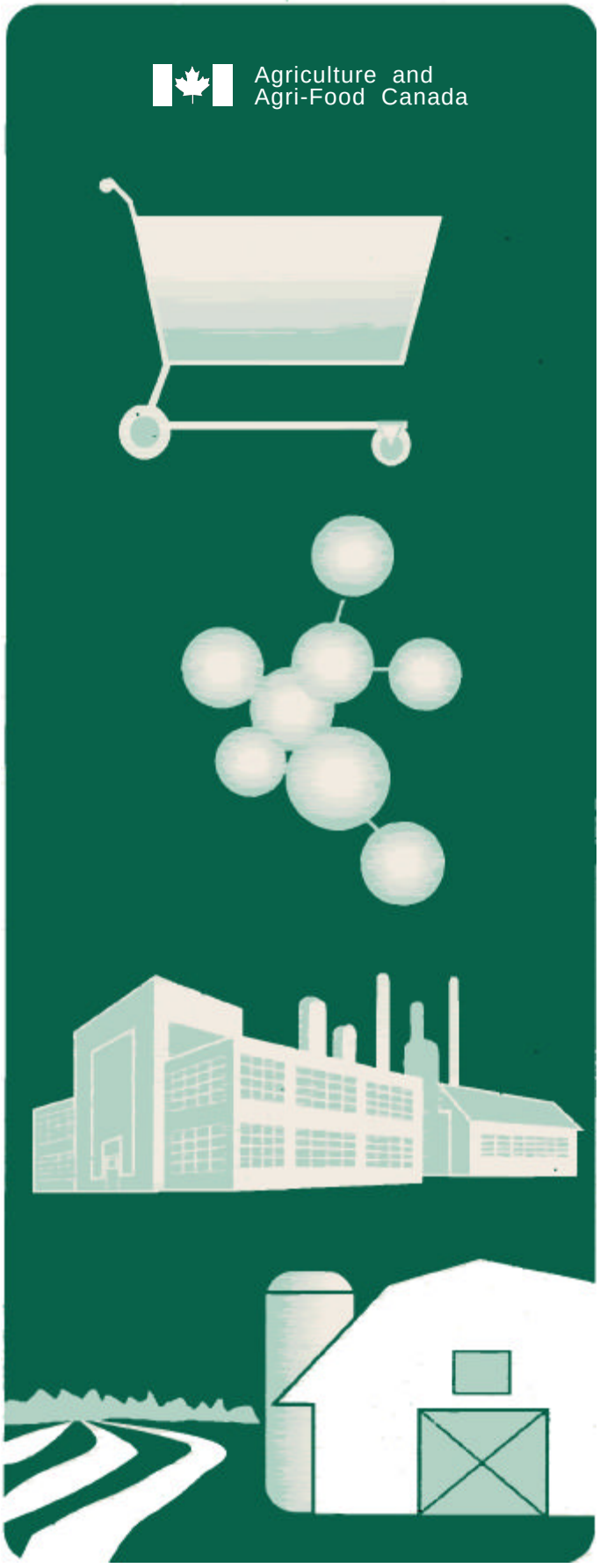

Research Branch
Technical Bulletin 2000-2E

Alberta Landforms

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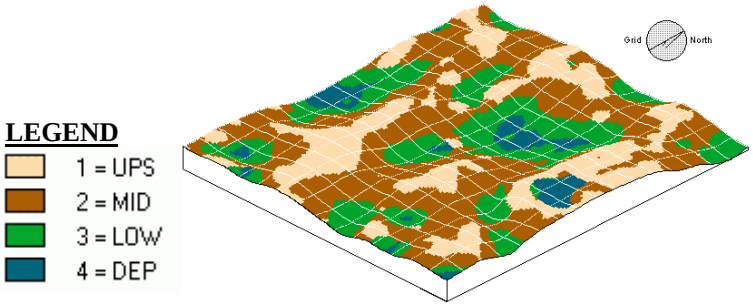

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Research Branch

Alberta Landforms

Quantitative Morphometric Descriptions and Classification of Typical Alberta Landforms

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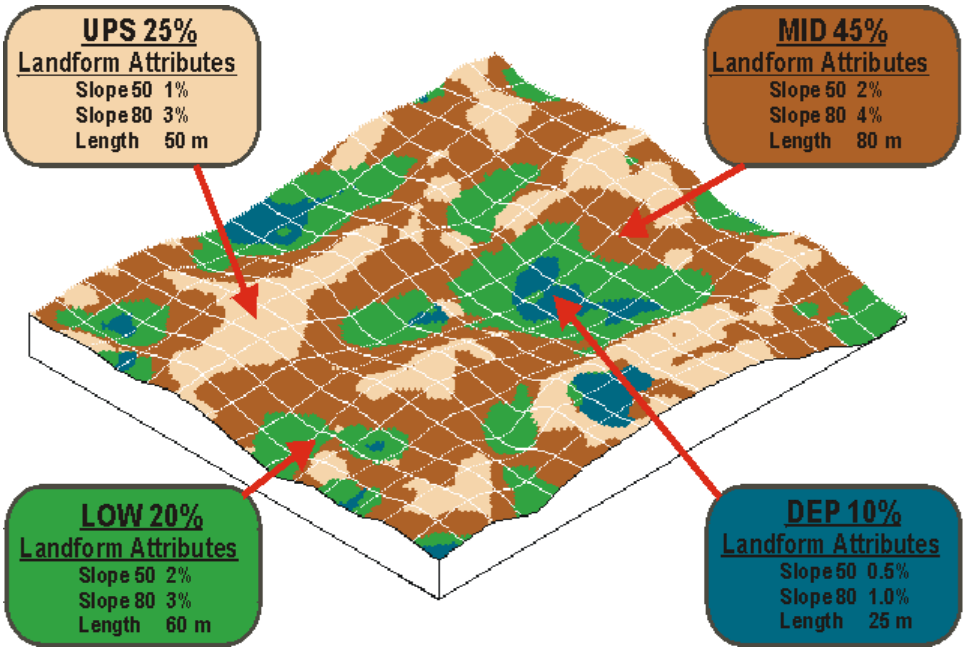
ABSTRACT

Most landscape related models need detailed, quantitative data about landform morphology (e.g. slope length, gradient, relief) in addition to data about soil properties. Current soil survey databases do not provide this kind of information.

This bulletin presents quantitative morphological descriptions and landform classifications for typical glaciated landforms in western Canada and documents the methods used to produce the descriptions. The analysis is based on high resolution DEMs (5-10 m spacing) for areas of 100 to 200 ha in size (minimum of 1/4 section). The results are then related to 53 landform types identified in the 1:100,000 soil survey database for Alberta, Canada. Morphometric descriptions are provided for the landform as a whole and for 4 defined landform segments (upper, mid, lower and depression) within each landform type.

The quantitative data provide necessary input for deterministic models and extend the utility of the soil survey databases in Alberta.



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We thank G.M. Coen for his encouragement and project management, J.A. Brierley for collaboration on the segmentation work and applications, D. J. Pennock, University of Saskatchewan, for his helpful discussions on technical issues and S. C. Nolan for her critical field assessments.

EXECUTIVE SUMMARY

Many existing and emerging applications of soil inventory data require detailed, quantitative data for input into deterministic simulation models and quantitative decision algorithms. These models generally require quantitative data on specific soil properties (e.g. organic carbon, percent sand) and on the landform attributes (e.g. percent slope, slope length) with which the soils or individual soil properties are associated.

Most current soil survey maps and digital databases provide very limited information about the range of morphometric characteristics of the landforms associated with each soil map unit. In Canada, the minimum data set represented by the National Soils Data Base (NSDB) records only one landform attribute for each map polygon, namely slope gradient expressed as a class. Another common limitation of many soil survey data bases (including the NSDB) is an inability to explicitly link each soil in a given polygon with a defined and described landscape position. If available at all, information on the location of mapped soils, relative to landform position, must be extracted from written descriptions of conceptualized soil map units presented in printed soil survey reports.

This report represents the culmination of a series of projects undertaken to address the above concerns. Procedures for the quantitative characterization of landform morphology and for segmenting landforms into facets, that are significant for water distribution and soil development, are described and their results are illustrated and evaluated.

The major thrust of the current research was to develop a procedure for the quantitative description of typical Alberta landforms. The approach taken was to process high resolution (5-10 m) digital elevation models (DEMs) for a limited number of locations selected as representative of the most extensive and agriculturally significant types of landforms in Alberta. DEMs for these “type” locations were processed to compute a series of terrain derivatives including slope gradient, aspect, profile and plan curvature, relief, slope length, relative slope position, a wetness index, watershed size and density and degree of drainage integration as measured by percent off-site drainage. Statistical summaries were prepared to describe the continuous and classed frequency distributions of these terrain derivatives. Data for 26 sites, representing 10 of the most extensive landform “types” identified in the Agricultural Region of Alberta Soil Inventory Database (AGRASID), were used to assign appropriate values for the main measures of landform morphology for each of the 53 AGRASID landscape models.

Several new concepts were developed to aid in describing the “type” landforms. One was the concept of “descriptive” versus ”effective” landform values for the attributes of slope length and relief. Descriptive values pertain to the entire landscape. They reflect an integration of the total slope length or relief as might be perceived by an individual viewing the landscape and attempting to devise a single number or measure to describe the dominant slope length or relief. Effective values represent an integrated assessment of how each cell in a regular grid would react in terms of its position in the landscape. Effective values are about half of the descriptive values and would be appropriate values to use in modeling applications. Another concept was that of a controlling value for various landform attributes. It is based on the observation that the upper 20% to 50% of the values for any landform feature effectively control how a site responds to many natural processes and uses. Therefore, a "controlling value" was defined as the 80th percentile on a distribution curve for critical landform attributes. The 80th percentile for slope gradient was found to correspond

very closely to the slope class identified by soil surveyors in reconnaissance mapping.

Quantitative statistical summary data prepared for 26 “type” locations provided a clear picture of the range and extent of variation in slope characteristics (gradient, length, relief) between different types of landforms. The dominant classes were consistent with those estimated by soil surveyors. However, values for slope length, obtained from processing high-resolution DEM data, were consistently longer than previous manual estimates. It was observed that surveyors’ perceptions of landscape scale reflected an appreciation of slope gradient more than relief. The landform descriptors l, m and h were defined in AGRASID as low, medium and high relief, but in fact were more closely related to low, moderate and high slope gradients. For example, a landform with a low dominant slope gradient (< 3%) but a long slope might exhibit up to 30 m of relief and still be labeled as a low relief (l) landform.

An evaluation of the statistical data for the 26 “type” locations confirmed that the major landform types defined for AGRASID exhibited consistent and meaningful differences in landform morphology. Hummocky landforms were characterized by short slopes (<150 m), short “repeat cycles”, relatively high watershed densities and low values for percent off-site drainage. Rolling landforms tended to exhibit long slopes (up to or exceeding 1000 m), long “repeat cycles”, relatively few watersheds and a relatively high off-site drainage index. Undulating landforms exhibited characteristics intermediate between hummocky and rolling but with lower slope gradients. Many undulating landforms exhibited the relatively long slopes characteristic of rolling landforms while others had shorter slopes that were quite similar to low relief hummocky landforms.

A second major focus of the present project was to subdivide and classify landforms in terms of components that were relatively uniform in terms of water distribution and soil development. A landform segmentation model (LSM) developed in a previous project was applied to classify each DEM into 15 landform facets. These elements were subsequently aggregated into four segments: namely, upper, mid, lower and depressional landform units. The proportion and characteristics of these segments were added to the "type" descriptions. Statistical summaries were also produced to describe mean values and frequency distributions for slope gradient, slope length and relief for each of the 4 defined landform segments. The ability to assign landform attributes, such as slope gradient, to each of the 4 simple landform segments is expected to prove highly useful as input to deterministic models or quantitative decision support systems.

The present project provides clear operational procedures to describe landforms in a quantitative manner and to subdivide the landforms into component parts that are meaningful for water / soil / vegetation relationships. It uses high resolution DEM data to develop detailed, quantitative descriptions of the morphology of “type” landforms as defined for soil survey databases and extrapolates that information to the complete suite of AGRASID models. The results add value to the Alberta digital soils database (AGRASID) by providing scientifically valid estimates for the major landform attributes (gradient, length, relief) for each defined “type” landform.

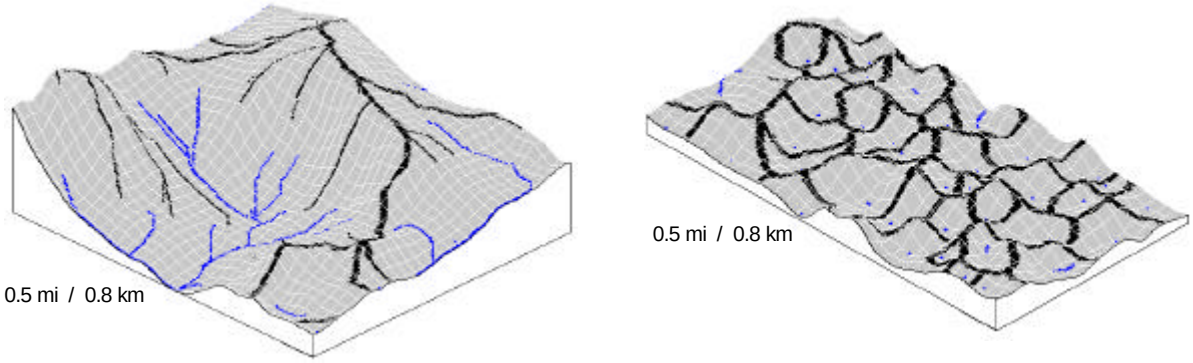
The morphometric data and landform classifications provide a necessary framework for linking mapped soils with associated landform positions. This linkage supports the application of crop growth models, degradation models or other models that require soil properties to be linked to landform attributes.

Following are examples of two type landforms illustrating the kinds of descriptive information that is generated and the kinds of differences that can be quantified between landform types. The 3D diagrams show the surface morphology of the landforms and the distribution of channels, divides and depressional watersheds.

Attribute summaries for two of the "type" landforms

Attribute descriptions		Landscapes	
		M(1)h (high relief rolling)	H(1)m (mod. hummocky)
slope gradient	**(%)**	**11**	**8**
relative relief	a) descriptive (m)	34	6
	b) effective (m)	18	3
slope length	a) descriptive (m)	600	150
	b) effective (m)	350	90
watershed	a) number / 100 ha	19	87
	b) off-site %	59	5

Soil surveys have traditionally only shown slope gradient. On that basis, the two example landforms would appear to be relatively similar. However, a review of the other information reveals very different situations as also illustrated in the following diagrams. The Rolling landform (left) has larger slopes, much greater relief and a greater proportion of off-site drainage than the Hummocky landform (right).



3D illustrations of Rolling (M1h) and Hummocky (H1m) landforms showing divides, channels and watersheds

Data obtained for "type" locations representing the main kinds of landforms in Alberta were extrapolated to provide estimated descriptions for the complete suite of 53 landform types that are described and used in the AGRASID soil survey database. The following tables can be added to existing soil survey databases to provide quantitative morphometric descriptions that can replace the previous qualitative landform descriptions.

Generalized morphological descriptions for the 53 AGRASID landform models

AGRASID landscape model		Slope			Watershed Density	Off-site drainage
code	description	gradient (%)	length (m)	relief (m)	# / 100ha	(%)
FP1	meander floodplain	2	500	2	20	45
FP2	braided channel	2	500	2	1	100
FP3	confined, terraced	3	500	5	3	90
L1	level plain	1	800	1	5	75
L2	closed basin	1	700	1	1	0
L3	level, terraced (not in valley)	1	800	3	5	75
U1l	undulating - low	2	250	3	30	35
U1h	undulating - high	4	250	5	30	35
IUl	inclined & undulating - low	2	400	5	15	50
IUh	inclined & undulating -high	4	500	10	12	55
H1l	hummocky - low	5	150	3	60	10
H1m	hummocky -medium	8	150	5	60	10
H1h	hummocky -high	20	200	20	50	15
H5l	hummocky over BR - low	5	200	10	30	35
H5m	hummocky over BR -medium	8	300	15	25	40
H5h	hummocky over BR -high	20	400	30	20	45
R2l	ridged - low	6	200	5	15	50
R2m	ridged - medium	9	300	10	10	60
R2h	ridged - high	20	400	20	5	75
D1l	longitudinal dune - low	6	200	5	50	15
D1m	longitudinal dune - medium	9	300	10	40	25
D1h	longitudinal dune - high	20	400	20	30	35
D2l	parabolic dune - low	6	100	3	20	45
D2m	parabolic dune - medium	9	125	5	15	50
D2h	parabolic dune - high	20	150	15	10	60
M1l	rolling - low	5	500	15	12	55
M1m	rolling -medium	8	600	25	8	65
M1h	rolling - high	10	800	40	5	75
HP1m	hummocky/plateau - medium	9	150	10	30	35
HP1h	hummocky/plateau - high	20	200	20	20	45
HR2m	hummocky/ridged - medium	9	200	10	30	35
HR2h	hummocky/ridged - high	20	300	20	20	45
I1l	inclined plain - low	2	1000	10	3	90
I3l	inclined to steep - low	8	300	20	3	90
I3m	inclined to steep - medium	15	500	50	2	95
I3h	inclined to steep - high	30	800	150	1	100
I4l	inclined with BR - low	8	300	20	3	90
I4m	inclined with BR - medium	15	500	50	2	95
I4h	inclined with BR - high	30	800	150	1	100
I5	steep with slumps	25	1000	200	20	45
SC1l	valley with floodplain - low	15	300	20	3	90
SC1h	valley with floodpl - steep	20	400	50	1	100
SC2	valley with terraces	20	500	60	5	75
SC3	v-shaped valley	15	200	10	1	100
SC4	sub-glacial channel	8	400	10	40	25
O1	level organic	1	400	1	5	75
O2	basin (bowl)	2	300	3	1	0
O3	channelled, ribbed, net	1	300	2	1	50
O4	sloping organic	2	300	3	2	95
O5	organic with mineral	3	400	5	30	35
W1	channel sloughs	5	400	5	50	15
W2	>50% sloughs	3	400	5	40	25
W3	large single water body	0	1000	0	1	0

General landform segment descriptions

AGRASID landscape model		Landform Segmentation Model - Landform segments															
		UPS[1]				MID				LOW				DEP			
		prop	gradient		length	prop	gradient		length	prop	gradient		length	prop	gradient		length
code	description	(%)	50	80	(m)	(%)	50	80	(m)	(%)	50	80	(m)	(%)	50	80	(m)
FP1	meander floodplain	10	2	3	50	40	1	2	200	40	1	2	200	10	0.5	1	50
FP2	braided channel	0	-	-	-	50	1	2	250	20	1	2	100	30	0.5	1	150
FP3	confined, terraced	10	2	5	50	20	2	3	100	60	2	3	300	10	0.5	1	50
L1	level plain	0	-	-	-	45	0.5	1	450	45	0.5	1	450	10	0.5	1	100
L2	closed basin	10	1	2	50	10	1	1	50	40	0.5	1	300	40	0.5	1	300
L3	level, terraced	15	1	2	100	60	1	1	500	20	1	1	150	5	0.5	1	50
U1l	undulating - low	20	1	2	50	50	1	2	120	15	1	2	40	15	0.5	0.5	40
U1h	undulating - high	25	2	4	60	45	3	4	115	20	2	3	50	10	0.5	1	25
IUl	inclined & undulating - low	20	1	2	80	55	1	2	220	20	1	2	80	5	0.5	1	20
IUh	inclined & undulating -high	20	2	4	100	50	3	4	250	25	2	3	125	5	0.5	1	25
H1l	hummocky - low	30	3	6	45	40	4	6	60	20	3	4	30	10	0.5	1	15
H1m	hummocky -med	30	6	9	50	35	6	9	50	25	5	7	35	10	1	1	15
H1h	hummocky -high	35	15	25	70	30	18	25	60	25	10	15	50	10	1	5	20
H5l	hummocky over BR - low	30	3	6	60	45	4	6	90	20	3	4	40	5	0.5	1	10
H5m	hummocky over BR -med	30	6	9	90	40	6	9	120	25	5	7	75	5	1	1	15
H5h	hummocky over BR -high	35	15	25	140	35	18	25	140	25	10	15	100	5	1	5	20
R2l	ridged - low	20	3	6	40	55	4	6	110	20	3	4	40	5	0.5	1	10
R2m	ridged - med	20	6	9	60	60	6	9	180	15	5	7	45	5	1	1	15
R2h	ridged - high	15	15	25	70	65	18	25	250	15	10	15	60	5	1	5	20
D1l	longitudinal dune - low	20	3	6	40	55	4	6	110	20	3	4	40	5	0.5	1	10
D1m	Longitudinal dune - med	20	6	9	60	60	6	9	180	15	5	7	45	5	1	1	15
D1h	longitudinal dune - high	15	15	25	70	65	18	25	250	15	10	15	60	5	1	5	20
D2l	parabolic dune - low	20	3	6	20	45	4	6	45	15	3	4	15	20	0.5	1	20
D2m	parabolic dune - med	20	6	9	20	50	6	9	60	10	5	7	15	20	1	1	25
D2h	parabolic dune - high	15	15	25	25	55	18	25	75	10	10	15	20	20	1	5	30
M1l	rolling - low	25	3	4	125	45	4	5	225	25	3	5	125	5	0.5	1	25
M1m	rolling -med	25	5	8	150	50	6	9	300	20	4	7	125	5	1	1	25
M1h	rolling - high	20	7	12	150	55	8	13	450	20	5	8	150	5	1	1	50
HP1m	hummocky/plateau - med	30	6	9	50	35	6	9	50	25	5	7	35	10	1	1	15
HP1h	hummocky/plateau - high	35	15	25	70	30	18	25	60	25	10	15	50	10	1	5	20
HR2m	hummocky/ridged - med	25	6	9	50	40	6	9	80	25	5	7	50	10	1	1	20
HR2h	hummocky/ridged - high	30	15	25	90	35	18	25	100	25	10	15	80	10	1	5	30
I1l	inclined plain - low	20	1	2	200	60	1	2	600	20	1	2	200	0			
I3l	inclined to steep - low	20	4	9	50	60	5	9	200	20	4	7	50	0			
I3m	inclined to steep - med	15	8	15	75	70	10	15	350	15	7	12	75	0			
I3h	inclined to steep - high	10	15	30	100	80	25	35	600	10	15	20	100	0			
I4l	inclined with BR - low	20	4	9	50	60	5	9	200	20	4	7	50	0			
I4m	inclined with BR - med	15	8	15	75	70	10	15	350	15	7	12	75	0			
I4h	inclined with BR - high	10	15	30	100	80	25	35	600	10	15	20	100	0			
I5	steep with slumps	20	12	25	200	55	25	35	550	20	10	20	200	5	3	8	50
SC1l	valley with floodplain - low	10	8	15	30	50	10	15	150	30	2	3	90	10	0	1	30
SC1h	valley with floodpl - steep	10	15	30	40	40	25	35	160	40	2	3	160	10	0	1	40
SC2	valley with terraces	10	15	30	50	30	25	35	175	50	2	3	225	10	0	1	50
SC3	v-shaped valley	15	8	15	30	70	10	15	140	15	7	12	30	0			
SC4	sub-glacial channel	30	6	9	120	30	6	9	120	30	5	7	120	10	1	1	40
O1	level organic	5	0.5	1	20	10	0.5	1	40	30	0.5	1	120	55	0	0.5	220
O2	basin (bowl)	0				0				30	1	3	100	70	0.5	1	200
O3	channelled, ribbed, net	5	1	2	10	10	1	2	30	20	1	2	50	65	1	1	200
O4	sloping organic	0				20	1	2	50	50	1	2	150	30	1	1	100
O5	organic with mineral	10	2	3	40	20	3	4	80	20	2	3	80	50	1	2	200
W1	channel sloughs	10	3	6	40	20	4	6	80	20	3	4	80	50	0	0	200
W2	>50% sloughs	10	2	3	40	20	3	4	80	20	2	3	80	50	0	0	200

1 Slope segments: UPS = upper slope, MID = mid slope, LOW = lower slope, DEP = depression, prop = proportion, gradient= slope gradient (50 = 50th percentile, 80 = 80th percentile), length = slope length

Table of Contents

List of Figures

List of Tables

BACKGROUND

Many existing and emerging applications of soil inventory data require detailed, quantitative data for input into deterministic simulation models and quantitative decision algorithms. These models generally require quantitative data on specific soil properties (e.g. organic carbon, percent sand) and on the landform attributes (e.g. percent slope, slope length) with which the soils or individual soil properties are associated.

Most current soil survey maps and digital databases provide very limited information about the range of morphometric characteristics of the landforms associated with each soil map unit. In Canada, the minimum data set represented by the National Soils Data Base (NSDB) (MacDonald and Valentine 1992) records only one landform attribute for each map polygon, namely slope gradient expressed as a class. Another common limitation of many soil survey data bases (including the NSDB) is an inability to explicitly link each soil in a given polygon with a defined and described landscape position. If available at all, information on the location of mapped soils, relative to landform position, must be extracted from written descriptions of conceptualized soil map units presented in printed soil survey reports.

In Alberta, the recently released Agricultural Region of Alberta Soil Inventory Database (AGRASID, Soil Inventory Working Group 1998) offered a new, standardized, seamless and consistent digital soil survey database for the agricultural portion of the province. AGRASID included in the description attached to each polygon a distinctive “landscape model”. These landscape models were based on general descriptions of landform surface expressions (undulating, rolling, hummocky etc.) defined for soil survey use in Canada (Soil Classification Working Group 1998) but were modified to suit Alberta conditions. For example, Hummocky was subdivided into low-relief, moderate-relief and high-relief variants. A total of 53 landscape models were described with a defined range of landform attributes, such as slope gradient, slope lengths, relief and drainage pattern. However, to date, these attributes have only been described in general qualitative terms (Soil Inventory Working Group 1998) and it has not proven possible to use this qualitative information effectively as input for automated applications of interpretive programs or simulation models.

Recent advances in the ability to collect and process digital elevation data made it practical to address these concerns. The literature contains numerous examples of digital elevation data being used to produce quantitative descriptions of landform morphology (Strahler, 1956; Speight, 1968; Evans, 1972; Pike, 1988; Zevenbergen and Thorne, 1987). Similarly, DEM data have been used to compute landform position (Skidmore, 1990) and to classify landforms into landform elements (Band, 1986; Fels and Matson, 1996; Irwin, 1997; Pennock et al, 1987, 1994). DEM data have also been used to predict the most likely locations of soils or individual soil properties in the landscape (Moore et al., 1993; Zhu et al., 1997). Most of these studies, however, applied to single research sites and were not linked to an operational soil survey database. It seemed reasonable to assume that detailed morphological analysis and classification of landforms at individual sites could be used to produce approximate generalized descriptions of the dominant landform attributes at other locations classified in the AGRASID database as having the same landform type. It was also assumed that detailed digital elevation models (DEMs) of sites selected as representative of the most common AGRASID landform types could be processed to compute a series of relevant and reliable terrain derivatives. It was further assumed that there would be significant and meaningful differences in landform morphology between the various landform types.

Starting in 1996, a series of projects were initiated to test the assumptions (MacMillan and Pettapiece, 1996). Procedures for the quantitative description of different types of landforms were developed (MacMillan and Pettapiece, 1997) and incorporated into a landform segmentation model (LSM) (MacMillan et al., 1998, 2000a). The LSM model was evaluated at several sites as the basis for precision farming management units (MacMillan et al., 2000a; Coen et al. 1999). The LSM defined units accounted for as much as 50-60% of the total within field variation in crop yield and in important, relatively stable, soil properties such as organic carbon, thickness of topsoil and solum depth at these sites. In addition, a simple expert system approach was developed to capture and apply soil surveyor tacit knowledge regarding the most likely distribution of Alberta soils relative to landform position (MacMillan et al. 2000b).

OBJECTIVES

The objective of this report is to document the procedures and results of the recent landform analysis developments including:

- Development of a standard protocol for the quantitative description of landforms
- Creation of quantitative descriptions for sites representative of typical Alberta landforms.
- Extrapolation of the detailed "typical site" data to the 53 AGRASID landform types.

MATERIALS AND METHODS

The initial developmental work involved three test sites that represented a range of landform conditions (MacMillan and Pettapiece, 1997). The results were then applied to sites representing typical AGRASID "landscape models" and finally extrapolated to the complete suite of 53 models. A basic assumption was that the area of application would relate to units of 100 to 200 ha (¼ to ½ section) in size. This was done with consideration that the common land management unit in western Canada is the ¼ section (160 ac, 100 ha) and that available soil survey databases are at scales of 1:50,000 to 1:100,000 with minimum map units of about 1 section in size (200 - 400 ha).

Only general discussions are presented for the procedures that are described in other reports.

Site selection

Using the AGRASID maps as an initial guide, the main landform types were identified. Where possible, sites were selected for which detailed DEM data were already available. For the remaining sites, locations were selected based on the availability of suitable large-scale (1:10,000 to 1:25,000) stereo aerial photography. Aerial Photographs were reviewed, or the sites visited, to ensure that they had landform characteristics representative of the descriptive model being analysed. As might be expected at a reconnaissance scale of mapping, there was some variation in landform characteristics and there were a few instances where the detailed site data were used to describe a landform model different than that assigned to the site in the AGRASID database. For example, for Site 5 the landform designation was changed from Hummocky to Ridged and Site 8 from moderate-relief to low-relief.

DEMs were produced for all new sites using conventional stereo photogrammetry. The selected sites (Table 1) represented the full range of landforms found in Alberta, excluding the mountains. The eight most common landform types accounted for about 90% of the area covered by the AGRASID database (the settled area of Alberta, excluding forest reserves and National Parks).

Acquisition and pre-processing of DEM data

The initial x, y, z point data for each site were obtained using a variety of data acquisition technologies including total station field surveys, vehicle mounted differential global positioning systems (DGPS), conventional stereo photogrammetry and automated extraction of DEMs using stereo auto-correlation. The x, y, z point data were then interpolated to a regular raster surface (a grid) using a variety of interpolation algorithms and programs. These included:

- inverse weighted distance (IWD) in Idrisi (Eastman, 1993) , ArcView 3 Spatial Analyst (ESRI, 1996) and Surfer (Golden Software Inc., 1997).
- thin plate spline (TPS) in Grass (U.S. Army, 1993)
- an exact fitting multi-quadric function (MQE) available in RSVP (Hemenway, 1995)

Table 1. Location and classification of the "type" landforms and methods used to acquire and surface the DEMs.

