,718+$112,299) = $26,000
- Town of Coaldale values do not require adjustment,

  = $194,600.
- Malloy Basin infrastructure is 3.5% (70 km/2000 km) of the length of the total SMRID infrastructure. Applicable damages within Malloy Basin of SMRID

  = 3.5% x $505,222 = $17,600

Therefore, total flood damages costs, extrapolated to 100 yr event, within Malloy basin

=$26,000 + $194,600 + $17,600 = **$238,000**

The $238,000 figure represents only defined, claimed damages to public and private property. As discussed previously, there are also potentially significant intangible costs to maintaining status quo, such as restricted development. Table 3.23 below displays a cost/benefit comparison of selected alternatives.

Table 3.23: Comparison of Upgrade Costs versus Expected and Averted Damages

Channel/Pond Upgrade Alternatives	Estimated Flooded Area	Upgrades Cost	Damages, $	Averted Damages, $	Intangible Costs
Alternative 1: Status Quo	487 ha	$0	$238,000 (from above)	$0	Economic impact of restricted development
Alternatives 3, 3A, 3B: Combination upgrade of ponds and channel (Scenario 5)	0 ha	$15M-$27M	$0	$238,000/event	
Partial Alternative 3: Upgrade channels to 2.0 L/s/ha, but no new storage; allow reduced flooding	363 ha	$4.8M	$177,000 (363/487 x $238,000)	$61,000/event	Economic impact of restricted development

3.8.3 Other Improvements

The preceding section primarily dealt with storage and channel improvements on the SMRID infrastructure. In addition to this, alternatives specific to the Town and County are discussed below.

3.8.3.1 Urban Improvements within Town of Coaldale

<u>**Interception of Rural Inflow to Town**</u>

An estimated 54% of the town's outflow (682,000 m^3 from the 100-year storm event) is from runoff entering the Town from catchments outside of Town boundaries. This external runoff has impact on the Town's operation with respect to required storage and control of the storm effluent quality. A proposed concept to intercept the external runoff into new drains constructed along the Town's perimeter is examined here.

The following assumptions and design criteria for this concept were used to determine rough cost estimates:

- New drains located approximately along northwest and south Town boundaries as illustrated in Figure 3.17. Exact alignment was not determined. Estimated order-of-magnitude length of drains: north interceptors 5 km; south interceptor 4 km.
- North inceptor captures runoff from catchments Malloy 3E and 3F. Peak 1:100 flow 8.1 m^3/s.
- South inceptor captures runoff from catchments SCOAL- 1A, 1B, 2, and COAL-2. Peak 1:100 flow 14.1 m^3/s.
- Cost estimate based on excavation of trapezoidal channel, no lining, with 2.5 side slopes, lineal slope .0005.

Under these assumptions, estimated costs to construct the interceptor drains are:

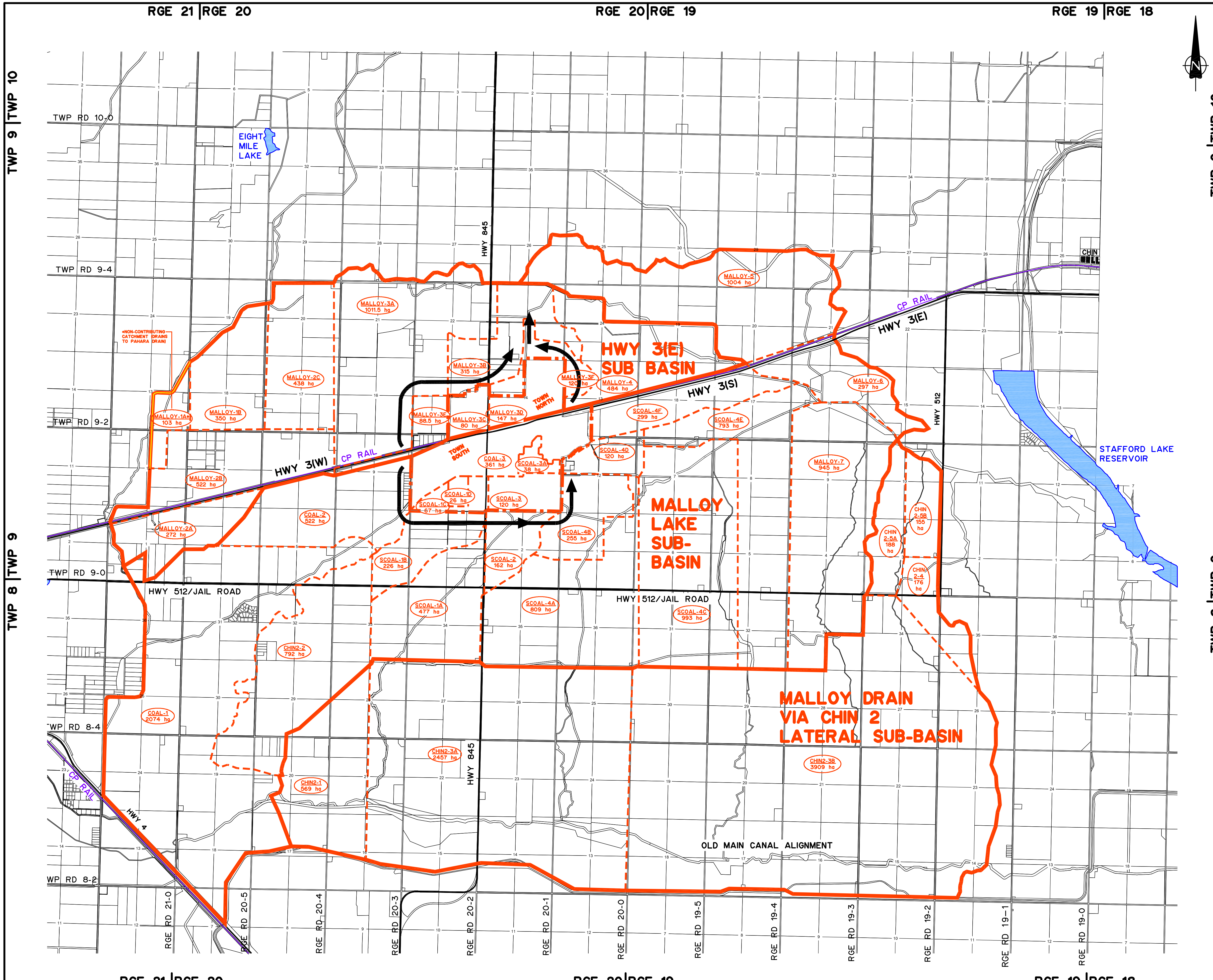
- North interceptor $3,000,000
- South interceptor $3,500,000

These costs are for channel construction only, and not including costs for accommodating existing roads and other infrastructure, which could easily double or triple the total cost.

With these interceptor drains in place, the comparative Town runoff volumes and detention storage (from a 1:100 Year Chicago Storm) would be as follows:

Table 3.24: Town of Coaldale Required Storage With Interceptor Drains In Place

	Existing Development	**Future Build-out**
Runoff, m^3	554,000	678,000
Available Storage, m^3	545,000	650,000



LEGEND

- INTERCEPTOR DRAIN
- TOWN BOUNDARY

NOTE:
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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
TOWN INTERCEPTOR DRAINS
CONCEPTUAL PLAN

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.17

Thus the Town would have almost enough storage to completely contain the 1:100-year runoff without any release during the storm event. The shortfall, 28,000 m^3 in the future build-out scenario, could be accommodated by allowing a release rate from its ponds of 0.32 m^3/s during the storm, which is equivalent to a unit release rate of 0.4 L/s/ha.

Dedicated Outlet for Town

In this concept, a pipeline and pump system would be constructed to pump all Town stormwater directly to the Oldman River, 14 km to the north. This would decouple the Town's storm system from the Malloy infrastructure, provide independence on the Town's drainage operations, and alleviate Town runoff loading on the Malloy.

The following assumptions and design criteria for this concept were used to determine rough cost estimates:

- Volume to pump = 554,000 m^3 current, 678,000 m^3 future build-out (Town runoff only)
- As a prerequisite to the assumption above, a bypass system to convey rural runoff around the Town would be required (see previous section)
- Pipeline distance to Oldman River = 14.5 km
- Allowable velocity in pipeline = 2.1 m/s
- Discharge rate to pipeline selected to achieve desired pump-out time of the filled storage ponds
- Costs shown do not include tie-ins, pumping, and additional piping to get all the Town's stormwater interconnected to a single pumping site

Under these assumptions the estimated costs for a pump station and pipeline are as follows:

Table 3.25: Cost Estimates For Town Pump station and Pipeline to Oldman River

Approximate Pump-out Time, days	Discharge rate, m3/s	Pipe		Pump house		Total Cost
		Diameter, mm	**Installed Cost**	**Capacity, HP**	**Installed cost**	
60	0.1	250	$2,047,500	275	$780,000	$2,828,000
40	0.16	300	$2,457,000	350	$877,500	$3,335,000
30	0.2	350	$2,866,500	400	$1,121,250	$3,988,000
20	0.33	450	$4,095,000	500	$1,170,000	$5,265,000

Including the interconnections in Town, and the prerequisite Alternative 5, total cost is in the order of **$10,000,000 to $14,000,000**.

To a small extent, diverting the Town water away from the Malloy system would reduce the costs to upgrade the Malloy infrastructure (the portion downstream of Town) that were presented in the previous section. Since the Town volume is about 8% of the total runoff volume, a crude estimate of the impact on cost would be a 8% reduction on the improvement costs for the infrastructure downstream (about half of total infrastructure), i.e. about 8% of 0.5 x $26M, = $1.04M.

3.8.3.2 Point Source Improvements

Future development in both the County and the Town should be encouraged to adopt LIDs (Low Impact Development) and BMPs (Best Management Practices) to reduce runoff volume at the source. This topic will be discussed in more detail in Section 4.

3.8.4 Phased Implementation of Capital Upgrades

As the extent of the proposed upgrades is too large to be constructed or funded as a single project, a phased implementation of Alternative 3 (upgrades to channels to 2.0 L/s/ha, plus new storage) is presented in this section. The total upgrade program is portioned into six phases, as shown below, and in Figures 3.18 and 3.19.

