Hydrodynamics of formation fluids related to depositional systems in the Bow Island-Viking succession (early Cretaceous) of western Saskatchewan.

Imasiku Anayawa Nyambe

*University of Windsor*

Follow this and additional works at: [https://scholar.uwindsor.ca/etd](https://scholar.uwindsor.ca/etd)

Recommended Citation


[https://scholar.uwindsor.ca/etd/2338](https://scholar.uwindsor.ca/etd/2338)
NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.
HYDRODYNAMICS OF FORMATION FLUIDS RELATED TO DEPOSITIONAL SYSTEMS IN THE BOW ISLAND-VIKING SUCCESSION (EARLY CRETACEOUS) OF WESTERN SASKATCHEWAN

by

Imasiku Anayawa Nyambe

A Thesis
Submitted to the Faculty of Graduate Studies and Research through the Department of Geology in Partial Fulfillment of the Requirements for the Degree of Master of Science at The University of Windsor

Windsor, Ontario, Canada
1989
C

Imasiku A. Nyambe

1989

All Rights Reserved
ABSTRACT

Detailed stratigraphic-sedimentologic analysis of subsurface data of Lower Colorado (Middle Albian-Cenomanian) strata indicate that the Viking Formation in west-central Saskatchewan contains sandstones deposited on a shallow marine shelf under dominantly regressive conditions. The formation is enveloped by largely argillaceous mudstones of the underlying Joli Fou Formation and the overlying Big River Formation, which were deposited under dominantly transgressive conditions. The Spinney Hill Sandstone is considered to be a distal fluvio marine deposit with a northeastern source. Deposition of the Viking Formation terminated sedimentation of the relatively deep-water Joli Fou Formation in the area.

The Viking Formation comprises a dominantly coarsening-upwards sandstone sequence, associated with mudstones, siltstones, shales and conglomerates occurring in reduced proportions. Ten lithofacies were identified on the basis of relative abundance of the main lithologies. Structurally, the area is characterized by domal and synclinal features with a gentle regional dip to the south. Structure in the area was influenced by proximity of the regional Sweetgrass Arch to the southwest and west, and drape folds which reflect palaeotopography at the sub-Mesozoic unconformity.
Lateral distribution of the Viking lithofacies shows an increasing mud content, decrease in grain size and thinning in a northeasterly direction. On the basis of the isopachous and lithofacies distribution, three facies belts were identified and designated subregions A, B and C. Subregion A contains relatively thick (21 - 53 m), well washed, coarsening-upward sandstones. Subregion B is composed of fairly clean sands, which are intermediate (16 - 21 m) in thickness. Subregion C contains thin (10 - 16 m) shaly sandstones and shales with an increased proportion of bedded shaly sandstones over bioturbated shaly sandstones. These variations, together with sedimentary structures, indicate deposition on a size-graded shelf in a shallow, marine setting. Subregion A and B facies represent nearshore shelf deposits while subregion C facies represent proximal shelf deposits. The dispersal of sands in the area was largely controlled by the Sweetgrass Arch. The resultant deposition on this shelf was by tidal and storm-generated currents. Deposition of the shelf sandstones was terminated by a progradation of shoreline westwards, which ended Viking sedimentation, initiating deposition of deeper-water mudstones of the Big River Formation.

The dominant groundwater flow pattern in the Viking Formation in the study area is to the northeast and north. The potentiometric surface of the Viking Formation indicates potentiometric cells and steeper potential gradients in subregion A (Bayhurst area only) and in subregion C. The remaining part of
the study area shows widely spaced contours. Four high fluid potential systems are identified in the area, from which fluids flow to the low potential areas. Fluid profiles indicate that the Viking Formation is presently an isolated hydrostratigraphic unit.

Integration of the stratigraphic-sedimentologic study with hydrodynamics revealed that high fluid potential areas correspond to relatively thick sand units and domal structures. Similarly, low fluid potentials areas correspond to relatively thin sand units and synclinal features. Potentiometric cells and steeper potential gradients correspond to lensing (thickness closures) of reservoir strata in the Viking Formation and are therefore indicative of the presence of permeability barriers between them.

Current hydrocarbon production coincides with the domal structures and the thick sand units (subregion A) and the lenticular sandstones (subregion C) of the Viking Formation. On the basis of hydrodynamics, it is associated with the potentiometric cells and steeper gradients. Prospective areas in the study area are highlighted on the basis of structure, lithology and hydrodynamics.
ACKNOWLEDGMENTS

I would like to thank the Canadian Commonwealth Scholarship and Fellowship Plan Committee for funding my graduate studies at the University of Windsor, Windsor, Ontario, Canada. Without them I do not think I would have set foot on Canadian soil.

My great indebtedness is due to Professor F. Simpson, first for allowing me to study under him, his conception of the project and for all his guidance over the past two years. His numerous suggestions for improvement in the preparation for the final text and accompanying illustrations for the thesis were very valuable. Indeed, his contributions to my education have been, and continue to be invaluable. Thanks also to Mr. Dale Rusling for reading through the manuscript and for his keen interest in my work.

Special thanks are due to my family: my wife, Elizabeth, and my two daughters: Anayawa and Pauline Sikopo. My wife's typing of the thesis from my horrible handwriting has made this thesis a reality. The contributions made by Anayawa and Pauline by scribbling on my finished drafting, made the redrafting unforgettable. Their lack of cooperation sometimes resulted in fruitful sleepless nights. To you all, I say good luck and best wishes.
TABLE OF CONTENTS

ABSTRACT....................................................................................... iv
ACKNOWLEDGEMENT................................................................. vii
LIST OF CONTENTS................................................................. viii
LIST OF FIGURES................................................................. xi
LIST OF TABLES............................................................... xiv

CHAPTER

I. INTRODUCTION.............................................................................. 1
1.1 Study Area........................................................................... 1
1.2 The Problem....................................................................... 1
1.3 Previous Work.................................................................. 3
  1.3.1 General Remarks......................................................... 3
  1.3.2 Previous Work on Bow Island-Viking Succession........... 4
  1.3.3 Previous Work on Hydrodynamics............................... 8
1.4 Scope of Study.............................................................. 10

II. REGIONAL GEOLOGY................................................................. 12
2.1 General Remarks............................................................ 12
2.2 Stratigraphy.................................................................... 13
  2.2.1 Joll Fou Formation....................................................... 17
  2.2.2 Bow Island-Viking Succession.................................... 18
  2.2.3 Big River Formation................................................... 20
2.3 Structure......................................................................... 21
  2.3.1 Basement Linear Features (Regional)......................... 24
  2.3.2 Basement Linear Features (Small-scale)..................... 24
  2.3.3 Solution-generated Collapse Features...................... 26
  2.3.4 Sub-Mesozoic Unconformity..................................... 27
2.4 Patterns of Fluid Migration............................................. 28
  2.4.1 Factors Controlling Fluid Flow................................. 30
    2.4.1.1 Topographic Effects......................................... 32
    2.4.1.2 Geologic Effects.............................................. 33
    (1) Effect of Permeability Variations............................ 34
    (2) Effect of Geological Structures.............................. 34
  2.5 Hydrocarbon Accumulation......................................... 37

III. STUDY METHODS................................................................. 39
3.1 General Remarks.......................................................... 39
3.2 Stratigraphic-sedimentologic Studies............................ 40
3.3 Hydrogeological Studies.............................................. 43
3.4 Computer Software Methods

IV DEPOSITIONAL SYSTEMS

4.1 General Remarks

4.2 Bow Island Formation

4.3 Viking Formation

4.3.0 Introduction

4.3.1 Lithofacies Description

4.3.1.1 Vertical Relationships

4.3.2 Areal Distribution

4.3.2.1 Cross-sections

4.3.2.2 Isopach Map

4.3.3 Discussion and Summary

4.3.4 Detailed Structure

4.3.4.1 Comparisons to other structure maps

4.3.4.2 Basement Related Structures

4.3.4.3 Discussion and Summary

4.4 Joli Fou Formation

4.4.0 Introduction

4.4.1 Lithofacies Description

Joli Fou Mudstone

Spinney Hill Sandstone

4.4.2 Areal Distribution

4.4.2.1 Cross-sections

Joli Fou Formation

Joli Fou Mudstone

Spinney Hill Sandstone

4.4.2.2 Isopach Maps

Joli Fou Formation

Joli Fou Mudstone

Spinney Hill Sandstone

4.5 Big River Formation

4.5.0 Introduction

4.5.1 Lithofacies Description

4.5.2 Areal Distribution

4.5.2.1 Cross-sections

4.5.2.2 Isopach Map

4.6 Interpretation

4.6.0 Viking Formation

4.6.1 Big River and Joli Fou Formations

4.6.2 Spinney Hill Sandstone

4.6.3 Summary

V. HYDRODYNAMICS OF FORMATION FLUIDS

5.1 General Remarks

5.2 Physiographic Setting

5.3 Potentiometric Surface

5.4 Patterns of Fluid Migration
5.5 Relationship to Lithology.............................. 186
5.6 Relationship to Hydrocarbon Accumulations........ 196
5.7 Discussion and Summary................................... 207

VI. ECONOMIC CONSIDERATIONS............................... 210

6.1 General Remarks........................................ 210
6.2 Integrated Exploration Strategy...................... 210
6.3 Prospective Areas...................................... 213

VII. CONCLUDING REMARKS..................................... 216

REFERENCES................................................................ 219

APPENDIX 1 - ELEVATIONS OF MAIN CORRELATION SURFACES OF
LOWER COLORADO SUCCESSION IN WESTERN
SASKATCHEWAN................................................................. 231

APPENDIX 2 - POTENTIOMETRIC DATA FOR BOW ISLAND - VIKING
SUCCESSION IN WESTERN SASKATCHEWAN..................... 253

VITAE AUCTORIS.............................................................. 264
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Location of the study area</td>
<td>2</td>
</tr>
<tr>
<td>2.0 Isopach map of the Colorado Group in Saskatchewan and Manitoba region</td>
<td>16</td>
</tr>
<tr>
<td>2.1 Basement features and edge of salt in the Prairie Evaporite (Middle Devonian) in relation to commercial hydrocarbon accumulations in Cretaceous strata of Southern Saskatchewan</td>
<td>23</td>
</tr>
<tr>
<td>3.0 Locational base map</td>
<td>pocket</td>
</tr>
<tr>
<td>4.0 Typical reference well logs</td>
<td>54</td>
</tr>
<tr>
<td>4.1 Stratigraphic cross-section of the Bow-Island-Viking succession, southeastern Alberta and western Saskatchewan. B - Location map showing line of cross-section</td>
<td>59</td>
</tr>
<tr>
<td>4.2 Subregions of the study area for description purposes</td>
<td>62</td>
</tr>
<tr>
<td>4.3 Location of stratigraphic cross-sections</td>
<td>88</td>
</tr>
<tr>
<td>4.4 Stratigraphic cross-section A - A'</td>
<td>89</td>
</tr>
<tr>
<td>4.5 Stratigraphic cross-section B - B'</td>
<td>91</td>
</tr>
<tr>
<td>4.6 Stratigraphic cross-section C - C'</td>
<td>92</td>
</tr>
<tr>
<td>4.7 Stratigraphic cross-section D - D'</td>
<td>94</td>
</tr>
<tr>
<td>4.8 Isopach map of the Viking Formation</td>
<td>97</td>
</tr>
<tr>
<td>4.9 Three-dimensional plot of the isopach surface of the Viking Formation</td>
<td>100</td>
</tr>
<tr>
<td>4.10 Viking Formation generalized facies belts</td>
<td>103</td>
</tr>
<tr>
<td>4.11 Structure contour map of the top of the Viking Formation</td>
<td>108</td>
</tr>
<tr>
<td>4.12 Three-dimensional plot of the structure surface of the Viking Formation</td>
<td>109</td>
</tr>
<tr>
<td>4.13 Structure contour map of the base of the Viking Formation</td>
<td>110</td>
</tr>
</tbody>
</table>
4.14 Structure contour map of the top of the Lower Colorado Subgroup ........................................... 111

4.15 Structure contour map of the base of the Lower Colorado Subgroup ........................................... 112

4.16 Location of the structural cross-sections .............. 122

4.17 Structural cross-section A - A' ............................... 123

4.18 Structural cross-section B - B' ............................... 124

4.19 Three-dimensional plot of the structure surface of the: 1) top of the Viking Formation; 2) base of the Viking Formation; 3) top of the Lower Colorado Subgroup; 4) base of the Lower Colorado Subgroup ..... 126

4.20 Dominant structural features in relation to basement features, solution-generated structures, and lithology .................................................. 129

4.21 Isopach map of the Joli Fou Formation .................. 143

4.22 Isopach map of the Joli Fou Mudstone .................... 145

4.23 Isopach map of the Spinney Hill Sandstone .............. 147

4.24 Isopach map of the Big River Formation ................ 158

4.25 Three-dimensional plot of the isopach surface of the Big River Formation ............................... 159

5.0 Physiographic setting of the study area .................. 172

5.1 Local potentiometric surface of the Viking Formation .. 174

5.2 Shut-in pressure - depth diagram of the Viking Formation ....................................................... 180

5.3 Regional potentiometric surface of the Viking Formation ....................................................... 181

5.4 Three-dimensional plot of the potentiometric surface of the Viking Formation .......................... 183

5.5 Fluid-pressure profiles for:
   1) Saskoil Leader No. three well (LSD 05-10-22-26W3);
   2) Cabri No. 1 well (LSD 01-23-24-28W3) .................. 193
5.6 Fluid-pressure profiles for:
1) Shell Rio Tinto Sceptre No. 2 (LSD 05-32-21-24W3);
2) Phillips Husky Bailey No. 1 (LSD 07-02-27-26W3);
3) Saskoil Totnes N 6 21 28 18 (LSD 06-21-28-18W3);
4) Texan Alsask 10 1 28 29 (LSD 10-01-28-29W3)........ 194

5.7 Fluid pressure profiles for:
1) Cdr's Sceptre 2 3 21 24 (LSD 02-03-21-24W3); 2) Spe
Mendham (LSD 07-25-21-27W3); 3) Charter Canadian
Devonian Empress 5 (LSD 05-21-22-29W3).............. 195

5.8 Fluid-pressure profiles for:
1) Arco Cramersbourg 13 19 22 20 (LSD 13-19-22-20W3);
2) Dome Provo Lancer No. 10 9 (LSD 10-09-22-21W3)..... 197

5.9 Regional potentiometric cells (from Figure 5.3) in
relation to lithology, prominent structure and basement
features, and commercial hydrocarbon accumulations in
the Viking Formation........................................ 203

5.10 Structure contour map of the top of the Viking
Sand in the Bayhurst gas pool area in relation
to the potentiometric surface of the Viking
Formation...................................................... 206

5.11 Structure contour map of the top of the Viking
Sand in the Plato oil pool area in relation
to the potentiometric surface of the Viking
Formation...................................................... 208
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Stratigraphic correlation chart for the Colorado and Montana Groups of Saskatchewan and adjacent areas</td>
<td>14</td>
</tr>
<tr>
<td>2.</td>
<td>Sequence elements, based on gross lithologic associations and layer properties, in cores of Colorado Group in Saskatchewan</td>
<td>105</td>
</tr>
<tr>
<td>3.</td>
<td>Summary of the results of the lithofacies description in the study area</td>
<td>106</td>
</tr>
<tr>
<td>4.</td>
<td>Sequence elements, depositional environments and generalised fluid-flow characteristics in the Viking Formation of west-central Saskatchewan</td>
<td>165</td>
</tr>
<tr>
<td>5.</td>
<td>Production of hydrocarbon from the Viking Formation (Early Cretaceous) in the study area</td>
<td>198</td>
</tr>
<tr>
<td>6.</td>
<td>Hierarchy of reservoir heterogeneities in sandstone bodies of the Colorado and Montana Groups (Cretaceous) in Saskatchewan</td>
<td>200</td>
</tr>
</tbody>
</table>
CHAPTER I

1.0 INTRODUCTION

1.1 Study Area

The area under consideration is located in western Saskatchewan, approximately between latitudes 50° 45' N and 51° 26' N (Figure 1.0). It is bounded by the Alberta border to the west and includes Range 15 west of the 3rd Meridian to the east. The area comprises Ranges 15 to 29W3, inclusive and Townships 21 to 28, inclusive.

1.2 The Problem

The mainly argillaceous strata of the Lower Colorado Subgroup (middle Albian-Cenomanian), were deposited in an epicontinental sea that occupied an asymmetrically subsiding basin, east of the Cordilleran mountains in western Canada. The Lower Colorado Subgroup represents two main transgressions and an intervening regression. The regression gave rise to relatively coarse siliciclastic rocks of the Bow Island-Viking succession that were laid down on the western shelf of the Colorado basin (Simpson, 1975).

The Bow-Island-Viking succession principally comprises three composite sand bodies (Bow Island Sands) which are correlative with the Viking Formation of western Saskatchewan.
Figure 1.0 Location of the study area.
The succession is a source of hydrocarbon production in Alberta and western Saskatchewan. However, despite extensive study and exploration drilling, it is possible that current production does not reflect the full potential of the sequence because of the wide variation in permeability encountered. An integrated study of the depositional systems that constitute the succession and the movement of formation fluids (hydrodynamics) within these systems could be of vital importance for optimum development of known hydrocarbon accumulations. Moreover, knowledge of this could provide an efficient method for delineating trends for strata with good reservoir potential.

1.3 Previous Work

1.3.1 General Remarks

The name Bow Island was originally applied to sandstones in the lower part of the Colorado Group in the Bow Island gas field of southern Alberta (Glaister, 1959). The term Viking was first used by Slipper (1917) for an oil-producing sandstone (Viking-Kinsella field, located near the town of Viking) in east-central Alberta. The Viking was originally classified as a member of the Colorado Group (Hunt, 1954), and was later upgraded to formation status (Stelck, 1958). The term Bow Island-Viking succession represents a regressive-transgressive wedge in the Colorado succession. Up to five main sand bodies (Bow Island Sands) in southeastern Alberta, and only one main sand body (Viking Formation) in southwestern Saskatchewan, are present in
the wedge (Simpson, 1979a). Sands of the Viking Formation and its equivalents have been known as hydrocarbon reservoirs since gas was first discovered in the Bow Island Formation at Bow Island, Alberta in 1909. Oil, on the other hand, was not discovered in the Viking Formation until 1949 in the Joseph Lake Field, 30 km to the southeast of Edmonton (Gammel, 1955). In study area, gas was discovered in 1951 and oil in 1968 in the Brock and Plato areas, respectively.

Since the time of the first discovery of oil, Viking Formation has been widely studied in attempts to explain the distribution of the sands and depositional environments. During this period of time, fluid flow studies also gained momentum starting with the development of the theoretical models followed by their application to hydrocarbon recovery.

The study area is immediately north of the transition from the Bow Island Formation of the southern plains to Viking Formation of the central plains and only the Viking Formation is represented here.

1.3.2 Previous Work on Bow Island-Viking Succession

Previous work on the Bow Island-Viking succession in western Canada was mainly concerned with the mode of deposition of the Viking sediments. Beach (1956) and Roessingh (1959) favoured turbidity-current deposition, while DeWiel (1956) and Jones
(1961a, b) favoured marine sedimentation in a broad, shallow epicontinental sea. The latter is now the widely accepted mode of deposition by most authors.


In Saskatchewan, studies of the Viking Formation were confined to the producing areas of the province notably in the west-central part of the province. Such studies include those of Reasoner and Hunt (1954a, b) in the Coleville-Buffalo area and Smiley oil field. They concluded that the structure of the Viking Sandstone was a result of draping and compaction of a largely argillaceous sequence over the sub-Cretaceous erosional surface. Evans (1970), in his study of the Dodsland-Hoosier area, suggested that the imbricated east-west elongated sandstone bodies are tidal-current deposits. In the Plato Viking Pool, Gillard and White (1970) divided the Viking sand reservoir in two distinct sand layers, the "A" and "B" sands in order of increasing age separated by an intervening shale. The two sand layers are overlain by an upper shale layer which forms the upper part of the Viking Formation.

Studies of the Viking Formation on a regional scale in west-central Saskatchewan were carried out by Jones (1961a, b), who described it as generally forming lenticular sandstones,
siltstones and shales. He regarded the formation as neritic or littoral in origin with possible beach deposition and expressed a similar view on its structure as that of Reasoner and Hunt (1954a,b). Simpson (1971) facilitated the systematic description of the gradational relationships between the dominantly fine-grained lithologies constituting the reservoir strata with introduction of a scheme of sequence elements to augment conventional rock classification.

The present study in western Saskatchewan is within the area covered by Jones (1961a) and includes the localised study of the Plato Viking Pool in the east by Gillard and White (1970). Lithologic descriptions of the unit in the area are presented by Simpson (1979d).

In south-eastern Saskatchewan, Price (1963) described the formation as forming a broad, diagonal band across the area with tongues or lobes extending towards the northeast. He stated that it represents a temporary regression in an overall, deep-water, transgressive sequence, consisting of underlying and overlying non-calcareous, marine shales. Staubo (1970) described the Viking Formation as forming narrow, elongate sandbodies deposited by tidal currents in a shallow, marine sea. The source of these sediments was the Canadian Shield to the east.

Recent studies in Saskatchewan which concentrated on stratigraphic-sedimentologic considerations and reservoir potential and were directed specifically at the Colorado Group were carried out by Simpson (1975; 1979a, b, c, d; 1980a, b, c;
1982a, b), Simpson and O'Connell (1979) and O'Connell (1981). Simpson (1975) regarded the Viking Formation as a dominantly regressive sequence, represented in the west by nearshore sands and tidal sand ridges on a thin, reworked, relict sediment layer, all passing basinward into mudstones and forming a graded shelf. Deposition on this western shelf was controlled by the Sweetgrass Arch which acted as a baffle to the dispersal of sands. Thick clastics of the Bow Island-Viking succession were laid down in the western Alberta basin as a result of erosion from the rapidly rising Cordilleras. These thin towards and across the arch on to the western shelf of the Williston Basin so that the remaining sand body is the Viking Formation which is present in the study area.

On the eastern shelf, the Viking Formation has an eastern provenance and is derived from erosion of the Precambrian Shield. Simpson and O'Connell (1979) found the Viking Formation of southeastern Saskatchewan to be stratigraphically higher than the Viking Formation of southwestern Saskatchewan. However, both eastern and western Viking sandstones are absent in the central portion of the basin, where an undifferentiated mudstone-siltstone sequence is present.

The hydrocarbon potential of these sand units was considered in most of the studies mentioned above. Notable contributions are those of Christopher et al. (1971) and Simpson (1982a, b). A
summary of main lithologic and structural controls of hydrocarbon occurrence in the Colorado Group of southern Saskatchewan is given by Simpson (1984a, b).

To the west of the area studied in the present account, Tizzard and Lerbekko (1975) investigated the Viking Formation in the Suffield area. They concluded that the formation consists essentially of two sand units called the Lower and Upper Viking sands, both representing barrier-bar complex deposits.

1.3.3 Previous Work on Hydrodynamics

Water flow is not only important in geological processes, but is also an important energy source in enhanced oil recovery. As a result, fluid flow studies gained significance particularly after the classic paper of Hubbert (1940). Hubbert's (1940) work on the theory of groundwater motion was the first published account of the basin-wide flow of the fluids that considered the problem in exact mathematical terms as a steady state phenomenon. This was followed by mathematical models of groundwater movements developed by Tóth (1962, 1963) based on the standard equation for fluid potential of Hubbert (1940).

Freeze and Witherspoon (1966, 1967, 1968) pointed out a number of restrictions to the Tóth models, and developed both analytical and numerical methods of analysis for a wide variety of different models. Fluid flow in the western Canadian basin as a whole was considered by Hitchon (1969a, b) using the Toth-Freeze-Witherspoon approach. Everdingen (1968) considered
the various energy potential fields coupled in a system. He noted that the energy gradient to which the fluids react comprises an aggregate of potential differences resulting from elevation and pressure, thermal, electric and chemical forces.

Studies on the application of hydrodynamics to the location of hydrocarbon accumulation and exploration are numerous. They include those of Hubbert (1953); Hill et al. (1961); Coustau (1977); Dickey and Cox (1977); and Prier (1979). Hubbert (1953) presented the concept of the effects of hydrodynamics on the entrapment of petroleum in his classic treatment of hydrodynamic conditions. The effect of hydrodynamic gradient on the trapping capability of stratigraphic barriers has been discussed by Hill et al. (1961). They demonstrated the use of hydrodynamics in reducing exploration costs and used a potentiometric map of the Viking Sandstone in central Alberta as an example. Prier (1979) gave a good review of the theory and applications of hydrodynamics to petroleum exploration.

A recent analysis of hydrodynamic factors in petroleum migration and entrapment was given by Davis (1987). He expanded Hubbert's equations and combined them with those of Plateau (1863-1866, in Davis, 1987) in order to allow the study of oil migration and entrapment patterns.

In western Saskatchewan, the regional flow pattern in the Viking Formation (Hill et al., 1961) and the underlying Mannville Group (Christopher, 1974; 1980) is to the northeast and north.
1.4 Scope of Study

Owing to lack of exposure in the study area, the study employed subsurface data accumulated over years of extensive exploration and development drilling. The subsurface data are geological and hydrogeological. Both data sets were derived from the Petrofiche System of International Petrodata Limited for 1987. These data formed the basis for integration of two different types of geological investigation:

(i) stratigraphic-sedimentologic study of the Viking Formation, in which variations in rock associations are described and explained with reference to the conditions of deposition; and

(ii) study of the hydrodynamics of formation waters in the Viking Formation.

The stratigraphic-sedimentologic study employs computer-generated structure-contour and isopachous maps, as well as stratigraphic and structural cross-sections based on geophysical well logs. An understanding of rock associations is based on lithologic descriptions of cored sections by Simpson (1979d).

The hydrogeologic part uses computer-generated maps of the potentiometric surface to delineate trends of water movement.

The results of the stratigraphic-sedimentologic study were compared with those from the hydrogeological work in order to determine local relationships between lithology and groundwater flow patterns (i.e. permeability variations controlled by
depositional settings, diagenesis, structural disturbance and solution-generated collapse structures). These relationships were then considered in light of current hydrocarbon production in the area, in order to delineate prospects.
CHAPTER II

2.0 REGIONAL GEOLOGY

2.1 General Remarks

The Phanerozoic strata of southern Saskatchewan form a northward-thinning sedimentary wedge up to about 1,500 m in thickness on the broad tectonic shelf, which occupies most of the area. The sedimentary sequence is up to 3,200 m thick in the northern extremity of the Williston Basin in the extreme southeastern part of the province. The succession comprises three major main divisions of sedimentary rocks, delimited by major unconformities and exhibiting important differences in gross lithology: a basal division (Lower Palaeozoic), a middle division (Ordovician through Mississippian), and an upper division (Triassic-Jurassic through Holocene) (Christopher et al., 1971; Kent and Simpson, 1973).

The upper division is composed of siliciclastic sediments and includes the Cretaceous beds which are the subject of this study. The Cretaceous strata were subdivided into Lower and Upper Cretaceous at the base of the Fish Scale Zone or Fish Scale Sandstone, which is a lithologic marker bed. They comprise three main groups: the older Mannville Group (Aptian-Albian), the middle Colorado Group (middle Albian to Santonian) and the younger Montana Group (Santonian-Maestrichtian).
The Colorado Group consists of predominantly marine, clastic sediments, in the lower part interdigitating with subordinate fluviomarine and also probably terrestrial deposits (Christopher et al., 1971). It is subdivided into lower and upper subgroups. The Lower Colorado Subgroup (middle Albian-Cenomanian) includes the Bow Island-Viking succession of western Saskatchewan.

Structurally, the Cretaceous succession in Saskatchewan forms a broad, gently dipping shelf termed a homocline. Deposition of the succession was controlled by the structural elements that were in existence in the area.

Hydrodynamics studies have indicated fluid flow in the western Canada sedimentary basin to be controlled by topography and geology (Hitchon, 1969a, b) with a general flow pattern from southwest to northeast for all hydrostratigraphic units.

2.2 Stratigraphy

The Cretaceous stratigraphy in southern Saskatchewan and adjacent areas in the northern Great Plains region is summarised in Table 1.

Cretaceous beds rest with slight angular unconformity on eroded Jurassic, Mississippian and Devonian strata, overlapping progressively older beds in a northeasterly direction. The sub-Cretaceous unconformity represents a major hiatus in the depositional history (Rudkin, 1964) over large parts of western Canada.
Table 1. Stratigraphic Correlation Chart for the Colorado and Montana Groups of Saskatchewan and Adjacent Areas (after Simpson, 1984).
The basal Cretaceous fluviatile sandstones and Early Cretaceous marine deposits are exposed only at scattered localities along the shield edge. Interdigitating continental fluviomarine and marine deposits of Late Cretaceous age and succeeding Tertiary continental sediments may be examined at numerous outcrops in river valleys and scarp faces of upland areas (Missouri Coteau, Wood Mountain, Cypress Hills) farther south (Kent and Simpson, 1973).

Lower Cretaceous sedimentary rocks form an essentially conformable series representative of the entire Early Cretaceous Epoch. With the possible exception of early Neocomian strata, all stages are represented (Rudkin, 1964). At the base of the Cretaceous sequence is the continental-littoral sandstones of the Mannville-Blairmore succession which is overlain disconformably by the Colorado Group, a dominantly argillaceous, though laterally variable marine succession (Simpson, 1975).

In Saskatchewan, the Colorado Group consists of predominantly marine, siliciclastic sediments overlain by the marine sandstones and siltstones of the Milk River Formation and equivalent shales of the Lea Park Formation (Santonian-Campanian) of the Montana Group. It ranges in thickness from more than 460 m in the southwest to less than 90 m in the central part of the province (Figure 2.0). Division of the Colorado strata into upper and lower subgroups is made at the base of the lower of two widespread coccolithic marker units, the Second (Lower)
Figure 2.0 Isopach map of the Colorado Group in Saskatchewan and Manitoba region (after Simpson, 1975).
White-Speckled Shale (Turonian) of western and south-central Saskatchewan and the coeval Favel Formation of eastern Saskatchewan and Manitoba (Simpson, 1979a, c; 1982b).

The Lower Colorado lithologies in the Colorado sea of Saskatchewan can be considered separately as western and eastern shelf facies of southwestern and southeastern Saskatchewan respectively, with south-central Saskatchewan coinciding with the middle of the basin proper (Simpson, 1979a).

In southwestern Saskatchewan, the vertical sequence of the Lower Colorado is that of the Joli Fou Formation at the bottom, overlain by the Bow Island-Viking succession, which in turn gives way to the Big River Formation. The succession is a regressive-transgressive wedge of relatively coarse-grained debris, equivalent to only the Second and Third Bow Island Sands. The shales and mudstones of the Big River Formation pass southward and westward into alternating layers of sandstone and shale known as the Spikes Sandstone. This sandstone unit is represented to the west by the uppermost sandstones of the Bow Island succession (Simpson, 1979a, c; 1982b).

In southeastern Saskatchewan, the Subgroup is divided from bottom upwards into the Joli Fou, Viking-Newcastle and Big River Formations.

2.2.1 Joli Fou Formation

The Joli Fou Formation, middle Albian in age, forms the base of the Lower Cretaceous Colorado Subgroup. It is about 33.5 m
thick in the Athabasca River type area, attaining a thickness of about 61 m in south-central Saskatchewan. It is underlain disconformably by the Pense Formation and equivalent sandstones of Blairmore-Mannville-Swan River sequence in southern Alberta and southern Saskatchewan. The formation is overlain by Bow Island-Viking succession. However, in the Rocky Mountain foothills of Alberta, it pinches out and is replaced by the Bow Island Formation. In parts of southern Saskatchewan, where the Viking Formation is absent, it forms a sequence of undifferentiated Lower Colorado Shale together with the Big River Formation. The Joli Fou Formation incorporates the Spinney Hill Sandstone and Cessford Sand of central Saskatchewan and southeastern Alberta respectively. In central Saskatchewan, the top of the formation is sharply defined by the base of the Flotten Lake Sand (Simpson, 1982b).

2.2.2 Bow Island-Viking Succession

The Bow Island-Viking succession forms a regressive, marine wedge of coarse-grained siliciclastic rocks in the Lower Colorado Subgroup stratigraphy. In southeastern Alberta and southwestern Saskatchewan, the wedge is represented by the Bow Island Formation which is Middle to Upper Albian in age. The unit is represented in southeastern Alberta by three main sand bodies termed First, Second, and Third Bow Island Sands in order of increasing age, which together with intervening mudstones and shales attain an aggregate thickness of 180 m (Simpson, 1979a).
A good example is in the Bow Island area, where it attains some 175 m in thickness (top of Mannville Group to the base of Fish-Scale Sandstone) with an aggregate sandstone thickness of 24.4 m. The sandstone bodies pass northwards and eastwards into shales and mudstones, referable to the upper Albian part of the Big River Formation and to the Joli Fou Formation respectively.

Thus, in the distal part of the northeastward-thinning wedge, the thicker Bow Island Formation is replaced by the Viking Formation of central and eastern Alberta and adjacent west-central Saskatchewan, which in turn separates the Joli Fou and the Big River Formations. In southwestern Saskatchewan, the Bow Island Sands appear to belong to the Second and Third Bow Island Sands, and pass into one sand body in western Saskatchewan. The Bow Island Formation is equivalent to the Blackleaf Formation of northwestern Montana (Simpson, 1979a, b; 1980b).

The Viking Formation, distal extension of the Bow Island Formation, is Upper Albian in age. It is a widespread and highly variable sedimentary succession, made up of drab conglomerates, sandstones, and siltstones, with intercalated mudstones, ranging in thickness from about 43 m in the southwest Saskatchewan to zero just south of the North Saskatchewan River. On geophysical well logs the lower contact of the formation is generally taken at the base of a sandstone or conglomerate, though a basal silty mudstone is locally observed (Jones, 1961a). The upper is taken at the top of a thin siltstone, located some distance above the main, sandy or silty part of the unit (Simpson, 1982b). The
gradational nature of the Viking strata makes it often difficult to subdivide the Viking succession into discrete lithological units, and therefore the lithological boundaries are often somewhat arbitrary (Jones 1961a).

The Viking Formation is correlative to the Flotten Lake Sand and Ashville Sand in southern/west-central Saskatchewan and southern Manitoba respectively. The Viking Formation in eastern Saskatchewan, though at a stratigraphically higher level within the Lower Colorado succession than the western Viking sequence, is equivalent to the Newcastle Formation of northeast Montana and north Dakota (Simpson and O'Connell, 1979).

2.2.3 Big River Formation

This formation, Upper Albian-Cenomanian in age, overlies the Bow Island-Viking Formation in southern Alberta and southern Saskatchewan. It forms the upper part of the Lower Colorado Subgroup. In some parts in the south-central and eastern Saskatchewan, where the Viking Formation is absent, it succeeds the Joli Fou Formation. It incorporates the interbedded fish-skeletal sandstones of the Fish-Scale Sandstone (Marker). The formation also includes the interbedded kaolinitic and shaly sandstones and non-calcareous mudstones of the northeastward-thickening St. Walburg Sandstone, and in east-central Saskatchewan, the kaolinitic sandstones and non-calcareous mudstones of the westward-thickening Okla Sandstone. The top of the formation is defined by calcareous
shales and shaly chalks of the Second White-Speckled Shale. This contact, so sharply defined both lithologically and on geophysical well logs, is commonly used as a subsurface datum. The contact is used as a stratigraphic datum in this study. A maximum thickness of 150 m is attained in southwestern Saskatchewan, thinning to about 43 m in east central Saskatchewan. The formation is equivalent to the Mowry and Belle Fourche Shales in Montana and North Dakota. In southern Manitoba, the sequence is represented by non-calcareous, variably bituminous shales, referable to the upper part of the Ashville Formation (Simpson, 1979a, 1982b).

The base of the Second White-Speckled Shale defines the bottom of the Upper Colorado Subgroup, which is Turonian to Santonian in age. The equivalent of this in Montana and North Dakota is the Greenhorn Formation, while in western Manitoba is the Favel Formation.

The Upper Colorado sequence is succeeded in the area by the Montana Group, which marks the eventual regression and disappearance of the Cretaceous sea.

2.3 Structure

The Cretaceous succession of western Canada was laid down along the margins of three different oceans: the Pacific, the Arctic, and the newly opened Atlantic (Stelick, 1975). The
mechanism of emplacement could be explained in the context of global tectonics as described by Sloss and Speed (1974). They emphasized the control of subsidence-sedimentation relationships within the cratonic interior by vertical motions of three main types (cratonic modes) arising in response to global tectonics. The vertical motions produced displacements of the entire craton as well as movements within cratonic interiors. One such mode, coincident with Colorado deposition and thus relevant to this study, was submergent in nature. It was characterised by differential subsidence of basins which were geographically separated by arches and domes indicating relative slower rates of subsidence. Also associated with it was a localised orogeny (Nevadan) close to the edge of the craton. This orogeny was a product of converging plate boundaries at the active continental margin. In addition, through the convergence-induced orogenesis, the submergent mode maintained the craton margin mountain chain above base level, resulting in high rate of sediment supply from the chain (Sloss and Speed, 1974). Thus, this led to the development of a marine regression, such as that responsible for the Bow Island-Viking clastic wedge (Simpson, 1979a).

It is therefore apparent that the distribution of lithofacies during sedimentation of the Phanerozoic succession has been influenced by existing structural features. In Saskatchewan and adjacent areas the main structural features (Figure 2.1) are:

(i) basement linear features (regional),
Figure 2.1 Basement features and edge of salt in the Prairie Evaporite (Middle Devonian) in relation to commercial hydrocarbon accumulations in Cretaceous strata of Southern Saskatchewan.
1) edge of Prairie Evaporite salt; 2) northern limit of Colorado (Cretaceous) strata; 3) structure contours on Precambrian surface (CI = 200 m); 4) gravity gradient showing positive and negative margins; 5) conductive geomagnetic anomaly; 6) oil and gas fields (after Simpson, 1984b).
(ii) basement linear features (small-scale),
(iii) solution-generated collapse features,
(iv) the sub-Mesozoic unconformity.

2.3.1 Basement Linear Features (Regional)

The basement, underlying the sedimentary sequence in this region, is believed to be a continuation of a highly metamorphosed greenstone belt set in a granitic-gneissose terrain, of the Churchill and Superior Precambrian provinces which are exposed to the north and to the east of Saskatchewan respectively. Basement regional features include a large, gently tilting tectonic shelf (a homocline) with a north to northwest strike and southerly dip averaging between 2.0 m/km and 3.7 m/km, increasing to 9.4 m/km in the northern part of the Williston Basin in southeast Saskatchewan and southwest Manitoba (Christopher et al., 1971).

Regional linear features include the east-northeast trending, northeast plunging Sweetgrass Arch and the east-northeast trending, south plunging North Battleford. The proximity of the Sweetgrass Arch to the study area as strongly influenced sedimentation in the area. The arch acted as a baffle to the dispersal of sands from the west across the western Colorado shelf (Simpson, 1979a).

2.3.2 Basement Linear Features (Small-Scale)

These are linear features of local extent, like the basement
regional features, are also defined by northeast- and northwest-trending gravity anomalies (Simpson, 1984a, b). Prominent features include the Swift Current and Val Marie Arches in western Saskatchewan, the Meadow Lake Escarpment in west-central Saskatchewan, and the southwesterly trending Nelson River structure in eastern Saskatchewan near the Manitoba border. The Nesson and Cedar Creek anticlines in North Dakota and Montana are prominent linear features. Local domal features and monadnocks are present and have been known to exert control on basin development.

Robinson et al. (1969) applied a spatial filtering technique to the study of topographic and structure contour maps and concluded from the structural trends discerned that the structures represent juxtaposed basement blocks, which have undergone differential, vertical movement repeatedly throughout Phanerozoic time. The same views were expressed by Kent (1974) on the basis of the many, mutually perpendicular, linear features with a dominant northwest-southeast trend in southern Saskatchewan. These were recognised on the basis of both subsurface data (structure contour and isopach maps) and airphoto expression.

Both the regional and small-scale basement features have exerted control on the distribution of sediments in the Colorado Sea in Saskatchewan. Their persistence throughout the depositional history of the western Canada sedimentary basin is indicative of the presence of fracture zones within the basement
that have been repeatedly reactivated by regional tectonic forces to produce similarly oriented structures (Simpson, 1979a). The present configuration of the Williston Basin, the Sweetgrass-North Battleford Arches and many of the smaller-scale features are Laramide in origin.

2.3.3 Solution-Generated Collapse Features

Salt deposits of the Middle Devonian Prairie Evaporite extend northwards from North Dakota, through Saskatchewan and Alberta as far as the Northwest Territories. However, there is a large salt-free depression in south-central Saskatchewan in the region of Swift Current platform (Figure 2.1). Other smaller-scale solution-formed depressions, such as the steep-sided, fracture-bound depression of the Rosetown Low, are also present.

In Saskatchewan, where the thickness of the salt is approximately 180 to 220 m, the effects of multistage salt solution have produced both regional and local features. The chief effect of the salt removal has been the creation of structural lows in the form of large depressed areas, elongated linear troughs or local circular depressions which are defined by dip reversals in strata younger than the Prairie Evaporite. These are accompanied by subsequent draping of strata and anomalous thickening and thinning of the sequences.

The linear nature of some of the northeasterly directed solution-generated structures and their parallel arrangement, reflecting the structural trends of the Churchill Province,
suggest that many of these features are basement-controlled (Kent, 1973). The solution-generated collapse features have led to the formation of structural lows and elongated trough forms within the region. Evidence of local salt solution in the study area is presented by the existence of sinks and salt solutions from seismic anomalies (Figure 4 in Simpson, 1984b, p. 218). These may have controlled the development of the structures in the area. However, large-scale circular structures are absent.

2.3.4 Sub-Mesozoic Unconformity

After the deposition of the Mississippian carbonates, the region was uplifted and subjected to prolonged erosion. This led to the development of karstic-trellis topography upon the exposed Devonian and Mississippian strata (Christopher et al., 1971). The linear solution depressions, which are typical of this topography, influenced the development of incised fluvial channel systems in these rocks.

These topographic features and the Jurassic-Cretaceous unconformity have influenced the deposition of Mesozoic sediments. The arrangement of the Mannville fluvial and fluvio marine channel sands was determined by the underlying network, developed at both unconformities (Christopher, 1974). This relationship is also evident within the Colorado succession. Jones (1961a) demonstrated the correspondence between elements of the sub-Cretaceous erosion surface and structural trends of the Viking Formation in western
Saskatchewan. He believed that this was due to compaction of sediments on the buried topography. This caused thinning of the Viking sediments over the highs or buried hills, thereby producing irregular, amoeboid or drape folding. Simpson (1979a) stated that the Viking lithofacies were influenced by sub-Cretaceous palaeotopography, in that tidal channels filled with a basal Viking conglomerate were cut into the bottom muds draping the cuesta at the erosional edge of the Mississippian carbonates in western Saskatchewan.

2.4 Patterns of Fluid Migration.

The flow of fluids through porous media is governed by a well recognised system of energy potential fields (fluid, thermal, electric, and chemical). It may be considered as a transient (unsteady-state) or steady-state phenomenon (Hitchon, 1976). However, in sedimentary strata, water is the fundamental fluid which genetically relates all mineral deposits. It is the medium for the transportation of materials in solution and suspension throughout the hydrologic cycle, and it takes part in reactions during the dissolution of minerals in sedimentary processes, and in the re-melting and crystallisation of igneous and metamorphic rocks (Hitchon, 1979).

The arrangement of the grains and crystals in sedimentary rocks usually leaves spaces (pores and channels) which are filled with fluids: water, air, gas, oil and tar. Just how much fluid is contained in the rock depends on the space, or porosity,
available. Porosity is the fraction of the total volume of a rock that is not occupied by the solid constituents and is expressed as a ratio of the fluid-filled volume of a rock to the total volume.

For a rock to be permeable, it must have connected pore spaces. The permeability of a formation is a measure of the ease with which fluid of a certain viscosity can flow through it, under a pressure gradient. It is measured parallel to the bedding planes of the reservoir rock (lateral permeability) and also at right angles to the bedding (vertical permeability).

Other relevant factors are:

(i) **Saturation**, which is the fraction of the pore volume that is filled with a given fluid, i.e. the ratio of the volume occupied by the fluid to the total pore volume.

(ii) **Capillary pressure**, which is the phenomenon by which water, or any wetting liquid is drawn up into, or retained in a capillary. The pores and the connecting throats in permeable and porous rocks are small enough to act as capillaries (Hilchie, 1978).

Porosity and permeability are of several types. In well log analysis in the oil industry, effective porosity, relative permeability and water saturation are the factors commonly measured and used. Relative permeability is the ratio of the amount of a specific fluid that will flow at the given
saturation, in the presence of other fluids, to the amount that would flow at a saturation of 100%, the pressure gradient and the other fluids being the same (Levorsen, 1967).

The distribution of porosity and permeability in the Viking sequence varies along the northeasterly depositional trend. The passage from a thick, nearshore Bow Island-Viking succession, through the proximal shelf sequence to a thin, distal Viking shelf sequence is accompanied by diminution of grain size. The nearshore Viking sequence, therefore, exhibits high porosity and permeability. The proximal shelf sequence of sediments shows a wide range of porosity and permeability while low ranges are largely confined to the distal shelf Viking sequence (Simpson, 1982b).

2.4.1 Factors Controlling Fluid Flow

Fluids in sedimentary basins are governed by a system of energy potential fields which include fluid potential (elevation and pressure), thermal, electro-osmotic, and chemico-osmotic forces coupled in a system. Hitchon (1969a, b) showed that the distribution of fluid potential and related patterns of fluid flow are strongly controlled by topography and geology in the western Canada sedimentary basin. The characteristics of the various energy potential fields are summarised below:

(i) Fluid potential

Defined by Hubbert (1953) as the amount of work required to transport a unit mass of fluid from an arbitrarily chosen datum
(usually sea level) to the position and state of the point considered. It possesses a gradient normal to surfaces of equal fluid potential called equipotential surfaces (North, 1985).

(ii) **Chemico-osmotic potential**

This is due to the difference in concentration between two aqueous solutions that are subjected to equal pressures and temperatures, and separated by a semi-permeable membrane. It will give rise to movement of water (not solute) from the more dilute to the more concentrated solution, thereby creating a pressure differential across the membrane called osmotic pressure (Everdingen, 1968).

(iii) **Thermal potential**

Hitchon (1984) considered this to be probably negligible as a force to move fluids, but clearly significant to geothermal regions. However, thermal changes cause thermoelastic responses in the solid matrix which act to change the pore volume and thus the fluid pressures, as well as the state of stress (Neuzil, 1986). Davis (1987) reported that changes in water temperature also change the coefficient of permeability and, hence, the transmissivity of the rock units. Increasing the temperature increases transmissivity and lowers the potentiometric surface gradient.

(iv) **Electro-osmotic potential**

This is generated by electric potentials resulting from the existence of telluric currents, and is generally assumed to have a negligible effect on fluid movement (Everdingen, 1968).
Of the four potentials above, fluid potential is the one of most widespread importance. At any point of the flow regime it is directly proportional to the hydraulic head at that point, with the constant of proportionality being the acceleration due to gravity.

On the other hand, chemico-osmotic potential is important in sedimentary basins with 1) a wide range in concentration of dissolved salts in formation waters and 2) shales which act as semi-permeable membranes (Hitchon, 1984). The pressure of an active chemico-osmotic potential manifests itself in the so-called anomalous pressures and salinities of the formation waters. The salinity is important in that the areal variations in the salinity of formation fluids can provide a basis for estimating the extent of regional fluid flow in subsurface aquifers. The presence of the Prairie Evaporite salt in the study area may have played a significant role in the generation of the so-called chemico-osmotic potentials which in turn could give rise to abnormal fluid pressures. Salinity maps, therefore are often included in reservoir studies (Simpson et al., 1987).

2.4.1.1 Topographic Effects

In any part of the basin, the dominant fluid potential corresponds closely to the fluid potential at the topographic surface in that part of the basin. Hitchon (1969a) using pressure data from the whole western Canada sedimentary basin,
showed that major upland and lowland areas correspond to major recharge and discharge regions respectively. Fluid flow is from the major upland (recharge) areas to the major lowland (discharge) areas.

In Saskatchewan, topographically, the sedimentary basin region is divided into two steppes by the eastward-facing Missouri Coteau scarp of southern Saskatchewan. The prevailing slope is to the east and elevations are mostly in the range of 214 to 610 m in the Cypress Hills Flat plains and undulating topography predominate further south. Their continuity is only interrupted by broad river valleys and a few areas of positive relief, where exposures of Late Cretaceous and younger sediments may occur (Christopher et al., 1971).

In the study area, notable physiographic features are local plains and uplands. The Saskatchewan River Plain has the lowest elevation of about 457 m, rising up to 853 m in the Missouri Coteau Upland and 823 m in the Bigstick Lake Plain to the north-east and south respectively (Acton et al., 1960). These positive relief features may have a significant influence on the movement of the fluids in the area.

2.4.1.2 Geologic Effects

On a local and regional scale, geology is a dominant factor controlling flow of liquids. Hitchon (1969b) demonstrated that reservoir characteristics of hydrostratigraphic units largely control the overall flow pattern. These units generally show a
widespread lithologic and hydraulic continuity, as in the northern Williston Basin region. The geological factors of importance, as outlined by Hitchon (1969b), are as follows:

(1) **Effect of Permeability Variations**

The theoretical implications of variations in subsurface permeability on fluid potential distribution patterns were discussed by Freeze and Witherspoon (1967). They demonstrated that a rock unit with relatively high permeability profoundly affects the regional flow pattern and, if it outcrops, acts as a drain that facilitates flow of fluid to the discharge areas. Its effects are:

(i) it tends to result in the flow paths becoming more vertical in the underlying, relatively less permeable unit, and

(ii) it tends to localise the discharge.

(2) **Effect of Geological Structures**

These structures include any type of structural deformation resulting from tectonic movement, from stratigraphically related factors (salt collapse, differential compaction) or from other factors (e.g. meteorite impact), which can give rise to faulting and fracturing that may permit vertical migration of formation fluids across otherwise impermeable stratigraphic barriers.
In Saskatchewan, the regional structural framework has been discussed under structure in some detail, and therefore warrants only brief mention here as:

(a) **Structural Anomalies Affecting Precambrian Basement Relief**

These include a homocline, the Sweetgrass and North Battleford Arches, the prominent lineaments of the Meadow Lake Escarpment and Nelson River feature, and local domal features and monadnocks. All these features may affect fluid pressures, in that local movement may be diverted from the regional flow of the area.

(b) **Stratigraphically Restricted (Post-Precambrian) "Structural" Features**

(i) **Solution-generated collapse structures**

These structures resulted from depositional anomalies and post-depositional adjustments within the Phanerozoic succession rather than tectonic activity. The upward movements of positive basement features during deposition of the Phanerozoic sequence led to folding of the sediments, as well as localization of vertical fluid migration up associated features (Wilson et al., 1963). This gave rise to solution of the Prairie Evaporite and collapse of the overlying strata.

(ii) **Differential compaction structures**

Positive relief features on the Precambrian erosion surface can give rise to differential compaction structures in the
underlying strata. Simpson and Dennison (1975) noted such features in Saskatchewan as in the Ashville Sand in the Lower Cretaceous Ashville Formation, an eastern equivalent to Viking Formation. Owing to the pressure exerted, fluids are expelled.

(c) Effects at unconformities

Knowledge of the regional and local stratigraphic framework is essential in the determination of the hydrodynamic flow regime. Of importance is the sub-Mesozoic unconformity, because it has a significant effect on the regional and local cross-formational flow of subsurface fluids between hydrostratigraphic units. It brings into juxtaposition strata of varied lithologies referable to different hydrostratigraphic units, as well as their incorporated fluid systems. The unconformity has impressed upon them the result of flow through strata of differing permeabilities.