Site #	Site name	Location	AGRASID model	DEM source	Interpolation method
1	Gibbons W	11-55-23 W4	U1l: Undulating - low relief	GPS field survey	TPS
2	Provost	07-40-01 W4	U1h: Undulating – high relief	GPS field survey	IWD
3	Lunty	5/4-41-15 W4	U1h: Undulating – high relief	Photogrammetry	IWD
4	Mundare	09-53-16 W4	H1l: Hummocky – low relief	GPS field survey	IWD
5	Gibbons E	11-55-23 W4	R1l: Ridged – low relief	GPS field survey	TPS
6	Stettler	18-38-21 W4	H1m: Hummocky – moderate relief	GPS field survey	TPS
7	Rumsey	16-34-19 W4	H1h: Hummocky - high relief	Photogrammetry	IWD
8	Haynes Creek	6/7-40-25 W4	M1l: Rolling - low relief	GPS field survey	TPS
9	Hussar	5/6-26-18 W4	M1h: Rolling - high relief	GPS field survey	TPS
10	Cypress hills	14-08-03 W4	I3h: Inclined - high relief	Photogrammetry	MQE
11	Medicine Hat	33-09-02 W4	IUh: Inclined & Undulating - high	Photogrammetry	MQE
12	Turner Valley	09-20-02 W5	IUl: Inclined & Undulating - low relief	Photogrammetry	MQE
13	Peace River	24-81-21 W5	I1l: Inclined - low relief	Photogrammetry	MQE
14	Wainwright	08-42-05 W4	D1l: Duned - low relief	Photogrammetry	MQE
15	Red Deer	34-29-21 W4	FP3: flood Plain -	Photogrammetry	MQE
16	Drumheller	06-30-21 W4	SC1h: Stream Channel - high relief	Photogrammetry	MQE
17	Airdrie 1	11-27-02 W5	U1h: Undulating - high relief	Photogrammetry	IWD
18	Airdrie 2	03-27-02 W5	U1h: Undulating - high relief	Photogrammetry	IWD
19	Airdrie 3	05-27-02 W5	M1h: Rolling - high relief	Photogrammetry	IWD
20	Olds north	24-32-01 W5	IUh: Inclined&Undulating - high	GPS field survey	TPS
21	Olds south	24-32-01 W5	IUh: Inclined&Undulating - high	GPS field survey	IWD
22	Leduc	18-49-24 W4	U1l: Undulating - low relief	GPS field survey	IWD
23	Didsbury	05-31-27 W4	IUl: Inclined&Undulating - low relief	GPS field survey	IWD
24	Stony Plain	24-52-01 W5	U1h: Undulating - high relief	Photogrammetry	TPS
25	Viking	13-48-13 W4	H1m: Hummocky - moderate relief	GPS field survey	TPS
26	Bow Island	03-11-10 W4	U1h: Undulating - high relief	GPS field survey	IWD

The initial raster surfaces were rotated, or subsets were extracted, to create full, complete DEMs oriented exactly NS and EW. Gray scale images of illuminated hillshade models and second derivatives (curvatures) were produced for each site and examined visually to identify obvious errors. Most DEMs contained observable patterns related to random or systematic error in the original input data or to artifacts introduced by the surfacing process. All DEMs were smoothed to some degree to remove this high frequency noise and enhance the long-range topographic signal in the data. Smoothing was accomplished using from 1 to 3 passes of mean (averaging) filters ranging in size from 3x3 up to 7x7, depending upon the type of terrain and the strength of the observed patterns of error.

Processing DEM data to compute terrain derivatives and landform element classifications

The landform segmentation model (LSM) suite of programs (MacMillan et al., 2000a) was used to compute values for a series of terrain derivatives for each grid cell in each DEM. There were two basic steps, each having a number of sub-steps. The first step involved computing a series of 37 different terrain derivatives for each DEM cell (Appendix 2, Table A2.1). The second step involved applying fuzzy logic (likelihood considerations) to convert selected raw terrain derivatives first into fuzzy landform attributes, then into fuzzy landform classifications and finally into a single “hard” landform classification for each grid cell.

A "fuzzy" approach was adopted in order to permit the classification model to be applicable to a wide variety of landforms without modification. Initial efforts to use other models defined using hard, Boolean rules resulted in having to adjust thresholds or create new rules for each new location. Fuzzy rules permit greater variation in landform attributes and can successfully resolve confusion arising from subtle differences in landform characteristics among different grid cells representative of similar landform facets. Each grid cell in a DEM is classified into the landform facet that it most closely resembles, regardless of whether all characteristics of the cell exactly match the modal characteristics used to define the landform facet.

Computing the basic terrain derivatives

The familiar terrain derivatives of slope, aspect, profile and plan curvature were computed using the finite difference algorithms of Eyton (1991) which operate on a regular 3x3 moving window passed over the raster data set. All other terrain derivatives required some form of cell to cell flow topology to be established. Two different kinds of flow topology algorithms were used.

A multiple-descent algorithm (Quinn et al., 1991) was used to compute the terrain derivatives of multiple flow up-slope area count (QAREA) and wetness index (QWETI). This algorithm routes flow from every cell to all of its down-slope neighbors. Flow accumulation is partitioned in proportion to the relative slope from each cell into each of its lower neighbors. All other terrain derivatives utilize information on flow topology computed using the single-descent algorithm (D8) of Jenson and Dominique (1988) which routes flow from any given cell to one and only one neighbor cell. This is usually the lowest neighbor cell except for cases where no neighbor cells are lower but one or more cells has the same elevation (e.g. flat areas). The LSM programs contain custom algorithms for routing flow across flat areas in a hydrologically consistent fashion.

Establishing correct single-descent flow topology was a critical preliminary requirement for all of the terrain derivatives related to absolute and relative relief, slope lengths and drainage characteristics. The topology for surface water flow was established in the following sequence:

- Each cell with at least one down-slope neighbor was assigned a drainage direction into the lowest neighbor.
- Flat cells with no down-slope neighbors were assigned logical flow directions into a neighbor cell of the same elevation.
- Flow paths were traced through all cells to delineate watersheds and assign each cell to an initial or first order watershed.
- Flow paths were traced through all cells to compute the single-direction up-slope area count for each cell.
- The DEM was processed to compute and store statistics on each first order watershed and on the location, volume, area, depth and pour points of any depression contained in the watershed.
- A procedure was implemented to selectively remove small depressions which had values for surface area, volume, or depth below a specified threshold value.
    - For this project, a critical threshold value of 0.15 m pit depth was used.
    - As each pond was removed, cells were reassigned to a new, larger, merged watershed and a new entry was added to the pond statistics database.
- The DEM was inverted and all of the above steps were reapplied to the inverted DEM to compute flow topology for notional up-slope flow from each grid cell to a peak (a pit in the inverted DEM).
    - This facilitated flowing “up-slope” from each cell to its closest associated divide or peak.
- The final flow topology data were used to define a set of complementary drainage divides and notional stream channels.
    - Channel cells were defined as all cells with a final up-slope area count in excess of a user specified threshold value. Through trial and error, a value of 7,500 m^2 was selected, which equated to 300 cells for DEMs with a 5 m grid spacing. Actual values varied from 200-400 cells.
    - Divide cells were defined in the same fashion using the inverted DEM. In addition, all cells along the boundary of a final watershed were considered to be divide cells.

All terrain derivatives pertaining to relief, slope length and drainage characteristics were computed only after drainage topology for each site had been completely defined (Figure 1).

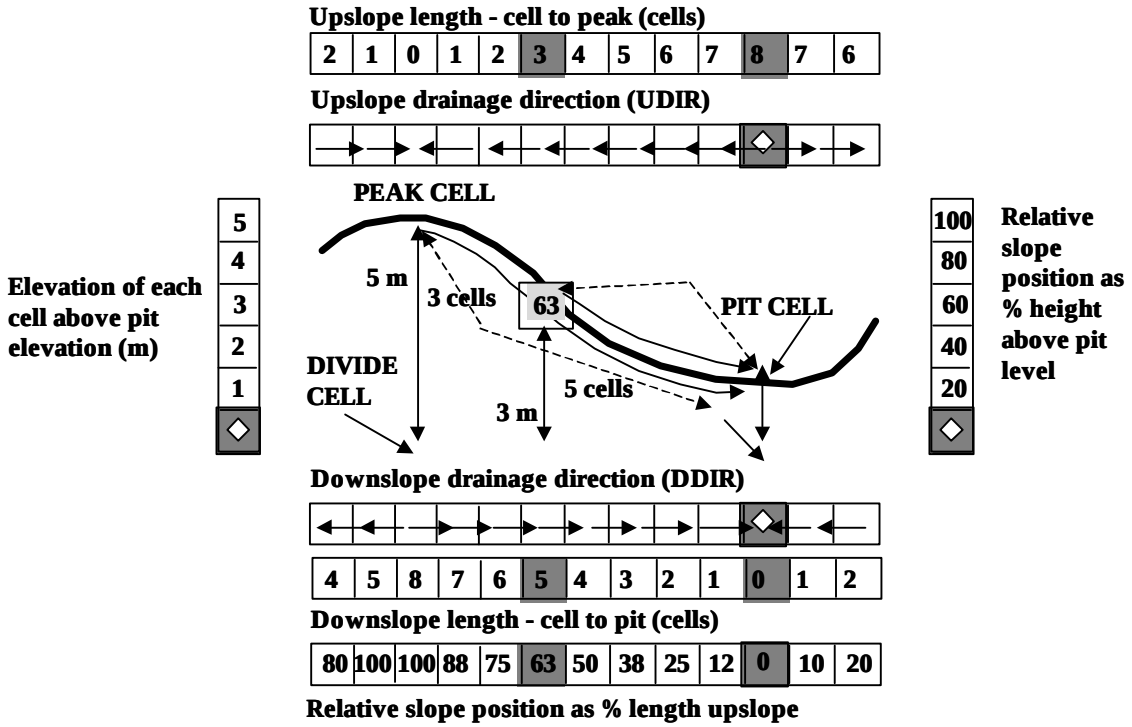


Figure 1. Illustration of the LSM procedures used to compute absolute and relative relief and slope lengths

The procedures for computing relative landform position required an ability to traverse flow paths from each grid cell, in both the up-slope and down-slope directions, until flow reached another cell defined as either a channel or a pit (for down-slope flow) or a divide or peak (for up-slope flow). Once the locations of these critical tie points were identified and recorded, it was possible to compute and store, for each cell, the following information:

- The flow path distance (N in grid cell units) from each cell to the closest associated cell classified as a channel, pit, divide or peak.
- The horizontal ground distance (L in m) from each cell to the closest associated cell classified as a channel, pit, divide or peak.
- The vertical change in elevation (Z in m) from each cell to the closest associated cell classified as a channel, pit, divide or peak.
- The relative slope position of the cell in the landscape computed in terms of both relief (Z) and slope length (L) relative to pits and peaks, channels and divides and maximum and minimum elevations within watersheds and within the data set as a whole.

Computing the landform element classification

Fifteen standard geomorphological landform facets (MacMillan et al., 2000a) were defined in terms of slope gradient, slope curvature and relative elevation (Table 2). These characteristics are basic to water partitioning in a landscape and hence are also related to vegetation and soil characteristics.

Table 2. General description of the 15 initial landform facets and 4 aggregated segments

Landform Segment	Component No	Facet name	Symbol	Facet description	Gradient Slope (%)	Curvature Plan °/100m	Curvature Profile °/100m
Upper Slope (UPS)	1	Level crest	LCR	level in upper slope	0 - 1	-	-
	2	Divergent shoulder	DSH	convex upper element which sheds water	> 1	>+5	-
	3	Upper depression	UDE	depression in upper slope position		-	-
Mid-Slope (MID)	4	Backslope2	BSL	rectilinear transition with little profile curvature	> 1	+5 to -5	<5
	5	Divergent backslope	DBS	sloping 'ridge'	> 1	+5 to -5	> +5
	6	Convergent backslope	CBS	sloping 'trough'	> 1	+5 to -5	< -5
	7	Terrace	TER	level in mid-slope must be > 2m above base	0 – 1	-	-
	8	Saddle 3	SAD	special case of a divergent footslope		< -5	> +5
	9	Midslope depression	MDE	depression in midslope position		-	-
Lower Slope (LOW)	10	Footslope	FSL	concave element that receives excess water and sediment		< -5	-
	11	Toeslope	TSL	rectilinear in lower slope	> 1	+5 to -5	-
	12	Fan	FAN	special case of a divergent toeslope	> 1	+5 to -5	> +5
	13	Lower slope mound	LSM	divergent shoulder in lower slope (must be > 2m high)	> 1	> +5	> +5
Depression (DEP)	14	Level lower slope	LLS	level in lower slope	0 – 1	-	-
	15	Depression	DEP	concave element in lowest part of landform	0-1	< -5	<0

The first step in linking the DEM to the landform segmentation was to select appropriate terrain derivatives to define the landform attributes needed to describe the facets. In all, 10 derivatives were used to compute 20 fuzzy landform attributes (Appendix 2 Table A2.2) for each cell in the DEM. Abstractions of fuzzy constructs such as relatively level, sloping, convex downslope, concave across slope, near the top or near the bottom were defined. The 20 fuzzy landform attributes were then used as input into a fuzzy landform classification that rated each grid cell on a scale of 0 to 100 in terms of its relative likelihood of belonging to each of 15 different landform facet classes (Appendix 2, Table 2.3). The class with the highest likelihood was assigned as the final "hardened" classification for each cell.

The last step was to aggregate the 15 facets into segments that were appropriate to the scale of investigation. Given the scale of 1:50,000 - 1:100,000, and knowing how the soil survey map units were constructed, the classification was consolidated into four segments (Table 2).

- Upper slopes (UPS): generally water shedding and in upper landform positions.
- Mid-Slopes (MID): generally water neutral and in mid-slope landform positions.
- Lower Slopes (LOW): generally water receiving and in lower landform positions.
- Depressions (DEP): generally undrained areas with ephemeral or permanent water accumulations.

Quantitative morphometric descriptions for the "type" landforms

Five landform attributes were selected for the standard description of landforms (MacMillan and Pettapiece, 1997). These were slope gradient, aspect, relief, slope length, and watershed characteristics (density and off-site drainage). These are the most frequently required landform attributes for input into deterministic models of crop growth, erosion and hydrological simulation. They are also frequently required for application of quantitative and qualitative decision rules.

Two aspects were considered in the descriptive analysis of landforms. The first was to select appropriate descriptive measures. The second was to accommodate the many repeating units that occur in the areas considered at this scale of analysis (100 - 200 ha). The computed attributes contained a single measure for the standard slope gradient and aspect derivatives. However, there were several options available for describing slope length and relief and several different measures of watershed characteristics. Two indices, representing two concepts were selected for each of these. For slope length and relief these were called "descriptive" and "effective" indices.

Slope length and relief were defined by "descriptive" and "effective" indices. Descriptive measures pertain to the entire landform (DEM) and are based on values derived from watershed analysis. They reflect an integration of the total slope length or relief as might be perceived by an individual viewing the landscape and attempting to devise a single number or measure to describe its dominant slope length or relief. The derivatives chosen to represent this attribute were "pit to peak" length and "pit to peak" relief (Figure 2). However, individual cells occupy the complete range of lengths and relief - from the pit to the peak. To run models, it is more appropriate to report a modal value than to assign all cells the same maximum total length or height. The second index represents this "effective" value and the derivatives chosen were the "cell to pit" length and "cell to pit" relief (Figure 2).

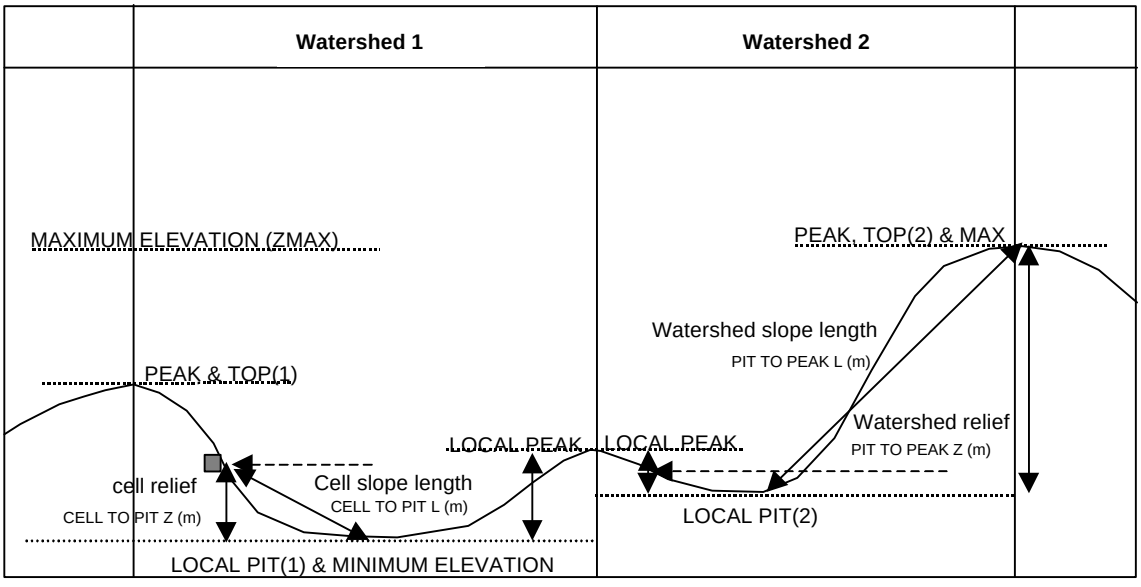


Figure 2. Illustration of the concepts of "descriptive" and "effective" relief and slope length

For watersheds, a calculation of the number of watersheds per 100 ha was used as a measure of relative watershed size and density. A calculation of the percent of the total area at a site that contributed to off-site drainage was selected to represent the degree of integration of surface drainage characteristic of a site. This was based on the proportion of the watersheds that drain off-site, beyond the boundary of the DEM.

A second consideration was how to represent, describe and illustrate the five selected attributes in the most effective and useful manner. As the number of watersheds and slopes ranged from one to over 100 in any one DEM, it was necessary to consider the attribute values from a statistical perspective. Both continuous and classed frequency distributions were graphed for gradient, aspect, relief and slope length (both descriptive and effective) for the entire landscape (see Appendix 1 for examples). As many quantitative models require a single value of slope length, gradient or some other landform attribute as input, a mean value was calculated from the distribution curves.

Experience and observation have shown that, in many cases, it is the higher, rather than the average, values that control both natural processes such as runoff or erosion and many of the management practices or land uses. Consider, for example, a landscape with slope gradients in the range of 0 – 20%. An average value of 10% may not properly reflect the actual constraints or hydrological behavior of that site. To address this concern a "controlling value" was defined as the 80th percentile on the cumulative curve for that particular attribute. That is, 80% of the total area will have values for gradient, length or relief that are smaller than the “controlling” value and 20% of the landscape will have values that are equal to or greater than the controlling value.

An alternative to selecting a single input value to represent an entire landscape is to sub-divide the landform into segments that have different characteristics and to evaluate each of them separately. The premise here is that not all parts of the landform react the same way to surface processes. For example, upper slopes are generally water-shedding, and lower slopes are generally water-receiving. The DEM cells for each segment defined by the LSM procedure were analyzed separately. Values for the 20th, 50th and 80th percentiles of slope gradients and lengths were calculated, evaluated for trends and extrapolated using the same general guidelines as for the whole landform analysis. Slope lengths of the individual segments were calculated using the 80th percentile of the respective DEM cells as statistical distance from the pit to the distal length for UPS, MID and LOW. For the DEP, the 20th percentile was used. These values were incorporated into the morphometric descriptions for the landforms (Tables 3, 4).

A standard, three-page, quantitative description template was developed and applied at each of the sites representative of a “type” landform. It included landform attributes pertaining to the entire site (Table 3) and the four landform segments at each site (Table 4).

Table 3. Attributes used to describe entire landforms included in the standard description.

No.	Attribute	Units	Derivative
	Determined from the DEM		
1	Slope gradient	%	SLOPE
2	Aspect	°	ASPECT
3	Descriptive relief: (pit to peak relief)	m	Pit2PeakZ
4	Effective relief: (cell to pit relief)	m	Z2Pit
5	Descriptive slope length: (pit to peak length)	m	Lpit2Peak
6	Effective slope length: (cell to pit length)	m	L2Pit
7	Watershed Index: Density of watersheds	#/100 ha.	CATDEN
8	Drainage Index: % off-site drainage	% off-site	PCTOFF
	Determined from the Landform Segmentation Model (LSM)		
9	Upper Slope Landform Segment	%	UPS
10	Mid-slope Landform Segment	%	MID
11	Lower slope Landform Segment	%	LOW
12	Depression Landform Segment	%	DEP

Table 4. Attributes used to describe the 4 basic landform segments.

Landform Attribute	Definition of the attribute	Measurement Units
Landform segment	Landform category code	
Areal extent	Proportion of the area	percent
Slope	Mean slope gradient for site	percent
Controlling slope gradient	Slope gradient (80th percentile)	percent
Minimum slope length	Slope length (20th percentile)	m
Controlling slope length	Slope length (80th percentile)	m
Controlling relief	Relief (80th percentile)	m

Extrapolating site data to produce generalized descriptions for AGRASID landform types.

The morphometric descriptions prepared for the 26 detailed “type” locations were reviewed for general values and obvious trends. For example, it was noted that landform class codes for low to high in any one series such as undulating or hummocky were associated with increasing slope gradient and slope length. Within that generalization there were also some trends. It was noted that there was a greater range of gradient and less relative difference in length for the rather complex hummocky landforms then the smoother, “simpler” undulating and rolling landforms. The latter, on the other hand, had a greater range in slope lengths but less range in slope gradient.

A spreadsheet was constructed from the values for slope gradient, slope length and relative relief for each of the represented landforms. Using the observed trends, the authors’ experience and the AGRASID descriptions as a reference, the values were generalized and anomalies removed to produce logical sequences. It was recognized that there were ranges of characteristics within any classification of natural features. The values were therefore

rounded off to the nearest (about) 10% of the range. That is, if the range was 0-10% then 1% increments were used or, if the range was 200 to 500 m then 50m increments were used. The resultant values were considered to be “typical” or average values for the respective landforms.

A second activity was to review the data for trends and relationships relative to the four generalized landform segments. The following were noted:

- Mid-slopes made up a lower proportion of hummocky landforms (about 35%) than in undulating and rolling landforms (about 50%) with inclined landforms having an even higher proportion (about 65%).

- Lower plus depression proportions tended to be slightly higher than upper alone. This was particularly true for the lower relief (undulating) landforms.

- The depression proportions were quite variable and often quite small so values were assigned based on our general knowledge:

- Hummocky and undulating were assigned 10% depressions.

- Inclined, ridged and rolling were assigned 5% depressions.

Using personal knowledge of Alberta landforms and the AGRASID descriptions for additional context the following guidelines were created to assist with extrapolation:

- Ridged (R) should be very similar to Inclined (I) but have a small additional amount of depressions.

- Rolling (M) should be similar to Ridged (M) but have more extensive UPS and LOW components.

- Longitudinal dunes should be the same as ridged. Parabolic dunes should have about 20% depressions.

- Inclined and Undulating landforms (IU) should be similar to undulating (U) but should contain fewer depressions.

- Hummocky overlying bedrock (H/BR) should be between Hummocky (H) and Rolling (M)

- Hummocky and Plateau (HP) landforms should be similar to Hummocky (H).

- Hummocky and Ridged (HR) should be similar to Hummocky (H) but with less extensive UPS.

- Inclined 4 (I4) should be the same as Inclined 3 (I3). Inclined 5 (I5) should be similar to Inclined 3 (I3) except for a little more DEP.

- Stream Channel landforms (SC) should be equivalent to Inclined landforms (I) plus Floodplains (FP).

- Assume 30% FP units included in SC1 units, 50% FP units in SC2 units, SC3 identical to

I3m, SC4 equivalent to Hm but with more extensive DEP elements.

- Organic 4 (O4) landforms are assumed similar to I3l. O5 landforms are assumed to be similar to U1h with 50% organic.

- W1 landform was assumed to be similar to H1l but with 50% water. W2 was assumed similar to U1h with 50% water.

The above considerations were used to assign descriptive values to each of the 53 AGRASID landscape types.

RESULTS

Quantitative morphological descriptions for sites representative of type landforms

Data summarizing and illustrating the subset of terrain attributes selected to characterize each site were collated and recorded for all sites using the previously described standard three-page template (Appendix 1). These site descriptions are analogous to detailed profile descriptions and laboratory analyses for pedons considered representative of named soil series. The principal conceptual difference is that the morphological data for "type" locations are generally statistical representations of several to many repeating cycles of individual landform entities (e.g. a hummock or ridge). In this sense, the landform data are more similar to a bulked soil sample taken from several closely spaced pedons. The landform data for a site include some measure of the variability of the attributes, however, no site is likely to exhibit the full range of variability that can occur within a defined landform type.

For purposes of general description and comparison, the limiting values (80th percentile of the distribution) of slope gradient, descriptive slope length and descriptive relief will be used along with the watershed indices (shaded columns in Table 5).

Level and Undulating Landforms

The Level landform, Ll (Site 13) had a very low slope gradient (1%) with a very long slope length (900m). As would be expected, it had relatively few defined watersheds (depressions) and an off-site drainage index of 40%. In reality, most precipitation would infiltrate in such a level landform except for instances where permeability was impeded such as when frozen or saturated.

The Undulating landforms all had slope gradients of 5% or less. The low-relief variants (U1l; sites 1, 22) had gradients of <2%, a descriptive relief of <4m and quite long slopes of 400m-500m. The high-relief variants (U1h; sites 2, 3, 17, 18, 26) had gradients of 2-5% but exhibited a wide range of slope lengths from 250m - 800m and a concomitant wide range in relief from 5m to 13m. It was apparent that some of the high-relief variants, such as site 2, were integrating towards Rolling landforms while others, such as site 3, were similar to Hummocky landforms. This is not surprising, as the only AGRASID field criterion used to separate Undulating from the other landform types was a slope gradient of <5%

The watershed characteristics were linked more closely to slope length than steepness with both low and high-relief variants having between 21 and 43 watersheds/100ha. This corresponds to an off-site drainage index of 12-50% with most in the 25% to 35% range.

"Inclined and Undulating" (IUl, IUh; Sites 11, 12, 20, 21, 23) was a separate category that had slope gradients (3-4%) and relief similar to the high-relief Undulating but differed in having longer slopes (600-1000m). The number of watersheds (7-29), while variable, was generally less than for Undulating. This is reflected in a higher off-site drainage index (17-100%). Initially, this kind of tilted undulating landform, that is common around the base of upland units, was difficult to meaningfully characterize. Modifications to the LSM processes used to define watersheds and slope lengths improved the ability to accommodate these complex landforms.

Rolling, Inclined and Ridged landforms

Rolling (M; sites 8, 9, 19), Inclined (I; site 10) and Ridged (R; site 5) all had slope lengths in excess of 600m. They had few watersheds (4 to 19 /100 ha) with off-site drainage indexes of generally >50% (29-100). Rolling, in particular, is a "large" landform that often will not be recognized using air photos (At large scales, individual inclined slopes are commonly mapped as separate units). Slope gradients ranged from 5% (low-relief) to 11% (high-relief) and relief was quite high (22-50 m).

Ridged were similar to Rolling but tended to have less convex and concave elements (narrower crests) and a greater extent of mid or backslopes (Site 5, pp. 46-48; Site 10, pp. 61-63).

The characteristic feature of Inclined landforms was their unidirectional orientation and a very high proportion (>50%) of midslope segments. They had few watersheds and an off-site drainage approaching 100%.

Hummocky and Duned landforms

Hummocky landforms are characterized by many enclosed depressions. This was reflected in high watershed densities(typically >70/100 ha) and low off-site drainage indexes of <10%. Slope gradients ranged from 4-5% for the low-relief variants (H1l; sites 4, 24) to 8-9% for moderate-relief forms (H1m; sites 5, 25) and up to 24% for the high-relief variants (H1h; site 7). Slope lengths, at 150 m to 250 m, were shorter than for the other landform types and relief tended to be relatively low given the steepness of the slopes.

Duned forms are also typically a chaotic assemblage of slopes and the one site analysed (D1l, Site 14) had characteristics similar to those for low-relief Hummocky (Site 22, pp. 97-99).

Miscellaneous Stream Channel units

The complex units along rivers, Stream Channels and Flood Plains (sites 15,16) are particularly difficult to describe statistically. The segmentation model appears to do a good job of defining the different facets and segments (Site 15, pp. 76-78; Site 16, pp. 79-81) but the statistical summaries are more difficult to evaluate. The descriptive relief charts are probably the most definitive with significant proportions of very low and high relief and little in between.

General discussion

A comparative summary of the basic landform characteristics for each site (Table 5) reveals systematic and significant differences between the different types of landforms defined for AGRASID. The values for slope gradient, slope length, relief and watershed characteristics were intuitively reasonable and consistent with expectations based on field experience. Specifically, a general increase was noted in slope gradient and relief in progressing from low relief, undulating landforms through somewhat higher relief hummocky landforms to high relief rolling and inclined landforms.

The biggest overlap in characteristics occurred between the high-relief Undulating (U1h) and the low-relief Hummocky (H1l) landform types. Slope gradients of both were in the 4-5% range and slope lengths ranged from 250-600 m for the U1h and 250-300 for the H1l. However, the hummocky sites tended to have higher numbers of watersheds/100 ha and lower percentages of off-site drainage. There is a natural progression from one to the other

and, as about 2/3 of the glacial landforms in Alberta fall into these two categories, it is not surprising that the separation is not clear. Any artificial boundary in a natural system transition zone is difficult to define. In spite of this, the differences for the central parts of the concepts make the split between Undulating and Hummocky meaningful and worth the effort.

Table 5. Summary of the principal morphometric characteristics for sites representative of "type" landforms

Site No.	Site Name	Landform Code	Gradient (%)		Length Descr		Length Effect		Relief Descr		Relief Effect		Shed /100ha	Off-site (%)
			50	80	50	80	50	80	50	80	50	80		
1	Gibbons (W)	U1l	0.9	2	344	500	186	350	2.6	4.0	1.1	2.5	21	50
2	Provost	U1h	2.5	4.0	294	450	133	250	6.4	10	2.9	5.0	36	30
3	Lunty	U1h	2.2	4.0	194	250	95	150	3.5	5.0	1.8	3.0	41	24
4	Mundare	H1l	2.1	4.0	213	300	115	175	2.8	5.0	1.2	2.0	41	7
6	Stettler	H1m	5.5	8.0	112	150	58	90	4.4	6.0	2.1	3.5	87	5
7	Rumsey	H1h	16	24	181	250	100	150	18	25	9.0	16	57	10
5	Gibbons (E)	R1l	1.9	3.0	472	800	289	500	7.5	12	3.4	7.0	11	48
8	Haynes Creek	M1l	3.4	5.0	600	800	305	500	17	22	9.0	15	9.0	29
9	Hussar	M1h	7.4	11	416	600	211	350	24	34	11	18	19	59
10	Cypress Hills	I3h	20	30	2176		1345		150	200	88	200	3.0	71
11	Medicine Hat	IUh	2.5	4.0	674	1000	390	700	13	24	7.0	13	12	47
12	Turner Valley	IUl	2.2	4.0	432	700	263	450	5.8	9.0	3.5	6.0	19	15
13	Peace River	Ll	0.7	1.0	544	900	290	500	3.2	6.0	1.8	4.5	12	40
14	Wainwright	D1l	2.6	4.0	161	250	90	150	3.1	5.0	1.5	2.5	49	9
15	Red Deer	FP3	8.2	12	1050		432	700	65	100	25	35	10	25
16	Drumheller	SC1h	33	70	1010		505	1000	90	150	44	90	18	4
17	Aidrie 1	U1h	1.6	3.0	378	600	169	300	5.8	11	3.0	6.0	32	36
18	Aidrie 2	U1h	3.4	5.0	312	450	165	300	8.0	13	4.2	8.0	37	29
19	Aidrie 3	M1h	4.7	7.0	909	1000	559	900	33	50	18	29	4.0	100
20	Olds north	IUh	1.5	3.0	483	700	282	450	8.1	13	4.2	8.0	18	22
21	Olds south	IUh	1.8	3.0	450	600	245	400	5.4	10	2.8	5.0	28	17
22	Leduc	U1l	0.8	2.0	264	400	121	200	1.9	3.0	0.9	2.0	43	12
23	Didsbury	IUl	2.3	3.0	906	1000	447	700	18	20	9.0	14	7	100
24	Stony Plain	U1h	2.9	5.0	182	250	78	125	4.1	6.0	1.8	3.0	70	15
25	Viking	H1m	5.6	9.0	132	175	66	100	5.5	8.0	2.4	4.5	79	8
26	Bow Island	U1h	1.9	2.0	352	600	201	350	4.8	8.0	2.3	4.0	25	52

The landform qualifiers l, m and h were defined for AGRASID as low-relief, moderate-relief and high-relief. However, the differences appear to be more closely related to dominant and maximum slope gradients than to the measures of relief or slope length. Also, the differences do not represent absolute values but rather are relative within any particular landform type. The qualifier “l” was associated with sites characterized by the lowest slope gradients (e.g. <= 2% for U, < 6% for H and M), while “h” was associated with the highest slope gradients (e.g. >4% for U, >9% for M and >15% for H).