Table 3.26: Proposed Phasing of Capital Upgrades

	Reach	Length upgraded, m	Culverts Replaced, ID#	Ponds Constructed, ID#	Constructed Cost
Phase 1				P15, P20	$8,786,322
	CL4		52,52A		$149,000
	CL5	400			$114,000
	M6A	1000			$297,000
	M7	1000	54, 54A		$798,000
					$10,144,322
Phase 2				P1,2,3,4,5,6,8	$5,573,878
	M8		56		$158,000
	M9	3000			$601,000
					$6,332,878
Phase 3				P17	$1,717,612
	M5	500	42,43		$344,000
	M6		51		$74,000
					$2,135,612
Phase 4				P12, P13, P18	$3,986,820
	SC1				$1,000,000
	SC2		30,35		$74,000
	SC4		39		$37,000
	SC5		47		$50,000
					$5,147,820
Phase 5				P16, P19	$1,373,740
	CL1	5000			$593,000
	C2A	2200	19		$26,000
					$1,992,740
Phase 6					
	M1		1,15		$32,000
	M2		20,29		$74,000
	LE3/4	4100	34,37		$649,000
					$755,000
Phase 7					
	C3	2500			**$749,000**
Total					$27,257,373

The rationale for which project components received scheduling priority used the following premises:

- The first phase is directed to storage and channel improvements in the Malloy Lake area, as this is where the worst bottlenecks and flooding problems are occurring.

- There is a general progression for channel improvements starting from the downstream end and working the upstream reaches. This strategy prevents a potential problem of upgrading one channel reach, only to then transfer increased flow rates to an un-upgraded reach further downstream.
- Construction of new detention storage has no adverse impacts either upstream or downstream. However, greater benefit is achieved by providing storage in the upstream reaches first. This is generally what has been done for the phases listed in Table 3.26.

The phase costs include constructed ponds only. Reduced costs could be realized by purchasing flood-affected land or acquiring easements, as has been discussed previously.

3.8.5 Projects Funding

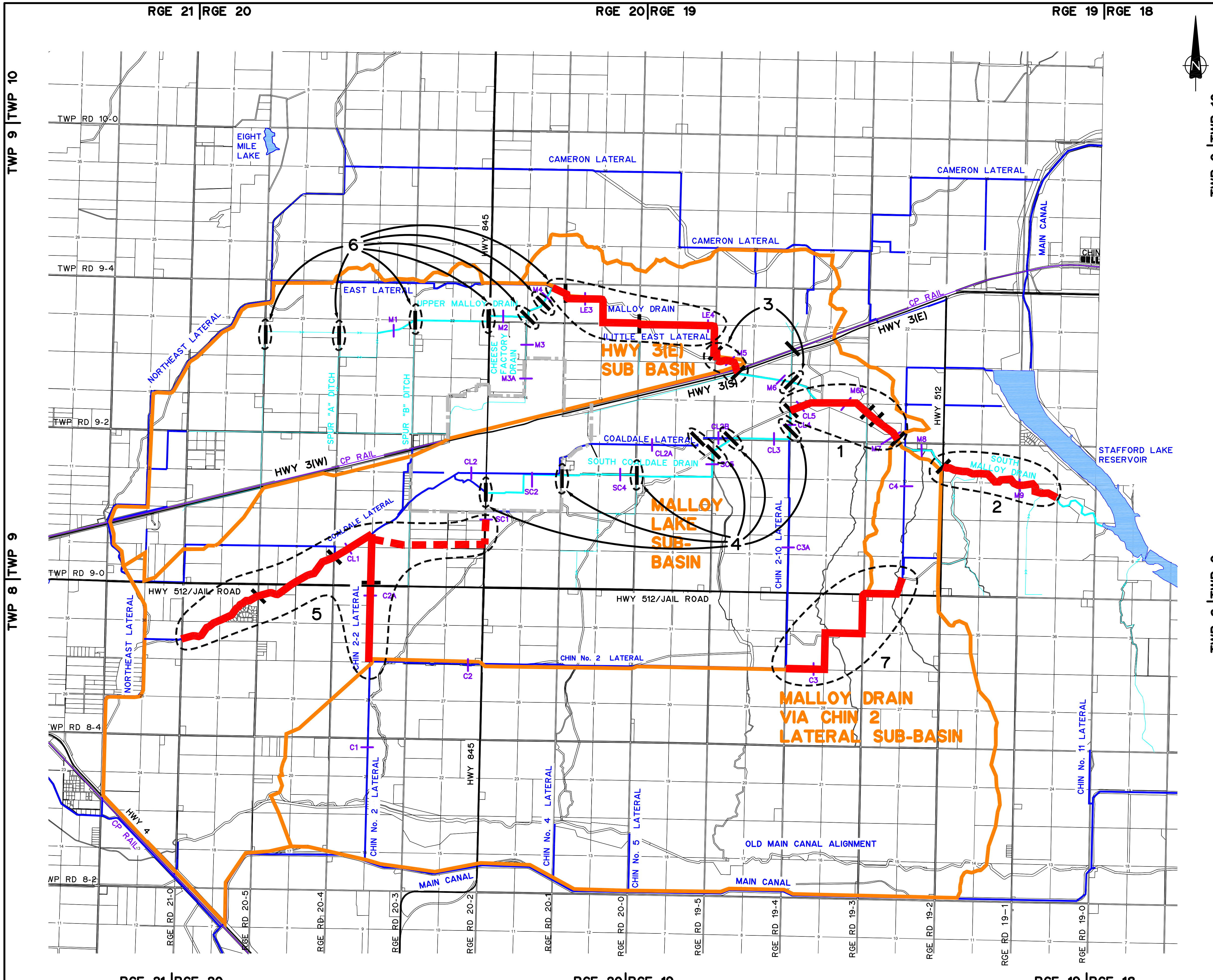
Funding for capital improvements may come from various sources:

- Federal or provincial grants
- Off-site levies to developers
- Surcharges to new and existing users
- Existing tax base
- Debenture or other borrowing mechanisms
- Contributions from Ducks Unlimited, or similar agencies, to developing natural ponds

It is acknowledged that funding from government sources would be required to implement the suggested improvements without incurring large debt. The status of various grant programs may be in a bit of flux at this time due to the fiscal constraints governments are facing in this period of recession.

To some extent it may be possible to shoulder some of the upgrade costs onto new developers through off-site levies. However, only so much of the costs could be transferred to them without making their projects uneconomical. As well, this revenue stream would be spread out over several years, and capital improvements may have to be deferred (or financed by borrowing) before being implemented.

A larger revenue base would be achieved by applying a form of surcharge to all users of the infrastructure, that is, all existing contributors to runoff. This option would probably be achieved through the establishment of a Drainage Utility, which is discussed further in Section 4.4.1.



LEGEND

- UPGRADED CHANNEL
- NEW CHANNEL
- UPGRADED CULVERT
- PHASE
- TOWN BOUNDARY

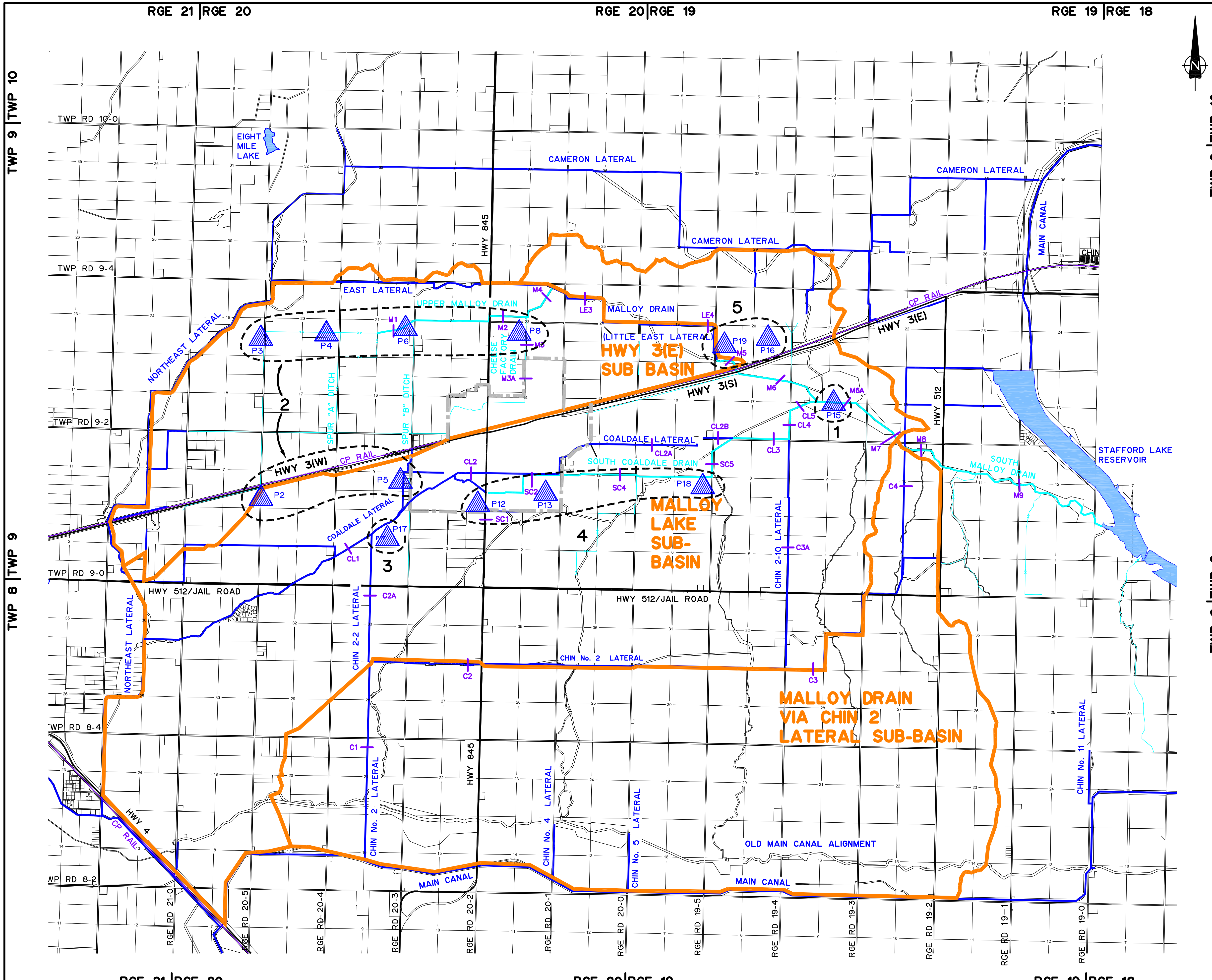
NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED.
ALL SCALE NOTATIONS INDICATED
(i.e. 1:40, 000 etc) ARE BASED ON
22" x 34" FORMAT DRAWINGS

MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PHASES OF PROPOSED CHANNEL AND
CULVERT UPGRADES

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.18



LEGEND

- ▲ PROPOSED CONSTRUCTED DETENTION POND
- - - - PHASE
- TOWN BOUNDARY

NOTE:
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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PHASES OF PROPOSED CONSTRUCTED DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.19

4.0 IMPLEMENTATION STRATEGIES

The preceding sections of this document mainly deal with background to, and analysis of the Master Drainage Plan. Section 3 deals with alternatives for constructed solutions to the basin problems. Another major component of the MDP is adoption and implementation. Adoption and implementation is a complex process to be carried out over several years, and warrants a section unto itself in forming this MDP.