Compaction of the Colorado and the Montana Groups above the unconformity has produced irregular folds which mimic the sub-Mesozoic (most importantly, sub-Cretaceous) palaeotopography, thus localising hydrocarbon production in these structures.

In the western Canada sedimentary basin, fluid flow is dominantly downward from the surface through much of the Cenozoic and Mesozoic strata where the salinities are lower than 35,000 ppm, and dominantly upward in the permeable deep Devonian and Cambrian strata (Majorowicz and Jessop, 1981). The overall flow pattern on a basin-wide scale is from southwest to northeast (Simpson et al., 1987).
Analysis of the stratigraphic and the various basement-related structures discussed will bring about an understanding of the conditions of deposition and the distribution of formation fluids in the study area.

2.5 Hydrocarbon Accumulation

The importance of the above structures and the associated depositional settings of the reservoir rocks is seen in the distribution of the hydrocarbon accumulations (Figure 2.1). In Saskatchewan, oil and gas are produced from reservoirs ranging in age from Ordovician to Cretaceous. Hydrocarbon production occurs at several locations along the Fourth Meridian in southwestern Saskatchewan, where mainly Mississippian strata yield light and medium crude oils with associated gas. The former localities produce light, medium and heavy oils and mostly non-associated gas from various Mississippian, Jurassic and Cretaceous reservoirs (Simpson, 1984a). Total production, for 1985, for example, was $11.612 \times 10^6 m^3$ of oil and $2.401 \times 10^6 m^3$ of gas (Saskatchewan Energy and Mines, 1985). The first commercial discovery of oil was in 1945 from the Lower Cretaceous Sparky Sand in the Lloydminster district (Christopher et al., 1971).

In the study area, production is restricted to the Cretaceous reservoir rocks of the Viking Formation of the Lower Colorado Subgroup. Production is from a total of ten pools (2 oil and 8 gas pools). The main important regional feature in the proximity of the area is the Sweetgrass Arch which restricted
dispersal of siliciclastic detritus across the western shelf and influenced development of large-scale structures in the region near the Fourth Meridian.
CHAPTER III

3.0 STUDY METHODS

3.1 General Remarks

The data base for this study consists of a total of over 600 well logs. The data were derived from the Petrofiche System of International Petrodata Limited for 1987. The contents of this system include well locations, elevations, core and core analysis, drill stem tests, formation tops and other data. These data formed the basis of two types of data; geological and hydrogeological data.

The geological data (Appendix I), made up of elevation depth (tops) of lithostratigraphic units (Lower Colorado Subgroup), were checked against geophysical data (well logs) from similar wells stored separately. This resulted in a data base comprising 512 wells (Figure 3.0, pocket), as only electrical well logs (mainly spontaneous potential and resistivity) were used. This gave a well density of 64 wells per township. In addition, lithologic descriptions of cores by Simpson (1979d) from 86 wells were used in the study.

The hydrogeological data (Appendix II) included drill-stem results from which elevations of potentiometric surfaces were calculated. In all, 252 wells were used giving a well density of 31 per township across the study area.
In the study area, the distribution of both types of data is largely concentrated within hydrocarbon production locales.

3.2 Stratigraphic-sedimentologic studies

Stratigraphic-sedimentologic studies were carried out from detailed core descriptions, from which ten lithofacies were defined on the basis of lithological associations (mode of occurrence and abundance) and conventional classification. Definition of the vertical succession of lithofacies, textures and sedimentary structures for depositional systems and interpretations of depositional environments were also carried out.

Correlations of the Lower Colorado strata in the area were made by use of geophysical well logs. Geophysical well logs are graphical plots of downhole variation in selected physical properties, mostly those of the rocks and their incorporated fluids. They are of several types and can be grouped under the headings: electric (spontaneous potential and resistivity), acoustic, radiation (gamma-ray and neutron), temperature, chemical, gravitational, mechanical (caliper) and photographic.

Electrical well logs were used to determine the correlation surfaces. The literature on this subject is voluminous and beyond the scope of this study. However, in this study, an electric log will be considered as a plot of certain electrical properties of the strata in the vicinity of the well bore (Gatlin, 1960; North, 1985). Two of such logs are the
spontaneous potential (SP) and resistivity. Gamma-ray logs were not available for most of the wells in the study area. The procedure is that of determining the expressions made by the Joli Fou (shales), Viking (sands) and Big River (shales) Formations. The SP log distinguishes between permeable (sands) and non-permeable formations (shales), with the curve consisting of more or less straight base line, corresponding to the shales, and deflections or peaks to the left opposite permeable strata.

In some cases, the curve may show a subdued response within permeable formations, where there is a high clay content. The response of the curve is affected mainly by the salinity contrast between the formation fluid and the drilling mud. The expression on the curve is virtually none where the mud resistivity is very close to the formation water resistivity. In cases where the mud resistivity is less than the formation-water resistivity, the curve is reversed.

On the other hand, resistivity of a formation is defined as the specific resistance which it offers to the flow of electrical current. The main use, therefore, of the resistivity log is to determine the boundaries of resistive formations. It exhibits lower values across permeable formations and higher values on non-permeable formations. Shale, for example, displays low resistivities which results in a base line corresponding to the shale values, because clay is a conductor. Consequently, the low
resistivity deflections opposite the permeable formations (sands) occur just to the right of this base line (Stratton and Ford, 1950; North, 1985) in the right-hand track of the well log.

Lateral depositional relationships between the Lower Colorado strata and areal distribution of the strata were shown by log cross-sections and isopach maps respectively. All log cross-sections were hung on a reliable log time-stratigraphic marker datum, the base of the Second White-Speckled Shale. Structural cross-sections were hung on a datum of 75 m above sea level. Elevation of correlation surfaces are depths measured in the well given with respect to a datum on the drilling rig about 3.7 m (12 ft) above ground known as the Kelly Bushing (KB). KB elevations are in turn given with respect to mean sea level (m.s.l.).

Isopachous maps represent variations in thickness of one stratigraphic unit or several combined (formation etc.) and were obtained by the difference between elevations for two selected correlation surfaces (usually the top and bottom of the unit, formation, etc.). They can be regarded at as paleostructure maps if one of the surfaces is considered as relatively smooth and flat when deposited (Robinson, 1982).

Structure contour maps were drawn to unravel the structure in the area. These were obtained by a simple subtraction of the correlation surface of interest from KB, as such subtraction gave
the elevation of a correlation surface with respect to m.s.l. Structure contour maps are drawn with mean sea-level as the structural datum.

3.3 Hydrogeological studies

These were carried out by means of potentiometric maps of the Viking Formation and fluid pressure profiles for selected wells, all derived from drill-stem test data.

Owing to the economics (evaluation of the reservoir without completing the well) of the drill stem test (DST), it is considered as a temporary completion of a well. The non-completion of the well reduces drilling costs.

The history of drill-stem testing dates back to 1926 with the advent of rotary drilling, when it emerged as a method of testing through the drill-stem and became known as "drill-stem testing". It was initially designed to sample the formation fluids and indicate presence of hydrocarbons and water. The mechanical tools of the test consist of a series of packers, valves and pressure recorders (Edwards and Winn, undated; Murphy, undated; Maier and Ripley, 1967).

With the advent of highly sensitive pressure recorders (late 1940s) and the development of advanced pressure building theory (early 1950s), more accurate evaluations of reservoir characteristics are available. This gives the operator many choices. Its capabilities have increased considerably, as well, to include information on static reservoir pressure, production
rate, transmissivity, damage ratio, potentiometric surface, permeability anomalies, etc. This information can all be provided from proper procedures and drill-stem test analysis (Edwards and Winn, undated; Maier and Ripley, 1967; Poollen, 1967). The introduction of these sensitive recorders and readers have reduced the measurement errors involved to approximately +/- 6.9 to 13.8 kPa at pressures as high as 27,580 to 34,475 kPa (Bredhoveff, 1965) while the recorder (Bourdon tube) is considered accurate to approximately +/- 1 percent of full scale (i.e., +/- 50 psi on a 5,000 psi gauge or +/- 100 psi on a 10,000 psi gauge) (Bradley, 1975).

The overall drill-stem test may consist of only one opening and closing of the test tool, one flow rate with one pressure drawdown and one pressure buildup to the final static pressure. However, it is a common practice nowadays to have two flowing periods during an individual test (Austin, 1983). The measuring technique given below is mainly from Hackbarth (1978) and Austin (1983).

The packers and recorders allow isolation and recording respectively of pressures in selected zones in a borehole or well. Though two methods are available, bottom hole and straddle, the test is similar in both cases.

The drill-stem test consists of four phases (Hackbarth, 1978). The first is the running-in phase which is followed by valve opening at a desired depth to allow for fluid flow periods. After each flow period (usually two) the valve is closed to allow
for pressure buildup and the recording of the pressures which are known as the initial and final shut-in pressures. The test is ended by the running out phase where the drill-stem equipment is pulled out.

Austin (1983), noted that accurate timing between periods is important for reliable results. He emphasized that shut-in time should never be less than 30 minutes and depending on well flow, appropriate timing is desired. For example, a good flow well to the surface should have shut in time at least half of the flowing time; average flow well should be equal to one and half flowing time while poor flow well should be twice the flow time.

Potentiometric maps and fluid profiles, two methods employed in this study, are commonly utilised in fluid pressure data analysis (Hill et al., 1961; McNeal, 1965; Levorsen, 1967; Hitchon, 1969a, 1969b; Dickey and Cox, 1977; Christopher, 1974, 1980; Tóth 1979, 1980; Hachbarth, 1978; Prier, 1979; Orr and Dutton, 1983; Bair et al., 1985; North, 1985; Dickey, 1986; Bachu et al., 1987; Tóth and Rakhit, 1988).

A potentiometric map is a method of expressing variation in fluid pressure data across an area. The potentiometric surface represents equipotential contours with respect to mean sea level. The surface is computed from elevations to which a column of a standard density fluid would rise above the test formation when subject only to atmospheric pressure (Robinson, 1982). Drill-stem test data from International Petrodata Limited is composed of the time the valve is open, duration of test (shut in
times), dates, initial and final shut in pressures. Owing to the fact that water will flow from zones of high potential to zones of low potential, not necessarily from zones of high pressure to zones of low pressure, it is therefore necessary to convert the pressure (kPa) from drill-stem data to potential (pressure head), expressed in metres of head above or below sea level by using the following formula below (Prier, 1979; Dickey, 1986):

\[ E = (KB - D) + (SIP/GW) \]

where

- \( E \): Elevation of the potentiometric surface with respect to sea level (m)
- \( KB \): Elevation of Kelly Bushing (KB) with respect to sea level (m)
- \( D \): Depth of pressure recorder with respect to KB (m)
- \( SIP \): Bottom hole shut in pressure (kPa)
- \( GW \): Fluid pressure gradient (9.795 kPa/m)

The fluid pressure gradient of 9.795 kPa/m (of fresh-water) is used since it gives a more accurate portrayal of the flow potential than taking into account the large variations in density corrections (Levorsen, 1967; Robinson, 1982). Orr and Dutton (1983) noted that data on fluid density for calculating true hydraulic heads are sparse and make density estimates hazardous. The potentiometric elevation data had to undergo culling procedures before they were posted to the Golden Graphics System Software.
Formation pressure is the most important reservoir property obtained from the drill-stem test chart for presentation on potentiometric maps. Depending on the time allowed for the shut-in period, static conditions may be achieved and in this case, shut-in pressure is read off directly from the chart. In some cases, extrapolation to infinite time using the Horner plot is required (Allen and Roberts, 1978) in order to extract the shut-in pressure. However, the question arises as to whether the shut-in pressure obtained from the chart (in this case, International Petrodata's Petrofiche System, 1987) reflects the virgin reservoir pressure. It can be seen from Figure 3.0 that drill-stem data in the study area are concentrated in an area from Townships 24 and 25, Range 16W3, to Township 28, Range 27W3, and to the northeast of it, and between Township 23, Range 25W3, and Township 24, Range 25W3, inclusive. Elsewhere, the distribution of data is patchy and scattered. Between Township 21, Range 15W3, and Township 22, Range 17W3, there are no data at all. Therefore data inspection and reduction had to be undertaken where necessary. Data reduction was accomplished by using one well per section. However, before the selection process was initiated, all DST data were evaluated in accordance with the procedure put forward by Bair et al. (1985).

Bair et al. (1985) used a screening process based on stringent criteria for the duration of initial shut-in pressure (ISIP) and final shut-in pressure (FSIP) and for the agreement of FSIP with ISIP within +/- 5% in their study. The time duration
measure was used to screen out tests that were for such a short
time that pressure equilibrium probably could not be attained
except in extremely permeable strata. The agreement of ISIP with
FSIP within +/- 5% screened tests that did not approach pressure
equilibrium.

On the basis of their classification (p. 201), the DST data
from the Viking Formation were divided accordingly and
evaluated. The time-duration criterion was not applied here,
owing to the fact that in most cases initial duration of less
than 30 minutes had final time duration of more than 30 minutes
and had the FSIP in agreement with the ISIP. Even where only one
shut-in pressure was available, the data were used.
Consequently, only the requirement of approximate equivalence of
ISIP and FSIP was applied.

The depths (D) of the bottom of the intervals tested were
used instead of the mid-point (Bair et al. 1985), since the
testing instrument lies at the bottom of the interval
(Christopher, 1974; Miller, 1976; Bacopoulos, 1988). Intervals
that included the three formations other than the Viking only,
were also used as indicated by Newman and Witherspoon (1969); and
Tóth (1980). They argued that short time tests like drill-stem
tests have negligible effects on the underlying and overlying
aquifers when testing an aquifer (Viking) in a multiple-aquifer
system confined by aquitards (Big River and Joli Fou Formations).
Fluid pressure profiles show the relationship between fluid pressure and depth in a single well or variation of fluid pressure against depth in the area. The profiles are constructed with the Kelly Bushing (KB) as datum and a fresh water gradient curve is included as reference. The interpretation of the profile is based on the principle of a continuous fluid system showing a straight-line relationship with depth and proportional to the fluid density (Prier, 1979; Robinson, 1982).

3.4 Computer Software Methods

The goal of any map-maker, human or otherwise, is to produce a "best-predictor" (Bugry, 1981). Computer contouring is a valuable time-saving technique used in analyzing large masses of data, in routine updating and further analysis of resulting surfaces. It has been used by various workers such as Paterson (1975), Robinson (1981), Robinson et al. (1981), Clark (1981), Bole (1981), Yeh et al. (1983), Jones and Johnson (1983) and Bachu et al. (1987).

All data as retrieved from the Petrofiche System of International Petrodata Limited (1987), geophysical well logs, and core wells were entered into spreadsheet files of the Framework II Software System, Version 1.1 (1986). Here the data were sorted and verified to ensure that formation top elevations from the Petrodata Limited (1987), geophysical well logs, and core wells were the same for a given well. Data from International Petrodata Limited that had no corresponding
geophysical well data were discarded, owing to the formation tops on the former representing mostly the Viking Sandstone instead of the Viking Formation.

The selected wells (Fig 3.0, pocket) were then used for computation of thicknesses of the formations, elevations for the structure maps and potentiometric elevations.

The data were at this point ready for use by the Golden Graphics System Software, Version 3.0 (Golden Software, Inc., 1987) to generate the various maps required. However, before such data were entered, the system required that the location of the data points (Z coordinates = value to be contoured) are transformed to X and Y coordinates. This was carried out by use of a template superimposed on the base map where the data points were plotted. Each Z value was then assigned an X and Y coordinates.

The Golden Graphics Software Package, Version 3.0 (1987), basically consists of three programs relevant to this study: the Grid, Topo and Surf Programs.

The Grid Program is a menu-driven program which creates and manipulates files of regularly spaced data points called grid files from irregularly spaced data (this data) by the selection of the random menu. As will be shown, this feature is the important component of the software as the other programs are generated from it (Walters, 1969). The Inverse Distance Squared (IDS) method used in this study uses a weighted average technique to determine the parameter values at the grid nodes from the XYZ
data. The weights are inversely proportional to the distance of
the grid node. Data points further away from a given grid node
will have less influence. The weighting process assigns a
function whose form depends upon the distance from the location
being estimated and the most distant point used in the
estimation. The function is scaled so that it extends from one
to zero over this distance. The weights that are assigned to the
control points are then adjusted to sum to 1.0 (Davis, 1986).
The accuracy of the method depends on the choice of option
settings of the menu (Waters, 1981; Bugry, 1981; Robinson,
1982). Included in the settings menu are the search (normal,
quadrant and octant) and grid size (density of final grid). The
normal search and 80 grid line density are used in this study.
However, it must be noted that the selection of the grid depends
on individual need and the problem to be analyzed (Walters, 1969;

Topo is also a menu-driven contouring program that creates
contour maps from gridded data in format used by the grid
program. Option settings menu include level (minimum and maximum
contour and contour interval), scale (map size), posting of data
and other menus. The posting of the data is very important for
visual examination as Bugry (1981) noted that one should first
produce the contour map, then alter it to fit a personal
interpretation of the data that corresponds to the known geology
of the area. Therefore all maps were examined, and adjusted
where necessary, before being traced on to the base maps as final
products.

Finally, Surf is an interactive, menu-driven graphics
program that produces three-dimensional surface representations
from the gridded data, in the format used by the grid program.
Base or skirt of the plot, axes (labelling of X, Y and Z), size
of the plot, post and view (projection, tilt, rotation angles
etc.) are some of the menu selections available in the program.
Labelling of the three-dimensional plots in this study follows
the labelling procedure of Yeh et al. (1983) and Plint et al.

For fluid-pressure profiles, the Harvard Graphics Software
Package Version 2.0 (1987) was used. Two variables are required
for the program: shut-in pressure (X axis) and depth (Y axis).
CHAPTER IV

4.0 DEPOSITIONAL SYSTEMS

4.1 General Remarks

A depositional system is considered as a unique system having similar attributes and deposited at a particular geological time (Selley, 1985). In western Saskatchewan, the Lower Colorado Subgroup of the Cretaceous period is represented by the Joli Fou Formation - Bow Island-Viking succession - Big River Formation. These three lithostratigraphic units were deposited during the transgressive inland seas in late Albian time (Williams and Stelck, 1975). They form the depositional systems that constitute the Lower Colorado Subgroup.

A typical stratigraphy of the three-package systems in western Saskatchewan is given in Figure 4.0. Over the years, distinction and correlation among these sediments were achieved by use of the combination of the core description and geophysical well logs (Jones, 1961a; Evans, 1970; Simpson, 1975, 1979b, c, 1982b). The gradational relationships between these packages greatly complicate attempts to correlate sandstone bodies from one well to another. Contacts with the Big River and Joli Fou Formations are relatively sharp in the south-west, while in the extreme northeast, the upper contact of the Viking Formation is
Figure 4.0 Typical reference well logs.
difficult to recognize consistently as illustrated by the indistinct deflections in the Socony Sohio Bickleigh 14 13 well (LSD 13-14-27-18W3) in Figure 4.0.

This study follows the pattern established by Jones (1961a) and Simpson (1975, 1979b, 1982b) in attempting to correlate siltstones and shaly, fine-grained sandstones, which give a characteristic resistivity response at the top of the Viking unit. In the study area, particularly in the north-east, the many interlaminated shales within the sandstones may be responsible for the low SP response (Figure 4.0). Apparently, this is also true for the silty and sandy markers within the Big River and the Joli Fou Formations. O'Connell (1981) noted the same effects in southeastern Saskatchewan.

In the Dodsland-Hoosier area just to the north of the study area, Evans (1970) used focused resistivity logs (Welex Guard Log or Schlumberger Laterolog) in order to define the finely interlaminated sandstone-shale reservoir typical of the Viking Formation. He found that the self-potential curve was so subdued that it was practically useless and in some places, erratic and misleading. Apparently, this is also true in the northeast part study area. In most cases, the deflection (picks) of the upper and lower surfaces of the Viking Formation are at different levels on the SP and resistivity logs. In such cases, judging by the literature (Doll 1948, Jones 1961a, Evans 1970 and
Simpson 1982b), the "pick" was made on the basis of the resistivity curve, as it is a more reliable indicator of formation boundaries.

In the Plato area, Gillard and White (1970) divided the formation into two divisions; the upper shale layer and the lower silty and sand horizon. The latter was further subdivided into sand A and B units on the basis of resistivity. However, this division is local in extent, and as such no divisions have been attempted in this study.

The surfaces used are the upper surface of the Mannville Group, the upper surface of the Spinney Hill Sandstone, the upper and lower surface of the Viking Formation and the upper surface of the Big River Formation (lower surface of the Second White-Speckled Shale). The lower surface of the Second White-Speckled shale is taken as the stratigraphic datum for the cross-sections. Owing to the diverse lithological variation in the area, no single well is designated as a reference section. However, the three wells shown in Figure 4.0 are used as reference sections for the three subregions identified in the present study.

The distinction between the Spinney Hill Sandstone and the Mannville Formation in the central-eastern part of the area is made on the basis of the former being more subdued on the SP and resistivity curve. The top of the Mannville Formation is still a
matter of controversy in central Saskatchewan, particularly where the Pense Formation does not occur and the Spinney Hill Sandstone rests on Mannville sandstones and shales.

The lateral strata relationships between the sediment packages are shown by log cross-sections and isopachous maps. Owing to the non-penetration of the Lower Colorado Subgroup by some of the wells, the sections show a reduced number of control wells relative to those on the data location map (Figure 3.0).

Structure contour maps were drawn on the upper and lower surface of the Lower Colorado Subgroup, (represented by upper surface of the Big River Formation and upper surface of the Mannville Formation respectively), and the upper and lower surfaces of Viking Formation.

4.2 Bow Island Formation

The Bow Island Formation, middle to upper Albian in age, is a coarse siliciclastic wedge in the Lower Colorado Subgroup. The type section of the formation is given by Bow Island No. 1 well (LSD 6-15-11-11W4) to the northwest of Bow Island, Alberta where it got its name. It attains a thickness of 175 m in the Bow Island area, where the aggregate thickness of sandstone is 24.4 m.

Distribution of the formation starts with much thicker composite sandstone bodies, termed First, Second and Third Bow Island Sands. They are made up of coarsening-upward sandy sequences in solitary and multistory arrangements in the
southeastern and south-western Saskatchewan, being replaced by the Viking Formation farther north and east (Figure 4.1). The Bow Island does not occur in the study area.

The Formation is composed of relatively well washed and variably shaly, fine- to coarse-grained sandstone, with interbedded siltstone and mudstone and with generally subordinate conglomerate and pebbly sandstone. The well washed sandstones consist predominantly of tabular cross-laminae and minor ripple-drift, trough types and horizontal laminae. The shaly sandstones include bioturbated deposits with mudstone partings and sequences made up of thin, graded sandstones and siltstones. Conglomerates are composed of varicoloured chert and reworked-relict, nodular phosphorite. Coalified plant fragments are locally abundant. The mudstones and shales are dark grey and non-calcareous. Bentonites and concretionary layers of siderite are also present (Simpson, 1980a, 1982b).

The above lithologies are all present in the distant Viking Formation which is the subject of the study area. However, considerable changes are in the thickness, the number of sandstone bodies and decrease in grain size. The Bow Island Formation consists of three main sand bodies which together with the intervening muds attain an aggregate thickness of 180 m in southeastern Alberta. The Viking Formation in the study area consists of only one sand body with an average thickness of 33 m.
Figure 4.1 Stratigraphic cross-section of the Bow-Island-Viking succession, southeastern Alberta and western Saskatchewan. BI = Bow Island Formation; V = Viking Formation. B - Location map showing line of cross-section (after Simpson, 1975).
4.3 Viking Formation

4.3.0 Introduction

As outlined in the general remarks, the Viking Formation in the study area is made up of highly variable lithological associations, consisting of sandstones, siltstones, mudstone and shales with thin conglomeratic beds and bentonitic intervals. The distribution of these sediments in the area varies laterally and vertically, and sandstone is the main constituent of the formation.

The gradational nature of the lithologies expressed in the core description makes subdivision into discrete lithological units in the area somewhat difficult. In addition, for example, cores recovered in the southwestern part of the study area are mainly from the upper part of the Viking Formation, with the maximum core length of 28 m at Oliphant Nrwc0 Gorefield 7 22 24 26 well (LSD 07-22-24-26W3). Consequently, the entire Viking Formation is represented in only a single core from the Imperial Highbury 10 35 well (LSD 10-35-25-26W3) in the area. In the remaining area, very few scattered wells have fully cored sections of the formation. In all there are five lithologies which make up the Viking Formation, namely sandstone, mudstone, siltstone, conglomerate and shale, in descending order of abundance. There are many variations within the lithologies; for example, the sandstones can be subdivided into five facies on the basis of grain size only. These are pebbly and pebbly muddy sandstone, muddy coarse-grained sandstone, muddy fine-grained
sandstone, muddy sandstone, and fine-grained sandstone. These
tend to occur together in one unit (fine-grained with coarse
sands and pebbles). Where they occur separately they are not
distinguishable on geophysical well logs and so, it is best to
group them under sandstone as one lithofacies, while the pebbly
and pebbly muddy sandstone are referable to a conglomerate
lithofacies. In addition, the lithologies occur in intermixed
layers, such that it is possible to delineate them into separate
lithofacies based on the relative abundance of the aforementioned
lithologies within a given unit interval. The units become so
frequent in occurrence vertically that they may shed some light
on the lithological variations in the area. Consequently, for
description purposes the area is considered in three parts using
the isolines of the isopach map of the Viking Formation discussed
in Section 4.3.2.2 as arbitrary boundaries (Figure 4.2): (i) the
southwestern region, (ii) the central region and (iii) the
northeastern region. The observed lithofacies in cores were
divided into ten lithofacies. These are:

Lithofacies 1- Sandstone

This lithofacies includes muddy coarse-grained, fine to very
fine-grained and muddy sandstone. The sandstone may be bedded or
bioturbated.

Lithofacies 2- Mudstone

This includes bentonitic mudstone.

Lithofacies 3- Siltstone
Figure 4.2 Subregions of the study area for description purposes. 1) location of wells; 2) wells with core description; 3) wells with drill-stem test data; 4) wells with both core description and drill-stem test data; 5) arbitrary boundaries of the subregions.
Lithofacies 4- Conglomerate

Included here are the pebbly and pebbly muddy sandstone, pebbly mudstone, and sandstone with intercalated conglomerate.

Lithofacies 5- Shale

Lithofacies 6- Sandstone with subordinate mudstone intercalations

The mudstone in this lithofacies can be continuous or discontinuous, and also may occur in form of interconnected partings throughout the sandstone.

Lithofacies 7- Alternation of sandstone and mudstone

The sandstone and mudstone occur as interlayers intercalated together, which can be regular or irregular.

Lithofacies 8- Alternation of siltstone/sandstone and mudstone

Lithofacies 9- Mudstone with subordinate siltstone and sandstone intercalations

This lithofacies is the opposite to lithofacies 6 in that the mudstone is the dominant lithology. The sandstone layers may be continuous and discontinuous, sometimes with the siltstone component missing. In places the dominant mudstone may alternate with the sandstone.

Lithofacies 10- Alternation of mudstone and siltstone

The above lithofacies are also identified in the largely argillaceous Joli Fou and Big River Formations, though in considerably reduced proportions particularly for the coarser-grained ones.
The following sections give a detailed and extensive presentation of the core description and areal distribution upon which many of the interpretations of the study are based. Therefore the reader wishing to avoid this extensive presentation is directed to Section 4.3.3 which provides discussion and summary.

4.3.1 Lithofacies Description

Lithofacies 1- Sandstone

The Viking sandstones are generally light-olive grey, predominantly fine-grained, but varying to coarse-grained. Induration varies from poor- to well-indurated. Mineralogically, the sandstones are quartz-rich, and micaceous, though carbonaceous material is often present. Glauconite is frequently present, while calcite is the main form of cement. Horizontal lamination to cross-bedding are present but often disturbed by burrowing which is extensive.

The sandstones attain a maximum thickness of 28 m in the Dome Provo Lancer 10 9 well (LSD 10-09-22-21W3) and the Oliphant Nwrco Gorefield 7 22 24 26 well (LSD 07-22-24-26W3) in the southwestern region. In the central region, the sandstone has an average thickness of 6 m with the maximum of 13 m in the Imperial Glidden 7-33-26-23 well (LSD 07-33-26-23W3). To the northeast, the sandstone units range in thickness from as low as 0.2 m to slightly above 8 m in the Imperial Brock 11 17 28 20 well (LSD 11-17-28-20W3).
The sandstone is varicoloured ranging from light olive grey to medium grey, with a predominant fine-grained texture often associated with scattered coarse sand, granules and pebbles. However, variation from very fine- to coarse-grained also occurs at various localities in the area. In the southwestern region, associations of the coarse sand, granules and pebbles in the fine-grained sandstone were observed in the Imperial Bayhurst 10 3V 24 25 well (LSD 10-03-24-25W3). At the Oliphant Nwrco Gorefield 7-22-24-26 well (LSD 07-22-24-26W3) an upward increase in grain size occurs, while in some cases, the pebbles have become so abundant that the sandstone qualifies as a pebbly sandstone and hence lithofacies 4. In the central region, medium- to coarse-grained sandstones were observed in the Imperial Cornfield 10 32 25 25 well (LSD 10-32-25-25W3), while to the northeast, locally the sandstone is predominantly very fine-grained, often with coarser sand, granules and pebbles, as in the Murphy et al. Kindersley 7 19 28 21 well (LSD 07-19-28-21W3).

It is obvious from this variation in grain size that the sandstone is generally poorly sorted except in a few cases. Examples are at the Dome Provo Lancer 10, 9 well (LSD 10-09-22-21W3), the Westerham No. 1 well (LSD 04-12-23-27W3) at the Husky-Phillips Coombe No. 1 well (LSD 16-21-23-24W3) in the southwestern region, Phillips Husky Warrior No. 1 well (LSD
11-09-27-25) in the central region, and at the Hudson's Bay Rosetown 14 17 28 16 well (LSD 14-17-28-16W3) in the northeastern region.

Compositionally, the sandstone is quartz-rich, micaceous, and slightly glauconitic with accessory pyrite. Minor constituents are the pyrite concretions and coalified plant debris. Fish scales are often present locally. The type of mica in these sandstones is not clear, however, in the northeastern region muscovite was observed in the Sohio Standard Elrose No. 4 well (LSD 09-10-26-16W3). Seemingly, the sandstone lacks abundant feldspar though it has been reported as a minor constituent (mainly plagioclase) in the literature (Jones 1961a; Simpson, 1982b). Feldspar has been observed at two locations only; one in the central region at Husky Phillips 1a Porte No. 1 well (LSD 16-29-26-25W3) where it occurs as prominent scattered grains together with quartz and chert in a generally medium and coarse sand fraction, and in the northeastern region at the Canus et al. N. Verendrye 12 32 28 23 well (LSD 12-32-28-23W3).

The cementing material is mainly calcite, so abundant in some cases such that Jones (1961a) termed the sandstone the "sandy-limestone". This was observed in the Husky-Phillips Prelate No. 11 28 well (LSD 11-28-23-25W3) in the southwestern region, where calcite is the main cement in the two sandstone intervals intersected giving a total thickness of 2 m. Other cementing materials include siderite and pyrite. A 0.2 m siderite cemented interval was observed at the Cnd Sup Lacadena 6
21 32 16 well (LSD 06-21-23-16W3) in the northeastern region of the area, while pyrite is often common in coarse-grained intervals. Matrix-rich sand was observed at the Mobil Oil Penkill X 1 16 well (LSD 01-16-27-19W3).

Sedimentary structures are variable ranging from horizontal lamination to cross-bedding. Extensive burrowing is a common feature in the unit throughout the entire area. In the southwestern region, cross-lamination was seen at the Husky-Phillips Coombe No. 1 well (LSD 16-21-23-28W3) and the Oliphant Nwrco Gorefield 4-2-25-27 well (LSD 04-02-25-27W3). Small-scale trough cross-laminae were noted in the Oliphant Nwrco Gorefield 7-22-24-26 well (LSD 07-22-24-26W3), while dune-scale cross-laminae were identified at the Imperial Bayhurst 6-16-24-25 well (LSD 06-16.24-25W3).

In the central region, cross-lamination has been observed in some places; for example, at the Imperial Athenian 16 22 24 22 well (LSD 16-22-24-22W3) where it is associated with several continuous mudstone intercalations up to 1.25 cm thick. Other minor structures are loading and injection phenomena, as well as asymmetrical ripples of quartzose sands, overlain by ferruginous silty mudstone intercalated with thin quartzoses and layers in the same horizon at Cnd-Sup Lacadena 6 21 23 16 well (LSD 06-21-23-16W3). Also, thin sand layers at Imperial Centre Field 13 10 26 21 well (LSD 13-10-26-21W3) exhibit overfolding. However, for the most part the sandstone is extensively burrowed. To the northeast, cross-lamination with a pinch and
swell structure was seen in Hudson's Bay Rosetown 14 17 28 16 well (LSD 14-17-28-16W3). The sandstone displays minor contortions in places.

Biogenic structures range from extensive burrowing to sand-filled, mud-lined tubes. Burrowing was mainly by fossil assemblages preserved as *Teichichnus*, *Phycodes*, *Spirophyton*, and *Chondrites*, probably in descending order of abundance. A good example where the four assemblages have been preserved is in the Oliphant Nwrco Gorefield 3 27 25 28 well (LSD 03-27-25-28W3) in the southwestern region. Bioturbation is the dominant sedimentary structure in the central region. In the northeastern region, burrowing was mainly with *Teichichnus* and *Phycodes*. Sand-filled, mud-lined tubes have been noted in the southwestern region of the area. Other structures include the oblique *Rhizocorallid* burrows seen in the Imperial Bayhurst 10 3V 24 25 well (LSD 10-03-24-25W3) and the Oliphant Nwrco Gorefield 7-22-24-26 well (LSD 07-22-24-26W3) in the southwestern region. Indeterminate light brown shell fragments with growth rings were observed at the latter locality. In the central region, undetermined, vertical, sand-filled *Rhizocorallid* burrows, were observed at Imperial Cornfield 10 32 25 25 well (LSD 10-32-25-25W3). Sand-filled tubular forms are also not uncommon. To the northeast, undetermined sand-filled tubular forms were seen in the Pinkham No. 1 well (LSD 10-33-27-25W3). Lithological associations within the sandstone in the southwestern region are mainly the minor interconnected partings
of the mudstone which are continuous and discontinuous, and frequently oblique. In the Oliphant Nwrco Gorefield 7-22-24-26 well (LSD 07-22-24-26W3), these partings contain abundant coalified plant debris which include coal pebbles and branched fragments. In the same well, the partings are associated with sandy layers up to 2.5 cm thick. One case of bentonite at the top of the sandstone unit was seen in the Oliphant Nwrco Gorefield 3 27 25 28 well (LSD 03-27-25-28W3). This layer has been transected by several minor faults.

Oil staining was observed in the sandstone intervals. This was observed in the Oliphant Nwrco Gorefield 4 2 25 27 (LSD 04-02-25-27W3) in the southwestern region and at Husky Phillips Marengo No. 2 well (LSD 10-27-28-27W3) in the central region. In the northeastern region in the Canus et al. S. Kindersley 12 23 28 23 well (LSD 12-23-28-23W3), the decrease in mud content paralleled an increase in oil showings.

Lithofacies 2 - Mudstone

The mudstone lithofacies is generally dark grey, argillaceous, and contains fish remains. Locally, it is silty, slightly calcareous, with minor pyrite bodies and in some cases scarce fish scales and teeth have been seen. Minor laminae and interlayers of siltstone and fine-grained calcareous sandstones up to 8 cm are present. Bentonitic mudstone intervals, which are part of this lithofacies are also not uncommon. Pelecypod and gastropod debris are associated with coarser-grained sediments.
This lithofacies has not been seen in the southwestern region of the area, while in the central region, it has been intersected at two localities with a maximum thickness of 2.6 m in the Cnd-Sup Lacadena 6 21 23 16 well (LSD 06-21-23-16W3). A bentonitic mudstone horizon was observed at Phillips Husky Warrior No. 1 well (LSD 11-09-27-25W3). The horizon is silty in horizontal or gently inclined laminae with intercalations of silty mudstone without bentonite up to 1.25 cm thick.

In the northeastern region of the area, the lithofacies is observed in Townships 26, 27 and 28, Ranges 18 and 19W3. A range of thickness from 0.2 m to slightly over 3 m is characteristic for the lithofacies.

Intercalated sets of siltstone and fine sandstone laminae were observed at one locality, but are usually very scarce. In the Socony Sohio Richlea 11 7 well (LSD 07-11-26-19W3), three shattered bentonite layers interbedded with biotite flakes were observed. These layers were each probably up to 5 cm in thickness. Near the top of the interval, where veins of siderite occur, small, dark grey mudstone flakes are concentrated. Also siderite-filled spherulites in ferruginous mudstone are present. At the Socony Sohio Bickleigh 14 13 well (LSD 13-14-27-18W3), a light greenish grey, fissile bentonitic shale with darker grey mudstone intercalations, at the top 15 cm of the interval was noted. Burrowing is scarce, except in this interval where small Telichichnus were noted. Bentonitic mudstone intervals are present at various localities throughout the area. A
cross-laminated bentonite with high clay content rests on 11.25 cm of very light grey to light greenish grey bentonite in the Marvel Kamalta Plato 14 7 25 17 well (LSD 14-07-25-17W3). In the Imperial Brock 6 19 28 20 well (LSD 06-19-28-20W3), two layers of fine-grained sandstone occur 10 cm from interval top. The top layer has high clay content.

Lithofacies 3- Siltstone

This lithofacies is scarce in the study area, only observed in the McMorran No. 1 Start Test well (LSD 06-11-28-20W3) in the northeastern region. The unit rests on a 20 cm olive-grey silty mudstone. It has a thickness of about 2 m. However, siltstone frequently occurs as discontinuous to continuous intercalations with fine-grained sandstone alternating with mudstone.

The siltstone is light bluish-grey, muddy, with abundant pyrite. Pelecypod fragments are also common.

Lithofacies 4- Conglomerate

The lithofacies is widespread in the study area, consisting mainly of coarse sand grains, granules and pebbles in matrix of sandstone, and in mudstone. The conglomerate may contain numerous mudstone partings, and is locally intercalated with sandstone. The lithofacies occurs within the uppermost part of the Viking Formation, with thickness ranging from 0.1 m to over 1 m.
In the southwestern region the lithofacies occurs at various locations with a maximum thickness of 1.5 m. In the Husky-Phillips Prelate No. 11, 28 well (LSD 11-28-23-25W3), the conglomerate is cemented by calcite. Jones (1961a) did not separate this unit from the calcareous sandstone that he termed "sandy limestone". Other locations are in the Imperial Bayhurst 10 3V 24 25 well (LSD 10-03-24-25W3) and the Oliphant Nwrco Gorefield well (LSD 07-21-24-25W3). At the latter, a 23 cm conglomerate and pebbly laminated sandstone lie at the bottom of a pebbly sandstone unit. Sandstone with intercalated conglomerate occurs in the Dome Provo Lancer 10, 9 well (LSD 10-09-22-21W3) while a conglomeratic sandstone was observed in the Sceptre No. 1 well (LSD 01-22-23-24W3). The former unit consists of quartz-rich, micaceous, fine-grained sandstone which is well sorted in horizontal and gently inclined laminae. Pebbles are concentrated with coarse sand and granules in layers which are one pebble thick scattered throughout the interval. The conglomeratic sandstone unit, on the other hand, contain abundant mud and silt matrix with numerous intercalated mudstone partings, and nodular pyrite concretions. The unit is burrowed with Teichichnus present.

In the central region, the lithofacies is concentrated in the northwest, observed at six localities. It has a maximum thickness of 0.7 m, and consists mainly of fine-grained sandstone sometimes silty but with scattered pebbles which are locally numerous. However, all sand grades may be present as in the
Marengo No. 1 well (LSD 10-26-28-27W3). Numerous interconnected mudstone partings may be present within these intervals as in the Alsask No. 1 well (LSD 10-07-28-28W3). The Imperial Centre Field 13 10 26 21 well (LSD 13-10-26-21W3) is the only well about mid-way in the central region and it reveals the unit to be coarse-grained with abundant scattered granules and pebbles throughout, embedded in abundant mud-silt matrix and numerous continuous, often interconnected mudstone partings. Coalified wood debris, and nodular pyrite development are also noted.

In the northeastern region, the thickest unit is only 0.4 m, in the Sohio Standard Elrose No. 4 (LSD 09-10-26-16W3). The conglomerate consists of pebbles and coarser sand-grade clasts irregularly distributed throughout fine-grained, muscovitic sandstone with discontinuous mudstone interlayers. A downward decrease in grain-size with increase in proportion of mudstone interlayers was observed in the interval, and it is burrowed with Teichichnus present. In the Canus et al. N Verendrye 12 32 28 24 well (LSD 12-32-28-24W3), a coarsening-upward sequence is characterized by coarse sand, granules and pebbles scattered throughout sandy siltstone grading upward to conglomerate with sand matrix and calcite cement, and with mudstone partings.

Lithofacies 5- Shale

This lithofacies is scarce in the Viking Formation, observed only in the northeastern region at the Socony Sohio Darcy 28 1 well
(LSD 01-28-28-19W3). The thickness of the horizon is 0.3 m. The shale is light grey to bluish-white, bentonitic with variable fissility.

Lithofacies 6- Sandstone with subordinate mudstone intercalations

The lithofacies consist of sandstone and mudstone lithologies. It ranges in thickness from as low as 0.2 m to 5.5 m. The sandstone in these layers is predominantly fine-grained, though in some cases, it may exhibit localized concentrations of coarser sand and coalified wood fragments. Calcite is the main cementing material.

The mudstone part occurs in the form of continuous and discontinuous intercalations either separately or together. It is commonly carbonaceous, silty, sometimes with abundant flakes of coalified plant debris and fish remains.

In the southwestern region, the maximum thickness of the unit is slightly over 5 m, averaging about a metre. The coarser sands were observed in the Imperial Bayhurst 6 16 24 25 well (LSD 06-16-24-25W3) and at the Oliphant Nwrcq Gorefield 3 27 25 28 well (LSD 03-27-25-28W3). In places the sandstone layers incorporate ferruginous mudstone which range in thickness from 1.3 to 3.8 cm, as in the Phillips Husky Lestwyn No. 1 well (LSD 11-14-24-25W3).
The sedimentary structures associated with the sandstone are horizontal lamination, cross-lamination and burrowing. In the 10E Fairbanks 6 19 23 24 well (LSD 06-19-23-24W3), horizontal laminae and ripple cross-laminae were observed. The same structures were noted in the Imperial Bayhurst 6 16 24 25 well (LSD 06-16-24-25W3) including trough cross-laminae.

The mudstone form layers and partings which are frequently interconnected, and the continuous layers are up to 3 cm thick as in the Phillips Husky Lestwyn No 1 well (LSD 11-14-24-25W3). Burrowing with sub-horizontal sand-filled tubes is common, and the trace fossils Telchichnus, Phycodes, Spirophyton and Chondrites were observed in the Oliphant Nwrco Gorefield 3 27 25 28 well (LSD 03-27-25-28W3).

In the central region, the unit occurs in the Husky Phillips Marengo No. 2 well (LSD 10-27-28-27W3) where it is about a metre thick. The mudstone layers have been burrowed with sub-horizontal sand-filled tubes.

In the northeastern region, the unit occurs throughout the area, from Township 25, Range 17W3, to Township 28, Range 24W3. The maximum thickness is 5.5 m with an average of 3 m. In the Socony Sohio Bickleigh 14 13 well (LSD 13-14-27-18W3), the sandstone contain abundant mud matrix, framework grains to medium grade coarse sand and scarce pebbles which are incorporated as floating grains. At three localities, coarsening-upward sequences were noted in these intervals. For example, in the Sohio Standard Elrose No. 3 well (LSD 09-14-26-16W3), a
coarse-grained, pebbly sandstone with pyrite cement was observed in the upper part of the interval. At other localities, occurrences of conglomeratic sandstone, occasionally with pebbles coated with a black patina are also common at the top of the units, as in the Canus Amoco et al. Fair'm't 7 28 28 24 well (LSD 07-28-28-24W3). Conversely, the coarse-grained and pebble material may be concentrated at the base of the interval, as in the Imperial Brock 6 19 28 20 well (LSD 06-19-28-20W3). Pyrite concretions are also present in these intervals.

Abundant pelecypod debris in the sandstone were noted in the Tide Water Saltburn Crown No. 1 well (LSD 04-18-23-16W3).

Sedimentary structures are not pronounced. However, sets of sandstone laminae disrupted by burrowing were observed at the Socony Sohio Bickleigh 14 13 well (LSD 13-14-27-18W3), and cross-lamination in places in the Canus Amoco et al. Fair'm't 7 28 28 24 well (LSD 07-28-28-24W3). Other structures include the extensive burrowing with Teichichnus and Chondrites present in the Sohio Standard Darcy No. 1 well (LSD 15-22-28-19W3) and with Teichichnus and Phycodes present in the Socony Sohio Darcy 28 1 well (LSD 01-28-28-19W3).

An economic aspect of lithofacies is the presence of oil-staining observed in the Canus Amoco et al. Fair'm't 7 28 28 24 well (LSD 7-28-28-24W3).

The mudstone part become continuous and more numerous downwards in the coarsening-upward intervals.
Lithofacies 7- Alternation of sandstone and mudstone

The lithofacies is made up of approximate equal amounts of alternating sandstone and mudstone. The unit is scarce in places and shows a thickness variation in the area from 0.2 m to about 4 m.

In the southwestern region, the unit was observed in the Phillips Husky Lestwyn No. 1 well (LSD 11-14-24-25W3) only. The sandstone part is fine-grained, exhibiting cross-laminated and bioturbated layers with numerous mudstone partings. The mudstone, on the other hand, is silty and micaceous. However, in the central region, the unit is widespread with a maximum thickness of 2.1 m and averaging 0.7 m thick.

The sandstone part is fine-grained, quartzose and micaceous, while the mudstone is carbonaceous, silty, and micaceous with flakes of coalified plant debris, and in places pelecypod debris. Dark grey shale layers, which are argillaceous, slightly calcareous with siltstone laminae, are present in the Tide Water Saltburn Crown No. 1 well (LSD 04-18-23-16W3). Also an uppermost 7.5 cm of laminated bentonitic mudstone was observed in the Cox Warrior 13 4 27 25 well (LSD 13-04-27-25W3) in the lithofacies.

Lamination is the common sedimentary structure, with cross-laminated continuous layers in sandstone observed in the Cox Warrior 13 4 27 25 well (LSD 13-04-27-25W3), as well as burrowing with Chondrites and Phycodes in the same interval.
In the northeastern region, as in the southwestern, the 3.8 m thick horizon was observed at one locality only, in the Sohio Standard Elrose No. 4 well (LSD 09-10-26-16W3). The sandstone is fine-grained, muscovitic and occurs as sets and cosets of inclined laminae up to 2.5 cm thick near the top and as discontinuous laminae towards the base. The mudstone is dark grey and argillaceous, and increases in abundance downwards. No burrowing was observed in this lithofacies.

Lithofacies 8- Alternation of siltstone/sandstone and mudstone

Lithofacies 8 is widespread in the northeastern region of the study area where the maximum thickness of 10 m was observed. In the central and the southwestern regions, the unit was observed at one locality with a thickness of about 3 m and two locations with slightly over a metre maximum thickness respectively.

In the southwestern region, the lithofacies were observed in the Tide Water Abbey Crown No. 2 well (LSD 01-31-21-18W3) and at the Imperial Highbury 10 35 well (LSD 01-35-25-26W3). The siltstone/sandstone at the latter is well sorted, micaceous, often glauconitic, with development of nodular and stratiform pyrite concretions and a 7.5 cm ferruginous silty mudstone with siderite-filled spherulites at a depth of 721.2 m. They also exhibit cosets of truncated cross-laminae, while at (LSD 01-31-21-18W3), horizontal and gently inclined laminae were
observed. The mudstone of the Tide Water Abbey Crown No. 2 well is burrowed with straight, sub-horizontal, sand-lined, mud-filled tubes and *Chondrites*.

In the central region, the Cox Warrior 13 4 27 25 well (LSD 13-04-27-25W3) exhibits the siltstone/sandstone as flattened lenses and continuous layers up to 2.5 cm thick associated with horizontal and gently inclined laminae. The mudstone is laminated, micaceous and frequently silty with fish remains.

Other lithological associations are a 10 cm of ferruginous silty mudstone with siderite-filled spherulites occurring 7.5 cm below top interval, 5 cm pebbly mudstone at 5 cm above the interval base and nodular pyrite concretions associated with sandstones.

Lamination and burrowing with *Chondrites* and undetermined tubular forms are present.

In the northeastern region, the unit is widespread, ranging in thickness from 0.3 m to 10 m. The siltstone/sandstone occur commonly as flattened lenses and continuous layers up to 1.25 cm thick associated with horizontal and gently inclined laminae. They are generally fine-grained, though coarser grades have been observed at several localities. In the Sohio Standard Darcy No. 1 well (LSD 15-22-28-19W3), intercalations of coarse-grained sandstone incorporating chert granules and small pebbles were seen. Also in the Amhess Fairmount 11 25 28 24 well (LSD 11 25 28 24W3), the uppermost 2.5 cm of interval is characterized by intermittent laminae of coarse sand with scattered granules and
pebbles. Sometimes the basal part of the interval may incorporate layers of coarse-grained sand, granules and small pebbles with calcite and subordinate pyrite cement, and abundant flakes of plant debris as in the Canus et al.Kindersley 12 32 28 23 well (LSD 12-32-28-23W3). An upward grain-size decrease was observed in the Imperial Brock 7 31 28 20 well (LSD 07-31-28-20W3) and in the Hudson's Bay Rosetown 14 17 28 16 well (LSD 14-17-28-16W3).

The mudstone part, as in the Kamalta Plato 14 24 24 17 well (LSD 14-24-24-17W3), is in some places characterized by scattered chert granules and pebbles. Also, bentonitic mudstone commonly resting on ferruginous silty mudstone with siderite-filled spherulites are present.

Also common are ferruginous mudstones of varying thickness sometimes with siderite-filled spherulites, and nodular and stratiform pyrite concretions.

Sedimentary structures are mainly cross-lamination, horizontal or gently inclined lamination commonly interrupted by burrowing. For example, in the Amhess Fairmount 11 25 28 24 well (LSD 11-25-28-24W3), the sandy layers are frequently contorted, overfolded and interrupted. The main fossil assemblage in these intervals are Chondrites (most common), Phycodes and Teichichnus. Burrowing with flattened pyritized and sand-filled forms is commonly observed as well.

Oil staining is concentrated in Township 28, Range 24W3.
Lithofacies 9—Mudstone with subordinate siltstone and sandstone intercalations

Lithofacies 9 reveals variable thickness from 0.3 to slightly over 10 m. It becomes abundant from the southwestern region to the northeastern region.

In the southwestern region, the lithofacies was observed in the Imperial Highbury 10 35 well (LSD 10-35-25-26W3) in two separate intervals, between 718.1 and 720.5 m, and 722.5 and 723.3 m. The former interval reveals a high proportion of fine-grained sandstone layers, while the latter contain an increase in sand content in lowermost 15 cm. The sandstone has locally developed glauconite while mudstone is locally silty with fish remains.

The central region shows an increase in occurrence of the lithofacies compared to the southwestern region, with a maximum thickness of 5.2 m and averaging 2.5 m. The siltstone/sandstone occur in continuous and discontinuous layers exhibiting gently inclined or horizontal laminae, and in flattened lenses. The layers are up to 1.25 cm thick. It is generally fine-grained, though medium-grained with scattered coarse sand grains and small pebbles are locally present. In the Cnd-Sup Lacadena 6 21 23 16 well (LSD 06-21-23-16W3), the proportion of mudstone was observed to increase downwards, thus demonstrating an upward increase in grain size in the interval between 638.5 and 639.6 m.
Other lithological associations are the common occurrence of ferruginous mudstones with siderite-filled spherulites, ranging in thickness from 2.5 cm to 15 cm, and the development of stratiform pyrite concretions.

