Salinity Mapping by Landscape

within the County of Vulcan, Alberta

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Abstract

This report presents a methodology for mapping salinity at a municipal scale and demonstrates this methodology for the County of Vulcan, a rural municipality in southern Alberta.

The report and accompanying map have been prepared as part of a larger project to map biophysical landscape units, called *Land Systems*, in the County of Vulcan. The Land Systems map will be used in municipal soil and water conservation planning by the County. Soil salinity is a major conservation issue in the County. The information on salinity location, extent, type and control measures presented in this report will help County planners to target conservation programs. In addition, the methodology can be applied to other Alberta municipalities where soil salinity is a concern.

The methodology has five main steps:

1. The location and extent of saline areas are mapped based on existing information including aerial photographs, maps, satellite imagery, assessment data and technical reports, as well as information from local personnel and field inspections.

2. Saline areas are classified on the basis of the mechanism causing the salinity. The mechanism is important because it determines which control measures are appropriate. Eight salinity types are recognized within the County of Vulcan. These are: contact/ slope change salinity, outcrop salinity, artesian salinity, depression bottom salinity, coulee bottom salinity, slough ring salinity, irrigation canal seepage salinity and natural/irrigation salinity.

3. Cost-effective, practical control measures are identified for each salinity type.

4. A colour-coded map at a scale of 1:200 000 is prepared showing salinity location, extent and type.

5. Ten cross-sections are prepared for areas in the County where salinity is moderate to severe. The cross-sections show elevation, parent material and salinity locations. The cross-section descriptions list salinity types, locations and control measures.

Analysis of the salinity mapping data shows that there are 2 539 saline areas in the County, covering a total of 14 808 ha (36 591 ac). Depression bottom salinity is the most common form of salinity (23.1% of saline areas in the County), followed by coulee bottom salinity (20.0% of saline areas), artesian salinity (19.9%), contact/slope change salinity (14%), irrigation salinity (11.2%), slough ring salinity (6.6%), natural/irrigation salinity (3.5%), and outcrop salinity (1.6%).

Acknowledgements

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Contents

Tables

Figures

Cross-Section Diagrams

1.0 Introduction

1.1 Background, Goal and Objectives

The project was carried out as part of a larger project to prepare a map of biophysical landscape units, called *Land Systems*, for the County of Vulcan (Kwiatkowski and Marciak 1994). The Land Systems map is for use in municipal soil and water conservation planning. Soil degradation is a key issue in conservation planning, and salinity is one of the major visible soil degradation problems affecting the County according to its Canada-Alberta Environmentally Sustainable Agriculture (CAESA) Agreement action plan. This salinity mapping project was conducted to better define the salinity problem for the County.

As well, salinity specialists, salinity technicians and agricultural fieldmen indicated a need for a detailed municipal-scale salinity inventory in Alberta. This information was seen as valuable for municipal and farm conservation planning and for providing salinity control recommendations at the farm level. Therefore this salinity mapping project was set up as a pilot project to develop a methodology for municipal-scale salinity mapping.

In an earlier study, Harker and Klaassen (1991) conducted salinity mapping by quarter section for a region in Saskatchewan. They classified salinity into three management groups (uplands/side-hill, plains transitional, and bedrock controlled) and applied recommendations to control salinity based on these management groups. The County of Vulcan project expands on the approach used in the Harker and Klaassen study by mapping the location of saline areas, and by classifying saline areas based on eight causal mechanisms, with control recommendations based on the mechanism.

Thus, the goal of this project is to present information on salinity location, extent and type in the County of Vulcan. The project's goal was achieved with the following objectives:

1. To derive and integrate existing salinity information for agricultural land in the County of Vulcan.
2. To determine salinity types based on the mechanisms causing the salinity.
3. To recommend appropriate control methods for each type of salinity.
4. To compile a map depicting salinity location, extent and type.

1.2 Methodology

This project developed and tested a standard methodology for mapping salinity. The process of salinity mapping consisted of five stages:

1. Scan aerial photographs and outline saline areas on a County base map. Refine the map based on satellite imagery, assessment data and other information sources.

2. Determine the types of salinity occurring in the County, based on hydrogeology, surface water flow, geology, topography, irrigation and soils. Determine appropriate cost-effective, practical control measures based on salinity types.

3. Prepare 10 representative cross-sections based on information from the Land Systems map, aerial photography and topographic maps. The cross-sections are located in areas where salinity is a significant part of the Land System. The cross-sections show elevation, parent material and salinity locations. The cross-section descriptions list salinity types, locations and control measures.

4. Field check the salinity data and submit the draft salinity information to a technical team consisting of a hydrogeologist, salinity specialist, and the local Agricultural Fieldman and District Agriculturist for review.

5. Prepare a colour-coded 1:200 000 map, showing salinity location, extent and type, and an accompanying report.

1.3 Information Sources

A variety of maps, photographs and other information sources were used for this project.

The County of Vulcan Land Systems map provided information on climate, soils, parent material, geology and soil degradation. Topographic data for the cross-sections were derived from NTS maps at a scale of 1:50 000. The Saline/Waterlogged Lands Map from the Bow River Irrigation District (1990) provided information on salinity in two categories: moderately and severely affected areas.

Aerial photographs from 1986 (scale of 1:15 000) and 1991 (scale of 1:30 000) were used to help determine the location, extent and type of salinity on a section-by-section basis. Comparing photographs from 1986 and 1991 helped to assess trends in salinity over the six-year period. Satellite imagery for the County of Vulcan was used, particularly to identify irrigated lands.

From its assessment files, the County of Vulcan provided a tabular database with salinity information for arable lands, by quarter section. The data were grouped into three classes: less than one-third of the quarter section affected by salinity; one-third to two-thirds affected by salinity; and more than two-thirds affected by salinity. These three categories were mapped by the Conservation and Development Branch of Alberta Agriculture, Food and Rural Development. The map was compared to the aerial photographs and field checked. In the northwest corner of the County, the salinity information from the assessment data did not completely match the salinity patterns shown in the aerial photographs from 1986 or 1991. Where they did not match, the salinity map was based on the aerial photographs.

The Salinity Investigation Reports prepared by Prairie Farm Rehabilitation Administration (PFRA) for 45 sites throughout the County were also valuable information sources (Prairie Farm Rehabilitation Administration various dates). These reports provided detailed data including information on drilling investigations and the severity and extent of salinity. Salinity Survey of Three Townships near Vulcan, Alberta (Leskiw and Reinl-Dwyer 1985) also provided useful information.

To ensure the accuracy of the salinity map and cross-sections, about one-third of the County was field checked. Local personnel were also consulted to verify the findings.

2.0 Classification and Management of Saline Seeps

2.1 Transportation of Salts

The dominant salts in the County of Vulcan are sodium and magnesium sulphates. Analyses of groundwater, saline soils and parent material suggest that the primary source of salts is bedrock and the secondary source is glacial till (Greenlee et al. 1968). Soils developed on the Paskapoo and Bearpaw bedrock formations contain relatively high salt levels.

Saline seeps form when saline groundwater rises to the ground surface. Contact and saline seeps (described in Section 2.2.1) develop when water in a recharge area percolates through the soil profile beyond the root zone and dissolves soluble salts (Figure 1). The water moves laterally to a lower position in the landscape and through capillarity rises to the surface, resulting in a saline seep. High evapotranspiration rates cause the capillary rise and the deposition of salts on the soil surface.

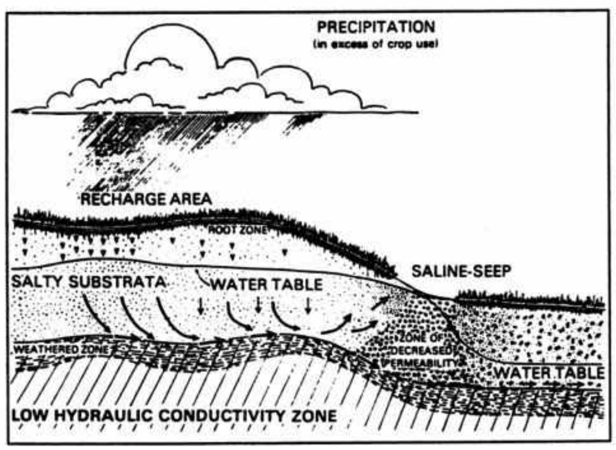


Figure 1. Generalized diagram of saline seep, recharge area, and the substrata formation that contributes to a saline seep (Brown et al. 1982)

Three types of flow may be recognized within a groundwater basin: local, intermediate and regional. A local flow system occupies a relatively small area with the recharge area at a higher elevation than the discharge area. An intermediate system consists of several interconnected local systems. A regional system has its recharge area at the water divide of a basin while the discharge area lies at the bottom of the basin. In the County of Vulcan, most of the groundwater flow systems are local, and the recharge areas are within a few hundred metres of their discharge area. Intermediate flow systems extend beyond 1 km (0.6 miles), while regional flow systems extend over several kilometres.