A number of broader issues will need to be addressed during implementation of the MDP, including:

- Increased and improved stormwater management plans.
- Implementation of new stormwater technologies (i.e. source control BMPs).
- Improved conformance to stormwater concepts and plans.
- Additional on-site facilities and associated easements.
- Improved operations and maintenance.
- Improved policy on development sites.
- Protection of natural drainage courses and pond areas.

Within the sections that follow, a number of the key components will be discussed.

4.1 Guiding Principles

A number of guiding principles are applicable to the MDP:

The study area is a combination of urban and rural land use, which requires different approaches to storm water capture and release.

Drainage solutions must be practical and cost-effective, particularly where areas are already built-out.
Where suitable, utilizing available natural storage will be considered to minimize construction costs.
Given that the current drainage infrastructure is under capacity, the most reasonable option for new developments would be storage facilities with very low release rates, or off-peak releases.

An immediate and permanent solution to all the existing problems is not practical. Due to high capital costs and budget restrictions, improvements will probably be required to be prioritized for phased implementation. Some improvements will likely be operational in nature (i.e. pumping plans), which can be more quickly implemented.

Improved policy must help alleviate future problems in new developments, while at the same time help to solve, or at least not aggravate, existing problems.

Small infill developments, though not desirable from a stormwater management perspective, may continue to be approved in the study area. The policies developed must be flexible enough to accommodate practical solutions in such developments.

4.2 Proposed Implementation Framework

A number of tools are proposed to facilitate implementation of the MDP. Some of these are general, others are applicable only to urban municipalities, and others are site specific and important especially to the development and design community.

4.2.1 Administrative Considerations

During the implementation process, consultation with a number of stakeholders, including Alberta Transportation, AENV, the Town, the County, and the SMRID, should be carried out. Some consideration should be given to discussions with the development community and local landowners. Timelines for the implementation will have to be established, especially in light of the anticipated constraints on funding for planned projects.

A difficulty with implementing a drainage plan over a catchment basin is the multiple jurisdictions involved. Some administrative models could alleviate these difficulties.

<u>Drainage Commission</u>

A drainage Commission would comprise of representatives from the major stakeholders, to conduct overall management of the drainage facilities. Ownership of the infrastructure would remain unchanged. However, decisions on operation, maintenance, and capital improvements would be in consideration of the decisions of the Commission.

Utility

As an alternative, a single entity could assume ownership of the drainage facilities and charge users for the service of maintaining it. Considerable negotiation would be required agree over several issues:

- Who would run the utility
- What facilities would become the property of the utility? Probably only the Malloy and South Coaldale drains, and the new ponds constructed in the County
- Compensation for transfer of property
- Grandfathering certain rights of use (for example, to allow SMRID to continue to use portions of drain for water delivery)
- User rates

Informal "Ad-Hoc" Drainage Committee

- More informal; more flexible
- Seeks cooperation and common ground

4.2.2 Interim Policies

Given limited resources, the Master Drainage Plan and the recommended improvements may not be fully implemented for a few years. Considering the strong pressure for development in the area, some interim policies may be appropriate. Policies aimed at infill developments, major development proposals, and emergency pumping plans are discussed further.

Small Development Proposals

By small developments, it is proposed to define them as residential developments of no more than three residences.

For small development proposals where no natural ponds exist, and the construction of dedicated stormwater storage facilities may be impractical, source control BMPs should be incorporated to maintain the peak flows and runoff volumes at or below current pre-development levels.
Where practical, these may be reduced below pre-development levels to account for impervious areas from existing development. Source control designs can aim to control runoff primarily from the proposed impervious areas being developed. Given that the performance of these facilities remains relatively unproven locally, an appropriate factor of safety should be incorporated into the design, or back-up storage volume provided. Such facilities may have to be dedicated to the public jurisdiction. Operation and maintenance obligations and responsibilities will have to be considered in more detail.

For small subdivisions where natural ponds and wetlands exist, a similar policy should be implemented. The natural ponds and wetlands should be maintained and dedicated via a legal instrument. Consideration should also be given to spill elevations, available active storage, normal pond levels, and the feasibility of incorporating the existing ponds into a more formal stormwater management facility with a controlled outlet.

<u>Major Development Proposals</u>

By major developments, it is proposed to define them as developments larger than three residences, or any non-residential development. Major developments could also include projects such as road paving. Major developments should include the upstream contributing areas within their stormwater management plans. Some oversizing of facilities will be required to meet the broader regional goals, and due consideration should be given to this in the development approval process. In keeping with this MDP, recommended policies are as follows:

- Zero discharge allowed during storm event. Release to be allowed only after a storm event, and upon approval of Drainage authority. (i.e. entire run-off volume of a 1:100-year storm to be stored on-site during the storm.)
- Maximum allowable post-event discharge rate equivalent to 0.4 L/s/ha.
- Provide an emergency spill of minimum 1-2 m^3/s capacity, or more as dictated by the size of the contributing catchment area.

- Ponds to require a minimum 150mm freeboard between full supply level (FSL) and spill elevation.
- Excess capacity being built into facilities to accommodate upstream contributing areas.
- Stormwater Plan prepared by a qualified professional to meet local jurisdiction and AENV requirements.
- Stormwater features to be within a Public Utility Lot.

4.2.3 Comprehensive Capital Plan

A *Comprehensive Capital Plan* should be developed to provide a "roadmap" for implementing capital improvements. The measures presented in Alternative 3, at a cost of **$27,000,000**, should be considered as part of the Comprehensive Capital Plan. Further analysis and decision-making will be required in the following areas during implementation of the Plan.

Pond Storage Facilities

The storage pond sites shown in the report figures are generally within existing natural depression areas and flooded areas. The locations shown are the most logical. However, the number and locations of these facilities and should be addressed on a site-specific basis. Some of the proposed pond sites are in fairly close proximity to each other, and consolidation may be worth considering.

Pond storage volumes will be dependent upon the unit run-off from the catchment areas and the available release rates. Area requirements will depend upon the volume required and the active storage depths. Consideration should be made whether to build for potential future development, or assume new development would provide their own storage.

Channel Upgrades

The scheduling of channel upgrades needs to be in a logical manner, in conjunction with the provision of new storage ponds, and in consideration of any impact on downstream areas.

Options for Flooded land Purchase or Easement Acquisition

Decide on which sites might be pursued for the option of purchasing land or flood easement rights.

Cost Funding and Allocation

Come to an agreement, through committee, on allocation of costs not covered by provincial grants that might be acquired. Develop and implement an off-site levy or similar means of cost recovery be implemented to provide an equitable sharing of the costs of regional facilities amongst benefiting areas.

4.2.4 Development Policies

Once capital improvements have been made, guidelines for future developments, in keeping with the MDP, should include:

- Establish 2.0 L/s/ha release rates from developments for both during a storm event, and post-event. Possibly consider different targets for small and large developments.
- Provide an emergency spill of minimum 1-2 m^3/s capacity, or more as dictated by the size of the contributing catchment area.
- Ponds to require a minimum 150mm freeboard between full supply level (FSL) and spill elevation.
- Stormwater Plan prepared by a qualified professional to meet local jurisdiction and AENV requirements.
- Stormwater facilities to be within a Public Utility Lot.
- Excess capacity to be built into facilities to accommodate outside areas.
- Policies adopted to encourage new developments to implement source control best management practices (BMPs), low impact strategies (LID's), and policies to promote long-term monitoring of the effectiveness of those BMP's and LID strategies.
- Larger single stormwater storage facilities be encouraged over numerous smaller facilities to allow practical gravity release structures and to avoid extremely low release rates that result in

small release orifices (prone to plugging with debris) or mechanical means of release (i.e. small pumps), and the resulting O&M concerns and high lifecycle costs.

- Oversize contributions or "endeavour to assist" mechanisms should be considered for developments where drainage infrastructure improvements outside its boundaries are proposed.
- Where small infill developments are being proposed, and not all policies are practical to fully implement, the jurisdiction, in conjunction with the committee, may approve site-specific stormwater plans provided that the fundamental principles of the MDP are incorporated, runoff volumes and peak flows are improved over pre-development conditions, downstream impacts are negligible, and upstream drainage areas have been accounted for.

4.2.5 Site-Specific Stormwater Policies for New Developments

A number of more site-specific development policies are recommended:

- Site-Specific Stormwater Management Plans be prepared for future subdivisions in the Study Area, and circulated to jurisdiction staff and AENV for comments and approval as required. Analysis and design should include:
  - A single event storm for on-site conveyance (i.e. 100-year return period, 1-hour event).
  - For stormwater storage and source controls, the largest active storage derived from:
    - A single event storm (i.e. 100-year, 24 hour);
    - Continuous model using available 1-hour rainfall data (typically 1960 to 1999).
  - Active (fluctuating) storage depths in ponds are assumed to be 1.0 m to 2.0 m.
  - Permanent storage volume based upon a minimum of 25 mm over the facility catchment area, with typical depths from 2.0 m to 3.0 m.
  - Modeling with locally accepted models (QHM, SWMHYMO, etc.).
  - Forebay sizing using locally accepted parameters and methods (i.e. Ontario MOE).
  - Facilities and pond design to meet AENV and locally accepted design guidelines.
- Existing available on-site storage should not be reduced from pre-development conditions, unless it can be clearly justified. There should be no net storage loss for new developments below the existing spill elevations. Compensation or substitution for loss of storage may be required.