The mudstone part is dark grey, laminated and micaceous where silty, frequently with fish remains and concentrations of pelecypod debris.

The common sedimentary structures in these horizons are laminations (horizontal and gently inclined laminae). A 0.5 cm cross-laminated layer of sandstone with the erosional lower surface exhibiting stratiform pyrite development was observed in the Provo Pinkham No. 1 34 well (LSD 01-34-27-26W3). Burrowing is scarce. The other important feature is the widespread loading and injection phenomena in the Cnd-Sup Lacadena 6 21 23 16 well (LSD 06-21-23-16W3).

The northeastern region sees even more of an increase in occurrence of the lithofacies, with a maximum thickness of 10.1 m and an average of about 3 m.

The siltstone and sandstone layers are variable in occurrence, from sets of cross or horizontal laminae to continuous layers with horizontal and gently inclined laminae. Sometimes these layers are discontinuous or disrupted by burrowing. Texturally, the sandstone varies from fine- to coarse-grained, though fine-grained is predominant. Coarser-grained laminae, ranging from silt to nearly medium sand grade are observed in the Socony Sohio Richlea 11 7 well (LSD
7-11-26-19W3). In the Socony Sohio Bickleigh 14 13 well (LSD 13-14-27-18W3), a very coarse-grained sandstone 6.25 cm thick was seen. The sandstone consist of abundant pyrite as cement and cubic crystals with coarsest grains up to granule size commonly coated with black patina. Small pebbles and coarse sand grains in upward increasing proportions in the uppermost 0.3 m was observed in the Imperial Brock 11 17 28 20 well (LSD 11-17-28-20W3) between about 704.1 and 705.6 m. Also at this interval, the lowermost 20 cm is characterized by a conglomeratic layer which exhibits overall normal grading, with intercalations of ferruginous mudstone, and is cemented by pyrite in the coarsest part.

The mudstone, on the other hand, is argillaceous, silty in places or sandy as in the Marvel Kamalta Plato 14 7 25 17 well (LSD 14-07-25-17W3). Fish remains are common and include well preserved scales, as in the Socony Sohio Darcy 28 1 well (LSD 1-28-28-19W3). In the Imperial Brock 11 17 28 20 well (LSD 11-17-28-20W3) the mudstone is silty, often occurring in horizontal laminae, of variable fissility, with fish remains, and several layers of ferruginous silty mudstone up to 3.75 cm in thickness. The proportion of mudstone commonly decreases upwards.

Other lithological associations, are the many occurrences of stratiform pyrite concretions (often associated with thicker sandstone layers) and ferruginous mudstone sometimes with siderite-filled spherulites. Ferruginous mudstone which ranges
in thickness from 3.75 cm to over 13 cm thick, and a 7.5 cm thick bentonitic mudstone at 680.3 m in the Tide Water Platte Crown No. 10 well (LSD 11-30-25-17W3) were observed.

Sedimentary structures are again in the form of sets of cross-laminae or horizontal laminae as in the Socony Sohio Darcy 28 1 well (LSD 01 28 28 19W3) in sandstones. However, bioturbation is common with Chondrites and Teichichnus present. Flattened pyritized burrows and mud-filled sand-lined tubes were observed in the Hudson's Bay Rosetown 14 17 28 15 well (LSD 14-17-28-15W3).

Oil staining is concentrated in Township 28, Range 24W3, as it seems to parallel an increased proportion of continuous sandstone layers and lenses in this area.

Lithofacies 10- Alternations of mudstone and siltstone layers

The lithofacies is of limited occurrence in the study area, being observed at two locations throughout the area. The maximum thickness of the unit is 5.5 m in the northeastern region. The lithofacies was not observed in the southwestern region. Its first appearance is in the central region in the Imperial Centre Field 13 10 26 21 well (LSD 13-10-26-21W3) in two separate intervals, with a maximum thickness of 3.6 m. In the thick interval, an increase in the proportion of siltstone towards the top of the interval was observed. In fact, the uppermost 15 cm
of the interval incorporating coarse sand, granules and small pebbles, as well as fish remains, illustrates a coarsening-upward phenomena. Sedimentary structures are in form of flattened horizontal burrows with concentration of fish remains.

In the northeastern region area, the unit occurs in the Sohio Standard Elrose No. 4 well (LSD 09-10-26-16W3). The siltstone is very fine-grained and muddy, occurring as strongly cemented layers in uppermost 0.6 m, and becoming more friable and sandy toward the base. The mudstone occurs as argillaceous shales containing fish remains, pyritized and glauconitic tubular burrows.

4.3.1.1 Vertical Relationships

The lithologic contacts between the intervals were not consistently picked on the geophysical well logs because of their gradational nature. Consequently the change in thickness of the various lithofacies associations which is obvious from southeast to the northwest, is seldom ascribed to one single lithofacies. However, it is obvious that the sandstones of lithofacies 1 are replaced by other lithofacies through the addition of mudstone. This may be true of lithofacies 6, 7, and 8 and even 9.

Regarding the lithological contacts within lithofacies and lithofacies contacts, the following have been observed:
(i) The contact between lithofacies 1 and 4 in the Oliphant Nwrco Gorefield well (07-21-24-26W3) reveals an irregular, erosional contact with sporadic distribution of pyrite cement at the base of lithofacies 4 where it rests on lithofacies 1.

(ii) In the Marvel Kamalta Plato 12 7 25 17 well (LSD 12-07-25-17W3), a basal pebble layer of lithofacies 1 with a maximum clast size of 4.5 cm resting on an eroded surface was observed within the lithofacies.

(iii) Lithofacies 8 in the Williams Creek Greenan 11 2 26 17 well (LSD 11-02-26-17W3) occurring as flattened lenses and layers revealed erosional interfaces and gradational tops.

(iv) Lithofacies 8 in the Pennant Brock East 11 22 28 19 well (LSD 11-22-28-19W3) exhibited layers with erosional contacts.

(v) Lithofacies 8 in the Amhess Fairmount 11 25 28 24 well (LSD 11-25-28-24W3), the sandstone layers displaying a continuous grading to mudstone, with sharp basal contacts.

(vi) Lithofacies 8 in the Canus Amoco et al Fair'm't 7 28 28 24 well (LSD 7-28-28-24W3), shows the siltstone/sandstone continuous layers revealing sharp lower boundaries and occurring as isolated lenses.

These variation contacts suggest probable losses of some of the coarse lithofacies as they are being replaced by more finer lithofacies.
4.3.2 Areal Distribution

This section discusses the areal distribution of the three formations within the study area. The distribution is studied by constructing geophysical well log cross-sections to show the relationships between the formations across the area, and by constructing isopach maps of the individual formations to show detailed changes in thickness in plan view.

4.3.2.1 Cross-Sections

Four stratigraphic cross-sections oriented perpendicular to the general strike of the Viking Formation were constructed to show lateral relationships in the study area. The cross-sections are labelled "A" through "D", and their locations are shown in Figure 4.3. The cross-sections are drawn in a southwest-northeast direction.

In all log cross-sections, spontaneous potential (SP) logs are shown to the left-hand track and resistivity logs in the right-hand one. Correlations were made possible largely on the basis of the resistivity curve as it is a more reliable indicator of lithology than the SP curve in this area as previously discussed. All log cross-sections are drawn using the base of the Second White-Speckled Shale as a datum.

Cross-section A - A' shows the relationship of the Lower Colorado strata at the south-eastern end of the study area (Figure 4.4). The density of the wells in this part is relatively sparse, so the selection of the line of section was
Figure 4.3 Location of stratigraphic cross-sections.

1) location of wells; 2) wells with core description;
3) wells with drill-stem test data; 4) wells with both
core description and drill-stem test data.
Figure 4.4 Stratigraphic cross-section A - A'

Legend
1. Imperial Wet Zone 16 21 19
2. Tide Water Abory Crown No. 7
3. Tide Water Reenho Crown No. 4
4. Tide Water Saltburn Crown No. 1
5. CDN-SUP Lacadena 6 21 23 16
6. Tide Water Imperial Plate Crown No. 1
7. CDN-SUP Almirona Sanctuary 6 21 23 15
8. Cowansell Mound 17 9 24 15
directed to maximum usage of the wells present. The section begins in the Imperial Miry Creek 3 6 21 19 well (LSD 03-06-21-19W3) (A) and ends in the Cowzanol Mondou 12 9 24 15 well (LSD 12-09-24-15W3) (A').

Cross-section B - B' is one of the two cross-sections constructed to show relationships between strata in the southeast region of the study area where well density is higher (Figure 4.5). The line of the section was chosen so as to pass through the centre of the highest well density, elongated in the northwest-southeast direction covering the area between Township 24, Range 16W3, and Township 25, Range 19W3. However, a number of wells, particularly in the highest density area along the section line are not included in the section because they only penetrate the Viking Formation and therefore do not show the lower part of the Lower Colorado succession. The section starts in the Cdrs Sceptre 2 3 21 24 well (LSD 02-03-21-24W3) (B) and ends in the Jagor Siebens et al., Elrose 7 11 27 15 well (LSD 07-11-27-15W3) (B').

The location of cross-section C - C' was designed to divide the study area into two equal parts, the southeast and the northwest. It was also intended, as with cross-section B - B', to intersect the high well density areas of southwest-central and northeast-central. Consequently, most of the wells are not used in the construction owing to non-penetration of the strata below the Viking base. Nevertheless, the section has a maximum number of 23 control wells used (Figure 4.6). The section begins in the
Inter City Burstall No. 2 well (LSD 01-01-21-29W3) (C) and ends in the Hudson's Bay Rosetown 15 24 28 16 well (LSD 15-24-28-16W3) (C').

Cross-section D - D' was constructed to reveal the trend in thickness change for strata in the northwest part of the study (Figure 4.7). Again, as with the previous sections described, control wells not penetrating the lower part of the Lower Colorado Subgroup below Viking base are not included, except in some instances where it was felt that the wells could be used for Viking thickness purposes only. The section starts in the Saskoil Cuthbert 7 27 25 29 well (LSD 07-27-25-29W3) (D) and ends in the Gulf Fairmount 16 27 28 24 well (LSD 16-27-28-24W3) (D').

On cross-section A - A', the Viking Formation shows a remarkable change in thickness laterally, decreasing northeastwards (Figure 4.4). It has a maximum thickness of 33 m in Township 21, Range 19W3 (A), followed by a sharp decrease to about 21 m in Township 21, Range 18W3, a distance of about 12 km. Thereafter, the figure shows a gradual decrease in Viking thickness to 14 m in Township 23, Range 15W3, followed by a slight increase to 15 m in Township 24, Range 15W3 (A').

Cross-section B - B' (Figure 4.5) reveals a distinct decrease in thickness along the section from 33 m in Township 21, Range 24W3, to 13 m in Township 27, Range 15W3, at the other end of the section. However, a slight increase of about a metre occurs between Township 22, Range 23W3, and Township 22, Range 22W3, after, a decrease from 33 m to 27 m in Township 22, Range
Figure 4.7 Stratigraphic cross-section D - D'

Legend

1. Sapelli Cutback 7 27 25 29
2. Cutback No.1
3. Texaco Cutback 4 17
4. Pantonio No.1
5. Eyre No.1
6. Prave Pinneam No.2
7. Pinneam No.1
8. Phillips Husky Fairmount A No.1
9. Husky Phillips Fairmount A No.1
10. Phillips Husky Lynhurst No.1
11. Gulf Fairmount 16 27 28 24
23W3. Also noticeable is a sharp decrease in thickness of 6 m from approximately 25 m in Township 26, Range 21W3, to 19 m in Township 23, Range 21W3.

On cross-section C - C', the Viking Formation shows a distinct decrease in thickness from about 54 m in Township 21, Range 29W3, to 13 m in Township 28, Range 16W3, at the other end of the section (Figure 4.6). This trend is characterized first by an abrupt decrease to 27 m in Township 23, Range 26W3, then an increase to 32 m in Township 24, Range 25W3. This is followed by a sharp decrease in thickness to 22 m in Township 24, Range 24W3, which eventually gently decreases to the end of the section (C'). Nevertheless, the area between Township 24, Range 24W3, and Township 28, Range 16W3, is characterized by minor 'decreases' and 'increases' in thickness. These variations are illustrated by a decrease in thickness from 19 m in Township 25, Range 22W3, to below 16 m (15.5 m) in Township 26, Range 21W3, increasing again to over 16 m (16.4 m) in Township 26, Range 20W3. In addition an increase between Township 27, Range 18W3, and Township 28, Range 16W3, from below 15 m (14.7 m) to slightly above 15 m (15.1 m) in Township 28, Range 17W3, before decreasing to 13 m at the end is seen. These variations are attributed to sand development in the area.

Cross-section D - D' (Figure 4.7) demonstrates that the Viking Formation decreases in thickness northeastwards, from 34 m in Township 25, Range 29W3, to 13 m in Township 28, Range 24W3.
The only variation in this section is an increase from about 13 m in Township 28, Range 25W3, to 15 m in Township 28, Range 24W3, before dropping to above 13 m in the same area. Another noticeable change is a sharp drop in thickness from 32 m in Township 26, Range 29W3, to 23 m in Township 26, Range 28W3.

4.3.2.2 Isopach Map

An isopach map of the Viking Formation was constructed to show the detailed pattern of thickness distribution for the formation in the area (Figure 4.8).

Figure 4.8 shows a strong linear northwest-southeast contour trend for isopachs of the Viking Formation in the southwestern and central regions of the area. Deviations from this are evident in the northeastern part of the study. The northeastern part is characterized by isolated thickness closures which lack clearly defined trends. However, west-east trend in two separate thickness contours open to the north is evident in Township 28, Ranges 17 to 21W3, and Ranges 23 to 26W3. The closures vary from regular elongated to very irregular in shape and are either closures of local minima or maxima. Within the southwestern region, thickness closures follow the northwesterly trend. They occupy a central portion of the region from Township 21 and 22, Range 21W3 to Townships 24 and 25, Range 27W3.

Minor isolated and scattered thickness anomalies are
Figure 4.8 Isopach map of the Viking Formation:
1) Contour lines (contour interval 1.0 feet); 
2) Approximate limits of the facies belts (subregions).
identifiable in the central region and are prevalent towards the 16 m contour line. Notable ones are the minimum and maximum anomalies in Townships 22 and 23, Range 18W3, Township 23 Range 17W3, respectively.

The northwest-southeast contour trend is consistent with the distinct decrease in thickness from the southwest to the northeast as effectively shown by the stratigraphic cross-sections particularly cross-section C - C' (Figure 4.6). The formation has a maximum thickness of over 53 m reached in the extreme southwest corner of the area. This gradually decreases northeastwards, and then slightly rapid to the minimum thickness closures ranging from 24 to 31 m, with a northwesterly trend. This is followed by an increase to the maximum thickness of 36 m in Township 24, Range 25W3, and to over 37 m in Township 22 Range 21W3 separated in between by a saddle-like feature with a minimum thickness of 27 m in Township 22, Ranges 22 and 23W3. Thereafter a sharp decrease in thickness within a short distance of 5 to 10 km to a thickness of 21 m.

The central region sees a gradual decrease in thickness characterized by wide spaced contours until the 16 m contour line is met. To the northeast of this line, the general pattern of thickness decrease from 16 to 13 m in the northeast corner is still observed, though it is broken by local minima and maxima closures. In Township 28, Range 19W3, a decrease in thickness to 13 m is reversed by an increase to over 16 m in the northern edge
of the locality. Another isolated trend is the one shown in Township 28, Ranges 24 and 25W3, where a decrease from 16 to over 10 m is observed in Range 24W3. These variations are highlighted in the three-dimensional surface plot of the formation (Figure 4.9) which is rotated and viewed from the northeast facing to the southwest. The three-dimensional plots of isopachous maps should be viewed as representing variation in thickness of a formation from the base line (taken horizontal and not necessarily representing a paleodepositional surface) to the upper surface. Consequently, at a certain point on the plot, the height (from bottom to top) represents the thickness of the formation at that point.

4.3.3 Discussion and Summary

The above lithofacies description has revealed a varied lateral distribution of the lithofacies across the study area. These can be observed from the thickness distribution and areal occurrence of the lithofacies, and hence the following generalizations are possible:

(i) Lithofacies 1 and 4 occur commonly in form of thick units in the southwestern region of the study area, and becoming thin in the central region and thinner in the northeast.

(ii) Lithofacies 2 and 3 are generally very scarce in the southwestern region, but gaining in proportion both in thickness and occurrence in the central region and more so in the northeast.
Figure 4.9 Three-dimensional plot of the isopach surface of the Viking Formation.
(iii) Lithofacies 5 was observed only in the northeastern region and therefore could be assumed to be very scarce and scarce in the southwestern region and the central region respectively.

(iv) Lithofacies 6, 7, 8, 9 and 10 have all shown tendency to increase both in frequency of occurrence and thickness northeastwards.

Considering the main Viking Formation component which is lithofacies 1 - sandstone, and its role in lithofacies 6, 7, 8 and 9, it is reasonable to suggest that the decrease in thickness of lithofacies 1 is due to the incorporation of the other lithofacies into the sandstone unit. Depending on the amount introduced, this gave rise to lithofacies 6, 7, and 8 and even 9. In other words, lithofacies 1 is being lost across the area northeastwards. This assumption is clearly supported by the disappearance of the well defined 'shoulder-like' deflections on geophysical well logs in the central and northeastern region, so salient in the southwestern region, while the lower sand units were sustained throughout. This transition is responsible for the difficulty in delineating the top of the Viking Formation in the northeast.

General increases in proportion of occurrence and thickness of lithofacies 2, 3, 5, 6, 7, 8, 9 and 10 in the Viking Formation correspond to an increase in reservoir inhomogeneities in form of mudstone, shale and siltstone so introduced in the sandstone units, and hence a decrease in grain size northeastwards.
On the basis of thickness variation of the formation, three regions are distinguished: the thick Viking Formation southwestern region, intermediate central region, and the thin northeastern region (Figure 4.2). On the basis of inhomogeneities, the area can be subdivided into clean, relatively clean, and shaly and shales respectively. The thickness observation is most effectively shown in the isopach map. The 21 m contour line approximates the change in lithofacies from the thicker Viking Formation composed mainly of thick sand units with relatively small amounts of mudstone/shale intercalations to that of relatively thick sand units, with an increased amount of heterogeneities. Similarly, the 16 m thickness contour marks the onset of shales and shaly sandstones of the northeastern region. Consequently, the study area is subdivided into 3 subregions using the contour lines as arbitrary delineating lines (21 and 16 m isolines). The area to the southwest of 21 m contour is designated subregion A, the area between 21 and 16 m contours as subregion B, and beyond 16 m (northeastern part) as subregion C (Figure 4.10). Subregion A is made up of thick, well washed sands with coarsening-upward sequences. Subregion B is transitional as it is made up of relatively clean sands. Subregion C is composed of shaly sandstones and shales.

The second aspect of this discussion, concerns the wide variation in mode of occurrence of the five main lithologies namely sandstone, mudstone, siltstone, conglomerate and shale
Figure 4.10 Viking Formation generalized facies belts.
that constitute the Lower Colorado strata of the study. This variation was recognized in 1971 by Simpson in a study of the Lower Colorado strata of west-central Saskatchewan. This led to the formulation of a scheme of sequence elements (Table 2), based on gross lithology and sedimentary structures, which places emphasis on abundance and lateral continuity of shale breaks (primary reservoir heterogeneities).

This scheme was evaluated, and the lithofacies described were matched with the sequence elements of the scheme to allow for correlation of the study area to the regional setting.

Based on Table 2, the ten lithofacies in the study area are placed as summarized in Table 3. In addition, the table shows the variation of porosity and permeability (after Simpson, 1982b) in the sequence elements as well as their generalized lateral distribution across the study area.

Consequently, subregion A is characterized by thick, well washed coarsening-upward sequences which are plugged at the top of the sequences by mineral cements (mostly calcite) referred to as secondary heterogeneities. Subregion B is characterized by type-III and II, and subregion C by type-II, III and I. Primary heterogeneities in subregions A and B are given by the muddy parts of the bioturbated shaly sandstones (Type-III), bedded shaly sandstones (Type-II) and mudstone (Type-I). The coarse-grained upper parts of type-III exhibit secondary heterogeneities. Increase in mud content from southwest to the
Table 2. Sequence Elements, Based on Gross Lithologic Associations and Layer Properties, in Cores of Colorado Group in Saskatchewan (Simpson, 1984).

<table>
<thead>
<tr>
<th>Sequence Element</th>
<th>Sub-Element</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>V conglomeratic element</td>
<td>(c) pebbly mudstone</td>
<td>coarse traction load and lag concentrates of nodular and broken concretionary material</td>
</tr>
<tr>
<td></td>
<td>(b) conglomerate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) pebbly sandstone</td>
<td></td>
</tr>
<tr>
<td>IV sandstone element</td>
<td>(a) sandstone with dune-scale cross-lamination</td>
<td>continuous mudstone layers frequently intercalated; best original porosity usually plugged by cement (siderite, calcite, pyrite)</td>
</tr>
<tr>
<td></td>
<td>(c) sandstone with trough cross-lamination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) sandstone with ripple-drift cross-lamination</td>
<td></td>
</tr>
<tr>
<td>III muddy sandstone-siltstone element</td>
<td>(a) flaser-bedded sandstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) bioturbated sandstone</td>
<td>continuity of mudstone layers mostly disrupted by biogenic reworking</td>
</tr>
<tr>
<td></td>
<td>(b) bioturbated muddy sandstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) bioturbated muddy siltstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(d) wavy-bedded, composite layers of sandstone, siltstone and mudstone</td>
<td></td>
</tr>
<tr>
<td>II siltstone-sandstone element</td>
<td>(c) wavy-bedded simple layers of sandstone, siltstone and mudstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) alternating mudstone and sandstone/siltstone with low-angle, planar cross-lamination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) lenticular-bedded siltstone and sandstone in mudstone</td>
<td></td>
</tr>
<tr>
<td>I mudstone element</td>
<td>(c) subordinate siltstone and sandstone in lenses and scarce continuous layers</td>
<td>frequently incorporate coquinoïd layers, bentonitic mudstones, siderite and calcite concretions, nodular phosphorite</td>
</tr>
<tr>
<td></td>
<td>(b) subordinate siltstone and sandstone in flattened lenses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) structureless mudstone</td>
<td></td>
</tr>
</tbody>
</table>

1 Arbitrary lower limit of thickness set at 1.0 ft. for convenience in core description
2 No preferred vertical order of occurrence implied
Table 3

Summary of the Results of the Lithofacies Description in the Study Area
hp = horizontal permeability; vp = vertical permeability; d = darcies; md = millidarcies.

<table>
<thead>
<tr>
<th>SEQUENCE ELEMENTS</th>
<th>LITHOFACIES DESCRIBED</th>
<th>POROSITY (after Simpson, 1982b)</th>
<th>PERMEABILITY</th>
<th>LATERAL AND AREAL DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE-V</td>
<td></td>
<td>hp = several hundred millidarcies</td>
<td></td>
<td>Decrease in thickness across the area in the northeast direction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vp &lt; hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE-IV</td>
<td></td>
<td>hp = several hundred millidarcies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>vp &lt; hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE-III</td>
<td></td>
<td>hp &lt; 10 md (in coarse-grained upper parts)</td>
<td></td>
<td>Increase in frequency of occurrence and thickness northeastward across the area.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vp &lt; hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE-II</td>
<td>3, 8, 10</td>
<td>hp &lt; 100 md</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>vp &lt; hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE-I</td>
<td>2, 5, 9</td>
<td>hp &lt; 10 md</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POROSITY</td>
<td></td>
<td>-</td>
<td>25 – 35%</td>
<td>intermediate</td>
</tr>
<tr>
<td>PERMEABILITY</td>
<td></td>
<td>-</td>
<td>hp = few hundred millidarcies</td>
<td>hp = 0 – 800 md</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>intermediate</td>
<td>-2000 md</td>
</tr>
</tbody>
</table>
northeast across the area expressed in an increase of type-I, type-II and III elements gave rise to a decrease in porosity and permeability in this direction.

On a regional scale, the general trend of the Viking Formation in the study area is continuous to the southwest, and to the north-northeast as illustrated in Figure 4.2. The attenuation of the formation further to the northeast indicates a northeasterly depositional trend.

This division of the study area into three lithofacies belts (Subregion A, Subregion B, and Subregion C) correlates well with the regional facies setting of the Viking Formation of Evans (1970). Interpretations of the above variation in terms of depositional history are given in Section 4.5.

4.3.4 Detailed Structure

The structure in the study area, for the greater part, is one of low "rolling" structural relief, lacking well defined trends (Figures 4.11 and 4.12). However, it is characterized by domal and basinal structural features.

The structure contour maps were constructed on the top (Figure 4.11), and the base (Figure 4.13) of the Viking Formation. For purposes of comparison, structure contour maps on top (Figure 4.14) and base (Figure 4.15) of the Lower Colorado Subgroup, taken at the top of the Big River and Mannville Formations respectively, were constructed as well. The map for the top of the Viking Formation was used as the reference format,
Figure 4.12 Three-dimensional plot of the structure surface of the top of the Viking Formation.
Figure 4.13 - Structure contour map of the base of the Viking Formation. The contour lines (contour interval = 5 m).
for description purposes and from which comparisons were made to the other maps. Descriptions of the structures are given according to the subregions reached in the sections on lithofacies descriptions and areal distribution (Subregion A, Subregion B, Subregion C).

Figure 4.11 shows the structure contour map on top of the Viking Formation. The three-dimensional plot of structure surface of the Viking Formation is given in Figure 4.12.

Subregion A

Domesal structures in this area are limited to two: the Bayhurst high with a well defined southeast-northwest trend (from Township 23, Range 24W3, to Township 25, Range 27W3) and the Abbey-Lacadena high with a north-south trend (Township 21, Range 19W3, to Township 22, Ranges 19 and 20W3) and a northwest extension.

The Abbey-Lacadena domes are separated from the Bayhurst high to the west by a broad saddle-like feature in the area. The saddle has its centre in Riverfront No. 1 well (LSD 01-29-23-22W3) with a relief of 17 m below sea level. The Abbey high is described below under subregion B.

The Bayhurst high is a domal structure with a closure of 32 m from 16 m below sea level to above 16 m in the Imperial Bayhurst 13 10 24 25 control well (LSD 13-10-24-25W3). Recent data, indicates that the areal extent of the Bayhurst dome is about 430 km^2. To the southeast and northwest, the beds dip
1.2 m/km while to the south and north, the dip ranges from 2.8 to 3.4 m/km. The dip is about 2 m/km in the west and 5 m/km in the east.

A domal structure trending northeast-southwest connecting control wells Inter City Burstall No. 2 (LSD 01-01-21-29W3) and Baysel Mobil Captet Leader 11 29 (LSD 11-29-22-27W3) occupies the southwestern corner of the map. The dome separates the parallel-oriented syncline to the southeast, and the broad Cabri syncline to the northwest. This interpretation seems to agree with an earlier interpretation by Kamen-Kaye (1953, in Jones, 1961a) rather than the one given by Jones (1961a). The interpretation is further supported by additional recent data.

Subregion B

The most noteworthy feature in this area is the Cabri basin (Township 24, Range 20W3) to the west and north of the Plato and Abbey-Lacadena domes respectively. The basin is defined by the Phillips Husky Guth No. 1 well (LSD 11-29-24-20W3) with a minimum elevation (relief) of 40 m below sea level. It has a closure of 20 m from 40 m below sea level, and extends broadly to the west, and north. The Abbey Lacadena-Plato domes form a broad structure in the southwest of the area, from the Plato dome centred in Township 24, Range 17W3, extending southwestwards to the Abbey high, centred at junction of Townships 21 and 22, Ranges 19 and 20W3.
Southwards of the Plato dome, beds dip at 1.5 m/km, extending down to their lowest elevation of about 50 m below sea level in the Rothwell Socony Matador 1 15 21 15 well (LSD 01-15-21-15W3). To the north, the Plato dome extends to the two domes described below, and steeply descends into a basin to the northeast. The dip is about 4 m/km. Owing to additional well control, the ill-defined Abbey-Lacadena high (Jones, 1961a) can now be considered as separate entity from the Plato dome. They are connected by a saddle-like feature. The Abbey high extends southwards to occupy the southeastern end of the subregion A.

The Plato dome (Township 24, Range 17W3) has a closure of about 10 m, from 5 m below sea level, with maximum relief of 6 m given in the Tide Water Imperial Plato Crown No. 7 well (LSD 10-29-24-17W3). The Abbey-Lacadena dome, on the other hand, has a maximum elevation of 0.3 m below sea level, with probably closure of 5 m from 5 m below sea level.

Other features include the minor domes of Warrior (Township 27, Range 25W3), and Alsask (Township 28, Range 28W3). Generally, subregion B is bounded by the domal structures. Good examples are the north and northeast flanks of the Bayhurst high and flanks of the Glidden-Inglenook dome described later in subregion C.

The Warrior dome is centred on a maximum relief of above 2 m below sea level given by Phillips Husky Warrior No. 1 well (LSD 11-09-27-25W3) with a closure of 6 m from 8 m below sea level.
The Alsask dome occurs in the west-central of Township 28, Range 28W3. It has a maximum elevation of 2 m below sea level centred on Alsask No. 1 control well (LSD 10-07-28-28W3), with a closure of 4 m from 6 m below sea level. South of the Alsask and Marengo domes, a broad syncline flanks them with a probable centre in the vicinity of the Townships 25 and 26, Range 29W3.

Subregion C

Subregion C is characterized by a belt of "high" structures separated by synclinal structures. The "highs" show a roughly northeast-southwest trend, with some being limited in areal extent. The synclinal structures are more or less oriented in the same directions as the highs, except in area around Township 28, Ranges 25 and 26W3, where a synclinal axis has a northwest-southeast trend.

The first of these structures is a synclinal feature which runs from the top northeast corner of Township 28, Range 15W3, through the controlling well of Hudson's Bay Rosetown (LSD 15-24-28-16W3) with elevation of 27.7 m below sea level, down southwestwards to include the two control wells of Chaplin Plato 9 2 27 17 well (LSD 09-02-27-17W3) with a relief of 33.5 m below sea level and Chaplin North Plato 11 11 27 17 well (LSD 11-11-27-17W3) with an elevation of 30.1 m below sea level. This is flanked by a broad "high", with the domes of Chipperfield, Totnes, and Darcy to the west superimposed within it. The high covers an area of approximately 325 km^2.
The Chipperfield dome, occupies about 55 km$^2$ of an area, centred in Township 28, Range 17W3. Maximum elevations of over 11 and 13 m above sea level are given by the control wells of Socony Sohio Chipperfield A 15 16 (LSD 06-15-28-17W3) and Spc Totnes 11 22 28 17 (LSD 11-22-28-17W3) respectively. It has a closure of 11 m from about 2 m above sea level.

The Totnes dome (Township 28, Range 18W3) lies to the southwest of the Chipperfield dome. The dome has a maximum relief of 11 m in Homestead Penn Totnes 10 9 28 18 well (LSD 10-09-28-18W3). It is of much greater in areal extent than previously assumed by Jones (1961a). The dome extends southwestwards to the east-central part of Township 27, Range 19W3, with a closure of about 10 m from 2 m above sea level. To the south, it is separated by a saddle-like feature at the junction of Township 26 and 27, Range 18W3, from the northern extension of the Plato dome. The northern extension of the Plato dome shows two superimposed domes; one in Township 26, Range 17W3, the other to the west in Range 18W3. Both have a maximum elevation of over 4 m above sea level given by the Jagor Greenan 6 14 26 17 well (LSD 06-14-26-17W3) (4.8 m) in the east, and by the Z. D. Penn Petrody Plato LSD 07-14-26-18W3 (4.3 m) to the west. The two domes are connected to the main Plato dome by an anticlinal feature, which is flanked to the west by a basin. To the southwest, beds drop gently into the Cabri basin centred in Township 24, Range 20W3.
The basin to the southeast of the two domes is centred in the Husky Wartime 7 29 25 16 control well (LSD 07-29-25-16W3), extending northeastwards to include Inc. Husky Plato 7 22 26 16 (LSD 07-22-26-16W3) with an elevation of 24 m below sea level, and southwestwards to Tide Water Crown Plato No. 11 well (LSD 11-11-25-17W3) with an elevation of 37 m below sea level. The minimum elevation (which happens to be the lowest minimum in the study area) is 98 m below sea level in the centre well (LSD 07-29-25-16W3). Owing to lack of data, Jones (1961a) interpreted this as a syncline open to the southeast. However, the present interpretation confirms his assumption that the syncline may be of limited extent. Addition of a control well (LSD 07-22-26-16W3) in the area eliminates the notion that the Elrose dome is connected to the Plato dome by an anticlinal structure. It is apparent that the Elrose dome, trending northwestward from Township 26, Range 15W3, to the west of Range 16W3, is a separate structure. The Elrose dome has a maximum elevation of about 6 m above sea in the Sohio Standard Elrose No. 2 well (LSD 11-18-26-15W3).

The Darcy dome (Township 28, Range 19W3) is situated further to the west of Chipperfield separated by a relatively low-lying area defined by the Socony Sohio Totnes 21 5 well (LSD 05-21-28-18W3) (1.3 m below sea level) and the Saskoil Totnes N 6 21 28 18W3 well (LSD 06-21-28-18W3) (1.8 m below sea level). The dome continues northeastwards into Township 29 (Jones, 1961a).
The Darcy-Chipperfield anticline is separated from the western highs by a syncline trending southwest-northeast passing from Township 28, Range 19W3, through Range 20W3, southwestwards into Township 27, Range 20W3. The syncline has minimum relief of 25 m below sea level in the ZD HB Petrody Brock 11 23 28 20 well (LSD 11-23-28-20W3). To the west of this, the Glidden-Brock high, an elongate, relatively narrow, irregularly shaped anticlinal structure is situated. Jones (1961a) termed it the Glidden-Brock anticlinal structure.

The Glidden-Brock high is bounded by the 5 m below sea level contour, with a general east-northeasterly trend from Township 28, Range 20W3, through 21W3, to Township 27, Range 21W3, through 24W3, slightly extending down into Township 26, Range 23 and 24W3. Superimposed upon this are two domes: the Brock dome (Township 28, Range 20W3) to the northeast, and the Glidden-Eatonia-Inglenook dome (Township 27, Range 22 through 24W3) to the southwest. The Glidden and Inglenook domes considered as separate structures by Jones (1961a) through a zero metre structure contour, in fact, cannot be demarcated by this contour. The addition of the wells Husky Glidden 7 17 27 23 (LSD 07-17-27-23W3) and ZD HB Petrody Glidden 11 25 27 23 (LSD 11-25-27-23W3), the area bounded by the zero structure contour of Jones (1961a), is apparently of maximum elevation given by 5 and 4 m above sea level with respect to the two wells. Therefore the Glidden and Inglenook domes are considered as one dome in this
study. The Brock dome in the area has the maximum elevation, and a closure of above 11 m reached in Imperial Brock 6-19V-28-20W3 well (LSD 06-19-28-20W3).

To the southwest of the Glidden-Eatonia-Inglenook dome, there is a gentle dip of 0.9 m/km into the saddle-like feature in Township 25, Range 25W3. However, to the south, the dip is slightly steeper at 1.3 m/km leading into the Cabri basin, but much gentler in the southeast into the north extension of the Cabri basin. Steeper dips ranging from 2 to 3 m/km are evident in the north and northeast.

The Lynnhurst dome (Township 28, Range 24W3) is separated from the Glidden-Brock high by a northeast-southwest trending syncline in the east, and from the Marengo-Alsask domes by the northwest-southeast trending syncline.

The Lynnhurst dome has a maximum relief of 6 m in the Fairmount et al. Kindersley 13 13 28 well (LSD 13-13-28-24W3) and the Canus et al. S Fairmount 16 14 28 24 well (LSD 16-14-28-24W3). The dome extends northwards into Township 29, and in the south, it extends westwards forming a nose. A closure of 11 m is estimated from 5 m below sea level.

The Marengo dome (Township 28, Range 27W3), also extends northwards into Township 29, with the maximum relief of 0.6 m below sea level given by the Husky Phillips Marengo No. 2 well (LSD 10-27-28-27W3).
Two structure log cross-sections were constructed (Figure 4.16); one (A - A') in the south of the study area connecting the Bayhurst dome, the northern extension of the Plato dome and the Elrose dome, the other (B - B') connecting the northern domal structures. The latter trends west-east from Range 29 to 15W3, Township 28.

Cross-section A - A' (Figure 4.17) starts in the Cabri syncline in Township 23, Ranges 28 and 29W3 (A - Highwood Precision Esty 10 23 23 29 well (LSD 10-23-23-29W3) into Bayhurst dome, then dropping into the western extension of the Cabri basin in Township 24, Range 24W3. Thereafter, is the northwesterly striking anticline before dropping into the Cabri basin. This is followed by the northern extension of the Plato dome and then steeply dropping into a conspicuous basin in Township 25, Range 16W3. A comparatively steep rise to the Elrose dome in the (A') ZD HD Petrody 10 5 26 15 well (LSD 10-05-26-15W3) is observed.

Cross-section B - B' (Figure 4.18) starts in the Alsask dome (A - Allied Embassy Alsask 11 12 28 29 well (LSD 11-12-28-29W3) intersecting the numerous domes and synclines as described up to the syncline in Township 28, Range 16W3 (A' - Hudson's Bay Rosetown 15 24 28 16 well (LSD 15-24-28-16W3).

4.3.4.1 Comparisons to other structure maps

The above interpretation of the structure on top of the Viking Formation, when compared to the other constructed contour plots (Figures 4.12, 4.13, and 4.14), showed to a large extent
Figure 4.16 Location of the structural cross-sections.
1) location of wells; 2) wells with core description;
3) wells with drill-stem test data; 4) wells with both core description and drill-stem test data.
similarities in the structural outlines, both domal and synclinal features. Where differences exist, these are attributed to a reduced number of control wells particularly to the underlying formations as most control wells were stopped within or just below the base of the Viking Formation. Consequently, the structures are somewhat subdued as they may be defined by a limited number of wells, sometimes even by one well. However, on the top of the Lower Colorado Subgroup (Figure 4.14) where well density is even higher, a noticeable change includes the appearance of two domes superimposed in the Bayhurst high in subregion A. One of these domes is in the north, with an almost east-west trend and the other in the south with a northwest-southeast trend. Apparently, similar domal structures are observed on the base of Viking Formation structural plot (Figure 4.13).

On the base of the Lower Colorado Subgroup (Figure 4.15), owing to reduced well density control, the greatly subdued regional dip on Figure 4.11 is more obvious here. The regional southerly dip ranges from 2 to 7 m/km.

The three-dimensional surface plots of these structures (Figure 4.19) correlates well with the top of Viking surface plots (1). Close examination of the plots shows spatial coincidence in both domal and basinal features. Minor variations that exist on the base of the Lower Colorado plot such as the absence of the 'V-shaped' synclinal feature seen in the top northeast corner of each of the three plots can be explained by a
Figure 4.19 Three-dimensional plot of the structure surface of the: 1) top of the Viking Formation; 2) base of the Viking Formation; 3) top of the Lower Colorado Subgroup; 4) base of the Lower Colorado Subgroup.
reduced number of control wells on this plot. Spatial coincidence of the structures on the structure maps strongly suggests that any variation on these plots is due to amount of data used rather than differences in structural setting. It also suggests that the structure in the area is a result of 'drape folding' (Jones, 1961a).

4.3.4.2 Basement-related structures

The present structure and configuration of the depositional systems in the study area were influenced by structural controls which are features of deep-seated origin complexly interrelated in origin. According to Christopher et al. (1971) and Simpson (1979a, 1982b, 1984a, b) the regional structures can be summed up as follows:

(i) Basement linear features of regional extent which are defined by major northeast-trending and subordinate northwest-trending and subordinate northwest-trending gravity anomalies;

(ii) Basement linear features of local extent which are also defined by northeast and northwest trending gravity anomalies that delineate fractures marking the boundaries of basement blocks that have undergone differential movement;
(iii) Solution collapse features associated with the Prairie Evaporite (Middle Devonian) which reflect the influence of deep-seated northeasterly and northwesterly trends; and

(iv) The palaeotopography of the sub-Cretaceous unconformity which was to a large extent controlled by (i), (ii) and (iii) resulting in marked variations in elevation.

In the study area, the structure is that of 'rolling' nature characterized by drape-folding over local 'domes' or highs as described under the section on structure (Figure 4.20). Basement linear features defined by gravity gradients are presented in the study by a negative margin that nearly divides the area into two from Township 21, Range 23W3, to Township 28, Range 21W3. A structural linear trending easterly from Township 24, Range 29W3, to Township 25, Range 15W3, is observed. The other occurs in the southeast corner of the area trending northeasterly. Proximity of the study area to the northeasterly trending Sweetgrass Arch has greatly influenced the deposition of the sediments and shaped the development of the local structural features.

The study area is within the area occupied by the Prairie Evaporite salt. Local salt solutions evident from seismic anomalies occur in Township 24, Ranges 22 and 23W3, and 19 and 20W3, and Range 15W3, centred on boundary of Townships 27 and 28 (Simpson, 1984b). Sinks also indicate development of local
Figure 4.20 Dominant structural features in relation to basement features, solution-generated structures, and lithology.
1) edge of Jurassic strata; 2) boundary of the Viking facies belts (subregions); 3) dome; 4) synclinal structure; 5) anticlinal structure; 6) structural linears; 7) gravity gradient showing negative margins; 8) Prairie Evaporite salt present; 9) local salt solution (seismic anomaly); 10) sinks.
solution-generated collapse structures. The salt solution anomaly in Township 24, Ranges 19 and 20W3, coincides with two of the sinks.

Subcrop is represented in the area by the edge of the Jurassic strata which passes through Township 21, Range 28W3, Township 22, Range 27W3, then following the boundary between Township 22 and 23, across subregion A to the eastern edge in subregion B.

The palaeotopography of the sub-Cretaceous unconformity which was controlled to a large extent by basement structural and solution-generated collapse features (Christopher et al., 1971) are responsible for the local structure of domes and synclines in the study area (Figure 2.1). These structures influenced the distribution of formation fluids such as hydrocarbons in the area.

4.3.4.3 Discussion and Summary

The structure in the study area, interpreted as one of 'rolling' structure with a southerly regional dip, ranging from 2 to 5 m/km as depicted in the southern part of the study, is characterized by the existence of domal and basinal structures (Figure 4.20). Spatial coincidence of the structure throughout the Lower Colorado succession is indicative of 'drape folding', due to compaction.
The description of these structures according to the subregions (A, B, and C) based on lithological variation makes a very close correlation between the structure and the Viking thickness variation.

In subregion A, the southeast-northwest trend of the Bayhurst high and the northwest extension of the Abbey-Lacadena dome seems to agree well with the northwesterly trend of the Viking Formation thickness. The saddle-like feature that connects the two domes, occupies an area that shows a disturbed Viking thickness in that it is of minimum thickness.

In subregion B, the western extension of the Cabri basin has its western edge coinciding remarkably with the boundary of subregion A and subregion B on the isopach map (Figure 4.20). The basin is centred in broadly spaced contours of the Viking Formation thickness averaging 17.5 m in Township 24, Range 20W3.

Subregion C, where numerous domes occur, shows the domes to be characterized by thickening of the formation with the deepest syncline in Township 25, Range 16W3, being associated with minimum Viking thickness of 13 m. Consequently, the Viking thickness variation of this area, often characterized by isolated closures, shows the closures to be closely related to the domal structure closures. This is also true in subregion A, where structural features could easily be linked to thickness anomalies particularly in the Bayhurst area.
These correlations are also generally applicable to the structural plots on top of the Lower Colorado Subgroup (Figure 4.14) and base of the Viking Formation (Figure 4.13).

4.4 Joli Fou Formation

4.4.0 Introduction

The Joli Fou Formation, Middle Albian in age, forms the base of the Lower Cretaceous Colorado Subgroup. In the study area, the formation consists of Joli Fou Mudstone underlain by the Spinney Hill Sandstone which is present in the central and eastern parts of the area.

The formation attains a maximum thickness of 56.1 m in Townships 24 and 25, Range 29W3. Lithologically, it is composed of dark grey, non-calcareous shale, with minor interbedded fine- and medium-grained sandstone. The sandstone occurs as lenses, commonly a few millimetres in thickness, composed of horizontal or very gently inclined laminae. Bioturbated, shaly sandstone forms scarce layers, several centimetres thick. In the upper part of the formation, the interbedded sandstone is quartzose and micaceous, while near the base, glauconitic sandstone and quartz arenite are common. Subordinate lithologies include bentonite, pelecypod coquinas, nodular phosphorite, and concretionary layers of calcite, siderite and pyrite (Simpson, 1982b).

The Joli Fou Mudstone exhibits a north-northeastward decrease in thickness.
The Spinney Hill Sandstone is named after the Spinney Hill No. 1 well (LSD 16-24-40-14W3), drilled near Spinney Hill, Saskatchewan. The new type well, designated by Edwards (1960), is the Liberal Canadian Southern New Devon Skyline No. 2 well (LSD 03-06-37-16W3).

4.4.1 Lithofacies Description
Core distribution in the Joli Fou Formation is erratic as in most cases coring was concentrated on the Viking Formation, especially the top part of it. This resulted to only one well cored in this formation in subregion A; three in subregion B and thirteen in subregion C. It is seen that a large number of cored wells exist in subregion C and this could be attributed to the shaly nature of the top of the Viking Formation, and therefore coring was directed to the lower sand horizons of the formation. This in some cases warranted over-coring into the underlying Joli Fou Formation. However, these wells are limited only to the Joli Fou Mudstone except for one well in the study area that penetrated to the Spinney Hill Sandstone.

Joli Fou Mudstone
Lithofacies 1- Sandstone
This lithofacies was not observed in subregion A and subregion B, but it is present at two localities in the Cdn-Sup Alminex Sanctuary 6 31 23 15 well (LSD 06-31-23-15W3) and in the Imperial Brock 6 19 28 20 well (LSD 06-19-28-20W3) in
subregion C. However, its thickness is minimal with only 30 cm as the maximum, and it has a high content of mud. The lithofacies is generally fine-grained, but scarce scattered chert pebbles and fish remains are also present in the former.

Lithofacies 2- Mudstone

The lithofacies range in thickness from as low as 0.3 m to 14 m. The mudstone is dark grey, predominantly argillaceous, with fish remains and occasionally pelecypod debris.

In the Imperial Highbury 10 35 well (LSD 10-35-25-26W3) in subregion A, only 2.5 m thick of core is composed of mudstone, while in subregion B the horizon was observed only in the Husky Phillips Madison 4 29 26 22W3 well (LSD 04-29-26-22W3). At the latter, the mudstone is silty and blocky.

In subregion C, the unit shows a range of thickness from 2.4 to 14 m and it was intersected in 4 wells between Township 26, Range 16 and Township 28, Range 19W3, inclusive. The mudstone, locally, may incorporate intercalations of fine-grained, glauconitic sandstone and siltstone.

Lithofacies 5- Shale

The shale unit was observed only in subregion C in the Schio Standard Elrose No. 3 well (LSD 09-14-26-16W3) with a thickness of 7.4 m. The shale is dark grey, argillaceous, with fish
remains. At 638.4 m, a 1.25 m thick laminated sandy siltstone layer separates two thin layers of chert pebbles within the interval.

Lithofacies 8- Alternation of siltstone/sandstone and mudstone

The maximum thickness of the lithofacies is 4.6 m in the Kamalta et al. Plato 12 34 24 17 well (LSD 12-34-24-17W3) in subregion C, where it occurs. It has an average thickness of about 2.5 m.

The sandstone part is very fine-grained, occurring in flattened lenses and continuous layers up to 2.5 cm thick, as in the Imperial Brock 6 19 28 20 well (LSD 06-19-28-20W3) while the mudstone is predominantly dark grey, silty in places with fish remains.

Lithofacies 9- Mudstone with subordinate siltstone and sandstone intercalations

The unit varies in thickness from 1.2 to 7.4 m, with widespread occurrence in subregion B and subregion C. The dominantly mudstone part is dark grey, silty and micaceous in places, with fish remains, while the siltstone/sandstone part is light olive grey, quartzose, micaceous, and slightly glauconitic in places. They occur in form of flattened lenses, continuous layers, and as gently inclined or horizontal laminae of variable thickness.
In subregion B, the maximum thickness of 5.5m is recorded in Husky Phillips Madison No. 1 well (LSD 04-29-26-22W3). Relatively coarse-grained intercalations of sandstone sometimes may include well sorted cosets of sandy cross-laminae and very muddy, bioturbated fine-grained sandstones as in the Imperial Glidden 7 33 26 23 well (LSD 07-33-26-23W3). Lithological associations include a light bluish-grey bentonitic mudstone layers in the LSD 04-29-26-22W3.

Subregion C shows the most widespread occurrence of the unit from Township 23, Range 15W3, to Township 28, Range 24W3. It has a maximum thickness of 7.4 m in the Cnd-Sup Alminex Sanctuary 6 31 23 15 well (LSD 06-31-23-15W3) with an average of about 4 m. The mudstone may contain plant fragments as observed in the Canus et al. S Fairmount 16 14 28 24 well (LSD 16-14-28-24W3). In the Cdn-Sup Alminex Sanctuary 6 31 23 15 well (LSD 06-31-23-15W3), between 605.9 and 613.3 m, several contorted laminated fine-grained sandstone layers up to 2.5 cm thick, with scattered chert pebbles were seen. Also a 3.75 cm cross-laminated, fine-grained sandstone with Spirophyton species is noted at 700.4 m in the Amhess Fairmount 11 25 28 24 (LSD 11-25-28-24W3). Bioturbation is the common sedimentary structure.

Spinney Hill Sandstone

The Spinney Hill Sandstone forms the lower part of the Joli
Fou Formation. In the study area, the sandstone was observed at one location in subregion B, in the Imperial Netherhill 11 17 27 21 well (LSD 11-17-27-21W3). At this locality, lithofacies 1 was not present. However, Simpson (1982b) described the Spinney Hill Sandstone as a greyish green and dusky yellowish green, very fine to coarse-grained, glauconitic sandstone interbedded with dark grey, non-calcareous repetitive, fining-upward sequences, each several metres thick. These sequences are composed of cross-laminated sandstone with minor, intercalated shale, replaced upward by regular alternations of sandstone and shale.

Lithofacies 6- Sandstone with subordinate mudstone intercalations

The sandstone is generally light grey, fine grained, though between 759.0 and 760.2 m, it is predominantly medium grained. It is fairly well indurated, quartz rich, micaceous occurring in composite cross-laminated layers up to 7.5 cm thick, often with biogenic disruption. In the same interval, the sandstone is glauconitic in places, with calcite cement and it incorporates abundant shell debris. The mudstone is dark grey and silty in places. The intervals locally exhibit fairly extensive burrowing with Chondrites and indeterminate sand-filled tubes.

Lithofacies 7- Alternation of sandstone and mudstone

The sandstone in these intervals is light olive grey to greenish grey, occurring in layers, sometimes as composites up to
5 cm thick with discontinuous mudstone intercalations. Between 748.3 and 759.0 m, the layers are made up of sets of cross-laminae which are locally disrupted. Mineralogically, it is predominantly quartzose, micaceous, slightly glauconitic, occasionally with high proportion of glauconite grains. The sandstones are extensively burrowed with Chondrites present as well as indeterminate mud-filled tubes and sand-filled tubes.

The mudstone part is dark grey, silty in places with abundant pelecypod debris.

Lithofacies 9- Mudstone with subordinate siltstone and sandstone intercalations

The mudstone is dark grey, horizontally laminated and where silty in places, pelecypod debris are present. The siltstone/sandstone is light grey, commonly in cross-laminated layers up to 2.5 cm thick, with erosional interfaces between 771.8 and 775.1 m. Extensively burrowed layers and flattened lenses, and also medium-and coarse-grained sandstone in scarce lenses are present. Chondrites and indeterminate straight and branching sand filled tubes are the characteristic burrow forms.