The watershed indices appear to be particularly useful as discriminating features. For example, the low-relief rolling (M1l) and hummocky (H1l) landforms had similar slope gradients but had very different water distribution characteristics. The index for off-site drainage suggests that most of the water in a hummocky landform will be retained on-site while inclined and rolling units could contribute most surface water to run-off. Undulating and ridged units have intermediate values.

Generalized morphological descriptions for all AGRASID landform models

The morphological descriptions for the 26 sites representing 10 landform types were extrapolated to produce generalized descriptions for all 53 landform types defined for AGRASID. These generalized morphological descriptions (Table 6) are consistent with the original conceptual descriptions published for the AGRASID landform types. They agree quite well with generally held concepts of the attributes of main landform types, such as undulating, hummocky or rolling.

It must be remembered that, as with any natural system, there are ranges of characteristics associated with the “landscape models”. These landform descriptions were targeted to match the scale of the AGRASID database (1:100 000). The usual size of map units at this scale is about 1,000 to 10,000 ha with the smallest delineation being about 100 ha. At this scale, delineated landforms consist of many repeating units with substantial variability in slope and relief characteristics. There may be five to ten knolls per km in a hummocky morainal area, each of which will exhibit morphological differences. In this context, it is important to remember that the values presented here are typical or median values based on analyses of DEMs for specific representative sites. The described values will likely fall at about the center of the expected range.

There should be no expectation that every slope in an area classified as a particular landform will match the specific description provided for that “type” landform. The “type” landform represents the landform class in the same manner that a typical soil pedon represents a soil series. It is also important to recognize that, while some quantitative data have been provided to assist with use and characterization of AGRASID landform types, the data represent only a portion of the variability normally associated with a reconnaissance scale of detail. This should not limit the use of the data, but simply provide a context for interpretation. There are no mutually exclusive boundaries involved. The ranges of similar landform types can and will overlap. This also accommodates the interpretation involved in the initial assignment of landscape types by the surveyor where it is not unusual for areas with similar landforms to be classed differently by different assessors.

Table 6. Generalized morphological descriptions for the 53 AGRASID landform models

AGRASID landscape model		Slope[1]			Watershed	Off-site
code	description	gradient (%)	length (m)	relief (m)	# / 100ha	drainage (%)
FP1	meander floodplain	2	500	2	20	45
FP2	braided channel	2	500	2	1	100
FP3	confined, terraced	3	500	5	3	90
L1	**level plain**	**1**	**800**	**1**	**5**	**75**
L2	closed basin	1	700	1	1	0
L3	level, terraced (not in valley	1	800	3	5	75
U1l[2]	**undulating - low**	**2**	**250**	**3**	**30**	**35**
U1h	**undulating - high**	**4**	**250**	**5**	**30**	**35**
IUl	inclined & undulating - low	2	400	5	15	50
IUh	**inclined & undulating -high**	**4**	**500**	**10**	**12**	**55**
H1l	**hummocky - low**	**5**	**150**	**3**	**60**	**10**
H1m	**hummocky -med**	**8**	**150**	**5**	**60**	**10**
H1h	**hummocky -high**	**20**	**200**	**20**	**50**	**15**
H5l	hummocky over BR - low	5	200	10	30	35
H5m	hummocky over BR -med	8	300	15	25	40
H5h	hummocky over BR -high	20	400	30	20	45
R2l	**ridged - low**	**6**	**200**	**5**	**15**	**50**
R2m	ridged - med	9	300	10	10	60
R2h	ridged - high	20	400	20	5	75
D1l	longitudinal dune - low	6	200	5	50	15
D1m	longitudinaldune - med	9	300	10	40	25
D1h	longitudinal dune - high	20	400	20	30	35
D2l	parabolic dune - low	6	100	3	20	45
D2m	parabolic dune - med	9	125	5	15	50
D2h	parabolic dune - high	20	150	15	10	60
M1l	**rolling - low**	**5**	**500**	**15**	**12**	**55**
M1m	rolling -med	8	600	25	8	65
M1h	**rolling - high**	**10**	**800**	**40**	**5**	**75**
HP1m	hummocky/plateau - med	9	150	10	30	35
HP1h	hummocky/plateau - high	20	200	20	20	45
HR2m	hummocky/ridged - med	9	200	10	30	35
HR2h	hummocky/ridged - high	20	300	20	20	45

Table 6 (continued). Generalized morphological descriptions for the 53 AGRASID landform models

AGRASID landscape model		Slope[1]			Watershed	Off-site
		gradient	length	relief		drainage
code	description	(%)	(m)	(m)	# / 100ha	(%)
I1l	inclined plain - low	2	1000	10	3	90
I3l	inclined to steep - low	8	300	20	3	90
I3m	inclined to steep - med	15	500	50	2	95
I3h	**inclined to steep - high**	**30**	**800**	**150**	**1**	**100**
I4l	inclined with BR - low	8	300	20	3	90
I4m	inclined with BR - med	15	500	50	2	95
I4h	inclined with BR - high	30	800	150	1	100
I5	steep with slumps	25	1000	200	20	45
SC1l	valley with floodplain - low	15	300	20	3	90
SC1h	Steep valley with floodplain	20	400	50	1	100
SC2	valley with terraces	20	500	60	5	75
SC3	v-shaped valley	15	200	10	1	100
SC4	sub-glacial channel	8	400	10	40	25
O1	level organic	1	400	1	5	75
O2	basin (bowl)	2	300	3	1	0
O3	channelled, ribbed, net	1	300	2	1	50
O4	sloping organic	2	300	3	2	95
O5	organic with mineral	3	400	5	30	35
W1	channel sloughs	5	400	5	50	15
W2	>50% sloughs	3	400	5	40	25
W3	large single water body	0	1000	0	1	0

[1] Gradient is the 80th percentile, length and relief are the median of the "descriptive" value.
[2] Those in bold are the analysed sites used as controls - others are estimated from the controls.

The following general considerations were used :

1. Ridged should be very similar to inclined with a little DEP
2. Rolling should be similar to ridged but have more UPS and LOW
3. Longitudinal dunes should be the same as ridged, Parabolic dunes should have about 20% depressions
4. Inclined and Undulating should be the same as undulating with a little less DEP
5. Hummocky / BR should be between H and M; Hummocky and Plateau same as hummocky; Hummocky and Ridged simmilar to H with less UPS.
6. Inclined 4 should be same as I3; I5 same as I3l with a little DEP
7. SC1&2 same as Inclined plus Floodplain (l = m, h = h) - assume 30% FP in l, 40% FP in h, 50% FP in SC2: SC3 same as Inclined m: SC4 = Hm with more DEP
8. O4 assume similar to Il; O5 assume U1h with 50% orgaqnic
9. W 1 assume H1l with50% water; W 2 assume U1h with 50% water

Morphological descriptions by landform segment for the AGRASID landform models

Summary statistics produced to describe the dominant morphological characteristics of each of the four, simple landform segments were also consistent with expectations based on field experience (Table 7).

The 50th percentile and 80th percentile slope gradients were included to clearly indicate different concepts and facilitate appropriate use of the values. The 80th percentile expresses what one sees when looking at a landform. The eye tends to integrate selectively and will usually ignore small undulations and flat areas. Model application, on the other hand, must recognize a range of values associated with any given segment. The 50th percentile value captures this concept more accurately. This may be seen in a comparison of upper and lower vs. mid slope values (cf. H1h). Upper and lower segments typically include more relatively level areas and the median value is substantially lower than the 80th percentile. The difference is generally less for mid-slope segments that include fewer level areas.

The majority of the landform models are composed of repeating units such as undulations or knolls (hummocks) etc. The slope lengths are an integration of all individual slopes or half cycles (from one crest or knoll to the adjoining depression or stream). In these instances, the sum of the individual segments is equal to the total slope length. However, for non-repeating units such as floodplains (FP) and stream channels (SC), the length measurement represents hill slopes on both sides of the channel and not a single slope. Using SC1h as an example, the 160 m of LOW includes 80 m of floodplain plus lower slope on either side of the river (on the average), the 160 m of MID includes 80 m of mid-slope on each bank and the 40m of UPS includes 20 m on each side. Any modeling of these landforms must recognize the composite nature of their segment estimates.

The same considerations of scale and variability expressed in the previous section also apply here.

Table 7. General landform segment descriptions

AGRASID landscape model		Landform Segmentation Model - Landform segments															
		UPS[1]				MID				LOW				DEP			
		prop	gradient		length	prop	gradient		length	prop	gradient		length	prop	gradient		length
codel	description	(%)	50	80	(m)	(%)	50	80	(m)	(%)	50	80	(m)	(%)	50	80	(m)
FP1	meander floodplain	10	2	3	50	40	1	2	200	40	1	2	200	10	0.5	1	50
FP2	braided channel	0	-	-	-	50	1	2	250	20	1	2	100	30	0.5	1	150
FP3	confined, terraced	10	2	5	50	20	2	3	100	60	2	3	300	10	0.5	1	50
L1	level plain	0	-	-	-	45	0.5	1	450	45	0.5	1	450	10	0.5	1	100
L2	closed basin	10	1	2	50	10	1	1	50	40	0.5	1	300	40	0.5	1	300
L3	level, terraced	15	1	2	100	60	1	1	500	20	1	1	150	5	0.5	1	50
U1l 2	**undulating - low**	**20**	**1**	**2**	**50**	**50**	**1**	**2**	**120**	**15**	**1**	**2**	**40**	**15**	**0.5**	**0.5**	**40**
U1h	**undulating - high**	**25**	**2**	**4**	**60**	**45**	**3**	**4**	**115**	**20**	**2**	**3**	**50**	**10**	**0.5**	**1**	**25**
IUl	inclined & undulating - low	20	1	2	80	55	1	2	220	20	1	2	80	5	0.5	1	20
IUh	**inclined & undulating - high**	**20**	**2**	**4**	**100**	**50**	**3**	**4**	**250**	**25**	**2**	**3**	**125**	**5**	**0.5**	**1**	**25**
H1l	**hummocky - low**	**30**	**3**	**6**	**45**	**40**	**4**	**6**	**60**	**20**	**3**	**4**	**30**	**10**	**0.5**	**1**	**15**
H1m	**hummocky -med**	**30**	**6**	**9**	**50**	**35**	**6**	**9**	**50**	**25**	**5**	**7**	**35**	**10**	**1**	**1**	**15**
H1h	**hummocky -high**	**35**	**15**	**25**	**70**	**30**	**18**	**25**	**60**	**25**	**10**	**15**	**50**	**10**	**1**	**5**	**20**
H5l	hummocky over BR - low	30	3	6	60	45	4	6	90	20	3	4	40	5	0.5	1	10
H5m	hummocky over BR -med	30	6	9	90	40	6	9	120	25	5	7	75	5	1	1	15
H5h	hummocky over BR -high	35	15	25	140	35	18	25	140	25	10	15	100	5	1	5	20
R2l	**ridged - low**	**20**	**3**	**6**	**40**	**55**	**4**	**6**	**110**	**20**	**3**	**4**	**40**	**5**	**0.5**	**1**	**10**
R2m	ridged - med	20	6	9	60	60	6	9	180	15	5	7	45	5	1	1	15
R2h	ridged - high	15	15	25	70	65	18	25	250	15	10	15	60	5	1	5	20
D1l	longitudinal dune - low	20	3	6	40	55	4	6	110	20	3	4	40	5	0.5	1	10
D1m	Longitudinal dune - med	20	6	9	60	60	6	9	180	15	5	7	45	5	1	1	15
D1h	longitudinal dune - high	15	15	25	70	65	18	25	250	15	10	15	60	5	1	5	20
D2l	parabolic dune - low	20	3	6	20	45	4	6	45	15	3	4	15	20	0.5	1	20
D2m	parabolic dune - med	20	6	9	20	50	6	9	60	10	5	7	15	20	1	1	25
D2h	parabolic dune - high	15	15	25	25	55	18	25	75	10	10	15	20	20	1	5	30
M1l	**rolling - low**	**25**	**3**	**4**	**125**	**45**	**4**	**5**	**225**	**25**	**3**	**5**	**125**	**5**	**0.5**	**1**	**25**
M1m	rolling -med	25	5	8	150	50	6	9	300	20	4	7	125	5	1	1	25
M1h	**rolling - high**	**20**	**7**	**12**	**150**	**55**	**8**	**13**	**450**	**20**	**5**	**8**	**150**	**5**	**1**	**1**	**50**

Table 7 (continued). General landform segment descriptions

Landscape Model		UPS				MID				LOW				DEP			
		prop	gradient		length	prop	gradient		length	prop	gradient		length	prop	gradient		length
Symbol	**Description**	**(%)**	**50**	**80**	**(m)**	**(%)**	**50**	**80**	**(m)**	**(%)**	**50**	**80**	**(m)**	**(%)**	**50**	**80**	**(m)**
HP1m	hummocky/plateau - med	30	6	9	50	35	6	9	50	25	5	7	35	10	1	1	15
HP1h	hummocky/plateau - high	35	15	25	70	30	18	25	60	25	10	15	50	10	1	5	20
HR2m	hummocky/ridged - med	25	6	9	50	40	6	9	80	25	5	7	50	10	1	1	20
HR2h	hummocky/ridged - high	30	15	25	90	35	18	25	100	25	10	15	80	10	1	5	30
I1l	inclined plain - low	20	1	2	200	60	1	2	600	20	1	2	200	0			
I3l	inclined to steep - low	20	4	9	50	60	5	9	200	20	4	7	50	0			
I3m	inclined to steep - med	15	8	15	75	70	10	15	350	15	7	12	75	0			
I3h	**inclined to steep - high**	**10**	**15**	**30**	**100**	**80**	**25**	**35**	**600**	**10**	**15**	**20**	**100**	**0**			
I4l	inclined with BR - low	20	4	9	50	60	5	9	200	20	4	7	50	0			
I4m	inclined with BR - med	15	8	15	75	70	10	15	350	15	7	12	75	0			
I4h	inclined with BR - high	10	15	30	100	80	25	35	600	10	15	20	100	0			
I5	steep with slumps	20	12	25	200	55	25	35	550	20	10	20	200	5	3	8	50
SC1l	valley with floodplain - low	10	8	15	30	50	10	15	150	30	2	3	90	10	0	1	30
SC1h	valley with floodpl - steep	10	15	30	40	40	25	35	160	40	2	3	160	10	0	1	40
SC2	valley with terraces	10	15	30	50	30	25	35	175	50	2	3	225	10	0	1	50
SC3	v-shaped valley	15	8	15	30	70	10	15	140	15	7	12	30	0			
SC4	sub-glacial channel	30	6	9	120	30	6	9	120	30	5	7	120	10	1	1	40
O1	level organic	5	0.5	1	20	10	0.5	1	40	30	0.5	1	120	55	0	0.5	220
O2	basin (bowl)	0				0				30	1	3	100	70	0.5	1	200
O3	channelled, ribbed, net	5	1	2	10	10	1	2	30	20	1	2	50	65	1	1	200
O4	sloping organic	0				20	1	2	50	50	1	2	150	30	1	1	100
O5	organic with mineral	10	2	3	40	20	3	4	80	20	2	3	80	50	1	2	200
W1	channel sloughs	10	3	6	40	20	4	6	80	20	3	4	80	50	0	0	200
W2	>50% sloughs	10	2	3	40	20	3	4	80	20	2	3	80	50	0	0	200
W3	large single water body	0				0				0				100	0	0	1000

1 Slope segments: UPS = upper slope, MID = mid slope, LOW = lower slope, DEP = depression
prop = proportion, gradient= slope gradient (50 = 50th percentile, 80 = 80th percentile), length = slope length

2 Those in **bold** are the analysed sites used as controls - all other values are estimated from the controls.

Potential uses of the quantitative data on landform morphology

Detailed morphological data for individual sites (Appendix 1) may be used in a manner similar to that in which detailed soil profile descriptions and analytical data for individual sites are used. Currently, users may locate data for a soil closely similar to one for which they have no detailed site data, but for which detailed data are required for input into a model. They may elect to use detailed soil data for a sampled site to provide reasonable, but highly specific, values for input into a model. Detailed morphological data for individual sites representative of "type" landforms may be used in the same way, as input into models applied at sites similar to the site at which the detailed data were collected.

Alternately, users may prefer to use generalized landform data (Tables 6 and 7) in a manner analogous to the present use of generalized soils data contained in the NSDB Soil Names File (SNF) and Soil Layer File (SNF). The SNF and SLF contain descriptions of generalized models of the central concepts associated with abstract soil series entities. These generalized values are typically produced using the expert knowledge of soil surveyors to review profile data for a large number of sites. The review is used to assist in manually assigning mean or modal values for various soil properties to named soil series. Users often elect to use the generalized data in the SNF and SLF when models or decision rules are being applied to large areas, for which the generalized values are more likely to be representative than a single site-specific value. The generalized data in the new landform model database (Tables 6 & 7) is analogous to generalized soils data in the SNF and SLF. It may be used in a similar manner, when no detailed site data are available from a very similar site, or when the object of analysis is itself a generalized or conceptual entity.

As previously discussed, some users may wish to select a single value of, for example, slope to represent an entire landform. The data presented here provide a variety of options for selecting single values to represent an entire landform. Options include the mean value, the central value of the dominant class or the "controlling" value, set at the 80th percentile. Alternately, users may define a controlling value more suitable to their needs by consulting the graphs of continuous frequency distribution and reading off the value of the morphological attribute of interest at a different percentile level (say the 90th percentile).

In many cases, it may prove more effective to analyze a particular landscape in terms of the sum of the morphological characteristics of its individual landform segments. For example, users may assign to each of the four simple landform segments a value for each landform characteristic of interest. The assigned value may again be any of the mean, the mode or the controlling value for that landform segment. Models or decision rules may be run four times, once for each landform segment, and the individual results combined to produce an overall result for the landform as a whole. This could be particularly useful for estimating erosion or run-off values when it is clear that not all parts of the landform react in a similar fashion.

Landscape segments have been shown to correlate quite well with general soil characteristics such as organic matter content, depth of solum and pH (MacMillan et al. 2000a, Coen et al. 1999). This is consistent with soil genesis principles that link moisture regime, vegetation and soils to landform positions (Ellis, 1932; Jenny, 1941) and completes the lost link back to soil survey procedures that use a landscape paradigm in the mapping process (Hudson, 1992). With this knowledge, landscape segmentation can be confidently used as a basis for estimating or extrapolating soil properties and management responses.

For example, a subsequent project used a simple expert system approach to capture and apply soil surveyor tacit knowledge regarding the most likely distribution of Alberta soils relative to landform position and to automatically assign soil types to landform position (MacMillan et al., 2000b).

It is envisaged that the landform morphology data will find use in two main ways. Firstly, individuals may wish to run a deterministic model or decision rule at a particular site, but may lack detailed morphological data for that site. In such cases, either detailed morphological descriptions of individual "type" locations or simplified descriptions contained in the generalized landform model database may be consulted to obtain reasonable values suitable for input into the models or decision rules for the site of current interest. The second likely use of the data will be to assist in generalizing the results of site specific research or modeling to other locations. Results of detailed modeling at a specific location may be considered to be valid for other locations with an equivalent AGRASID landform classification and equivalent landform morphology.

In the longer term, it is envisaged that high resolution DEMs (5-10 m) may become widely available providing comprehensive coverage for entire areas of interest. Therefore, the approach of using detailed data for selected sites taken as representative of "type" landforms as surrogate data for unsampled areas might have a limited shelf life. It may ultimately be supplanted by the use of actual data at any site of interest. In this case, the procedures for computing and summarizing terrain derivatives outlined here may offer guidance for the most appropriate ways to describe the morphology of landforms for areas for which comprehensive DEM coverage exists.

Users considering applying the techniques described in this bulletin to their own DEM data sets should be aware of a number of procedural issues and methodological concerns associated with processing high-resolution digital elevation data to compute measures of landform morphology. Several of the more relevant procedural issues are identified and discussed in Appendix 3.

SUMMARY AND CONCLUSIONS

This report presents operational procedures to provide quantitative descriptions of the morphometric characteristics of landforms and to classify landforms using Digital Elevation Models. It also shows how the procedures can be automated and applied successfully to a wide range of landform types.

Calculations of slope gradient and aspect from DEM data have previously been reported in the soil survey and GIS literature for individual sites. This project provides statistical summary data for a comprehensive range of morphometric attributes and landform classifications for a large number of landform types.

The programs to compute absolute and relative relief, slope length and relative slope position utilize cell to cell flow path topology to explicitly compute linkages from each cell to the closest cells defined as pits, peaks, divides or channels. This appears to represent an improvement over currently available programs for computing relief and slope position.

The detailed morphological data have been used to classify landforms into landform facets that are meaningful in terms of landscape processes and soil development. The initial 15 facets were grouped into 4 simpler segments that relate well to the recognition of soil types and soil distribution at a reconnaissance scale of information (as represented by the AGRASID database).

The ability to directly link the morphological descriptions to a digital soil survey database (AGRASID) via the landform model code facilitates access to and use of the soil survey data. It extends and adds value to the original soil survey database. This is particularly pertinent for the application of crop growth models, degradation models or other models that are based on soil and water characteristics related to landform position.

Providing data on the morphological characteristics of four simple landform segments gives users the opportunity to apply models or decision rules to different components of a polygon with different landform and soil attributes. This supports more meaningful and realistic modeling results.

RECOMMENDATIONS

1. Field testing should be conducted over a wide range of landform situations in other physiographic regions to validate the accuracy and applicability of this landform characterization and segmention model.

2. Further work should be undertaken to improve the description of depressions.

3. National standards for terms and protocols should be considered to facilitate comparison and consistency of results and applications. Specific areas include:

   - Guidelines and protocols for the production of suitable DEMs
   - Standard definitions of landform facets and landform segments
   - Standard protocols and accepted threshold values for segmenting landforms and characterizing their components.

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APPENDICES

APPENDIX 1.

Quantitative descriptions for selected AGRASID landform types

This appendix contains standard 3 page descriptions for each of the 26 sites selected as "type" locations deemed representative of one of the major landform types defined for use in the AGRASID digital database.

Each 3 page description contains the following information elements.

The first page provides documentation of the procedures followed in acquiring, surfacing and processing a high-resolution digital elevation model for a given site. It identifies the legal location of the site, its location in UTM coordinates, the size of the area covered by the DEM and the horizontal ground dimensions of a DEM cell. The table under the heading "Landform Description" provides a succinct summary of the principal morphological characteristics of the site when considered as a single landform entity. In this table, Dom-1 Value and Dom-2 Value indicate the dominant and subdominant classes, in terms of relative aerial extent, for each of the listed attributes. Two graphical illustrations are also included, one a schematic cross section and the other a 2D rendering of the site as an illuminated hillshade image. The 2D cross section can be used to gain an appreciation for the amount of relief typical of the landform at that site and of the length and complexity of slopes and slope gradients. The hillshade image offers a pseudo 3D illustration that can help users to gain an improved appreciation of the complexity and scale of landform features at a given site.

The second page contains a series of 8 graphs that present a summary of the statistical data on the distribution of 8 landform attributes of interest at each site. The graphs summarize the distribution of slope gradient, aspect, descriptive and effective relief, descriptive and effective slope length and landform classifications (15 and 4 unit) at the site. Solid lines on the graphs portray the continuous cumulative frequency distributions for each of these 8 attributes for each site. Bar graphs portray the percent extent of defined classes of slope gradient, aspect, relief and slope length as well as landform classification. Users could define classes with different class boundaries than used here and determine the percent extent of the site that falls within their classes of interest through reference to the continuous distribution curves. This page summarizes data for only 8 of the more than 37 terrain derivatives or landform indices computed for each site. These 8 were selected, as they were believed to be the most important in terms of differentiating different landform types. They are also the information items most frequently required as input into deterministic models and quantitative decision rules. Similar data on continuous and classed frequency distributions were computed for the remaining 29 terrain derivatives. These have been archived in a comprehensive backup database, but are not presented or discussed in this report.

The third page presents 3D illustrations of the 15 and 4 unit landform classifications draped over topography. These are provided to assist users in visualizing the landscape and in evaluating the reasonableness and potential utility of the landform classification and landform descriptions for a given site. The percent extent of the 15 units is indicated in the table above the 3D figure of the 15-unit classification. The table above the 3D figure of the 4-unit generalization provides data on not only the percent extent of the 4 landform categories, but also on the effective and descriptive slope length, gradient and relief associated with each of the 4 classes. Reported values for slope length by landform segment should correspond with the typical slope lengths of each segment as portrayed on the 3D figures.

SITE NO. 01 Landform Type: U1l

Site Identification: Gibbons West Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	346890.0	347590.0	5956870.0	5957620.0

Legal Location	Site Name	Landform Type	Comments
NW-11-55-23-W4	Gibbons W 1/2	U1l	Low relief undulating. Weeds prominent in low spots

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	0.9%	2.0%	1.0-2.0%	0-1.0%
Descriptive Relief (Pit to Peak) (m)	2.6 m	4.0 m	2-5 m	1-2 m
Effective Relief (Cell to Pit) (m)	1.1 m	2.5 m	0-1 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	343.9 m	500 m	300-500 m	200-300 m
Effective Slope Length (Cell to Pit m)	186.5 m	350 m	300-500 m	200-300 m
No. Watersheds per 100 ha	21/ 100 ha			
Percent Off-site Drainage	50.1%			

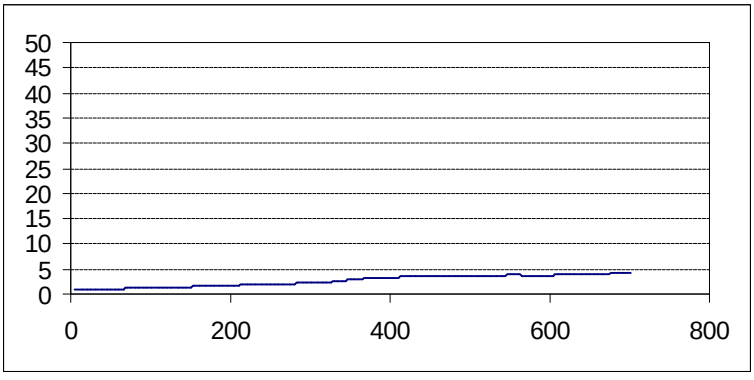
Origin and pre-processing of original DEM X, Y, Z data

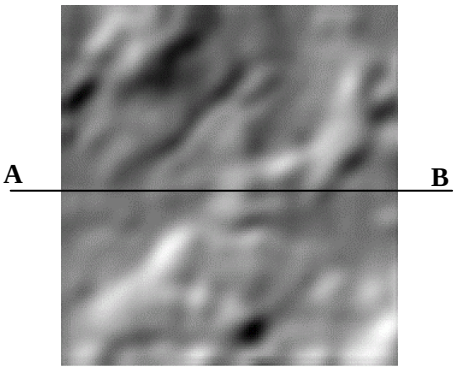
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	A. Svederus	Differential GPS Field Survey	Gib1GPS	39,944
DEM Surfacing:	AAFRD	S. Nolan	GRASS Thin Plate Spline (TPS)	Gib1DEM.img	56,357
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q01DEM.img	21,000

Evolution of the DEM from initial X, Y, Z data to final working surface

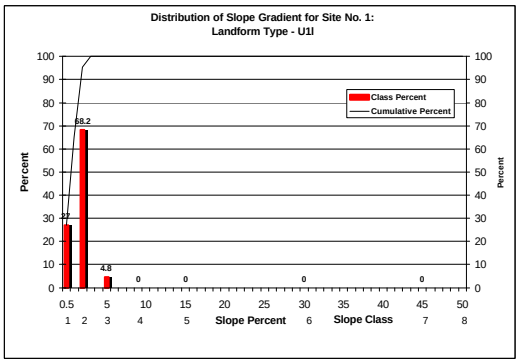
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Gib1DEM.img	346835	348455	5956810	5957610	174	324	5 m	Smoothed by TPS
2	Gib2DEM.img	346835	348455	5956810	5957610	174	324	5 m	Convert mm to m
3	G2SDEM.img	346890	348225	5956870	5957620	150	267	5 m	Subset of Gib2
4	G5mDEM.img	346890	348225	5956870	5957620	150	267	5 m	1 5x5 mean filter to 3
5	G57DEM.img	346890	348225	5956870	5957620	150	267	5 m	1 7x7 mean filter to 4
6	Q01DEM.img	346890	347590	5956870	5957620	150	140	5 m	Subset of W 1/2 only
7	Q01DEMa.img	346890	347590	5956870	5957620	150	140	5 m	ASCII Export of 6

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

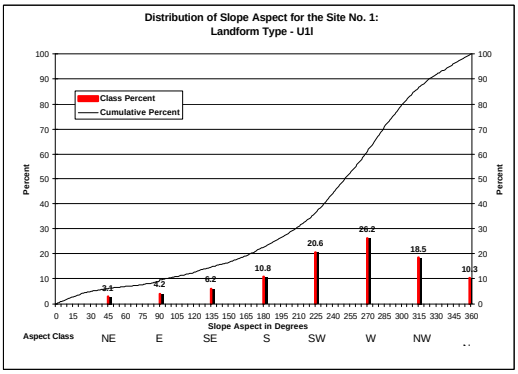




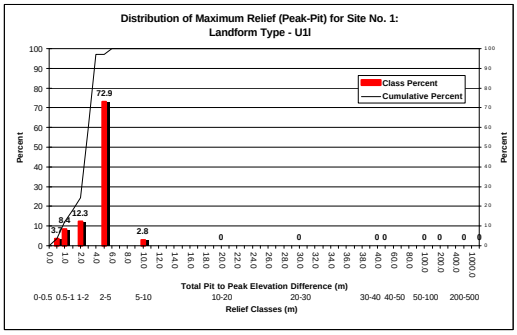
Site No: 01 Gibbons West Site Landform Type:U1l