- Natural depressional areas and ponds, whether they occur in the upslope or lower downslope areas should be protected and dedicated, as they contribute to the groundwater recharge in the area, and their natural storage capabilities can attenuate peak flows during storm events.
- Lowest opening on houses to be a minimum 0.5 m above an identified and surveyed spill elevation. In extreme circumstances where this cannot be achieved within trap low areas, at the discretion of the approving authority, house elevations could be established at least 2.0 m above an established long-term pond elevation and provisions made for emergency pumping.
- Landscaping and lot grading to not obstruct or constrict natural drainage and spill paths.
- Downstream drainage routes be field inspected, characterized, and any constrictions or potential impacts be assessed.
- Outlets must be developed that do not adversely impact downstream parcels or drainage routes.
- Gravity outlets (preferred) or pumping plans be developed to allow the level of natural or constructed ponds to accommodate the 100-year return period single event and continuous rain events (whichever is larger).

4.2.6 Storm Response Plan

The purpose of a storm response plan is to identify the procedures that the Town, County, and SMRID can follow in response to drainage concerns and associated damage or risk due to imminent flooding during a storm event.

A comprehensive response Plan would include the following information:

- A prioritized *Emergency Pumping Plan* adopted to address existing drainage concerns, based on a priority rating system and potential risk to property.
- Policies to provide guidelines for the acceptance of emergency pumped or hauled stormwater from developments.
- Location map of known hotspot and problem areas.
- Specific description and action plans for known hotspot and problem areas.
- Compilation of historic action taken for specific areas.
- Contact list or internal staff and other stakeholders and emergency responders.

- List of contractors and suppliers available for response actions.
- Forms for documenting actions taken in the field as well as post-event follow-up requirements.

MPE developed a Flooding Action Plan for the Bearspaw area in Rockyview County, with several components that should be included in a similar plan for the Malloy Basin. The Bearspaw Flood Action Plan included the following features:

- A general outline and basin map describing the drainage concerns, potential flooding areas, and risks of property damage. This portion of the document can be used to educate landowners and the public at large justifying the need for response actions.
- Identify levels of drainage concerns and establish priority. For example,
    - **Potential Drainage Concerns and Associated Flooding** – when an abnormal condition is observed or identified (i.e. such as high pond water levels, serious road embankment erosion, high creek or drainage course levels, etc) and/or a significant rainfall is forecast; which, without intervention, may lead to flooding or damage in accordance to the criteria set out in this Plan.
    - **Imminent Drainage Concerns or Flooding** – when flooding and/or damage associated with flooding has occurred or has a significant probability of occurring within 24 hours. Imminent concerns would receive priority over potential concerns.
    - A Procedure Statement outlining in broad terms how each jurisdiction would respond to a concern, and how priorities are established. There may be three Statements applicable to the three jurisdictional parties individually (Town, County, and SMRID), or a single Statement if they form a single response group. The following Procedure Statement has been modified from the Bearspaw Plan, and is presented for example only:
    - The group will respond to drainage concerns on a prioritized basis using the following response criteria:
    - In order of priority:
        1. Public Health and Safety
        2. Impact to Public or Irrigation Infrastructure
        3. Damage to Property – As a direct result of public or irrigation infrastructure (i.e. roads and canals)

4. Loss of Business
5. Loss of Property

- All requests will go through a formal review and documentation process to allow the Response Group to pre-screen drainage concerns based on the response priority criteria and to properly document the request, decisions made and actions undertaken.
- Pending available manpower and resources, the following typical response times to assess the drainage concern will be targeted:

Priority	Response Time
Public Health and Safety	Within 48 hours
Impact to Public or Irrigation Infrastructure	Within 48 hours
Damage to Property	Within 7 days
Loss of Business	Within 14 days
Loss of Property	Within 21 days

- Criteria for each priority level. Again, modifying from the Bearspaw Plan as an example:

1. <u>Public Health and Safety</u>
   - Significant threat to life safety
   - loss of emergency vehicular access (i.e. cuts off access to residents)
   - flooding a septic field that could impact other properties (i.e. flooded field can run off to other lower lying properties)
2. <u>Public or Irrigation Infrastructure</u>
   - damage to road infrastructure or requires protection to prevent damage
   - damage to canal or irrigation infrastructure that could impact public facilities
3. <u>Damage to Property</u>
   - property negatively impacted as a result of Public or Irrigation owned infrastructure
4. <u>Loss of Business</u>
   - restricting access / ability to operate

- damage or loss of building structure
- Response Group will not respond to reports of flooded golf courses, fields, or agricultural lands; except in cases where Public or Irrigation owned infrastructure or Public or Irrigation approved developments are a direct cause.

5. Private Property
   - local flooding of septic field
   - Response Group will not respond to reports of flooded basements or private property not directly a result of Public or Irrigation owned infrastructure
   - Identify known hot spot locations, their response priority and temporary measures. A hot spot Action Plan could have the following format:

     Name

     Response Priority:

     Description of Problem:

     Temporary Solutions:

Detailed procedures:

- Criteria for the shutdown or cutting of roads to alleviate flooding.
- A list of proposed locations for allowed pump truck discharge sites.
- Procedures for documenting responses, and for maintaining preparedness.
- Contact lists showing contact information for jurisdictional staff, contractors and suppliers relevant to flood response, and potentially affected stakeholders.

5.0 CONCLUSIONS

The area known as the Malloy Drainage Basin is located in and around the Town of Coaldale and covers an area of approximately 22,000 hectares. The area is drained through a complex series of natural and constructed canals and drains with the majority of this water discharging into Stafford Reservoir via the Malloy Drain. The area historically has experienced flooding during significant rainfall and snow melt events, most notably from the events experienced in 2002 and 2005.

The 2002 storm occurred during the period of June 8th to 10th, 2002. Conditions prior to the storm were recorded as the wettest on record creating saturated soil conditions. During this period a total rainfall of 143 mm was recorded for the Lethbridge area. This storm has been classified as greater than a 1:100 yr storm event.

In 2005 two storm events were experienced, the first event happened in the June and a second event occurred in October which is unusual for this area. Rainfall records show that June 2005 was the wettest month on record, although the flooding and damage was not as wide spread.

These two storm events, plus the recurrent flooding experienced since the area was settled, prompted the County of Lethbridge, Town of Coaldale and the St. Mary River Irrigation District jurisdictions to form a steering committee to investigate alternatives to help alleviate flooding and set design parameters for future development within the Basin. This report is the result of a study conducted by MPE on behalf of the steering committee.

The jurisdictional members of the steering committee represent different sectors of the local population and have different goals and objectives. The varied goals and objectives have been compiled by MPE through interviews and committee meetings. The jurisdictions realize that the pressures of economic growth and land development will not subside, and guidelines improvement strategies must be developed and put in place that deals with storm water for any future developments. Some of the perspectives of each of the jurisdictions can be summarized as follows.

Alberta Environment

Alberta Environment (AE) is the regulatory authority for stormwater management in the Province of Alberta and is responsible in the development and enforcement of the Environmental Protection and Enhancement Act and the Water Act.

Their interest in this project is to provide technical expertise in identifying and clarifying the legislative requirements with respect to stormwater management.

Alberta Transportation

Alberta Transportation (AT) is responsible for highways and associated bridge infrastructure in the study area. The care of water with respect to highway and bridge infrastructure includes stormwater and irrigation water. AT, may provide financial assistance through various Provincial grant programs to address capital costs of key structural components. Pertaining to drainage improvements, AT would consider funding larger capacity structures, should they be warranted, at replacement time.

Town of Coaldale

Coaldale is experiencing growth, particularly in the area of residential subdivisions. Over the past several years, the Town of Coaldale, which is situated in the center of the basin, has invested a considerable amount of resources into stormwater management and look forward to forming a partnership which will address immediate and long term stormwater management. The Town receives as much run-off from adjacent rural lands as is generated within its own boundaries, which taxes its stormwater system. Yet at the same time, through its conveyance agreement with SMRID, the Town is obliged to detain all stormwater during a rain event, which results in large stormwater pond requirements. Options to remedy this situation are required.

County of Lethbridge

Economic growth is occurring along the Highway 3 corridor between Lethbridge and Coaldale and this pressure to develop agricultural land will intensify. In addition, urban residents are moving to country residential subdivisions and are demanding the same level of services that Cities and Towns offer. With the limited capacity of the Malloy system, there is virtually no room for additional runoff, and so guidelines must be established that can allow new development without impacting the system. In addition to mitigating flood damage, the County of Lethbridge is keen on forming a partnership with the Town of Coaldale and the SMRID so that its interests with regards to level of service can improve and continue to facilitate responsible and sustainable development growth in the area.

St. Mary River Irrigation District

The SMRID is the owner of the constructed drains within the Malloy Drainage system, and is a water supplier for agriculture, commercial, municipal and domestic use throughout the Malloy Basin. SMRID is concerned because the Malloy Drainage system was not designed to handle the level of development that has occurred within the basin. The volume of runoff will increase and steps need to be taken limit the amount of water being diverted into the drainage system and limit when this water can be diverted into the drainage system.

The study area has been examined in two aspects. Section 3 dealt with a technical analysis of the basin, its hydrology, and infrastructure. Then physical improvements to the system were evaluated. Section 4 discusses issues such implementation of improvements, administrative bodies, future development, operational guidelines, and flood response planning.

Technical analysis first involved an evaluation of system hydrology. This task study included four major components:

1. Identification of each major drainage catchments and physical drainage constraints.
2. Modeling of the individual drainage areas given the existing constraints, natural ponds/depression areas, Town of Coaldale Stormwater Management ponds and the Town's allowable release rates.
3. Conveyance of stormwater flow via Coaldale Lateral, South Coaldale Drain, Upper Malloy Drain/Little East Lateral, Chin2 Lateral, and South Malloy Drain to Stafford Reservoir.
4. Model calibration to generate runoff within sub-catchments of the Study Area similar to Associated Engineering Services Limited (AESL, 1979) Study for the 1978 storm.

Several storm scenarios were modeled for the purposes of this report, including:

- The recorded events from August, 1978, June, 2002, and June, 2005;
- A continuous model covering the period 1960-1995;

- Synthetic rain events based on the Chicago Storm, AB TRANS Run-off Depth Method, and Probable Maximum Flood (PMF).

The "Chicago Storm" event was used as the base storm in the modeling exercises where various scenarios for upgrading the infrastructure were examined. This storm is the typical 1:100 year storm event that has been accepted by governing authorities throughout North America as a standard storm in determining instantaneous and total flows from a storm event. For the Malloy Basin, the Chicago Storm generates 109.9mm of precipitation over 24 hours.