4.4.2 Areal Distribution

The distribution of the Joli Fou Formation, Joli Fou Mudstone and Spinney Hill Sandstone is described in this section based on log cross-sections and isopach maps.
4.4.2.1 Cross-sections

Joli Fou Formation

The lateral distribution of the Joli Fou Formation is described below followed by the distribution of the members. Similar stratigraphic cross-sections are used here as outlined in Section 4.3.2.1 under the Viking Formation. All cross-sections run from southwest to the northeast.

Cross-section A - A' (Figure 4.4) shows a decrease in thickness of the formation from 55 m in Township 21, Range 19W3, to an average of 43 to 45 m in Township 24, Range 15 and 16W3.

Cross-section B - B' (Figure 4.5) reveals a thickening from slightly over 47 m in Township 21, Range 24W3, to a maximum of 54 m in Township 23, Range 20W3, and then thinning to a low of 41 to 42 m in Townships 25 Range 17W3, and 26 Range 16W3, respectively.

Cross-section C - C' (Figure 4.6) shows a general increase though with a variation from 41 m in Township 21, Range 29W3, to a maximum of 53 m in Township 23, Range 26W3, and then thinning to 31 m in Township 28, Range 17W3.

Cross-section D - D' (Figure 4.7) shows a variation of increase and decrease in thickness with the maximum of 55 m in Township 26, Range 29W3, and a minimum of only 44 m in Township 28, Range 25W3. Overall, the thickness changes in this area is very minimal.
Joli Fou Mudstone

Cross-section A - A' (Figure 4.4) shows a dramatic decrease in thickness of mudstone from 28 m in Township 21, Range 19W3, to 17 m in Township 24, Range 16W3, from here an increase of about 2 m is observed, to 19 m in Township 23, Range 15W3.

Cross-section B - B' (Figure 4.5) shows a general decrease in mudstone thickness, first starting with thicknesses ranging from 47 to 50 m in the Townships 21 and 22 Ranges 24 and 23 respectively, then dropping sharply to slightly over 23 m in Township 22, Range 22W3. This is followed by an increase in thickness of over 3 m to 26.6 m in Township 23, Range 20W3, then a decrease to 14.6 m in Township 26, Range 16W3. The maximum thickness in the first wells (Figure 4.5) are due to the absence of the Spinney Hill Sandstone in this area.

The mudstone shows a variation in thickness along the cross-section C - C' (Figure 4.6). However, the general trend is that of a decrease in thickness towards the northeast. It starts with an increase from 41 m in Township 21, Range 29W3, to 52 m in Township 23, Range 27W3, then a decrease to 46 m in Township 23, Range 26W3, accompanied by an increase to 53 m in the same locality. A slight drop to over 50 m in Township 24, Range 25W3, is observed followed by a sharp decrease of about 23-24 m to 27-28 m in Township 24, Range 24W3. This sharp decrease in thickness can again be explained by the appearance of the Spinney Hill Sandstone. From there a general decrease in thickness to 20 m is seen in Township 26, Range 20W3, then an increase to
22 m in Township 27, Range 20W3, followed by a decrease to 15 m in Township 27, Range 19W3. Furthermore, an increase to 19 m is seen in Township 27, Range 18W3, accompanied by a decrease up to 14 m in Township 28, Range 17W3, followed by a 2 m increase to 16 m in Township 28, Range 16W3.

The Joli Fou Mudstone shows a general decrease in thickness northeastwards, though variations exist along the cross-section D - D' (Figure 4.7). It has a thickness change from 53 m in Township 25, Range 29W3 (D) to 52 m in Township 27, Range 27W3, thereafter a gradual decrease to 44 m in Township 28, Range 25W3. From here a sharp decrease to 29-27 m in Township 28, Range 24W3, is characteristic. The sharp decrease in thickness is explained by the appearance of the Spinney Hill Sandstone.

**Spinney Hill Sandstone**

Owing to the non-penetration of the base of this unit by some of the control wells on cross-section A - A' (Figure 4.4), a definite thickness trend for the sandstone is difficult to make. However, where delineated, the sandstone has an average thickness of between 25 and 26 m. The section reveals increases in thickness towards both ends (A and A') in Township 21, Range 19W3 (A=26.5 m) and in Township 23, Range 15W3 (A'=26.8 m).

On cross-section B - B' (Figure 4.5) the sandstone is absent in the first two wells as it pinches out to the west of Township 22, Range 22W3, indicating non-deposition of the sandstone in this part of the area. The member picks up from here with a
variation in thickness ranging from 24 m to over 27 m. The sandstone reaches a thickness of slightly over 27 m in Township 23, Ranges 20 and 21W3, before decreasing, and again increasing to 27.5 m in Township 26, Range 16W3.

For most of the southwest part along cross-section C - C' (Figure 4.6), the Spinney Hill Sandstone is absent, as it pinches out to the south-west of Township 24, Range 24W3. The sandstone appears with a thickness of over 26 m in Township 24, Range 24W3, and then decreases to about 22 m in Township 25, Range 23W3. An increase from here, is observed to 29 m in Township 26, Ranges 21W3, followed by a decrease to 17 m in Township 28, Range 17W3.

The sandstone is absent on cross-section D - D' (Figure 4.7) until in Township 28, Range 24W3, where a thickness of 22 m, is observed from D towards D'. A decrease in thickness of 2 m to 20 m is seen in Township 28, Range 24W3. Unfortunately, this does not tell us enough to allow formulation of the sandstone thickness trend on this section, and hence is inconclusive.

4.4.2.2 Isopach Maps

Joli Fou Formation

The isopach map of the Joli Fou Formation is given in Figure 4.21. The figure reveals widespread and narrow elongated bands of variable orientation and thickness. It is thickest in Townships 24 and 25, Range 29W3, with a maximum thickness of over 56 m. The minimum thickness of slightly above 27 m is seen in
Township 28, Range 18W3. Though there is a general thinning from Bayhurst area (subregion A to the southwest corner in contrast to the Viking Formation), it is interesting to note that the formation is thickest in subregion A and thins northeastwards to subregion C. This trend is most obvious in the northeast-central of the area. In this area, the formation shows a southeast-northwest contour trend. This supports what has been observed in the cross-sections across the area.

_ Joli Fou Mudstone_

The isopach map for the Joli Fou Mudstone is shown in Figure 4.22. The Joli Fou Mudstone shows a general trend of thinning towards the northeast-east. From the southwest corner, northeastwards, the Joli Fou shows an increase in thickness to over 55 m in the Township 24, Range 26W3. Thereafter, the thickness decrease gently, then sharply, as indicated by the closeness in contour lines, to over 26 m in an approximately north-south contour trend from Township 28, Range 24W3, to Township 21, Ranges 22 and 23W3. This is explained by the pinching out of the Spinney Hill Sandstone, which underlies this unit in the eastern-central part of the area. In this area, the formation shows a gentle decrease in thickness to an average of 13.5 m in Townships 25 and 26, Range 16W3, and Township 28, Range
Figure 4.22 Isopach map of the Joll Fou Mudstone.
1) contour lines (contour interval = 1 m).
17W3. However, there are variations in thickness within the area as at LSD 10-06-28-17W3 of 17 m and at LSD 10-09-28-18W3 of 11.5 m. The latter is the minimum thickness of the Joli Fou Mudstone in the study area.

This trend is also seen from west to east. Another anomalous area is an area in the southeast corner of the map, trending southwest-northeast between Township 21, Range 21W3, and Township 23, Range 15W3. This area shows an elongated band of gentle sloping to the north-east.

**Spinney Hill Sandstone**

The isopach map of the Spinney Hill Sandstone is shown in Figure 4.23. One peculiar feature of the thickness of the Spinney Hill Sandstone is the pinchout of the sandstone beyond Range 24W3, westerly in an approximate north-south direction from Township 28, Range 25W3 down to Township 21, Range 23W3.

The Spinney Hill thickness does not show a general trend of thinning and thickening in a particular direction. However, it shows a broad thick band in the central part of the study area, elongated to the north, and south. This band is defined by the 26 m thickness contour, increasing to over 28 m in two isolated patches. One band is centred in Township 26, Range 21W3 (29 m) and the other in Township 26, Range 19W3 (28 m). To the south of the two isolated patches, another body defined by the 27 m contour is observed covering Township 23 and 24, Range 20W3.
The three are separated by a minor "decrease" in thickness in Township 25, Range 20W3. To the northeast of this broad band, the formation decreases in thickness to the minimum of 15.6 m in the area in Township 28, Range 18W3, thereafter sharply increasing to over 25 m in Township 28, Range 17W3. The maximum thickness of the formation is reached in Township 25, Range 15W3, of over 30 m flanked to the southwest by a decrease at the junction between Ranges 16 and 17W3, of Township 24. The absence of the sandstone in the western part of the area, and the general thickening in the east-northeast, reveals a depositional trend to the west-northwest.

Both Spinney Hill Sandstone and Joli Fou Mudstone show variable thickness. The stratigraphic cross-sections and isopach maps show that the contact of the former with the overlying and flanking Joli Fou Mudstone is gradational. Interpretation of the observed variation in the sandstone and distribution are given in Section 4.5.

4.5 Big River Formation

4.5.0 Introduction

The Big River Formation (upper Albian-Cenomanian) of the Lower Colorado Subgroup, takes its name from the Big River Provincial Forest region of west central Saskatchewan. The type section is in the Duval Saskatoon 6-18-36-6 well (LSD 06-18-36-06W3) in central Saskatchewan. The maximum thickness of the formation is 150 m in southwestern Saskatchewan.
The Big River Formation is composed of dark grey, non-calcareous shale and mudstone of variable fissility, with minor, interbedded, fine- and medium-grained sandstone and coarse-grained siltstone. The sandstone and siltstone occur as lenses and as graded layers composed of horizontal or very gently inclined laminae. Bioturbated, shaly sandstone and siltstones form relatively scarce layers. Sand-grade pelecypod debris, and fish-skeletal material form skeletal calcarenites and phosphatic sandstones respectively. Thin layers of chert pebbles also occur. Subordinate lithologies include bentonite, nodular phosphorite and concretionary layers of siderite, calcite and pyrite (Simpson, 1982b).

4.5.1 Lithofacies Description

The lithofacies description of the Big River Formation is limited owing to lack of core from the formation. No well has a complete cored section of the formation in the area as coring was concentrated towards the base of the formation. The interests of the oil companies were directed towards the Viking Formation.

Lithofacies 1- Sandstone

This lithofacies was observed in the Oliphant Nwrco Gorefield 6 12 25 27 well (LSD 6-12-25-27W3) in the subregion A only, with a maximum thickness of half a metre.
The sandstone is fine-grained, with subordinate medium coarse sand granules, small pebbles, and fish remains. Occasionally, the sandstone is seen to be very muddy, with predominant fine sand sometimes occurring as flattened lenses. Interconnected mudstone partings, sometimes numerous, may be present in these sandstone units. Between 701.0 and 701.5 m, 20 cm below the interval top, up to 2.5 cm of a wedging out interbedded bentonitic mudstone was observed. Nodular pyrite concretions are also present.

Sedimentary structures are restricted to burrowing, which is usually in the form of indeterminate, flattened, tubular, and sand-filled burrows.

Lithofacies 2- Mudstone

The mudstone lithofacies is the most widespread unit in the formation. It has a maximum thickness of 18 m in the subregion C in the McMorrnan No. 1 Start Test well (LSD 06-11-28-20W3). The mudstone is dark grey, argillaceous, silty in places with scarce siltstone and fine-grained sandstone intercalations. Fish remains and pelecypod debris are not uncommon.

In subregion A, the Husky-Phillips Prelate No. 11 28 well (LSD 11-28-23-25W3) revealed 10.4 m mudstone incorporating various thicknesses of ferruginous and laminated bentonitic mudstone.
In subregion B, at three control wells where the unit was observed, a narrow range in thickness from 2 to 3 m was seen. Again ferruginous mudstone and stratiform pyrite concretions are the minor constituents in the units.

Subregion C, with a high density of cores from the formation, shows an average thickness of 5 m of the unit. In addition to the common minor constituents in the mudstone, phosphatic bodies concentrated in laminae were observed in the Marvel Kamalta Plato 14 7 25 17 well (LSD 14-07-25-17W3).

Lithofacies 5- Shale

This lithofacies was observed at two localities, in the Sohio Standard Elrose No. 3 well (LSD 09-14-26-16W3) and the Murphy et al. Kindersley 7 19 28 21 well (LSD 07-19-28-21W3) in subregion C. The maximum thickness of 11 m is recorded in the former. It can be described as dark grey, argillaceous, with fish remains, and locally silty. Pelecypod debris are also present. Associated with the shale are horizontally laminated bentonitic mudstone layers at 732.7 m and 10 cm of ferruginous mudstone in LSD 07-19-28-21W3.

Lithofacies 6- Sandstone with subordinate mudstone intercalations

This unit has been observed at two localities: in the Canus et al. N Verendrye 12 32 28 23 well (LSD 12-32-28-23W3) and the Phillips Husky Fairmount A well (LSD 07-14-28-25W3), with
the latter having the maximum thickness of 3.7 m.

The dominant sandstone part is very muddy, very fine-grained, quartzose, micaceous, and slightly glauconitic with numerous, closely spaced mudstone partings.

The mudstone is dark grey, silty, laminated, with silty parts burrowed with mud-filled Chondrites. Sedimentary structures include extensive burrowing with Chondrites, Phycodes and straight sand-filled tubular forms.

Nodular pyrite concretions and bentonitic mudstone occurring as laminated layers 1.5 cm thick are the common associations.

Lithofacies 8- Alternation of siltstone/sandstone and mudstone

Locally coalified wood fragments and sometimes carbonaceous material are characteristic features of the mudstone where silty. Only at one place was the mudstone seen as blocky.

Associated with these mudstones, in places, are the presence of flattened pyritized burrows sometimes horizontal, as at the Imperial Bayhurst 7 17V 24 25 well (LSD 07-17-24-25W3). At this place the burrows are up to 0.25 cm in width.

Lithofacies 9- Mudstone with subordinate siltstone and sandstone intercalations

The lithofacies forms a major part of the Big River Formation. The mudstone, which constitutes a major component in these units is dark grey, micaceous, argillaceous and laminated
where silty. Fish remains are often present. Locally concentrations of pelecypod debris are present.

The sandstone/siltstone occurs often as flattened lenses, horizontal or gently inclined laminae forming continuous and discontinuous layers of variable thickness up to 7.5 cm. The continuous layers may be cross-laminated. The sandstone is fine-grained, though scarce coarse sand and granules, scattered small pebbles or intermittent laminae do occur locally. Compositionally, it is quartz-rich, micaceous and slightly glauconitic in places, and locally rich in matrix.

In subregion A, the lithofacies has thickness reaching over 20 m in the Tide Water Abbey Crown No. 2 well (LSD 01-31-21-18W3) with an overall average of over 6 m. In the Oliphant Nwrco Gorefield well (LSD 07-21-24-26W3), the mudstone is characterized by abundant pelecypod debris, ranging in size from calcite prisms to disarticulated valves of *Inoceramus*.

Locally coalified wood fragments and sometimes carbonaceous material are characteristic features of the mudstone where silty. Only at one place was the mudstone seen as blocky.

Associated with these mudstones, in places, are the presence of flattened pyritized burrows sometimes horizontal, as in the Imperial Bayhurst 7 17V 24 25 well (LSD 07-17-24-25W3). At this place the burrows are up to 0.25 cm in width. In the mudstone layers, chert with patina was observed in the Cuthbert No. 1 well (LSD 06-02-26-29W3).
The dominant sedimentary structures are the horizontal or gently inclined laminae and cross-lamination, which are locally disrupted by folding and fracturing as in the Oliphant Nwrco Gorefield well (LSD 07-21-24-26W3). Ripple lamination was observed in the same well. In the Imperial Highbury 10 35 well (LSD 10-35-25-26W3), a 5 cm fine-grained cross-laminated quartzose sandstone exhibits groove moulds and burrow infillings on the sole. Other structures include straight, sub-horizontal, sand-lined mud-filled tubes and *Chondrites* in the Tide Water Abbey Crown No. 2 well (LSD 01-31-21-18W3), tubular burrows in the Imperial Bayhurst 10 3V 24 25 well (LSD 10-03-24-25W3), and flattened tubes with sand or pyrite infilling, up to 1.5 cm wide in the Imperial Bayhurst 6 16 24 25 well (LSD 06-16-24-25W3).

Minor constituents in the units in the three subregions are ferruginous silty mudstone, sometimes with siderite-filled spherulites ranging in size to over 12 cm, and stratiform and nodular pyrite concretions. Bentonite mudstone layers are also common, with varying thickness up to 10 cm. However, they are not continuous, as indicated by a 2.5 cm thick interbedded bentonitic mudstone, which wedges out in the Oliphant Nwrco Gorefield 6 12 25 27 well (LSD 06-12-25-27W3).

The maximum thickness observed in subregion B is 10.6 m in the Imperial Athenian 16 22 24 22 well (LSD 16-22-24-22W3), with an average of 4 m. In the Imperial Cornfield 10 32 25 25 well (LSD 10-32-25-25W3), the mudstone incorporates bentonitic siltstones, and it is structureless in a separate unit.
Sedimentary structures, in addition to lamination include straight, flattened pyritized and sand filled burrows. An erosional lower contact was observed in the Imperial Centre Field 13 10 26 21 well (LSD 13-10-26-21W3).

In subregion C, the unit occurs extensively, with a minimum thickness of 1.2 m in Sohlo Standard Darcy No. 1 well (LSD 15-22-28-19W3) and a maximum of 14.3 m in the Norvanian Marvel Plato 12 17 25 18 well (LSD 12-17-25 18W3). It has an average thickness of 6 m. The laminated silty parts of the mudstone may be burrowed, with mud-filled Chondrites and flattened pyritized sand-filled burrows.

Lithofacies 10- Alternation of mudstone and siltstone layers

This unit has been observed at one location, in the B A Juckneiss 13 15 well (LSD 13-15-22-23W3) with a thickness of 3.2 m in subregion A. The siltstone is olive grey, sandy, micaceous, in places glauconitic, occasionally associated with developments of stratiform pyrite concretions up to 0.75 cm thick. It is burrowed with Chondrites. The mudstone, on the other hand, is dark grey, silty, with fish remains.

4.5.2 Areal Distribution

This section describes the distribution of the formation in the area by use of log cross-sections and an isopach map. Again, the same stratigraphic cross-sections are used.
4.5.2.1 Cross-sections

The Big River Formation exhibits some variation in thickness across cross-section A - A' (Figure 4.4). The maximum thickness of 113 m is recorded in Township 21, Range 18W3, after an increase of 8 m from 105 m in Township 21, Range 19W3. From the 113 m mark, the thickness decreases to the minimum for the section of 102 m in Township 23, Range 16W3. This northeastwards trend is interrupted by an increase to 105 m in Township 24, Range 15W3 (A').

The formation shows a decrease along cross-section B - B' (Figure 4.5), first from 107 m in Township 21, Range 24W3, to 99 m in Township 22, Range 22W3, then an increase to over 110 m in Township 23, Range 21W3. There is a general decrease in thickness to 90 m in Township 26, Range 16W3, from which a slight increase of 1 m to the end of the section is observed.

Along cross-section C - C' (Figure 4.6), the Big River Formation is characterized by variation in thickness. The maximum thickness of 100 m is reached in Township 25, Range 23W3. A decrease in thickness in opposite directions from here is observed, decreasing to 89 m in Township 22, Range 28W3, to the southwest, and to 87 m in Township 28, Range 16W3 (C') to northeast. Apparently, the latter thickness is the minimum thickness of the formation along this section. In general terms there is an increase in thickness to 100 m, then a drop to 87 m in the northeast.
This formation shows no definite trend in that it is characterized by variation in thickness along the line of cross-section D - D' (Figure 4.7). The maximum thickness is 95 m in Township 27, Range 26W3, which is followed by a general decrease to the northeast, though with variations in between, to 92 m in Township 28, Range 24W3, at the end of the section. However, the minimum thickness of 85 m in Township 25, Range 29W3, lies to the southwest of the maximum.

4.5.2.2 Isopach Map

Isopach map (Figure 4.24) was constructed to show the thickness distribution of the formation in the study area. The three-dimensional plot is given in Figure 4.25.

The formation shows continuous contours of thickness that lacks well-defined trends. Generally, a decrease in thickness is observed from the southeast and south to the northwest and north. The maximum thickness in the range of 114 to 115 m in southeast corner of the area, decrease broadly to a range of 81 to 94 m in the west-northwest-north and northeast. Deviation in continuous contours is more evident in the north where thickness closures are dominant. A minimum thickness of 81 m is seen at Township 25, Range 28W3, and Township 28, Range 29W3. These variations were also shown on cross-sections.

In comparison, to the variation of thickness of the Viking Formation, the Big River Formation also shows continuous contours of thickness in subregion A and B. Dominant local minima and
Figure 4.25 Three-dimensional plot of the isopach surface of the Big River Formation.
maxima thickness closures of the Big River Formation are observed in subregion C. Another similarity is the general decrease in thickness in the northerly direction.

4.6 Interpretation

A detailed account about mode and environment of deposition of the Lower Colorado succession is given by Simpson (1982b) and therefore the origin of the succession is adequately covered therein and is adequate for the purpose of this study. However, in this section the lithological descriptions and areal distributions of the Lower Colorado strata in the study area discussed in Chapter IV are evaluated to augment the already favoured shallow-water marine origin for the succession (Deviel, 1956; Jones, 1961a, b).

Analysis of the lithofacies and their relationships in cores, and distributions of strata in the three formations (Joli Fou, Viking and Big River) reveal certain facts about the sediments of the three depositional systems in the study area. In particular analysis of the Viking Formation, which is represented in a large amount of cored sections revealed the following:

(i) The lithological associations giving rise to the various lithofacies within the formations.

(ii) The systematic textural differentiation in the Viking
Formation, marked by passage from thick relatively well-sorted, clean sandstones to poorly sorted and increasingly finer-grained lithofacies in northeasterly direction to subregion C.

(iii) There are a number of coarsening-upward sequences, and localised fining-upwards sequences.

(iv) A large variation in sedimentary structures, from simple gently inclined and horizontal laminae to complex cross-bedding, ripple and even dune scale bedding, some injection phenomena, contortions and folds.

(v) Extensive bioturbation with commonly occurring *Teichichnus, Chondrites, Spirophyton, Phycodes* and *Rhizocorallium* species.

(vi) Some indications, at least local, of erosional surfaces, sharp and gradational contacts within the lithologies of the lithofacies.

(vii) The systematic change in thickness northeastward of the Viking Formation across the study area.

(viii) The gradational contacts of the Joli Fou and Big River Formations with the Viking Formation.

These features are interpreted on the basis of the history of the depositional environment which brought about the variation in lithofacies associations. The changes in environment were due to changes in sea level, which in turn were largely controlled by the regional structural setting of the environment.
4.6.0 Viking Formation

The sudden appearance of sand at the base of the Viking Formation represents the first sediments of the formation. The gradational nature of the contact between Joli Fou and Viking Formations, indicates absence of erosive scouring in the area. This is supported by the isopach map and the stratigraphic cross-sections. The appearance of the sand indicates the beginning of coarse sediment aggradation in the area (progradation of the shoreline to the northeast and north).

The dominant trace fossils in the sediments are all well known indicators of marine conditions. Their presence indicate low sedimentation rates and that deposition of the sequences was slow or intermittent at shallow levels. Muds in the form of mudstones form an important component of the lithofacies 6 to 10 and their occurrence together with the trace fossils support a shelf setting as the depositional environment. The coarsening-upward sequences present in the lithofacies are indicative of increasing sediment aggradation on the shelf through time. Such sequences are interpreted as deposits produced in response to gradual shallowing of the depositional environment through time (progradation of the shoreline).

Presence of sedimentary structures such as rippled or cross-bedded strata suggest even a more shallower environment was present such as a near shore. Fine lamination of siltstone and mudstone indicate sedimentation in very quiet-water conditions.
These could be interpreted as normal sedimentation conditions immediately following the transgression, and are indicative of a shelf environment. However, periodic interruption of the quiet water conditions might have led to events that deposited the thin intercalations of coarse-grained sandstone. The intercalations can be explained as deposits of frequent storms which eroded the transgressive shoreline to the southwest/west, and deposited the eroded material in the study area. Sharp contacts between lithofacies or within lithofacies indicate ending of transgression surges which in most cases were rather rapid and undoubtedly erosive in nature. Large thicknesses of trough cross-bedding are due to waves induced by longshore currents flowing to the west. The loading and injection phenomena, contortions and minor folds in the sediments may indicate spontaneous liquidations of soft, unconsolidated sands to a relatively abrupt increase in superincumbent load (Simpson, 1982b). Tidal currents, augmented from time to time by storm waves, could have created all bedding features observed in the coarse-grained sediments of the Viking Formation. The Viking sands may further have been affected by intermittent bottom currents, as indicated by eroding scour structures in some mudstones. The irregular thin sand and silt layers within many of the mudstone sequences are regarded as storm layers deposited from moving suspensions, derived from stirred-up bottom deposits.
Carbonaceous and organic matter so abundant in the sediments may indicate the influence of a fluvio-deltaic system which could transport great quantities of this material into the marine environment. Occurrences of fish-skeletal debris as the main component in both intercalated mudstones and lower surfaces of sandstone layers, probably reflect concentration by storm-generated currents.

The isopach map and cores of the Viking Formation show the thickest and coarsest sands are present in subregion A (southwestern region) of the area, and a decrease in thickness accompanied by an increase in mud content to subregion C (northeastern region). This type of distribution pattern indicates of an environment where sediments were delivered to the area in the southwest and reworked by alongshore processes in a shore-parallel pattern.

The systematic change in thickness, textural differentiation, variation in sedimentary structures, and the variety in lithological associations (lithofacies) can be explained by sedimentation on a size-graded shelf, where deposits become finer-grained with increasing distance from the source. Walker (1984) considered in detail the nature of shelf deposits, and indeed the change in facies in the Viking Formation can be explained by deposition on a size-graded shelf. Simpson (1975, 1982b) designated such lithologic associations according to position relative to the postulated shoreline (Table 4.0) as:

<table>
<thead>
<tr>
<th>SEQUENCE ELEMENT</th>
<th>NEARSHORE DEPOSITS</th>
<th>PROXIMAL SHELF DEPOSITS</th>
<th>DISTAL SHELF DEPOSITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>scarce, material coarser than sand usually concentrated in thin layers making up minor proportions of other elements</td>
<td>abundant, highest permeabilities (several hundred md) in diamictic bodies belonging to lower parts of clinobeds; primary and secondary heterogeneities very numerous</td>
<td>absent, material coarser than sand occurs as scattered clasts or as thin layers within other elements</td>
</tr>
<tr>
<td>IV</td>
<td>abundant; planar foresets give rise to highest horizontal permeabilities (several hundred md to &gt;2D) especially near top of sequence; porosities in range 25 to 35 per cent; primary heterogeneities more numerous downward; secondary heterogeneities at top of sequence</td>
<td>scarce; occur in upper part of sequence where present</td>
<td>very scarce, though well sorted fine-grained sandstone layers may make up minor proportions of type II and III elements</td>
</tr>
<tr>
<td>III</td>
<td>relatively scarce; usually found near base of sequence, proportion of mudstone intercalations increases downward</td>
<td>abundant; variable horizontal permeability (&lt;0.01 md to several hundred md); porosities in range 20 to 30 per cent; form coarsening-upward units in upper parts of clinobeds; primary heterogeneities in lower parts; secondary heterogeneities near element tops</td>
<td>common; high mud content; variable but usually low horizontal permeability (&lt;0.01 md to several tens of md); porosities in range 15 to 25 per cent</td>
</tr>
<tr>
<td>II</td>
<td>scarce, occur near base of sequence</td>
<td>abundant; variable horizontal permeability (&lt;0.01 md to several hundred md); porosities in range 15 to 25 per cent; form lower parts of clinobeds; downward increase in mud content</td>
<td>common in lower part of sequence*</td>
</tr>
<tr>
<td>I</td>
<td>very scarce</td>
<td>common; occur near top of succession and as intercalations</td>
<td>abundant; occur near top of succession and as intercalations</td>
</tr>
</tbody>
</table>

1 Main producing lithology of Bayhurst natural gas field
2 Smiley-Worap "Viking chart" oil reservoir
3 Crude oil and natural gas reservoirs of the Dodsland-Hoosier "Viking sand" production trend, Brock, Glidden, Greener, Plato, Toinas
4 Unity natural gas reservoir
(i) nearshore deposits, characterized by thick well sorted sandstones,
(ii) proximal shelf deposits, largely made up of poorly sorted, often coarse-grained sediments, as well as alternations of fine-grained sandstone and mudstone, and
(iii) distal shelf deposits, containing poorly sorted fine-grained, muddy sandstones and siltstones, with scarce pebble layers.

Nearshore and proximal shelf deposits are present in the study area while distal deposits are absent. Subregion A is made-up of nearshore deposits which pass transitionally through subregion B to the proximal shelf deposits of subregion C. The nearshore deposits of subregion A must have arisen through settling particles of a given size at a particular null line, characterized by oscillating equilibrium of wave-surge and gravitational forces affecting the particles, to give a seaward-fining textural gradient on the shoreface (Murray, 1967). Progradation of the shoreline must have given rise to the coarsening-upward sequences. Proximal shelf deposits, on the other hand, were deposited by random-walk dispersion with net seaward transport of particles brought about by currents both storm-generated (Swift et al., 1971) and tidal in nature. The large-scale isolated sand bodies indicated by thickness closures in subregion C could be a result of tidal currents. The Viking Formation, except for the fine-grained uppermost part of the proximal shelf of subregion C, is thus indicative of regression
on a graded shelf. The resultant distribution of sediments on
the size-graded shelf by tidal and storm-generated waves was
obviously accompanied by the deterioration in
porosity-permeability in the northeasterly direction paralleling
the diminution of grain size in this direction.

The Viking sequence is thus dominated by regressive
conditions in upward-coarsening lithologies which account for the
most part of the thickness. These are succeeded by a very thin
upward-fining part in subregion C, i.e. the wedge is asymmetric.
The gradation from Viking to Big River sediments consists of thin
beds of intermediate sandy and muddy lithologies. This gradation
represents a transgression in which either the sediment supply
was drastically reduced or there was an abrupt change in
depositional setting. The onset of this transgression
represented by the appearance of the mudstones of the Big River
Formation terminated the regressive Viking Formation deposition.

4.6.1 Big River and Joli Fou Formations

At the onset of the Lower Colorado deposition, marine
conditions marking the initial stages of the early transgressive
phase were already established over the study area for the
deposition of the Joli Fou Formation. Comparable conditions to
the Joli Fou Formation deposition probably were restored during
the early part of the Big River transgression phase at the end of
the Viking regression.
The thick, monotonous sequences of dark grey, largely argillaceous mudstones of the two formations, containing much fish-skeletal debris and widespread bioturbation, obviously indicate deeper marine environment. The shoreline was too far to the southwest and background sedimentation conditions dominated with pelagic settling of mud and occasional silts giving rise to siltstone interbeds. Occasional storms still affected sedimentation however, mostly depositing sands and siltstone layers in the mudstone. The lessening of the storm-generated waves allowed suspension clouds to settle, forming parallel, evenly laminated layers. This origin could account for the widespread distribution of the persistent siltstone and sandstone layers, lenses and intercalations which are evident even on geophysical well logs.

4.6.2 Spinney Hill Sandstone

Lack of cores in the study area limits the evaluation of the Spinney Hill Sandstone. Core of this sandstone came from one well in subregion B. Therefore variation of the sandstone in the area is not conclusive. However, generalizations can be drawn from the isopach map and from the literature.

The isopach map and the cross-sections reveal the wedging out of the Spinney Hill Sandstone in the westerly direction. Simpson (1982b), on a regional scale, noted a generalized fractionation of detrital grains, such that there is southerly increase in both the proportion of very fine and fine-grained
sandstone and the overall intercalated mudstones. The wedging-out and size-grade indicate a north/east source area. The distribution of sands are thought to have been for the most part, through lateral migration of tidal channels.

The southerly location of the study area with respect to the western arbitrary limit of the sandstone places the Spinney Hill Sandstone in this area in the distal fluviomarine deposits of the central facies belt of Simpson (1982b), laid down in a deltaic setting.

4.6.4 Summary

The changes in sea level and the overall deposition of the sediments were controlled to a large extent by the structural setting of the depositional environment. The differential subsidence of basins which are geographically separated by arches and domes indicate slower rates of subsidence. Maintenance of the mountain chain above base level by the submergence mode as discussed in Chapter II could have resulted into a high rate of sediment supply, and led to development of the progradation of the shoreline. This could result into the marine-regression responsible for the Viking Formation deposition in the area. The proximity of the study area to the Sweetgrass Arch indicates that the area was under constant influence of the arch for the dispersal of the sands and development of the local domal structural features.
CHAPTER V

5.0 HYDRODYNAMICS OF FORMATION FLUIDS

5.1 General Remarks

Hydrodynamics involves the study of subsurface fluids (formation fluids - water, gas, oil), their composition in static and dynamic environments, subsurface pressures and other physical characteristics of reservoirs and permeability barriers (Prier, 1979).

Movement of formation fluids is easily facilitated by the absence of 'impermeable' material within homogeneous permeable strata. The main reservoir strata of the Lower Colorado succession in western Saskatchewan belong to the Viking Formation, a regressive-transgressive siliciclastic wedge enveloped in the shales of the Joli Fou and Big River Formations.

The Viking Formation consists of permeable siliciclastics (sandstones), which farther from the Cordilleran source area grade into relatively low-permeability, fine-grained siliciclastics, intercalated by shaly material in the north-east of the study area. The Joli Fou and Big River Formations, on the other hand, consist of dominantly mudstones and shales which are of low permeability and on a regional scale act as major confining units, retarding flow between the overlying and underlying aquifers to the Viking aquifer.
In this section, formation pressures derived from drill tests were employed in considerations of hydrodynamics. Potentiometric maps constructed from these were used to infer the dynamics of the fluids in the formation and permeability differences which in turn can be inferred on the basis of variation in spacing of the potentiometric contours (Prier, 1979). In addition, selected fluid profiles were constructed to examine the causes of the anomalies on the potentiometric map, and for the detection of subnormal (depressurised) and abnormal (overpressurised) fluid conditions. Inferences from the former are based on the theory that pressure continuity is depicted by a straight-line relationship in the fluid profile (interconnection of the Viking to the underlying and overlying formations). The anomalous nature of the pressures can be deduced from the position of the data points relative to the pressure gradient for fresh water (9.795 kPa/m).

5.2 Physiographic Setting

The study area shows varied topographic relief (Figure 5.0) with the maximum elevation (relief) in the range of 610 to 853 m in the Missouri Coteau Upland, occupying Township 28, Ranges 16 and 17W3, extending southward up to Township 24, Ranges 16 and 17W3. This is also found in parts of Townships 22, 24 and 25, Range 15W3. Minimum relief in the range of 457 to 594 m occupies
an area along the South Saskatchewan River, and to the east of the Missouri Coteau Upland (Township 28, Range 15W3, southwards to Township 25, occupying the junction of Ranges 15 and 16W3).

The area to the north and northeast of the South Saskatchewan River is occupied by the Snipe Lake Plain with a relief between 640 and 701 m and includes the Natural Hills Upland of higher relief (701 to 762 m) in the northwest part of the study area. The Bigstick Lake Plain occupies the area south of the river with higher relief of between 701 to 823 m (Acton et al., 1960).

The variation in topographic relief (457 to 853 m), though it may seem minimal, may have an effect on the hydrodynamic environment on a local scale in the area. It has been shown by Hitchon (1969a) as one of the factors responsible for generation of pressure differentials resulting in fluid flow from high areas (recharge) to low areas (discharge).

5.3 Potentiometric Surface

A potentiometric map expresses variation in fluid potential across an area. The potentiometric surface is represented as equipotential lines, drawn with respect to sea level as a datum. Fluid flow is perpendicular to contours on the potentiometric surface from settings of high to settings of low fluid potential.

Figure 5.1 shows the local potentiometric map of the Viking Formation. The figure shows anomalous potentiometric low and high cells. Owing to the anomalies, the potentiometric drop
Figure 5.1 Local potentiometric surface of the Viking Formation
1) equipotential lines (contour interval = 40 m); 2) potentiometric low; 3) potentiometric high;
4) facies belts (subregions); 5) oil and gas fields.
across the area of about 120 m (from 680 m in the southwest to 560 m in the northeast-central) is seen only when the area is viewed within its regional setting. Hill et al. (1961) showed the regional flow to the northeast in the area which can only be inferred in certain portions of the study area, for example, the south-central part, below Township 23, in subregion A. The potentiometric slope changes on the anomalies are generally gentler (13 to 45 m/km) in subregions A and B, and steeper (40 to 96 m/km) in subregion C.

These anomalies are characterized by closed contours or potentiometric cells with values exceeding 680 m and less than 500 m above sea level for the highs (mounds) and lows (depressions) respectively. The distribution of these anomalies is quite variable. The anomalous potentiometric highs are concentrated in the southwest of the area, while the lows are in the north and northeast. The southwestern and central regions anomalies show a generally north-south trend. The northeastern anomalies are generally oriented in a northwest-southeast direction. A characteristic deviation from these trends is shown by the low which begins with a north-south trend in Township 23, Range 23W3, and then swings southwestwards, and then to a northwestly direction.

More specifically, numerous cells are superimposed in the northwest-southeast-trending Bayhurst area in subregion A, from Township 23, Range 25W3, to Township 25, Range 27W3. Other cells
in the area include isolated highs delineated by the 720 m contour to the west of the Bayhurst pressure ridge, and by the 680 m contour to the southwest around Township 22, Range 21W3.

In subregion B, cells include the Plato high in Township 24, Range 18W3, and a high centred in Township 25, Ranges 21 and 22W3, both delineated by the 680 m contour. A minor high is observed in Township 27 Range 25W3.

In subregion C, a characteristic potentiometric high is centred on potentiometric elevation of 848 m (which is the maximum elevation for the area) in the Brock West area, Township 29, Range 20W3. Others include a minor one in Township 28, Range 19W3.

The depressions, on the other hand, form salient features particularly in the subregion C part of the study as follows:

1) An alignment of potentiometric low cells, separated by highs or saddle-like features, occur in the area beginning in east-central part (Township 25, Range 16W3) extending northwestwards to Township 28, Range 25W3, and to the northeast. This trend of southeast to northwest forms the most conspicuous feature in the study area. From Township 25, Range 16W3, northwestwards, there is first a depression centred on Township 25, Range 17W3, and Township 25, Range 18W3. The northwestward end of this depression has a lowest elevation of 3 m below sea level in the study area (Range 18W3). A minor depression in Township 25, Range 19W3, is connected to the former by a 600 m contour. The depression in Township 26, Range 21W3, in subregion
B is centred on an elevation of 236 m above sea level and is elongated in northwest-southeast direction. This depression is separated by a high-pressure ridge averaging 660 m above sea level from a depression of an elevation of 32 m in Township 27, Range 23W3, which broadens from here to the west, southwest and northwest to Township 28, Range 25W3, and Township 27, Range 25W3. To the southwest, a potentiometric low cell is observed in Township 27, Range 26W3 in subregion B.

(ii) Depressions to the northeast of this major trend include a depression in Township 28, Range 18W3, and part of Range 19W3, connected southeastwards by a 600 m contour to a depression in Township 27, Range 18W3. These form an almost northwest and southeast trend. In Township 28, Range 20W3, another low is observed.

(iii) Depressions in the south-central part of the area, of which two are significant; one closed by a 600 m potentiometric contour in Township 23, Range 23W3, and the other centred on a relatively high hydraulic head of 477 m in Township 23, Range 20W3. The former coincides approximately with the eastern and southeastern margins of the Bayhurst dome. Also minor lows occur in the Bayhurst area in the northern and southern flanks of the dome.

The local potentiometric surface of the Viking Formation as presented above indicates the present fluid-flow patterns in the area, and that the many anomalies may be accounted for by geological factors such as salt solution and related disruption.
of strata, cross-formational flow and physico-chemical parameters, such as temperature and osmosis. However, many studies have indicated that such anomalous features might have resulted from petroleum production (Bair et al., 1985). Owing to oil and gas production, as well as enhanced (e.g. water flooding) secondary recovery operations at certain locales, the fluid pressure might have been altered, and hence the hydrogeologic regime. Dickey (1986) noted that pools discovered at a later date had much lower reservoir pressures indicating that pressure had been drawn down by the production of hydrocarbon and water. The high-density well distribution and the production locales of the study area coincide with anomalies on the potentiometric map.

In an effort to produce a potentiometric map from which inferences of the fluid flow-patterns on a regional scale in the study could be made, a second assessment and culling of data was undertaken. This was done by superimposing the petroleum production map on the potentiometric map, as production has resulted in under-pressurises and in some cases over-pressurises in these areas.

In culling of the data, the dates when the drill-stem tests were noted and the commencement date for production in the various pools in the area were considered. The drill-stem tests taken after the commencement of production were regarded as being influenced by production, that is, not representative of the
virgin reservoir pressure, and therefore discarded. Figure 5.2 shows the extent of variation in shut-in pressure in relation to the depth in the Viking Formation in the area.

The potentiometric surface of the Viking Formation from these data is given in Figure 5.3. This figure is a close approximation of the regional flow system in the area in that it shows the dominant flow pattern to the north and northeast. Deviations to this are seen in the Bayhurst area (around Townships 24 and 25, Ranges 25 to 29W3) of subregion A and B. The figure shows a potentiometric drop of 130 m, from 690 m in the southwest to 560 m in the northeast across the area. In subregions A and B around the Bayhurst area, slopes in the range of 4 to 8 m/km occur while the southeastern and central parts of the subregions show a gradient of approximately 2 m/km to the north. The southwest corner has a slope of 2 to 3 m/km to the north. In contrast, subregion C shows steeper gradients in the range of 5 to 20 m/km to the northeast and north.

The surface shows potentiometric low cells oriented in a northwesterly direction in subregion A and northwestern part of subregion B. The lows are separated by a high cell open to the northwest which begins in Township 24, Range 25W3, to Township 25 and 26, Range 29W3. The remaining parts of the subregion A and B are characterized by widely spaced contours. A high-pressure system begins in the southern edge of the area centred along mid-way in Range 21 and 22W3, Township 21, up to Township 26, where it swings northwestwards to Township 28, Range 25W3, in the
Figure 5.2 Shut-in pressure - depth diagram of the Viking Formation.
Figure 5.3 Regional potentiometric surface of the Viking Formation.
1) equipotential lines (contour interval = 10 m);
2) potentiometric low; 3) potentiometric high;
4) facies belts (subregions);
5) fluid flow direction; 6) oil and gas fields.
north. A second high-pressure system is located outside the study area in the southwest. A minor one is centred in Township 26, Range 15W3.

Subregion C shows a more closely spaced contours which are continuous and sinuous. The contours of the potentiometric surface show a west-east trend along Township 28, swinging southwards in Range 17W3, in a sinuous pattern. In Township 25, Range 18W3, the contours of the potentiometric surface swing into a northwest-southeast trend and continue in this direction to the eastern edge of the area. Potentiometric cells in the area also show a west-east trend with minor variations.

Comparison of Figures 5.1 and 5.3 show variation in potentiometric cells notably in the Bayhurst area of subregion A. A high cell in Township 22, Range 26W3, in Figure 5.1 is replaced by a low in Figure 5.3. This high is defined by a single well test, which made it rather unrealistic. An examination of the test data in the second culling revealed that the test consisted of only one shut-in pressure instead of two (ISIP and FSIP) as most of the tests in the area. Its anomalously high pressure in relation to adjacent pressures rendered it unacceptable. Similar variation on the two maps can be explained by the removal of tests on the basis of one shut-in pressure, proximity to or located within hydrocarbon production, date of test, and general fit of the data in the same location. The three-dimensional plots of Figures 5.1 and 5.3 given in Figure 5.4 show the characteristic features of the two potentiometric surfaces.
Figure 5.4 Three-dimensional plot of the potentiometric surface of the Viking Formation
1) local (of Figure 5.1); 2) regional (of Figure 5.3)
The potentiometric surface of the Mannville Group (Christopher, 1974; 1980) is similar to the Viking Formation surface (Figure 5.3): both indicate that flow is to the north and northeast and that the southwestern region has the highest potentiometric surface with a potentiometric low cell approximately coinciding in part with the northern flank of the Bayhurst dome. However, as will be seen, fluid profiles indicate that no hydraulic connection exists between the Viking and the Mannville aquifers.

5.4 Patterns of Fluid Migration

Toth (1962, 1963) and Freeze and Witherspoon (1967) developed mathematical models of ground-water movement that indicate that the distribution of fluid potential and related patterns of fluid flow are strongly influenced by topography and geology. The importance of these factors in controlling fluid flow in the western Canada sedimentary basin as a whole has been demonstrated by Hitchon (1969a, 1969b). On a basin-wide scale, the overall flow pattern is from southwest to northeast, controlled largely by reservoir characteristics of the major hydrostratigraphic units, which generally show widespread lithologic and hydraulic continuity in the northern Williston Basin region (Simpson, 1987). In western Saskatchewan, northeastward fluid migration in Phanerozoic strata has been shown by various works (Milner, 1956; Christopher, 1974, 1980).
From the potentiometric map (Figure 5.1) it appears that the hydraulic regime in the Viking Formation is dominated by localized anomalous potentiometric lows and highs. The flow pattern is irregular, originating from the local potentiometric high cells to low cells.

The regional potentiometric map (Figure 5.3) shows three hydraulic systems characterized by two pressure ridges (divides) within the area, and the third located outside the study area in the southwest as discussed. A minor pressure ridge is centred in Township 26, Range 15W3, in the locality of the Elrose dome. The flow is from these into the potentiometric low cells. The open pressure system in the Bayhurst feeds the depressions to the south and southwest and to the north and northeast. The south/southwest low seem to coincide with Cabri syncline of Jones (1961a). The second divide that begins in Township 21, Ranges 21 and 22W3, feeds mostly the northeastern parts of the area. The cause for the high potential in this second divide may be attributed to occurrences of localized salt solution as indicated by seismic anomalies and sinks in the area. Bacopoulos (1988) noted a definite correlation between salt-solution structures and the presence of continuous pressure systems, which are in turn expressed on potentiometric surfaces by coincidence of potentiometric high cells. Being sites of cross-formational flow, the structures could have given rise to the high fluid pressure system in this area.
The gentler slopes of subregions A and B (except for the Bayhurst area) indicated by wider spacing of the potentiometric contours implies that the Viking Formation has high permeability relative to subregion C. The high permeability allows for continuity in fluid pressure in subregion A, and the many potentiometric low cells (Figure 5.1) and increased slope (Figure 5.3) in subregion C of the study area are therefore indications of permeability barriers.

Topographically (Figure 5.0), the correspondence of a general high relief (710 - 823 m) area, south of the South Saskatchewan River to high potential in the area, and some localised areas of high relief in the northwest suggest a possible influence of topography on groundwater flow. However, despite this correspondence, current topography has no effect on fluid potential distribution in the confined Viking aquifer as will be seen in Section 5.5.

Comparison of the structure contour map on top of the Viking Formation (Figure 4.11) and the regional potentiometric map (Figure 5.3) shows generally that potentiometric mounds are associated with the structural domes and depressions with the structural synclines.

5.5 Relationship to Lithology

The marine sandstone and siltstone bodies, referable to the Colorado Group of western Saskatchewan, exhibit varying degrees
of shaliness which in part reflects lithologic gradation with the enveloping shales and mudstones (Simpson 1975, 1979b, 1984b).

In western Saskatchewan, the stacked multistorey sandstone bodies of the Bow Island Formation give way to a single sandstone body, the Viking Formation, which occurs in the area of study. As shown in the lithofacies description and their areal distribution considered in Chapter IV, the Viking Formation exhibits major variations in shaliness and thickness.

Three subdivisions were distinguished on this basis: thick sand units of subregion A, relatively thick sands of subregion B and thin shaly sands and shales of the subregion C. This increase in shaliness parallels that of the decrease in grain size in a northeasterly direction.

Subregion A lithologies are characterized by type-IV elements comprising widespread, well-washed sandstones in planar foresets. These sandstone bodies exhibit coarsening-upward sequences with alternating layers of sandstone/siltstone and mudstone (bedded shaly sandstones) succeeded by bloturbated shaly sandstones. In turn they are characterized by upward decrease in the frequency and thickness of primary heterogeneities (shale breaks), porosity-permeability gradients of improved reservoir quality paralleling the upward increase in sand size, and the occurrence of secondary heterogeneities (cementation barriers) in the top pebbly sandstones and conglomerates. The sandstone bodies are overlain by the well-washed cross-laminated sandstones at the top of the units.
Porosities are generally in the range 25 to 35%, and maximum horizontal permeabilities can be up to 2000 millidarcies from a few hundred millidarcies (Simpson, 1984b). Fluid flow is therefore easier in the upper parts of the Viking Formation.

The lithofacies of subregion B is composed of dominant, relatively thick clean sand units characterised by an almost uniform thickness ranging from 16 to 21 m. The sandstone/siltstone units in this region still exhibit coarsening-upward sequences, but are usually thinner than in the southwest. They progressively become closer to bedded shaly sandstones (type-II elements) succeeded upwards by bioturbated shaly sandstone (type-III elements) of subregion C. The units include subordinate pebbly sandstones and conglomerates, again common near the top of the units. Primary heterogeneities are abundant in the lower part of the sequence and secondary heterogeneities are associated with the tops of the units. The continuous and nearly uniform thickness and minimum variation result in easier fluid flow.

Subregion C is made up largely of bedded shaly sandstone (type-II elements) succeeded by bioturbated shaly sandstones (type-III elements). The Viking Formation consists to a large extent of an upper layer which is largely a shale component, highly subdued on geophysical well logs, and the lower portion composed of silt and fine sand. In the Plato area for example, the lower portion was divided into two sand units named 'A' and 'B' on the basis of resistivity logs (Gillard and White, 1970).
Owing to the prominent shaly intercalations which are often continuous in the sand units, the primary heterogeneities are more important than the secondary heterogeneities. In fact, in the Plato Pool, the upper portion (shale) acts as a cap for the hydrocarbons which occur in the two sand layers.

Porosities of 20 to 30% are typical in the bioturbated layers, while 15 to 25% are confined to the bedded shaly sandstones. Permeabilities of up to several hundred millidarcies characterize the units (Simpson, 1984b). Fluid flow in these units might be limited to the lower portions of the formation (laterally), while vertical flow may be important in the upper parts.

Consequently, comparison of the potentiometric maps (Figures 5.1 and 5.3) with the isopach map (Figure 4.8) reveals that both the potentiometric high cells (Figure 5.1) and the high-pressure systems (ridges – Figure 5.3) in subregion A correspond to the thicker sand units in the area, i.e. the maximum formation thickness closures of Bayhurst area and the Abbey northwest extension in Township 22, Range 21W3. The highest pressure system of the southwest corner is also associated with maximum formation thickness in the study area. The potentiometric low cells (Figure 5.3) in the area corresponds to the area southwest of the Bayhurst high with minimum Viking Formation thickness closure. Similarly, the potentiometric low of the northern flank corresponds to reduced thickness. The closeness of potentiometric contours in the Bayhurst area (Figure 5.3) in
comparison to the Abbey-Lacadena area indicates lack of permeability barriers in the latter. The steeper potential slopes and anomalies in the former are explained by the proximity of the area to the facies change boundary, sudden drop in thickness of the formation and occurrence of secondary heterogeneities.