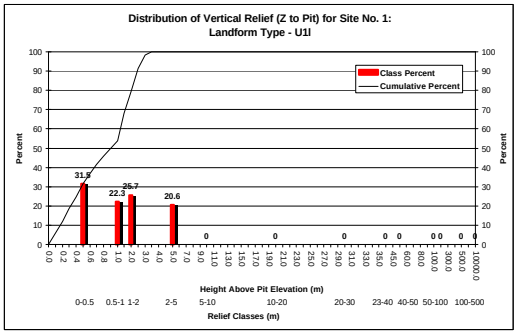
a) Slope gradient (%)



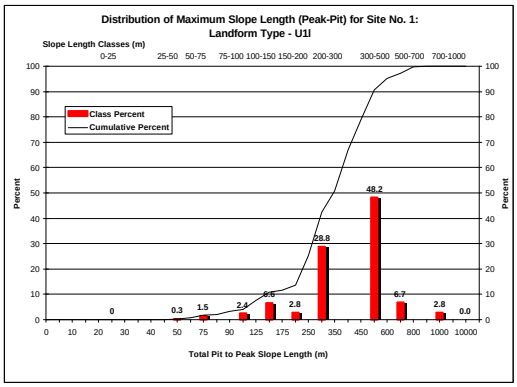
b) Slope aspect (degrees)



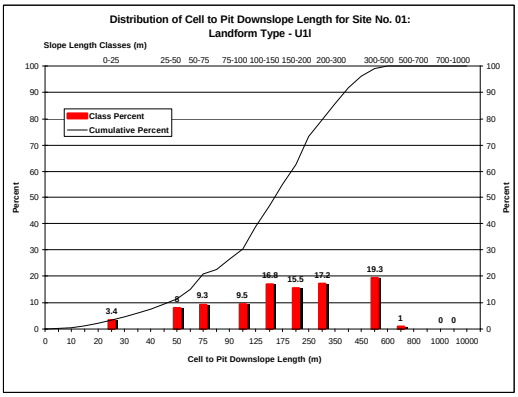
c) Descriptive relief (pit to peak) (m)



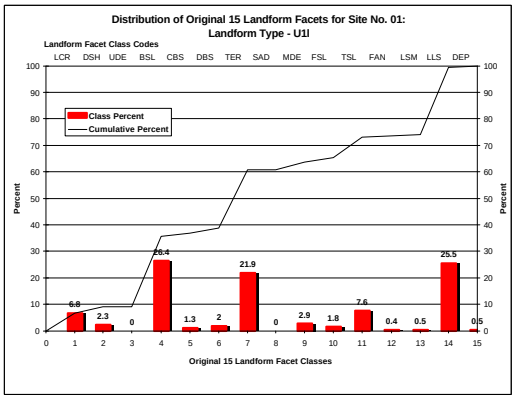
d) Effective relief (cell to pit) (m)



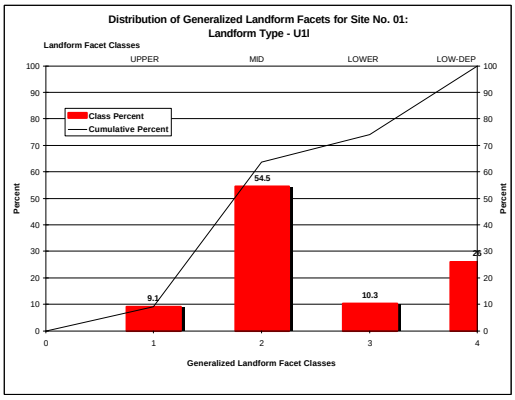
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



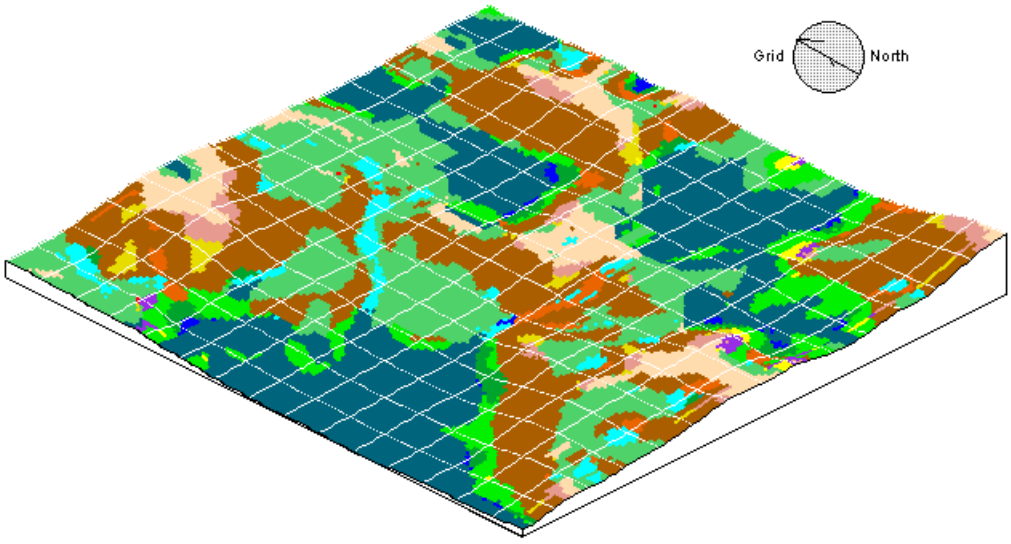
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

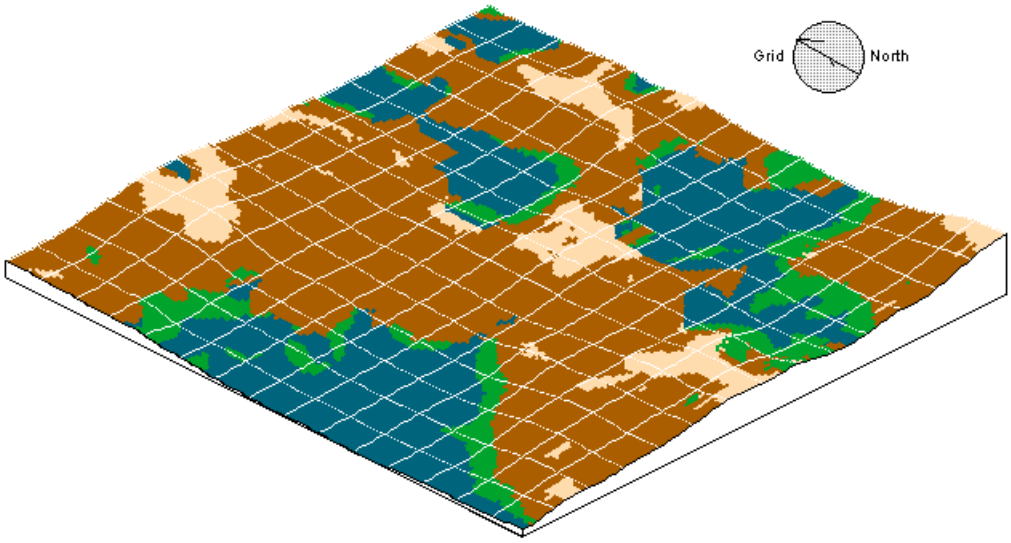
Site No: 01 **Gibbons West Site** **Landform Type: U1l**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
6.8	2.3	0.0	26.4	1.3	2.0	21.9	0.0	2.9	1.8	7.6	0.4	0.5	25.5	0.5



a) 3D view of the Gibbons Site W 1/2: 15 unit landform classification - no post classification filters

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		9.1	0.76	1.29	166.7	412.5	2.88
MID		54.5	0.92	1.50	125.9	350.2	2.14
LOW		10.3	1.15	1.58	46.1	161.5	0.76
DEP		26.0	0.45	0.67	36.4	130.9	0.47



b) 3D view of the Gibbons site W 1/2: 4 unit landform element generalization - no post classification filters

SITE NO. 02 Landform Type: U1h

Site Identification: Provost Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	558700	559635	5807780	5808700

Legal Location	Site Name	Landform Type	Comments
SE-07-40-01-W4	Provost Site	U1h	Agriculture & Agri-Food Canada bench mark site

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.5%	4.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	6.4 m	10.0 m	5-10 m	2-5 m
Effective Relief (Cell to Pit) (m)	2.9 m	5.0 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	293.7 m	450 m	300-500 m	200-300 m
Effective Slope Length (Cell to Pit m)	133.3 m	250 m	100-150 m	50-75 m
No. Watersheds per 100 ha	36/ 100 ha			
Percent Off-site Drainage	30.2 %			

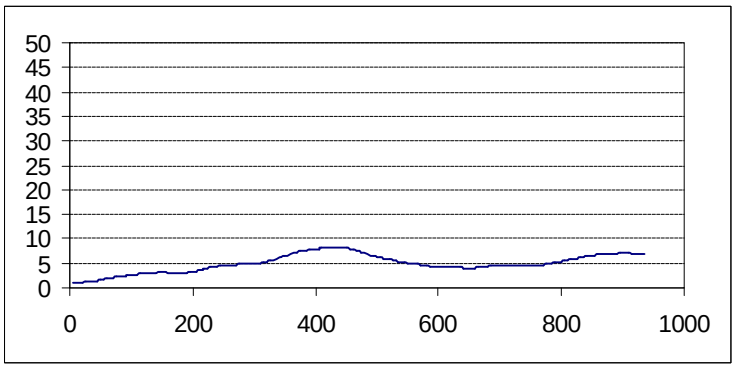
Origin and pre-processing of original DEM X, Y, Z data

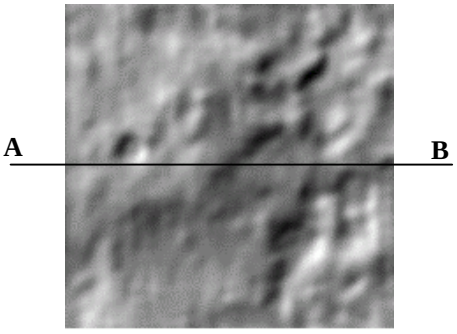
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFC	B. Walker	Total Station Field Survey	PROV_PTS.txt	1903
DEM Surfacing:	LandMapper	R. MacMillan	ArcView 3 IWD nearest 20	Prov2DEM.img	34,408
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q05DEM.img	34,408

Evolution of the DEM from initial X, Y, Z data to final working surface

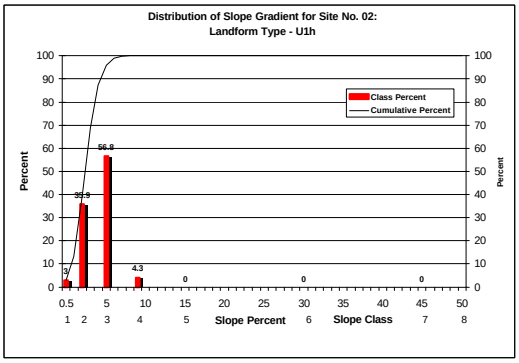
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	PROV2DEM	558700	559635	5807780	5808700	184	187	5 m	IWD surface
2	U1hDEMf1.img	558700	559635	5807780	5808700	184	187	5 m	3x3 mean filter to 1
3	U1hDEMf2.img	558700	559635	5807780	5808700	184	187	5 m	3x3 mean filter to 2
4	U1hDEMf5.img	558700	559635	5807780	5808700	184	187	5 m	5x5 mean filter to 1
5	Q02m5x5.img	558700	559635	5807780	5808700	184	187	5 m	5x5 mean filter to 4
6	Q02m55a.img	558700	559635	5807780	5808700	184	187	5 m	ASCII export of 5

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

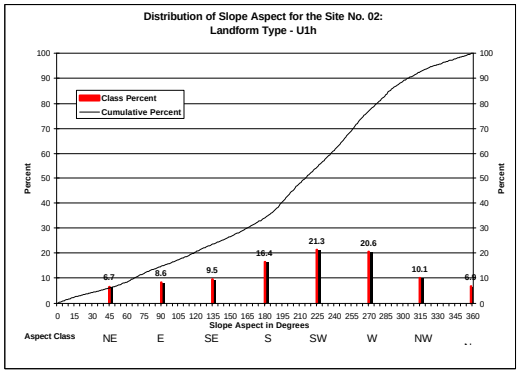




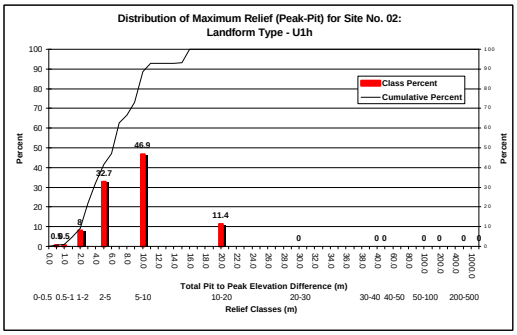
Site No: 02 Provost Site Landform Type:U1h



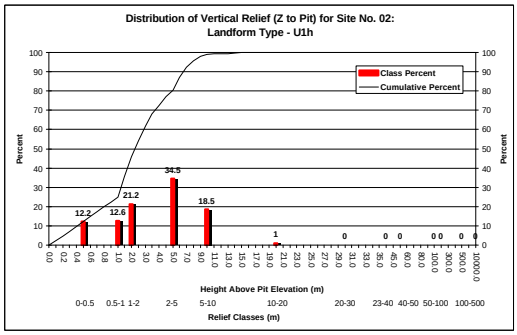
a) Slope gradient (%)



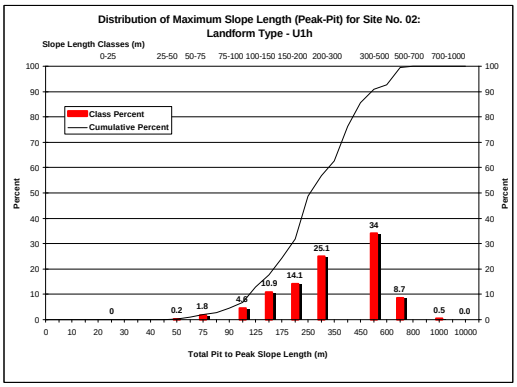
b) Slope aspect (degrees)



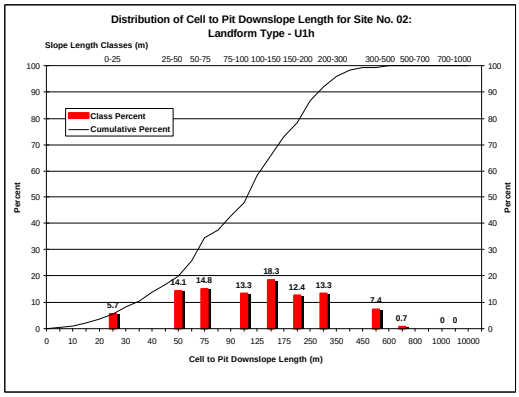
c) Descriptive relief (pit to peak) (m)



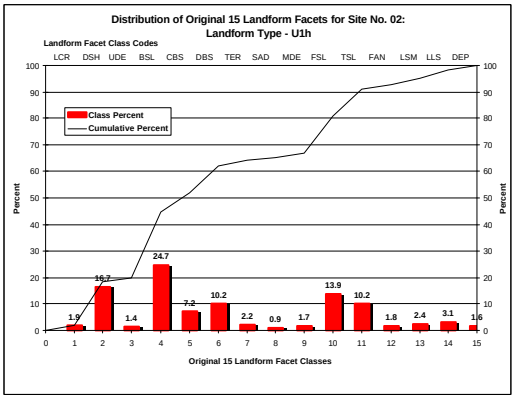
d) Effective relief (cell to pit) (m)



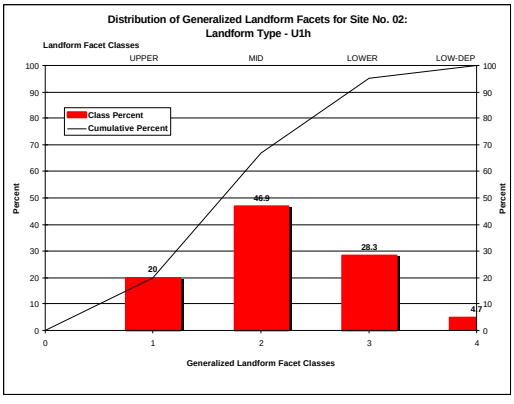
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



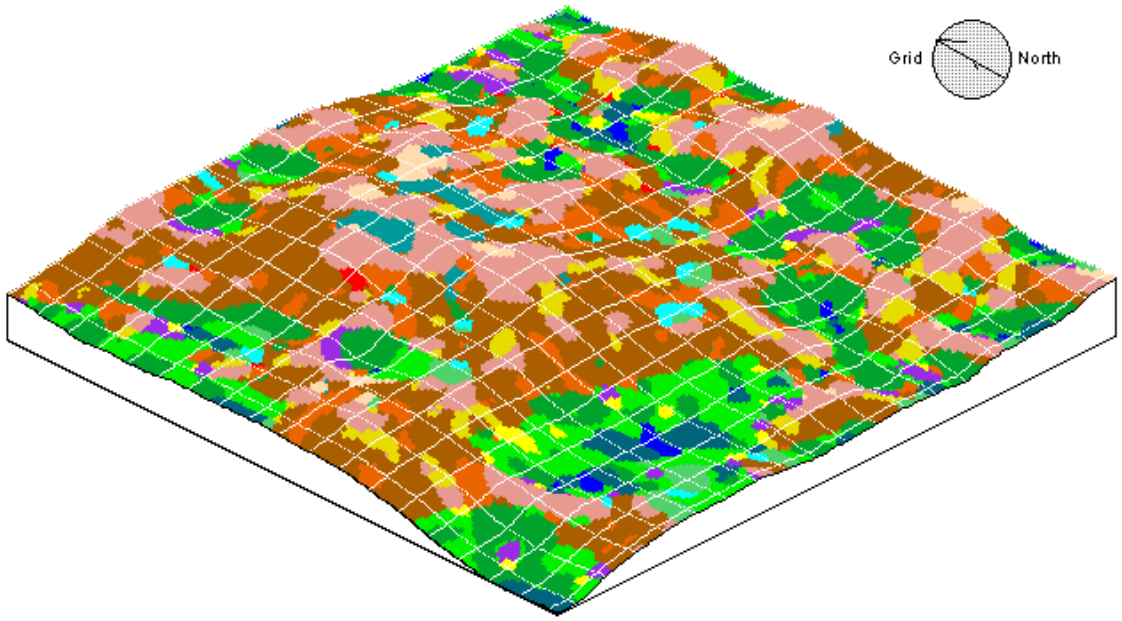
g) Landform classification into 15 facets



h) Landform classification generalized into 4

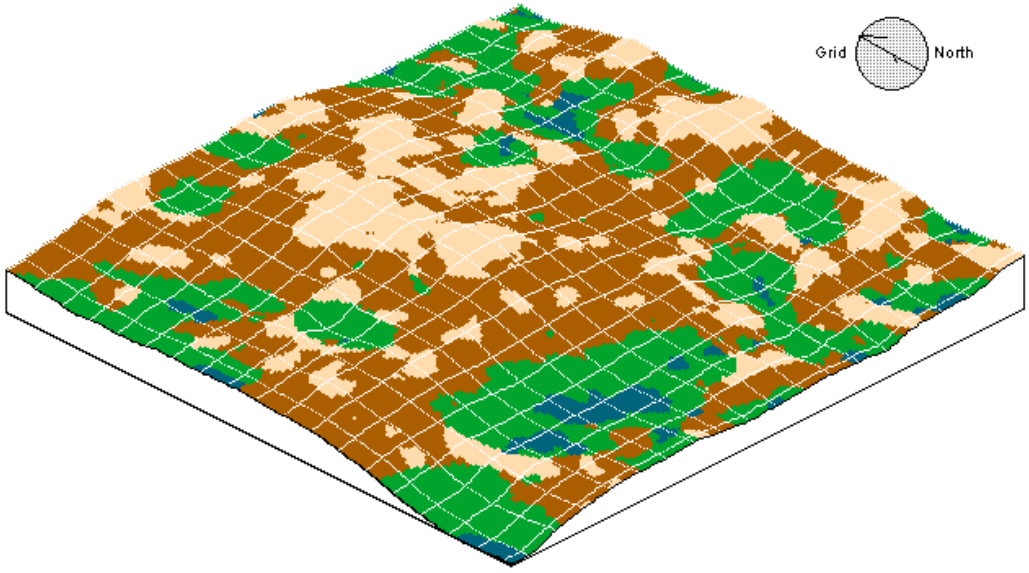
Site No: 02 **Provost Site** **Landform Type: U1h**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
1.9	16.7	1.4	24.7	7.2	10.2	2.2	0.9	1.7	13.9	10.2	1.8	2.4	3.1	1.6



a) 3D view of the Provost Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		20.0	2.38	3.63	81.1	285.9	6.62
MID		46.9	2.55	3.61	76.9	241.2	5.45
LOW		28.3	2.27	3.46	29.2	103.5	1.61
DEP		4.7	0.7	0.89	15.8	75.2	0.69



b) 3D view of the Provost Site: 4 unit landform element generalization - 1 5x5 post classification modal filter

SITE NO. 03 Landform Type: U1h

Site Identification: Lunty Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	424630	425330	5820000	5820800

Legal Location	Site Name	Landform Type	Comments
E5, W4, 41-15-W4	Lunty Site	U1h	Alberta Research Council research site (M. Trudell)

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.2 %	4.0 %	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	3.5 m	5.0 m	2-5 m	5-10 m
Effective Relief (Cell to Pit) (m)	1.8 m	3.0 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	193.8 m	250 m	200-300 m	150-200 m
Effective Slope Length (Cell to Pit m)	94.9 m	150 m	100-150 m	50-75 m
No. Watersheds per 100 ha	41.1/ 100 ha			
Percent Off-site Drainage	23.8 %			

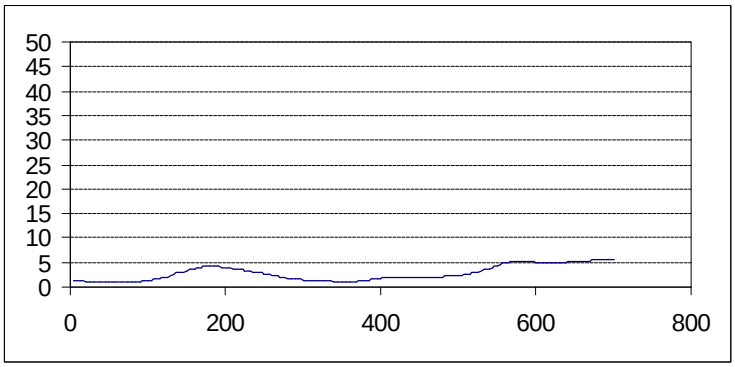
Origin and pre-processing of original DEM X, Y, Z data

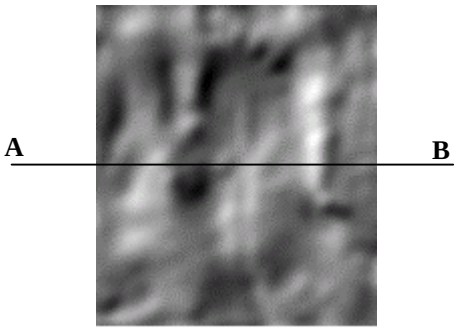
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	ARC	M. Trudell	Floating dot photogrammetry	ORIGINAL.pts	Unknown
DEM Surfacing:	ARC	M. Trudell	Surface 2 IWD	ORIGINAL.dem	23,667
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Lu75dem.img	22,400

Evolution of the DEM from initial X, Y, Z data to final working surface

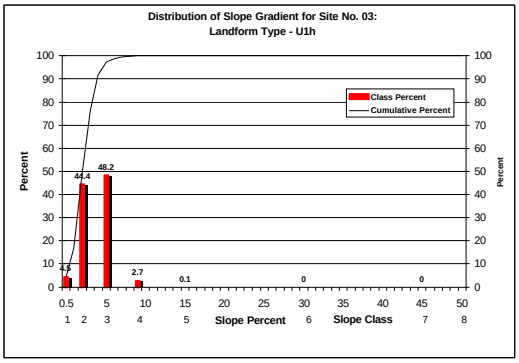
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Original.dem	424630	525365	5819995	5820800	161	147	5 m	First IWD surface
2	G5dem.img	424630	525330	5820000	5820800	160	140	5 m	Sub-set of 1
3	Lu5m7dem.img	424630	525330	5820000	5820800	160	140	5 m	7x7 mean filter to 2
4	Lu75dem.img	424630	525330	5820000	5820800	160	140	5 m	5x5 mean filter to 3
5	Lu75dema.img	424630	525330	5820000	5820800	160	140	5 m	ASCII export to LSM

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

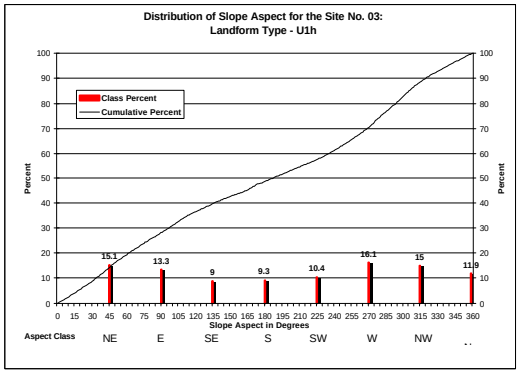




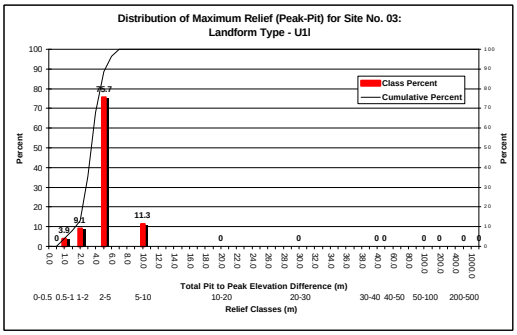
Site No: 03 Lunty Site Landform Type: U1h



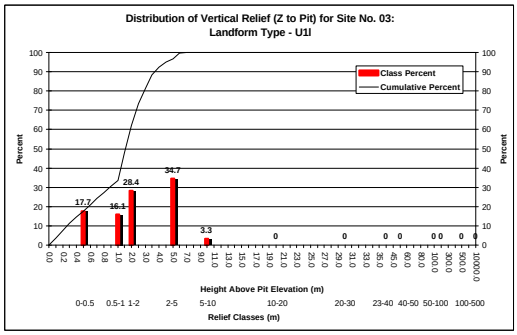
a) Slope gradient (%)



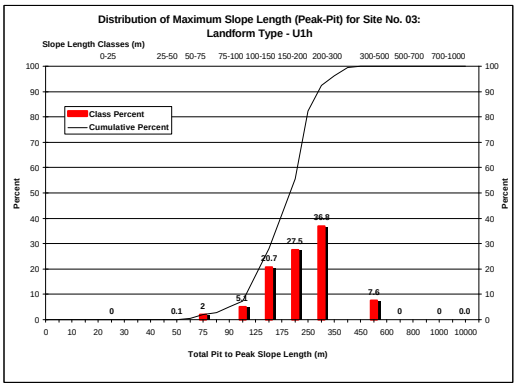
b) Slope aspect (degrees)



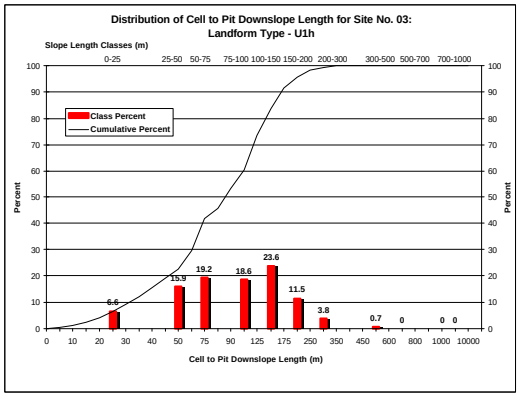
c) Descriptive relief (pit to peak) (m)



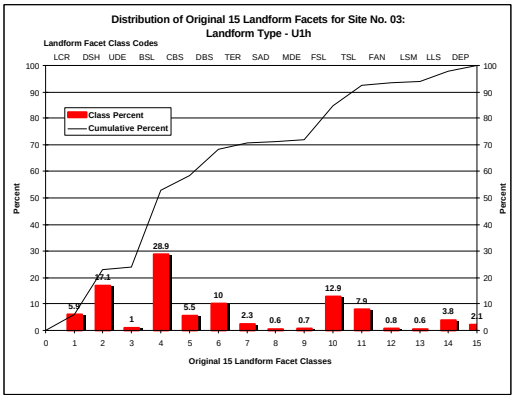
d) Effective relief (cell to pit) (m)



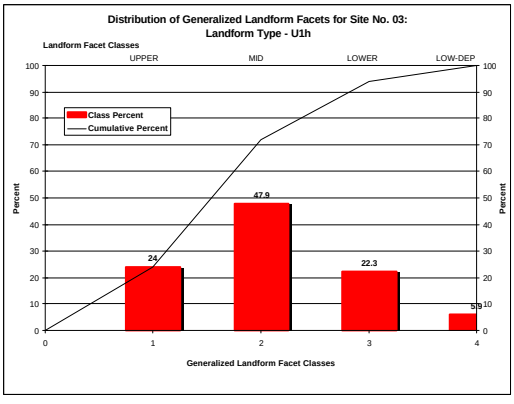
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



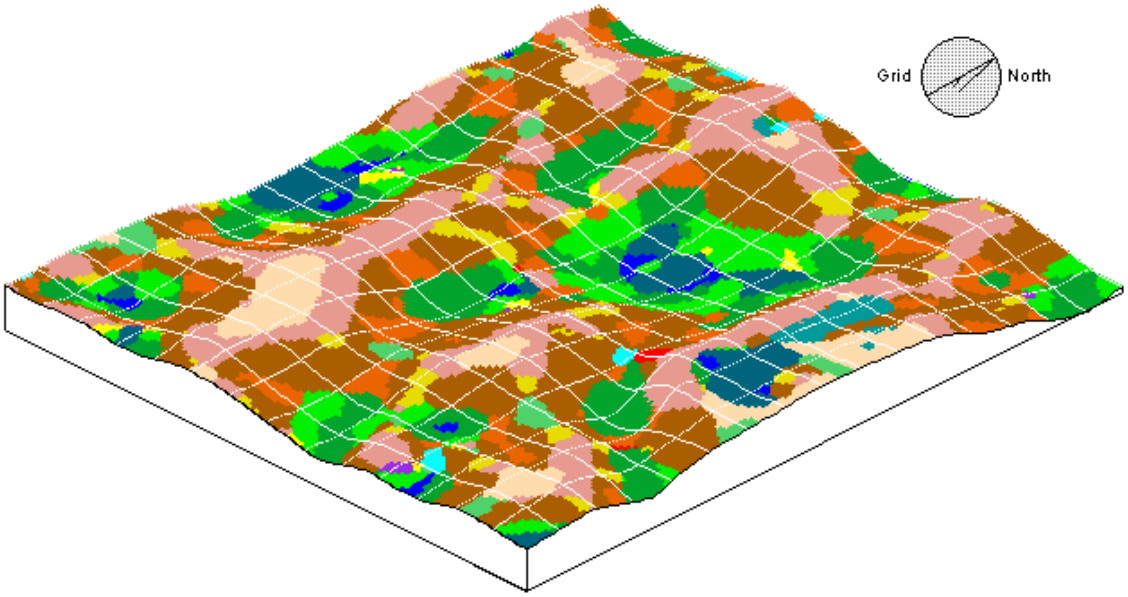
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