The modeling showed that the expected runoff far exceeds the existing capacity of many portions of the Malloy Drain. The capacity of the Malloy Drain, downstream of Highway 3, for run-off has been estimated at less than 15 m^3/s at some sections, while the modeling shows that 50 m^3/sec can be expected from a 1:100 year storm.

Visually observed flooding areas generally coincided with the locations that the model showed the drain as lacking capacity.

The runoff amounts for different land uses and catchments within the study area are shown below in Table 3.5.

Table 3.5: Existing Catchment Areas Assumed in the Model and Runoff from the 100-Year 24-Hour Event (109.9 mm Rainfall)

	Modeled Areas				Actual Areas		
Area Breakdown	**Rural (ha)**	**Urban & Surrounding (ha) [Note 1]**	**Total Area (ha)**		**Rural (ha)**	**Town (ha) [Note 2]**	**Total Area (ha)**
To Malloy Drain N. of Hwy. 3	3,601	227			3,612	216	3,828
To E. Culverts N. of Hwy. 3	1,004				1,004		
To Hwy. 3 South Ditch	821	361			838.5	343.5	1,182
To Coaldale Lateral	2,986				2,986		
To S. Coaldale Drain	3,715	251			3,727	239	3,966
To Malloy Lake Direct	1,242				1,242		
Sub-Total	***13,369***	***839***			***13,409.5***	***798.5***	***14,208***
To Chin 2 Lateral	**7,454**				**7,454**		**7,454**
TOTAL AREA	**20,823**	**839**	**21,662**		**20,863.5**	**798.5**	***21,662***

	Town Only (ha) [Note 2]	**AT Highways (ha) [Note 3]**	**County Roads (ha) [Note 4]**	**HMQ & SMRID ROW (ha) [Note 5]**	**CPR & AB Rail (ha) [Note 6]**	**Remainder Rural (ha) [County]**	***Total***
Area Breakdown	**770**	**212**	**273**	**230**	**44**	**20,133**	***21,662***
Average Runoff (mm)	**72**	**77**	**78**	**73**	**61**	**30**	***32***
Total Runoff (m^3)	**554,400**	**163,240**	**211,575**	**166,750**	**26,708**	**6,039,900**	***7,162,573***
Runoff Coefficient (%)	**66%**	**70%**	**71%**	**66%**	**55%**	**27%**	**29%**
% of Total Runoff	**7.7%**	**2.3%**	**3.0%**	**2.3%**	**0.4%**	**84.3%**	**100.0%**
Total discharge, m^3	**1,263,000** (Note 7)	**5,899,573**					**7,162,573**
% of Total Discharge	**17.60%**	**82.40%**					**100.00%**

Notes:

1) Urban Area includes Town, SMRID ROW (13.25 ha) within the Town, Highway ROW (15.33 ha) within the Town, plus some immediate rural roads and land assumed as "near urban" fringe. The total urban area assumed in the model is 5 % more than the actual Town area, so modeling is slightly conservative to better account for small pockets of urbanization (acreages) within the rural areas.

2) Town area includes SMRID ROW (13.25 ha) and Highway ROW (15.33 ha) within the Town boundaries. Town area net of these areas is 770 ha.

3) AT Highway ROW area provided courtesy of County of Lethbridge GIS System.

4) County Roads ROW area estimated by MPE for developed county road allowances.

5) HMQ (Her Majesty the Queen) represents Provincial irrigation lands (24.8 ha) and is combined with SMRID irrigation ROW area (205.6 ha); areas courtesy of County of Lethbridge GIS System.

6) CPR ROW area (42.3 ha) and AB Rail ROW area (1.3 ha) are combined; areas courtesy of County of Lethbridge GIS System.

7) Includes runoff from Highway, CPR, and SMRID ROW within Town boundaries; and runoff from contributing upstream rural catchments.

Conclusions from Model – Town Issues

- Catchment into Cottonwood requires significantly more storage than available as confirmed by modeling results. To mitigate flooding potentials in the Cottonwood area, a Pond P17 (see Figure 3.1), and a large Cottonwood Pond (or a rural pond just upstream of Cottonwood Development Lands), are proposed to intercept the rural flows. Current modeling results suggest a pond of about 380,000 m^3 near the vicinity of cottonwood interim Pond (P12). Alternatively, an interceptor drain to carry rural stormwater to Coaldale Lateral prior to entering Cottonwood area as a bypass concept has also been proposed (see Figure 3.17).

- The Town's East Storm Pond (P14) under the existing condition scenario with the current pond operating procedure (pump starting and running through the storm event duration) does not spill though comes to very close to spill. If this was operationally changed to pump only after a storm event (zero stormwater release reality), the pond would spill significantly (approximately 404,500 m^3). Under the build-out condition, with the pump running through the storm (current operating procedure), the east pond (P14) would spill ±18,000 m^3 and the Town South Ponds (P10) also require significantly more storage than available (286,740 m^3 = 375,250 m^3 less available volume of 88,510 m^3). There will be also a spill of about 19,000 m^3 from the Jennie Emery Pond (P10D) to the South Coaldale Drain. This is due to assumed additional land use development west of the Town and intensification within the Town.
- To avoid spill primarily in the areas south of Highway 3, both the existing ponds will have to be expanded or new ponds added in the "existing" developed areas, and all new developments and intensification areas must construct their own storm ponds. The existing ponds south of Highway 3 were originally designed on the assumption of 'flow through' ponds that released during storm events, and that the new zero stormwater release policy means the ponds are undersized. This is the biggest impact on the Town's existing ponds south of Hwy 3.
- Pond P5 proposed, immediately west of Range Rd. 20-3, needs to be developed to mitigate flooding in the Town and protect the Evergreen Estates development in the County.
- Prior to significant urban development occurring in the Cottonwood and Evergreen/West Coaldale areas, a more refined hydrologic modeling analysis accompanied by a more detailed ground-proofing is highly recommended to confirm storage required to protect future developments from flooding. Both areas are shown to be seriously deficient of storage based upon the assumptions in this modeling analysis, and this should be mitigated before the area intensifies further.
- North Coaldale is not as great an issue as the Town north storm ponds are being designed for after storm release. These storm ponds are currently undersized, but upon implementation of all the phases, will be designed to contain the 1:100 year storm volume and with the provision of control gates closed during the storm event.

Conclusions from Model – Rural Issues

- South Malloy Lake is the main flooding area but does not affect large population. However, this location is prime location for a proposed pond to mitigate flooding in the basin.
- North and south rural areas, especially Ponds P2, P3, P4, P5, P6, and P16 locations are naturally flooded rural fields and in some cases (P4, P5 and P6) overtop roads. These areas are prime locations for natural flood easements, land purchase or as a last resort constructed ponds.

Conclusions from Model – Solutions

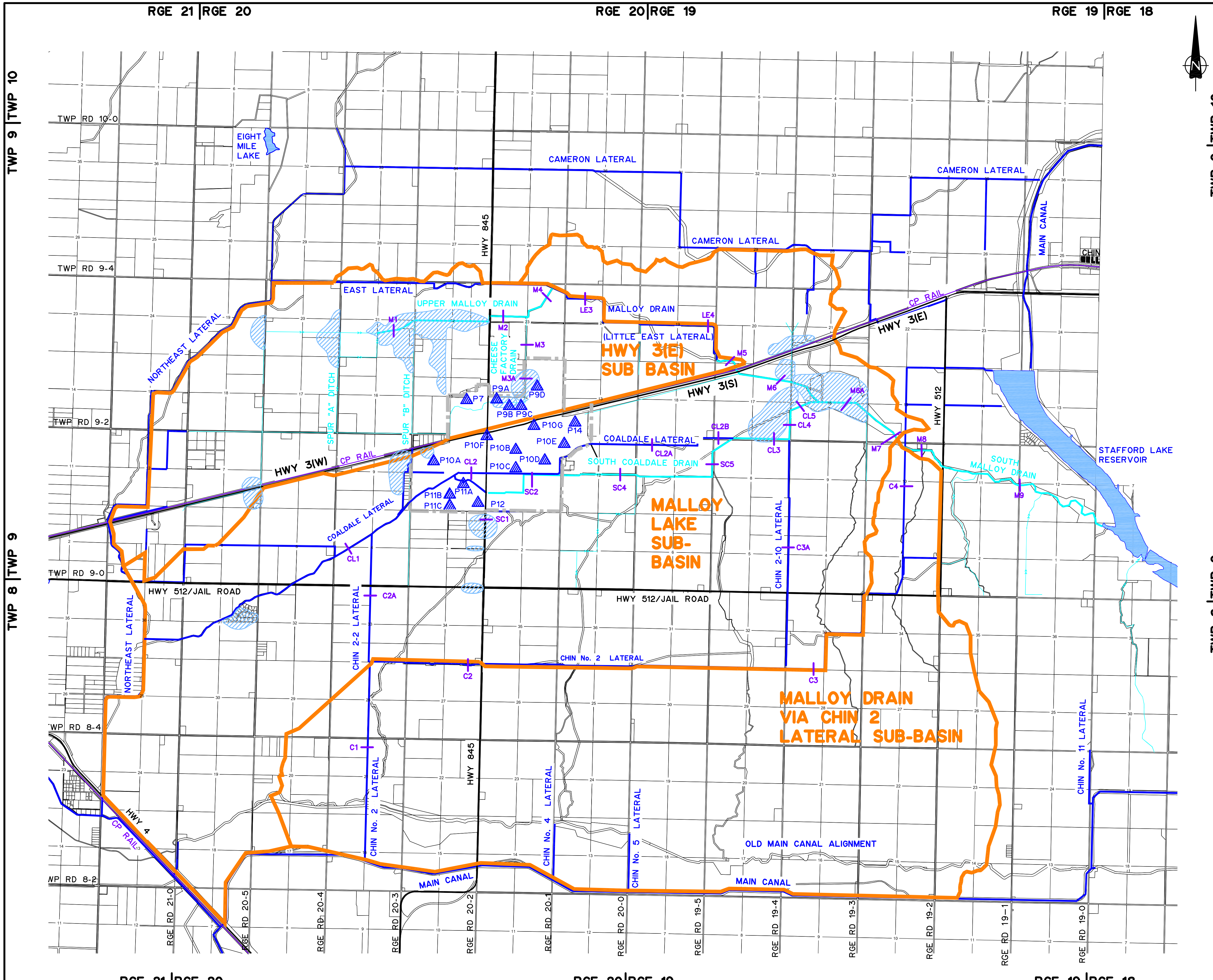
- Not all the existing ponds and natural storage (proposed pond) areas are in the proper place in the basin to attenuate flows during flood events and utilize the existing volume effectively. The possible use of Town's abandoned reservoirs and lagoon site for future storage should be explored.
- Since the carrying capacity of the Malloy Drain south of Highway 3 is the critical bottleneck in the basin, providing storage upstream of the Malloy Lake at identified locations would mitigate frequent flooding.