Groundwater movement is influenced by topography as follows:

- On larger, flat areas, groundwater movement is minimal or even impeded.
- In areas with one large slope, regional systems are prevalent.
- In large valleys, regional systems predominate.
- In areas with well-defined local relief (e.g. hummocky or rolling landscapes), local systems are prevalent.

2.2 Salinity Types

Based on hydrogeology, surface water flow, geology, topography, irrigation and soils, eight types of salinity are recognized within the County of Vulcan. The eight types can be grouped into six dryland (rainfed land) and two irrigation types as follows.

2.2.1 Dryland Salinity Types

1. Contact and Slope Change Salinity

Contact salinity and slope change salinity are grouped together because they cannot be differentiated on aerial photographs and because the same methods are used to control both types (see Section 2.3). The two types are described as follows:

a. *Contact salinity* occurs where a permeable water-bearing surface layer, located on top of a non/lesser permeable layer (such as a fine textured layer), thins out. This forces the groundwater flow closer to the surface (Figure 2). Contact salinity dominates in the sandy, gently rolling area around Carmangay. The saline areas occur between eroded ridges and have irregular shapes and edges. (The seep forms are distinctly different from the elongated, southwest - northeast oriented, smooth-edged eroded ridges and therefore can be detected on aerial photographs). Contact salinity may also occur at the shoulders of coulees or as scattered seeps not associated with low lying areas.

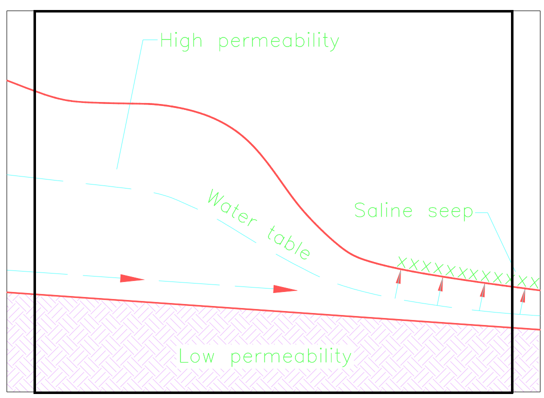


Figure 2. Contact salinity

b. *Slope change salinity* occurs where the slope decreases. This decrease results in a slowing of the groundwater flow and a shallower water table (Figure 3). This type of seep expands upslope.

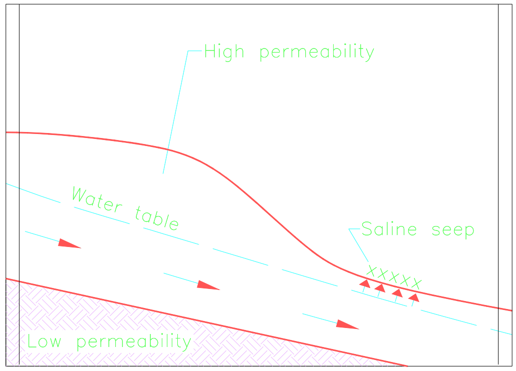


Figure 3. Slope change salinity

2. Outcrop Salinity

Outcrop salinity occurs where a permeable, water-bearing layer, such as a coal seam or a sandstone or fractured bedrock layer, outcrops at or near the surface (Figure 4). Outcrop salinity occurs along a slope at similar elevations. In the County of Vulcan, a large area of outcrop salinity occurs on the west shoulder of the Blackspring Ridge.

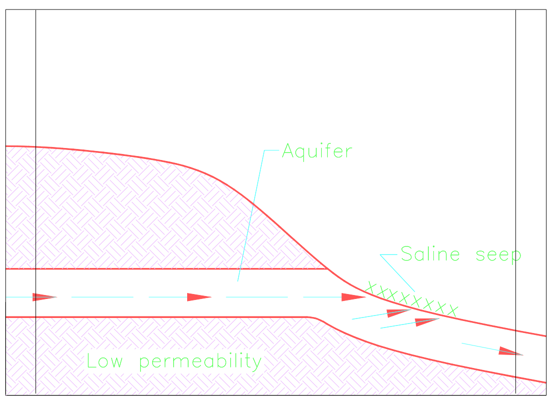


Figure 4. Outcrop salinity

3. Artesian Salinity

Artesian salinity occurs where water from a pressurized aquifer rises to or near the ground surface (Figure 5). It is usually associated with intermediate or regional groundwater flow systems. If the pressure is large enough, the water flows to the surface and produces a flowing well, spring or soap hole. Artesian seeps can be identified from the presence of these flow features and from hydrogeological maps.

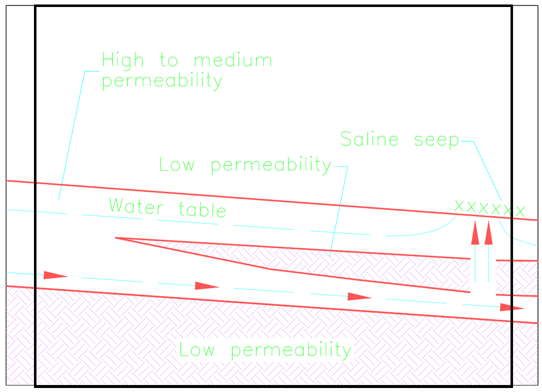


Figure 5. Artesian salinity

4. Depression Bottom Salinity

Depression bottom salinity occurs in low lying areas. Surface water is trapped temporarily in these low lying areas until the water drains off and/or infiltrates the soil. The water in the soil flows upslope through the upper soil in an unsaturated state and then surfaces to evaporate and deposit salt at the edge of the ponded area (Figure 6). Once the surface water has disappeared, groundwater from the water table rises by capillary action to the surface in and around the previously ponded area. Depression bottom seeps are well defined with distinct, rounded edges. In the County of Vulcan, depression bottom salinity is very common. It occurs in several landscape with poor drainage, particularly in rolling and hummocky areas.

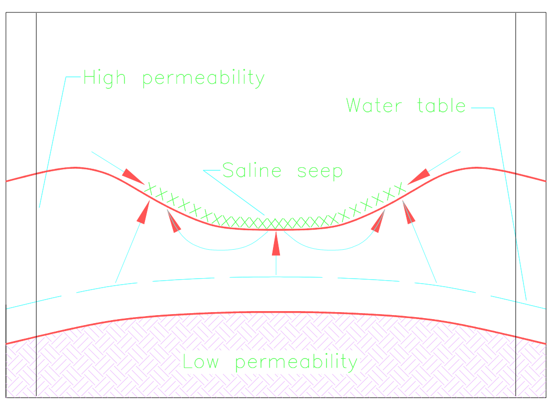


Figure 6. Depression bottom salinity

5. Coulee Bottom Salinity
Coulee bottom salinity forms in the bottoms of coulees and drainage courses by the same mechanism as depression bottom salinity but on a larger scale.

6. Slough Ring Salinity
This type of salinity occurs as a ring of salt immediately adjacent to a permanent water body (Figure 7). Water infiltrates from the water body into the permeable upper soil layer and flows upslope as shallow groundwater in an unsaturated state through this layer. The water may also flow downward, raising the water table. Water from the unsaturated lateral flow and from capillary rise from the water table emerges at the surface where it evaporates, leaving salts at the edge of the slough.

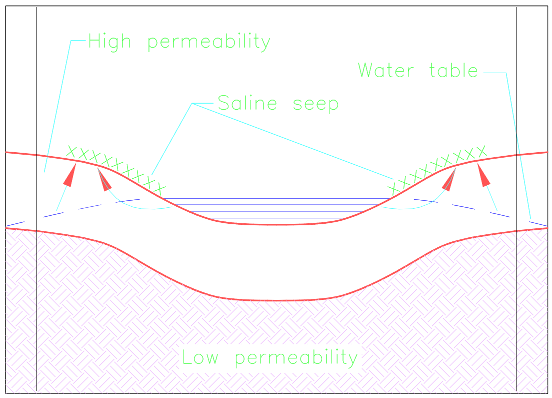


Figure 7. Slough ring salinity

2.2.2 Irrigation Salinity Types

1. Canal Seepage Salinity
This type of seep is dominant in irrigated areas where leakage from canals contributes to seeps (Figure 8).

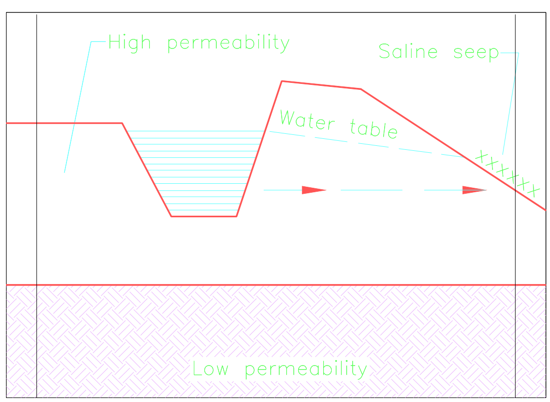


Figure 8. Canal seepage salinity

2. Natural/Irrigation Salinity
These seeps result from one or more of: natural seepage, canal seepage and excess irrigation. All seeps located on irrigated land and some distance from canals and supply ditches are given this classification.