Subregion B of the isopach map corresponds to more widely spaced potentiometric contours with a few isolated lows. This suggests lack of permeability barriers in the area, which is obviously supported by the lithofacies description and areal distribution of the formation. However, subregion C, with its irregular isopach trends for isolated sand lenses, shows numerous occurrences of potentiometric lows, closeness in contours and steeper gradients. The west-east trending contours of the potentiometric surface (Figure 5.3) coincide with the two separate west-east thickness trends in Township 28, Ranges 23 to 26W3, and Ranges 17 to 21W3, before swinging southwards in a sinuous pattern. Indeed, though most of these lows and highs could be attributed to hydrocarbon production, in fact they might also be explained by lithological variation and mineralogy, and hence lower permeability. Tóth and Rakhit (1988) linked potentiometric flexures to the existence of sand lenses and their orientation in the Bow Island Formation of Alberta. The many irregularities (flexures) in flow may equally be attributed to lensing of the Viking lithofacies of the study as it is such a common feature. The increase in primary heterogeneities relative
to the other areas result in variable distribution of permeability (up to several hundred millidarcies), and thus perturbation of the potentiometric surface. A good example is in the southwest end. This trend parallels that of the sand lens and delimiting permeability barriers.

In the Bayhurst area in subregion A, the potentiometric high cell centred in the Dungloe No. 1 (U.S.D 08-35-23-26W2) control generally fine-grained with horizontal or gently inclined laminae. The permeable laminae could be effective conduits for fluid movement, and hence giving a high pressure reading. A

presence of burrows locally may provide vertical communication across these thin mudstone intercalations commonly associated
with the sandstone lenses and layers. Also, the intercalations themselves may influence vertical fluid flow, as stated by Weber (1982). In the Glidden area (Township 27, Range 24W3), testing was in the conglomerate and sandstone lithofacies, which may be responsible for easier movement of fluids in the absence of secondary heterogeneities (cements) and thus give rise to a high fluid pressure.

In view of the inconclusiveness of the sources of high pressures, fluid profiles were examined to identify any possible cross-formational flow. It appears that there is no correlation between the underlying strata and the Viking Formation from the two wells with high pressures in the formation and drill-stem test data of the underlying strata (Figure 5.5). Fluid flow continuity is also lacking in the medium pressure wells (Figure 5.6) and apparently even with the overlying strata (Figure 5.7). This suggests that the Viking Formation forms a discrete hydrostratigraphic unit separate from the underlying and overlying units. This is in agreement with the findings of Christopher (1974), who noted that strata below the Joli Fou shale form a hydrologic continuum because of the sub-Success and sub-Cantuar unconformities. Maxey (1964) defined an hydrostratigraphic unit as a body of rock of considerable lateral extent which composes a geologic framework incorporating a distinct hydrologic system. The hydraulic isolation of the Viking Formation may suggest that recurrent basement activation, does not facilitate cross-formational flow to the formation.
Figure 5.5 Fluid-pressure profiles for:
1) Saskoil Leader No. three well (LSD 05-10-22-26W3);
2) Cabri No. 1 well (LSD 01-23-24-28W3).
VKNG: Viking Formation; DTRL: Detrital Formation;
MDGP: Madison Group; JRSC: Jurassic Formation.
Figure 5.6 Fluid-pressures profiles for:
1) Shell Rio Tinto Sceptre No. 2 (LSD 05-32-21-24W3);
2) Phillips Husky Bailey No. 1 (LSD 07-02-27-26W3);
3) Saskoil Totnes N 6 21 28 18 (LSD 06-21-28-18W3);
4) Texan Alsask 10 1 28 29 (LSD 10-01-28-29W3).
VKNG: Viking Formation; LGVB: Lower Gravelbourg Formation;
DTRL: Detrital Formation; MDGP: Madison Group;
BDBR: Birdbear Formation; MNVL: Mannville Formation;
SPNL: Spinney Hill Sandstone; BKKN: Bakken Formation;
LRSV: Lower Shaunavon Formation; PCMB: Pre-Cambrian.
Figure 5.7 Fluid pressure profiles for:
1) Cdr. Sceptre 232124 (LSD 02-03-21-24W3); 2) Spe Mendham (LSD 07-25-21-27W3); 3) Charter Canadian Devonian Empress 5 (LSD 05-21-22-29W3).
MLKR: Milk River Formation;  LPRK: Lea Park Formation;
VKNG: Viking Formation;  MNVL: Mannville Formation;
BDBR: Birdbear Formation;  MDGP: Madison Group.
However, hydrologic continuum is implied in only two locations (Figure 5.8). It is very likely therefore that the abnormal pressures in the Viking Formation are probably from a combination of the factors considered in detail by Bradley (1975) and summarised here as: (i) epeirogenic movements with associated erosion and/or deposition, (ii) thermal expansion or contraction of fluids reacting to temperature changes, (iii) osmosis, (iv) chemical action of pore waters trapped in a sealed formation, (v) carbonization of organic matter in sediments, and (vi) buoyancy due to the hydrocarbon column of the reservoir. Consideration of how each of these factors has contributed to abnormal pressures in the formation is beyond the scope of this study. However, some of these factors are discussed in Chapter II. The existence of secondary heterogeneities (cements) in subregion A and primary heterogeneities (shale breaks) in subregion C are responsible for the confining of high and low fluid potentials in domal and synclinal features respectively. Without the heterogeneities, the pressures would have equalised to hydrostatic.

5.6 Relationship to Hydrocarbon Accumulations

Hydrocarbon production in the Viking has been concentrated in west-central Saskatchewan and eastern Alberta. Simpson (1984) gives a summary of production in Saskatchewan showing a total of 28 pools (8 oils, 20 gas pools). Ten of these (2 oils and 8 gas pools) occur in the study area as summarized in Table 5. The
Figure 5.8 Fluid-pressures profiles for:
1) Arco Cramersbourg 13 19 22 20 (LSD 13-19-22-20W3);
2) Dome Provo Lancer No. 10 9 (LSD 10-09-22-21W3).
VKNG: Viking Formation; MNVL: Mannville Group;
BDBR: Birdbear Formation; SRSR: Souris River Formation;
MDGP: Madison Group; BKKN: Bakken Formation.
Table 5

Production of Hydrocarbon from the Viking Formation (Early Cretaceous) in the Study Area (from Saskatchewan Energy and Mines, 1983a, b and 1985)

<table>
<thead>
<tr>
<th>POOL</th>
<th>DISC DATE</th>
<th>DRIVE</th>
<th>DEPTH</th>
<th>NET</th>
<th>PAY</th>
<th>POR</th>
<th>H2O</th>
<th>SAT</th>
<th>ERGO D</th>
<th>OIP/IGIP</th>
<th>EST</th>
<th>IER</th>
<th>CUM PROD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(M)</td>
<td></td>
<td>(M)</td>
<td></td>
<td>%</td>
<td></td>
<td>%</td>
<td>TECH (M$^3$)</td>
<td>(M$^3$)</td>
<td>%</td>
<td></td>
<td>(M$^3$)</td>
</tr>
<tr>
<td>Plato Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol. Unit No. 1</td>
<td>68</td>
<td>SGD</td>
<td>644</td>
<td>1.86</td>
<td>0.85</td>
<td></td>
<td>22.0</td>
<td>38.0</td>
<td>6.50</td>
<td>4.240</td>
<td>0.276</td>
<td>0.266</td>
<td></td>
</tr>
<tr>
<td>Non-Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.627</td>
<td>0.283</td>
<td>0.395</td>
<td></td>
</tr>
<tr>
<td>Plate North Oil</td>
<td>78</td>
<td>SGD</td>
<td>705</td>
<td>2.88</td>
<td>0.98</td>
<td></td>
<td>23.0</td>
<td>35.0</td>
<td>10.00</td>
<td>1.135</td>
<td>0.113</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>Bayhurst Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol. Unit</td>
<td>58</td>
<td>--</td>
<td>661</td>
<td>2.71</td>
<td>2.19</td>
<td></td>
<td>25.0</td>
<td>14.5</td>
<td></td>
<td>2567.7</td>
<td>1951.4</td>
<td>1858.5</td>
<td></td>
</tr>
<tr>
<td>Brock Gas Unit</td>
<td>51</td>
<td>--</td>
<td>716</td>
<td>1.98</td>
<td>1.98</td>
<td></td>
<td>24.6</td>
<td>14.5</td>
<td></td>
<td>1747.9</td>
<td>448.2</td>
<td>305.8</td>
<td></td>
</tr>
<tr>
<td>Greenan Gas</td>
<td>69</td>
<td>--</td>
<td>655</td>
<td>2.71</td>
<td>2.71</td>
<td></td>
<td>25.0</td>
<td>25.0</td>
<td></td>
<td>465.8</td>
<td>354.0</td>
<td>288.6</td>
<td></td>
</tr>
<tr>
<td>Totnes Gas Vol. Unit</td>
<td>69</td>
<td>--</td>
<td>613</td>
<td>2.71</td>
<td>2.71</td>
<td></td>
<td>25.0</td>
<td>25.0</td>
<td></td>
<td>155.2</td>
<td>118.0</td>
<td>107.1</td>
<td></td>
</tr>
<tr>
<td>Non-Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>122.0</td>
<td>101.1</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>232.7</td>
<td>326.0</td>
<td>245.0</td>
<td></td>
</tr>
<tr>
<td>Bayhurst W Gas Vol. Unit</td>
<td>68</td>
<td>--</td>
<td>694</td>
<td>1.62</td>
<td>0.88</td>
<td></td>
<td>30.5</td>
<td>21.0</td>
<td></td>
<td>484.0</td>
<td>229.9</td>
<td>79.4</td>
<td></td>
</tr>
<tr>
<td>Glidden Gas Vol. Unit</td>
<td>53</td>
<td>--</td>
<td>691</td>
<td>0.88</td>
<td>0.88</td>
<td></td>
<td>21.0</td>
<td>21.0</td>
<td></td>
<td>484.0</td>
<td>229.9</td>
<td>79.4</td>
<td></td>
</tr>
<tr>
<td>Brock E Gas</td>
<td>67</td>
<td>--</td>
<td>720</td>
<td>0.51</td>
<td>0.51</td>
<td></td>
<td>24.0</td>
<td>24.0</td>
<td></td>
<td>310.0</td>
<td>103.1</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>Harengo Gas</td>
<td>54</td>
<td>--</td>
<td>728</td>
<td>1.89</td>
<td>1.89</td>
<td></td>
<td>25.0</td>
<td>25.0</td>
<td></td>
<td>323.7</td>
<td>246.0</td>
<td>6.0</td>
<td></td>
</tr>
</tbody>
</table>
first to be discovered was a gas pool spudded in August 1951 in Phillips Brock No. 1 well (LSD 13 29 28 20W3) (Jones, 1961a). Since then drilling into and through the Viking Formation has resulted in the discovery of other pools with the last discovery made in 1978 at Plato North (oil pool).

Currently, Saskoil Limited is engaged in a multi-well drilling program at Alsask in Township 28, Range 29W3. The first well in the program, cased as Viking gas well, has given test rates exceeding \(85 \times 10^3 \text{ m}^3\) per day, and if successful, construction of a processing plant is under way (Saskoil Limited, 1987).

From the explorationist's point of view, Simpson (1984b) made reference to the study of reservoir heterogeneities by Alpay (1972). Table 6 shows three levels of heterogeneities: microscopic, macroscopic and meagascopic.

Microscopic heterogeneities are those that occur as pore-to-pore variations in the texture of a reservoir unit related to the pore-size distribution, pore geometry, dead-end pore space and types of pore occlusion. Macroscopic heterogeneities are a function of textural variation within a sequence of reservoir strata and are correlated between adjacent wells. Megascopic heterogeneities are defined primarily on the stratigraphic and structural framework of the reservoir. The last two are significant as they can be used for the definition of drilling targets and hence exploration strategy. Such considerations are also important for the definition of future
Table 6. Hierarchy of Reservoir Heterogeneities in Sandstone Bodies of the Colorado and Montana Groups (Cretaceous) in Saskatchewan (after Alpay, 1972 in Simpson, 1984)

<table>
<thead>
<tr>
<th>MICROSCOPIC</th>
<th>MACROSCOPIC</th>
<th>MEGASCOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Scale of Individual Pores</td>
<td>Lithologic Variation</td>
<td>Lithologic Variation</td>
</tr>
<tr>
<td>A. pore-size distribution</td>
<td>Between Wells</td>
<td>on Scale of Field</td>
</tr>
<tr>
<td>3. pore geometry</td>
<td>A. stratification</td>
<td>or Regional in Extent</td>
</tr>
<tr>
<td>C. pore occlusion</td>
<td>characteristics</td>
<td></td>
</tr>
<tr>
<td>5. dead-end pore space</td>
<td>B. porosity-permeability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>characteristics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<—— PRODUCTIONIST ———>      <—— EXPLORATIONIST ———>

UTILITY
prospective areas in the Viking Formation in general, and in the area of study in particular. A trap occurs when the net effect of water drive, buoyancy, and capillary pressure results in zero movement of the hydrocarbon (Davis, 1987; Garven, 1989). Water drives are an important factor when the boundaries of the strata have very low dips of less than 5 degrees. Bouyancy force which is normally in the dip direction is therefore the most important driving force in most areas. Changes in permeability and thickness of transport strata cause changes in potentiometric surface gradients. An increase in permeability and thickness of transport strata result in gentler potentiometric surface gradients. These changes are in turn brought about by stratigraphic variation (which cause variation in porosity) and by fluid variation (primarily due to changes in thermal conditions) as noted by Davis (1987).

The maps drawn of the potentiometric surface using pressure data from drill-stem tests should show clearly the location of the stratigraphic permeability barriers which are the traps of hydrocarbons. Most reservoirs have abnormally low initial reservoir pressures on the flanks of the structural basins. This implies that in these areas, complete seals are present for aquifers to continue having subnormal pressure for a long time. They can thus be interpreted as indicating existence of lack of permeability, probably characterized by permeability pinchouts which are associated with clastic wedges or anomalous thickening.
and thinning of strata (Swanson, 1972; Dickey and Cox, 1977). Anomalous local thickening and thinning of sandstones is a common feature in subregion C.

Figure 5.9 shows the location of the hydrocarbon pools in relation to potentiometric surface, dominant structural features and lithology in the area. It is evident from the figure that two pools (Bayhurst and Bayhurst East gas pools) are associated with the potentiometric high divide of the southwest flanked on both sides by synclinal features with low fluid potential. The remaining pools, including the two Plato oil fields, are found in subregion C which is characterised by changes in and distortions of the potentiometric slope. It is not surprising that subregion B area has no proven hydrocarbon accumulation. The generally wide and even spacing of the potentiometric contours in this area is indicative of continuity of permeability and hence easy migration of hydrocarbons. McNeal (1965) noted that any connection of permeable strata from one to another through a stringer or even a fraction of a centimetre thick could cause the migration. This may be true for the Plato Central dome closure in subregion B area. A connection between this closure and the northern flanks could have caused the oil to migrate to its present location. Consideration of stratigraphic barriers, structural and hydrodynamic regime can help explain the scenario presented here. Obviously the variation in lithology, porosity and permeability acted as barriers to hydrocarbon accumulation. Assuming a southern source for the hydrocarbon in the area, the
Figure 5.9 Regional potentiometric cells (from Figure 5.3) in relation to lithology, prominent structure, basement features and commercial hydrocarbon accumulations in the Viking Formation.

1) boundary of the Viking facies belts (subregions); 2) dome; 3) synclinal structure; 4) anticlinal structure; 5) potentiometric low; 6) potentiometric high; 7) edge of Jurassic strata; 8) structural linears; 9) gravity gradient showing negative margins; 10) Prairie Evaporite salt present; 11) local salt solution (seismic anomaly); 12) sinks; 13) oil and gas fields.
many pools in subregion C relative to the other two areas (A and Subregion B) confirms the significance of the lithological variations and its associated reservoir characteristics in these accumulations. Increase in the abundance of shale breaks and existence of secondary heterogeneities near the tops of the units could have been effective seals for the hydrocarbons. This is strongly supported by the absence of such accumulations in the Plato central and Abbey-Lacadena domes in subregion B. However, the overwhelming association of the pools with the domal structures in the area suggests that stratigraphy played a role secondary to that of structure in the localisation of hydrocarbons.

Jones (1961a) explained the existence of dry holes within producing and favourable locations on the basis of lithological changes and structures in this area. He noted that the attenuation of sand layers localized hydrocarbons within those parts of structures where the layers are developed. In structures where sand development was present but no hydrocarbon, he considered the possibility of an existence of superimposed structures as likely traps of hydrocarbons and therefore warranted additional drilling. Hydrodynamics was not considered by Jones (1961a), although some local gas-water contacts were examined by him.

The general 'rolling' structure dipping southwestwards means migration up dip by the hydrocarbons and they accumulate when confronted with these macroscopic heterogeneities. The migration
was obviously aided by the pattern of flow to the northeast and north. In the Bayhurst area, the downdip water flow on the south and southwest flank opposite the updip hydrocarbon migration could have aided the hydrocarbon accumulation even more.

More specifically, two examples are used to illustrate these concepts; one in subregion A and the other in subregion C. Figure 5.3 and 5.9 show two divides within the study area as discussed and both are considered feeders of water to the low fluid potential areas.

In subregion A, the Bayhurst gas accumulation is associated with the Bayhurst dome and close to the limit of subregion A which is a major thickness change. Figure 5.10 shows the structure contour map of the top of the Viking Sand in the Bayhurst area in relation to the potentiometric surface of the Viking Formation. Comparison of the producing wells to that of fluid flow pattern shows the distribution of wells confined in the dome closure. The movement of water from this dome to the north/northeast and south/southwest probably forced the accumulation to spread rather than being flanked to one edge of the dome.

In subregion C, where a second divide feeds water to the north and northeast parts of the area, the Plato area gives a good example. The producing area lies to the north of the Plato Central dome with a northwest-southeast orientation. The structure contours of the top of the Viking Sand in relation to the potentiometric surface of the Viking Formation of this area
Figure 5.10 Structure contour map of the top of the Viking Formation in the Bayhurst gas pool area in relation to the potentiometric surface of the Viking Formation. 1) gas well; 2) abandoned dry well; 3) equipotential lines (contour interval = 10 m); 4) structure contour lines (contour interval = 5 m).
are shown in Figure 5.11. The location of the producing and non-producing wells are given also. The water flow in the area is generally to the north and northeast (Figures 5.3 and 5.9). It can be seen that the accumulation is localized at the flanks of this structure despite the central dome being generally of high relief. The absence of permeability barriers between the central dome and the production area have resulted in relocation of the accumulation to the northern flank of the structure.

Gillard and White (1970) noted that the basin in Township 25, Range 16W3, seemed to have been an important factor in petroleum accumulation. It is possible that oil could still be trapped further downdip by porosity pinch-out along the easterly and southerly flanks of the basin. Davis (1987) noted that the resulting changes, very characteristic in subregion C, in potentiometric gradients in a structure of low dip can cause significant changes in both entrapment potential and location of the trap on the structure. These potentiometric gradients which are confined to the flanks of the structures indeed indicate stratigraphic barriers responsible for the localization of the accumulations in these areas.

5.7 Discussion and Summary

Generally, the regional flow pattern in the study is to north and northeast (Figure 5.3), which is greatly subdued by the present hydraulic regime (Figure 5.1). Two divides are prominent in the area and greatly influence the flow system.
Figure 5.11 Structure contour map of the top of the Viking Formation in the Plato oil pool area in relation to the potentiometric surface of the Viking Formation.  
1) oil well; 2) gas well; 3) abandoned dry well; 4) equipotential lines (contour interval = 10 m); 5) structure contour lines (contour interval = 5 m).
The generally wide spacing of potentiometric contours in most parts of subregion A and subregion B indicates lack of stratigraphic permeability barriers, and therefore lack of hydrocarbon accumulation. On the basis of stratigraphic control, the only likelihood of hydrocarbon accumulation is along the northern edge of subregion A. Hydrocarbon occurrence is associated with the close spaced potentiometric contours and steeper gradients of subregion C. The numerous domal structures, anomalous thickening and thinning, and lithological variations of the formation are important features in the hydrocarbon trapping in this area.

Fluid profiles have shown no hydraulic connection of the Viking Formation to the underlying and overlying strata, indicating that the Viking is an isolated hydrostratigraphic unit. Lack of fracture systems in thick Joli Fou and Big River Formations in the study might have inhibited cross-formational flow.
CHAPTER VI

6.0 ECONOMIC CONSIDERATIONS

6.1 General Remarks

The Lower Colorado sandstone bodies (Middle Albian to Upper Albian) have yielded commercial quantities of light oil and non-associated gas in western Saskatchewan since 1945 (Saskatchewan Energy of Mines, 1983a, 1983b). The conventional reservoirs of the Viking Formation in western Saskatchewan have accounted for virtually all the initial established reserves of crude oil in the Colorado Succession.

In the study area, the Viking producing areas are given in Table 4 (modified from Simpson, 1984b).

6.2 Integrated Exploration Strategy

Since current hydrocarbon production from the Viking Formation is associated with porosity-permeability gradients of improved reservoir quality paralleling the upward increase in sand size in structures reflecting relief features of the buried pre-Cretaceous erosion surface, it is necessary to consider generally the controls of hydrocarbon accumulation in order to outline exploration strategy.

Simpson (1984a, b) outlined the main controls of hydrocarbon accumulations in the Colorado and Montana strata as lithological

210
and structural. The main lithological controls are:

(i) the occurrence of enveloping argillaceous strata associated with the main reservoir units

(ii) the basinward attenuation of the reservoir units (mostly sandstone and siltstone bodies)

(iii) the basinward diminution of grain size in reservoir units (observed in most sandstone and siltstone bodies)

(iv) the common dominance of upward coarsening of lithologies making up the main reservoir strata, and

(v) the occurrence of concretionary capping lithologies in the sites of best original permeability near the tops of coarsening-upward sequences.

The main structural controls are:

(i) basement linear features of regional extent

(ii) basement linear features of local extent

(iii) solution-generated collapse features associated with the Prairie Evaporite (Middle Devonian) and

(iv) the palaeotopography of the sub-Cretaceous unconformity.

Some of these features are shown in Figure 2.1 in Chapter II.

These general lithological controls on hydrocarbon accumulation are characteristic in the Viking Formation of the study area as seen in Chapter IV. Briefly, subregion A is characterized by type-IV elements with good reservoir characteristics, that is, good porosity and permeability with relatively few inhomogeneities. The dominance of
coarsening-upward of lithologies capped by concretionary lithologies is a very characteristic feature in this area. Subregion B and subregion C are mainly type-II and III elements characterized by generally primary heterogeneities (shale breaks) and consequently, of generally lower porosities and permeabilities. In both cases, the sand bodies are enveloped in the thick type-I and II elements of the Joli Fou and Big River Formations.

On the structural part (Figure 5.9) basement features of regional extent affecting the study are the structural linears evidenced by gravity anomalies, and the palaeotopography of the sub-Cretaceous unconformity evidenced by the erosional scarps along the edge of Jurassic strata. These were considered in Chapter IV. Superimposition of current production in the area to the structure contour map (Figure 5.9) shows that all production areas are associated with the domal structures and hence these are mainly structural traps. Previous exploration strategy, therefore, was directed to the structural traps and probably with some stratigraphic consideration. This is evident from the location of data points on structure map that priorities were directed to the structures (domal), but subregion B with no significant domal features received low priority.

The third component of hydrodynamics introduced in this study, may aid in delineation of future prospects as the movement of groundwater localizes hydrocarbons. Consequently, an integrated exploration strategy that examines the structure and
then employs hydrodynamics to predict areas of likely stratigraphic permeability barriers might be the answer to this problem. The delineation of such barriers could result in economic prospects because future traps are more likely to be stratigraphic and hydrodynamic rather than structural.

6.3 Prospective Areas
An integrated approach using structural, stratigraphic and hydrodynamic re-examination of the area could lead to economic catches. From the location of the well-point data in the study, it seems all the prospective areas have been exploited. However, this might not be the case, when one considers the Plato area and the current development going on in the Alsask dome region.

Hydrodynamic maps display exploration anomalies such as stratigraphic barriers. These can be used on a regional basis for locating prospective areas and with accurate, corrected pressure data, for outlining of individual prospects. On the stratigraphic point of view, the abrupt decrease in thickness from subregion A to subregion B area accompanied by dominantly type-IV elements in subregion A to type-II in subregion B makes this trend prospective in the area. If this trend is checked against the structure and the hydrodynamic map, prospective areas are targeted at the flanks of the structural domes and basins.

There is a decrease in thickness and grain size northeastward from subregion B to subregion C. Subregion C is characterised by thickness closures which are so evident on the
isopachous map and are outlined to some extent on the potentiometric map. These closures indicate occurrence of sandstone lenses with probably permeability pinchouts at their margins and hence making these margins to be prospective areas. Prospecting in these type- II elements should also be targeted at the flanks of structural basins and domes which coincide with potentiometric cells and steeper potential gradients in subregion C. Movement of water to the north and northeast makes the northern and northeastern flanks of the structural domes future prospective areas. Delineation of the structural basins in the area is very important as generally oil and gas is associated with troughs/synclines and domes/anticlines respectively in west-central Saskatchewan. Plato oil pool on the flanks of the basin is a good example in the study area.

The criteria for the localisation of hydrocarbon accumulation is thus based on the presence of domal features for structure (Figure 4.11), thick sand units and lensing for lithology (Figure 4.8) and presence of potentiometric cells and steeper potential gradients for hydrodynamics (Figures 5.1 and 5.3). On this basis future prospective areas in the study, in order of decreasing importance are:

(i) the southern and northern flanks of the structural syncline separating the Lynnhurst and the Eatonia-Glidden-Inglenook domes (in Townships 27 and 28, Ranges 23 and 24W3), i.e. the flanks of the domes, also the southern flank of the latter;
(ii) the southern and northern flanks of the Elrose dome (Township 26, Range 15W3);

(iii) the northeastern flank of the Chipperfield dome (Township 28, Ranges 16 and 17W3, and parts of Township 27, Range 17W3);

(iv) the southern and possibly northern flanks of the salient basin of Township 25, Range 16W3, the northern and southern flanks of the Plato oil and Greenan gas pools respectively which may not be fully exploited at present;

(v) the northwestern extension of the Bayhurst dome (in Townships 25 and 26, Ranges 27 to 29W3).

Furthermore, locations (i), (ii) and in part (iii) have discovery wells which were completed and considered as capable of production (Saskatchewan Energy and Mines, 1954), but had not been intensively explored. These wells are: H.P Verendrye No. 1 (LSD 7-19-28-23W3) and H.P Eatonia No. 1 (LSD 4-32-26-24W3) for location (i), Sohio Standard Elrose No. 1 (LSD 14-12-26-16W3) for location (ii) and Socony Sohio Totnes No. 21-5 (LSD 5-21-28-18W3) for location (iii). In addition location (i) is strongly favoured owing to oil showings in cored sections as seen in the lithofacies description in the area.
CHAPTER VII

7.0 CONCLUDING REMARKS

1. Subsurface data from exploratory and development wells were used in the construction of computer-generated structure and isopach maps, as well as cross-sections based on geophysical well logs. Rock associations were determined from lithologic descriptions.

2. Analysis of the results indicates that the Lower Colorado succession was deposited in a shallow-marine environment. The first sediments were the mudstones of the Joli Fou Formation interpreted as transgressive deposits. The Spinney Hill Sandstone has its source in the north and east and is interpreted as a distal fluviomarine deposit of deltaic origin. The onset of the first sands of the regressive Viking Formation terminated the transgression. Progradation of the shoreline westwards gave rise to the sedimentation of the mudstones of the Big River Formation.

3. The Viking Formation consists of coarsening-upward sandstone sequences, indicative of a shallowing depositional environment through time. Areal and lateral distribution of the Viking lithofacies show an increasing mud content, decrease in grain size and thinning in a northeasterly direction. Porosity-permeability distribution paralleled that of the decrease in grain size in the northeasterly direction. This
distribution pattern indicates deposition on a size graded shelf. On the basis of isopachous and lithofacies distribution the area was divided into three facies belts (A, B and C) relative to their position on this shelf. Subregion A consisting of dominantly thick, well washed sandstones (type-IV) and subregion B with intermediate facies as nearshore shelf deposits. Subregion C composed of thin shaly sandstones and shales as proximal shelf deposits. The overall dispersal of sediments in the formation was controlled by the Sweetgrass Arch and deposition by tidal and storm-generated currents.

4. The study area exhibits a gently rolling structure characterised by domal and synclinal features with regional dip to the south which is evident when viewed within its regional setting. The structures are a result of 'drape folding', largely influenced by sub-Mesozoic unconformity and the Sweetgrass Arch to the southwest and west.

5. Shut-in pressures from drill stem tests were employed for the construction of potentiometric maps of the Viking Formation and fluid-pressure profiles for the second part of the study.

6. Fluid flow is generally to the northeast and north and is influenced by geology. Four high fluid potential systems are identified in the area from which fluids flow to the low potential areas. Fluid profiles indicate that the Viking Formation is an isolated hydrostratigraphic unit. Integration of the hydrodynamic data with the facies belts indicate a general lack of stratigraphic permeability barriers in subregions A
and B. Subregion C facies is characterized by the presence of permeability pinchouts. Spatial coincidence of features on potentiometric surface and the structure contour maps respectively indicates that domal structures are regions of high fluid potential and the synclines as low potential areas.

7. Integration of the results of the sedimentologic - stratigraphic study, hydrodynamics and current hydrocarbon production show a close association of hydrocarbons to the domal structures, thick sand units and lensing, and potentiometric cells and steeper potential slopes in the area. The absence of hydrocarbon production in apparently favourable stratigraphic settings indicates that hydrodynamics and stratigraphic traps were secondary to structure in the localization of the hydrocarbons.

8. Hydrodynamics can be used to highlight areas of permeability pinchouts on the basis of potentiometric cells and variations in potentiometric slope. Prospective areas in the study therefore can be delineated effectively by use of hydrodynamics. The boundaries of the facies belts (subregion A and B, and B and C), subregion C, and the northeast and north flanks of the domal structures are prospective for hydrocarbons.
REFERENCES


Murphy, W. C., (undated). The interpretation and calculation of formation characteristics from formation test data. Halliburton Services, Duncan, Oklahoma, 19p.


Saskatchewan Department of Mineral Resources, Report No. 155. 15p. and 19 maps.


Plateau, J. A. F., 1863-1866. Experimental and theoretical research on figures of equilibrium of a liquid mass withdrawn from the action of gravity. Smithsonian Institute Annual Reports.