Based on the information obtained from the model, four Alternatives were developed and investigated to help deal with the problems being experienced throughout the basin during a Storm Event.

Alternative 1 "Status Quo"

This alternative maintains the status quo. Storm events will happen and flooding will occur. Fields will be inundated and crops damaged. Some County roads will be overtopped, and possibly subject to damage. Claims for flood damage will be submitted to the appropriate agency and dealt with by insurance companies or through the legal system. The advantage of this alternative is that no capital expenditures are incurred. The disadvantage is that the problem never goes away and future generations will have to deal with this problem. Potential problems include further deterioration of infrastructure, exposure to lawsuits for damages, and discouragement of new development in the area. It will be difficult to obtain approval for any new developments because of concerns they would adversely impact landowners already subject to flooding. Future land development, and the associated economic contribution to the area, is hampered unless system improvements can be made.

Cost = flood damages + intangibles



LEGEND

LAND EXPECTED TO EXPERIENCE RECURRENT FLOODING

TOWN BOUNDARY

NOTE:
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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
ALTERNATIVE 1: STATUS QUO

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.15

Alternative 2 "Buy Out Frequently Affected Lands"

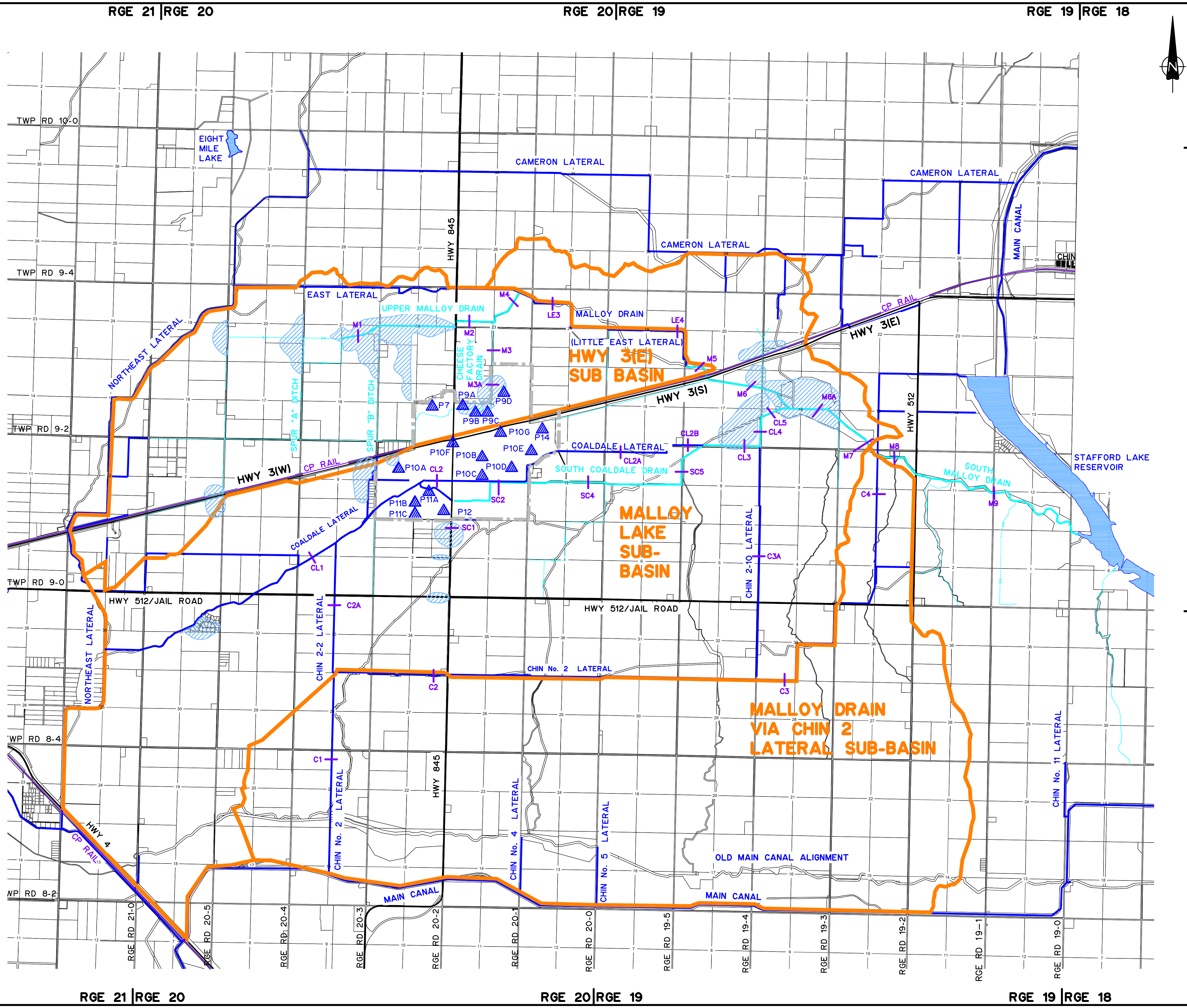
This alternative is similar to Alternative 1, in that no infrastructure improvements are made. However, property damage claims and legal action are largely avoided. This alternative does not address potential damage to roads and drainage works infrastructure. There also would be the same development constraints as in Alternative 1.

Cost = $7,208,000

Alternative 2A "Obtain Flood Easements on Frequently Affected Lands"

Same as above, except that flood-affected lands are covered by a flood easement agreement rather than outright purchase. These agreements may be more difficult to negotiate.

Cost = $1,450,000



LEGEND

FLOOD-AFFECTED LAND TO PURCHASE OR ACQUIRE EASEMENT

TOWN BOUNDARY

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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
ALTERNATIVES 2 AND 2A: PURCHASE FLOOD-AFFECTED LANDS

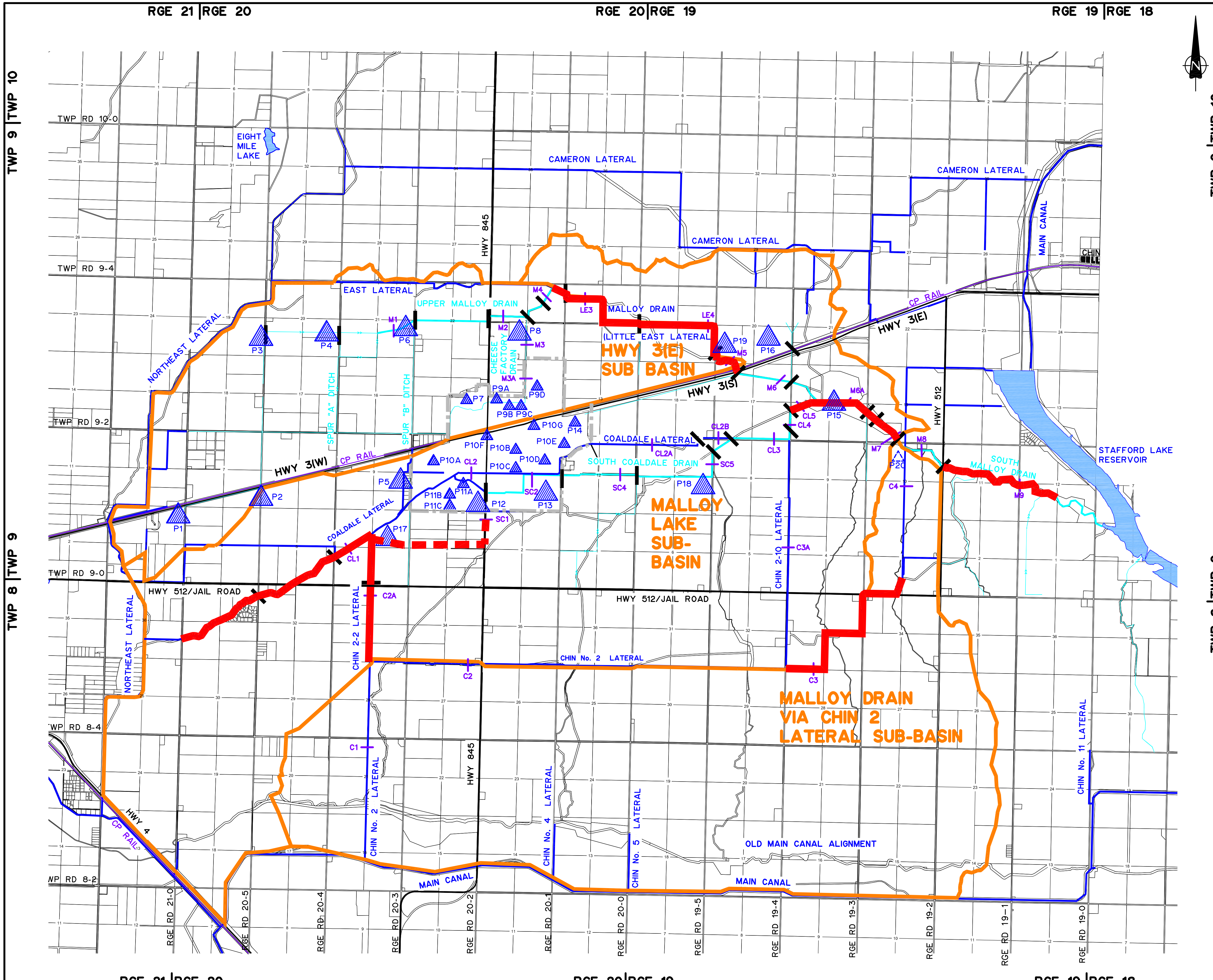
DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.16

Alternative 3 "Combination of Storm Detention Ponds and Enlargement of Existing Drainage Works"

Modeled in Scenarios 1-7, this Alternative allows for the construction of stormwater detention ponds throughout the basin in conjunction with increases in channel capacity. Large amounts of stormwater will be detained until the storm event has passed, and then water will be released slowly into the system as capacity permits.