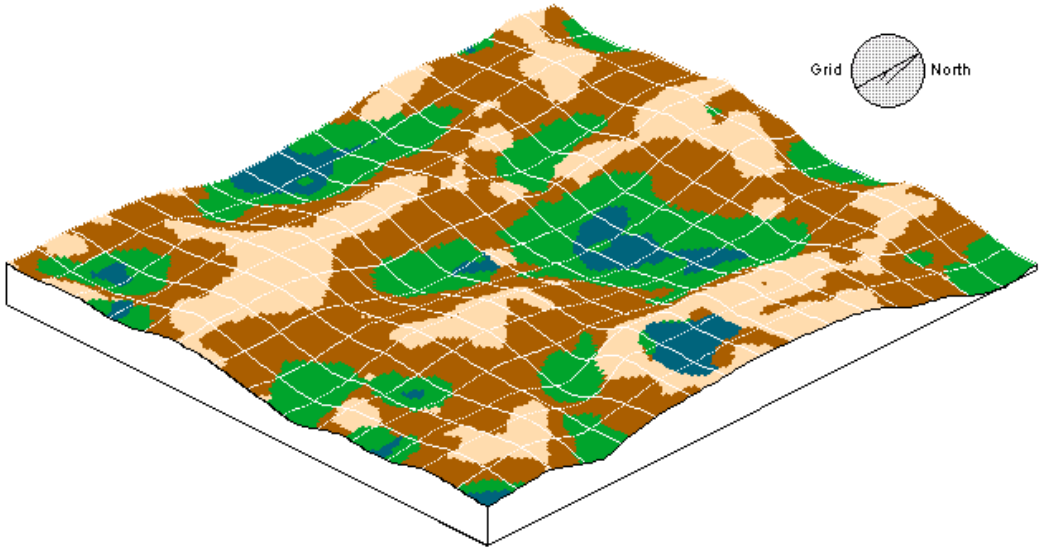
Site No: 03 Lunty Site Landform Type: U1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
5.9	17.1	1.0	28.9	5.5	10.0	2.3	0.6	0.7	12.9	7.9	0.8	0.6	3.8	2.1



a) 3D view of the Lunty Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		24.0	1.65	2.77	85.8	183.1	4.3
MID		47.9	2.36	3.47	63.7	136.9	2.67
LOW		22.3	2.08	3.08	25.5	71.3	0.89
DEP		5.9	0.63	0.85	14.1	54.1	0.27



b) 3D view of the Lunty Site: 4 unit landform element generalization - 1 5x5 post classification modal filter

SITE NO. 04 Landform Type: H1l

Site Identification: Mundare Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	413100	414900	5934600	5936400

Legal Location	Site Name	Landform Type	Comments
09-53-16-W4	Mundare Site	H1l	PARI research farm. DEM was difficult to produce

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.1 %	4.0	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	2.8 m	5.0 m	2-5 m	1-2 m
Effective Relief (Cell to Pit) (m)	1.2 m	2.0 m	0-1 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	213.2 m	300 m	100-150 m	200-300 m
Effective Slope Length (Cell to Pit m)	115.4 m	175 m	50-75 m	100-150 m
No. Watersheds per 100 ha	41.4/ 100 ha			
Percent Off-site Drainage	6.5 %			

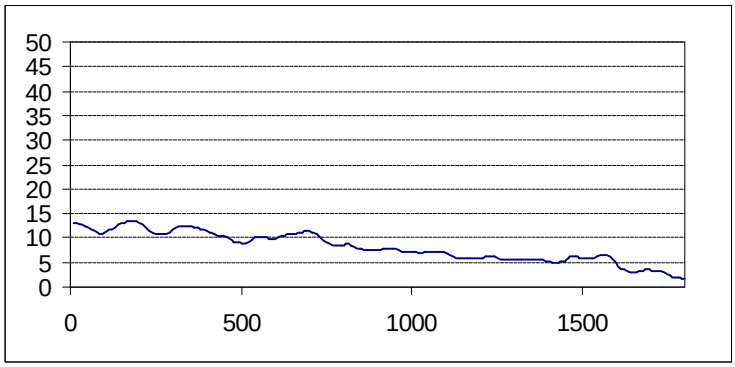
Origin and pre-processing of original DEM X, Y, Z data

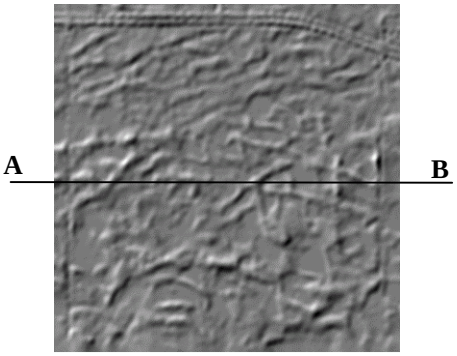
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFC	B. Walker	Total Station Field Survey	Mu3xyz.txt	16,465
DEM Surfacing:	LandMapper	R MacMillan	Idrisi IWD nearest 12 points	Q04IWD.img	129,600
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q0410m.img	32,400

Evolution of the DEM from initial X, Y, Z data to final working surface

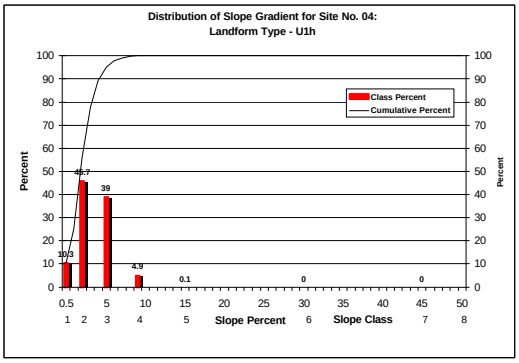
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Q04IWD.img	413100	414900	5934600	5936400	360	360	5	Idrisi IWD surface
2	Q04m55.img	413100	414900	5934600	5936400	360	360	5	1 5x5 mean filter to 1
3	Q04m53.img	413100	414900	5934600	5936400	360	360	5	1 3x3 mean filter to 2
4	Q0410m.img	412995	414955	5934602	5936482	180	180	10	Resample 3 to 10 m
5	Q04av3a.img	412995	414955	5934602	5936482	180	180	10	ASCII export to LSM
6	Q04DEM.dbf	412995	414955	5934602	5936482	180	180	10	DBF version of 5

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

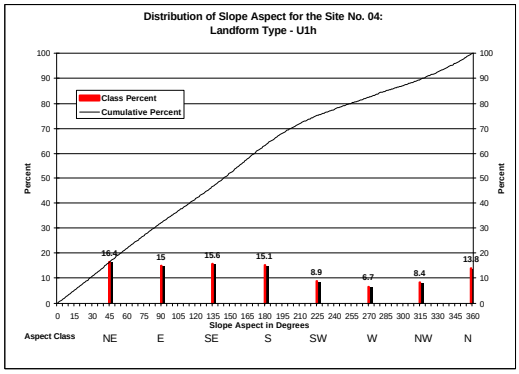




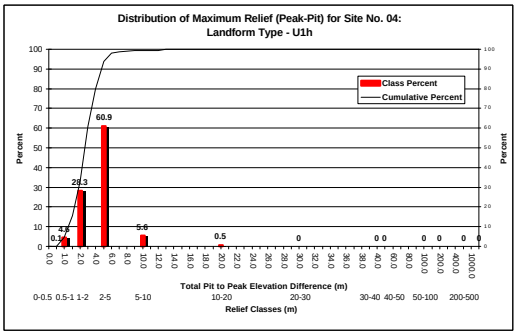
Site No: 04 Mundare Site Landform Type: H1l



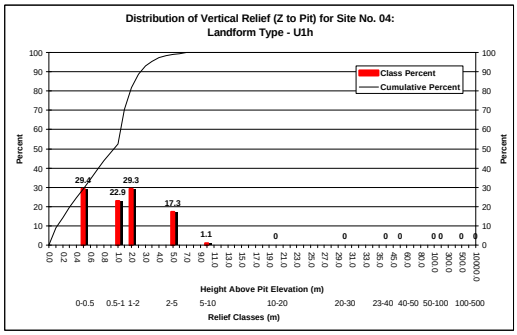
a) Slope gradient (%)



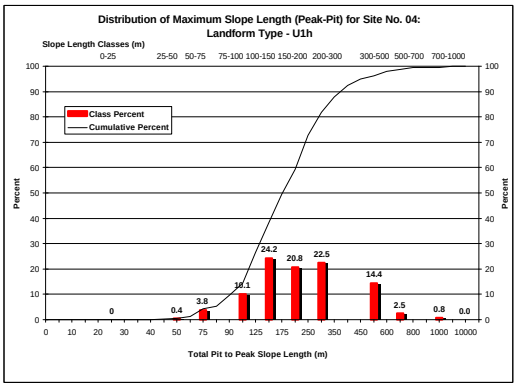
b) Slope aspect (degrees)



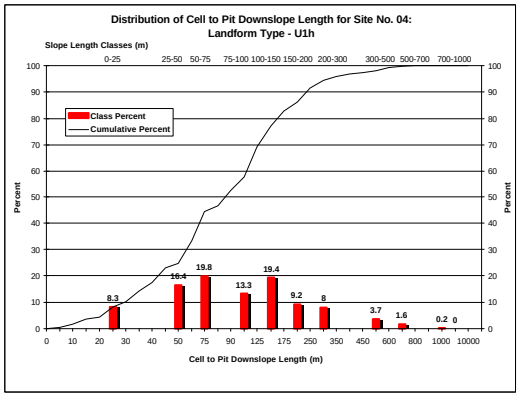
c) Descriptive relief (pit to peak) (m)



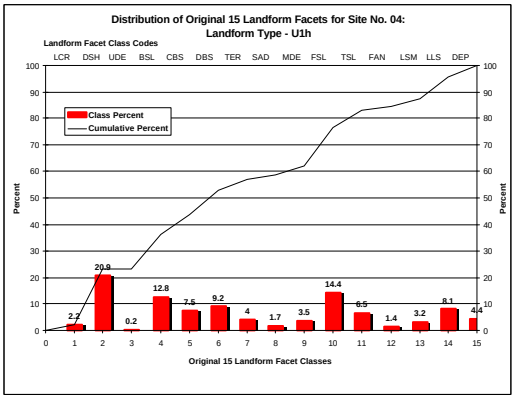
d) Effective relief (cell to pit) (m)



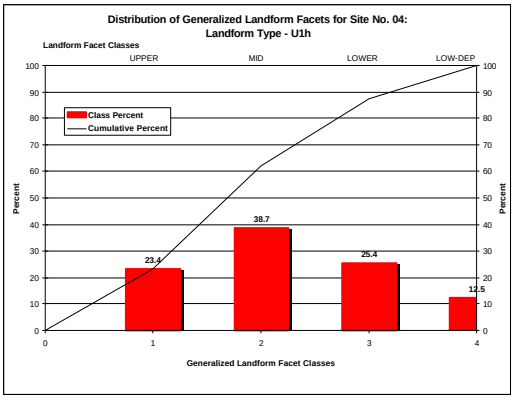
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



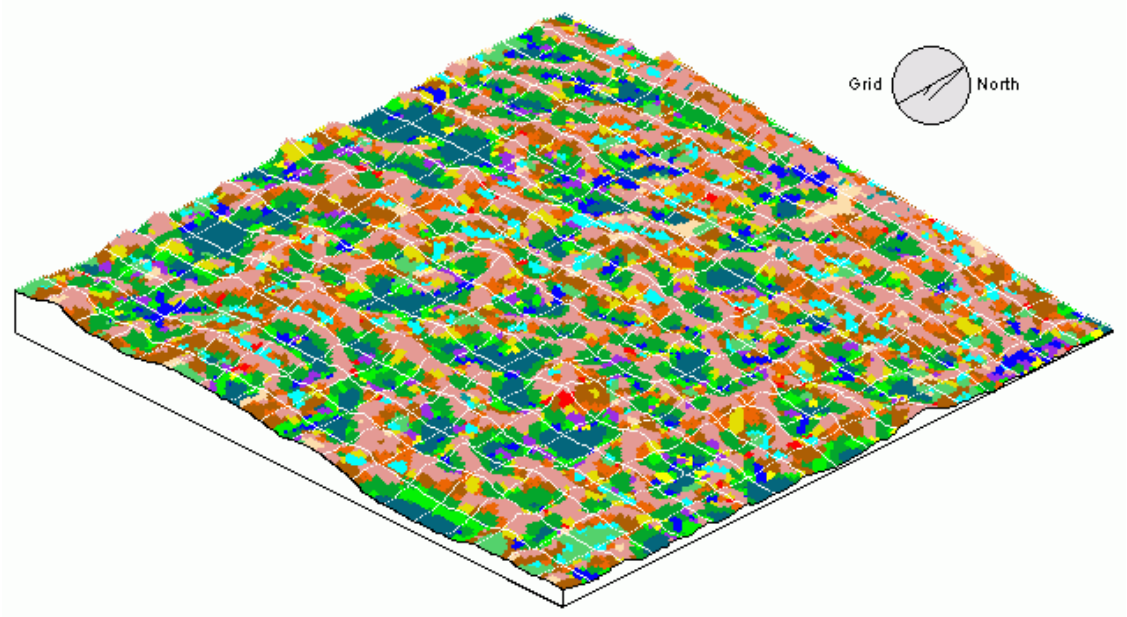
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

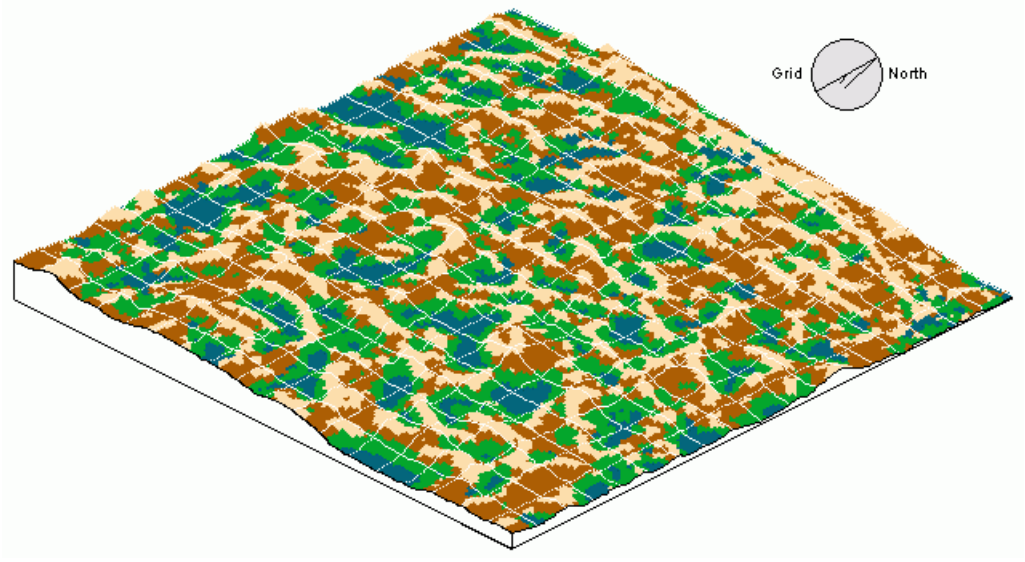
Site No: 04 **Mundare Site** **Landform Type: H1l**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
2.2	20.9	0.2	12.8	7.5	9.2	4.0	1.7	3.5	14.4	6.5	1.4	3.2	8.1	4.4



a) 3D view of the Mundare Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		23.4	2.21	3.61	64.4	205.9	2.87
MID		38.7	1.95	3.39	65.0	201.9	2.04
LOW		25.4	1.91	2.94	29.2	95.3	0.74
DEP		12.5	0.50	0.82	20.0	72.4	0.28



b) 3D view of the Mundare Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 05 Landform Type: R2l

Site Identification: Gibbons East Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	347475	348225	5956870	5957620

Legal Location	Site Name	Landform Type	Comments
NE-11-55-23-W4	Gibbons E 1/2	R2l	Ridged topography, AGRASID maps as hummocky

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	1.9%	3.0%	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	7.5 m	12.0 m	10-20 m	2-5 m
Effective Relief (Cell to Pit) (m)	3.4 m	7.0 m	2-5 m	5 -10 m
Descriptive Slope Length (Pit to Peak m)	471.6 m	800 m	300-500 m	500-700 m
Effective Slope Length (Cell to Pit m)	289.4 m	500 m	300-500 m	200-300 m
No. Watersheds per 100 ha	11.3/ 100 ha			
Percent Off-site Drainage	47.6 %			

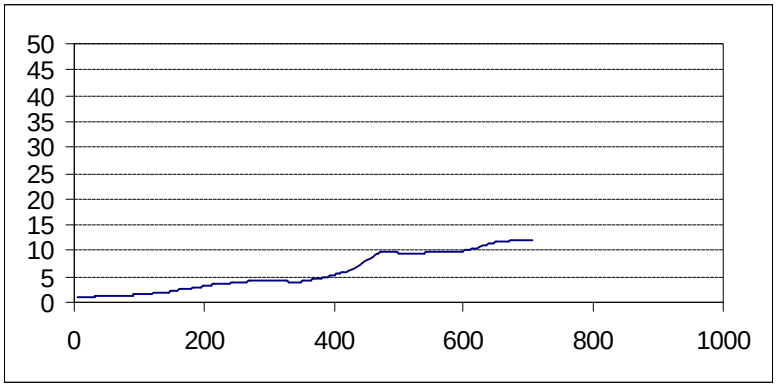
Origin and pre-processing of original DEM X, Y, Z data

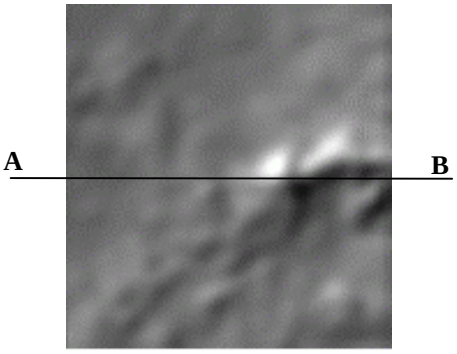
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	A. Svederus	Differential GPS Field Survey	Gib1GPS	39,944
DEM Surfacing:	AAFRD	S. Nolan	GRASS Thin Plate Spline (TPS)	Gib1DEM.img	56,357
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q05DEM.img	21,150

Evolution of the DEM from initial X, Y, Z data to final working surface

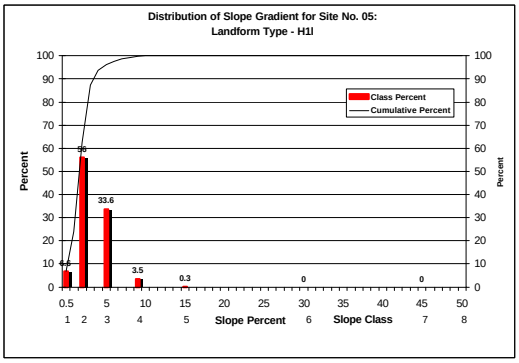
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Gib1DEM.img	346835	348455	5956810	5957610	174	324	5 m	Smoothed by TPS
2	Gib2DEM.img	346835	348455	5956810	5957610	174	324	5 m	Convert mm to m
3	G2SDEM.img	346890	348225	5956870	5957620	150	267	5 m	Subset of Gib2
4	G5mDEM.img	346890	348225	5956870	5957620	150	267	5 m	1 5x5 mean filter to 3
5	G57DEM.img	346890	348225	5956870	5957620	150	267	5 m	1 7x7 mean filter to 4
6	Q05DEM.img	347520	348225	5956870	5957620	150	141	5 m	Subset of E 1/2 only
7	Q05DEMa.img	347520	348225	5956870	5957620	150	141	5 m	ASCII Export of 6

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

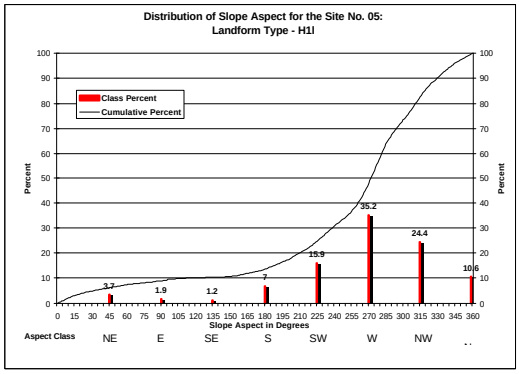




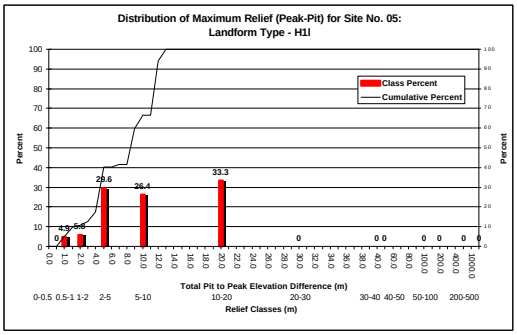
Site No: 05 Gibbons East Site Landform Type:R2l



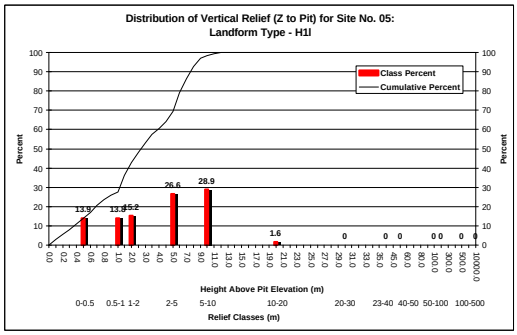
a) Slope gradient (%)



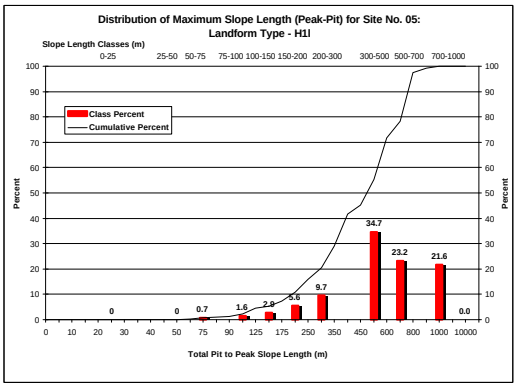
b) Slope aspect (degrees)



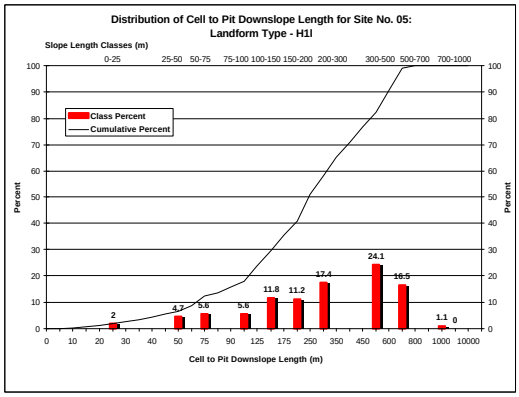
c) Descriptive relief (pit to peak) (m)



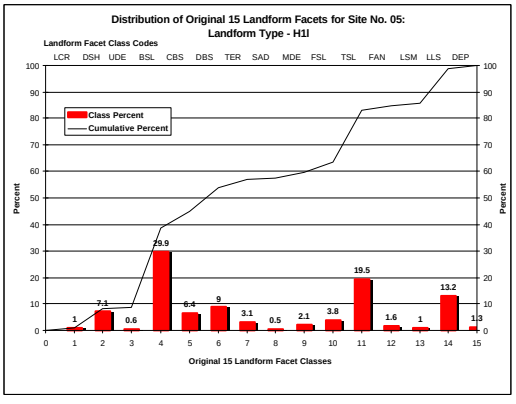
d) Effective relief (cell to pit) (m)



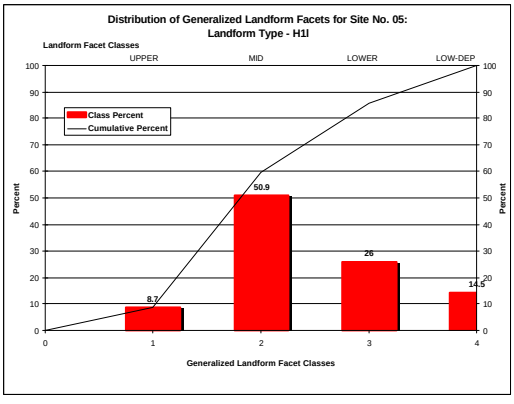
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



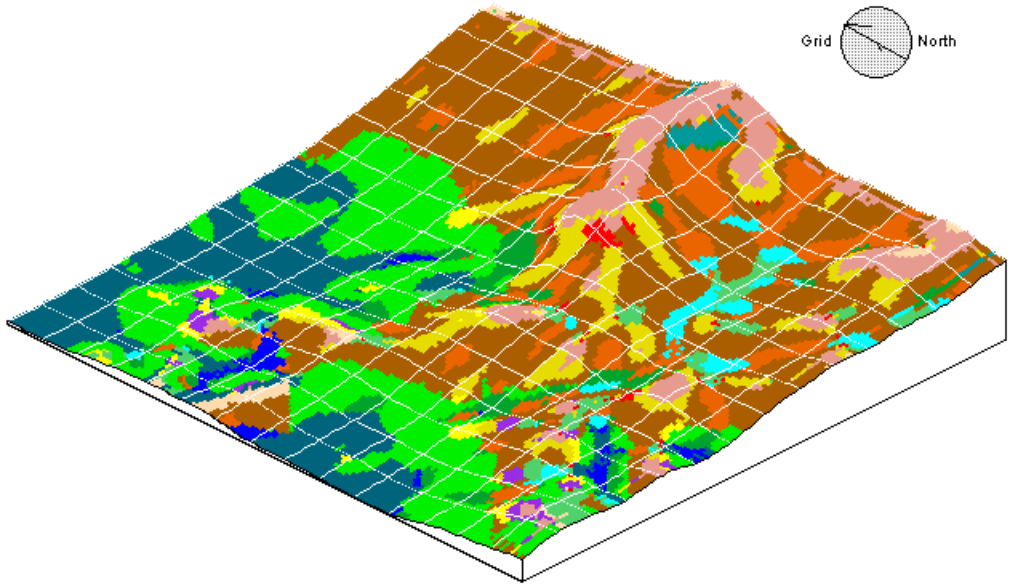
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

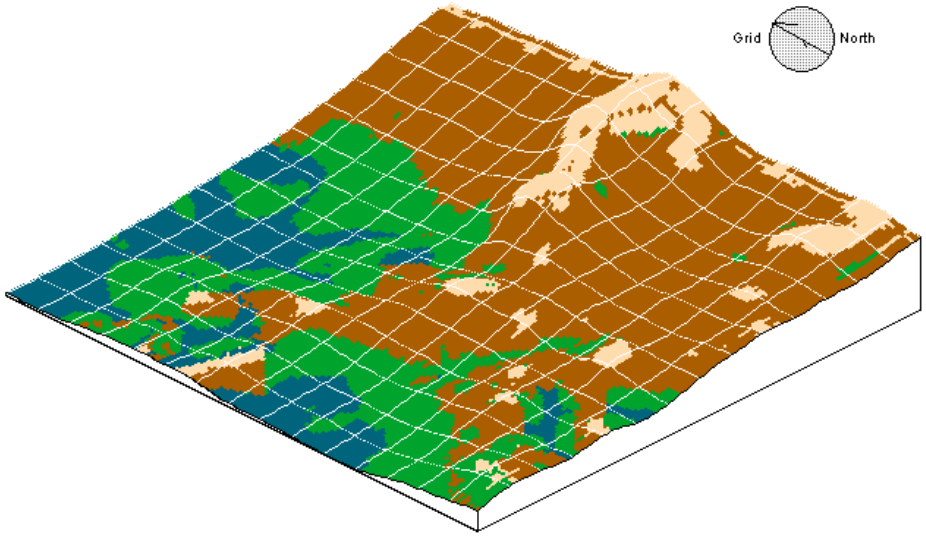
Site No: 05 **Gibbons East Site** **Landform Type: R2l**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
6.8	2.3	0.0	26.4	1.3	2.0	21.9	0.0	2.9	1.8	7.6	0.4	0.5	25.5	0.5



a) 3D view of the Gibbons Site E 1/2: 15 unit landform classification - no post classification modal filters.

UNIT	COLOR	AREA (%)	SLOP 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		9.1	0.76	1.29	166.7	412.5	2.88
MID		54.5	0.92	1.50	125.9	350.2	2.14
LOW		10.3	1.15	1.58	46.1	161.5	0.76
DEP		26.0	0.45	0.67	36.4	130.9	0.47



b) 3D view of the Gibbons Site E 1/2: 4 unit landform element generalization - no post classification modal filters.