## APPENDIX 1 - ELEVATION OF MAIN CORRELATION SURFACES OF LOWER COLORADO SUCCESSION IN WESTERN SASKATCHEWAN.

<table>
<thead>
<tr>
<th>WELL NAME</th>
<th>WELL LOCATION</th>
<th>X.B (m)</th>
<th>DEPTH OF HORIZON</th>
<th>BELOW KELLY RUSHING (KB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rothwell Socony Matader 1 15 21 15</td>
<td>LSD 01-15-21-15W3</td>
<td>667.5</td>
<td>602.6</td>
<td>717.2</td>
</tr>
<tr>
<td>Rothwell Socony Cabri 5 18 21 16</td>
<td>LSD 05-18-21-16W3</td>
<td>659.9</td>
<td>585.3</td>
<td>695.5</td>
</tr>
<tr>
<td>Rothwell Socony Cabri 9 3 21 17</td>
<td>LSD 09-03-21-17W3</td>
<td>657.5</td>
<td>572.4</td>
<td>687.6</td>
</tr>
<tr>
<td>Rothwell Socony Cabri 10 3 21 18</td>
<td>LSD 10-03-21-18W3</td>
<td>660.2</td>
<td>522.1</td>
<td>633.4</td>
</tr>
<tr>
<td>Tide Water Abbey Crown No.2</td>
<td>LSD 01-31-21-18W3</td>
<td>585.2</td>
<td>481.6</td>
<td>594.4</td>
</tr>
<tr>
<td>Imperial Mry Creek 3 6 21 19</td>
<td>LSD 03-06-21-19W3</td>
<td>667.8</td>
<td>562.7</td>
<td>668.1</td>
</tr>
<tr>
<td>Ba Abbey Andreas 1 19 21 19</td>
<td>LSD 01-19-21-19W3</td>
<td>578.2</td>
<td>470</td>
<td>580.6</td>
</tr>
<tr>
<td>Arco Abbey 8 18 21 20</td>
<td>LSD 08-18-21-20W3</td>
<td>684.6</td>
<td>596.8</td>
<td>706.5</td>
</tr>
<tr>
<td>As Astra et al Abbey 10 23 21 20</td>
<td>LSD 10-23-21-20W3</td>
<td>577.9</td>
<td>473.7</td>
<td>583.7</td>
</tr>
<tr>
<td>Ba Abbey Bachmeier 1 33 21 20</td>
<td>LSD 01-33-21-20W3</td>
<td>584.3</td>
<td>481.6</td>
<td>585.2</td>
</tr>
<tr>
<td>Socony Soho Lancer 13 8</td>
<td>LSD 08-13-21-22W3</td>
<td>688.5</td>
<td>607.8</td>
<td>716.6</td>
</tr>
<tr>
<td>Bossort et al Portreeve 13 14 21 22</td>
<td>LSD 13-14-21-22W3</td>
<td>695.6</td>
<td>615.6</td>
<td>726.3</td>
</tr>
<tr>
<td>Rio Prado Lemsford 4 17</td>
<td>LSD 04-17-21-23W3</td>
<td>700.7</td>
<td>623</td>
<td>726</td>
</tr>
<tr>
<td>A.I.S. Portreeve 7 28 21 23</td>
<td>LSD 07-28-21-23W3</td>
<td>702.6</td>
<td>622.4</td>
<td>722.7</td>
</tr>
<tr>
<td>Shell Rio-Tinto Sceptre No.1</td>
<td>LSD 14-31-21-23W3</td>
<td>689.5</td>
<td>609.6</td>
<td>710.2</td>
</tr>
<tr>
<td>Cdrs Sceptre 2 3 21 24</td>
<td>LSD 02-03-21-24W3</td>
<td>705</td>
<td>628.5</td>
<td>735.8</td>
</tr>
<tr>
<td>Shell Rio Tinto Sceptre No.2</td>
<td>LSD 05-32-21-24W3</td>
<td>700.1</td>
<td>619.4</td>
<td>723.3</td>
</tr>
<tr>
<td>Numac Banner Leader 8 11 21 26</td>
<td>LSD 08-11-21-26W3</td>
<td>685.5</td>
<td>608.1</td>
<td>710.2</td>
</tr>
<tr>
<td>Vand Hnndhmn 11 16 21 26W3</td>
<td>LSD 11-16-21-26W3</td>
<td>694</td>
<td>615.7</td>
<td>715.4</td>
</tr>
<tr>
<td>10B Speayer 15 21 21 26</td>
<td>LSD 15-21-21-26W3</td>
<td>680.9</td>
<td>603.5</td>
<td>699.8</td>
</tr>
<tr>
<td>Saskoil Leader No.2</td>
<td>LSD 07-24-21-26W3</td>
<td>684.9</td>
<td>607.6</td>
<td>709.3</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.R (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VKNS TOP(m)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>10E Speyer 7 31 21 26</td>
<td>LSD 07-31-21-26W3</td>
<td>678.2</td>
<td>619.3</td>
<td>714.4</td>
</tr>
<tr>
<td>Baysel Mobil Okalta Can Pet Leader 7 30</td>
<td>LSD 07-30-21-27W3</td>
<td>713.2</td>
<td>648</td>
<td>744</td>
</tr>
<tr>
<td>Inter City Burstall No.2</td>
<td>LSD 01-01-21-29W3</td>
<td>727.9</td>
<td>662.3</td>
<td>752.6</td>
</tr>
<tr>
<td>Inter City Gas No.3</td>
<td>LSD 09-11-21-29W3</td>
<td>734.6</td>
<td>667.5</td>
<td>757.1</td>
</tr>
<tr>
<td>Inter City Burstall No.3</td>
<td>LSD 10-29-21-29W3</td>
<td>718.7</td>
<td>657</td>
<td>749.2</td>
</tr>
<tr>
<td>Tide Water Tuberose Crown No.1</td>
<td>LSD 16-17-22-15W3</td>
<td>621.5</td>
<td>523</td>
<td>638.3</td>
</tr>
<tr>
<td>Tide Water Bear Crown No.1</td>
<td>LSD 04-18-22-16W3</td>
<td>637.9</td>
<td>543.5</td>
<td>650.7</td>
</tr>
<tr>
<td>Tide Water Neosho Crown No.1</td>
<td>LSD 04-18-22-17W3</td>
<td>583.1</td>
<td>492.5</td>
<td>601.3</td>
</tr>
<tr>
<td>Tide Water Lacadena Crown No.1</td>
<td>LSD 16-33-22-18W3</td>
<td>588.6</td>
<td>479</td>
<td>591.3</td>
</tr>
<tr>
<td>Abbey Crown No.1</td>
<td>LSD 03-18-22-19W3</td>
<td>638.6</td>
<td>527.3</td>
<td>641.3</td>
</tr>
<tr>
<td>Chevron Spring Creek 12 21 22 19</td>
<td>LSD 12-21-22-19W3</td>
<td>635.2</td>
<td>521.9</td>
<td>641.3</td>
</tr>
<tr>
<td>Pinn et al Abbey 7 30 22 19</td>
<td>LSD 07-30-22-19W3</td>
<td>631.2</td>
<td>529.1</td>
<td>640.1</td>
</tr>
<tr>
<td>Chevron Spring Creek 6 2 22 20</td>
<td>LSD 06-02-22-20W3</td>
<td>612</td>
<td>502.9</td>
<td>615.7</td>
</tr>
<tr>
<td>Allied Norseman Abbey 16 13 22 20</td>
<td>LSD 16-13-22-20W3</td>
<td>639.2</td>
<td>530.7</td>
<td>640.7</td>
</tr>
<tr>
<td>Arco Craersberg 13 19 22 20</td>
<td>LSD 13-19-22-20W3</td>
<td>633.1</td>
<td>532.8</td>
<td>545.9</td>
</tr>
<tr>
<td>Ad Astra et al Flaxhill 10 1 22 21</td>
<td>LSD 10-01-22-21W3</td>
<td>599.2</td>
<td>503.5</td>
<td>606.9</td>
</tr>
<tr>
<td>Doae Provo Lancer 10 9</td>
<td>LSD 10-09-22-21W3</td>
<td>676</td>
<td>575.2</td>
<td>677.3</td>
</tr>
<tr>
<td>Doae Provo Lancer 6 22 21</td>
<td>LSD 06-22-22-21W3</td>
<td>656.2</td>
<td>562.6</td>
<td>668.7</td>
</tr>
<tr>
<td>Dekalb et al Cdr Lancer 6 31 22 21</td>
<td>LSD 06-31-22-21W3</td>
<td>698.3</td>
<td>611.4</td>
<td>721.5</td>
</tr>
<tr>
<td>Fairmont Siebens Lancer 7 6 22 22</td>
<td>LSD 07-06-22-22W3</td>
<td>603.4</td>
<td>606.2</td>
<td>709.3</td>
</tr>
<tr>
<td>CDR NE Lescord 12 30 22 22</td>
<td>LSD 12-30-22-22W3</td>
<td>678.8</td>
<td>596.5</td>
<td>695.9</td>
</tr>
<tr>
<td>Bossort et al Portreeve 15 10 22 23</td>
<td>LSD 15-10-22-23W3</td>
<td>690.1</td>
<td>604.4</td>
<td>707.7</td>
</tr>
<tr>
<td>B A Juckneiss 13 15</td>
<td>LSD 13-15-22-23W3</td>
<td>691.9</td>
<td>609</td>
<td>709.4</td>
</tr>
<tr>
<td>CDR Lamsford 9 16 22 23</td>
<td>LSD 09-16-22-23W3</td>
<td>695.6</td>
<td>608.4</td>
<td>711.1</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>DG RIVER TOP (m)</td>
<td>VXNG TOP (m)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------------------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Bossert et al Portreeve 1 22 22 24</td>
<td>LSD 01-02-22-24W3</td>
<td>690.1</td>
<td>610.2</td>
<td>715.7</td>
</tr>
<tr>
<td>10E Sceptre R/A 4 19 22 24</td>
<td>LSD 04-19-22-24W3</td>
<td>694.9</td>
<td>620.9</td>
<td>718.7</td>
</tr>
<tr>
<td>Rio Prado Sceptre 9 26</td>
<td>LSD 09-26-22-24W3</td>
<td>680</td>
<td>594.7</td>
<td>692.8</td>
</tr>
<tr>
<td>Dekalb et al Cdr Sceptre 10 32 22 24</td>
<td>LSD 10-32-22-24W3</td>
<td>672.4</td>
<td>588.3</td>
<td>681.2</td>
</tr>
<tr>
<td>HB Banner Prelate 9 5 22 25</td>
<td>LSD 09-05-22-25W3</td>
<td>683.4</td>
<td>598</td>
<td>698</td>
</tr>
<tr>
<td>Hudson's Bay Prelate 16 22 22 25</td>
<td>LSD 16-22-22-25W3</td>
<td>665.7</td>
<td>591.3</td>
<td>683.4</td>
</tr>
<tr>
<td>Hudson's Bay Prelate 13 33 22 25</td>
<td>LSD 13-33-22-25W3</td>
<td>672.7</td>
<td>584.6</td>
<td>681.8</td>
</tr>
<tr>
<td>Saskoil Leader No. Three</td>
<td>LSD 05-10-22-26W3</td>
<td>672.4</td>
<td>609</td>
<td>701</td>
</tr>
<tr>
<td>10E Prussia 4 20 22 26</td>
<td>LSD 04-20-22-26W3</td>
<td>673.6</td>
<td>609.9</td>
<td>707.1</td>
</tr>
<tr>
<td>Cdn-Sup Leader 6 20 22 27</td>
<td>LSD 06-20-22-27W3</td>
<td>685.2</td>
<td>614.5</td>
<td>706.2</td>
</tr>
<tr>
<td>Baysel Mobil Canpet Leader 11 29</td>
<td>LSD 11-29-22-27W3</td>
<td>703.2</td>
<td>634</td>
<td>723</td>
</tr>
<tr>
<td>Mobil Oil South Estuary 11 13</td>
<td>LSD 13-11-22-28W3</td>
<td>706.8</td>
<td>640.1</td>
<td>729.1</td>
</tr>
<tr>
<td>10E Bullshead Hill 4 20 22 28</td>
<td>LSD 04-20-22-28W3</td>
<td>699.5</td>
<td>638.3</td>
<td>730</td>
</tr>
<tr>
<td>10E Bullshead Hill R/A 13 25 22 28</td>
<td>LSD 13-25-22-28W3</td>
<td>682.8</td>
<td>619</td>
<td>709.3</td>
</tr>
<tr>
<td>Pan Am A-1 Estuary 4 28 22 28</td>
<td>LSD 04-28-22-28W3</td>
<td>696.5</td>
<td>638.9</td>
<td>731.5</td>
</tr>
<tr>
<td>Charter Canadian Devonian Empress No.5 21</td>
<td>LSD 05-21-22-29W3</td>
<td>689.2</td>
<td>625.8</td>
<td>718.1</td>
</tr>
<tr>
<td>Tide Water Sanctuary Crown No.1</td>
<td>LSD 16-17-23-15W3</td>
<td>602.6</td>
<td>509</td>
<td>612.7</td>
</tr>
<tr>
<td>Con-Sup Alainex Sanctuary 6 31 23 15</td>
<td>LSD 06-31-23-15W3</td>
<td>507</td>
<td>484.6</td>
<td>589.8</td>
</tr>
<tr>
<td>Tide Water Saltburn Crown No.1</td>
<td>LSD 04-18-23-16W3</td>
<td>623.9</td>
<td>519.7</td>
<td>621.5</td>
</tr>
<tr>
<td>Cdn-Sup Lacadena 6 21 23 16</td>
<td>LSD 06-21-23-16W3</td>
<td>623.9</td>
<td>522.7</td>
<td>626.1</td>
</tr>
<tr>
<td>Vand Siebells Lacadena 11 23 23 17</td>
<td>LSD 11-23-23-17W3</td>
<td>604.1</td>
<td>503.5</td>
<td>610</td>
</tr>
<tr>
<td>Tide Water Pluto Crown No.1</td>
<td>LSD 04-29-23-17W3</td>
<td>584.3</td>
<td>479.5</td>
<td>584.6</td>
</tr>
<tr>
<td>Sinclair Lacadena 3 34</td>
<td>LSD 03-34-23-17W3</td>
<td>602.5</td>
<td>497.7</td>
<td>602.3</td>
</tr>
<tr>
<td>Tide Water Tyner Crown No.1</td>
<td>LSD 04-29-23-18W3</td>
<td>612</td>
<td>516.6</td>
<td>623.9</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>BE RIVER TOP (m)</td>
<td>VKNG TOP (m)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Cankee Tyner 7A 22 23 19</td>
<td>LSD 07-22-23-19W3</td>
<td>611.1</td>
<td>521.5</td>
<td>624.2</td>
</tr>
<tr>
<td>Cankee Tyner 10 25 23 20</td>
<td>LSD 10-25-23-20W3</td>
<td>636.7</td>
<td>545.9</td>
<td>646.5</td>
</tr>
<tr>
<td>Husky Phillips Fairdale No.1</td>
<td>LSD 08-29-23-20W3</td>
<td>648.7</td>
<td>551.7</td>
<td>658.4</td>
</tr>
<tr>
<td>Pina Eston 11 13 23 21</td>
<td>LSD 11-13-23-21W3</td>
<td>583.1</td>
<td>482.8</td>
<td>593.4</td>
</tr>
<tr>
<td>Phillips Husky Owen A No.1</td>
<td>LSD 06-19-23-21W3</td>
<td>686.7</td>
<td>596.5</td>
<td>701.6</td>
</tr>
<tr>
<td>Arco Eston 9 28 23 21</td>
<td>LSD 09-28-23-21W3</td>
<td>633.4</td>
<td>533.4</td>
<td>642.8</td>
</tr>
<tr>
<td>Riverfront No.1</td>
<td>LSD 01-29-23-22W3</td>
<td>730.6</td>
<td>644.6</td>
<td>747.7</td>
</tr>
<tr>
<td>Husky Inc Sceptre 7 31 23 22</td>
<td>LSD 07-31-23-22W3</td>
<td>701.3</td>
<td>615.7</td>
<td>720.2</td>
</tr>
<tr>
<td>Canus et al Lemsford 11 7 23 23</td>
<td>LSD 11-07-23-23W3</td>
<td>683.7</td>
<td>595.6</td>
<td>694.6</td>
</tr>
<tr>
<td>Lemsford No.1</td>
<td>LSD 08-10-23-23W3</td>
<td>695.2</td>
<td>612</td>
<td>710.8</td>
</tr>
<tr>
<td>Pan Am A-1 Estonia 4 21 23 23</td>
<td>LSD 04-21-23-23W3</td>
<td>719.6</td>
<td>625.8</td>
<td>723.3</td>
</tr>
<tr>
<td>Phillips Husky River A No.1</td>
<td>LSD 11-27-23-23W3</td>
<td>725.1</td>
<td>635.5</td>
<td>737.6</td>
</tr>
<tr>
<td>Inc Husky Fairbanks 11 17 23 24</td>
<td>LSD 11-17-23-24W3</td>
<td>677.9</td>
<td>580.6</td>
<td>675.1</td>
</tr>
<tr>
<td>10E Fairbanks 6 19 23 24</td>
<td>LSD 06-19-23-24W3</td>
<td>677.6</td>
<td>576.1</td>
<td>669.3</td>
</tr>
<tr>
<td>Sceptre No.1</td>
<td>LSD 01-22-23-24W3</td>
<td>679.4</td>
<td>593.7</td>
<td>686.4</td>
</tr>
<tr>
<td>10E Fairbanks 11 25 23 24</td>
<td>LSD 11-25-23-24W3</td>
<td>720.9</td>
<td>628.8</td>
<td>727.9</td>
</tr>
<tr>
<td>Saskoil Sceptre 11 27 23 24</td>
<td>LSD 11-27-23-24W3</td>
<td>677.6</td>
<td>593.8</td>
<td>681.5</td>
</tr>
<tr>
<td>10E Fairbanks 6 29 23 24</td>
<td>LSD 06-29-23-24W3</td>
<td>677.6</td>
<td>591.9</td>
<td>686.4</td>
</tr>
<tr>
<td>Prelate No.1</td>
<td>LSD 04-13-23-25W3</td>
<td>681.8</td>
<td>582.2</td>
<td>678.2</td>
</tr>
<tr>
<td>Phillips-Husky Prelate No.2</td>
<td>LSD 02-22-23-25W3</td>
<td>665.7</td>
<td>579</td>
<td>659.4</td>
</tr>
<tr>
<td>Imp Red Bird 6 25 23 25</td>
<td>LSD 06-25-23-25W3</td>
<td>595.9</td>
<td>504.7</td>
<td>592.7</td>
</tr>
<tr>
<td>Imp Red Bird 7 27 23 25</td>
<td>LSD 07-27-23-25W3</td>
<td>586.1</td>
<td>488.6</td>
<td>577</td>
</tr>
<tr>
<td>Husky-Phillips Prelate No.11 28</td>
<td>LSD 11-28-23-25W3</td>
<td>683.4</td>
<td>588.3</td>
<td>677.9</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------</td>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Quasar Trend Bayhurst 6 31 23 25</td>
<td>LSD 06-31-23-25W3</td>
<td>664.2</td>
<td>572.1</td>
<td>662.3</td>
</tr>
<tr>
<td>Imp Red Bird 10 32 23 25</td>
<td>LSD 10-32-23-25W3</td>
<td>666.6</td>
<td>570.9</td>
<td>660.2</td>
</tr>
<tr>
<td>Husky-Phillips Prelate 7 35</td>
<td>LSD 07-35-23-25W3</td>
<td>684.3</td>
<td>586.1</td>
<td>675.7</td>
</tr>
<tr>
<td>Leader No.1</td>
<td>LSD 13-11-23-26W3</td>
<td>643.7</td>
<td>562</td>
<td>655.5</td>
</tr>
<tr>
<td>Dungloe No.1</td>
<td>LSD 08-35-23-26W3</td>
<td>590.7</td>
<td>595.9</td>
<td>687</td>
</tr>
<tr>
<td>Westerham No.1</td>
<td>LSD 04-12-23-27W3</td>
<td>657.1</td>
<td>597.1</td>
<td>687.3</td>
</tr>
<tr>
<td>Husky-Phillips Coombe No.1</td>
<td>LSD 16-21-23-28W3</td>
<td>687.3</td>
<td>634</td>
<td>723.3</td>
</tr>
<tr>
<td>Highwood Precision Esty 10 23 23 29</td>
<td>LSD 10-23-23-29W3</td>
<td>686.4</td>
<td>638.9</td>
<td>726</td>
</tr>
<tr>
<td>Blue A et al Mondou 6 7 24 15</td>
<td>LSD 06-07-24-15W3</td>
<td>609.9</td>
<td>515.5</td>
<td>615</td>
</tr>
<tr>
<td>Cowzanoi Mondou 12 9 24 15</td>
<td>LSD 12-09-24-15W3</td>
<td>612</td>
<td>518.8</td>
<td>623.3</td>
</tr>
<tr>
<td>Inc Husky Mondou 10 29 24 15</td>
<td>LSD 10-29-24-15W3</td>
<td>624.5</td>
<td>543.2</td>
<td>637.3</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.3</td>
<td>LSD 07-04-24-16W3</td>
<td>646.8</td>
<td>545.9</td>
<td>650.1</td>
</tr>
<tr>
<td>Zd Hb Petody Plato 10 7 24 16</td>
<td>LSD 10-07-24-16W3</td>
<td>688.8</td>
<td>590.1</td>
<td>688.2</td>
</tr>
<tr>
<td>Zd Hb Petody Plato 10 9 24 16</td>
<td>LSD 10-09-24-16W3</td>
<td>610.2</td>
<td>518.6</td>
<td>613.3</td>
</tr>
<tr>
<td>Bonanza Tricent Plato 10 10 24 16</td>
<td>LSD 10-10-24-16W3</td>
<td>596.8</td>
<td>498.3</td>
<td>601.4</td>
</tr>
<tr>
<td>Bonanza Tricent Plato 4 15 24 16</td>
<td>LSD 04-15-24-16W3</td>
<td>601.7</td>
<td>505.1</td>
<td>603.5</td>
</tr>
<tr>
<td>ZD HB Petody Plato 6 27 24 16</td>
<td>LSD 06-27-24-15W3</td>
<td>654.1</td>
<td>555.7</td>
<td>655.3</td>
</tr>
<tr>
<td>J.N.C. Husky Plato 7 30 24 16</td>
<td>LSD 07-30-24-16W3</td>
<td>719</td>
<td>623.3</td>
<td>719.9</td>
</tr>
<tr>
<td>Sinclair Tyner 2 6</td>
<td>LSD 02-06-24-17W3</td>
<td>589.2</td>
<td>483.1</td>
<td>587.7</td>
</tr>
<tr>
<td>Tide Water Plato Crown No.8</td>
<td>LSD 06-11-24-17W3</td>
<td>620.6</td>
<td>517.3</td>
<td>617.2</td>
</tr>
<tr>
<td>Long Is Plato 16 14 24 17</td>
<td>LSD 16-14-24-17W3</td>
<td>681.8</td>
<td>585.8</td>
<td>686.4</td>
</tr>
<tr>
<td>Zd Hb Petody Plato 16 21 24 17</td>
<td>LSD 16-21-24-17W3</td>
<td>662.9</td>
<td>562.1</td>
<td>662.6</td>
</tr>
<tr>
<td>Kamalta Plato 14 24 24 17</td>
<td>LSD 14-24-24-17W3</td>
<td>705.6</td>
<td>611.1</td>
<td>707.4</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP (m)</td>
<td>VKNG TOP (m)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Zd Hb Petrody Plato 10 25 24 17</td>
<td>LSD 10-25-24-17W3</td>
<td>748.6</td>
<td>652.3</td>
<td>748.6</td>
</tr>
<tr>
<td>Trend Plato 10 26 24 17</td>
<td>LSD 10-26-24-17W3</td>
<td>728.2</td>
<td>632.8</td>
<td>730</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.7</td>
<td>LSD 10-29-24-17W3</td>
<td>604.1</td>
<td>503.2</td>
<td>598.3</td>
</tr>
<tr>
<td>Houston Kamalta Plato 16 33</td>
<td>LSD 16-33-24-17W3</td>
<td>713.5</td>
<td>618.4</td>
<td>712.3</td>
</tr>
<tr>
<td>Long Is Kex Plato 2 34 24 17</td>
<td>LSD 02-34-24-17W3</td>
<td>712</td>
<td>612.6</td>
<td>712.2</td>
</tr>
<tr>
<td>Kamalta et al Plato 12 34 24 17</td>
<td>LSD 12-34-24-17W3</td>
<td>717.5</td>
<td>621.8</td>
<td>717.8</td>
</tr>
<tr>
<td>Jagor et al Plato 6 35 24 17</td>
<td>LSD 06-35-24-17W3</td>
<td>751.6</td>
<td>651.7</td>
<td>748.6</td>
</tr>
<tr>
<td>Sinclair Lacadena 16 24 24 18</td>
<td>LSD 16-24-24-18W3</td>
<td>577.3</td>
<td>478.3</td>
<td>579.1</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.5</td>
<td>LSD 10-28-24-18W3</td>
<td>611.1</td>
<td>514.5</td>
<td>613.6</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.1</td>
<td>LSD 09-22-24-19W3</td>
<td>630.9</td>
<td>542.5</td>
<td>647.4</td>
</tr>
<tr>
<td>Phillips Husky Guth No.1</td>
<td>LSD 11-29-24-20W3</td>
<td>645.3</td>
<td>580.6</td>
<td>685.8</td>
</tr>
<tr>
<td>Imperial Owensville 8 15 24 21</td>
<td>LSD 08-15-24-21W3</td>
<td>666.3</td>
<td>577.6</td>
<td>680.3</td>
</tr>
<tr>
<td>Norvanian Rex Snipe Lake 8 21 24 21</td>
<td>LSD 08-21-24-21W3</td>
<td>676.4</td>
<td>590.4</td>
<td>696.8</td>
</tr>
<tr>
<td>Imperial Athenian 16 22 24 22</td>
<td>LSD 16-22-24-22W3</td>
<td>726.9</td>
<td>635.8</td>
<td>744.3</td>
</tr>
<tr>
<td>18E Riverfront 11 16 24 23</td>
<td>LSD 11-16-24-23W3</td>
<td>666.6</td>
<td>590.7</td>
<td>688.8</td>
</tr>
<tr>
<td>Saskoil Sceptre 6 15 24 24</td>
<td>LSD 06-15-24-24W3</td>
<td>703.8</td>
<td>624.8</td>
<td>723.9</td>
</tr>
<tr>
<td>Phillips Husky Dankin No.1</td>
<td>LSD 11-20-24-24W3</td>
<td>695.9</td>
<td>615.4</td>
<td>713.8</td>
</tr>
<tr>
<td>Husky Inc Eatonia 6 32 24 24</td>
<td>LSD 06-32-24-24W3</td>
<td>719.3</td>
<td>640.1</td>
<td>737.9</td>
</tr>
<tr>
<td>Imperial Bayhurst 10 1 24 25</td>
<td>LSD 10-01-24-25W3</td>
<td>684.9</td>
<td>595.6</td>
<td>681.2</td>
</tr>
<tr>
<td>Imperial Bayhurst 10 3V 24 25</td>
<td>LSD 10-03-24-25W3</td>
<td>676.4</td>
<td>585.2</td>
<td>671.5</td>
</tr>
<tr>
<td>Imperial Bayhurst Road 8 5 24 25</td>
<td>LSD 08-05-24-25W3</td>
<td>674.2</td>
<td>581.3</td>
<td>668.1</td>
</tr>
<tr>
<td>Imperial Bayhurst 13 6</td>
<td>LSD 12-06-24-25W3</td>
<td>669.6</td>
<td>583.4</td>
<td>672.7</td>
</tr>
<tr>
<td>Imperial Bayhurst 7 9V 24 25</td>
<td>LSD 07-09-24-25W3</td>
<td>678.5</td>
<td>583.7</td>
<td>673.3</td>
</tr>
<tr>
<td>Imperial Bayhurst 10 10V 24 25</td>
<td>LSD 10-10-24-25W3</td>
<td>680.3</td>
<td>577.3</td>
<td>664.5</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Imp Bayhurst 13 10 24 25</td>
<td>LSD 13-10-24-25W3</td>
<td>680.9</td>
<td>579.7</td>
<td>664.5</td>
</tr>
<tr>
<td>Imp Bayhurst 7 11V 24 25</td>
<td>LSD 07-11-24-25W3</td>
<td>677.6</td>
<td>583.1</td>
<td>672.4</td>
</tr>
<tr>
<td>Phillips Husky Lestwyn No.1</td>
<td>LSD 11-14-24-25W3</td>
<td>689.5</td>
<td>591.3</td>
<td>681.2</td>
</tr>
<tr>
<td>Bayhurst Unit 5 15 24 25</td>
<td>LSD 05-15-24-25W3</td>
<td>682.1</td>
<td>580.9</td>
<td>668.1</td>
</tr>
<tr>
<td>Imperial Bayhurst 6 16 24 25</td>
<td>LSD 06-16-24-25W3</td>
<td>678.2</td>
<td>577.3</td>
<td>666.3</td>
</tr>
<tr>
<td>SPC Bayhurst 7 16 24 25</td>
<td>LSD 07-16-24-25W3</td>
<td>680.6</td>
<td>580</td>
<td>668.3</td>
</tr>
<tr>
<td>Imperial Bayhurst 7 17V 24 25</td>
<td>LSD 07-17-24-25W3</td>
<td>681.8</td>
<td>584.6</td>
<td>675.1</td>
</tr>
<tr>
<td>Imperial Bayhurst 7 18V 24 25</td>
<td>LSD 07-18-24-25W3</td>
<td>676.4</td>
<td>576.4</td>
<td>666.3</td>
</tr>
<tr>
<td>Imperial Bayhurst 11 19V 24 25</td>
<td>LSD 11-19-24-25W3</td>
<td>677.6</td>
<td>581.9</td>
<td>666.6</td>
</tr>
<tr>
<td>Imperial Bayhurst 7 22 24 25</td>
<td>LSD 07-22-24-25W3</td>
<td>686.7</td>
<td>593.8</td>
<td>680.9</td>
</tr>
<tr>
<td>Gulf Bayhurst 6 28 24 25</td>
<td>LSD 06-28-24-25W3</td>
<td>681.5</td>
<td>595.3</td>
<td>683</td>
</tr>
<tr>
<td>Phillips Husky Quinney Well No.1</td>
<td>LSD 07-29-24-25W3</td>
<td>678.8</td>
<td>590.7</td>
<td>677.3</td>
</tr>
<tr>
<td>Cowzanoil Eatonia 6 35 24 25</td>
<td>LSD 06-35-24-25W3</td>
<td>694</td>
<td>595.5</td>
<td>688.2</td>
</tr>
<tr>
<td>Imperial Gorefield 13 10</td>
<td>LSD 13-10-24-26W3</td>
<td>689.8</td>
<td>595.9</td>
<td>686.1</td>
</tr>
<tr>
<td>Quasar Trend Bayhurst 6 11 24 26</td>
<td>LSD 06-11-24-26W3</td>
<td>684</td>
<td>585.2</td>
<td>676.3</td>
</tr>
<tr>
<td>Imperial Gorefield 5 17 24 26</td>
<td>LSD 05-17-24-26W3</td>
<td>684.9</td>
<td>599.8</td>
<td>689.8</td>
</tr>
<tr>
<td>Oliphant - NW Gorfield 10 18 24 26</td>
<td>LSD 10-18-24-26W3</td>
<td>690.1</td>
<td>604.4</td>
<td>694</td>
</tr>
<tr>
<td>Oliphant NWR Gorefield</td>
<td>LSD 07-21-24-26W3</td>
<td>695.2</td>
<td>610.5</td>
<td>701.3</td>
</tr>
<tr>
<td>Oliphant Nwrcr Gorefield 7 22 24 26</td>
<td>LSD 07-22-24-26W3</td>
<td>683.7</td>
<td>589.5</td>
<td>679.4</td>
</tr>
<tr>
<td>Imperial Gorefield Road 1 23 24 26</td>
<td>LSD 01-23-24-26W3</td>
<td>680.3</td>
<td>589.5</td>
<td>679.7</td>
</tr>
<tr>
<td>West Bayhurst Unit 11 28 24 26</td>
<td>LSD 11-28-24-26W3</td>
<td>682.4</td>
<td>596.8</td>
<td>684.9</td>
</tr>
<tr>
<td>Phillips Husky Dome Garfield No.1</td>
<td>LSD 07-29-24-26W3</td>
<td>702.3</td>
<td>616.3</td>
<td>703.5</td>
</tr>
<tr>
<td>Husky Inc et al Cabri 7 16 24 27</td>
<td>LSD 07-16-24-27W3</td>
<td>628.2</td>
<td>558.4</td>
<td>650</td>
</tr>
<tr>
<td>Oliphant Nwrcr Gorefield 9 27 24 27</td>
<td>LSD 09-27-24-27W3</td>
<td>668.1</td>
<td>593.8</td>
<td>683.7</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B</td>
<td>BG RIVER</td>
<td>VKNG</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------</td>
<td>------</td>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>Gulf Cabri Lake 3 30 24 27</td>
<td>LSD 03-30-24-27W3</td>
<td>618.3</td>
<td>554</td>
<td>647</td>
</tr>
<tr>
<td>Dome Cabri 11 8 24 28</td>
<td>LSD 11-08-24-28W3</td>
<td>727.8</td>
<td>675</td>
<td>766</td>
</tr>
<tr>
<td>Cabri No.1</td>
<td>LSD 01-23-24-28W3</td>
<td>706.2</td>
<td>656.2</td>
<td>743.7</td>
</tr>
<tr>
<td>Josephine No.1</td>
<td>LSD 01-23-24-29W3</td>
<td>676.4</td>
<td>615.7</td>
<td>702.9</td>
</tr>
<tr>
<td>2d-Hb Petrody Elrose 6 7 25 15</td>
<td>LSD 06-07-25-15W3</td>
<td>608.7</td>
<td>521.5</td>
<td>618.7</td>
</tr>
<tr>
<td>2d-Hb Petrody Elrose 6 15 25 15</td>
<td>LSD 06-15-25-15W3</td>
<td>638.6</td>
<td>552.6</td>
<td>646.8</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.2</td>
<td>LSD 11-28-25-15W3</td>
<td>624.5</td>
<td>532.8</td>
<td>626.7</td>
</tr>
<tr>
<td>2d-Hb Petrody Elrose 6 35 25 15</td>
<td>LSD 06-35-25-15W3</td>
<td>618.4</td>
<td>525.8</td>
<td>622.7</td>
</tr>
<tr>
<td>Williams Creek Elrose 6 3 25 16</td>
<td>LSD 06-03-25-16W3</td>
<td>594.1</td>
<td>504.7</td>
<td>599.2</td>
</tr>
<tr>
<td>Husky Wartime 7 29 25 16</td>
<td>LSD 07-29-25-16W3</td>
<td>633.1</td>
<td>634.3</td>
<td>731.5</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.6</td>
<td>LSD 06-34-25-16W3</td>
<td>628.5</td>
<td>577.9</td>
<td>664.5</td>
</tr>
<tr>
<td>Carribbean Plato 4 2 25 17</td>
<td>LSD 04-02-25-17W3</td>
<td>755</td>
<td>665.7</td>
<td>756.5</td>
</tr>
<tr>
<td>Barnwell et al Plato 2 3 25 17</td>
<td>LSD 02-03-25-17W3</td>
<td>743.1</td>
<td>658.4</td>
<td>748.6</td>
</tr>
<tr>
<td>Kamalta Plato 6 4 25 17</td>
<td>LSD 06-04-25-17W3</td>
<td>722.1</td>
<td>633.7</td>
<td>728.6</td>
</tr>
<tr>
<td>Hol Kamalta 14 5 25 17</td>
<td>LSD 14-05-25-17W3</td>
<td>668.1</td>
<td>578.5</td>
<td>674.2</td>
</tr>
<tr>
<td>IPP-Trex Plato 10 6 25 17</td>
<td>LSD 10-06-25-17W3</td>
<td>654.7</td>
<td>560.8</td>
<td>662</td>
</tr>
<tr>
<td>Sun Ltd Plato 14 6 25 17</td>
<td>LSD 14-06-25-17W3</td>
<td>657.5</td>
<td>563.3</td>
<td>657.5</td>
</tr>
<tr>
<td>Houston et al Plato 4 7 25 17</td>
<td>LSD 04-07-25-17W3</td>
<td>663.5</td>
<td>569.1</td>
<td>661.1</td>
</tr>
<tr>
<td>Barnwell et al Plato 5 7 25 17</td>
<td>LSD 05-07-25-17W3</td>
<td>662</td>
<td>562.4</td>
<td>657.8</td>
</tr>
<tr>
<td>Marvel Kamalta Plato 12 7 25 17</td>
<td>LSD 12-07-25-17W3</td>
<td>644.3</td>
<td>544.1</td>
<td>635.5</td>
</tr>
<tr>
<td>Marvel Kamalta Plato 14 7 25 17</td>
<td>LSD 14-07-25-17W3</td>
<td>640.1</td>
<td>537.7</td>
<td>635.5</td>
</tr>
<tr>
<td>Hb Plato 12 8 25 17</td>
<td>LSD 12-08-25-17W3</td>
<td>637.3</td>
<td>548.6</td>
<td>648.6</td>
</tr>
<tr>
<td>Houston Kamalta Plato 4 9 25 17</td>
<td>LSD 04-09-25-17W3</td>
<td>689.9</td>
<td>603.5</td>
<td>699.2</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>BG RIVER TOP (m)</td>
<td>VKNG TOP (m)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------------------</td>
<td>--------</td>
<td>------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Tide Water Crown Plato No.11</td>
<td>LSD 11-11-25-17W3</td>
<td>720.5</td>
<td>666.9</td>
<td>757.4</td>
</tr>
<tr>
<td>IPP-Trex Plato 16 16 25 17</td>
<td>LSD 16-16-25-17W3</td>
<td>683.1</td>
<td>612.9</td>
<td>705</td>
</tr>
<tr>
<td>Sun Ltd Plato 4 18 25 17</td>
<td>LSD 04-18-25-17W3</td>
<td>633.7</td>
<td>538.6</td>
<td>632.2</td>
</tr>
<tr>
<td>Tide Water Plato Crown No.10</td>
<td>LSD 11-20-25-17W3</td>
<td>669.3</td>
<td>579.1</td>
<td>676</td>
</tr>
<tr>
<td>Norvanian et al Plato 12 21 25 17</td>
<td>LSD 12-21-25-17W3</td>
<td>673</td>
<td>587.3</td>
<td>683.7</td>
</tr>
<tr>
<td>Barnwell et al Plato 12 23 25 17</td>
<td>LSD 12-23-25-17W3</td>
<td>692.5</td>
<td>623.6</td>
<td>716.3</td>
</tr>
<tr>
<td>Madison Kamalta Plato 10 29 25 17</td>
<td>LSD 10-29-25-17W3</td>
<td>677</td>
<td>586.1</td>
<td>678.8</td>
</tr>
<tr>
<td>Tide Water Plato Crown No.10</td>
<td>LSD 11-30-25-17W3</td>
<td>669.3</td>
<td>xxx</td>
<td>676</td>
</tr>
<tr>
<td>Barnwell et al Plato 10 33 25 17</td>
<td>LSD 10-33-25-17W3</td>
<td>661.1</td>
<td>567.5</td>
<td>660.2</td>
</tr>
<tr>
<td>Hudson's Bay Oil &amp; Gas Greenan 6 36</td>
<td>LSD 06-36-25-17W3</td>
<td>650.2</td>
<td>568.1</td>
<td>660.8</td>
</tr>
<tr>
<td>Hol et al Plato 14 1 25 18</td>
<td>LSD 14-01-25-18W3</td>
<td>609.6</td>
<td>513.6</td>
<td>607.9</td>
</tr>
<tr>
<td>Houston et al Plato 16 3 25 18</td>
<td>LSD 16-03-25-18W3</td>
<td>588.6</td>
<td>497.1</td>
<td>598.6</td>
</tr>
<tr>
<td>Tide Water Plato Crown No.9</td>
<td>LSD 10-11-25-18W3</td>
<td>595.9</td>
<td>506</td>
<td>603.8</td>
</tr>
<tr>
<td>Arco Plato 6 12 25 18</td>
<td>LSD 06-12-25-18W3</td>
<td>648</td>
<td>554.1</td>
<td>646.2</td>
</tr>
<tr>
<td>Arco Plato 12 12 25 18</td>
<td>LSD 12-12-25-18W3</td>
<td>621.2</td>
<td>530.4</td>
<td>625.1</td>
</tr>
<tr>
<td>Arco Plato 14 12 25 18</td>
<td>LSD 14-12-25-18W3</td>
<td>618.7</td>
<td>528.2</td>
<td>625.4</td>
</tr>
<tr>
<td>Marvel Kamalta Plato 2 13 25 18</td>
<td>LSD 02-12-25-18W3</td>
<td>633.7</td>
<td>543.5</td>
<td>637.9</td>
</tr>
<tr>
<td>Arco Plato 10 14 25 18</td>
<td>LSD 10-14-25-18W3</td>
<td>648.9</td>
<td>562.1</td>
<td>654.1</td>
</tr>
<tr>
<td>Arco Plato 12 14 25 18</td>
<td>LSD 12-14-25-18W3</td>
<td>633.7</td>
<td>543.5</td>
<td>640.1</td>
</tr>
<tr>
<td>Hol Kamalta Plato 16 15 25 18</td>
<td>LSD 16-15-25-18W3</td>
<td>636.4</td>
<td>545.8</td>
<td>639.5</td>
</tr>
<tr>
<td>Norvanian Marvel Plato 12 17 25 18</td>
<td>LSD 12-17-25-18W3</td>
<td>629.7</td>
<td>538.3</td>
<td>636.1</td>
</tr>
<tr>
<td>Norvanian Plato 8 19 25 18</td>
<td>LSD 08-19-25-18W3</td>
<td>651.7</td>
<td>562.1</td>
<td>656.5</td>
</tr>
<tr>
<td>Trend Plato 14 20 25 18</td>
<td>LSD 14-20-25-18W3</td>
<td>664.2</td>
<td>571.2</td>
<td>666</td>
</tr>
<tr>
<td>Barnwell et al Plato 2 21 25 18</td>
<td>LSD 02-21-25-18W3</td>
<td>662</td>
<td>571.2</td>
<td>670.9</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>BC RIVER TOP (m)</td>
<td>VKNG TOP (m)</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Cn Expl Plato 14 21 25 18</td>
<td>LSD 14-21-25-18W3</td>
<td>660.5</td>
<td>570</td>
<td>665.8</td>
</tr>
<tr>
<td>Arco Plato 2 22 25 18</td>
<td>LSD 02-22-25-18W3</td>
<td>653.5</td>
<td>566.3</td>
<td>660.5</td>
</tr>
<tr>
<td>Arco Plato 4 22 25 18</td>
<td>LSD 04-22-25-18W3</td>
<td>652</td>
<td>562</td>
<td>656.2</td>
</tr>
<tr>
<td>Arco Plato 12 22 25 18</td>
<td>LSD 12-22-25-18W3</td>
<td>656.8</td>
<td>563.9</td>
<td>663.5</td>
</tr>
<tr>
<td>Houston Kaalita 4 23 25 18</td>
<td>LSD 04-23-25-18W3</td>
<td>648.9</td>
<td>558.7</td>
<td>654.7</td>
</tr>
<tr>
<td>Tide Water Plato Crown No.12</td>
<td>LSD 08-24-25-18W3</td>
<td>651.4</td>
<td>558.7</td>
<td>654.4</td>
</tr>
<tr>
<td>Barnwell et al Plato 2 25 25 18</td>
<td>LSD 02-25-25-18W3</td>
<td>641.3</td>
<td>544.1</td>
<td>639.5</td>
</tr>
<tr>
<td>Arco Houston Plato 4 28 25 18</td>
<td>LSD 04-28-25-18W3</td>
<td>658.7</td>
<td>567.5</td>
<td>668.7</td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.1</td>
<td>LSD 10-28-25-18W3</td>
<td>661.7</td>
<td>573</td>
<td>671.2</td>
</tr>
<tr>
<td>Arco Trend Plato 2 29 25 18</td>
<td>LSD 02-29-25-18W3</td>
<td>657.1</td>
<td>567.8</td>
<td>664.5</td>
</tr>
<tr>
<td>Arco Trend Plato 16 30 25 18</td>
<td>LSD 16-30-25-18W3</td>
<td>656.1</td>
<td>576</td>
<td>669</td>
</tr>
<tr>
<td>Barnwell et al Plato 2 31 25 18</td>
<td>LSD 02-31-25-18W3</td>
<td>662.9</td>
<td>569.7</td>
<td>666.9</td>
</tr>
<tr>
<td>Trend Arco Richlea 16 25 25 19</td>
<td>LSD 16-25-25-19W3</td>
<td>659.3</td>
<td>567.5</td>
<td>664.8</td>
</tr>
<tr>
<td>Trend Arco Richlea 16 28 25 19</td>
<td>LSD 16-28-25-19W3</td>
<td>670.3</td>
<td>580.3</td>
<td>680.6</td>
</tr>
<tr>
<td>Trend Arco Richlea 2 36 25 19</td>
<td>LSD 02-36-25-19W3</td>
<td>658.4</td>
<td>569.7</td>
<td>664.5</td>
</tr>
<tr>
<td>Zd Nb Petrody Eston 6 19 25 20</td>
<td>LSD 06-19-25-20W3</td>
<td>683.4</td>
<td>602.6</td>
<td>695.8</td>
</tr>
<tr>
<td>Husky Phillips Eston No.1</td>
<td>LSD 07-29-25-20W3</td>
<td>677.6</td>
<td>594.4</td>
<td>694.9</td>
</tr>
<tr>
<td>Inc Husky Richlea 7 34 25 20</td>
<td>LSD 07-34-25-20W3</td>
<td>683.4</td>
<td>601.4</td>
<td>702.3</td>
</tr>
<tr>
<td>Norena C No.1</td>
<td>LSD 06-29-25-22W3</td>
<td>686.7</td>
<td>610.2</td>
<td>707.1</td>
</tr>
<tr>
<td>Phillips Husky Dome Tuscola No.1</td>
<td>LSD 07-29-25-23W3</td>
<td>687</td>
<td>607.2</td>
<td>707.1</td>
</tr>
<tr>
<td>Norvenian H1 Nor Eatonia 11 6 25 24</td>
<td>LSD 11-06-25-24W3</td>
<td>709.3</td>
<td>621.2</td>
<td>712.3</td>
</tr>
<tr>
<td>Zd Nb Petrody Eatonia 6 7 25 24</td>
<td>LSD 06-07-25-24W3</td>
<td>708.4</td>
<td>624.8</td>
<td>718.7</td>
</tr>
<tr>
<td>Jager Ortega Bayhurst 6 22 25 24</td>
<td>LSD 06-22-25-24W3</td>
<td>692.1</td>
<td>619.4</td>
<td>717.2</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP (m)</td>
<td>VKNP TOP (m)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------</td>
<td>---------</td>
<td>------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Jagor W Bayhurst 11 4 25 25</td>
<td>LSD 11-04-25-25W3</td>
<td>686.4</td>
<td>609.9</td>
<td>702.5</td>
</tr>
<tr>
<td>Norvienia Hi Nor Eatonia 10 11 25 25</td>
<td>LSD 10-11-25-25W3</td>
<td>698.9</td>
<td>619.3</td>
<td>713.5</td>
</tr>
<tr>
<td>Imperial Cornfield 10 32 25 25</td>
<td>LSD 10-32-25-25W3</td>
<td>727.6</td>
<td>643.7</td>
<td>741.3</td>
</tr>
<tr>
<td>Imperial Highbury Road 1 3 25 26</td>
<td>LSD 01-03-25-26W3</td>
<td>686.1</td>
<td>605.9</td>
<td>693.7</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 4 6 25 26</td>
<td>LSD 04-06-25-26W3</td>
<td>693.4</td>
<td>616.9</td>
<td>702.6</td>
</tr>
<tr>
<td>West Bayhurst Unit 9 7 25 26</td>
<td>LSD 09-07-25-26W3</td>
<td>689.5</td>
<td>614.8</td>
<td>701.3</td>
</tr>
<tr>
<td>Imperial Highbury 10 35</td>
<td>LSD 10-35-25-26W3</td>
<td>701.6</td>
<td>623.9</td>
<td>718.1</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 4 2 25 27</td>
<td>LSD 04-02-25-27W3</td>
<td>683.4</td>
<td>605.9</td>
<td>691.3</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 6 12 25 27</td>
<td>LSD 06-12-25-27W3</td>
<td>693.1</td>
<td>615.7</td>
<td>701</td>
</tr>
<tr>
<td>Cabri Lake 7 16 25 27</td>
<td>LSD 07-16-25-27W3</td>
<td>675.7</td>
<td>603.5</td>
<td>690.7</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 14 17 25 27</td>
<td>LSD 14-17-25-27W3</td>
<td>610.8</td>
<td>536.4</td>
<td>621.8</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 8 22 25 27</td>
<td>LSD 08-22-25-27W3</td>
<td>688.5</td>
<td>614.8</td>
<td>701</td>
</tr>
<tr>
<td>Imperial Ross Moir Road 16 35 25 27</td>
<td>LSD 16-35-25-27W3</td>
<td>691.9</td>
<td>620</td>
<td>714.1</td>
</tr>
<tr>
<td>Provo Cabri Lake No.7 9</td>
<td>LSD 07-09-25-28W3</td>
<td>714.8</td>
<td>666</td>
<td>747.7</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 7 23 25 28</td>
<td>LSD 07-23-25-28W3</td>
<td>701.3</td>
<td>647</td>
<td>734.6</td>
</tr>
<tr>
<td>Oliphant Nwrcn Gorefield 3 27 25 28</td>
<td>LSD 03-27-25-28W3</td>
<td>746.8</td>
<td>687</td>
<td>771.1</td>
</tr>
<tr>
<td>Phillips Husky Border No.1</td>
<td>LSD 07-09-25-29W3</td>
<td>747.4</td>
<td>693.1</td>
<td>779.7</td>
</tr>
<tr>
<td>Compadre Cuthbert 11 23 25 29</td>
<td>LSD 11-23-25-29W3</td>
<td>778.8</td>
<td>721.5</td>
<td>807.7</td>
</tr>
<tr>
<td>CS Cuthbert 7 25 25 29</td>
<td>LSD 07-25-25-29W3</td>
<td>780.6</td>
<td>724.2</td>
<td>812.6</td>
</tr>
<tr>
<td>Saskoil Cuthbert 7 27 25 29</td>
<td>LSD 07-27-25-29W3</td>
<td>794</td>
<td>740</td>
<td>825.4</td>
</tr>
<tr>
<td>Ceja Alsask 10 27 25 29</td>
<td>LSD 10-27-25-29W3</td>
<td>800.4</td>
<td>748.6</td>
<td>831.5</td>
</tr>
<tr>
<td>Jagor et al Elrose 1A 3 26 15</td>
<td>LSD 01-03-26-15W3</td>
<td>626.7</td>
<td>531.6</td>
<td>624.2</td>
</tr>
<tr>
<td>2D HB Petro dy 10 5 26 15</td>
<td>LSD 10-05-26-15W3</td>
<td>622.4</td>
<td>529.7</td>
<td>623.6</td>
</tr>
<tr>
<td>Sohio Standard Elrose No.2</td>
<td>LSD 11-18-26-15W3</td>
<td>620</td>
<td>525.2</td>
<td>614.2</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>--------------------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ZD W4 Petro dy Elrose 6 23 26 15</td>
<td>LSD 06-23-26-15W3</td>
<td>621.8</td>
<td>533.7</td>
<td>625.8</td>
</tr>
<tr>
<td>Gold Lake et al Greenan 10 5 26 16</td>
<td>LSD 10-05-26-16W3</td>
<td>632.8</td>
<td>576.1</td>
<td>665.1</td>
</tr>
<tr>
<td>Jagor Sunex Greenan 6 7 26 16</td>
<td>LSD 06-07-26-16W3</td>
<td>629.4</td>
<td>557.8</td>
<td>645.3</td>
</tr>
<tr>
<td>Golden Lake et al Greenan 6 9 26 16</td>
<td>LSD 06-09-26-16W3</td>
<td>628.2</td>
<td>562.7</td>
<td>650.4</td>
</tr>
<tr>
<td>Sohio Standard Elrose No.4</td>
<td>LSD 09-10-26-16W3</td>
<td>631.9</td>
<td>550.5</td>
<td>637</td>
</tr>
<tr>
<td>Sohio Standard Elrose No.1</td>
<td>LSD 14-12-26-16W3</td>
<td>627.6</td>
<td>533.4</td>
<td>621.8</td>
</tr>
<tr>
<td>Jagor Elrose 6 13 26 16</td>
<td>LSD 06-13-26-16W3</td>
<td>626.7</td>
<td>532.4</td>
<td>618.4</td>
</tr>
<tr>
<td>Jagor Elrose 7 14 26 16</td>
<td>LSD 07-14-26-16W3</td>
<td>622.1</td>
<td>532.5</td>
<td>622.1</td>
</tr>
<tr>
<td>Sohio Standard Elrose No.3</td>
<td>LSD 09-14-26-16W3</td>
<td>623</td>
<td>532.2</td>
<td>623.6</td>
</tr>
<tr>
<td>Inc Husky Plato 7 22 26 16</td>
<td>LSD 07-22-26-16W3</td>
<td>623.9</td>
<td>557.8</td>
<td>648</td>
</tr>
<tr>
<td>Williams Creek Greenan 11 2 26 17</td>
<td>LSD 11-02-26-17W3</td>
<td>648.6</td>
<td>551.1</td>
<td>645</td>
</tr>
<tr>
<td>Kamalta Plato 5 4 26 17</td>
<td>LSD 05-04-26-17W3</td>
<td>655.6</td>
<td>656.1</td>
<td>657.4</td>
</tr>
<tr>
<td>Kamalta Plato 11 6 26 17</td>
<td>LSD 11-06-26-17W3</td>
<td>665.1</td>
<td>574.8</td>
<td>668.1</td>
</tr>
<tr>
<td>Project Kamalta Plato 13 6 26 17</td>
<td>LSD 13-06-26-17W3</td>
<td>666.9</td>
<td>573.3</td>
<td>669.3</td>
</tr>
<tr>
<td>Norvenian Kex Greenan 6 7 26 17</td>
<td>LSD 06-07-26-17W3</td>
<td>653.2</td>
<td>558.7</td>
<td>655.3</td>
</tr>
<tr>
<td>Williams Creek Greenan 10 8 26 17</td>
<td>LSD 10-08-26-17W3</td>
<td>650.7</td>
<td>557.2</td>
<td>652.6</td>
</tr>
<tr>
<td>H.B. North Plato 1 9 26 17</td>
<td>LSD 01-09-26-17W3</td>
<td>661.1</td>
<td>565.7</td>
<td>657.8</td>
</tr>
<tr>
<td>Mad Frhld Kex Greenan</td>
<td>LSD 06-10-26-17W3</td>
<td>649.8</td>
<td>545</td>
<td>636.4</td>
</tr>
<tr>
<td>Ashland Greenan 11 12 26 17</td>
<td>LSD 11-12-26-17W3</td>
<td>633.7</td>
<td>548.3</td>
<td>634.6</td>
</tr>
<tr>
<td>Jagor Greenan 11 13 26 17</td>
<td>LSD 11-13-26-17W3</td>
<td>624.2</td>
<td>535.8</td>
<td>629.1</td>
</tr>
<tr>
<td>Wartime No.1</td>
<td>LSD 02-14-26-17W3</td>
<td>631.2</td>
<td>536.4</td>
<td>630</td>
</tr>
<tr>
<td>Jagor Greenan 6 15 26 17</td>
<td>LSD 06-15-26-17W3</td>
<td>646.2</td>
<td>548.6</td>
<td>642.5</td>
</tr>
<tr>
<td>Williams Creek Greenan 7 16 26 17</td>
<td>LSD 07-16-26-17W3</td>
<td>656.5</td>
<td>564.5</td>
<td>655.9</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>BG RIVER TOP (m)</td>
<td>VKNG TOP (m)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Williams Creek Greenan 7 16 26 17</td>
<td>LSD 07-17-26-17W3</td>
<td>661.1</td>
<td>567.2</td>
<td>662.3</td>
</tr>
<tr>
<td>Williams Creek Greenan 6 19 26 17</td>
<td>LSD 06-19-26-17W3</td>
<td>663.5</td>
<td>569.5</td>
<td>664.5</td>
</tr>
<tr>
<td>Jagor Greenan 7 21 26 17</td>
<td>LSD 07-21-26-17W3</td>
<td>651.1</td>
<td>562</td>
<td>657.1</td>
</tr>
<tr>
<td>Ashland Greenan 7 22 26 17</td>
<td>LSD 07-22-26-17W3</td>
<td>640.7</td>
<td>549.2</td>
<td>638.9</td>
</tr>
<tr>
<td>Jagor Sunex Greenan 7 23 26 17</td>
<td>LSD 07-23-26-17W3</td>
<td>628.5</td>
<td>537.1</td>
<td>632.5</td>
</tr>
<tr>
<td>Jagor Greenan 6 24 26 17</td>
<td>LSD 06-24-26-17W3</td>
<td>623.9</td>
<td>552.9</td>
<td>647.4</td>
</tr>
<tr>
<td>Rynco Sunex Greenan 6 25 26 17</td>
<td>LSD 06-25-26-17W3</td>
<td>632.2</td>
<td>558.1</td>
<td>652.3</td>
</tr>
<tr>
<td>Norvanian Kamalta Plato 15 25 26 17</td>
<td>LSD 15-25-26-17W3</td>
<td>637</td>
<td>573</td>
<td>659.3</td>
</tr>
<tr>
<td>H.B. North Plato 15 27 26 17</td>
<td>LSD 15-27-26-17W3</td>
<td>637.3</td>
<td>563</td>
<td>659</td>
</tr>
<tr>
<td>Norvanian Kamalta Plato 9 34 26 17</td>
<td>LSD 09-34-26-17W3</td>
<td>642.8</td>
<td>592.8</td>
<td>681.5</td>
</tr>
<tr>
<td>ZD HB Petrody Kildare 10 9 26 18</td>
<td>LSD 10-09-26-18W3</td>
<td>660.7</td>
<td>574.2</td>
<td>668.4</td>
</tr>
<tr>
<td>HB North Plato 3 13 26 18</td>
<td>LSD 03-13-26-18W3</td>
<td>669</td>
<td>575.8</td>
<td>665.4</td>
</tr>
<tr>
<td>Z.D. Penn Petrody Plato</td>
<td>LSD 07-14-26-18W3</td>
<td>666.6</td>
<td>566.9</td>
<td>662.3</td>
</tr>
<tr>
<td>Pennant N Plato 1 22 26 18</td>
<td>LSD 01-22-26-18W3</td>
<td>664.2</td>
<td>567.8</td>
<td>661.4</td>
</tr>
<tr>
<td>ZD HB Petrody Kildare 10 27 26 18</td>
<td>LSD 10-27-26-18W3</td>
<td>672.3</td>
<td>587.7</td>
<td>681.5</td>
</tr>
<tr>
<td>ZD Penn Petrody Richlea 10 29</td>
<td>LSD 10-29-26-18W3</td>
<td>663.2</td>
<td>574.2</td>
<td>670.3</td>
</tr>
<tr>
<td>Bighart Plato 4 2 26 19</td>
<td>LSD 04-02-26-19W3</td>
<td>672.1</td>
<td>585</td>
<td>680.1</td>
</tr>
<tr>
<td>Trend Arco Richlea 8 3 26 19</td>
<td>LSD 08-03-26-19W3</td>
<td>672.4</td>
<td>583.4</td>
<td>682.1</td>
</tr>
<tr>
<td>Trend Arco Richlea 10 5 26 19</td>
<td>LSD 10-05-26-19W3</td>
<td>683.4</td>
<td>599.8</td>
<td>701.6</td>
</tr>
<tr>
<td>Socony Sochio Richlea 11 7</td>
<td>LSD 07-11-26-19W3</td>
<td>655.9</td>
<td>572.7</td>
<td>670.3</td>
</tr>
<tr>
<td>ZD-HB Petrody Richlea 10 13 26 19</td>
<td>LSD 10-13-26-19W3</td>
<td>670.3</td>
<td>586.1</td>
<td>677</td>
</tr>
<tr>
<td>W.R.P.L. Plato 16 15 26 19</td>
<td>LSD 16-15-26-19W3</td>
<td>673.3</td>
<td>586.2</td>
<td>682.3</td>
</tr>
<tr>
<td>ZD HB Petrody Richlea 6 27 26 19</td>
<td>LSD 06-17-26-19W3</td>
<td>684.6</td>
<td>601.4</td>
<td>700.4</td>
</tr>
<tr>
<td>Bighart Plato 4 21 26 19</td>
<td>LSD 04-21-26-19W3</td>
<td>681.2</td>
<td>598</td>
<td>695</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B</td>
<td>BG RIVER</td>
<td>VKN G</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
<td>------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>Bighart Plato 6 23 26 19</td>
<td>LSD 06-23-26-19W3</td>
<td>675.4</td>
<td>587.5</td>
<td>682</td>
</tr>
<tr>
<td>ZD Penn Petrody Richlea 11 24 26</td>
<td>LSD 11-24-26-19W3</td>
<td>672.7</td>
<td>586.4</td>
<td>682.7</td>
</tr>
<tr>
<td>ZD HB Petrody Richlea 10 27 26 19</td>
<td>LSD 10-27-26-19W3</td>
<td>680</td>
<td>591.6</td>
<td>685.5</td>
</tr>
<tr>
<td>Bighart Saskoil Plato 6 29 26 19</td>
<td>LSD 06-29-26-19W3</td>
<td>688.3</td>
<td>609</td>
<td>701</td>
</tr>
<tr>
<td>W. R. P. L. Plato 12 31 26 19</td>
<td>LSD 12-31-26-19W3</td>
<td>688.2</td>
<td>607.8</td>
<td>703.8</td>
</tr>
<tr>
<td>Merland Plato N 14 32 26 19</td>
<td>LSD 14-32-26-19W3</td>
<td>682.3</td>
<td>597.5</td>
<td>688</td>
</tr>
<tr>
<td>Bighart Plato 10 23 26 20</td>
<td>LSD 10-23-26-20W3</td>
<td>696.8</td>
<td>619.5</td>
<td>714.5</td>
</tr>
<tr>
<td>Westar Plato N 9 25 26 20</td>
<td>LSD 09-25-26-20W3</td>
<td>689.5</td>
<td>611.5</td>
<td>706.1</td>
</tr>
<tr>
<td>ZD HB Petrody Eston 7 27 26 20</td>
<td>LSD 07-27-26-20W3</td>
<td>700.1</td>
<td>624.5</td>
<td>716.9</td>
</tr>
<tr>
<td>Bighart Saskoil Plato 10 36 26 20</td>
<td>LSD 10-36-26-20W3</td>
<td>694.8</td>
<td>615</td>
<td>711</td>
</tr>
<tr>
<td>Imperial Centre Field 13 10 26 21</td>
<td>LSD 13-10-26-21W3</td>
<td>688.2</td>
<td>608.4</td>
<td>703.5</td>
</tr>
<tr>
<td>ZD HB Petrody Snipe Lake 10 25 26 21</td>
<td>LSD 10-25-26-21W3</td>
<td>693.4</td>
<td>618.1</td>
<td>710.2</td>
</tr>
<tr>
<td>Phillips Husky Dome Snipe No.1</td>
<td>LSD 07-28-26-21W3</td>
<td>695.9</td>
<td>612.6</td>
<td>708.7</td>
</tr>
<tr>
<td>Inc Husky Madison 10 24 26 22</td>
<td>LSD 10-24-26-22W3</td>
<td>694.6</td>
<td>610.8</td>
<td>705.6</td>
</tr>
<tr>
<td>Husky Phillips Madison No. 1</td>
<td>LSD 04-29-26-22W3</td>
<td>694.3</td>
<td>604.1</td>
<td>698</td>
</tr>
<tr>
<td>ZD HB Petrody Glidden 11 23 26 23</td>
<td>LSD 11-23-26-23W3</td>
<td>696.5</td>
<td>604.1</td>
<td>697.1</td>
</tr>
<tr>
<td>Imperial Glidden 7 33 26 23</td>
<td>LSD 07-33-26-23W3</td>
<td>676</td>
<td>582.2</td>
<td>677.9</td>
</tr>
<tr>
<td>Husky Phillips Eatonia A No.1</td>
<td>LSD 04-29-26-24W3</td>
<td>733.7</td>
<td>640.7</td>
<td>734.6</td>
</tr>
<tr>
<td>Husky Phillips Eatonia A-2</td>
<td>LSD 09-29-26-24W3</td>
<td>726.9</td>
<td>634</td>
<td>729.1</td>
</tr>
<tr>
<td>Husky Imperial Pinkham No.1</td>
<td>LSD 01-31-26-24W3</td>
<td>745.2</td>
<td>651.7</td>
<td>748.3</td>
</tr>
<tr>
<td>Husky-Phillips-Eatonia No.1</td>
<td>LSD 04-32-26-24W3</td>
<td>744.9</td>
<td>669.3</td>
<td>746.8</td>
</tr>
<tr>
<td>Husky Phillips La Porte No.1</td>
<td>LSD 16-29-26-25W3</td>
<td>751.9</td>
<td>665.7</td>
<td>766.3</td>
</tr>
<tr>
<td>ZD HB Petrody La Porte 1 27 26 26</td>
<td>LSD 01-27-26-25W3</td>
<td>749.8</td>
<td>672.1</td>
<td>762.9</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Texaco Cuthbert 4 17</td>
<td>LSD 04-17-26-28W3</td>
<td>742.8</td>
<td>685.5</td>
<td>777.5</td>
</tr>
<tr>
<td>Cuthbert No.1</td>
<td>LSD 06-02-26-29W3</td>
<td>765.4</td>
<td>706.5</td>
<td>796.1</td>
</tr>
<tr>
<td>Jagor Siebens et al Blrose 7 11 27 15</td>
<td>LSD 07-11-27-15W3</td>
<td>601.1</td>
<td>518.2</td>
<td>609.6</td>
</tr>
<tr>
<td>Jagor Rosetown 10 12 27 16</td>
<td>LSD 10-12-27-16W3</td>
<td>611.1</td>
<td>537.1</td>
<td>625.4</td>
</tr>
<tr>
<td>Hudsons Bay Rosetown 4 16 27 16</td>
<td>LSD 04-16-27-16W3</td>
<td>648.3</td>
<td>594.4</td>
<td>680</td>
</tr>
<tr>
<td>Chaplin Plato 9 2 27 17</td>
<td>LSD 09-02-27-17W3</td>
<td>674.2</td>
<td>515.7</td>
<td>707.7</td>
</tr>
<tr>
<td>Fife Kal Chipperfield 10 7 27 17</td>
<td>LSD 10-07-27-17W3</td>
<td>659.6</td>
<td>578.5</td>
<td>671.5</td>
</tr>
<tr>
<td>Spc HB Bickleigh 7 8 27 17</td>
<td>LSD 07-08-27-17W3</td>
<td>657.1</td>
<td>572.4</td>
<td>664.3</td>
</tr>
<tr>
<td>Chaplin North Plato 11 11 27 17</td>
<td>LSD 11-11-27-17W3</td>
<td>638.3</td>
<td>574.2</td>
<td>668.4</td>
</tr>
<tr>
<td>Fife Kal Chipperfield 6 17 27 17</td>
<td>LSD 06-17-27-17W3</td>
<td>660.8</td>
<td>577.3</td>
<td>668.4</td>
</tr>
<tr>
<td>Fife Kal Chipperfield 4 23 27 17</td>
<td>LSD 04-23-27-17W3</td>
<td>669</td>
<td>621.2</td>
<td>711.1</td>
</tr>
<tr>
<td>Spc Chipper Field 11 35 27 17</td>
<td>LSD 11-35-27-17W3</td>
<td>688.8</td>
<td>604.1</td>
<td>698.3</td>
</tr>
<tr>
<td>Spc Totnes 11 5 27 18</td>
<td>LSD 11-05-27-18W3</td>
<td>675.7</td>
<td>580</td>
<td>675</td>
</tr>
<tr>
<td>Homestead Penn Totnes 14 7 27 18</td>
<td>LSD 14-07-27-18W3</td>
<td>688.8</td>
<td>596.5</td>
<td>688.5</td>
</tr>
<tr>
<td>Spc HB Totnes 11 8 27 18</td>
<td>LSD 11-08-27-18W3</td>
<td>670.9</td>
<td>578.5</td>
<td>670</td>
</tr>
<tr>
<td>Spc Totnes 11 9 27 18</td>
<td>LSD 11-09-27-18W3</td>
<td>661</td>
<td>577.5</td>
<td>671</td>
</tr>
<tr>
<td>Homestead Penn Totnes 8 12 27 18</td>
<td>LSD 08-12-27-18W3</td>
<td>658.1</td>
<td>581.3</td>
<td>673.2</td>
</tr>
<tr>
<td>Socony Sohio Bickleigh 14 13</td>
<td>LSD 13-14-27-18W3</td>
<td>629.1</td>
<td>548</td>
<td>640.1</td>
</tr>
<tr>
<td>Spc Totnes 10 16 27 18</td>
<td>LSD 10-16-27-18W3</td>
<td>657.5</td>
<td>575</td>
<td>665.5</td>
</tr>
<tr>
<td>Spc Totnes 10 17 27 18</td>
<td>LSD 10-17-27-18W3</td>
<td>665.6</td>
<td>574</td>
<td>662</td>
</tr>
<tr>
<td>Pennant Totnes S 8 19 27 18</td>
<td>LSD 08-19-27-18W3</td>
<td>679.7</td>
<td>583.7</td>
<td>677.3</td>
</tr>
<tr>
<td>Spc Totnes 11 22 27 18</td>
<td>LSD 11-22-27-18W3</td>
<td>647.9</td>
<td>556.8</td>
<td>650</td>
</tr>
<tr>
<td>Spc Totnes 11 23 27 18</td>
<td>LSD 11-23-27-18W3</td>
<td>634.3</td>
<td>540.8</td>
<td>639.5</td>
</tr>
<tr>
<td>Spc Totnes 11 24 27 18</td>
<td>LSD 11-24-27-18W3</td>
<td>634</td>
<td>546.5</td>
<td>635.8</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP (m)</td>
<td>VNG TOP (m)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------</td>
<td>---------</td>
<td>------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Hudsons Bay Rosetown 13 25 27 18</td>
<td>LSD 13-25-27-18W3</td>
<td>610.5</td>
<td>518.8</td>
<td>605.9</td>
</tr>
<tr>
<td>Tipco HB et al Totnes 6 26 27 18</td>
<td>LSD 06-26-27-18W3</td>
<td>648.6</td>
<td>554.4</td>
<td>643.4</td>
</tr>
<tr>
<td>Spc Totnes 10 27 27 18</td>
<td>LSD 10-27-27-18W3</td>
<td>617.2</td>
<td>519.1</td>
<td>611.7</td>
</tr>
<tr>
<td>Homestead Penn Totnes 10 28 27 18</td>
<td>LSD 10-28-27-18W3</td>
<td>646.2</td>
<td>548.5</td>
<td>641</td>
</tr>
<tr>
<td>Homestead Penn Totnes 11 34 27 18</td>
<td>LSD 11-34-27-18W3</td>
<td>612</td>
<td>522.7</td>
<td>604.1</td>
</tr>
<tr>
<td>Westar Saskoil Plato W 1 6 27 19</td>
<td>LSD 01-06-27-19W3</td>
<td>690</td>
<td>605</td>
<td>701</td>
</tr>
<tr>
<td>Pennant Penkill S 13 11 27 19</td>
<td>LSD 13-11-27-19W3</td>
<td>680.6</td>
<td>591.6</td>
<td>682.8</td>
</tr>
<tr>
<td>Mobil Oil Penkill X 1 16</td>
<td>LSD 01-16-27-19W3</td>
<td>684.3</td>
<td>593.6</td>
<td>684.3</td>
</tr>
<tr>
<td>Pennant Totnes 7 2 4 27 19</td>
<td>LSD 07-24-27-19W3</td>
<td>682.8</td>
<td>587.6</td>
<td>681.5</td>
</tr>
<tr>
<td>Spc Totnes 7 25 27 19</td>
<td>LSD 07-25-27-19W3</td>
<td>679.4</td>
<td>588.9</td>
<td>680.9</td>
</tr>
<tr>
<td>Pennant Penkill M 9 31 27 19</td>
<td>LSD 09-31-27-19W3</td>
<td>704.4</td>
<td>620.9</td>
<td>712.3</td>
</tr>
<tr>
<td>Imperial Penkill 8 33 27 19</td>
<td>LSD 08-33-27-19W3</td>
<td>711.7</td>
<td>619</td>
<td>717.8</td>
</tr>
<tr>
<td>Spc Totnes 10 34 27 19</td>
<td>LSD 10-34-27-19W3</td>
<td>689.8</td>
<td>606.6</td>
<td>699.2</td>
</tr>
<tr>
<td>Homestead Penn Totnes 4 36 27 19</td>
<td>LSD 04-36-27-19W3</td>
<td>689.2</td>
<td>607.5</td>
<td>693.7</td>
</tr>
<tr>
<td>Herland et al Plato W 16 1 27 20</td>
<td>LSD 16-01-27-20W3</td>
<td>697.9</td>
<td>616</td>
<td>706.5</td>
</tr>
<tr>
<td>Homestead Penn Mcmorran 7 11 27 20</td>
<td>LSD 07-11-27-20W3</td>
<td>705.3</td>
<td>637.6</td>
<td>733.7</td>
</tr>
<tr>
<td>2D HB Petropy Mcmorran 11 17 27 20</td>
<td>LSD 11-17-27-20W3</td>
<td>708.1</td>
<td>625.1</td>
<td>715.9</td>
</tr>
<tr>
<td>Murphy et al Kindersley 10 15 27 21</td>
<td>LSD 10-16-27-21W3</td>
<td>712.6</td>
<td>623.6</td>
<td>716.3</td>
</tr>
<tr>
<td>Imperial Netherhill 11 17 27 21</td>
<td>LSD 11-17-27-21W3</td>
<td>706.5</td>
<td>617.8</td>
<td>710.2</td>
</tr>
<tr>
<td>Saskoil Brock 7 28 27 21</td>
<td>LSD 07-28-27-21W3</td>
<td>720.5</td>
<td>633.7</td>
<td>725.4</td>
</tr>
<tr>
<td>Phillips Husky Milrea No.1</td>
<td>LSD 10-29-27-21W3</td>
<td>721.2</td>
<td>631.5</td>
<td>723.3</td>
</tr>
<tr>
<td>Imperial Bostonia Road 9 10 27 22</td>
<td>LSD 09-10-27-22W3</td>
<td>706.5</td>
<td>619.7</td>
<td>713.8</td>
</tr>
<tr>
<td>Sap Bostonia R/A 12 11 27 22</td>
<td>LSD 12-11-27-22W3</td>
<td>706.5</td>
<td>619.7</td>
<td>714.8</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>LOCATION</td>
<td>K.B (m)</td>
<td>BC RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Sangren No.1</td>
<td>LSD 07-29-27-22W3</td>
<td>712</td>
<td>616.9</td>
<td>710.2</td>
</tr>
<tr>
<td>2D HB Petrody Sandgren 11 35 27 22</td>
<td>LSD 11-35-27-22W3</td>
<td>733.7</td>
<td>637</td>
<td>731.2</td>
</tr>
<tr>
<td>2D HB Petrody Glidden 6 7 27 23</td>
<td>LSD 06-07-27-23W3</td>
<td>681.2</td>
<td>586.1</td>
<td>679.7</td>
</tr>
<tr>
<td>Husky Glidden 10 11 27 23</td>
<td>LSD 10-11-27-23W3</td>
<td>684.3</td>
<td>587.7</td>
<td>682.1</td>
</tr>
<tr>
<td>Husky Mesa Glidden 11 15 27 23</td>
<td>LSD 11-15-27-23W3</td>
<td>675</td>
<td>581.6</td>
<td>671.2</td>
</tr>
<tr>
<td>Husky Glidden 7 17 27 23</td>
<td>LSD 07-17-27-23W3</td>
<td>677.3</td>
<td>581.3</td>
<td>672.3</td>
</tr>
<tr>
<td>Imperial Inglenook Road 1 23 27 23</td>
<td>LSD 01-23-27-23W3</td>
<td>685.2</td>
<td>589.2</td>
<td>683.7</td>
</tr>
<tr>
<td>2D HB Petrody Glidden 11 25 27 23</td>
<td>LSD 11-25-27-23W3</td>
<td>697.7</td>
<td>604.4</td>
<td>696.8</td>
</tr>
<tr>
<td>Husky Mesa Glidden 11 30 27 23</td>
<td>LSD 11-30-27-23W3</td>
<td>674.8</td>
<td>588.6</td>
<td>678.3</td>
</tr>
<tr>
<td>Mesa et al. Glidden 11 2 27 24</td>
<td>LSD 11-02-27-24W3</td>
<td>596.2</td>
<td>601</td>
<td>696</td>
</tr>
<tr>
<td>Etonia B No.1</td>
<td>LSD 02-04-27-24W3</td>
<td>738.5</td>
<td>641.9</td>
<td>737.9</td>
</tr>
<tr>
<td>Husky Phillips Etonia No.B2</td>
<td>LSD 14-04-27-24W3</td>
<td>726.9</td>
<td>634</td>
<td>730</td>
</tr>
<tr>
<td>Bighart Glidden 16 4 27 24</td>
<td>LSD 16-04-27-24W3</td>
<td>717.3</td>
<td>624</td>
<td>716</td>
</tr>
<tr>
<td>Husky Mesa Glidden 10 11 27 24</td>
<td>LSD 10-11-27-24W3</td>
<td>691</td>
<td>593.8</td>
<td>687.6</td>
</tr>
<tr>
<td>Imperial Husky Phillips Glidden 7 13</td>
<td>LSD 07-13-27-24W3</td>
<td>690.7</td>
<td>596.2</td>
<td>688.2</td>
</tr>
<tr>
<td>Glidden No.1</td>
<td>LSD 07-14-27-24W3</td>
<td>693.1</td>
<td>596.8</td>
<td>689.5</td>
</tr>
<tr>
<td>Phillips Husky Glidden No.2</td>
<td>LSD 07-15-27-24W3</td>
<td>692.2</td>
<td>595.3</td>
<td>689.8</td>
</tr>
<tr>
<td>Husky Mesa Glidden 7 16 27 24</td>
<td>LSD 07-16-27-24W3</td>
<td>709.3</td>
<td>616.3</td>
<td>709.6</td>
</tr>
<tr>
<td>Besharah No.1</td>
<td>LSD 11-35-27-24W3</td>
<td>687</td>
<td>608.7</td>
<td>698.6</td>
</tr>
<tr>
<td>Cox Warrior 13 4 27 25</td>
<td>LSD 13-04-27-25W3</td>
<td>777.2</td>
<td>689.8</td>
<td>785.8</td>
</tr>
<tr>
<td>Husky Phillips Warrior No.1</td>
<td>LSD 11-09-27-25W3</td>
<td>773.6</td>
<td>678.8</td>
<td>776</td>
</tr>
<tr>
<td>Husky Phillips Warrior No.11 10</td>
<td>LSD 11-10-27-25W3</td>
<td>767.2</td>
<td>681.8</td>
<td>774.5</td>
</tr>
<tr>
<td>Saskoil Warrior 6 16 27 25</td>
<td>LSD 10-16-27-25W3</td>
<td>777.5</td>
<td>696.8</td>
<td>791.9</td>
</tr>
<tr>
<td>Imperial Warrior 7 18 27 25</td>
<td>LSD 07-13-27-25W3</td>
<td>764.1</td>
<td>683.4</td>
<td>776.3</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VRNG TOP(m)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------</td>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Imperial Warrior No.10 29 27 25</td>
<td>LSD 10-29-27-25W3</td>
<td>769.9</td>
<td>690.1</td>
<td>788.2</td>
</tr>
<tr>
<td>Pinkham No.1</td>
<td>LSD 10-33-27-25W3</td>
<td>768.1</td>
<td>686.7</td>
<td>778.8</td>
</tr>
<tr>
<td>Phillips Husky Bailey No.1</td>
<td>LSD 07-02-27-26W3</td>
<td>744.3</td>
<td>657.1</td>
<td>752.9</td>
</tr>
<tr>
<td>Husky Bailey 7 11 27 26</td>
<td>LSD 07-11-27-26W3</td>
<td>740.7</td>
<td>659.9</td>
<td>752.9</td>
</tr>
<tr>
<td>Imperial Bailey No.11 17 27 26</td>
<td>LSD 11-17-27-26W3</td>
<td>709</td>
<td>629.1</td>
<td>722.1</td>
</tr>
<tr>
<td>Provo Pinkham No.1 34</td>
<td>LSD 01-34-27-26W3</td>
<td>723.6</td>
<td>642.2</td>
<td>737</td>
</tr>
<tr>
<td>Mantario No.1</td>
<td>LSD 01-05-27-27W3</td>
<td>695.2</td>
<td>627.0</td>
<td>717.2</td>
</tr>
<tr>
<td>Eyre No.1</td>
<td>LSD 06-10-27-27W3</td>
<td>684.3</td>
<td>615.1</td>
<td>703.8</td>
</tr>
<tr>
<td>Husky Marenco 7 29 27 27</td>
<td>LSD 07-29-27-27W3</td>
<td>714.1</td>
<td>652</td>
<td>742.2</td>
</tr>
<tr>
<td>Dome Marenco 7 8 27 28</td>
<td>LSD 07-08-27-28W3</td>
<td>685.9</td>
<td>628</td>
<td>717</td>
</tr>
<tr>
<td>Bighart Saskoils Alsask 10 27 27 28</td>
<td>LSD 10-27-27-28W3</td>
<td>647.5</td>
<td>576</td>
<td>663.7</td>
</tr>
<tr>
<td>Texcan Alsask 16 22 27 29</td>
<td>LSD 16-22-27-29W3</td>
<td>700.1</td>
<td>620.6</td>
<td>712.5</td>
</tr>
<tr>
<td>Hudson's Bay Rosetown 14 24 28 16</td>
<td>LSD 14-17-28-16W3</td>
<td>677.6</td>
<td>602.6</td>
<td>697.1</td>
</tr>
<tr>
<td>Hudson's Bay Rosetown 15 24 28 15</td>
<td>LSD 15-24-28-16W3</td>
<td>620</td>
<td>560.5</td>
<td>647.7</td>
</tr>
<tr>
<td>Fife Kal Bonnievale 10 6 28 17</td>
<td>LSD 10-06-28-17W3</td>
<td>643.1</td>
<td>554.7</td>
<td>647.7</td>
</tr>
<tr>
<td>Oro Kal Bonnievale 7 9 28 17</td>
<td>LSD 07-09-28-17W3</td>
<td>659.3</td>
<td>564.5</td>
<td>652.6</td>
</tr>
<tr>
<td>Fife Kal Bonnievale 12 10 28 17</td>
<td>LSD 12-10-28-17W3</td>
<td>675.1</td>
<td>574.2</td>
<td>664.8</td>
</tr>
<tr>
<td>Socony Sohio Chipperfield A 15 6</td>
<td>LSD 06-15-28-17W3</td>
<td>655.9</td>
<td>554.7</td>
<td>644.3</td>
</tr>
<tr>
<td>Spc Bad Lake 6 16 28 17</td>
<td>LSD 06-15-28-17W3</td>
<td>660.2</td>
<td>562.4</td>
<td>651.8</td>
</tr>
<tr>
<td>Fife Kal Bonnievale 8 19 28 17</td>
<td>LSD 08-19-28-17W3</td>
<td>638.6</td>
<td>541.9</td>
<td>634.9</td>
</tr>
<tr>
<td>Fife Kal Bonnievale 16 19 28 17</td>
<td>LSD 16-19-28-17W3</td>
<td>634.6</td>
<td>540.4</td>
<td>631.5</td>
</tr>
<tr>
<td>Saskoil Bonnievale 12 20 28 17</td>
<td>LSD 12-20-28-17W3</td>
<td>661.7</td>
<td>563.6</td>
<td>655.9</td>
</tr>
<tr>
<td>Tocnes 11 22 28 17</td>
<td>LSD 11-22-28-17W3</td>
<td>680.5</td>
<td>581</td>
<td>667.5</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------</td>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Oro Kal Bonnievale 2 30 28 17</td>
<td>LSD 02-30-28-17W3</td>
<td>639.5</td>
<td>546.5</td>
<td>634</td>
</tr>
<tr>
<td>Hudsons Bay Rosetown 4 34 28 17</td>
<td>LSD 04-34-28-17W3</td>
<td>685.2</td>
<td>591.3</td>
<td>681.5</td>
</tr>
<tr>
<td>Homestead Penn Totnes 10 5 28 18</td>
<td>LSD 10-05-28-18W3</td>
<td>684.6</td>
<td>590.7</td>
<td>679.9</td>
</tr>
<tr>
<td>Spc Totnes 10 6 28 18</td>
<td>LSD 10-06-28-18W3</td>
<td>684.3</td>
<td>595</td>
<td>684.8</td>
</tr>
<tr>
<td>Pennant Totnes N 12 7 28 18</td>
<td>LSD 12-07-28-18W3</td>
<td>711.4</td>
<td>621.3</td>
<td>713.2</td>
</tr>
<tr>
<td>Spc HB Totnes 7 8 28 18</td>
<td>LSD 07-08-28-18W3</td>
<td>696.2</td>
<td>602</td>
<td>691.6</td>
</tr>
<tr>
<td>Homestead Penn Totnes 10 9 28 18</td>
<td>LSD 10-09-28-18W3</td>
<td>629.4</td>
<td>532.2</td>
<td>618.4</td>
</tr>
<tr>
<td>Socony Sohio Totnes 21 5</td>
<td>LSD 05-21-28-18W3</td>
<td>675.1</td>
<td>585.5</td>
<td>676.4</td>
</tr>
<tr>
<td>Saskoil Totnes N 6 21 28 18</td>
<td>LSD 06-21-28-18W3</td>
<td>670.6</td>
<td>580</td>
<td>672.4</td>
</tr>
<tr>
<td>Pife Kal D Arcy 6 29 28 18</td>
<td>LSD 06-29-28-18W3</td>
<td>723.3</td>
<td>628.5</td>
<td>721.5</td>
</tr>
<tr>
<td>Sohio Standard D &gt; Arcy No.2</td>
<td>LSD 11-15-28-19W3</td>
<td>716.9</td>
<td>624.8</td>
<td>718.1</td>
</tr>
<tr>
<td>Pennant Brock E 6 16 28 18</td>
<td>LSD 06-16-28-19W3</td>
<td>714.8</td>
<td>623.6</td>
<td>716.3</td>
</tr>
<tr>
<td>Pennant Brock E 6 17 28 19</td>
<td>LSD 10-17-28-19W3</td>
<td>700.4</td>
<td>609.5</td>
<td>700.1</td>
</tr>
<tr>
<td>Pennant Brock 14 19 28 19</td>
<td>LSD 14-19-28-19W3</td>
<td>684.3</td>
<td>604.1</td>
<td>698.3</td>
</tr>
<tr>
<td>Pennant Brock East 11 22 28 19</td>
<td>LSD 12-22-28-19W3</td>
<td>719.9</td>
<td>630</td>
<td>719.9</td>
</tr>
<tr>
<td>Sohio Standard D &gt; Arcy No.1</td>
<td>LSD 15-22-28-19W3</td>
<td>717.5</td>
<td>622.4</td>
<td>711.4</td>
</tr>
<tr>
<td>Socony Sohio D Arcy 23 15</td>
<td>LSD 15-23-28-19W3</td>
<td>712.9</td>
<td>623.6</td>
<td>714.5</td>
</tr>
<tr>
<td>Sohio Standard D Arcy No.3</td>
<td>LSD 16-27-28-19W3</td>
<td>711.7</td>
<td>621.8</td>
<td>704.1</td>
</tr>
<tr>
<td>Socony Sohio D Arcy 28 1</td>
<td>LSD 01-28-28-19W3</td>
<td>704.4</td>
<td>612.6</td>
<td>698.9</td>
</tr>
<tr>
<td>Socony Sohio D Arcy 31 2</td>
<td>LSD 02-31-28-19W3</td>
<td>703.8</td>
<td>624.8</td>
<td>720.2</td>
</tr>
<tr>
<td>2D HB Petrody Brock 11 5 28 20</td>
<td>LSD 11-05-28-20W3</td>
<td>705.6</td>
<td>620.3</td>
<td>712.6</td>
</tr>
<tr>
<td>McMorrnan No.1 Start Test</td>
<td>LSD 11-11-28-20W3</td>
<td>724.8</td>
<td>641.6</td>
<td>733</td>
</tr>
<tr>
<td>Imperial Brock 11 17 28 20</td>
<td>LSD 11-17-28-20W3</td>
<td>706.5</td>
<td>612</td>
<td>702.6</td>
</tr>
<tr>
<td>Brock Unit 11 18 28 20</td>
<td>LSD 11-18-28-20W3</td>
<td>701</td>
<td>608.1</td>
<td>697.7</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K: B</td>
<td>3G RIVER</td>
<td>VNG</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------</td>
<td>------</td>
<td>----------</td>
<td>-----</td>
</tr>
<tr>
<td>Imperial Brock 6 19 28 20</td>
<td>LSD 06-19-28-20W3</td>
<td>705</td>
<td>608.7</td>
<td>698.6</td>
</tr>
<tr>
<td>Husky Phillips Brock No.8</td>
<td>LSD 07-20-28-20W3</td>
<td>706.5</td>
<td>612.6</td>
<td>704.1</td>
</tr>
<tr>
<td>ZD HB Petrody Brock 11 23 28 20</td>
<td>LSD 11-23-28-20W3</td>
<td>717.2</td>
<td>647.4</td>
<td>742.2</td>
</tr>
<tr>
<td>Brock No.5</td>
<td>LSD 11-27-28-20W3</td>
<td>708.7</td>
<td>620.3</td>
<td>707.7</td>
</tr>
<tr>
<td>Brock No.2</td>
<td>LSD 11-28-28-20W3</td>
<td>705.6</td>
<td>610.8</td>
<td>704.7</td>
</tr>
<tr>
<td>Brock No.1</td>
<td>LSD 13-29-28-20W3</td>
<td>716.6</td>
<td>624.5</td>
<td>711.7</td>
</tr>
<tr>
<td>Brock No.6</td>
<td>LSD 11-30-28-20W3</td>
<td>711.7</td>
<td>618.7</td>
<td>711.4</td>
</tr>
<tr>
<td>Imperial Brock 7 31 28 20</td>
<td>LSD 07-31-28-20W3</td>
<td>719.3</td>
<td>634.6</td>
<td>723.9</td>
</tr>
<tr>
<td>Brock No.3</td>
<td>LSD 11-32-28-20W3</td>
<td>719</td>
<td>630.9</td>
<td>716.3</td>
</tr>
<tr>
<td>Brock No.4</td>
<td>LSD 06-33-28-20W3</td>
<td>704.1</td>
<td>612.6</td>
<td>699.8</td>
</tr>
<tr>
<td>Newburg No.1</td>
<td>LSD 11-02-28-21W3</td>
<td>707.7</td>
<td>616.3</td>
<td>709.3</td>
</tr>
<tr>
<td>ZD-HB Petrody Newburg 16 5 28 21</td>
<td>LSD 16-05-28-21W3</td>
<td>732.4</td>
<td>653.8</td>
<td>743.1</td>
</tr>
<tr>
<td>Husky Phillips Newburg No.2</td>
<td>LSD 10-11-28-21W3</td>
<td>710.5</td>
<td>624.8</td>
<td>714.8</td>
</tr>
<tr>
<td>Brock Unit No.7 12</td>
<td>LSD 07-12-28-21W3</td>
<td>705.9</td>
<td>619.3</td>
<td>707.7</td>
</tr>
<tr>
<td>Murphy et al Kindersley 7 19 28 21</td>
<td>LSD 07-19-28-21W3</td>
<td>722.4</td>
<td>647.1</td>
<td>739.3</td>
</tr>
<tr>
<td>Imperial Brock 7 25 28 21</td>
<td>LSD 07-25-28-21W3</td>
<td>715.4</td>
<td>634.6</td>
<td>723.9</td>
</tr>
<tr>
<td>Imperial Netherhill 10 33 28 21</td>
<td>LSD 10-33-28-21W3</td>
<td>728.8</td>
<td>652</td>
<td>753.2</td>
</tr>
<tr>
<td>Imperial Turvin Road 1 1 28 22</td>
<td>LSD 01-01-28-22W3</td>
<td>723.9</td>
<td>637.6</td>
<td>730.6</td>
</tr>
<tr>
<td>Husky Phillips Inglenook No.1</td>
<td>LSD 01-04-28-22W3</td>
<td>733.3</td>
<td>641.3</td>
<td>732.7</td>
</tr>
<tr>
<td>Murphy et al Kindersley 11 13 28 22</td>
<td>LSD 11-13-28-22W3</td>
<td>730</td>
<td>641.3</td>
<td>734</td>
</tr>
<tr>
<td>Pennant Hur Kindersley 11 16 28 22</td>
<td>LSD 11-16-28-22W3</td>
<td>732.4</td>
<td>661.4</td>
<td>755.6</td>
</tr>
<tr>
<td>Phillips Husky Turvin No.1</td>
<td>LSD 06-19-28-22W3</td>
<td>704.1</td>
<td>633.4</td>
<td>722.4</td>
</tr>
<tr>
<td>Gao Verendrye East 6 20 28 22</td>
<td>LSD 06-20-28-22W3</td>
<td>713.5</td>
<td>649.2</td>
<td>740.1</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>BG RIVER TOP (m)</td>
<td>VKNG TOP (m)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------------------</td>
<td>---------</td>
<td>------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Murphy et al Kindersley 7 24 28 22</td>
<td>LSD 07-24-28-22W3</td>
<td>745.8</td>
<td>667.5</td>
<td>757.1</td>
</tr>
<tr>
<td>Verendrye No.1</td>
<td>LSD 01-19-28-23W3</td>
<td>685.8</td>
<td>591.3</td>
<td>691.9</td>
</tr>
<tr>
<td>Bighart Kindersley 7 19 28 23</td>
<td>LSD 07-19-28-23W3</td>
<td>666.9</td>
<td>575</td>
<td>670</td>
</tr>
<tr>
<td>Canus et al S Kindersley 12 23 28 23</td>
<td>LSD 12-23-28-23W3</td>
<td>687.3</td>
<td>605.9</td>
<td>701</td>
</tr>
<tr>
<td>Amerada Triad Kindersley 10 30 28 23</td>
<td>LSD 10-30-28-23W3</td>
<td>678.2</td>
<td>590.1</td>
<td>683.4</td>
</tr>
<tr>
<td>Gulf Kindersley 13 31 28 23</td>
<td>LSD 13-31-28-23W3</td>
<td>673.9</td>
<td>594</td>
<td>679</td>
</tr>
<tr>
<td>Canus et al N Verendrye 12 32 28 23</td>
<td>LSD 12-32-28-23W3</td>
<td>671.2</td>
<td>597.1</td>
<td>692.5</td>
</tr>
<tr>
<td>Gao Verendrye 1 33 28 23</td>
<td>LSD 01-33-28-23W3</td>
<td>673.3</td>
<td>584.9</td>
<td>682.1</td>
</tr>
<tr>
<td>Canus et al Fairmount 11 11 28 24</td>
<td>LSD 11-11-28-24W3</td>
<td>680</td>
<td>594.1</td>
<td>687.3</td>
</tr>
<tr>
<td>Fairmount et al Kindersley 13 13 28</td>
<td>LSD 13-13-28-24W3</td>
<td>688.5</td>
<td>590.7</td>
<td>682.8</td>
</tr>
<tr>
<td>Canus et al S Fairmount 16 14 28 24</td>
<td>LSD 16-14-28-24W3</td>
<td>692.8</td>
<td>594.4</td>
<td>686.7</td>
</tr>
<tr>
<td>Imperial Fairmount Road 4 16 28 24</td>
<td>LSD 04-16-28-24W3</td>
<td>694.3</td>
<td>602.9</td>
<td>704.7</td>
</tr>
<tr>
<td>Husky Phillips Fairmount No.1</td>
<td>LSD 08-19-28-24W3</td>
<td>695.6</td>
<td>610.2</td>
<td>700.4</td>
</tr>
<tr>
<td>Merland Kindersley 6 24 28 24</td>
<td>LSD 06-24-28-24W3</td>
<td>667.8</td>
<td>573.5</td>
<td>664</td>
</tr>
<tr>
<td>Amhess Fairmount 11 25 28 24</td>
<td>LSD 11-25-28-24W3</td>
<td>686.4</td>
<td>594.4</td>
<td>687</td>
</tr>
<tr>
<td>Bighart HB Kindersley 6 26 28 24</td>
<td>LSD 05-26-28-24W3</td>
<td>676.3</td>
<td>581.5</td>
<td>677.5</td>
</tr>
<tr>
<td>Phillips Husky Lynnhurst No.1</td>
<td>LSD 09-27-28-24W3</td>
<td>670</td>
<td>576.4</td>
<td>670</td>
</tr>
<tr>
<td>Gulf Fairmount 16 27 28 24</td>
<td>LSD 16-27-28-24W3</td>
<td>666.2</td>
<td>584</td>
<td>675.5</td>
</tr>
<tr>
<td>Canus Amoco et al Fair'mt 7 28 28 24</td>
<td>LSD 07-28-28-24W3</td>
<td>684.6</td>
<td>601.4</td>
<td>694.9</td>
</tr>
<tr>
<td>Canus et al S Ted 4 35 28 24</td>
<td>LSD 04-35-28-24W3</td>
<td>666.3</td>
<td>583.7</td>
<td>681.5</td>
</tr>
<tr>
<td>Phillips Husky Fairmount A No.1</td>
<td>LSD 07-14-23-25W3</td>
<td>697.7</td>
<td>628.5</td>
<td>723</td>
</tr>
<tr>
<td>I.N.C. Husky Marengo 11 11 28 26</td>
<td>LSD 11-11-28-26W3</td>
<td>727.9</td>
<td>652</td>
<td>744</td>
</tr>
<tr>
<td>Allied Embassy Marengo 11 28 28 26</td>
<td>LSD 11-28-28-26W3</td>
<td>745.2</td>
<td>670.9</td>
<td>765</td>
</tr>
<tr>
<td>Allied Embassy Marengo 10 15 28 27</td>
<td>LSD 10-15-28-27W3</td>
<td>741.3</td>
<td>666.3</td>
<td>759.7</td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>EG RIVER TOP(m)</td>
<td>VKNG TOP(m)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-------------------</td>
<td>---------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Dome Provo Haco Marengo 11 16</td>
<td>LSD 11-16-28-27W3</td>
<td>721.8</td>
<td>643.1</td>
<td>738.5</td>
</tr>
<tr>
<td>Allied Embassy Marengo 10 22 28 27</td>
<td>LSD 10-22-28-27W3</td>
<td>731.2</td>
<td>641.9</td>
<td>735.2</td>
</tr>
<tr>
<td>McBride et al Section 24 28 27</td>
<td>LSD 04-24-28-27W3</td>
<td>759</td>
<td>685.8</td>
<td>774.2</td>
</tr>
<tr>
<td>Husky Phillips Marengo No.3</td>
<td>LSD 10-25-28-27W3</td>
<td>761.7</td>
<td>684.9</td>
<td>775.1</td>
</tr>
<tr>
<td>Marengo No.1</td>
<td>LSD 10-26-28-27W3</td>
<td>750.1</td>
<td>672.1</td>
<td>755.3</td>
</tr>
<tr>
<td>Cavaller et al Marengo 11 26 28 27</td>
<td>LSD 11-26-28-27W3</td>
<td>761.1</td>
<td>676.7</td>
<td>764.7</td>
</tr>
<tr>
<td>Husky Phillips Marengo No.2</td>
<td>LSD 10-27-28-27W3</td>
<td>717.5</td>
<td>630.3</td>
<td>718.1</td>
</tr>
<tr>
<td>Allied Embassy Marengo 7 28 28 27</td>
<td>LSD 07-28-28-27W3</td>
<td>694.3</td>
<td>611.1</td>
<td>699.5</td>
</tr>
<tr>
<td>McBride Alcon Marengo 10 32</td>
<td>LSD 10-32-28-27W3</td>
<td>694.3</td>
<td>616</td>
<td>706.5</td>
</tr>
<tr>
<td>Spc Marengo 7 33 28 27</td>
<td>LSD 07-33-28-27W3</td>
<td>694</td>
<td>611.5</td>
<td>707</td>
</tr>
<tr>
<td>Spc Allied Box Marengo 7 34 28 27</td>
<td>LSD 07-34-28-27W3</td>
<td>716</td>
<td>627.9</td>
<td>716.9</td>
</tr>
<tr>
<td>Allied Embassy Marengo 6 35 28 27</td>
<td>LSD 06-35-28-27W3</td>
<td>720.5</td>
<td>638.6</td>
<td>730.3</td>
</tr>
<tr>
<td>Alsask No.1</td>
<td>LSD 10-07-28-28W3</td>
<td>686.7</td>
<td>600.2</td>
<td>688.8</td>
</tr>
<tr>
<td>McBride Marengo R/A N. B. 16 8 28 28</td>
<td>LSD 16-08-28-28W3</td>
<td>663.2</td>
<td>580</td>
<td>668.1</td>
</tr>
<tr>
<td>Phillips Merid No.1</td>
<td>LSD 04-19-28-28W3</td>
<td>674.5</td>
<td>592.8</td>
<td>682.1</td>
</tr>
<tr>
<td>McBride Al Con R/A W. B. 4 II 28 28</td>
<td>LSD 04-22-28-28W3</td>
<td>668.4</td>
<td>586.4</td>
<td>680.6</td>
</tr>
<tr>
<td>McBride Marengo R/A W Boundary 4 25</td>
<td>LSD 04-25-28-28W3</td>
<td>698.6</td>
<td>617.2</td>
<td>709.3</td>
</tr>
<tr>
<td>Texcan Alsask 10 1 28 29</td>
<td>LSD 10-01-28-29W3</td>
<td>694</td>
<td>617.5</td>
<td>704.1</td>
</tr>
<tr>
<td>Allied Embassy Alsask 11 12 28 29</td>
<td>LSD 11-12-28-29W3</td>
<td>705</td>
<td>623.6</td>
<td>712.3</td>
</tr>
<tr>
<td>Can-Tex et al Alsask 11 35 28 29</td>
<td>LSD 11-35-28-29W3</td>
<td>709.9</td>
<td>631.5</td>
<td>713.2</td>
</tr>
</tbody>
</table>
APPENDIX 2 - POTENTIALMERIC DATA FOR VIKING FORMATION IN WESTERN SASKATCHEWAN.