The most cost-effective of these scenarios (see figure below) is a combination of 623,000 m^3 of new constructed storage and upgrading 26 km of channels to a capacity of 2.0 L/s/ha, at a total estimated cost of **$27,250,000**.

Cost = $27,250,000



LEGEND

- CONSTRUCTED DETENTION POND
- UPGRADED CHANNEL
- NEW CHANNEL
- UPGRADED CULVERT
- TOWN BOUNDARY

NOTE:
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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 5: CONSTRUCT COMBINATION CHANNEL UPGRADES AND DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.13

Alternative 3A

Purchasing land for natural ponding sites is about 50% of the cost of actually constructing storage at those sites, and where applicable would reduce the costs for this Alternative by $6,500,000.

Cost = $20,700,000

Alternative 3B

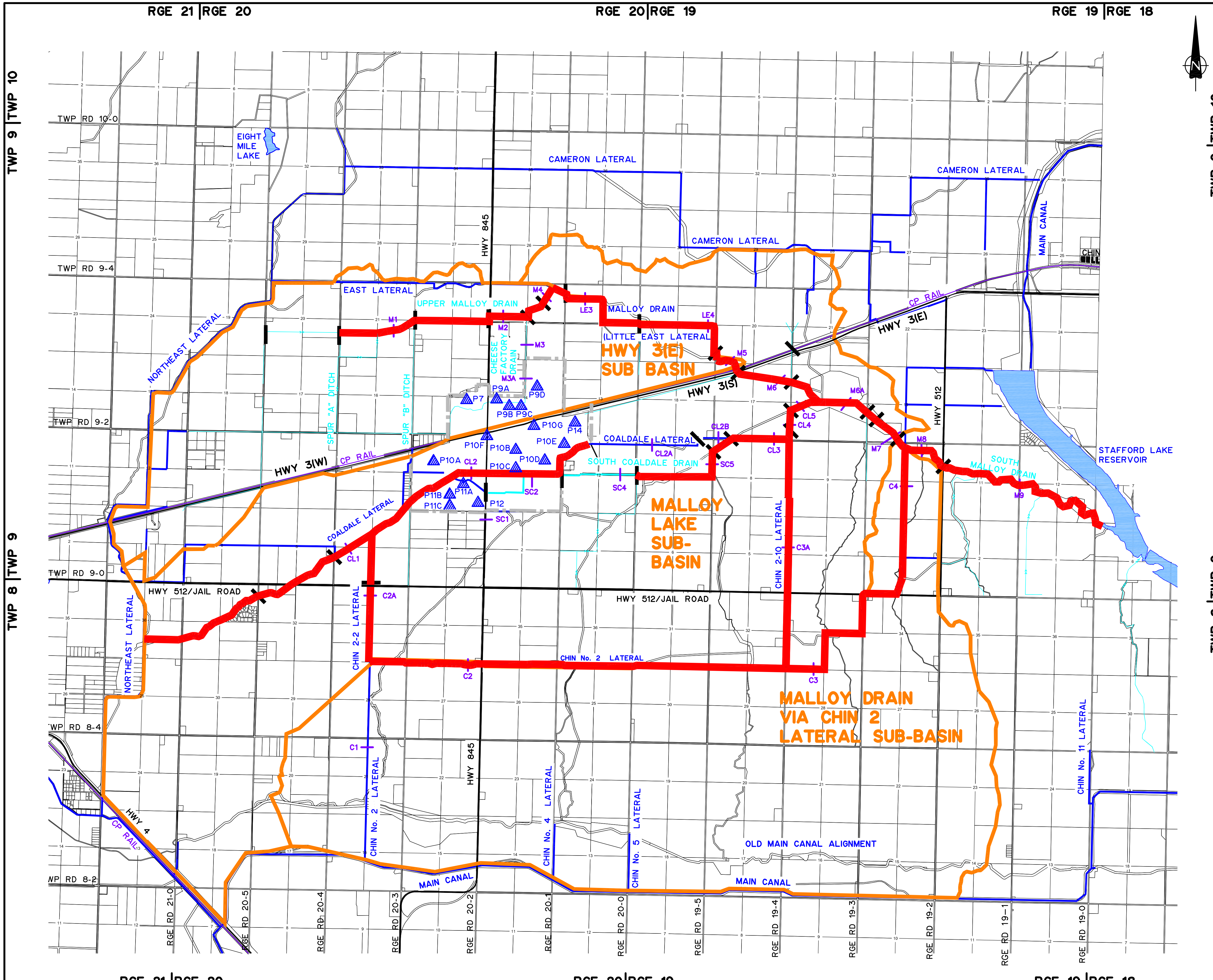
Acquisition of flood easements (whereby land ownership is unchanged) is about 15% of the cost of the constructed pond cost, and where applicable would reduce the total of this Alternative by $12,000,000. This does not include periodic payments (at a pre-agreed rate structure) when damages occur after flood event.

Cost = $15,200,000

Alternative 4 "Fully Expand the Malloy Drain"

The modeling (Scenario 8) shows that over 100 m^3/s can be experienced at the downstream end of the Malloy Drain, if the channels upstream are expanded to convey all the run-off. The size of drain required to handle this flow rate is very large and expensive to build and maintain. The estimated cost to construct a drain of this size is estimated at $30,500,000.

Cost = $30,500,000



LEGEND

- CONSTRUCTED DETENTION POND
- UPGRADED CHANNEL
- UPGRADED CULVERT
- TOWN BOUNDARY

NOTE:
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COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
SCENARIO 8: FULL CHANNEL UPGRADES AND NO NEW DETENTION PONDS

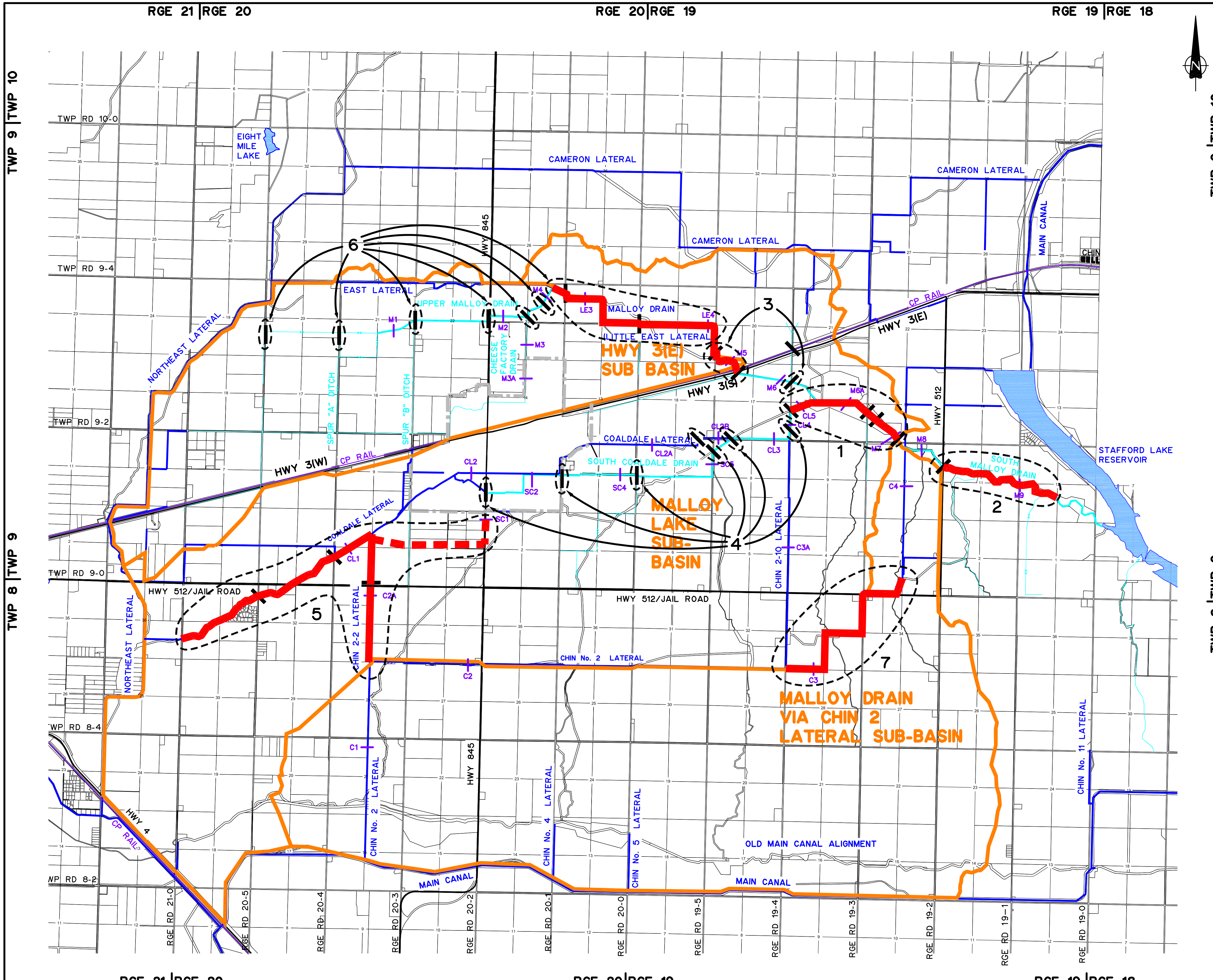
DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.14

Additional comments pertaining to upgrade scenarios follows below:

- Without a more detailed analysis, the sizing and cost estimation for channel upgrades is order of magnitude only that allows a relative comparison of costs between scenarios.
- The feasibility of channel upgrades is reasonably high, since construction would be on existing right-of ways, and would not require significant additional land.
- However, development of pond sites, whether constructed or purchased land, is more contingent on acquiring land for the pond site, which may not always be easy.
- Operationally, upgraded channels may present issues such as reduced capacity over time due to accumulated weed growth. It is also more difficult to provide controlled overflow sites in channels during events larger than the design storm, whereas provision of an emergency spill from a pond is usually feasible.
- Channels, especially one upstream of storage sites can be affected by short intense storms, with higher peak flows than the design storm. Pond storage depends more on the total volume of runoff, not the peak rate, and is not affected by short, intense storms.

Phased Implementation of Capital Upgrades

As the extent of the proposed upgrades is too large to be constructed or funded as a single project, a phased implementation of Alternative 3 (upgrades to channels to 2.0 L/s/ha, plus new storage) is proposed. The total upgrade program is portioned into six phases, as shown in Figures 3.18 and 3.19.