2.3 Salinity Controls

Salinity is a complex problem caused by climatic, hydrogeological and agricultural factors. The possibilities of moderating the effects of climate and hydrogeological processes are limited and/or expensive. Therefore appropriate agricultural practices are used to help prevent or control saline seeps. The emphasis in this report is on cost-effective, agronomic measures. Specifically, cropping systems are recommended that intercept the available soil water in a recharge area before the water moves below the crop root zone.

Recommended control methods for the types of salinity found in the County of Vulcan are summarized in Table 1 and described in more detail in Sections 2.3.1 to 2.3.7.

2.3.1 Biological Controls

2.3.1.1 Flexible Cropping

In *flexible cropping*, fields are seeded if stored soil moisture and rainfall probabilities are favourable for satisfactory crop yields, and fallowed only if yield prospects are unfavourable (Jackson and Krall 1978). Flexible cropping involves careful management and planning; it is often simpler to use continuous cropping.

Snow trapping may increase stored soil moisture for recropping. Techniques to trap and manage snow include:

- *tall stubble/alternate height stubble* - Leaving tall stubble or strips of stubble at different heights increases stored soil moisture (Nicholaichuk 1979).
- *shelterbelts* - The ability of shelterbelts to trap snow can be manipulated by such practices as tree pruning and species selection.

2.3.1.2 Deep-Rooted Crops

Deep-rooted crops prevent the build-up of groundwater, lower the water table, dry out the subsoil and restore the water storage capacity of the soil (Brown et al. 1982). The most commonly grown deep-rooted dryland crop is alfalfa. It roots up to 6 m (20 ft) in four to five years and uses more than 760 mm (30 in.) of water per year. Perennial deep-rooted crops also increase soil organic matter content, improve soil structure and reduce soil erosion.

Table 1. Salinity types and control methods in the County of Vulcan

Salinity Type	Control
1. contact/slope change salinity	- salt-tolerant grasses in saline area and alfalfa in upslope recharge area (recharge area may be about three times area of seep)
2. outcrop salinity	- salt-tolerant grasses in saline area
3. artesian salinity	- salt-tolerant grasses in saline area - where applicable, install relief wells connected to suitable outlet
4. depression bottom salinity	- salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide - appropriate structural controls
5. coulee bottom salinity	- salt-tolerant grasses in saline area - appropriate structural controls
6. slough ring salinity	- deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough - appropriate structural controls
7. irrigation canal seepage salinity	- structural controls to prevent canal seepage (canal lining, cut-off curtains) and/or subsurface drainage of affected area
8. natural/irrigation salinity	- appropriate structural controls for irrigation-related salinity - salt-tolerant grasses for natural salinity

Alfalfa should be seeded into a firm, moist seed bed as shallowly as possible at a rate of about 7 kg/ha (6.2 lbs/ac). It can be seeded using a conventional seeder. Hoe drills often give the most effective results because of good depth control and packing capability. Disk drills work best if the seed bed is uniform and moderately firm. However, in loose soil, disk drills may place the seed too deeply, and in very firm soil, they may leave the seed on the soil surface. Both conditions result in poor germination.

Recharge areas identified during a salinity investigation should be seeded to alfalfa. On average, recharge areas are about three times larger than their saline seep. The best time for seeding alfalfa is early spring. Alfalfa should be seeded without any companion crops because competition will deter establishment of the alfalfa stand.

Alfalfa has the ability to use atmospheric nitrogen through a symbiotic relationship with rhizobia nodule bacteria. Therefore, alfalfa inoculated with rhizobia will require less nitrogen fertilizer. Phosphorus, potassium and sulphur are important nutrients for optimum production.

Alfalfa requires 5 kg of phosphorus per tonne of yield (10 lbs per ton of yield). This nutrient is very immobile in the soil and so application prior to seeding is highly recommended.

When alfalfa is seeded in a recharge area, it usually takes about five years to lower the water table in the associated saline seep. Once the water table is lowered to an acceptable level, the recharge area may be converted to cereal crops for a few years. The best approach is usually to establish a rotation of five years of alfalfa followed by three years of cereal crops. The cereals should be continuously cropped.

2.3.1.3 Salt-Tolerant Crops

Saline areas should not be left bare for extended periods. Very saline soils should be seeded to a mixture of salt-tolerant forage crops (Table 2). Saline areas are often wet, so crops may need to be tolerant of both salt and excess moisture. When electrical conductivity measurements exceed 8 to 10 mS/cm, salt-tolerant seed mixtures usually give the best results.

Establishing deep-rooted vegetation on a saline seep can be very difficult. Salt-tolerant grasses can be seeded in the fall when the saline seeps are dry and accessible. Seeding rates for saline seeps, especially when planted in the fall, should be double those for non-saline areas.

2.3.2 Structural Controls

2.3.2.1 Surface Drainage

Surface drainage of recharge and/or discharge areas can be used to control seeps (VanderPluym 1982). An open, shallow trench is normally used; deep trenches will obstruct farming operations. Trenches can be constructed with farm or contractor's equipment at a reasonable cost.

Grassed waterways are often used to drain excess surface water. Typical grassed waterways are broad, shallow channels with shallow slopes that carry water at slow speeds, preventing soil erosion. Grassed waterways ideally have channel slopes of less than 1% and side slopes of less than 25%. The channel should be at least 15 cm (5.9 in.) deep and 5 m (16 ft) wide. The grass should extend at least 5 m (16 ft) on both sides of the channel. A commonly used forage mix for grassed waterways is:

- brome or pubescent wheatgrass	- 10 kg/ha (9 lbs/ac), plus
- creeping red fescue	- 5 kg/ha (4.5 lbs/ac), plus
- crested wheatgrass	- 5 kg/ha (4.5 lbs/ac), plus
- alfalfa	- 10 kg/ha (9 lbs/ac), plus
- fall rye	- 1 kg/ha (0.9 lbs/ac)

Table 2. Forage crops for saline soils and flooded areas (Henry et al. 1987)

Salinity Rating*	Forage Mix	Seeding Rate for Hay or Pasture (kg/ha)
	a. Soils with Little or No Spring Flooding (up to 2 weeks)	
Slight to Moderate (2-6 dS/m)	bromegrass + Russian wild ryegrass + alfalfa (Rambler)	4+4+4
	bromegrass + slender wheatgrass + alfalfa (Rambler)	4+4+4
	Russian wild ryegrass + alfalfa	6+3
	altai wild ryegrass + alfalfa	10+3
	crested wheatgrass + alfalfa	7+3
	altai wild ryegrass	11
	slender wheatgrass + sweet clover (short-term stands and not over 1 week of flooding)	8+6
Severe (6-10 dS/m)	bromegrass + Russian wild ryegrass + slender wheatgrass	4+4+4
	altai wild ryegrass + alfalfa	10+3
	altai wild ryegrass	11
	tall wheatgrass (moist districts or seepage areas)	12
Very Severe (10-15 dS/m)	Russian wild ryegrass + slender wheatgrass	4+4
	altai wild ryegrass + alfalfa	10+3
	altai wild ryegrass	10
	tall wheatgrass (moist districts or seepage areas)	12
	b. Soils with Spring Flooding (2 to 5 weeks)	
Little or No (0-2 dS/m)	reed canarygrass + bromegrass	4+6
	reed canarygrass + timothy	4+4
	timothy + bromegrass	4+6
	altai wild ryegrass + alfalfa	10+3
	altai wild ryegrass	11
Slight to Moderate (2-6 dS/m)	reed canarygrass + bromegrass	4+6
	reed canarygrass + bromegrass + slender wheatgrass	4+6+6
	altai wild ryegrass + alfalfa	10+3
	altai wild ryegrass	11
Severe to Very Severe (6-15 dS/m)	altai wild ryegrass + alfalfa	10+3
	slender wheatgrass	8
	altai wild ryegrass	11
	tall wheatgrass	12

* Electrical conductivity based on saturated paste

2.3.2.2 Subsurface Drainage

Although subsurface drainage has been used widely on irrigated lands and is considered to be an important control measure for irrigation salinity and waterlogging, its use for dryland saline seep control is much less common. Shallow groundwater in permeable material may be drained with tile drainage upslope from the seeps. If the water is of good quality, it could be stored and used for stock water.

2.3.2.3 Relief Wells

Soap holes or springs may be effectively controlled using relief wells. The wells should be completed in the pressurized water-bearing layer. The wells may flow free and could be connected to a buried pipe 1 to 2 m (3.3 to 6.6 ft) deep. If the water is of good quality, it could be used for domestic or livestock purposes.