SITE NO. 06 Landform Type: H1m

Site Identification: Stettler Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	363180	364010	5792125	9792580

Legal Location	Site Name	Landform Type	Comments
NW-18-38-21-W4	Stettler	M1h	Good example of knob & kettle hummocky topography

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	5.5%	8.0%	5.0-9.0%	2.0-5.0%
Descriptive Relief (Pit to Peak) (m)	4.4 m	6.0 m	2-5 m	5-10 m
Effective Relief (Cell to Pit) (m)	2.1 m	3.5 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	111.5 m	150 m	100-150 m	75-100 m
Effective Slope Length (Cell to Pit m)	58.3 m	90 m	25-50 m	50-75 m
No. Watersheds per 100 ha	87/ 100 ha			
Percent Off-site Drainage	4.8%			

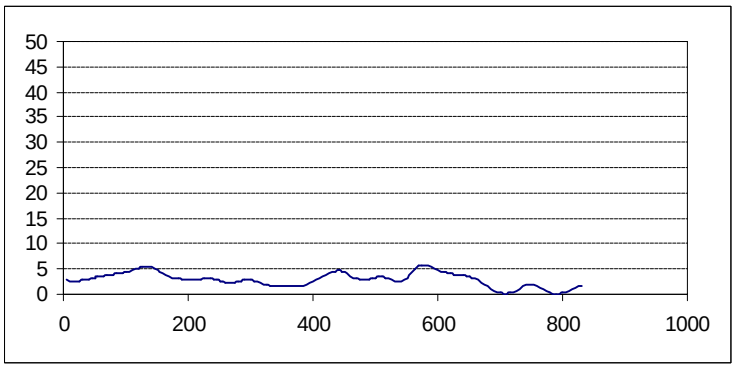
Origin and pre-processing of original DEM X, Y, Z data

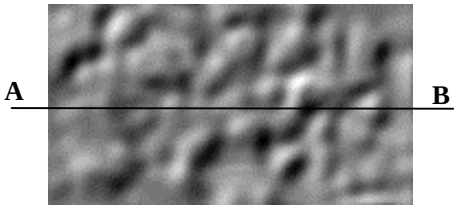
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	G. Lohstraeter	Differential GPS Field Survey	S2GPS	18,776
DEM Surfacing:	AAFRD	S. Nolan	GRASS Thin Plate Spline (TPS)	S2DEM.img	15,106
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	S2DEM.img	15,106

Evolution of the DEM from initial X, Y, Z data to final working surface

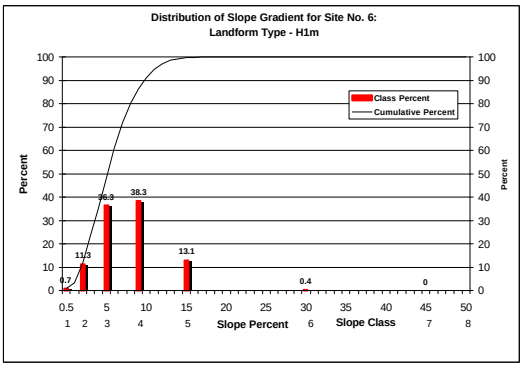
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	S2DEM.img	363179	364007	5792124	5792578	91	166	5 m	Smoothed by TPS
2	ST13DEM.img	363179	364007	5792124	5792578	91	166	5 m	Convert mm to m
3	H1mDEM.img	363179	364007	5792124	5792578	91	166	5 m	Identical to 2
4	H1mDEM.txt	363179	364007	5792124	5792578	91	166	5 m	ASCII export file
5	S06DEM3m	363179	364007	5792124	5792578	91	166	5 m	Filtered with 3x3 mean
6	S06DEM3a	363179	364007	5792124	5792578	91	166	5 m	ASCII version of 5
7									

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

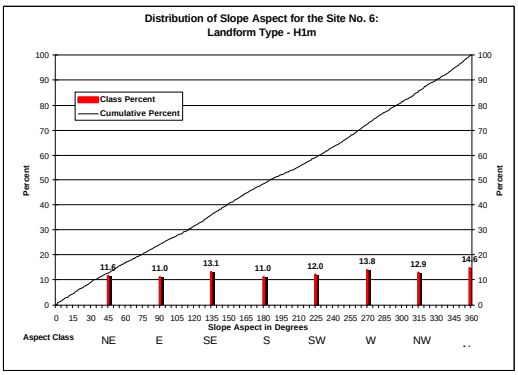




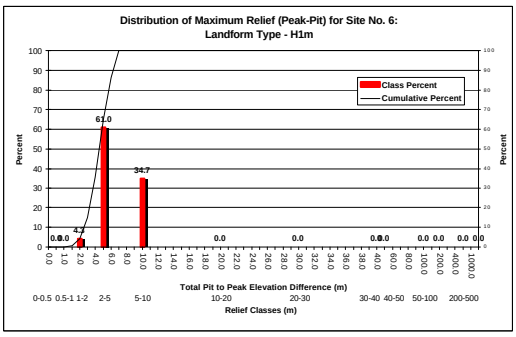
Site No: 06 Stettler Site Landform Type: H1m



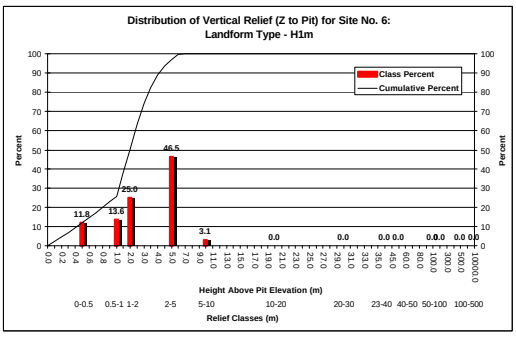
a) Slope gradient (%)



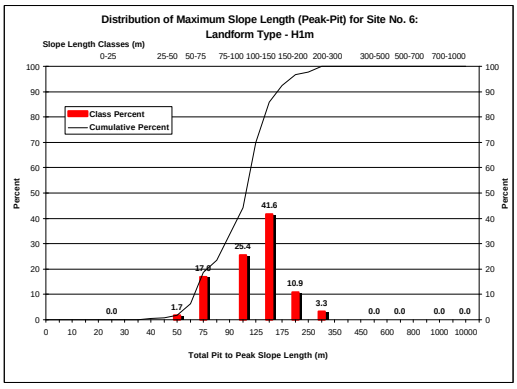
b) Slope aspect (degrees)



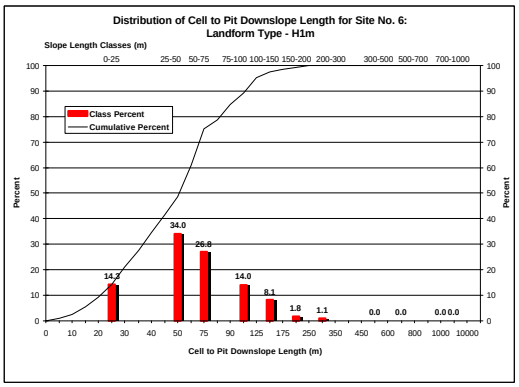
c) Descriptive relief (pit to peak) (m)



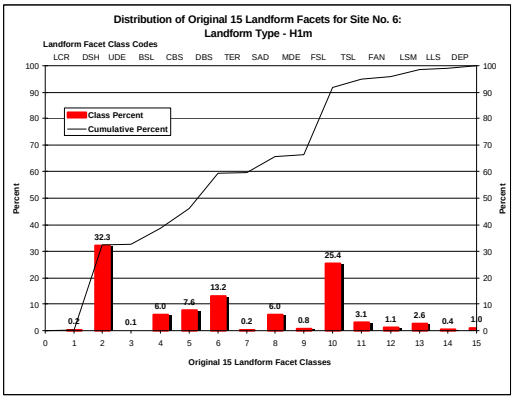
d) Effective relief (cell to pit) (m)



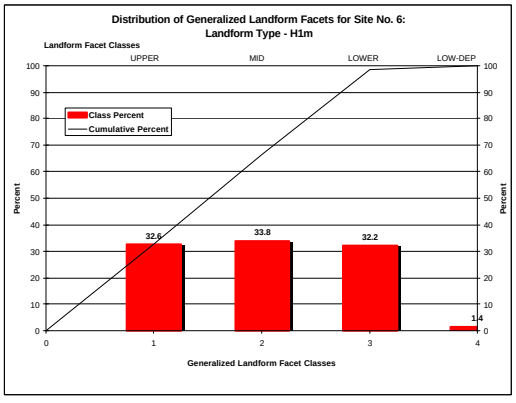
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



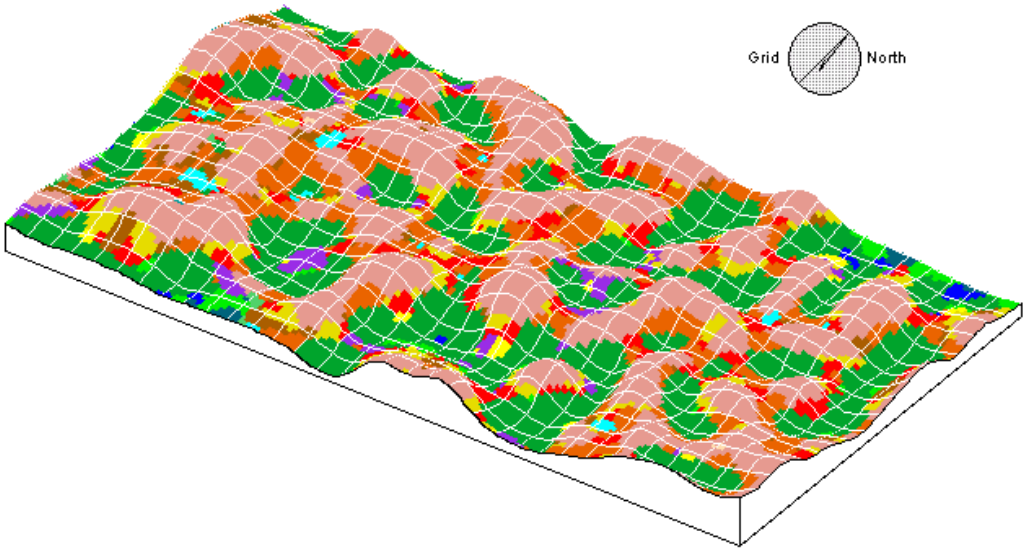
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

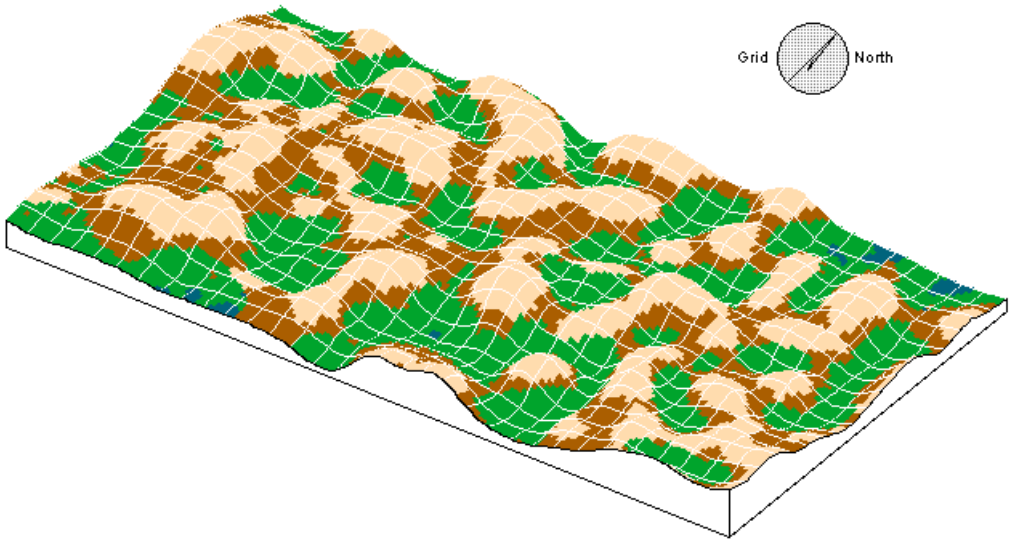
Site No: 06 **Stettler Site** **Landform Type: H1m**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
0.2	32.3	0.1	6.0	7.6	13.2	0.2	6.0	0.8	25.4	3.1	1.1	2.6	0.4	1.0



a) 3D view of the Stettler Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UP		32.6	5.45	8.43	62.3	95.8	6.6
MID		33.8	5.75	8.61	60.8	88.1	5.6
LOW		32.2	4.42	6.91	28.9	50.4	4.7
DEP		1.4	0.72	1.04	28.4	46.2	1.1



b) 3D view of the Stettler Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 07 Landform Type: H1h

Site Identification: Rumsey Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	386562	387542	5751767	5752642

Legal Location	Site Name	Landform Type	Comments
S16, N9,-34-19-W4	Rumsey Site	H1h	Excellent example of strong knob & kettle topography

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	15.5%	24.0%	15.0 -30.0%	9.0 -15.0%
Descriptive Relief (Pit to Peak) (m)	18.4 m	25.0 m	10-20 m	20-30 m
Effective Relief (Cell to Pit) (m)	9.4 m	16.0 m	10-20 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	181.1 m	250 m	150-200 m	200-300 m
Effective Slope Length (Cell to Pit m)	100.3 m	150 m	100-150 m	50-75 m
No. Watersheds per 100 ha	56.8/ 100 ha			
Percent Off-site Drainage	9.7 %			

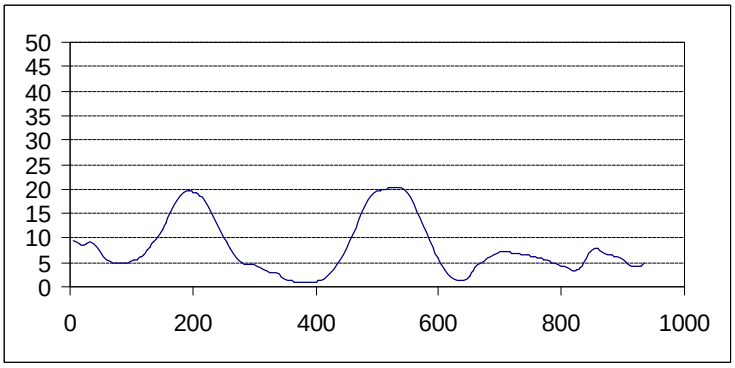
Origin and pre-processing of original DEM X, Y, Z data

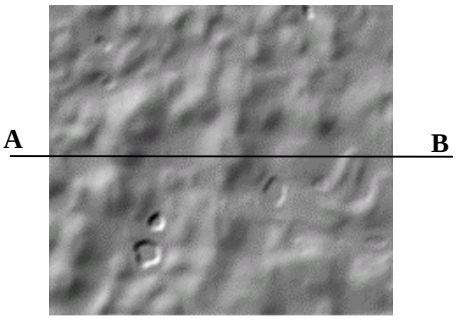
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	3419w4.txt	38,211
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fit MQE surface	3419w45m.img	36,381
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q07DEM.img	34,496

Evolution of the DEM from initial X, Y, Z data to final working surface

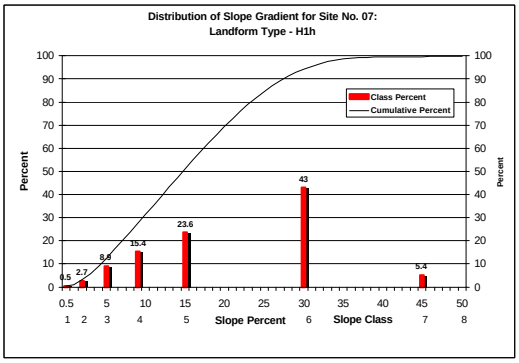
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	3419w45m.img	386522	387557	5751752	5752652	181	201	5 m	Exact fit, no filter
2	3419fix5.img	386522	387557	5751752	5752652	181	201	5 m	Fix pond problems
3	3419f5m3.img	386522	387557	5751752	5752652	181	201	5 m	1, 3x3 mean to 2
4	H1hDEM.img	386562	387542	5751767	5752642	176	196	5 m	Sub-set of 3
5	Q07DEM.img	386562	387542	5751767	5752642	176	196	5 m	ASCII export file
									Identical to 4

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

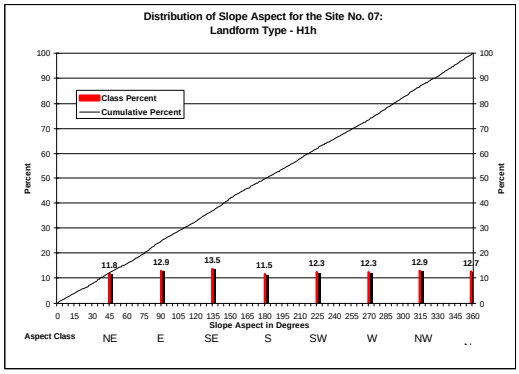




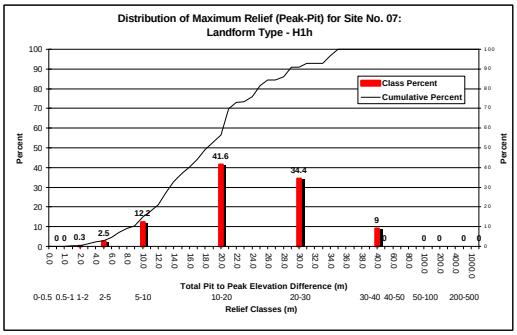
Site No: 07 Rumsey Site Landform Type:H1h



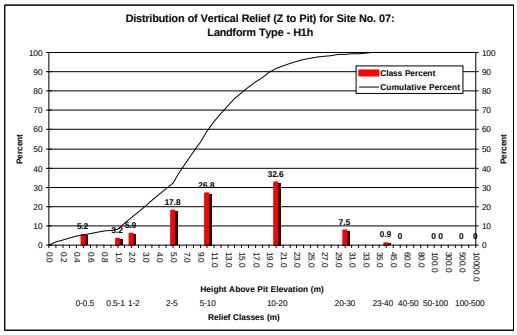
a) Slope gradient (%)



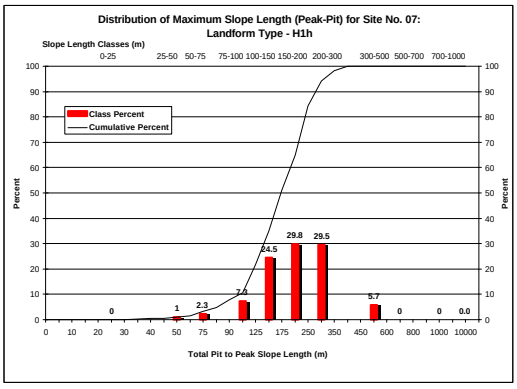
b) Slope aspect (degrees)



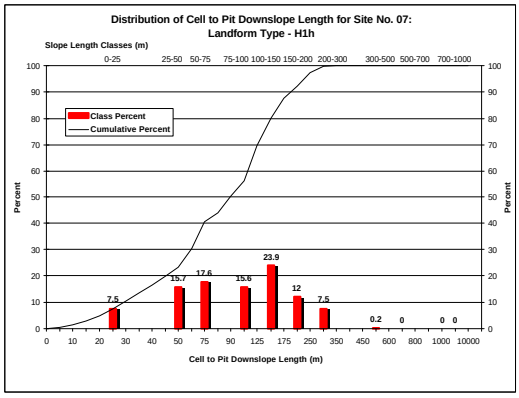
c) Descriptive relief (pit to peak) (m)



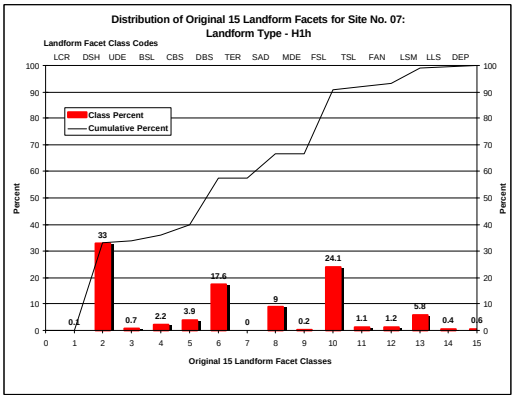
d) Effective relief (cell to pit) (m)



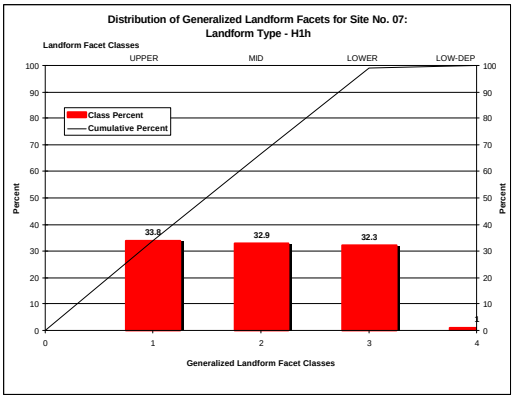
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



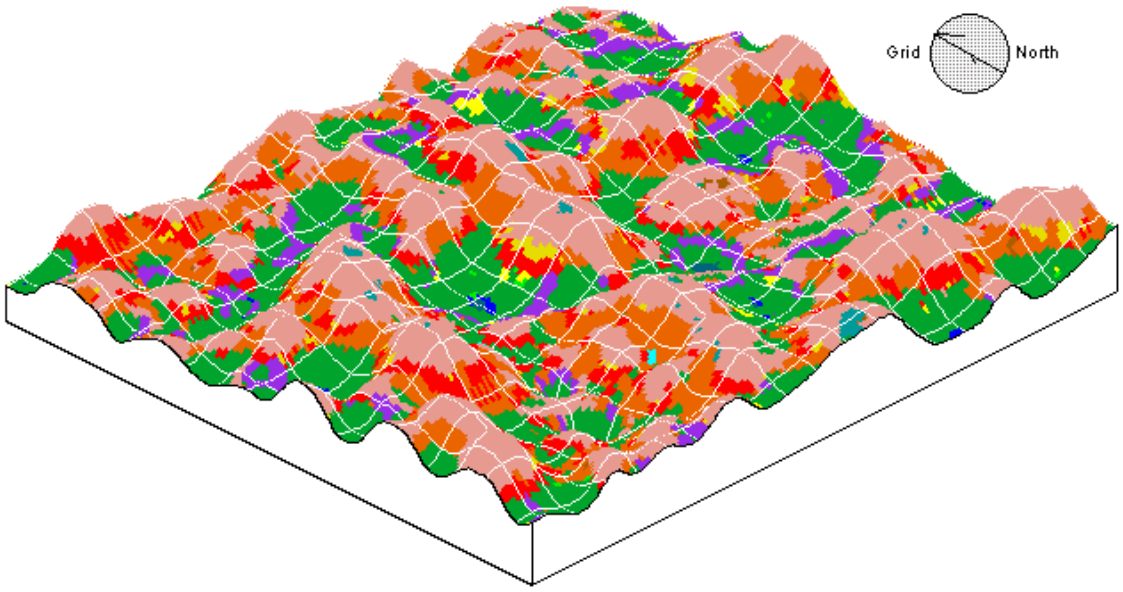
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

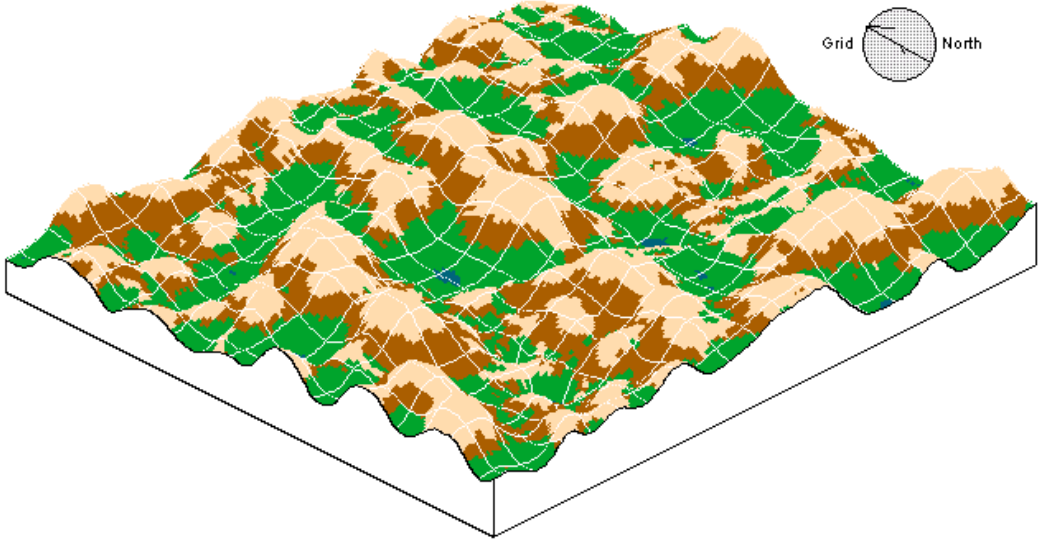
Site No: 07 **Rumsey Site** **Landform Type: H1h**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
0.1	33.0	0.7	2.2	3.9	17.6	0.0	9.0	0.2	24.1	1.1	1.2	5.8	0.4	0.6



a) 3D view of the Runsey Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		33.8	15.7	24.1	78.9	179.1	19.8
MID		32.9	18.6	25.8	66.4	154.6	14.6
LOW		32.3	10.8	17.9	25.0	82.2	5.3
DEP		1.0	0.6	1.3	7.1	32.3	0.7



b) 3D view of the Rumsey Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 08 Landform Type: M1l

Site Identification: Haynes Creek Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	323785	324605	5810397	5811637

Legal Location	Site Name	Landform Type	Comments
NE6 SE7, 40-25-W4	Haynes Creek Site	M1l	Agriculture & Agri-Food Canada bench mark site

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	3.4%	5.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	17.0 m	22.0 m	20-30 m	10-20 m
Effective Relief (Cell to Pit) (m)	8.9 m	15.0 m	10-20 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	600.0 m	800 m	700-1000 m	300-500 m
Effective Slope Length (Cell to Pit m)	305.4 m	500 m	300-500 m	200-300 m
No. Watersheds per 100 ha	8.9/ 100 ha			
Percent Off-site Drainage	79.1 %			

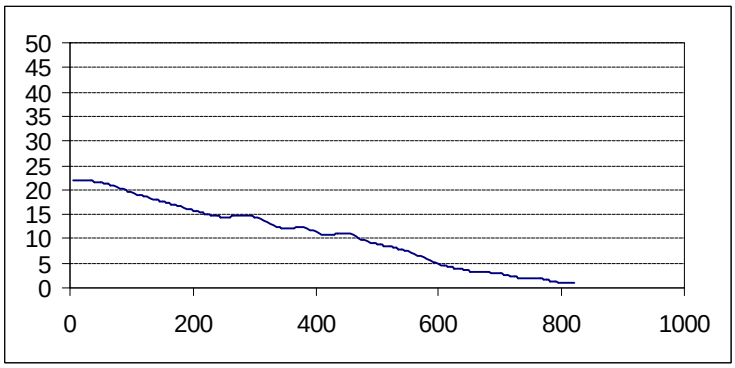
Origin and pre-processing of original DEM X, Y, Z data

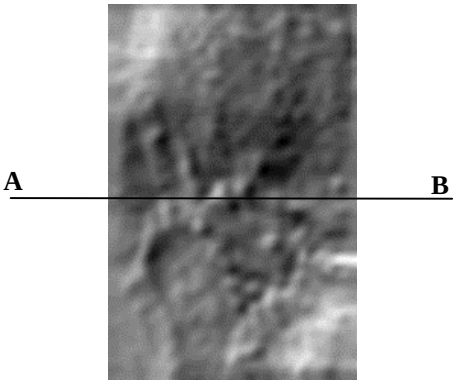
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFC	J. Tajek	Differential GPS Survey	Lacom_pt.txt	12,321
DEM Surfacing:	LandMapper	P. Smith	ArcView 3 IWD nearest 20	L3DEM.img	40,672
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q08DEM.img	40,672

Evolution of the DEM from initial X, Y, Z data to final working surface

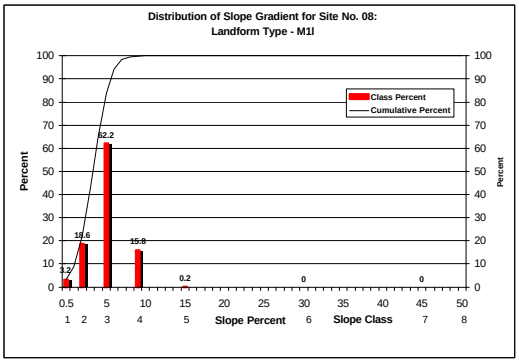
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	L3DEM.img	323785	324605	5810397	5811367	248	164	5 m	Initial TPS Surface
2	L3DEM7x.img	323785	324605	5810397	5811367	248	164	5 m	1 7x7 mean to 1
3	L4DEM.img	323785	324605	5810397	5811367	248	164	5 m	1 3x3 mean to 2
4	L4DEM7x.img	323785	324605	5810397	5811367	248	164	5 m	1 3x3, 1 7x7 to 1
5	L4DEM7xa.img	323785	324605	5810397	5811367	248	164	5 m	ASCII export file
6	Q08DEM.img	323785	324605	5810397	5811367	248	164	5 m	Identical to 4&5

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

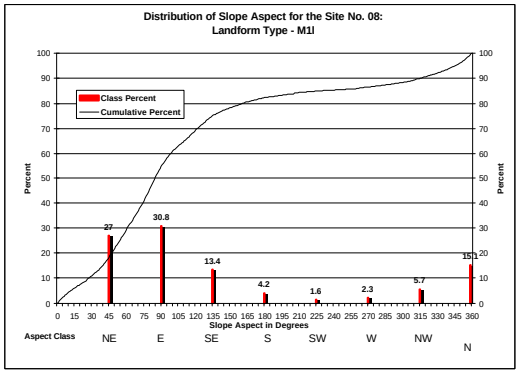




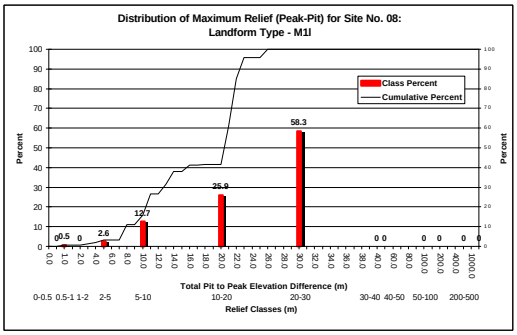
Site No: 08 Haynes Creek Site Landform Type: M1l



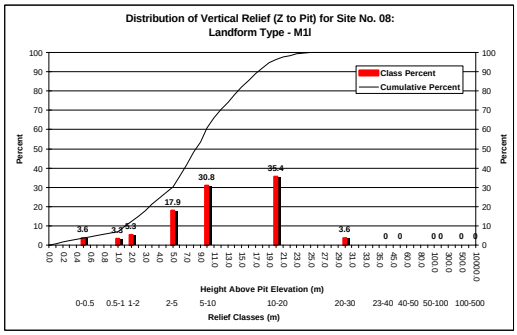
a) Slope gradient (%)



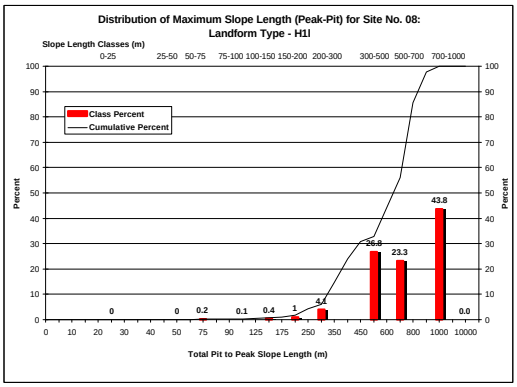
b) Slope aspect (degrees)



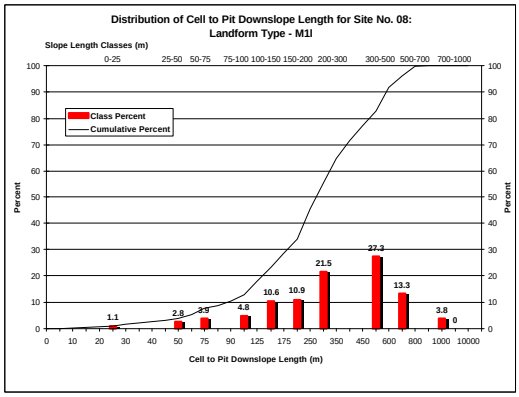
c) Descriptive relief (pit to peak) (m)



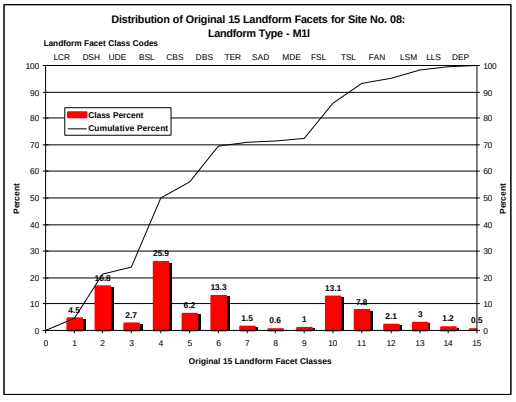
d) Effective relief (cell to pit) (m)