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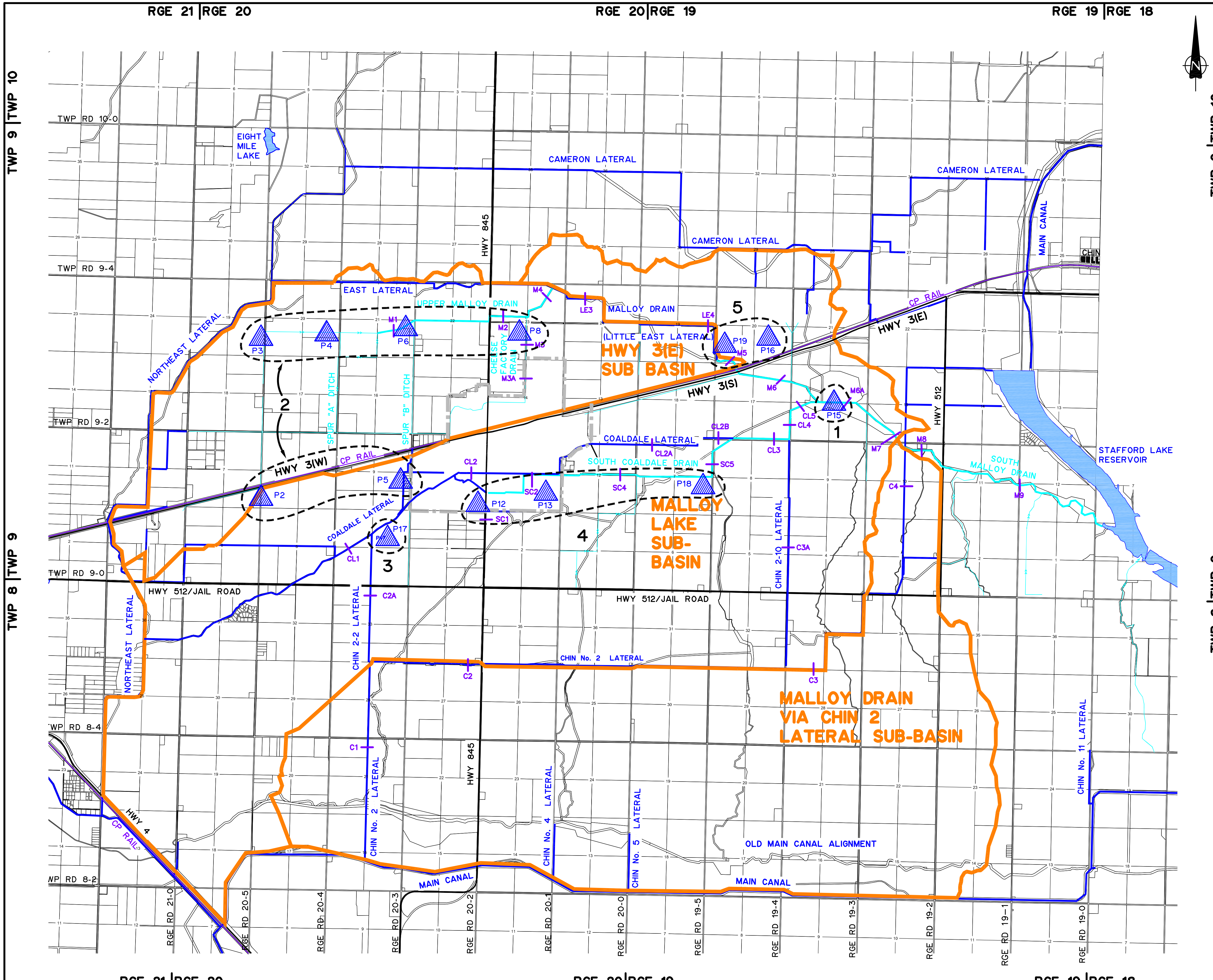
COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PHASES OF PROPOSED CHANNEL AND CULVERT UPGRADES

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.18



LEGEND

- PROPOSED CONSTRUCTED DETENTION POND
- PHASE
- TOWN BOUNDARY

NOTE:
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MPE Engineering Ltd.

COUNTY OF LETHBRIDGE

MALLOY DRAIN
DRAINAGE BASIN PLAN
PHASES OF PROPOSED CONSTRUCTED DETENTION PONDS

DESIGNED	K.P.	CHECKED	
DRAWN	J.H.	JOB	1755-045-00
SCALE	1:40,000	SHEET	
DATE	JANUARY, 2010	FIGURE	3.19

Town Infrastructure

Additionally, two Alternatives were developed to deal with specific constraints with Town infrastructure.

Alternative 5 "Interception of Rural Inflow at Town Edge"

An estimated 54% of the Town's outflow (682,000 m^3 is the outflow from the 100-year storm event) is from run-off entering the Town from catchments outside of Town boundaries. This external run-off has impact on the Town's operation with respect to required storage and control of the storm effluent quality. A proposed concept to intercept the external run-off into new drains constructed along the Town's perimeter was examined.

Estimated costs to construct the interceptor drains are:

- North interceptor: $3,000,000
- South interceptor: $3,500,000

These costs are for channel construction only, and not including costs for accommodating existing roads and other infrastructure, which could easily double or triple the total cost.

Alternative 6 "Dedicated Outlet for Coaldale Stormwater to the Oldman River"

This alternative examined the possibility of diverting storm water from the Town of Coaldale north 14 km to the Oldman River via pipeline. To be practical, this alternative requires that runoff from upstream rural catchments be excluded from the pumped flow, through the construction of interceptor drains as in Alternative 5 above, or construction of storage ponds to collect the upstream rural runoff. The cost of this pipeline and pumping system (excluding the costs to interconnect all the Town's stormwater to a single pumping site, is estimated at **$2,800,000 to $5,300,000**, depending on the size of pipeline chosen, and the rate with which the Town would want to empty its storage ponds. Including the interconnections in Town, and the prerequisite Alternative 5, total cost is in the order of **$10,000,000 to $14,000,000**.

Benefit Analysis

A rough assessment of averted damages (i.e. benefits) resulting from upgrades to the Malloy drainage system was determined using statistics obtained from the Alberta Emergency Management Agency (AEMA, which administers disaster recovery funding). The table (Table 3.23) below displays a cost/benefit comparison of selected alternatives.

Table 3.23: Comparison of Upgrade Costs versus Expected and Averted Damages

Channel/Pond Upgrade Alternatives	Estimated Flooded Area	Upgrades Cost	Damages, $	Averted Damages, $	Intangible Costs
Alternative 1: Status Quo	487 ha	$0	$238,000 (from above)	$0	Economic impact of restricted development
Alternatives 3, 3A, 3B: Combination upgrade of ponds and channel (Scenario 5)	0 ha	$15M-$27M	$0	$238,000/event	
Partial Alternative 3: Upgrade channels to 2.0 L/s/ha, but no new storage; allow reduced flooding	363 ha	$4.8M	$177,000 (363/487 x $238,000)	$61,000/event	Economic impact of restricted development

Interim Measures

Until upgrades to the system can be implemented, future developments will have to provide storage for 100% of their runoff during a storm event, and discharge no more than 0.4 L/s/ha after the storm, in order to not impact the system. Once the system is upgraded throughout the basin to a capacity of 2 L/s/ha, as suggested above, developments can discharge during a storm at the system capacity (2 L/s/ha). The storage requirements will thereby be reduced. Stormwater Best Management Practices will still apply.

6.0 RECOMMENDATIONS

1. Initiate the adoption and Implementation of this MDP. Two possible administrative models could alleviate the difficulty with implementing a drainage plan over a catchment basin with multiple jurisdictions involved, and should be evaluated further.
    - Drainage Commission
    - Utility
2. Given limited resources, the Master Drainage Plan and the recommended improvements may not be fully implemented for a few years. Considering the strong pressure for development in the area, some interim policies are appropriate.
    - For small development proposals, defined as residential developments of no more than three residences, source control BMPs should be incorporated to maintain the peak flows and runoff volumes at or below current pre-development levels.
    - For "major" developments (those greater than three residences)
        - Zero discharge allowed during storm event. Release to be allowed only after a storm event, and upon approval by Drainage authority. (i.e. entire runoff volume to be stored on-site during the storm.)
        - Maximum allowable post-event discharge rate equivalent to 0.4 L/s/ha.
        - Major developments should include the upstream contributing areas within their stormwater management plans.
3. A *Comprehensive Capital Plan* should be developed to provide a "roadmap" for implementing capital improvements. The measures presented in Alternative 3, at a cost of **$27,000,000**, should be considered as part of the Comprehensive Capital Plan. Further analysis and decision-making will be required in the following areas and incorporated into the Plan.
    - The number and locations of required storage ponds should be addressed on a site-specific basis.
    - The scheduling of channel upgrades needs to be in a logical manner, in conjunction with the provision of new storage ponds, or in designated natural storage areas, and in consideration of any impact on downstream areas.
    - Decide on which sites might be pursued for the option of purchasing land or flood easement rights.

  - Come to an agreement, through committee, on allocation of costs not covered by provincial grants that might be acquired.
  - Develop and implement an off-site levy or similar means of cost recovery be implemented to provide an equitable sharing of the costs of regional facilities amongst benefiting areas.
4. Once capital improvements have been made, guidelines for future developments, in keeping with the MDP, should include:
  - Establish 2.0 L/s/ha release rates from developments for both during a storm event, and post-event. Possibly consider different targets for small and large developments.
  - Stormwater Plan prepared by a qualified professional to meet local jurisdiction and AENV requirements.
  - Stormwater facilities to be within a Public Utility Lot.
  - Excess capacity to be built into facilities to accommodate outside areas.
  - Policies adopted to encourage new developments to implement source control best management practices (BMPs), low impact strategies (LID's), and policies to promote long-term monitoring of the effectiveness of those BMP's and LID strategies.
5. A *Storm Response Plan* should be prepared to identify the procedures that the Town, County, and SMRID can follow in response to drainage concerns and associated damage or risk due to imminent flooding during a storm event.
  - A prioritized *Emergency Pumping Plan* be developed and adopted to address existing drainage concerns, based on a priority rating system and potential risk to property.
  - Develop policies to provide guidelines for the acceptance of emergency pumped, gravity-released, or hauled stormwater from developments.

7.0 REFERENCES

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