3.0 Location, Type and Control of Saline Seeps in the County of Vulcan

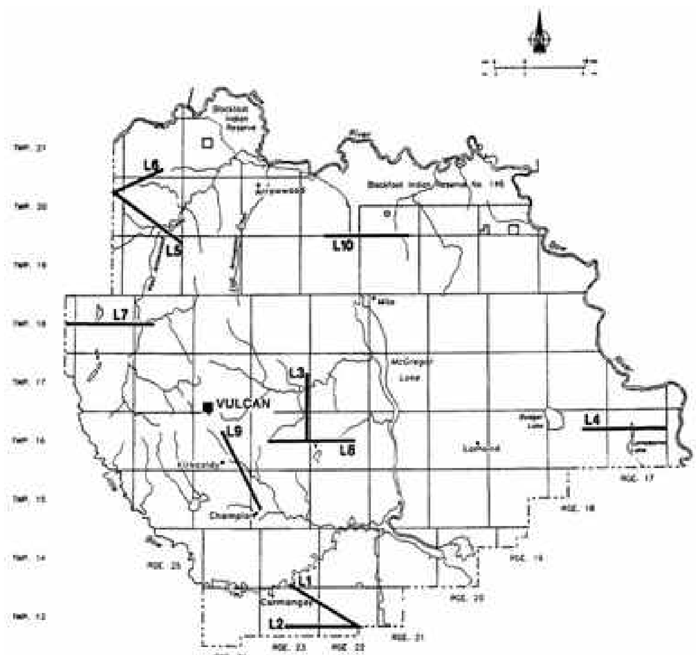
Analysis of the salinity mapping data for the County of Vulcan shows that there are 2 539 saline areas in the County, covering a total of 14 808 ha (36 591 ac). Depression bottom salinity is the most common form of salinity (23.1% of saline areas in the County), followed by coulee bottom salinity (20.0% of saline areas), artesian salinity (19.9%), contact/slope change salinity (14%), irrigation salinity (11.2%), slough ring salinity (6.6%), natural/irrigation salinity (3.5%), and outcrop salinity (1.6%).

Cross-sections were prepared for those areas in the County with moderate to severe salinity. The locations of the 10 cross-section are shown on Figure 9. The names for the cross-sections are adopted from Kwiatkowski and Marciak (1994) for easy reference to the Land Systems descriptions in that report. Figure 10 shows the Land Systems for the County. The Land Systems map, aerial photographs, geological information, topographical maps and field tours of the County provided information on the cross-sections.

Each cross-section diagram shows:

- saline seep locations (based on aerial photographs);
- topography, including features such as sloughs and irrigation canals;
- parent material; and
- local bedrock.

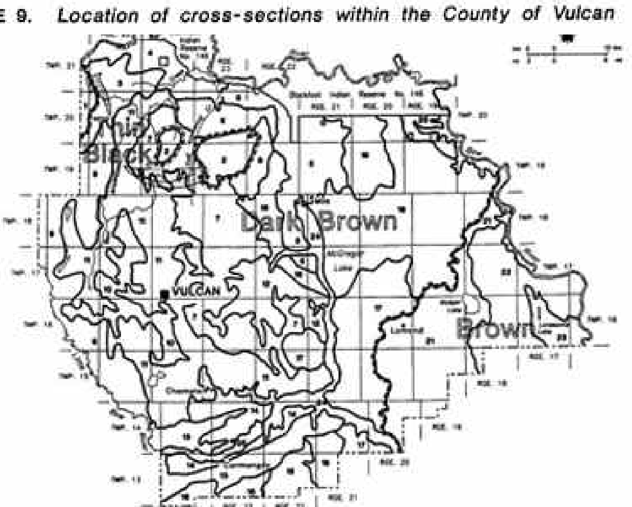
The seep locations are labelled for reference to the cross-section description. Each cross-section description states the types of saline seeps, their locations and the appropriate control measures.



LEGEND:

Cross-Sections — County Boundary

FIGURE 9. *Location of cross-sections within the County of Vulcan*



LEGEND:

Land System Boundary — County Boundary — Soil Zone Boundary

KEY FOR LAND SYSTEM NAMES:

No.	Name	No.	Name	No.	Name
1	Glenview Upland	10	Enslgn Upland	19	Liberty Upland
2	Buffalo Hills Upland	11	Kirkcaldy Plain	20	Bow River Plain
3	West Arrowwood Upland	12	Snake Creek Plain	21	Travers Plain
4	Willow Island Plain	13	Carmangay Plain	22	Bow City Plain
5	Milo Plain	14	Champion Plain	23	Lonesome Plain
6	Anastasia Upland	15	Blackspring Ridge Upland	24	Bow River and McGregor Shore Land (miscellaneous)
7	Thigh Hills Upland	16	Peacock Plain	25	Little Bow Valley (miscellaneous)
8	East Buffalo Hills Upland	17	Armada Upland		
9	Harronton Plain	18	McGregor Lake Upland		

FIGURE 10. *Land Systems of the County of Vulcan (Kwiatkowski and Marciak 1993)*

3.1 Line 1 - Champion Plain, Carmangay Plain and Blackspring Ridge Upland

Carmangay Plain

Site A:

Type:	- contact and slope change salinity
Location:	- lower lying areas between ridges on Carmangay Plain
Control:	- salt-tolerant grasses in saline seep; alfalfa in recharge area

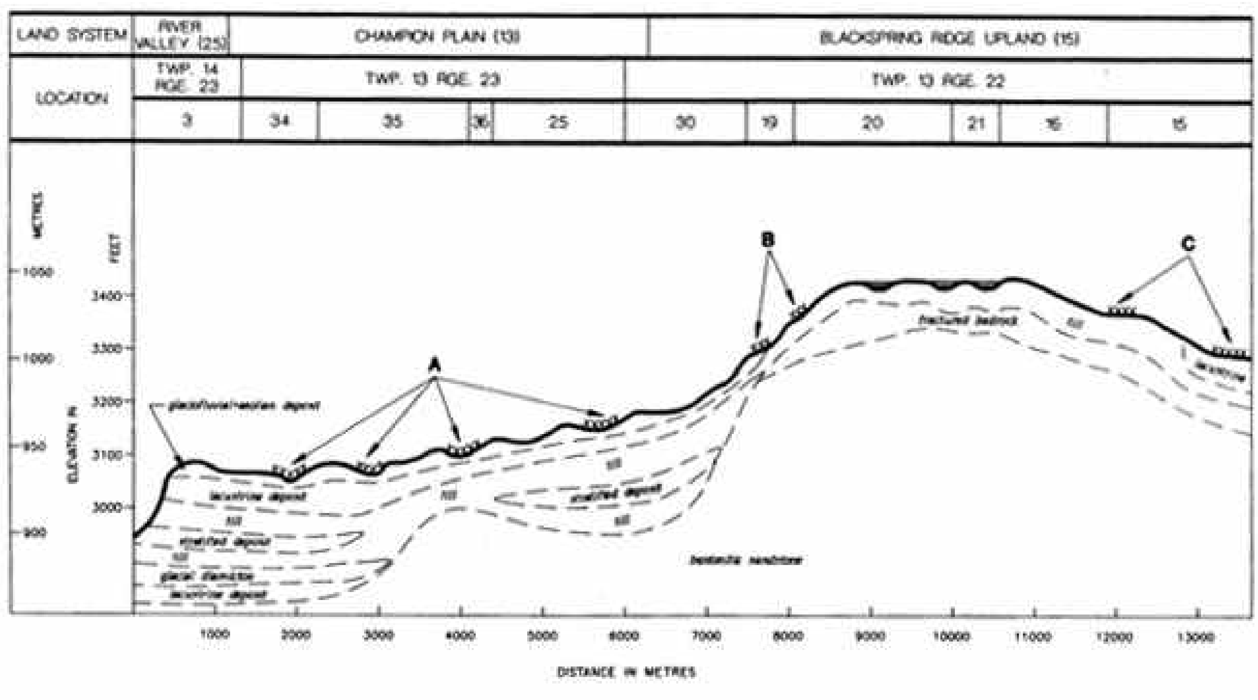
Blackspring Ridge Upland

Site A:

Type:	- contact and slope change salinity
Location:	- northeast mid slope of Blackspring Ridge
Control:	- salt-tolerant grasses in saline seep; alfalfa in recharge area

Site B:

Type:	- outcrop salinity
Location:	- at the foot of Blackspring Ridge
Control:	- salt-tolerant grasses in saline area



LINE 1 - CHAMPION PLAIN AND BLACKSPRING RIDGE UPLAND

3.2 Line 2 - Peacock Plain and Blackspring Ridge Upland

Peacock Plain

Site A:

Type: - slough ring salinity
Location: - areas around Peacock slough
Control: - deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough or reservoir
- appropriate structural controls

Site B:

Type: - artesian salinity
Location: - east side of the Peacock Plain
Control: - salt-tolerant grasses in saline area
- where applicable, install relief wells connected to a suitable outlet