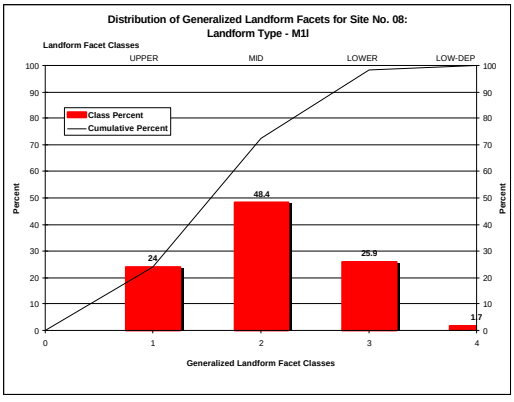
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



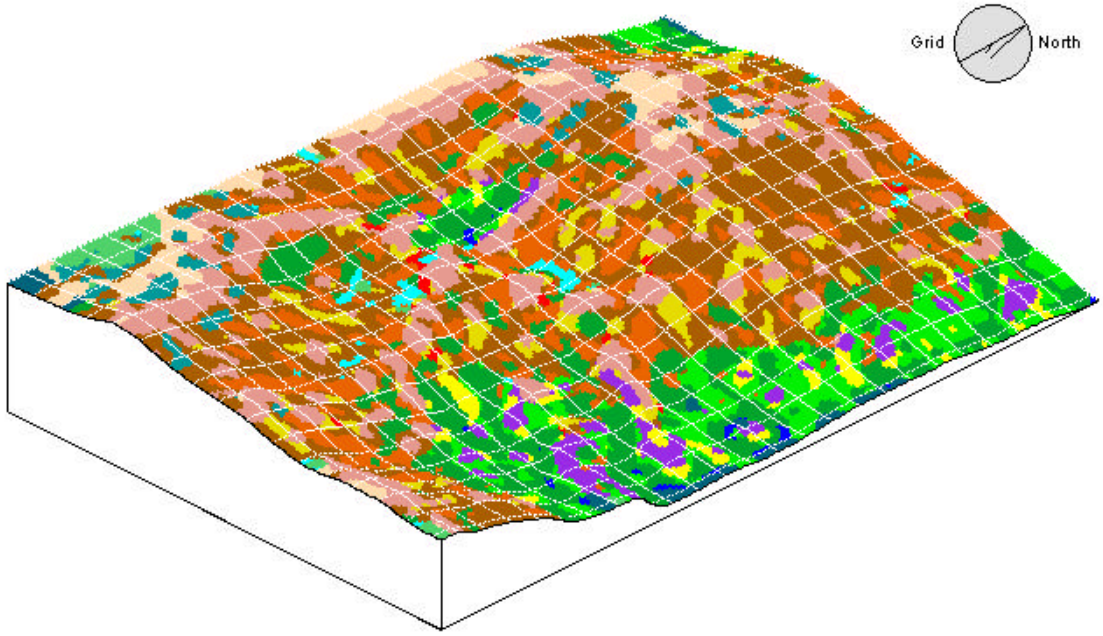
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

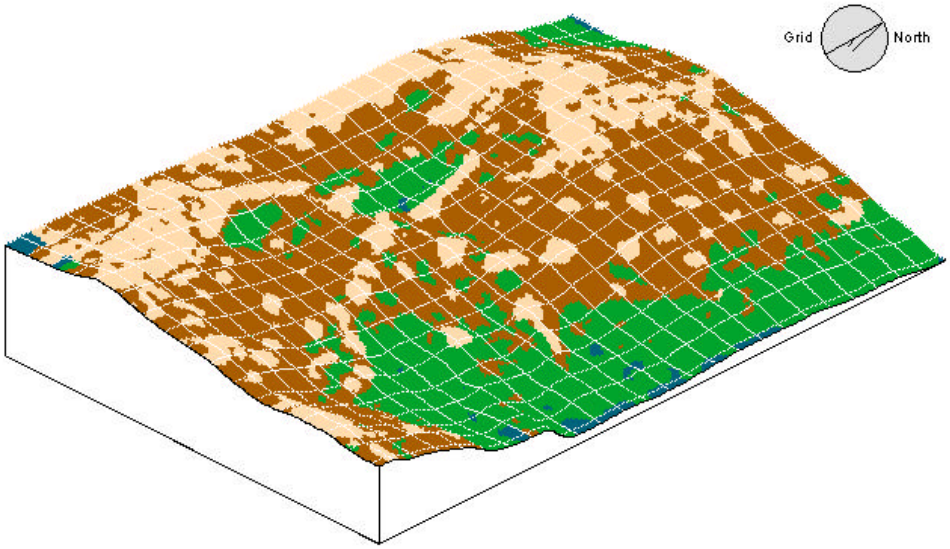
Site No: 08 **Haynes Creek Site** **Landform Type: M1l**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
1.9	16.7	1.4	24.7	7.2	10.2	2.2	0.9	1.7	13.9	10.2	1.8	2.4	3.1	1.6



a) 3D view of the Haynes Creek Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		20.0	2.38	3.63	81.1	285.9	6.62
MID		46.9	2.55	3.61	76.9	241.2	5.45
LOW		28.3	2.27	3.46	29.2	103.5	1.61
DEP		4.7	0.7	0.89	15.8	75.2	0.69



b) 3D view of the Haynes Creek Site: 4 unit landform element generalization - 1 5x5 post classification modal filter

SITE NO. 09 Landform Type: M1h

Site Identification: Hussar Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	395264	396152	5671313	5672078

Legal Location	Site Name	Landform Type	Comments
S ½ 5&6, 26-18-W4	Hussar Site	M1h	Alberta Agriculture precision farming research site

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	7.4%	11.0%	5.0 -9.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	23.5 m	34.0 m	30-40 m	10-.20 m
Effective Relief (Cell to Pit) (m)	10.5 m	18.0 m	5-10 m	10-20 m
Descriptive Slope Length (Pit to Peak m)	416.7 m	600 m	300-500 m	500-700 m
Effective Slope Length (Cell to Pit m)	211.0 m	350 m	300-500 m	200-300 m
No. Watersheds per 100 ha	19.1/ 100 ha			
Percent Off-site Drainage	59.0 %			

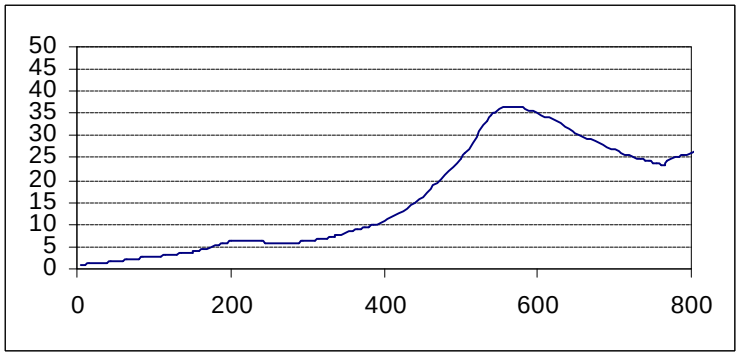
Origin and pre-processing of original DEM X, Y, Z data

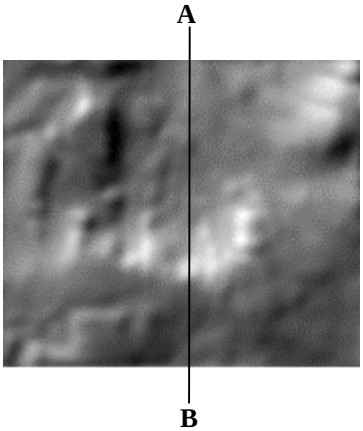
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	G. Lohstraeter	Differential GPS Field Survey	HussXYZ.txt	39,215
DEM Surfacing:	AAFRD	S. Nolan	GRASS TPS (Spline)	HussDEM6.img	31,374
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q09DEM.img	27,234

Evolution of the DEM from initial X, Y, Z data to final working surface

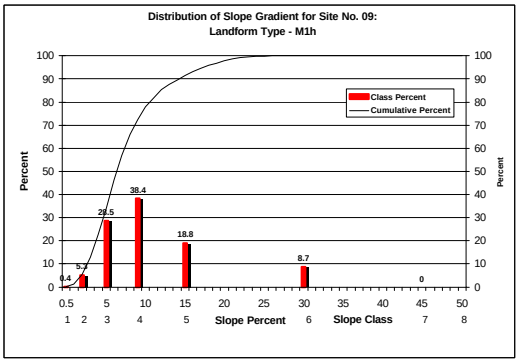
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Hussdem6.img	395239	396182	5671283	5672113	166	189	5 m	Starting TPS surface
2	Hussdem7.img	395239	396182	5671283	5672113	166	189	5 m	Convert mm to m
3	HS1_dem.img	395264	396152	5671313	5672078	153	178	5 m	Sub-set of 2
4	HS2_dem.img	395264	396152	5671313	5672078	153	178	5 m	1, 3x3 mean to 3
5	HS3_dem.img	395264	396152	5671313	5672078	153	178	5 m	1, 3x3 mean to 4
6	HS4_dem.img	395264	396152	5671313	5672078	153	178	5 m	1, 3x3 mean to 5
7	Q09dem.img	395264	396152	5671313	5672078	153	178	5 m	6 Exported to ASCII

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

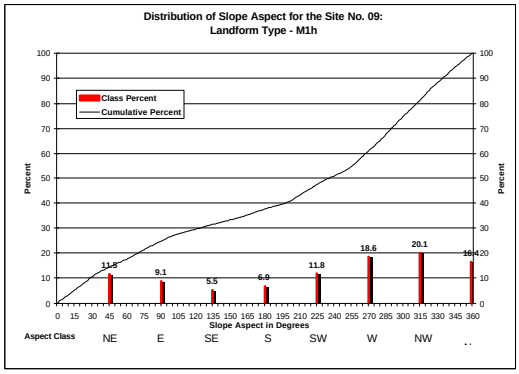




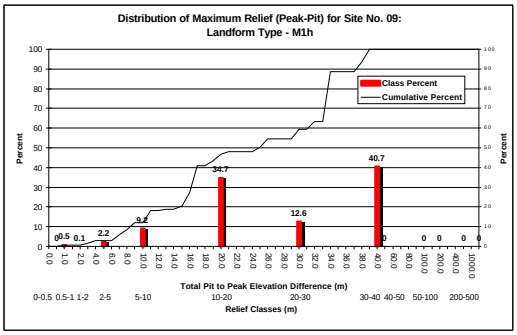
Site No: 09 Hussar Site Landform Type: M1h



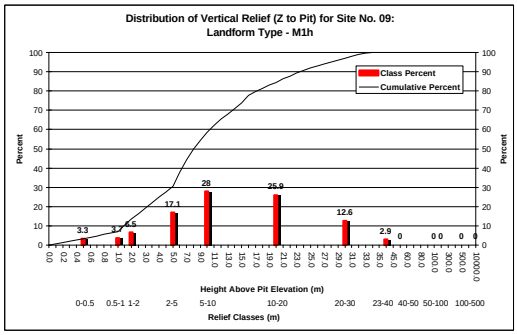
a) Slope gradient (%)



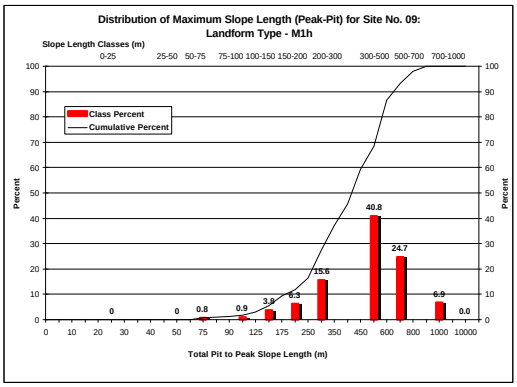
b) Slope aspect (degrees)



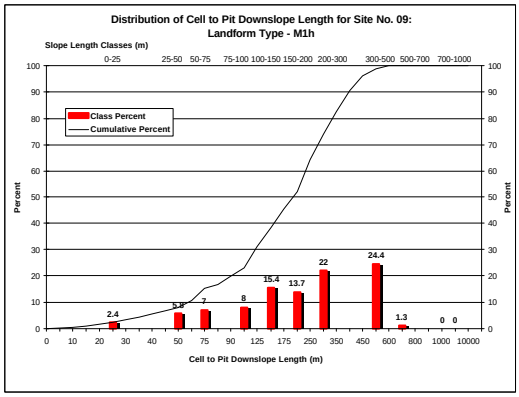
c) Descriptive relief (pit to peak) (m)



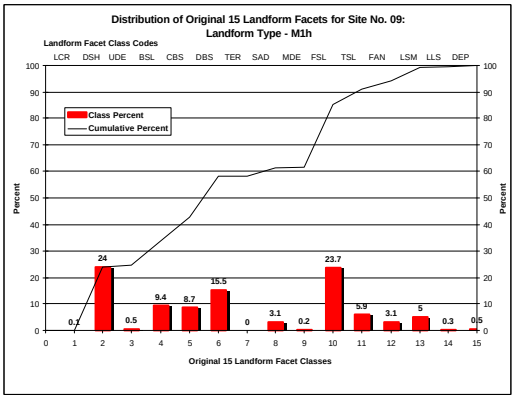
d) Effective relief (cell to pit) (m)



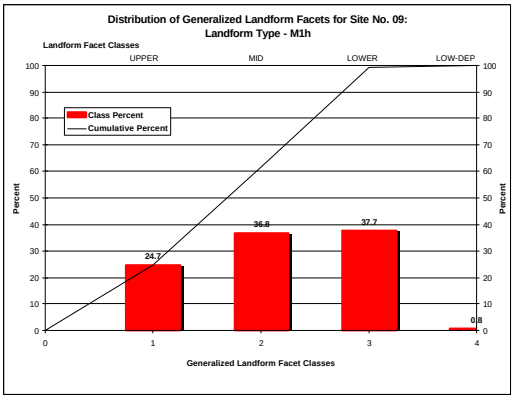
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



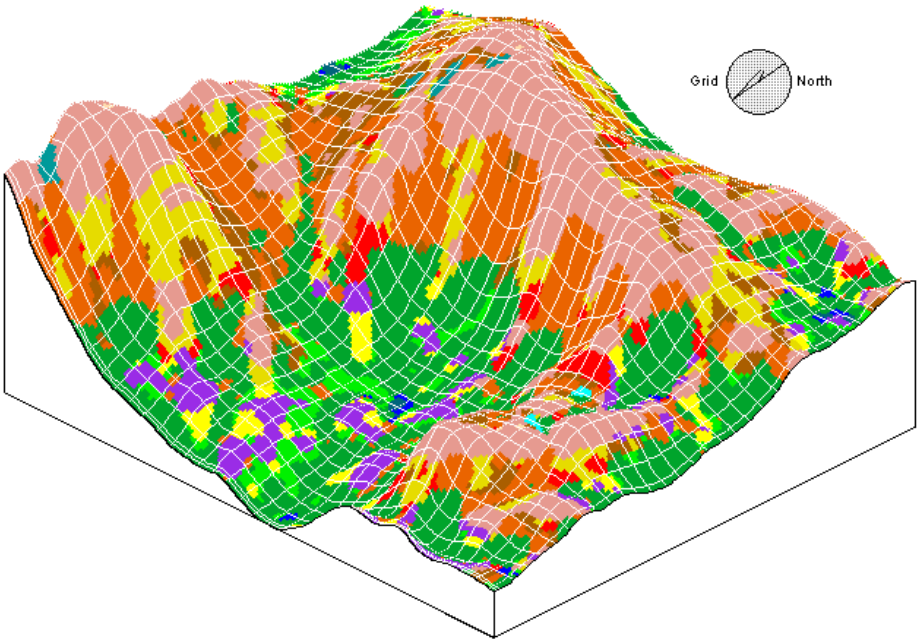
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

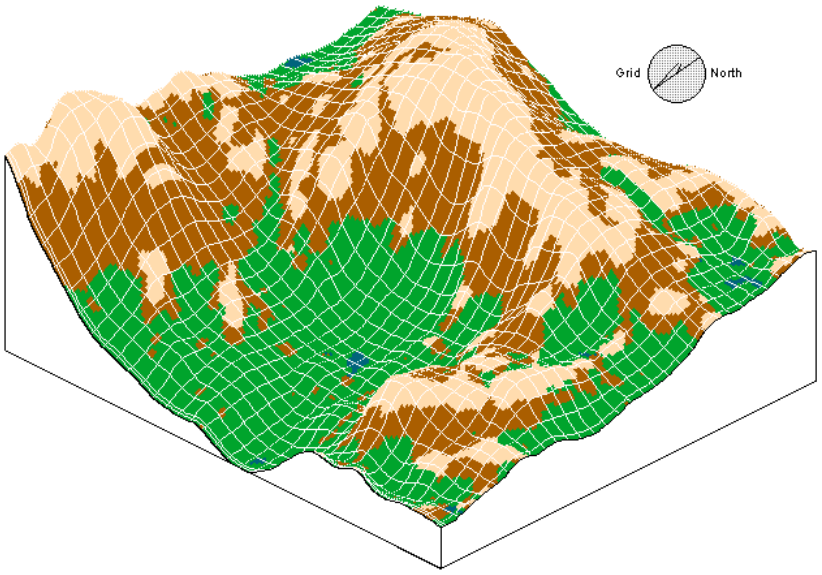
Site No: 09 **Hussar Site** **Landform Type: M1h**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
0.1	24.0	0.5	9.4	8.7	15.5	0.0	3.1	0.2	23.7	5.9	3.1	5.0	0.3	0.5



a) 3D view of the Hussar Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		24.7	6.8	11.8	159.4	388.0	27.6
MID		36.8	7.7	12.9	138.8	363.5	18.8
LOW		37.7	5.2	7.8	52.6	192.2	6.9
DEP		0.8	0.8	1.3	15.8	61.0	0.9



b) 3D view of the Hussar Site: 4 unit landform element generalization - 1 5x5 post classification modal filter

SITE NO. 10 Landform Type: I3h

Site Identification: Cypress Hills Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	549915	551590	5498425	5500595

Legal Location	Site Name	Landform Type	Comments
14-08-03-W4	Provost Site	I3h	Long, steep, gullied slopes coming off the Cypress Hills

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	19.8 %	30.0%	15.0 -30.0%	9.0 -15.0%
Descriptive Relief (Pit to Peak) (m)	149.7 m	200.0 m	100-200 m	50-100 m
Effective Relief (Cell to Pit) (m)	88.2 m	200.0 m	100-200 m	50-100 m
Descriptive Slope Length (Pit to Peak m)	2175.8 m	> 1000 m	> 1000 m	300-500 m
Effective Slope Length (Cell to Pit m)	1345.1 m	> 1000 m	> 1000 m	700-1000 m
No. Watersheds per 100 ha	2.7/ 100 ha			
Percent Off-site Drainage	70.5 %			

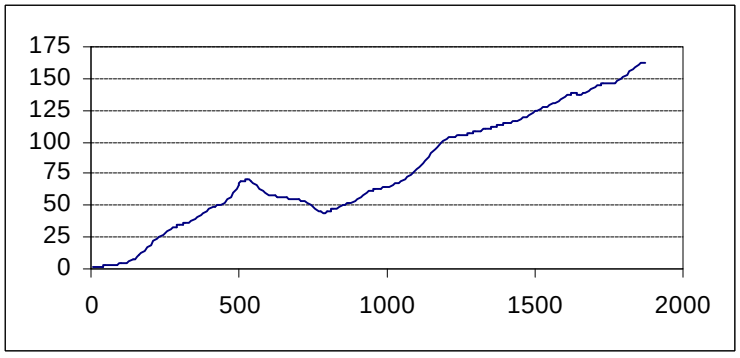
Origin and pre-processing of original DEM X, Y, Z data

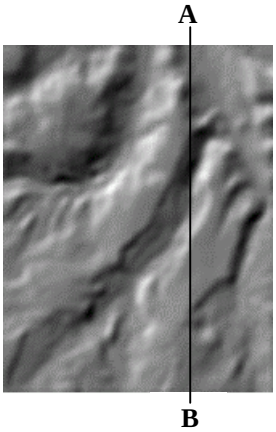
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	0803W4.txt	
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE	0803W4.img	155,803
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q10DEM.img	36,239

Evolution of the DEM from initial X, Y, Z data to final working surface

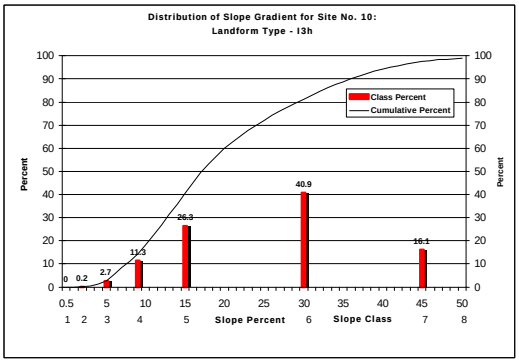
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	0803w4.img	549890	551620	5498370	5500610	449	347	5 m	QSURF surface
2	0803f.img	549890	551620	5498370	5500610	449	347	5 m	1, 3x3 mean to 1
3	I3hDEM.img	549915	551590	5498425	5500595	435	336	5 m	Sub-set of 2
4	Q10dem10.img	549915	551590	5498425	5500595	217	167	10 m	Aggregate 3 to 10 m
5	Q10dem5m.img	549915	551590	5498425	5500595	217	167	10 m	1, 3x3 mean to 4
6	Q10dem5a.img	549915	551590	5498425	5500595	217	167	10 m	ASCII export of 5
7	Q10dem.img	549915	551590	5498425	5500595	217	167	10 m	Same as 6, used in LSM

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

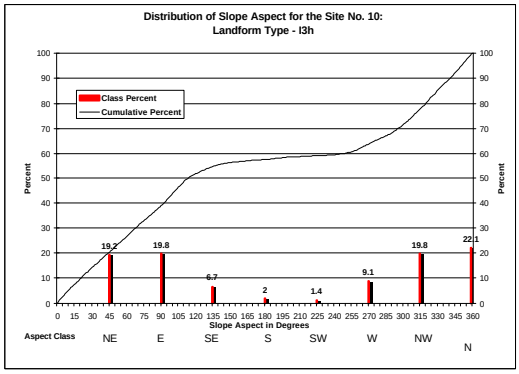




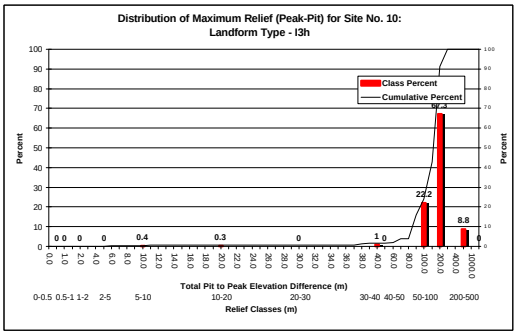
Site No: 10 Cypress Hills Site Landform Type: I3h



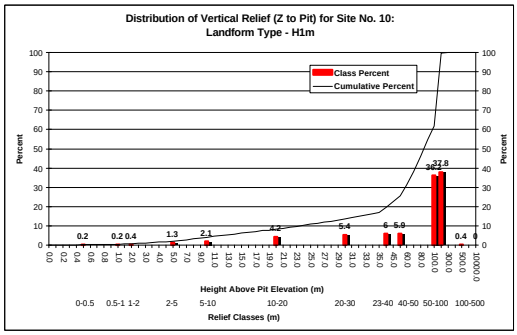
a) Slope gradient (%)



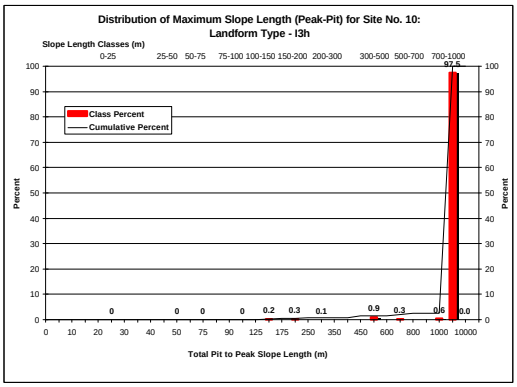
b) Slope aspect (degrees)



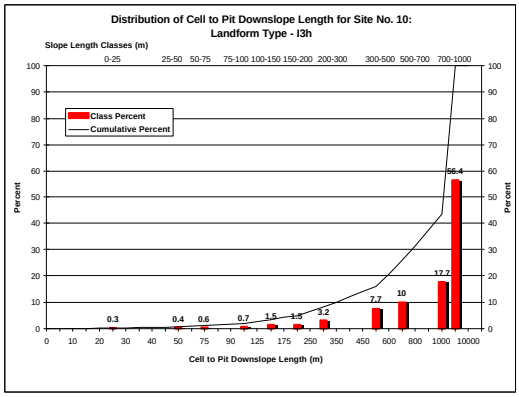
c) Descriptive relief (pit to peak) (m)



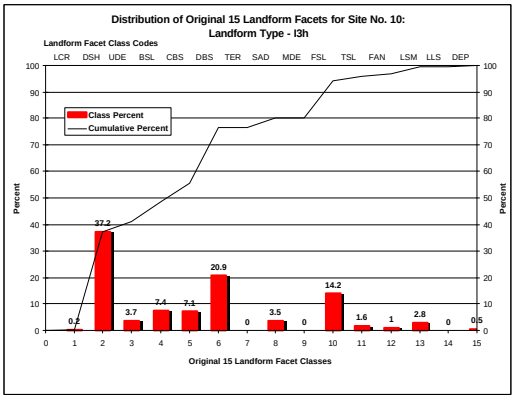
d) Effective relief (cell to pit) (m)



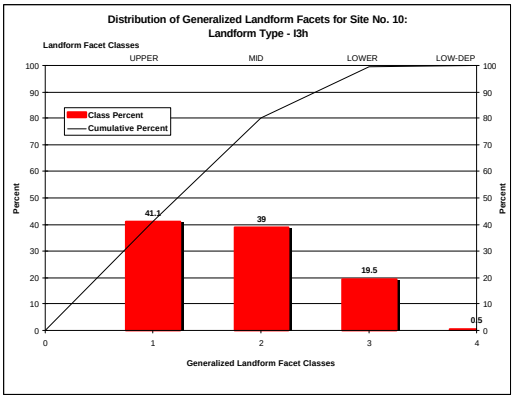
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



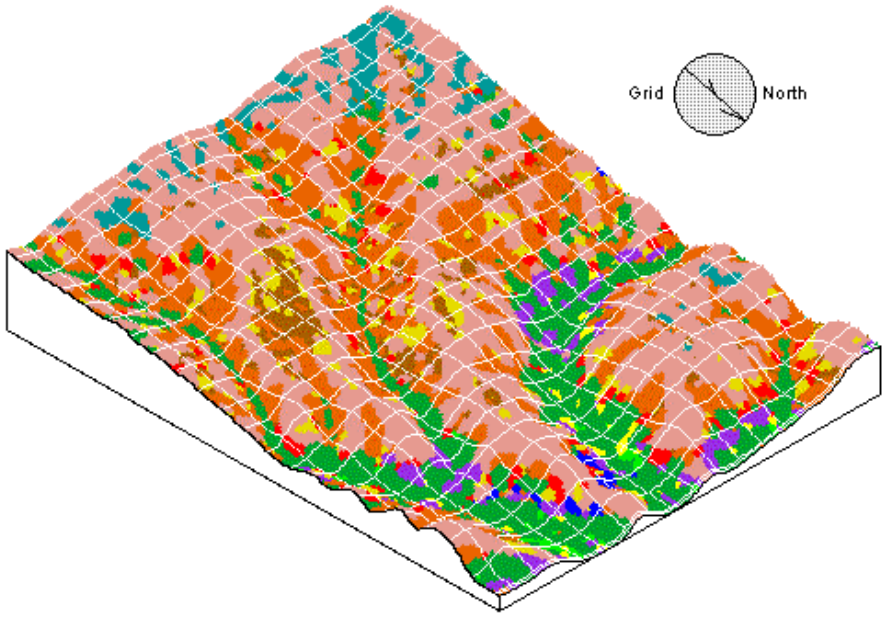
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

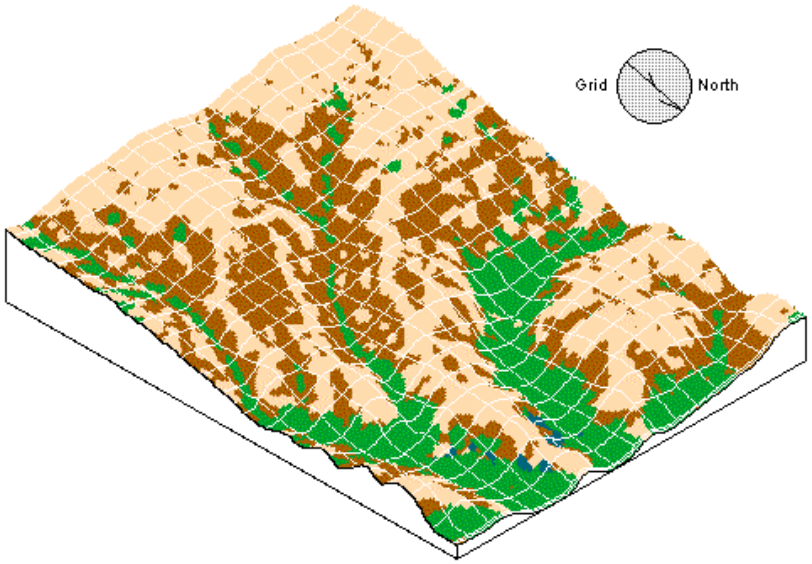
Site No: 10 Cypress Hills Site Landform Type: I3h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
0.2	37.2	3.7	7.4	7.1	20.9	0.0	3.5	0.0	14.2	1.6	1.0	2.8	0.0	0.5



a) 3D view of the Cypress Hills Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		41.1	15.8	26.9	866.7	2570.9	163.3
MID		39.0	18.9	31.3	714.1	2079.2	121.5
LOW		19.5	16.6	28.0	178.5	933.0	50.7
DEP		0.5	26.5	33.6	225.1	394.8	27.3



b) 3D view of the Cypress Hills Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 11 Landform Type: IUh

Site Identification: Medicine Hat Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	554130	556030	5513880	5515880

Legal Location	Site Name	Landform Type	Comments
Sec 33-09-02-W4	Medicine Hat Site	IUh	Selected by AAFC based on air photo suitability

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.5%	4.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	13.0 m	24.0 m	10-20 m	5-10 m
Effective Relief (Cell to Pit) (m)	7.2 m	13.0 m	2-5 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	674.3 m	>1000 m	>1000 m	300-500 m
Effective Slope Length (Cell to Pit m)	390.3 m	700 m	300-500 m	200-300 m
No. Watersheds per 100 ha	11.8/ 100 ha			
Percent Off-site Drainage	47.1 %			