ISIT = INITIAL SHUT IN TIME; PSIT = FINAL SHUT IN TIME; ISIP = INITIAL SHUT IN PRESSURE; PSIP = FINAL SHUT IN PRESSURE; E = ELEVATION OF THE POTENTIALMERIC SURFACE WITH RESPECT TO SEA LEVEL (m); kPa = kilo Pascal; m = metre; min = minute.

<table>
<thead>
<tr>
<th>WELL NAME</th>
<th>WELL LOCATION</th>
<th>X.3 (m)</th>
<th>INTERVAL TESTED (m)</th>
<th>ISIT (min)</th>
<th>PSIT (min)</th>
<th>ISIP (kPa)</th>
<th>PSIP (kPa)</th>
<th>E (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tide Water Abbey Crown No.2</td>
<td>LSD 01-31-21-18W3</td>
<td>585.2</td>
<td>592.3 - 595.9</td>
<td>20</td>
<td>6378</td>
<td>640.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BA Abbey Andreas 1 19 21 19</td>
<td>LSD 01-19-21-19W3</td>
<td>578.2</td>
<td>575.1 - 580.3</td>
<td>15</td>
<td>15</td>
<td>6715</td>
<td>6660</td>
<td>675.5</td>
</tr>
<tr>
<td>AG Astra et al Abbey 10 23 21 20</td>
<td>LSD 10-23-21-20W3</td>
<td>577.9</td>
<td>582.2 - 586.4</td>
<td>45</td>
<td>60</td>
<td>6736</td>
<td>6729</td>
<td>679.2</td>
</tr>
<tr>
<td>BA Abbey Bachmeier 1 33 21 20</td>
<td>LSD 01-33-21-20W3</td>
<td>584.3</td>
<td>587.7 - 593.8</td>
<td>32</td>
<td>30</td>
<td>6660</td>
<td>6591</td>
<td>670.4</td>
</tr>
<tr>
<td>Cders Sceptre 2 3 21 24</td>
<td>LSD 02-03-21-24W3</td>
<td>705</td>
<td>733.7 - 740.1</td>
<td>30</td>
<td>30</td>
<td>6964</td>
<td>6805</td>
<td>675.9</td>
</tr>
<tr>
<td>Shell Rio Tinto Sceptre No.2</td>
<td>LSD 05-22-21-24W3</td>
<td>700.1</td>
<td>716.9 - 729.1</td>
<td>30</td>
<td>30</td>
<td>6205</td>
<td>604.5</td>
<td></td>
</tr>
<tr>
<td>Vand Hendham 11 16 21 26W3</td>
<td>LSD 11-16-21-26W3</td>
<td>694</td>
<td>705.6 - 711.3</td>
<td>30</td>
<td>60</td>
<td>7012</td>
<td>7012</td>
<td>697.6</td>
</tr>
<tr>
<td>Sastoil Leader No.2</td>
<td>LSD 07-24-21-26W3</td>
<td>684.9</td>
<td>711.4 - 720.5</td>
<td>30</td>
<td>30</td>
<td>6757</td>
<td>654.2</td>
<td></td>
</tr>
<tr>
<td>Spe Hendham</td>
<td>LSD 07-25-21-27W3</td>
<td>683.1</td>
<td>703.8 - 717.8</td>
<td>30</td>
<td>120</td>
<td>7012</td>
<td>6977</td>
<td>681.2</td>
</tr>
<tr>
<td>Bayssel Mobil Okalita Can Pet Leader 7</td>
<td>LSD 07-10-21-27W3</td>
<td>713.2</td>
<td>740.7 - 746.8</td>
<td>30</td>
<td>6598</td>
<td>640.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter City Barnstall No.2</td>
<td>LSD 01-01-21-29W3</td>
<td>727.9</td>
<td>757.1 - 762.3</td>
<td>15</td>
<td>1171</td>
<td>697.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter City Gas No.3</td>
<td>LSD 10-29-21-29W3</td>
<td>718.1</td>
<td>740.6 - 750.0</td>
<td>15</td>
<td>7135</td>
<td>685.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arco Cramersberg 13 19 22 20</td>
<td>LSD 13-19-22-20W3</td>
<td>633.1</td>
<td>646.2 - 655.3</td>
<td>60</td>
<td>90</td>
<td>6771</td>
<td>6674</td>
<td>669.1</td>
</tr>
<tr>
<td>AD Astra et al Flaxhill 10 1 22 21</td>
<td>LSD 10-01-22-21W3</td>
<td>599.2</td>
<td>605.0 - 609.0</td>
<td>30</td>
<td>60</td>
<td>6736</td>
<td>6729</td>
<td>677.9</td>
</tr>
<tr>
<td>Murphy Lancer 16 12 22 21</td>
<td>LSD 16-12-22-21W3</td>
<td>616.6</td>
<td>628.0 - 637.0</td>
<td>60</td>
<td>60</td>
<td>6755</td>
<td>6790</td>
<td>673.3</td>
</tr>
<tr>
<td>Done Provo Lancer No.6 22 22 21</td>
<td>LSD 06-22-22-21W3</td>
<td>656.2</td>
<td>670.3 - 672.7</td>
<td>30</td>
<td>30</td>
<td>6833</td>
<td>6534</td>
<td>681.1</td>
</tr>
<tr>
<td>B &amp; Jockness 13 15</td>
<td>LSD 13-15-22-23W3</td>
<td>659.1</td>
<td>708.7 - 716.0</td>
<td>30</td>
<td>30</td>
<td>6847</td>
<td>6826</td>
<td>677.0</td>
</tr>
<tr>
<td>Sastoil Leader No. Three</td>
<td>LSD 05-10-22-25W3</td>
<td>672.4</td>
<td>702.3 - 711.4</td>
<td>30</td>
<td>30</td>
<td>6518</td>
<td>840.8</td>
<td></td>
</tr>
<tr>
<td>Cdn-Sup Leader 6 20 22 27</td>
<td>LSD 06-20-22-27W3</td>
<td>685.2</td>
<td>705.6 - 746.8</td>
<td>60</td>
<td>60</td>
<td>7198</td>
<td>7177</td>
<td>673.3</td>
</tr>
<tr>
<td>Bayssel Mobil et al Leader 11 29</td>
<td>LSD 11-29-22-27W3</td>
<td>703.2</td>
<td>725.4 - 734.6</td>
<td>30</td>
<td>6619</td>
<td>644.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobil Oil South Estuary 11 13</td>
<td>LSD 13-11-22-28W3</td>
<td>706.8</td>
<td>730.9 - 734.3</td>
<td>60</td>
<td>6895</td>
<td>676.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