Site C:

Type: - outcrop salinity
Location: - lower slopes of the Blackspring Ridge
Control: - salt-tolerant grasses in saline area

Blackspring Ridge Upland

Site D:

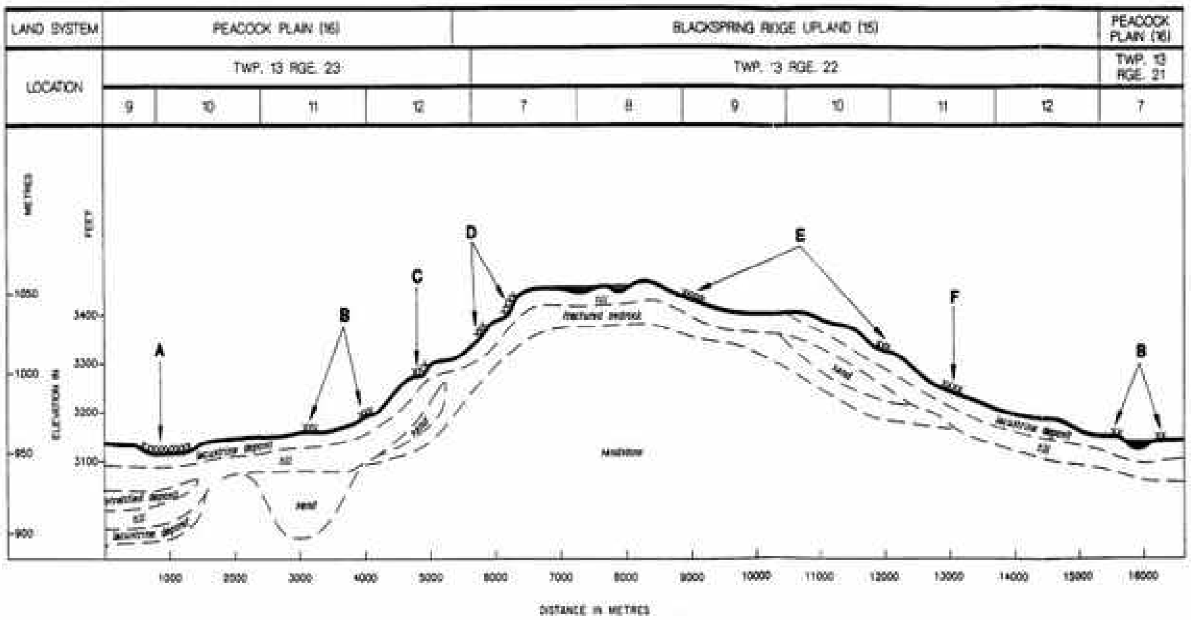
Type: - coulee bottom salinity
Location: - coulees on the west side of Blackspring Ridge
Control: - salt-tolerant grasses in saline area
- appropriate structural controls

Site E:

Type: - contact and slope change salinity
Location: - east slope of the Blackspring Ridge
Control: - salt-tolerant grasses in saline seep; alfalfa in recharge area

Site F:

Type: - depression bottom salinity
Location: - east side of Blackspring Ridge
Control: - salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
- appropriate structural controls



LINE 2 - PEACOCK PLAIN AND BLACKSPRING RIDGE UPLAND

3.3 Line 3 - Thigh Hills Upland and Snake Creek Plain

Thigh Hills Upland

Site A:

Type: - artesian salinity
Location: - lower lying areas in the Thigh Hills Upland
Control: - salt-tolerant grasses in saline area
- where applicable, install relief wells connected to a suitable outlet

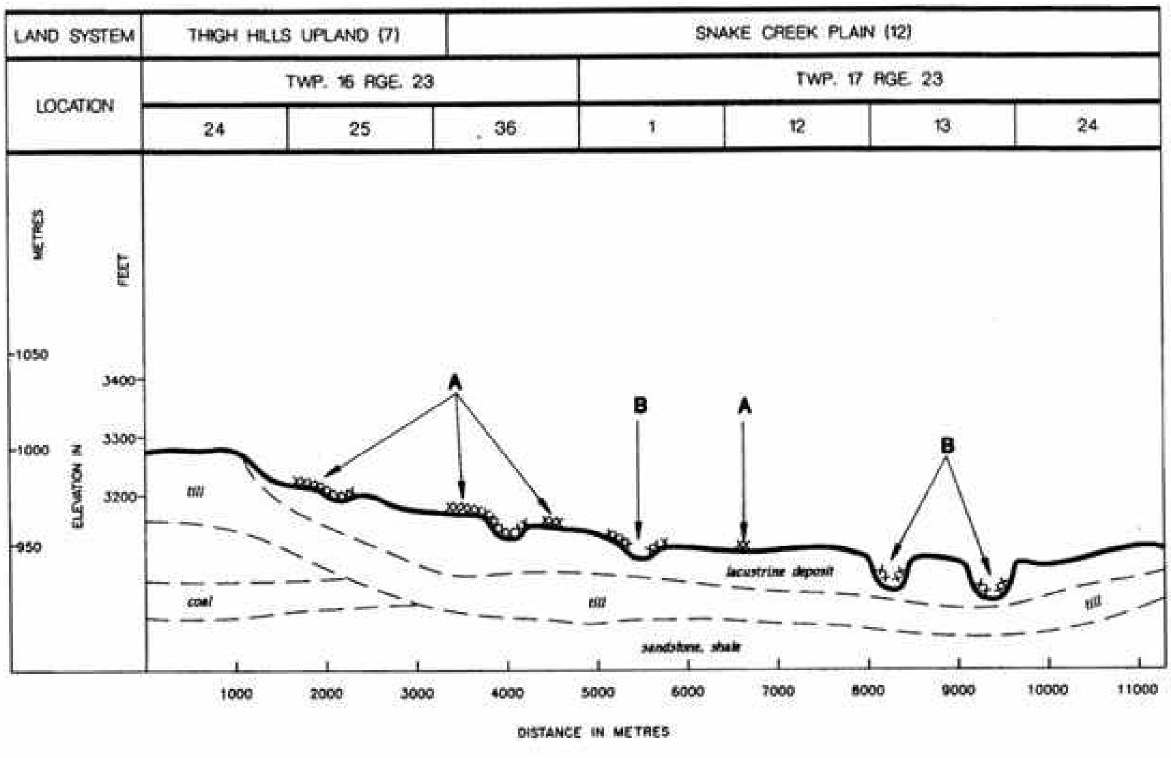
Snake Creek Plain

Site A:

Type: - artesian salinity
Location: - lower lying areas within the Snake Creek Plain
Control: - salt-tolerant grasses in saline area
- where applicable, install relief wells connected to a suitable outlet

Site B:

Type: - coulee bottom salinity
Location: - north side of Snake Creek Plain
Control: - salt-tolerant grasses in saline area
- appropriate structural controls



LINE 3 - THIGH HILLS UPLAND AND SNAKE CREEK PLAIN

3.4 Line 4 - Bow City Plain and Lonesome Plain

Bow City Plain

Site A:

Type: - irrigation canal seepage salinity
Location: - lower lying areas within the Bow City Plain along irrigation canals
Control: - structural controls to prevent canal seepage (canal lining, cut-off curtains) and/or subsurface drainage of affected area

Site B:

Type: - contact and slope change salinity
Location: - lower lying areas on the Bow City Plain
Control: - salt-tolerant grasses saline seep; alfalfa in recharge area

Site C:

Type: - natural/irrigation salinity
Location: - flat, irrigated areas apart from main irrigation system
Control: - salt-tolerant grasses for natural salinity
- structural controls for irrigation-related salinity (canal lining, cut-off curtains) and/or subsurface drainage of affected area

Site D:

Type: - slough ring salinity
Location: - around sloughs and reservoirs on Bow City Plain
Control: - deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough or reservoir
- appropriate structural controls

Site E:

Type:	-	coulee bottom salinity
Location:	-	along coulees on Bow City Plain
Control:	-	salt-tolerant grasses in saline area
	-	appropriate structural controls

Site F:

Type:	-	depression bottom salinity
Location:	-	lower lying areas on Bow City Plain
Control:	-	salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
	-	appropriate structural controls

Lonesome Plain

Site D:

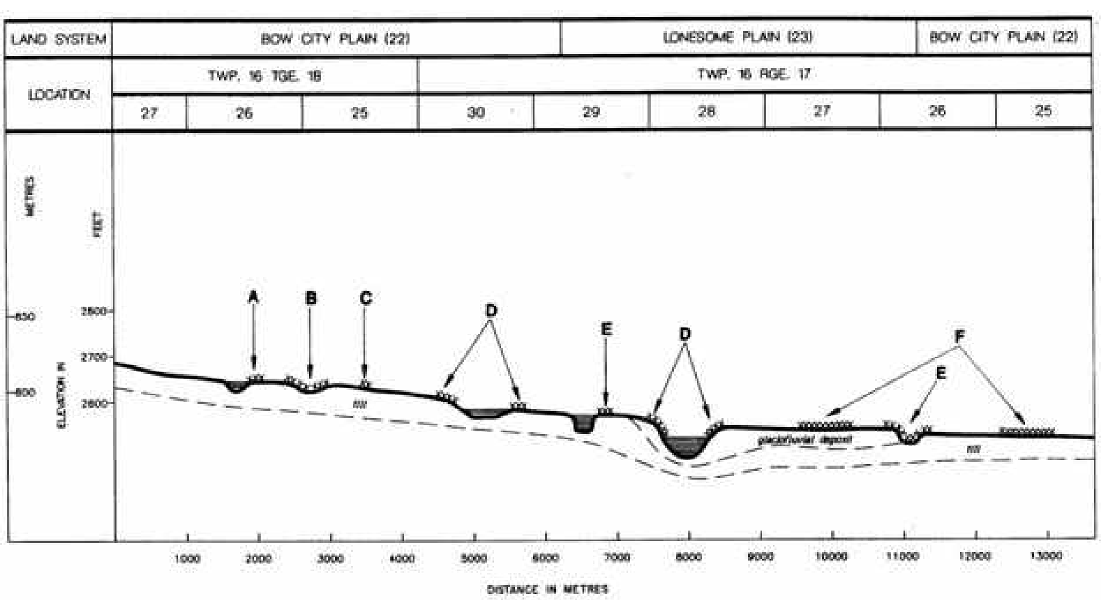
Type:	-	slough ring salinity
Location:	-	around sloughs and reservoirs on Lonesome Plain
Control:	-	deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough or reservoir
	-	appropriate structural controls

Site E:

Type:	-	coulee bottom salinity
Location:	-	along coulees on Lonesome Plain
Control:	-	salt-tolerant grasses in saline area
	-	appropriate structural controls

Site F:

Type:	-	depression bottom salinity
Location:	-	lower lying areas on Lonesome Plain
Control:	-	salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
	-	appropriate structural controls



LINE 4 - BOW CITY PLAIN AND LONESOME PLAIN

3.5 Line 5 - Glenview Upland, West Arrowwood Upland, Kirkcaldy Plain and Thigh Hills Upland

Glenview Upland

Site A:

Type: - depression bottom salinity
Location: - lower lying positions on Glenview Upland
Control: - salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
- appropriate structural controls

West Arrowwood Upland

Site B:

Type: - slough ring salinity
Location: - areas around sloughs and reservoirs on West Arrowwood Upland
Control: - deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough or reservoir
- appropriate structural controls

Kirkcaldy Plain

Site A:

Type: - depression bottom salinity
Location: - lower lying areas on Kirkcaldy Plain
Control: - salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
- appropriate structural controls

Site C:

Type: - contact and slope change salinity
Location: - lower, depressional areas in Kirkcaldy Plain
Control: - salt-tolerant grasses in saline seep; alfalfa in recharge area

3.6 Line 6 - Glenview Upland and West Arrowwood Upland

Glenview Upland

Site A:

Type: - depression bottom salinity
Location: - east side of Glenview Ridge
Control: - salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
- appropriate structural controls

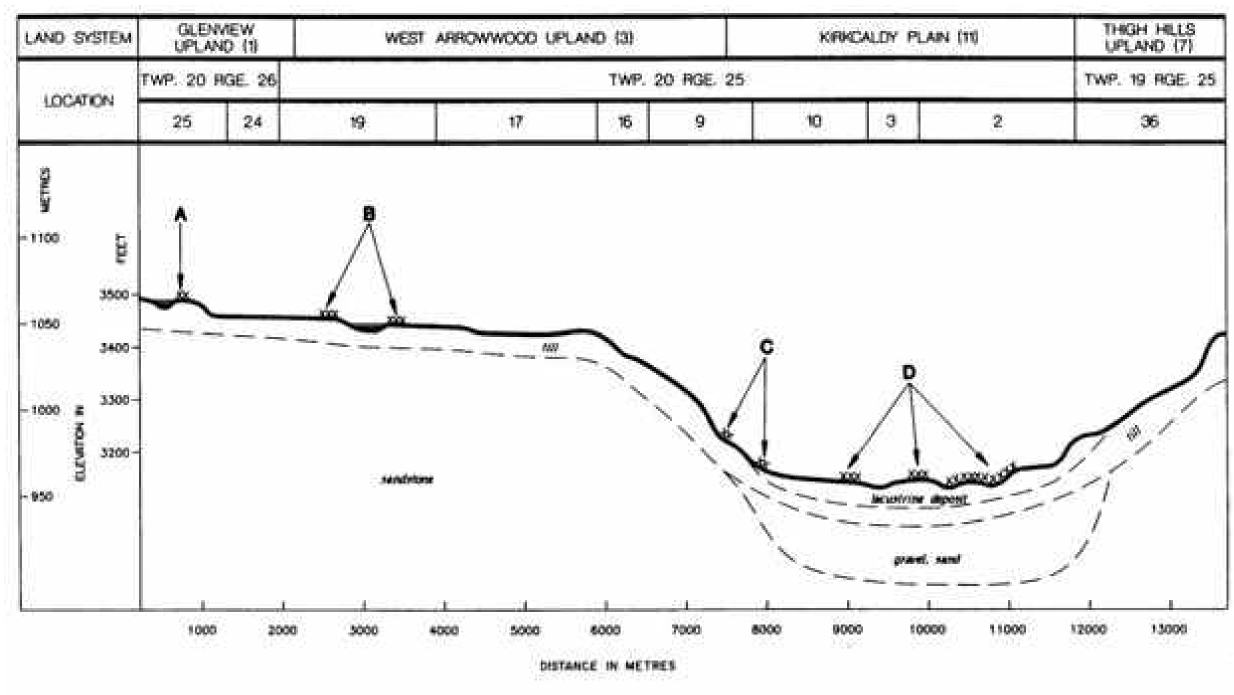
West Arrowwood Upland

Site A:

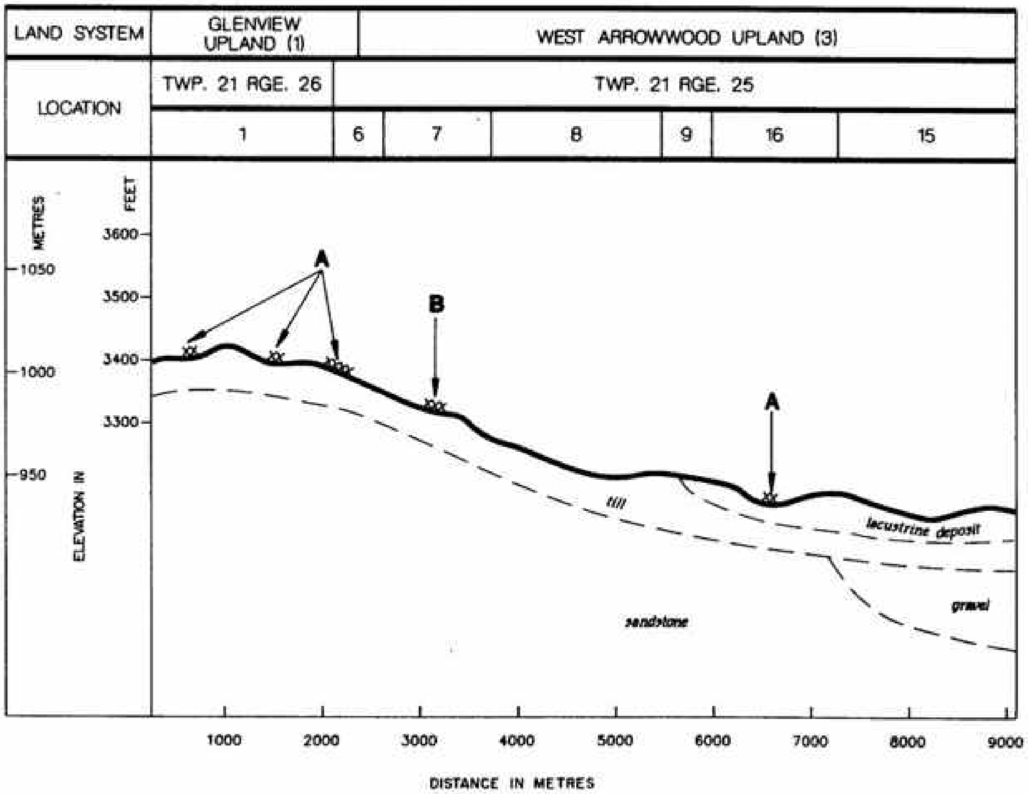
Type: - depression bottom salinity
Location: - east side of Glenview Ridge
Control: - salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
- appropriate structural controls

Site B:

Type: - contact and slope change salinity
Location: - east side of Glenview Ridge
Control: - salt-tolerant grasses in saline seep; alfalfa in recharge area