253
<table>
<thead>
<tr>
<th>VHL</th>
<th>NAME</th>
<th>VHL LOCATION</th>
<th>X.B (m)</th>
<th>INTERVAL TESTED (m)</th>
<th>ISIT (min)</th>
<th>PSIT (min)</th>
<th>ISIP (pka)</th>
<th>PSIP (pka)</th>
<th>Z (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Charter Canadian Devonian Empress 5</td>
<td>LSD 05-21-22-16W3</td>
<td>689.2</td>
<td>709.6 - 720.9</td>
<td>50</td>
<td>6060</td>
<td>668.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tide Water Sanctuary Crown No.1</td>
<td>LSD 16-17-23-15W3</td>
<td>602.6</td>
<td>617.2 - 620.3</td>
<td>20</td>
<td>6722</td>
<td>668.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cond Sup Lacadena 6 21 23 16</td>
<td>LSD 06-21-23-16W3</td>
<td>623.9</td>
<td>625.8 - 643.4</td>
<td>60</td>
<td>6060</td>
<td>666.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tide Water Plum Crown No.1</td>
<td>LSD 04-29-22-17W3</td>
<td>504.3</td>
<td>592.5 - 587.0</td>
<td>15</td>
<td>6550</td>
<td>666.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sinclair Lacadena 3 34</td>
<td>LSD 03-34-23-17W3</td>
<td>605</td>
<td>605.6 - 630.9</td>
<td>15</td>
<td>6722</td>
<td>6674</td>
<td>660.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cankey Tyner TA 22 23 19</td>
<td>LSD 07-22-23-19W3</td>
<td>611.1</td>
<td>623.3 - 650.1</td>
<td>30</td>
<td>6640</td>
<td>6664</td>
<td>638.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cankey Tyner 10 25 23 20</td>
<td>LSD 10-25-23-20W3</td>
<td>636.7</td>
<td>646.3 - 676.0</td>
<td>30</td>
<td>6729</td>
<td>6405</td>
<td>647.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fairdale No.1</td>
<td>LSD 08-29-23-20W3</td>
<td>648.6</td>
<td>660.5 - 664.2</td>
<td>-</td>
<td>4826</td>
<td>477.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phillips Husky Oven A No.1</td>
<td>LSD 06-19-23-21W3</td>
<td>686.7</td>
<td>701.0 - 703.5</td>
<td>15</td>
<td>6008</td>
<td>604.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Husky Inc Sceptre 7 31 22 22</td>
<td>LSD 07-31-23-22W3</td>
<td>701.3</td>
<td>714.8 - 727.3</td>
<td>60</td>
<td>6867</td>
<td>6819</td>
<td>674.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phillips Husky River A No.1</td>
<td>LSD 12-27-23-23W3</td>
<td>737.6</td>
<td>739.1 - 740.7</td>
<td>15</td>
<td>2965</td>
<td>287.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inc Husky Fairbanks 11 17 23 24</td>
<td>LSD 11-17-23-24W3</td>
<td>677.9</td>
<td>672.7 - 676.7</td>
<td>30</td>
<td>6447</td>
<td>6116</td>
<td>659.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108 Fairbanks 6 19 23 24</td>
<td>LSD 06-19-23-24W3</td>
<td>677.6</td>
<td>673.3 - 675.1</td>
<td>34</td>
<td>6543</td>
<td>6543</td>
<td>670.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>108 Fairbanks 11 25 23 24</td>
<td>LSD 11-25-23-24W3</td>
<td>720.9</td>
<td>719.1 - 730.9</td>
<td>30</td>
<td>6812</td>
<td>6731</td>
<td>685.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saskoil Sceptre 17 27 23 24</td>
<td>LSD 11-27-23-24W3</td>
<td>677.6</td>
<td>675.7 - 682.4</td>
<td>60</td>
<td>6419</td>
<td>6390</td>
<td>649.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prelate No.1</td>
<td>LSD 04-13-23-25W3</td>
<td>681.8</td>
<td>676.7 - 680.9</td>
<td>15</td>
<td>4654</td>
<td>476.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phillips Husky Prelate No.2</td>
<td>LSD 02-22-23-25W3</td>
<td>665.7</td>
<td>657.1 - 659.6</td>
<td>10</td>
<td>6205</td>
<td>639.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Husky Phillips Prelate No.11 20</td>
<td>LSD 11-28-23-25W3</td>
<td>683.4</td>
<td>678.5 - 680.0</td>
<td>15</td>
<td>6205</td>
<td>636.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quasar Trend Bayhorse 6 31 23 25</td>
<td>LSD 06-31-23-25W3</td>
<td>664.2</td>
<td>652.3 - 663.5</td>
<td>30</td>
<td>6419</td>
<td>6371</td>
<td>656.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Imp Red Bird 10 32 23 25</td>
<td>LSD 10-32-23-25W3</td>
<td>666.6</td>
<td>656.2 - 662.9</td>
<td>30</td>
<td>6640</td>
<td>6591</td>
<td>681.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Husky Phillips Prelate No.7 35</td>
<td>LSD 07-35-23-25W3</td>
<td>684.3</td>
<td>675.1 - 678.8</td>
<td>8</td>
<td>6412</td>
<td>6378</td>
<td>660.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dunglee No.1</td>
<td>LSD 08-35-23-26W3</td>
<td>690.7</td>
<td>687.3 - 691.0</td>
<td>15</td>
<td>6378</td>
<td>650.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inc Husky Wendan 10 29 24 15</td>
<td>LSD 10-29-24-15W3</td>
<td>624.5</td>
<td>640.1 - 652.9</td>
<td>33</td>
<td>5426</td>
<td>5426</td>
<td>525.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TD HB Petropy Plato 10 7 24 15</td>
<td>LSD 10-07-24-16W3</td>
<td>688.8</td>
<td>690.4 - 705.6</td>
<td>60</td>
<td>6371</td>
<td>6371</td>
<td>633.6</td>
<td></td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>FSIT (min)</td>
<td>ISIP (pK)</td>
<td>FSIP (pK)</td>
<td>Z (m)</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------</td>
<td>---------</td>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Bonanza Tricent Plato 4 15 24 16</td>
<td>LSD 04-15-24-16W</td>
<td>601.7</td>
<td>605.0 - 614.5</td>
<td>60</td>
<td>60</td>
<td>6350</td>
<td>6178</td>
<td>635.5</td>
<td></td>
</tr>
<tr>
<td>Sinclair Tyner 2 6</td>
<td>LSD 02-06-24-17W</td>
<td>589.2</td>
<td>591.0 - 614.8</td>
<td>10</td>
<td>10</td>
<td>6653</td>
<td>6633</td>
<td>653.6</td>
<td></td>
</tr>
<tr>
<td>Tide Water Plato Crown No.8</td>
<td>LSD 06-11-24-17W</td>
<td>620.6</td>
<td>617.2 - 622.1</td>
<td>30</td>
<td>60</td>
<td>6205</td>
<td>688.1</td>
<td>632.0</td>
<td></td>
</tr>
<tr>
<td>Long Is Plato 16 14 24 17</td>
<td>LSD 16-14-24-17W</td>
<td>681.4</td>
<td>682.8 - 705.6</td>
<td>30</td>
<td>60</td>
<td>6977</td>
<td>6799</td>
<td>688.5</td>
<td></td>
</tr>
<tr>
<td>1D HB Petrody Plato 16 21 24 17</td>
<td>LSD 16-21-24-17W</td>
<td>662.9</td>
<td>664.5 - 681.2</td>
<td>30</td>
<td>60</td>
<td>6522</td>
<td>6398</td>
<td>647.6</td>
<td></td>
</tr>
<tr>
<td>Kamalta Plato 14 24 17</td>
<td>LSD 14-24-24-17W</td>
<td>705.6</td>
<td>701.0 - 740.7</td>
<td>30</td>
<td>60</td>
<td>6302</td>
<td>6164</td>
<td>608.3</td>
<td></td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.7</td>
<td>LSD 10-23-24-17W</td>
<td>694.1</td>
<td>601.4 - 604.4</td>
<td>30</td>
<td>60</td>
<td>6033</td>
<td>615.6</td>
<td>615.6</td>
<td></td>
</tr>
<tr>
<td>Houston Kamalta Plato 16 33</td>
<td>LSD 16-33-24-17W</td>
<td>713.5</td>
<td>718.1 - 748.3</td>
<td>60</td>
<td>60</td>
<td>4171</td>
<td>4027</td>
<td>391.0</td>
<td></td>
</tr>
<tr>
<td>Long Is Rex Plato 2 34 24 17</td>
<td>LSD 02-34-24-17W</td>
<td>712</td>
<td>722.6 - 755.9</td>
<td>30</td>
<td>50</td>
<td>6205</td>
<td>5888</td>
<td>589.6</td>
<td></td>
</tr>
<tr>
<td>Jagor et al Plato 6 35 24 17</td>
<td>LSD 06-35-24-17W</td>
<td>751.6</td>
<td>753.5 - 780.3</td>
<td>60</td>
<td>90</td>
<td>7522</td>
<td>7391</td>
<td>739.2</td>
<td></td>
</tr>
<tr>
<td>Sinclair Lacadena 16 24 18</td>
<td>LSD 16-24-24-18W</td>
<td>577.3</td>
<td>579.1 - 597.4</td>
<td>15</td>
<td>60</td>
<td>6516</td>
<td>645.1</td>
<td>645.1</td>
<td></td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.5</td>
<td>LSD 10-28-24-18W</td>
<td>611.1</td>
<td>612.0 - 615.7</td>
<td>20</td>
<td>70</td>
<td>7067</td>
<td>716.9</td>
<td>716.9</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Guth No.1</td>
<td>LSD 11-29-24-20W</td>
<td>645.3</td>
<td>685.8 - 688.8</td>
<td>15</td>
<td>70</td>
<td>5807</td>
<td>553.4</td>
<td>553.4</td>
<td></td>
</tr>
<tr>
<td>Norwegian Rex Snipe Lake 8 21 24 21</td>
<td>LSD 08-21-24-21W</td>
<td>676.4</td>
<td>694.9 - 716.0</td>
<td>60</td>
<td>60</td>
<td>7053</td>
<td>6805</td>
<td>680.5</td>
<td></td>
</tr>
<tr>
<td>Imperial Athenian 16 22 24 22</td>
<td>LSD 16-22-24-22W</td>
<td>726.9</td>
<td>744.9 - 749.5</td>
<td>30</td>
<td>30</td>
<td>6943</td>
<td>6460</td>
<td>686.2</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Banko No.1</td>
<td>LSD 11-22-24-24W</td>
<td>695.9</td>
<td>713.2 - 717.5</td>
<td>15</td>
<td>6205</td>
<td>611.9</td>
<td>611.9</td>
<td>611.9</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 10 1 24 25</td>
<td>LSD 10-01-24-25W</td>
<td>684.9</td>
<td>679.7 - 682.8</td>
<td>15</td>
<td>30</td>
<td>6977</td>
<td>6695</td>
<td>714.4</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 10 3V 24 25</td>
<td>LSD 10-03-24-25W</td>
<td>676.4</td>
<td>673.3 - 676.4</td>
<td>30</td>
<td>70</td>
<td>6688</td>
<td>6571</td>
<td>682.8</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 13 6</td>
<td>LSD 13-06-24-25W</td>
<td>683.6</td>
<td>672.4 - 675.1</td>
<td>30</td>
<td>6784</td>
<td>687.1</td>
<td>687.1</td>
<td>687.1</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 7 9V 24 25</td>
<td>LSD 07-09-24-25W</td>
<td>678.5</td>
<td>672.4 - 676.0</td>
<td>30</td>
<td>70</td>
<td>6584</td>
<td>6557</td>
<td>674.7</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Lestwy No.1</td>
<td>LSD 11-14-24-25W</td>
<td>689.5</td>
<td>681.5 - 684.6</td>
<td>15</td>
<td>7515</td>
<td>772.1</td>
<td>772.1</td>
<td>772.1</td>
<td></td>
</tr>
<tr>
<td>Bayhurst Unit 5 15 24 25</td>
<td>LSD 05-15-24-25W</td>
<td>682.1</td>
<td>661.1 - 674.8</td>
<td>60</td>
<td>70</td>
<td>4933</td>
<td>4916</td>
<td>509.9</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 6 16 24 25</td>
<td>LSD 06-16-24-25W</td>
<td>678.2</td>
<td>670.9 - 673.6</td>
<td>60</td>
<td>29</td>
<td>6550</td>
<td>6550</td>
<td>676.0</td>
<td></td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pKPa)</td>
<td>PSIP (pKPa)</td>
<td>R (m)</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------</td>
<td>---------</td>
<td>---------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
<td>------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 7 17V 24 25</td>
<td>LSD 07-17-24-25W3</td>
<td>681.8</td>
<td>674.5 - 677.5</td>
<td>30</td>
<td>50</td>
<td>6615</td>
<td>680.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 7 18V 24 25</td>
<td>LSD 07-18-24-25W3</td>
<td>676.4</td>
<td>666.0 - 688.7</td>
<td>15</td>
<td>15</td>
<td>6709</td>
<td>681</td>
<td>692.6</td>
<td></td>
</tr>
<tr>
<td>Imperial Bayhurst 7 22 24 25</td>
<td>LSD 07-22-24-25W3</td>
<td>686.7</td>
<td>681.8 - 683.7</td>
<td>33</td>
<td>30</td>
<td>6660</td>
<td>6647</td>
<td>682.9</td>
<td></td>
</tr>
<tr>
<td>Gulf Bayhurst 6 28 24 25</td>
<td>LSD 06-28-24-25W3</td>
<td>681.5</td>
<td>680.0 - 690.0</td>
<td>75</td>
<td>120</td>
<td>4159</td>
<td>4152</td>
<td>417.1</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Quinney Well No.1</td>
<td>LSD 07-29-24-25W3</td>
<td>678.8</td>
<td>678.8 - 681.8</td>
<td>15</td>
<td>15</td>
<td>6205</td>
<td>630.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial Forefield 13 10</td>
<td>LSD 13-10-24-26W3</td>
<td>689.8</td>
<td>684.9 - 687.9</td>
<td>30</td>
<td>15</td>
<td>494.6</td>
<td>494.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quasax Trend Bayhurst 6 11 24 26</td>
<td>LSD 06-11-24-26W3</td>
<td>684</td>
<td>675.0 - 678.5</td>
<td>30</td>
<td>60</td>
<td>6081</td>
<td>6074</td>
<td>626.3</td>
<td></td>
</tr>
<tr>
<td>Imperial Forefield 5 17 24 26</td>
<td>LSD 05-17-24-26W3</td>
<td>684.9</td>
<td>689.8 - 693.4</td>
<td>10</td>
<td>30</td>
<td>6784</td>
<td>6695</td>
<td>684.1</td>
<td></td>
</tr>
<tr>
<td>Oliphant Nwgr Forefield</td>
<td>LSD 07-21-24-26W3</td>
<td>695.2</td>
<td>701.0 - 703.2</td>
<td>24</td>
<td>30</td>
<td>6715</td>
<td>6702</td>
<td>677.5</td>
<td></td>
</tr>
<tr>
<td>Oliphant Nwgr Forefield 7 22 24 26</td>
<td>LSD 07-22-24-26W3</td>
<td>683.7</td>
<td>683.7 - 686.4</td>
<td>30</td>
<td>15</td>
<td>6702</td>
<td>6702</td>
<td>681.5</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Dome Garfield No.1</td>
<td>LSD 07-29-24-26W3</td>
<td>702.3</td>
<td>701.3 - 704.4</td>
<td>15</td>
<td>15</td>
<td>6329</td>
<td>644.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabri No.1</td>
<td>LSD 01-23-24-28W3</td>
<td>706.2</td>
<td>745.2 - 748.3</td>
<td>15</td>
<td>15</td>
<td>7639</td>
<td>737.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1D-MB Petrody Elrose 6 7 25 15</td>
<td>LSD 06-07-25-15W3</td>
<td>608.7</td>
<td>622.4 - 633.7</td>
<td>60</td>
<td>90</td>
<td>5461</td>
<td>5405</td>
<td>532.5</td>
<td></td>
</tr>
<tr>
<td>Saskoil Precam Elrose 13 34 25 15</td>
<td>LSD 13-34-25-15W3</td>
<td>627.4</td>
<td>625.0 - 637.0</td>
<td>60</td>
<td>120</td>
<td>6297</td>
<td>6124</td>
<td>633.3</td>
<td></td>
</tr>
<tr>
<td>Williams Creek Elrose 6 3 25 16</td>
<td>LSD 06-03-25-16W3</td>
<td>594.1</td>
<td>597.4 - 616.9</td>
<td>30</td>
<td>30</td>
<td>5950</td>
<td>5936</td>
<td>584.7</td>
<td></td>
</tr>
<tr>
<td>MB Plato 2 4 25 17</td>
<td>LSD 02-04-25-17W3</td>
<td>724.8</td>
<td>734.6 - 750.1</td>
<td>120</td>
<td>42</td>
<td>818</td>
<td>61.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marvel Kamalta Plato 14 7 25 17</td>
<td>LSD 14-07-25-17W3</td>
<td>640.1</td>
<td>637.6 - 649.8</td>
<td>45</td>
<td>45</td>
<td>5171</td>
<td>5018</td>
<td>518.2</td>
<td></td>
</tr>
<tr>
<td>Tide Water Plato Crown No.11</td>
<td>LSD 11-11-25-17W3</td>
<td>720.5</td>
<td>750.6 - 771.1</td>
<td>30</td>
<td>30</td>
<td>1724</td>
<td>125.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tide Water Plato Crown No.10</td>
<td>LSD 11-15-25-17W3</td>
<td>669.3</td>
<td>684.3 - 690.7</td>
<td>30</td>
<td>30</td>
<td>621</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barnwell et al Plato 10 33 25 17</td>
<td>LSD 10-33-25-17W3</td>
<td>661.1</td>
<td>664.5 - 670.0</td>
<td>30</td>
<td>60</td>
<td>5909</td>
<td>5902</td>
<td>594.4</td>
<td></td>
</tr>
<tr>
<td>Hudson's Bay Oil &amp; Gas Greenan 6 36</td>
<td>LSD 06-36-25-17W3</td>
<td>660.2</td>
<td>667.5 - 675.4</td>
<td>60</td>
<td>60</td>
<td>6853</td>
<td>6874</td>
<td>684.4</td>
<td></td>
</tr>
<tr>
<td>Hol et al Plato 14 1 25 18</td>
<td>LSD 14-01-25-18W3</td>
<td>609.6</td>
<td>609.3 - 640.7</td>
<td>30</td>
<td>60</td>
<td>6040</td>
<td>5874</td>
<td>585.5</td>
<td></td>
</tr>
<tr>
<td>Houston et al Plato 16 3 25 18</td>
<td>LSD 16-03-25-18W3</td>
<td>588.4</td>
<td>598.9 - 630.9</td>
<td>30</td>
<td>45</td>
<td>6529</td>
<td>6378</td>
<td>624.3</td>
<td></td>
</tr>
<tr>
<td>Tide Water Plato Crown No.9</td>
<td>LSD 10-11-25-18W3</td>
<td>595.9</td>
<td>602.0 - 606.2</td>
<td>15</td>
<td>15</td>
<td>4402</td>
<td>447.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>KB (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pPa)</td>
<td>PSIP (pPa)</td>
<td>R (m)</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------</td>
<td>--------</td>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Arco Plato 6 12 25 18</td>
<td>LSD 06-12-25-18W3</td>
<td>648</td>
<td>649.2 - 679.7</td>
<td>30</td>
<td>75</td>
<td>6109</td>
<td>5990</td>
<td>592.0</td>
<td></td>
</tr>
<tr>
<td>Arco Plato 14 12 25 18</td>
<td>LSD 14-12-25-18W3</td>
<td>618.7</td>
<td>629.1 - 664.6</td>
<td>40</td>
<td>90</td>
<td>5378</td>
<td>5378</td>
<td>521.6</td>
<td></td>
</tr>
<tr>
<td>Marvel Canalta Plato 2 13 25 18</td>
<td>LSD 02-13-25-18W3</td>
<td>631.7</td>
<td>635.5 - 662.9</td>
<td>30</td>
<td>32</td>
<td>6647</td>
<td>6571</td>
<td>651.5</td>
<td></td>
</tr>
<tr>
<td>Arco Plato 12 14 25 18</td>
<td>LSD 12-14-25-18W3</td>
<td>633.7</td>
<td>645.0 - 666.0</td>
<td>30</td>
<td>95</td>
<td>6626</td>
<td>6578</td>
<td>644.2</td>
<td></td>
</tr>
<tr>
<td>CN Expl Plato 14 21 25 18</td>
<td>LSD 14-21-25-18W3</td>
<td>660.5</td>
<td>670.9 - 683.5</td>
<td>30</td>
<td>90</td>
<td>5714</td>
<td>5674</td>
<td>566.9</td>
<td></td>
</tr>
<tr>
<td>Arco Plato 2 22 25 18</td>
<td>LSD 02-22-25-18W3</td>
<td>653.5</td>
<td>666.0 - 690.4</td>
<td>30</td>
<td>90</td>
<td>6612</td>
<td>6378</td>
<td>638.1</td>
<td></td>
</tr>
<tr>
<td>Arco Houston Plato 4 20 25 18</td>
<td>LSD 04-20-25-18W3</td>
<td>658.7</td>
<td>669.3 - 692.5</td>
<td>33</td>
<td>90</td>
<td>800</td>
<td>758</td>
<td>47.9</td>
<td></td>
</tr>
<tr>
<td>Tide Water Imperial Plato Crown No.4</td>
<td>LSD 10-28-25-18W1</td>
<td>661.7</td>
<td>679.1 - 682.1</td>
<td>20</td>
<td></td>
<td>172</td>
<td></td>
<td>-2.4</td>
<td></td>
</tr>
<tr>
<td>Trend Arco Richlea 16 25 19</td>
<td>LSD 16-25-25-19W3</td>
<td>659.3</td>
<td>666.0 - 685.8</td>
<td>30</td>
<td>90</td>
<td>6881</td>
<td>6681</td>
<td>655.5</td>
<td></td>
</tr>
<tr>
<td>Trend Arco Richlea 16 20 19</td>
<td>LSD 16-20-25-19W3</td>
<td>670.3</td>
<td>689.3 - 710.2</td>
<td>30</td>
<td>90</td>
<td>5447</td>
<td>5206</td>
<td>516.2</td>
<td></td>
</tr>
<tr>
<td>Trend Arco Richlea 2 36 25 19</td>
<td>LSD 02-36-25-19W3</td>
<td>658.4</td>
<td>671.8 - 685.8</td>
<td>30</td>
<td>75</td>
<td>6619</td>
<td>6254</td>
<td>648.4</td>
<td></td>
</tr>
<tr>
<td>3D HD Pctrd DY Eston 6 19 25 20</td>
<td>LSD 06-19-25-20W3</td>
<td>677.6</td>
<td>655.9 - 695.8</td>
<td>30</td>
<td>60</td>
<td>6791</td>
<td>6778</td>
<td>671.1</td>
<td></td>
</tr>
<tr>
<td>Husty Phillips Eston No.1</td>
<td>LSD 07-29-25-20W3</td>
<td>683.4</td>
<td>701.3 - 705.6</td>
<td>25</td>
<td></td>
<td>6819</td>
<td></td>
<td>674.0</td>
<td></td>
</tr>
<tr>
<td>Phillips Husty Dome Tescola No.1</td>
<td>LSD 07-29-25-23W3</td>
<td>687</td>
<td>714.5 - 721.2</td>
<td>15</td>
<td></td>
<td>6205</td>
<td></td>
<td>593.3</td>
<td></td>
</tr>
<tr>
<td>Jagor Ortega Bayhurst 6 22 25 24</td>
<td>LSD 06-22-25-24W3</td>
<td>693.1</td>
<td>710.2 - 744.0</td>
<td>30</td>
<td>60</td>
<td>6857</td>
<td>6853</td>
<td>650.2</td>
<td></td>
</tr>
<tr>
<td>Jagor N Bayhurst 11 4 25 25</td>
<td>LSD 01-04-25-25W3</td>
<td>696.4</td>
<td>701.0 - 744.6</td>
<td>60</td>
<td>60</td>
<td>6598</td>
<td>6598</td>
<td>685.4</td>
<td></td>
</tr>
<tr>
<td>CN Expl Batavia 8 35 25 25</td>
<td>LSD 08-35-25-25W3</td>
<td>708.4</td>
<td>710.0 - 770.0</td>
<td>60</td>
<td>90</td>
<td>6509</td>
<td>6307</td>
<td>603.0</td>
<td></td>
</tr>
<tr>
<td>Oliphant NWrco Gorefield 4 6 25 26</td>
<td>LSD 04-06-25-26W3</td>
<td>693.4</td>
<td>702.3 - 706.2</td>
<td>30</td>
<td>60</td>
<td>6805</td>
<td>6805</td>
<td>681.9</td>
<td></td>
</tr>
<tr>
<td>Imperial Highbury 10 35</td>
<td>LSD 10-35-25-26W3</td>
<td>701.6</td>
<td>724.2 - 725.7</td>
<td>15</td>
<td>16</td>
<td>6274</td>
<td>6274</td>
<td>616.4</td>
<td></td>
</tr>
<tr>
<td>Oliphant NWrco Gorefield 4 2 25 27</td>
<td>LSD 04-02-25-27W3</td>
<td>683.4</td>
<td>690.1 - 694.3</td>
<td>20</td>
<td>30</td>
<td>6853</td>
<td>6812</td>
<td>688.7</td>
<td></td>
</tr>
<tr>
<td>Oliphant NWrco Gorefield 6 12 25 27</td>
<td>LSD 06-12-25-27W3</td>
<td>693.1</td>
<td>702.6 - 705.9</td>
<td>34</td>
<td>116</td>
<td>6778</td>
<td>6888</td>
<td>690.4</td>
<td></td>
</tr>
<tr>
<td>Oliphant NWrco Gorefield 14 17 25 27</td>
<td>LSD 14-17-25-27W3</td>
<td>610.8</td>
<td>630.9 - 640.1</td>
<td>35</td>
<td>60</td>
<td>6864</td>
<td>6864</td>
<td>681.7</td>
<td></td>
</tr>
<tr>
<td>Oliphant NWrco Gorefield 8 22 25 27</td>
<td>LSD 08-22-25-27W3</td>
<td>688.5</td>
<td>694.6 - 704.7</td>
<td>30</td>
<td>60</td>
<td>6853</td>
<td>6798</td>
<td>683.4</td>
<td></td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.B (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIIT (min)</td>
<td>ISIP (pKPa)</td>
<td>PSIP (pKPa)</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------</td>
<td>---------</td>
<td>---------------------</td>
<td>------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Provo Cabri Lake No.7</td>
<td>LSD 07-09-25-28W3</td>
<td>714.8</td>
<td>747.7 - 752.2</td>
<td>10</td>
<td>6504</td>
<td>6504</td>
<td>534.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oliphant Wnrco Gorefield</td>
<td>LSD 03-27-25-28W3</td>
<td>746.8</td>
<td>766.6 - 774.2</td>
<td>30</td>
<td>7019</td>
<td>7019</td>
<td>689.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Border No.1</td>
<td>LSD 07-09-25-28W3</td>
<td>747.4</td>
<td>772.7 - 781.8</td>
<td>30</td>
<td>6897</td>
<td>677.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Cuthbert 7 25 25 29</td>
<td>LSD 07-27-25-29W3</td>
<td>780.6</td>
<td>805.0 - 815.3</td>
<td>60</td>
<td>7019</td>
<td>7019</td>
<td>681.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saskoll Cuthbert 7 27 25 29</td>
<td>LSD 07-27-25-29W3</td>
<td>794</td>
<td>824.8 - 830.9</td>
<td>60</td>
<td>7157</td>
<td>7150</td>
<td>693.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceja Alsask 10 27 25 29</td>
<td>LSD 10-05-26-15W3</td>
<td>800.4</td>
<td>830.3 - 836.4</td>
<td>45</td>
<td>7033</td>
<td>6971</td>
<td>602.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D-HB Petro DY 10 5 26 15</td>
<td>LSD 10-26-16W3</td>
<td>622.4</td>
<td>625.4 - 630.3</td>
<td>60</td>
<td>6398</td>
<td>6105</td>
<td>637.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Sunex Greenan 6 7 26 16</td>
<td>LSD 06-07-26-16W3</td>
<td>629.4</td>
<td>643.1 - 660.8</td>
<td>30</td>
<td>6888</td>
<td>6853</td>
<td>671.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golden Lake et al Greenan</td>
<td>LSD 06-09-26-16W3</td>
<td>628.2</td>
<td>650.1 - 675.4</td>
<td>15</td>
<td>6274</td>
<td>6240</td>
<td>598.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sobio Standard Elrose No.4</td>
<td>LSD 09-10-26-16W3</td>
<td>631.9</td>
<td>639.5 - 650.4</td>
<td>15</td>
<td>5171</td>
<td>5171</td>
<td>509.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Elrose 6 13 26 16</td>
<td>LSD 06-13-26-16W3</td>
<td>626.7</td>
<td>616.9 - 642.0</td>
<td>30</td>
<td>6054</td>
<td>5840</td>
<td>502.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Elrose 7 14 26 16</td>
<td>LSD 07-14-26-16W3</td>
<td>622.1</td>
<td>617.2 - 639.2</td>
<td>30</td>
<td>5626</td>
<td>5530</td>
<td>557.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inc Husky Plato 7 22 26 16</td>
<td>LSD 07-22-26-16W3</td>
<td>623.9</td>
<td>650.4 - 665.7</td>
<td>30</td>
<td>5840</td>
<td>5619</td>
<td>554.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams Creek Greenan 11 2 26 17</td>
<td>LSD 11-02-26-17W3</td>
<td>648.6</td>
<td>649.2 - 669.6</td>
<td>32</td>
<td>6915</td>
<td>6846</td>
<td>685.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Kamalta Plato 13 6 26 17</td>
<td>LSD 13-06-26-17W3</td>
<td>666.9</td>
<td>671.5 - 697.1</td>
<td>30</td>
<td>6302</td>
<td>6150</td>
<td>613.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norvian Kex Greenan 6 7 26 17</td>
<td>LSD 06-07-26-17W3</td>
<td>653.2</td>
<td>657.1 - 664.5</td>
<td>60</td>
<td>6840</td>
<td>6833</td>
<td>687.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams Creek Greenan 10 8 26 17</td>
<td>LSD 10-08-26-17W3</td>
<td>650.7</td>
<td>655.3 - 682.8</td>
<td>50</td>
<td>6812</td>
<td>6757</td>
<td>664.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Greenan 11 13 26 17</td>
<td>LSD 11-13-26-17W3</td>
<td>624.2</td>
<td>627.9 - 649.2</td>
<td>30</td>
<td>6578</td>
<td>6398</td>
<td>646.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams Creek Greenan 7 16 26 17</td>
<td>LSD 07-16-26-17W3</td>
<td>656.5</td>
<td>655.3 - 684.3</td>
<td>30</td>
<td>6819</td>
<td>6812</td>
<td>663.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams Creek Greenan 7 17 26 17</td>
<td>LSD 07-17-26-17W3</td>
<td>661.1</td>
<td>664.5 - 682.8</td>
<td>35</td>
<td>6405</td>
<td>6791</td>
<td>673.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams Creek Greenan 6 19 26 17</td>
<td>LSD 06-19-26-17W3</td>
<td>663.5</td>
<td>663.9 - 673.6</td>
<td>30</td>
<td>6578</td>
<td>6536</td>
<td>661.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Greenan 7 21 26 17</td>
<td>LSD 07-21-26-17W3</td>
<td>551.1</td>
<td>555.3 - 682.8</td>
<td>35</td>
<td>6433</td>
<td>6491</td>
<td>663.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Sunex Greenan 7 23 26 17</td>
<td>LSD 07-23-26-17W3</td>
<td>528.5</td>
<td>630.9 - 652.3</td>
<td>60</td>
<td>6750</td>
<td>6750</td>
<td>665.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jager Greenan 6 24 26 17</td>
<td>LSD 06-24-26-17W3</td>
<td>523.9</td>
<td>646.2 - 667.5</td>
<td>30</td>
<td>6853</td>
<td>6778</td>
<td>656.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pKa)</td>
<td>PSIP (pKa)</td>
<td>R (m)</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
<td>---------</td>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Norvanian Kamalta Plato 15 25 26 17</td>
<td>LSD 15-25-26-17W3</td>
<td>637</td>
<td>656.8 - 687.0</td>
<td>45</td>
<td>90</td>
<td>6736</td>
<td>6522</td>
<td>637.7</td>
<td></td>
</tr>
<tr>
<td>H.B. North Plato 15 27 26 17</td>
<td>LSD 15-27-26-17W3</td>
<td>637.2</td>
<td>660.2 - 691.0</td>
<td>60</td>
<td>60</td>
<td>6426</td>
<td>6502</td>
<td>643.2</td>
<td></td>
</tr>
<tr>
<td>Norvanian Kamalta Plato 9 34 26 17</td>
<td>LSD 09-34-26-17W3</td>
<td>642.8</td>
<td>642.8 - 704.1</td>
<td>30</td>
<td>60</td>
<td>6543</td>
<td>6643</td>
<td>605.7</td>
<td></td>
</tr>
<tr>
<td>Mauville et al Greenman 11 12 26 18</td>
<td>LSD 11-12-26-18W3</td>
<td>659.6</td>
<td>675.0 - 687.0</td>
<td>28</td>
<td>125</td>
<td>6258</td>
<td>6247</td>
<td>621.5</td>
<td></td>
</tr>
<tr>
<td>HB North Plato 3 13 26 18</td>
<td>LSD 03-13-26-18W3</td>
<td>669</td>
<td>665.1 - 698.0</td>
<td>60</td>
<td>60</td>
<td>6764</td>
<td>6684</td>
<td>661.6</td>
<td></td>
</tr>
<tr>
<td>Pennant N Plato 1 22 25 18</td>
<td>LSD 01-22-25-18W3</td>
<td>664.2</td>
<td>660.5 - 678.8</td>
<td>30</td>
<td>60</td>
<td>6764</td>
<td>6695</td>
<td>676.0</td>
<td></td>
</tr>
<tr>
<td>ID HB Petrody Kildare 10 27 26 18</td>
<td>LSD 10-27-26-18W3</td>
<td>673.3</td>
<td>684.0 - 698.0</td>
<td>60</td>
<td>90</td>
<td>6819</td>
<td>6791</td>
<td>671.4</td>
<td></td>
</tr>
<tr>
<td>ID Penn Petrody Richlea 10 29</td>
<td>LSD 10-25-26-18W3</td>
<td>662.3</td>
<td>669.3 - 676.7</td>
<td>60</td>
<td>60</td>
<td>6743</td>
<td>6702</td>
<td>674.9</td>
<td></td>
</tr>
<tr>
<td>ID HB Petrody Eston 10 7 26 20</td>
<td>LSD 10-07-26-10W3</td>
<td>693.4</td>
<td>710.2 - 722.4</td>
<td>60</td>
<td>90</td>
<td>6929</td>
<td>6909</td>
<td>678.4</td>
<td></td>
</tr>
<tr>
<td>Imperial Centre Field 13 10 26 21</td>
<td>LSD 13-10-26-21W3</td>
<td>688.2</td>
<td>705.6 - 709.0</td>
<td>30</td>
<td>30</td>
<td>6826</td>
<td>6826</td>
<td>676.1</td>
<td></td>
</tr>
<tr>
<td>ID HB Petrody Snipe Lake 10 25 26 21</td>
<td>LSD 10-25-26-21W3</td>
<td>693.4</td>
<td>715.7 - 725.7</td>
<td>60</td>
<td>35</td>
<td>6626</td>
<td>6433</td>
<td>644.2</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Dome Snipe No.1</td>
<td>LSD 07-28-26-21W3</td>
<td>595.9</td>
<td>714.5 - 720.5</td>
<td>15</td>
<td>2551</td>
<td>235.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inc Husky Madison 10 24 26 22</td>
<td>LSD 10-24-26-22W3</td>
<td>694.6</td>
<td>705.9 - 714.8</td>
<td>30</td>
<td>60</td>
<td>6936</td>
<td>6722</td>
<td>687.9</td>
<td></td>
</tr>
<tr>
<td>ID BB Petrody Glidden 11 23 26 23</td>
<td>LSD 11-23-26-23W3</td>
<td>698.5</td>
<td>696.5 - 708.7</td>
<td>60</td>
<td>90</td>
<td>6598</td>
<td>6584</td>
<td>661.4</td>
<td></td>
</tr>
<tr>
<td>Texaco Cuthbert 4 17</td>
<td>LSD 04-17-24-28W3</td>
<td>742.8</td>
<td>771.2 - 783.3</td>
<td>30</td>
<td>30</td>
<td>6943</td>
<td>6729</td>
<td>688.3</td>
<td></td>
</tr>
<tr>
<td>Champlin Plato 9 2 27 17</td>
<td>LSD 09-02-17-17W3</td>
<td>674.2</td>
<td>710.2 - 725.4</td>
<td>45</td>
<td>20</td>
<td>6895</td>
<td>6885</td>
<td>652.7</td>
<td></td>
</tr>
<tr>
<td>Fife Kal Chipperfield 10 7 27 17</td>
<td>LSD 10-07-27-17W3</td>
<td>659.6</td>
<td>670.6 - 688.8</td>
<td>5</td>
<td>90</td>
<td>6681</td>
<td>6557</td>
<td>652.3</td>
<td></td>
</tr>
<tr>
<td>Spc HB Bickleigh 7 8 27 17</td>
<td>LSD 07-08-27-17W3</td>
<td>657.1</td>
<td>653.8 - 693.4</td>
<td>60</td>
<td>60</td>
<td>6729</td>
<td>6584</td>
<td>650.7</td>
<td></td>
</tr>
<tr>
<td>Champlin North Plato 11 11 27 17</td>
<td>LSD 11-11-27-17W3</td>
<td>638.3</td>
<td>667.5 - 698.0</td>
<td>30</td>
<td>60</td>
<td>6633</td>
<td>6401</td>
<td>617.5</td>
<td></td>
</tr>
<tr>
<td>Fife Kal Chipperfield 6 17 27 17</td>
<td>LSD 06-17-27-17W3</td>
<td>660.8</td>
<td>670.6 - 685.8</td>
<td>30</td>
<td>90</td>
<td>6805</td>
<td>6778</td>
<td>669.7</td>
<td></td>
</tr>
<tr>
<td>Fife Kal Chipperfield 4 23 27 17</td>
<td>LSD 04-23-27-17W3</td>
<td>669</td>
<td>713.2 - 734.6</td>
<td>30</td>
<td>90</td>
<td>6950</td>
<td>6133</td>
<td>644.0</td>
<td></td>
</tr>
<tr>
<td>Spc Chipper Field 11 35 27 17</td>
<td>LSD 11-35-27-17W3</td>
<td>648.8</td>
<td>658.0 - 723.9</td>
<td>30</td>
<td>60</td>
<td>6722</td>
<td>6667</td>
<td>651.2</td>
<td></td>
</tr>
<tr>
<td>SPC Totnes 11 5 27 18</td>
<td>LSD 11-05-27-18W3</td>
<td>675.7</td>
<td>677.0 - 683.0</td>
<td>30</td>
<td>40</td>
<td>6590</td>
<td>6550</td>
<td>665.5</td>
<td></td>
</tr>
<tr>
<td>WELL</td>
<td>NAME</td>
<td>WELL LOCATION</td>
<td>K.B (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pKPa)</td>
<td>PSIP (pKPa)</td>
<td>R (m)</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
<td>---------------</td>
<td>---------</td>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>Homestead Penn Totes 14</td>
<td>7 27 18</td>
<td>LSD 14-07-27-18W3</td>
<td>688.8</td>
<td>691.9 - 699.2</td>
<td>45</td>
<td>60</td>
<td>668</td>
<td>6667</td>
<td>672.4</td>
</tr>
<tr>
<td>Spc BH Totes 11</td>
<td>8 27 18</td>
<td>LSD 11-08-27-18W3</td>
<td>670.9</td>
<td>665.4 - 699.5</td>
<td>30</td>
<td>60</td>
<td>5585</td>
<td>5454</td>
<td>541.6</td>
</tr>
<tr>
<td>Spc Totes 11</td>
<td>9 27 18</td>
<td>LSD 11-09-27-18W3</td>
<td>661</td>
<td>672.9 - 679.0</td>
<td>60</td>
<td>90</td>
<td>656</td>
<td>651</td>
<td>45.0</td>
</tr>
<tr>
<td>Homestead Penn Totes 8</td>
<td>12 27 18</td>
<td>LSD 08-12-27-18W3</td>
<td>658.1</td>
<td>670.6 - 688.8</td>
<td>45</td>
<td>60</td>
<td>4840</td>
<td>4737</td>
<td>463.4</td>
</tr>
<tr>
<td>Socopi Sobio Bickleigh 14</td>
<td>13</td>
<td>LSD 13-14-27-18W3</td>
<td>629.1</td>
<td>641.0 - 650.1</td>
<td>15</td>
<td>15</td>
<td>4137</td>
<td>4137</td>
<td>401.4</td>
</tr>
<tr>
<td>Spc Totes 11</td>
<td>22</td>
<td>LSD 11-22-27-18W3</td>
<td>647.9</td>
<td>645.0 - 671.7</td>
<td>60</td>
<td>90</td>
<td>6458</td>
<td>6406</td>
<td>635.5</td>
</tr>
<tr>
<td>Spc Totes 11</td>
<td>23 27 18</td>
<td>LSD 11-23-27-18W3</td>
<td>634.3</td>
<td>634.9 - 648.9</td>
<td>60</td>
<td>135</td>
<td>6522</td>
<td>6219</td>
<td>651.3</td>
</tr>
<tr>
<td>Hudsons Bay Rosetown 13</td>
<td>25 27 18</td>
<td>LSD 13-25-27-18W3</td>
<td>610.5</td>
<td>610.1 - 635.7</td>
<td>60</td>
<td>60</td>
<td>6826</td>
<td>6633</td>
<td>670.7</td>
</tr>
<tr>
<td>Tipco BH et al Totes 6</td>
<td>26 27 18</td>
<td>LSD 06-26-27-18W3</td>
<td>646.5</td>
<td>646.2 - 670.0</td>
<td>60</td>
<td>60</td>
<td>6729</td>
<td>6695</td>
<td>665.6</td>
</tr>
<tr>
<td>Homestead Penn Totes 10</td>
<td>28 27 18</td>
<td>LSD 10-28-27-18W3</td>
<td>646.2</td>
<td>637.0 - 653.5</td>
<td>45</td>
<td>60</td>
<td>6198</td>
<td>6157</td>
<td>625.5</td>
</tr>
<tr>
<td>Mobil Oil Penkill X 1 16</td>
<td></td>
<td>LSD 01-16-27-19W3</td>
<td>684.3</td>
<td>688.8 - 690.0</td>
<td>60</td>
<td></td>
<td>667</td>
<td></td>
<td>646.5</td>
</tr>
<tr>
<td>CN Expl Plato North</td>
<td></td>
<td>LSD 02-19-27-19W3</td>
<td>698.2</td>
<td>715.0 - 740.0</td>
<td>120</td>
<td></td>
<td>5961</td>
<td>5961</td>
<td>558.8</td>
</tr>
<tr>
<td>Pennant Totes 7</td>
<td>24 27 19</td>
<td>LSD 07-24-27-19W3</td>
<td>682.8</td>
<td>682.8 - 702.6</td>
<td>60</td>
<td>120</td>
<td>6702</td>
<td>6385</td>
<td>664.4</td>
</tr>
<tr>
<td>Spc Totes 7</td>
<td>25 27 19</td>
<td>LSD 07-25-27-19W3</td>
<td>675.4</td>
<td>671.2 - 707.1</td>
<td>30</td>
<td>60</td>
<td>6509</td>
<td>6212</td>
<td>636.8</td>
</tr>
<tr>
<td>Homestead Penn Totes 4</td>
<td>36 27 19</td>
<td>LSD 04-36-27-19W3</td>
<td>689.2</td>
<td>686.3 - 710.2</td>
<td>45</td>
<td>60</td>
<td>6791</td>
<td>6681</td>
<td>672.3</td>
</tr>
<tr>
<td>ID-BB Petrody McMorrin 11</td>
<td>17 27 20</td>
<td>LSD 11-17-27-20W3</td>
<td>708.1</td>
<td>721.8 - 730.0</td>
<td>45</td>
<td>9</td>
<td>6846</td>
<td>6681</td>
<td>677.0</td>
</tr>
<tr>
<td>Imperial Netherhill 11</td>
<td>17 27 21</td>
<td>LSD 11-17-27-21W3</td>
<td>706.5</td>
<td>717.8 - 719.3</td>
<td>9</td>
<td></td>
<td>4137</td>
<td></td>
<td>403.6</td>
</tr>
<tr>
<td>Saskoil Brock 7</td>
<td>28 27 21</td>
<td>LSD 07-28-27-21W3</td>
<td>720.5</td>
<td>731.4 - 736.1</td>
<td>60</td>
<td>60</td>
<td>6771</td>
<td>6743</td>
<td>675.7</td>
</tr>
<tr>
<td>Phillips Husky Milrea No.1</td>
<td></td>
<td>LSD 10-29-27-21W3</td>
<td>721.2</td>
<td>723.9 - 728.8</td>
<td>10</td>
<td></td>
<td>6412</td>
<td></td>
<td>647.0</td>
</tr>
<tr>
<td>Sangrea No.1</td>
<td></td>
<td>LSD 07-29-27-22W3</td>
<td>712</td>
<td>713.2 - 716.9</td>
<td>15</td>
<td></td>
<td>6550</td>
<td></td>
<td>653.8</td>
</tr>
<tr>
<td>ID BB Petrody DI Sandgren 11</td>
<td>35 27 22</td>
<td>LSD 11-35-27-22W3</td>
<td>733.7</td>
<td>731.3 - 739.4</td>
<td>60</td>
<td>90</td>
<td>6336</td>
<td>6247</td>
<td>641.2</td>
</tr>
<tr>
<td>ID-BB Petrody Glidden 6</td>
<td>7 27 23</td>
<td>LSD 06-07-27-23W3</td>
<td>681.2</td>
<td>680.9 - 694.9</td>
<td>60</td>
<td>90</td>
<td>6529</td>
<td>6158</td>
<td>652.9</td>
</tr>
<tr>
<td>Husky Glidden 10</td>
<td>11 27 23</td>
<td>LSD 10-11-27-23W3</td>
<td>684.3</td>
<td>684.0 - 690.7</td>
<td>60</td>
<td>90</td>
<td>6509</td>
<td>6267</td>
<td>658.1</td>
</tr>
<tr>
<td>WELL</td>
<td>NAME</td>
<td>WELL LOCATION</td>
<td>L.B. (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pKPa)</td>
<td>PSIP (pKPa)</td>
<td>K (m)</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------</td>
<td>---------------</td>
<td>----------</td>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>ZD HB Petro DY</td>
<td>Glidden 11 25 27 23</td>
<td>LSD 11-25-27-23W3</td>
<td>697.7</td>
<td>693.4 - 704.1</td>
<td>60</td>
<td>30</td>
<td>6626</td>
<td>6516</td>
<td>670.1</td>
</tr>
<tr>
<td>Husky Mesa</td>
<td>Glidden 11 30 27 23</td>
<td>LSD 11-30-27-23W3</td>
<td>674.8</td>
<td>673.0 - 676.0</td>
<td>60</td>
<td>324</td>
<td></td>
<td></td>
<td>31.9</td>
</tr>
<tr>
<td>Imperial Husky Phillips Glidden 7 13</td>
<td>LSD 07-13-27-24W3</td>
<td>690.7</td>
<td>690.4 - 694.0</td>
<td>20</td>
<td>7239</td>
<td></td>
<td></td>
<td>735.8</td>
<td></td>
</tr>
<tr>
<td>Glidden No.1</td>
<td></td>
<td>LSD 07-12-27-24W3</td>
<td>693.1</td>
<td>688.8 - 694.9</td>
<td>15</td>
<td>6136</td>
<td></td>
<td></td>
<td>624.6</td>
</tr>
<tr>
<td>Phillips Husky Glidden No.2</td>
<td></td>
<td>LSD 07-15-27-24W3</td>
<td>692.2</td>
<td>691.0 - 694.0</td>
<td>20</td>
<td>6026</td>
<td></td>
<td></td>
<td>695.1</td>
</tr>
<tr>
<td>Besarah No.1</td>
<td></td>
<td>LSD 11-35-27-24W3</td>
<td>687</td>
<td>698.0 - 731.5</td>
<td>30</td>
<td>4102</td>
<td></td>
<td></td>
<td>374.3</td>
</tr>
<tr>
<td>Cox Warrior 13 4 27 25</td>
<td></td>
<td>LSD 13-04-27-25W3</td>
<td>777.2</td>
<td>786.7 - 803.1</td>
<td>30</td>
<td>6881</td>
<td>6715</td>
<td>676.6</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Warrior No.1</td>
<td></td>
<td>LSD 11-09-27-25W3</td>
<td>773.6</td>
<td>779.7 - 784.6</td>
<td>30</td>
<td>6516</td>
<td></td>
<td></td>
<td>654.2</td>
</tr>
<tr>
<td>Husky Phillips Warrior No. 11 10</td>
<td></td>
<td>LSD 11-10-27-25W3</td>
<td>767.2</td>
<td>770.5 - 787.8</td>
<td>20</td>
<td>3344</td>
<td></td>
<td></td>
<td>326.8</td>
</tr>
<tr>
<td>Imperial Warrior 7 18 27 25</td>
<td></td>
<td>LSD 07-18-27-25W3</td>
<td>764.1</td>
<td>770.7 - 785.8</td>
<td>15</td>
<td>6915</td>
<td>6543</td>
<td>684.3</td>
<td></td>
</tr>
<tr>
<td>Pinkham No.1</td>
<td></td>
<td>LSD 10-33-27-25W3</td>
<td>768.1</td>
<td>785.8 - 788.4</td>
<td>10</td>
<td>4206</td>
<td></td>
<td></td>
<td>408.1</td>
</tr>
<tr>
<td>Phillips Husky Bailey No.1</td>
<td></td>
<td>LSD 07-02-27-26W3</td>
<td>744.3</td>
<td>745.2 - 757.4</td>
<td>30</td>
<td>6185</td>
<td></td>
<td></td>
<td>618.3</td>
</tr>
<tr>
<td>Imperial Bailey No.11 17 27 26</td>
<td></td>
<td>LSD 11-17-27-26W3</td>
<td>709</td>
<td>719.9 - 726.0</td>
<td>15</td>
<td>4654</td>
<td></td>
<td></td>
<td>458.1</td>
</tr>
<tr>
<td>Provo Pinkham No.1 34</td>
<td></td>
<td>LSD 01-34-27-26W3</td>
<td>723.6</td>
<td>742.2 - 745.8</td>
<td>17</td>
<td>5998</td>
<td></td>
<td></td>
<td>590.2</td>
</tr>
<tr>
<td>Eyre No.1</td>
<td></td>
<td>LSD 06-10-27-27W3</td>
<td>684.3</td>
<td>705.6 - 710.2</td>
<td>15</td>
<td>6205</td>
<td></td>
<td></td>
<td>607.6</td>
</tr>
<tr>
<td>Bighart Saskoil Alsask 10 27 28</td>
<td></td>
<td>LSD 10-27-27-28W3</td>
<td>647.5</td>
<td>664.3 - 668.5</td>
<td>30</td>
<td>6855</td>
<td>6852</td>
<td>678.9</td>
<td></td>
</tr>
<tr>
<td>Texcan Alsask 16 22 27 29</td>
<td></td>
<td>LSD 15-27-27-29W3</td>
<td>700.1</td>
<td>713.5 - 718.4</td>
<td>60</td>
<td>6026</td>
<td></td>
<td></td>
<td>6640</td>
</tr>
<tr>
<td>Saskoil Precau Wco Alsask 6 36 27 29</td>
<td></td>
<td>LSD 05-36-27-29W3</td>
<td>711.5</td>
<td>724.0 - 728.5</td>
<td>60</td>
<td>6722</td>
<td></td>
<td></td>
<td>6646</td>
</tr>
<tr>
<td>Fife Kal Bonnievale 12 10 28 17</td>
<td></td>
<td>LSD 12-10-28-17W3</td>
<td>675.1</td>
<td>667.5 - 682.8</td>
<td>50</td>
<td>6826</td>
<td>6715</td>
<td>689.2</td>
<td></td>
</tr>
<tr>
<td>Fife Kal Bonnievale 8 19 28 17</td>
<td></td>
<td>LSD 08-19-28-17W3</td>
<td>638.5</td>
<td>634.0 - 662.9</td>
<td>35</td>
<td>6350</td>
<td>6081</td>
<td>624</td>
<td></td>
</tr>
<tr>
<td>Fife Kal Bonnievale 16 19 28 17</td>
<td></td>
<td>LSD 16-19-28-17W3</td>
<td>634.5</td>
<td>627.9 - 647.4</td>
<td>30</td>
<td>6157</td>
<td>6060</td>
<td>615.8</td>
<td></td>
</tr>
<tr>
<td>Homestead Penn Totes 10 5 28 18</td>
<td></td>
<td>LSD 10-05-28-18W3</td>
<td>684.6</td>
<td>679.7 - 701.0</td>
<td>60</td>
<td>6709</td>
<td>6709</td>
<td>668.5</td>
<td></td>
</tr>
<tr>
<td>Spc Totes 10 6 28 18</td>
<td></td>
<td>LSD 10-06-28-18W3</td>
<td>684.3</td>
<td>684.9 - 719.9</td>
<td>60</td>
<td>3420</td>
<td>3289</td>
<td>313.6</td>
<td></td>
</tr>
<tr>
<td>WELL NAME</td>
<td>WELL LOCATION</td>
<td>X.R (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ST (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pKpa)</td>
<td>PSIP (pKpa)</td>
<td>RE (m)</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
<td>---------</td>
<td>---------------------</td>
<td>----------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>Spc BB Totnes 7 8 24 18</td>
<td>LSD 07-08-28-18W3</td>
<td>696.2</td>
<td>690.4 - 725.4</td>
<td>30</td>
<td>60</td>
<td>4426</td>
<td>4392</td>
<td>422.7</td>
<td></td>
</tr>
<tr>
<td>Saskoil Totnes W 6 21 28 18</td>
<td>LSD 06-21-28-18W3</td>
<td>670.6</td>
<td>666.3 - 700.1</td>
<td>60</td>
<td>120</td>
<td>6633</td>
<td>6571</td>
<td>647.7</td>
<td></td>
</tr>
<tr>
<td>Peannst Brook E 6 16 28 18</td>
<td>LSD 06-16-28-19W3</td>
<td>714.8</td>
<td>719.3 - 742.2</td>
<td>45</td>
<td>120</td>
<td>6571</td>
<td>6564</td>
<td>684.3</td>
<td></td>
</tr>
<tr>
<td>Peannst Brook E 6 17 28 19</td>
<td>LSD 10-17-28-19W3</td>
<td>700.7</td>
<td>702.9 - 708.4</td>
<td>30</td>
<td>180</td>
<td>6578</td>
<td>6530</td>
<td>663.6</td>
<td></td>
</tr>
<tr>
<td>Peannst Brook East 11 22 28 19</td>
<td>LSD 11-22-28-19W3</td>
<td>729.9</td>
<td>719.3 - 728.5</td>
<td>60</td>
<td>60</td>
<td>6750</td>
<td>6516</td>
<td>680.5</td>
<td></td>
</tr>
<tr>
<td>Socony Sobio D Arcy 23 15</td>
<td>LSD 15-23-28-19W3</td>
<td>712.9</td>
<td>712.0 - 732.7</td>
<td>30</td>
<td>60</td>
<td>6205</td>
<td>633.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peannst Brook East 8 27 28 19</td>
<td>LSD 08-27-28-19W3</td>
<td>715.7</td>
<td>721.2 - 730.0</td>
<td>60</td>
<td>60</td>
<td>6667</td>
<td>6357</td>
<td>666.4</td>
<td></td>
</tr>
<tr>
<td>Socony Sobio D Arcy 28 1</td>
<td>LSD 01-28-28-19W3</td>
<td>794.4</td>
<td>702.3 - 728.8</td>
<td>20</td>
<td>60</td>
<td>6205</td>
<td>609.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socony Sobio D Arcy 31 2</td>
<td>LSD 02-31-28-19W3</td>
<td>703.8</td>
<td>721.8 - 727.9</td>
<td>20</td>
<td>60</td>
<td>6205</td>
<td>609.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D BB Petrody Brock 11 5 28 20</td>
<td>LSD 11-05-28-20W3</td>
<td>705.6</td>
<td>716.3 - 726.6</td>
<td>30</td>
<td>60</td>
<td>4902</td>
<td>4875</td>
<td>479.5</td>
<td></td>
</tr>
<tr>
<td>Imperial Brock 11 17 28 20</td>
<td>LSD 11-17-28-20W3</td>
<td>706.5</td>
<td>705.6 - 715.4</td>
<td>15</td>
<td>60</td>
<td>6550</td>
<td>659.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brock Unit 11 18 28 20</td>
<td>LSD 11-18-28-20W3</td>
<td>701</td>
<td>703.2 - 724.3</td>
<td>70</td>
<td>50</td>
<td>6599</td>
<td>435.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D BB Petrody Brock 11 23 28 20</td>
<td>LSD 11-23-28-20W3</td>
<td>717.2</td>
<td>746.8 - 754.7</td>
<td>30</td>
<td>60</td>
<td>5509</td>
<td>5509</td>
<td>524.9</td>
<td></td>
</tr>
<tr>
<td>Imperial Brock 7 31 28 20</td>
<td>LSD 07-31-28-20W3</td>
<td>719.3</td>
<td>722.4 - 733.7</td>
<td>15</td>
<td>60</td>
<td>8446</td>
<td>847.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brock Unit No.7 12</td>
<td>LSD 07-12-28-21W3</td>
<td>705.9</td>
<td>709.3 - 713.8</td>
<td>20</td>
<td>60</td>
<td>6171</td>
<td>622.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murphy et al Kindersley 7 19 28 21</td>
<td>LSD 07-19-28-21W3</td>
<td>722.4</td>
<td>743.1 - 753.8</td>
<td>60</td>
<td>90</td>
<td>6060</td>
<td>6054</td>
<td>581.3</td>
<td></td>
</tr>
<tr>
<td>Murphy et al Kindersley 11 12 28 22</td>
<td>LSD 11-12-24-22W3</td>
<td>737.9</td>
<td>742.5 - 748.3</td>
<td>60</td>
<td>90</td>
<td>6495</td>
<td>6226</td>
<td>652.7</td>
<td></td>
</tr>
<tr>
<td>Murphy et al Kindersley 11 13 28 22</td>
<td>LSD 11-13-24-22W3</td>
<td>730</td>
<td>734.6 - 743.7</td>
<td>60</td>
<td>60</td>
<td>6123</td>
<td>6088</td>
<td>611.4</td>
<td></td>
</tr>
<tr>
<td>Phillips Husky Turvin No.1</td>
<td>LSD 06-19-24-12W3</td>
<td>704.1</td>
<td>725.7 - 729.4</td>
<td>15</td>
<td>60</td>
<td>6798</td>
<td>668.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gao Verendyrne East 6 20 28 22</td>
<td>LSD 06-20-28-22W3</td>
<td>713.5</td>
<td>743.7 - 746.8</td>
<td>30</td>
<td>90</td>
<td>6316</td>
<td>6309</td>
<td>611.5</td>
<td></td>
</tr>
<tr>
<td>Murphy et al Kindersley 7 24 28 22</td>
<td>LSD 07-24-28-22W3</td>
<td>745.8</td>
<td>759.0 - 769.6</td>
<td>60</td>
<td>60</td>
<td>6095</td>
<td>6088</td>
<td>598.5</td>
<td></td>
</tr>
<tr>
<td>CM Expl Verendyrne 16 31 28 22</td>
<td>LSD 16-31-28-22W3</td>
<td>713.3</td>
<td>742.0 - 781.0</td>
<td>60</td>
<td>90</td>
<td>6269</td>
<td>6243</td>
<td>572.3</td>
<td></td>
</tr>
<tr>
<td>Verendyrne No.1</td>
<td>LSD 01-19-28-23W3</td>
<td>685.8</td>
<td>696.2 - 704.4</td>
<td>15</td>
<td>60</td>
<td>5447</td>
<td>541.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canus et al S. Kindersley 12 23 28 23</td>
<td>LSD 12-23-28-23W3</td>
<td>687.3</td>
<td>708.4 - 718.1</td>
<td>60</td>
<td>60</td>
<td>6724</td>
<td>6550</td>
<td>661.8</td>
<td></td>
</tr>
<tr>
<td>WELL</td>
<td>NAME</td>
<td>WELL LOCATION</td>
<td>KB (m)</td>
<td>INTERVAL TESTED (m)</td>
<td>ISIT (min)</td>
<td>PSIT (min)</td>
<td>ISIP (pKa)</td>
<td>PSIP (pKa)</td>
<td>E (m)</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>--------</td>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>Gao Verendrye 1</td>
<td>33 28 23</td>
<td>LSD 01-33-28-23W3</td>
<td>673.3</td>
<td>690.1 - 696.2</td>
<td>30</td>
<td>120</td>
<td>6515</td>
<td>6515</td>
<td>642.3</td>
</tr>
<tr>
<td>Ambess Fairmount 11</td>
<td>25 24 24</td>
<td>LSD 11-25-28-24W3</td>
<td>686.4</td>
<td>691.0 - 701.6</td>
<td>60</td>
<td>60</td>
<td>6771</td>
<td>6453</td>
<td>676.1</td>
</tr>
<tr>
<td>Gulf Fairmount 16</td>
<td>27 28 24</td>
<td>LSD 16-27-28-24W3</td>
<td>666.2</td>
<td>678.0 - 719.0</td>
<td>180</td>
<td>6680</td>
<td>629.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canus Anoco et al Fairw't 7</td>
<td>28 28 24</td>
<td>LSD 07-28-28-24W3</td>
<td>684.6</td>
<td>700.4 - 710.2</td>
<td>60</td>
<td>60</td>
<td>6771</td>
<td>6474</td>
<td>665.7</td>
</tr>
<tr>
<td>Gulf Fairmount 7 34</td>
<td>28 24</td>
<td>LSD 07-34-28-24W3</td>
<td>664.5</td>
<td>691.0 - 701.5</td>
<td>62</td>
<td>182</td>
<td>6671</td>
<td>6671</td>
<td>644.1</td>
</tr>
<tr>
<td>Canus et al S Ted 4 35</td>
<td>28 24</td>
<td>LSD 04-35-28-24W3</td>
<td>666.3</td>
<td>685.5 - 685.2</td>
<td>60</td>
<td>60</td>
<td>5012</td>
<td>4792</td>
<td>688.8</td>
</tr>
<tr>
<td>Gulf Kindersley 7 36</td>
<td>28 24</td>
<td>LSD 07-36-28-24W3</td>
<td>683.2</td>
<td>698.0 - 703.0</td>
<td>66</td>
<td>179</td>
<td>6490</td>
<td>6490</td>
<td>642.8</td>
</tr>
<tr>
<td>Phillips Husky Fairmount &amp; No.1</td>
<td></td>
<td>LSD 07-14-28-25W3</td>
<td>697.7</td>
<td>728.5 - 734.6</td>
<td>15</td>
<td>2620</td>
<td>230.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allied Embassy Marengo 11</td>
<td>28 28 26</td>
<td>LSD 11-28-28-26W3</td>
<td>745.2</td>
<td>768.1 - 778.2</td>
<td>15</td>
<td>6688</td>
<td>653.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Husky Phillips Marengo No.3</td>
<td></td>
<td>LSD 10-25-28-27W3</td>
<td>761.7</td>
<td>774.2 - 781.8</td>
<td>20</td>
<td>6895</td>
<td>683.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cavaller et al Marengo 11</td>
<td>26 28 27</td>
<td>LSD 11-26-28-27W3</td>
<td>761.1</td>
<td>765.4 - 776.3</td>
<td>30</td>
<td>60</td>
<td>6647</td>
<td>6591</td>
<td>663.4</td>
</tr>
<tr>
<td>Husky Phillips Marengo No.2</td>
<td></td>
<td>LSD 10-27-28-27W3</td>
<td>717.5</td>
<td>722.4 - 730.3</td>
<td>35</td>
<td>5805</td>
<td>579.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allied Embassy Marengo 7 28</td>
<td>20 27</td>
<td>LSD 07-28-28-27W3</td>
<td>694.3</td>
<td>679.7 - 707.1</td>
<td>30</td>
<td>120</td>
<td>6674</td>
<td>668.6</td>
<td></td>
</tr>
<tr>
<td>McBride Alcen Marengo 10</td>
<td>32</td>
<td>LSD 10-32-28-27W3</td>
<td>694.3</td>
<td>713.2 - 726.9</td>
<td>15</td>
<td>15</td>
<td>6543</td>
<td>6564</td>
<td>676.2</td>
</tr>
<tr>
<td>Spc Allied Box Marengo 7 24</td>
<td>28 27</td>
<td>LSD 07-34-28-27W3</td>
<td>716</td>
<td>722.4 - 728.5</td>
<td>30</td>
<td>120</td>
<td>6744</td>
<td>6755</td>
<td>680.1</td>
</tr>
<tr>
<td>Allied Embassy Marengo 6 35</td>
<td>24 27</td>
<td>LSD 06-35-28-27W3</td>
<td>729.5</td>
<td>724.5 - 746.8</td>
<td>60</td>
<td>30</td>
<td>6750</td>
<td>6633</td>
<td>667.8</td>
</tr>
<tr>
<td>Alskan No.1</td>
<td></td>
<td>LSD 10-07-28-24W3</td>
<td>688.7</td>
<td>694.9 - 699.5</td>
<td>15</td>
<td>6550</td>
<td>655.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McBride Marengo R/A W Boundary 4 25</td>
<td></td>
<td>LSD 04-25-28-24W3</td>
<td>699.6</td>
<td>711.7 - 733.3</td>
<td>45</td>
<td>30</td>
<td>6571</td>
<td>6571</td>
<td>636.2</td>
</tr>
<tr>
<td>Allied Embassy Alskan 11 12</td>
<td>28 29</td>
<td>LSD 11-12-24-29W3</td>
<td>705</td>
<td>709.9 - 733.1</td>
<td>30</td>
<td>6715</td>
<td>6385</td>
<td>651.5</td>
<td></td>
</tr>
</tbody>
</table>
VITAE AUCTORIS

Full Name: Imasiku Anayawa Nyambe
Date of Birth: May 17, 1957
Nationality: Zambian
Education:
  - January, 1965-December, 1969
    Qualification:
    - Nalwash Primary School, Senanga, Zambia.
  - January, 1970-October, 1972
    Qualification:
    - Sitotii Mission Primary School, Senanga, Zambia.
  - January, 1972-December, 1974
    Qualification:
    - Zambia Primary School Leaving Certificate.
  - January, 1975-December, 1976
    Qualification:
    - Senanga Secondary School, Senanga, Zambia.
  - September, 1977-August, 1982
    Qualification:
    - Cambridge School Certificate.
  - September, 1987-August, 1989
    Qualification:
    - University of Zambia, Lusaka, Zambia.
    - Bachelor of Mineral Sciences (Geology).
    - Master of Science (Sedimentology).
Experience:
  - September 1982-December, 1986
    - Staff Development Fellow. University of Zambia, Lusaka, Zambia.
  - January 1987-To date
Figure 3.0 Locational base map.
1) location of wells; 2) wells with core
3) wells with drill-stem test data; 4) we
core description and drill-stem test data