LINE 5 - GLENVIEW UPLAND, WEST ARROWWOOD UPLAND, KIRKCALDY PLAIN AND THIGH HILLS UPLAND



LINE 6 - GLENVIEW UPLAND AND WEST ARROWWOOD UPLAND

3.7 Line 7 - Herronton Plain and Kirkcaldy Plain

Herronton Plain

Site A:

Type:	- contact and slope change salinity
Location:	- lower lying areas in Herronton Plain
Control:	- salt-tolerant grasses in saline seep; alfalfa in recharge area

Site B:

Type:	- slough ring salinity
Location:	- areas around sloughs in Herronton Plain
Control:	- appropriate structural controls
	- deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough or reservoir

Site C:

Type:	- artesian salinity
Location:	- lower lying areas in Herronton Plain
Control:	- salt-tolerant grasses in saline area
	- where applicable, install relief wells connected to a suitable outlet

Kirkcaldy Plain

Site A:

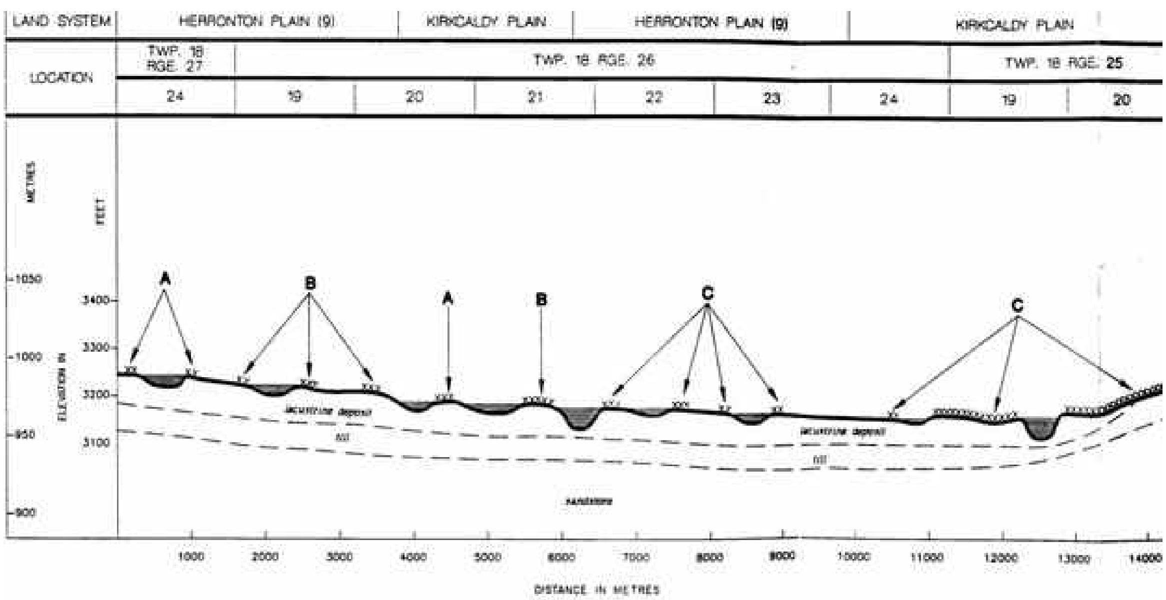
Type:	- contact and slope change salinity
Location:	- lower lying areas in Kirkcaldy Plain
Control:	- salt-tolerant grasses in saline seep; alfalfa in recharge area

Site B:

Type:	- slough ring salinity
Location:	- areas around sloughs in Kirkcaldy Plain
Control:	- appropriate structural controls - deep-rooted and salt-tolerant grasses in a 20 to 60 m (65 to 195 ft) band around slough or reservoir

Site C:

Type:	- artesian salinity
Location:	- lower lying areas in Kirkcaldy Plain
Control:	- salt-tolerant grasses in saline area - where applicable, install relief wells connected to a suitable outlet



LINE 7 - HERRONTON PLAIN AND KIRKCALDY PLAIN

3.8 Line 8 - Snake Creek Plain and Thigh Hills Upland (east-west line)

Snake Creek Plain

Site A:

Type: - depression bottom salinity
Location: - mid slope of east portion of Thigh Hills Upland
Control: - salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
- appropriate structural controls

Thigh Hills Upland

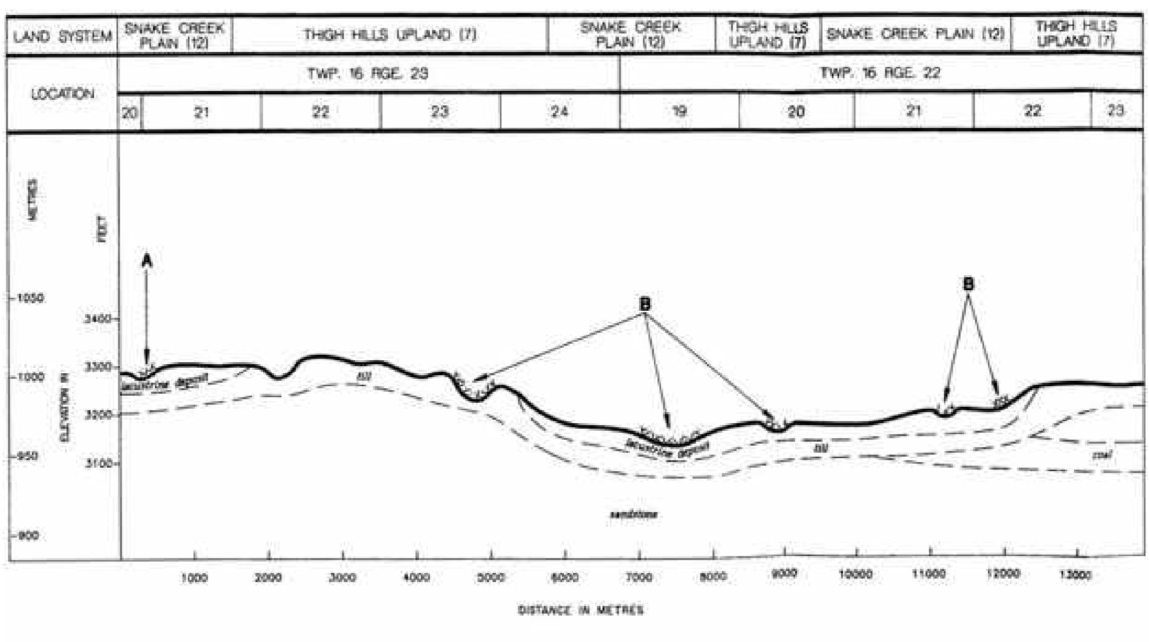
Site B:

Type: - artesian salinity
Location: - west part of Snake Creek Plain (mid slope)
Control: - salt-tolerant grasses in saline area
- where applicable, relief wells connected to a suitable outlet

Snake Creek Plain

Site B:

Type: - artesian salinity
Location: - east part of Snake Creek Plain (mid slope)
Control: - salt-tolerant grasses in saline area
- where applicable, install relief wells connected to a suitable outlet



LINE 8 - SNAKE CREEK PLAIN AND THIGH HILLS UPLAND (east-west line)

3.9 Line 9 - Kirkcaldy Plain and Champion Plain

Kirkcaldy Plain

Site A:

Type:	- contact and slope change salinity
Location:	- lower lying areas and on slopes in vicinity of Kirkcaldy
Control:	- salt-tolerant grasses in saline seep; alfalfa in recharge area

Site B:

Type:	- artesian salinity
Location:	- depressional areas in vicinity of Champion and Kirkcaldy
Control:	- salt-tolerant grasses in saline area
	- where applicable, install relief wells connected to a suitable outlet

Site C:

Type:	- coulee bottom salinity
Location:	- lower lying areas in vicinity of Kirkcaldy
Control:	- salt-tolerant grasses in saline area
	- appropriate structural controls

Champion Plain

Site C:

Type:	- coulee bottom salinity
Location:	- coulees in vicinity of Champion
Control:	- salt-tolerant grasses in saline area
	- appropriate structural controls

Site D:

Type:	- depression bottom salinity
Location:	- lower lying areas in vicinity of Champion
Control:	- salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide
	- appropriate structural controls

3.10 Line 10 - East Buffalo Hills Upland and Milo Plain

Milo Plain

Site A:

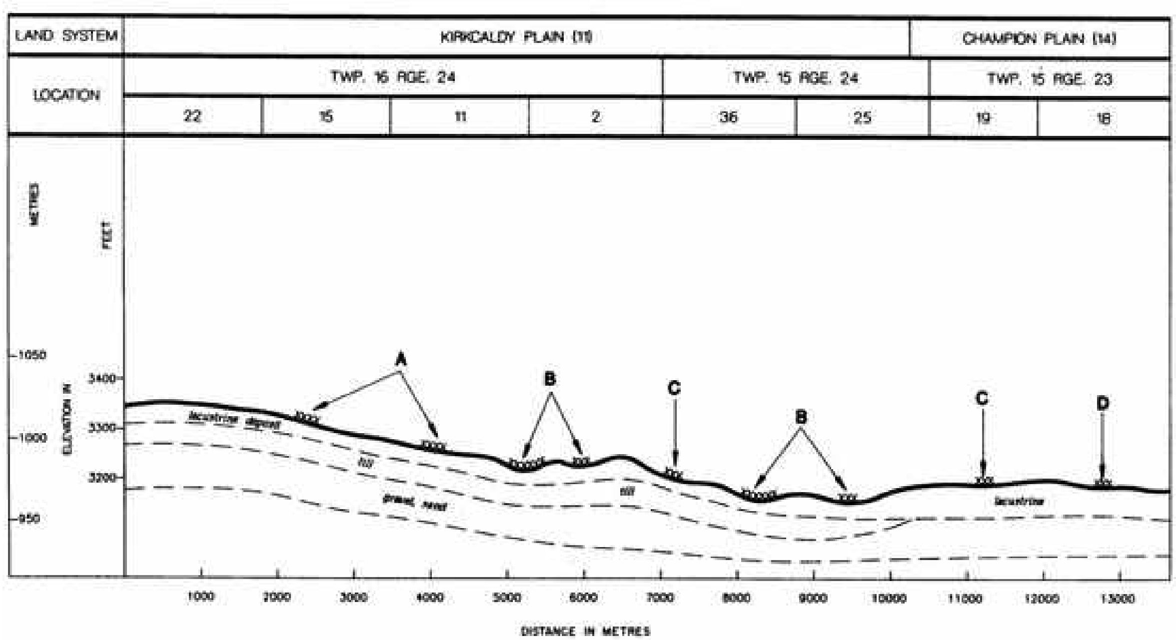
Type:	- depression bottom salinity
Location:	- west and east sides of irrigation canal
Control:	- salt-tolerant grasses in saline area and along edge of depression in band 50 to 150 m (165 to 490 ft) wide - appropriate structural controls

Site B:

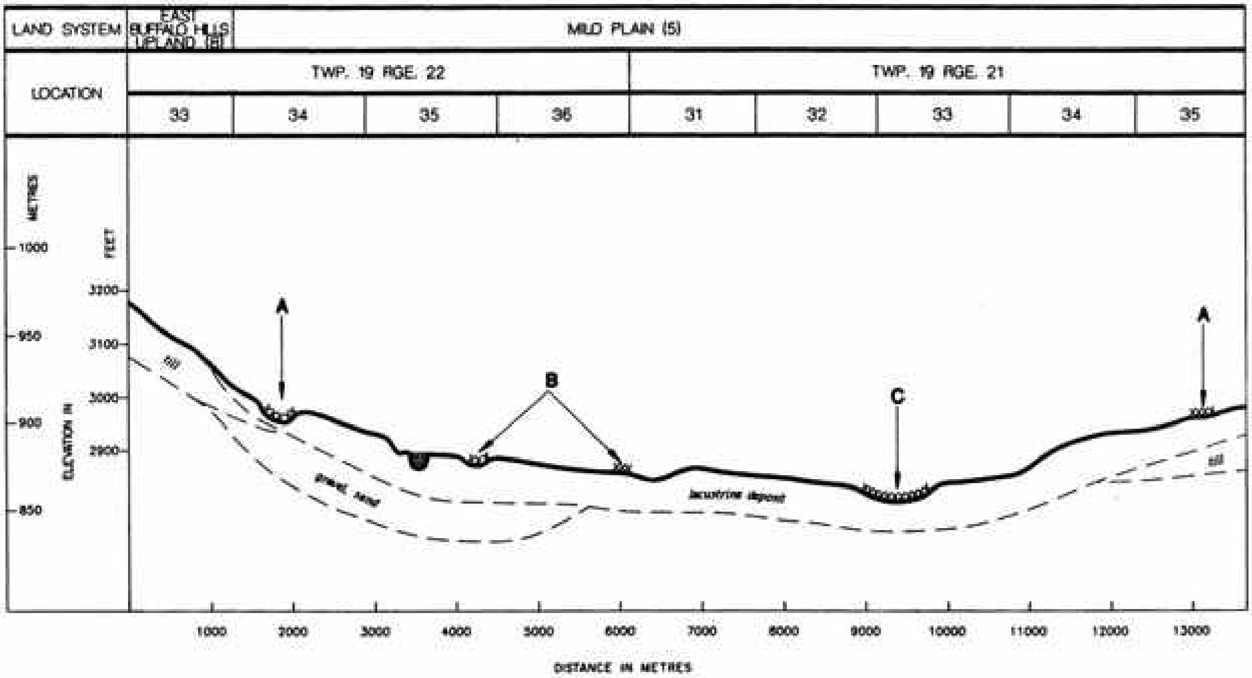
Type:	- coulee bottom salinity
Location:	- coulees 10 km (6 mi) north of Milo
Control:	- salt-tolerant grasses in saline area - appropriate structural controls

Site C:

Type:	- artesian salinity
Location:	- lower lying areas 10 km (6 mi) north of Milo
Control:	- salt-tolerant grasses in saline area - where applicable, install relief wells connected to a suitable outlet



LINE 9 - KIRKCALDY PLAIN AND CHAMPION PLAIN



LINE 10 - EAST BUFFALO HILLS UPLAND AND MILO PLAIN

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Appendix: Glossary of Terms

Aquiclude - A body of earth material with low permeability, which can absorb water but cannot transmit it at a rate sufficient for economic extraction by wells. (VanderPluym and Harron 1992)

Aquifer - A body of earth material capable of transmitting water through its pores at a rate sufficient for water supply purposes. (VanderPluym and Harron 1992)

Aquifuge - A body of earth material which is impervious and nonabsorptive. (VanderPluym and Harron 1992)

Artesian groundwater - Groundwater confined under an aquiclude or an aquifuge, so that water rises above the base of the aquiclude or aquifuge in a nonpumping well which penetrates it. (VanderPluym and Harron 1992)

Bedrock - The solid rock that underlies the soil and regolith or that is exposed at the surface. (Agriculture Canada 1976)

Capillarity - 1) The degree to which a material or an object containing minute openings or passages, when immersed in a liquid, will draw the surface of the liquid above the hydrostatic level. Unless otherwise defined, the liquid is generally assumed to be water. 2) The phenomenon by which water is held in interstices above the normal hydrostatic level, due to attraction of the molecules in the walls of an interstice for the molecules of the water and the attraction of the water molecules for one another. (VanderPluym and Harron 1992)

Electrical conductivity - An electrical conductivity (EC) measurement can be used to determine the salt content of soil in a saturated soil paste extract. The EC value is usually expressed in deciSiemens/metre (dS/m). For example, topsoil with an EC value of 2 dS/m is considered non-saline; topsoil with an EC value of 16 is very saline.

Flex cropping - Cropping according to spring soil moisture conditions. That is, seeding when the spring soil moisture is adequate.

Groundwater - 1) Water that is passing through or standing in the soil and the underlying strata. It is free to move by gravity. (Agriculture Canada 1976). 2) Water in the ground that is in the zone of saturation, from which wells, springs and groundwater runoff are supplied. (VanderPluym and Harron 1992)

Lacustrine deposit - Sediments deposited in lake water and later exposed either by lowering of the water level or by uplifting of the land. These sediments usually range in texture from sands to clays. (Agriculture Canada 1976)

Parent material - The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil has developed by pedogenic processes. (Agriculture Canada 1976)

Permeability, soil - 1) The ease with which gases and liquids penetrate or pass through a bulk mass of soil or a layer of soil. Because different soil horizons vary in permeability, the specific horizon should be designated. 2) The property of a porous medium that relates to the ease with which gases or liquids can pass through it. (Agriculture Canada 1976)

Saline soil - A non-sodic soil containing enough soluble salts to interfere with the growth of most crop plants. The conductivity of the saturation extract is greater than 4 dS/m (at 25°C), the exchangeable sodium percentage is less than 15, and the pH is usually less than 8.5. (Agriculture Canada 1976)

Salinity, soil - The amount of soluble salts in a soil, expressed in terms of percentage, parts per million, or other convenient ratios. (Agriculture Canada 1976)

Seepage - 1) The escape of water downward through the soil. (Agriculture Canada 1976). 2) The emergence of water from the soil along an extensive line, in contrast to a spring where water emerges from a local spot. (Agriculture Canada 1976). 3) The slow movement of water through small cracks, pores, interstices, etc. of a material into or out of a body of surface or subsurface water (VanderPluym and Harron 1992). 4) The loss of water by infiltration from a canal, reservoir or other body of water, or from a field. (VanderPluym and Harron 1992)

Till - Unstratified sediment deposited directly by a glacier and consisting of clay, sand, gravel and boulders intermingled in any proportion. (Agriculture Canada 1976)

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