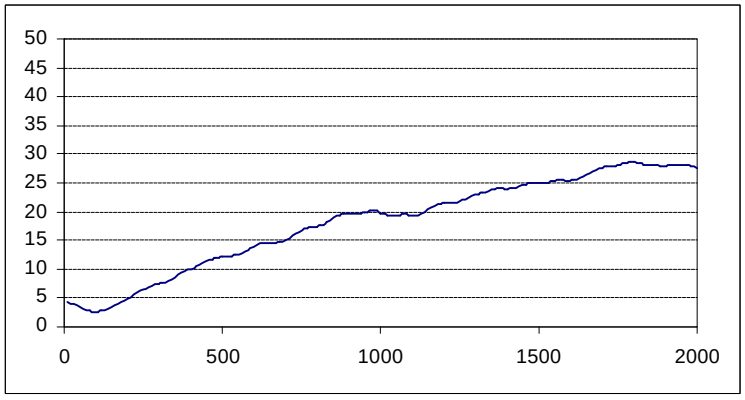
Origin and pre-processing of original DEM X, Y, Z data

Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	0902w4.xyz	38,897
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE	0902w4.img	152,781
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q11dem.img	38,000

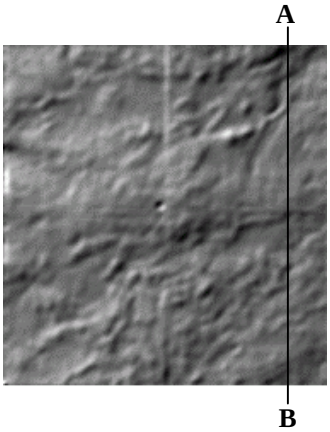
Evolution of the DEM from initial X, Y, Z data to final working surface

DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	0902w4.img	554130	556030	5513880	5515880	401	381	5 m	QSURF MQE surface
2	S92DEMf.img	554130	556030	5513880	5515880	401	381	5 m	3x3 mean filter to 1
3	S92m7x7.img	554130	556030	5513880	5515880	401	381	5 m	7x7 mean filter to 2
4	S9210m.img	554130	556030	5513880	5515880	200	190	10 m	3 aggregated to 10 m
5	S9210ma.img	554130	556030	5513880	5515880	200	190	10 m	ASCII export of 4
6	Q11DEM.img	554130	556030	5513880	5515880	200	190	10 m	Used for LSM

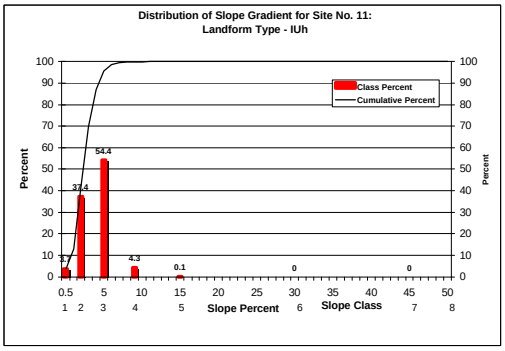
Site Illustration: Schematic Cross Section:



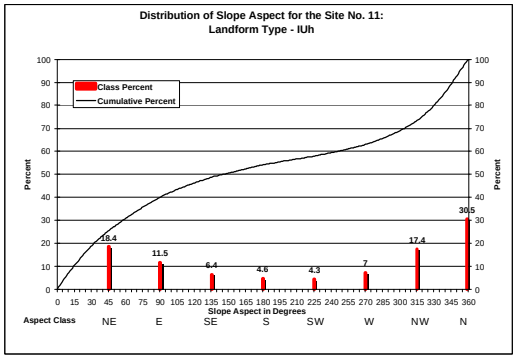
Hillshade of final DEM:



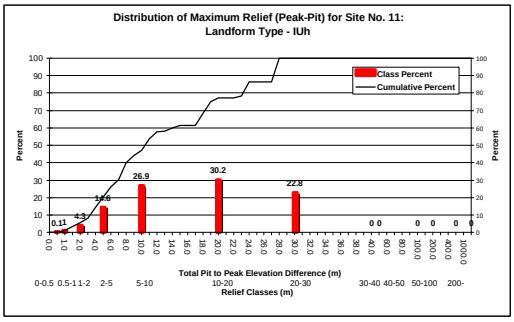
Site No: 11 Medicine Hat Site Landform Type: IUh



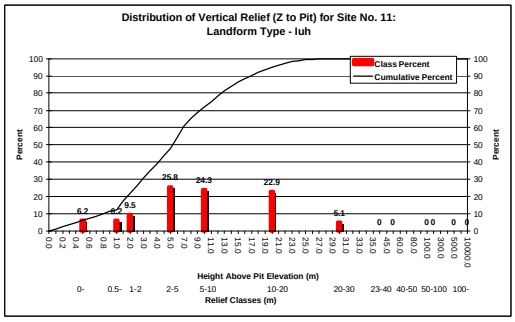
a) Slope gradient (%)



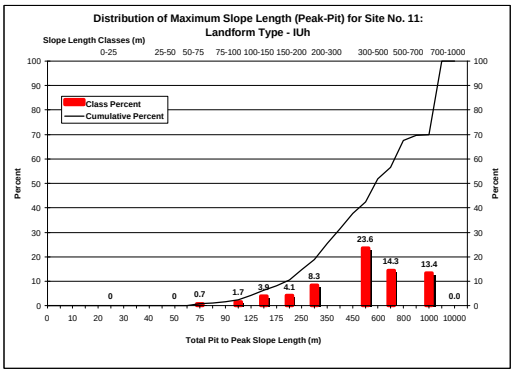
b) Slope aspect (degrees)



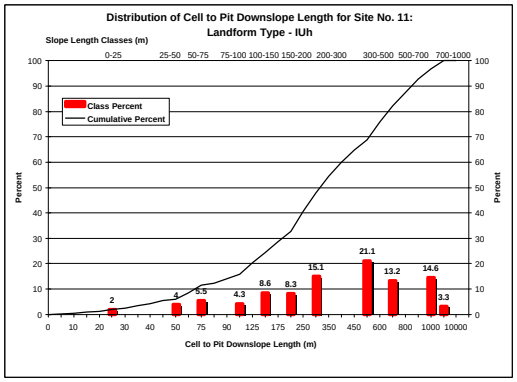
c) Descriptive relief (pit to peak) (m)



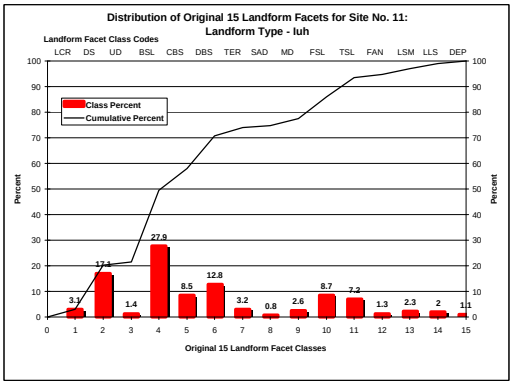
d) Effective relief (cell to pit) (m)



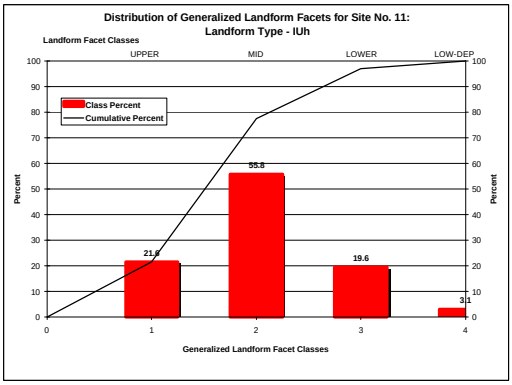
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



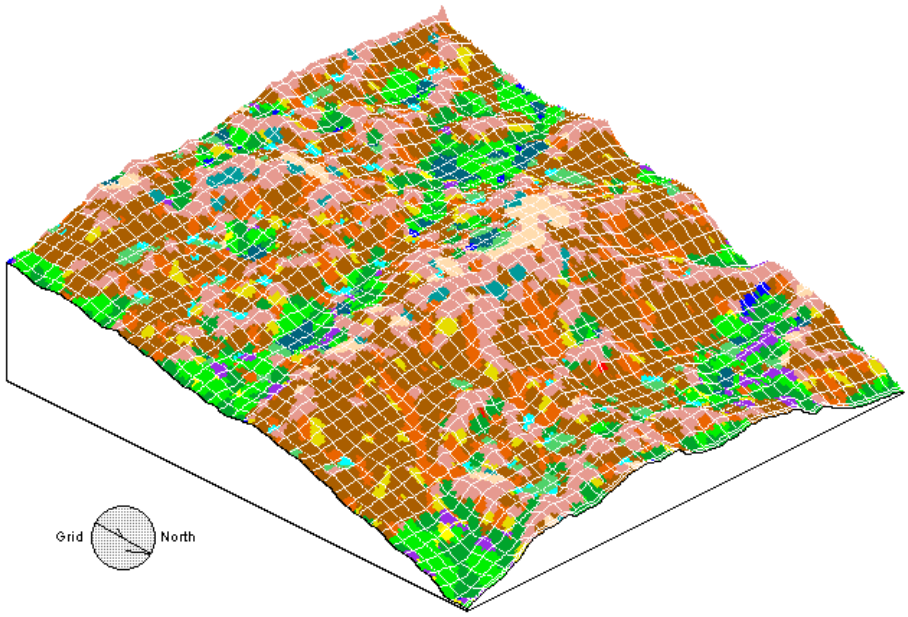
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

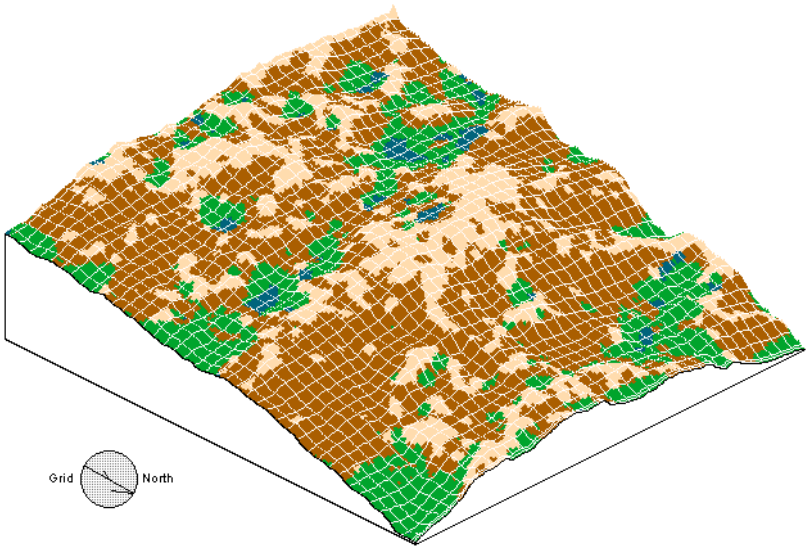
Site No: 11 Medicine Hat Site Landform Type: IUh

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
3.1	17.1	1.4	27.9	8.5	12.8	3.2	0.8	2.6	8.7	7.2	1.3	2.3	2.0	1.1



a) 3D view of the Medicine Hat Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		21.6	2.29	3.57	209.7	881.7	16.9
MID		55.8	2.40	3.60	186.4	701.9	13.1
LOW		19.6	2.19	3.30	50.8	257.8	4.2
DEP		3.1	0.61	0.90	22.5	141.6	0.8



b) 3D view of the Medicine Hat Site: 4 unit landform element generalization - 1 5x5 post classification modal filter

SITE NO. 12 Landform Type: IUl

Site Identification: **Turner Valley Site**

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	**695648**	**697178**	**5616338**	**5617808**

Legal Location	Site Name	Landform Type	Comments
Sec 09-20-02-W5	Turner Valley Site	IUl	Selected by AAFC based on air photo suitability

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.2%	4.0%	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	5.8 m	9.0 m	5-10 m	2-5 m
Effective Relief (Cell to Pit) (m)	3.5 m	6.0 m	2-5 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	432.1 m	700 m	300-500 m	200-300 m
Effective Slope Length (Cell to Pit m)	263.1 m	450 m	200-300 m	300-500 m
No. Watersheds per 100 ha	18.7/ 100 ha			
Percent Off-site Drainage	15.1 %			

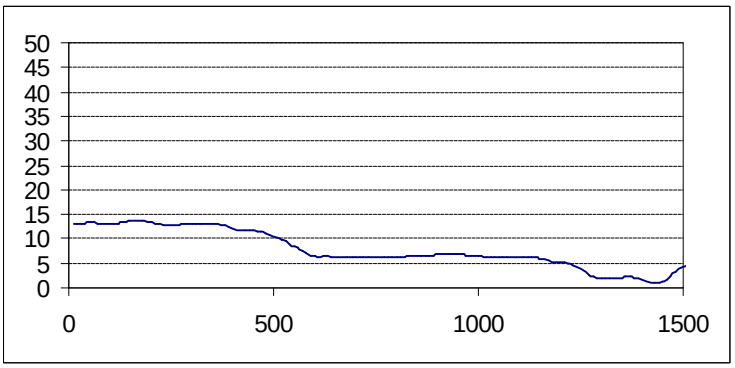
Origin and pre-processing of original DEM X, Y, Z data

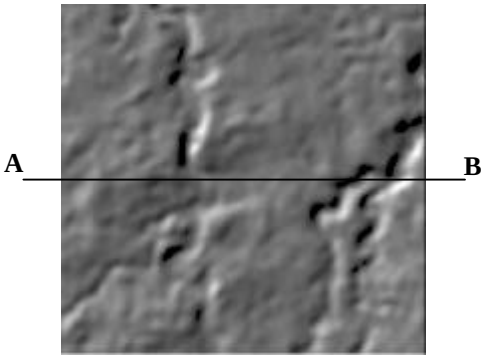
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	2002w5.asc	25,753
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE	Qs2002w5.img	110,889
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Qs10m7a.img	22,491

Evolution of the DEM from initial X, Y, Z data to final working surface

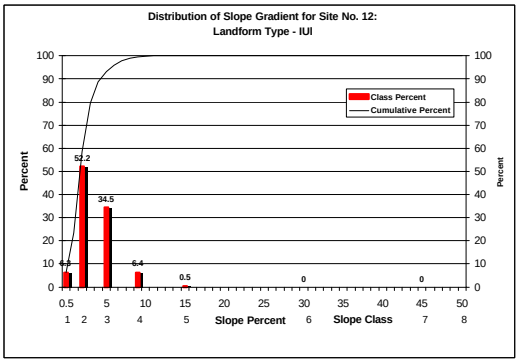
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Qs2002w5.img	695583	697248	5616213	5617878	333	333	5 m	QSURF MQE surface
2	Qs2002ss.img	695648	697183	5616338	5617808	294	307	5 m	Windowed subset of 1
3	Qs200277.img	695648	697183	5616338	5617808	294	307	5 m	7x7 mean filter to 2
4	Qs200275.img	695648	697183	5616338	5617808	294	307	5 m	5x5 mean filter to 3
5	Qa200275.img	695648	697183	5616338	5617808	294	307	5 m	ASCII export of 4
6	Qs10m77.img	695648	697178	5616338	5617808	147	153	10 m	3 aggregated to 10 m
7	Qs10m7a.img	695648	697178	5616338	5617808	147	153	10 m	ASCII export of 6

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

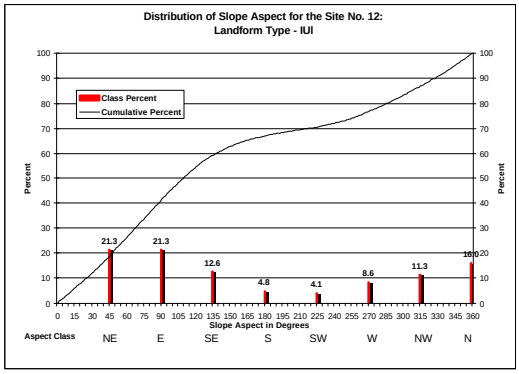




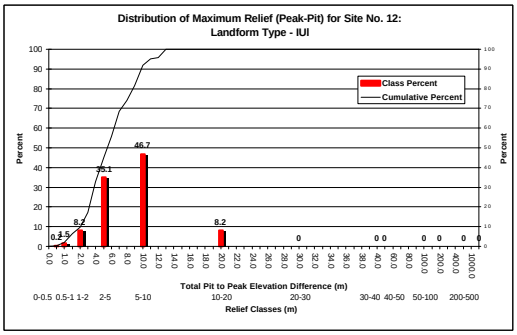
Site No: 12 Turner Valley Site Landform Type: IUl



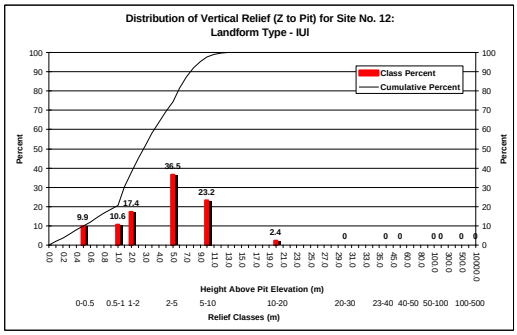
a) Slope gradient (%)



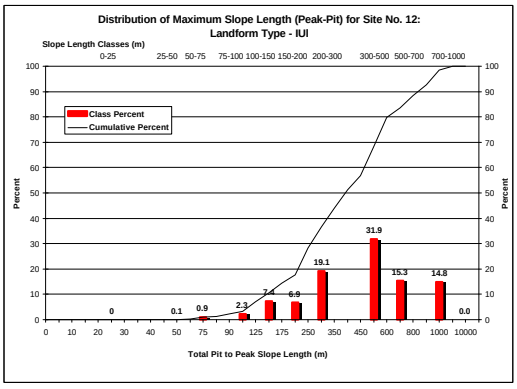
b) Slope aspect (degrees)



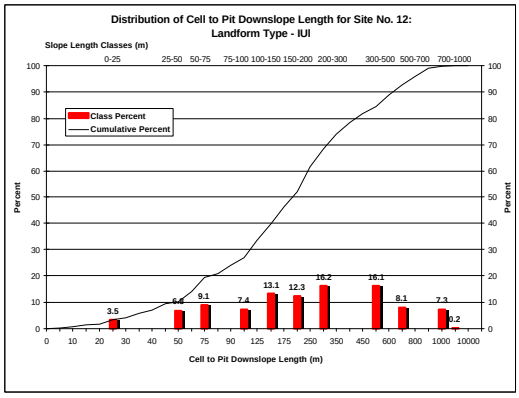
c) Descriptive relief (pit to peak) (m)



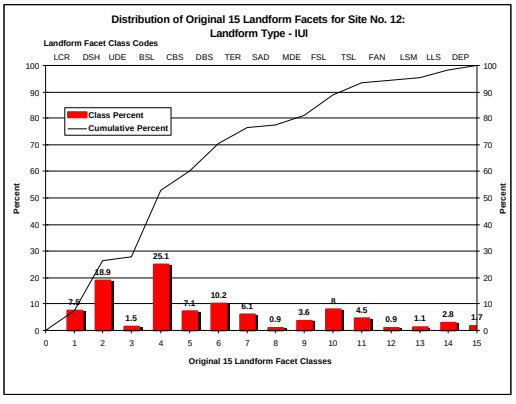
d) Effective relief (cell to pit) (m)



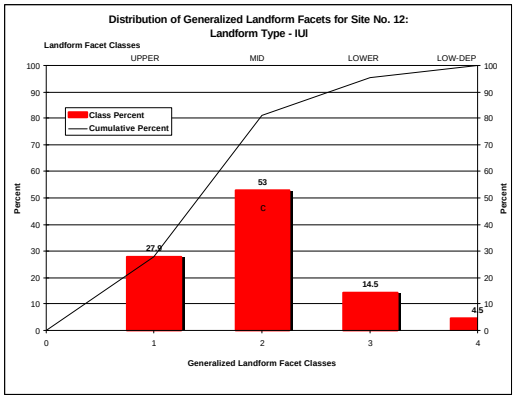
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



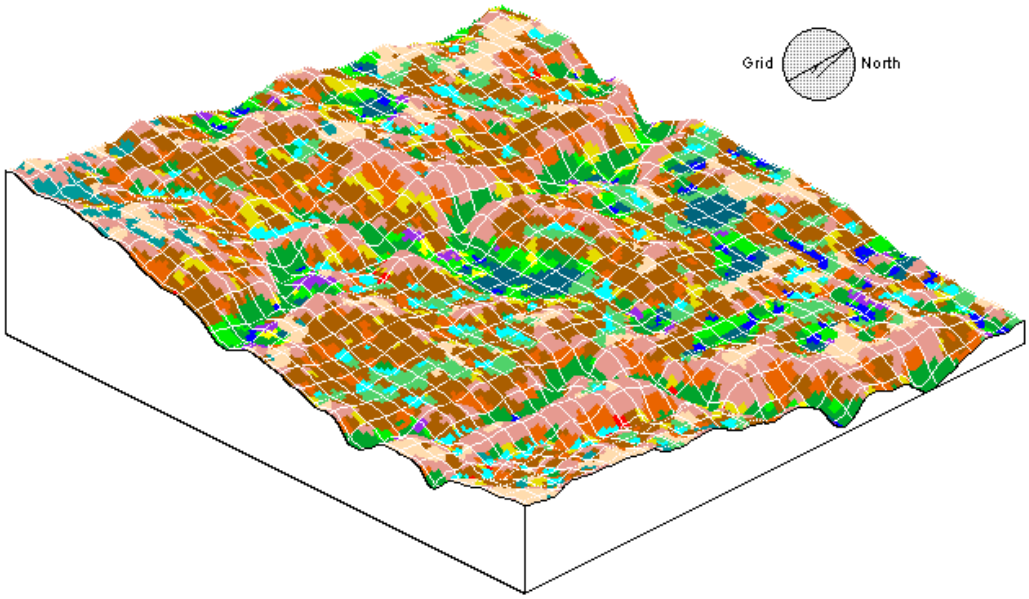
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

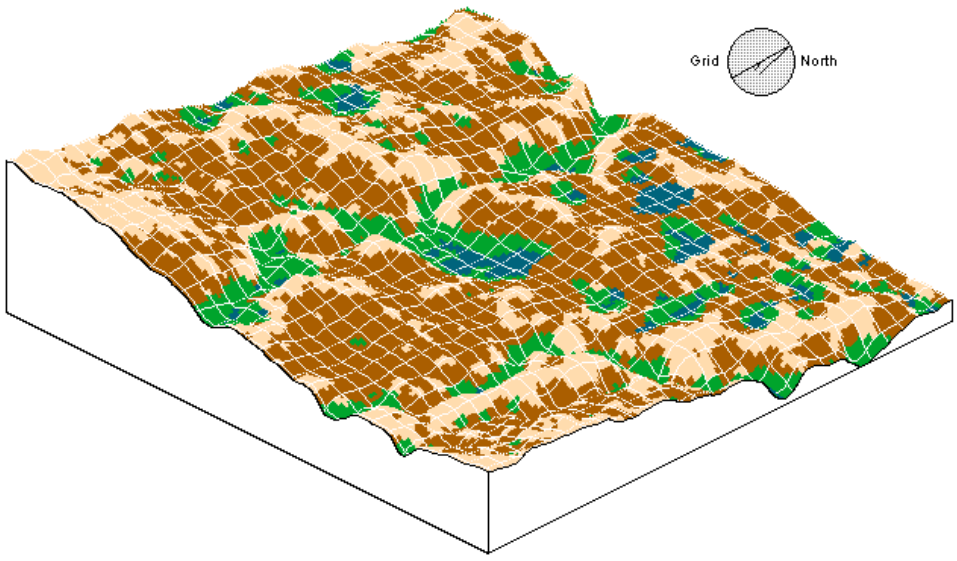
Site No: 12 **Turner Valley Site** **Landform Type: IUl**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
3.1	17.1	1.4	27.9	8.5	12.8	3.2	0.8	2.6	8.7	7.2	1.3	2.3	2.0	1.1



a) 3D view of the Turner Valley Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		21.6	2.29	3.57	209.7	881.7	16.9
MID		55.8	2.40	3.60	186.4	701.9	13.1
LOW		19.6	2.19	3.30	50.8	257.8	4.2
DEP		3.1	0.61	0.90	22.5	141.6	0.8



b) 3D view of the Turner Valley Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 13 Landform Type: Ll

Site Identification: Peace River Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	489773	491163	6208423	6209993

Legal Location	Site Name	Landform Type	Comments
Sec 24-81-21-W5	Peace River Site	U1l	Selected by AAFC based on air photo suitability

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	0.7%	1.0%	1.0 -2.0%	0.0 -1.0%
Descriptive Relief (Pit to Peak) (m)	3.2 m	6.0 m	5-10 m	1-2 m
Effective Relief (Cell to Pit) (m)	1.8 m	4.5 m	0-1 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	544.1 m	900 m	300-500 m	700-1000 m
Effective Slope Length (Cell to Pit m)	290.4 m	500 m	300-500 m	200-300 m
No. Watersheds per 100 ha	12.4/ 100 ha			
Percent Off-site Drainage	39.9 %			

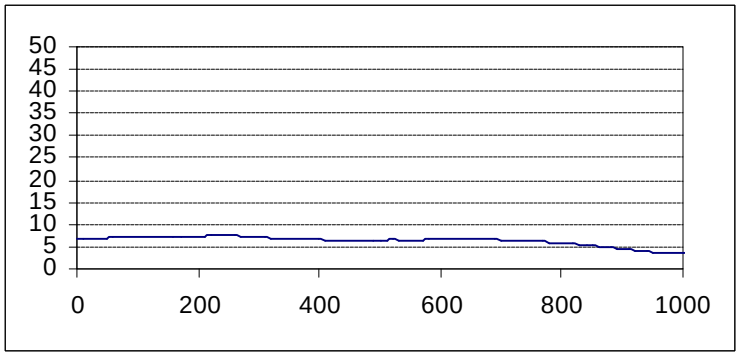
Origin and pre-processing of original DEM X, Y, Z data

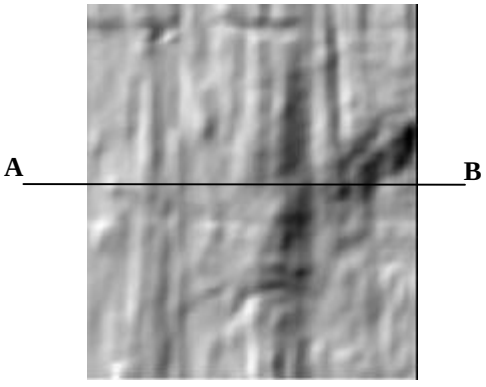
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	8121w5.asc	87,885
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE	Qs8121w5.img	87,885
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	PR10_75a.img	21,823

Evolution of the DEM from initial X, Y, Z data to final working surface

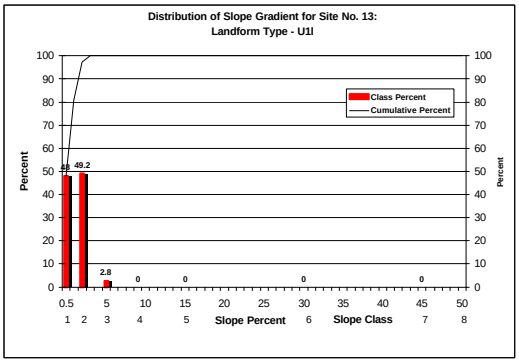
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Qs8121w5.img	489773	491168	6208418	6209993	315	279	5 m	QSURF MQE surface
2	Qs8121m7.img	489773	491168	6208418	6209993	315	279	5 m	7x7 mean filter to 1
3	Qs812175.img	489773	491168	6208418	6209993	315	279	5 m	5x5 mean filter to 2
4	PR10_75.img	489773	491163	6208423	6209993	157	139	10 m	3 aggregated to 10 m
5	PR10_75.img	489773	491163	6208423	6209993	157	139	10 m	ASCII export of 4

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

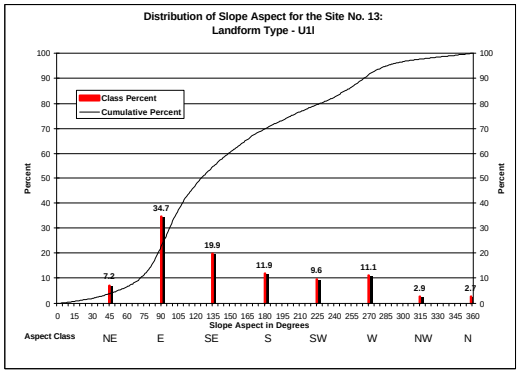




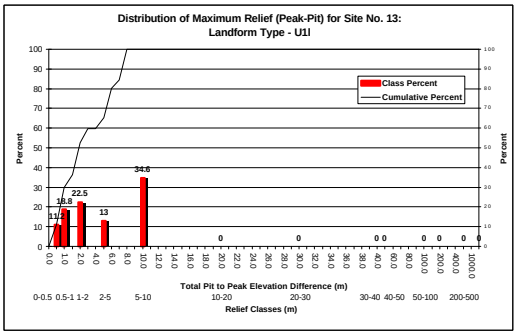
Site No: 13 Peace River Site Landform Type: Ll



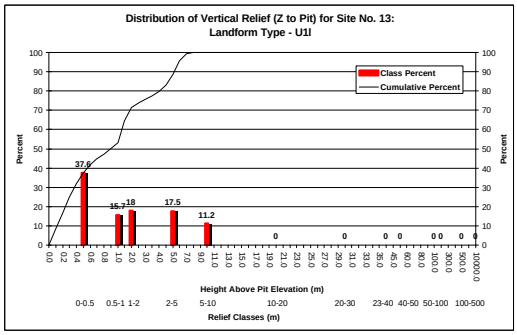
a) Slope gradient (%)



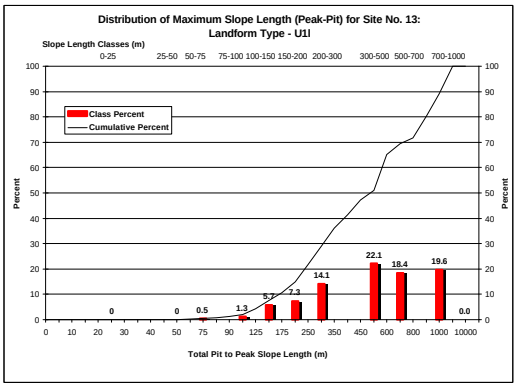
b) Slope aspect (degrees)



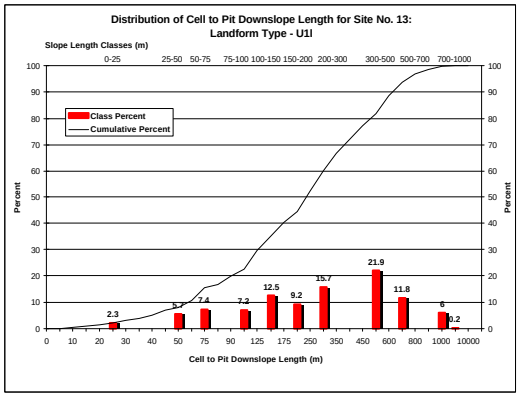
c) Descriptive relief (pit to peak) (m)



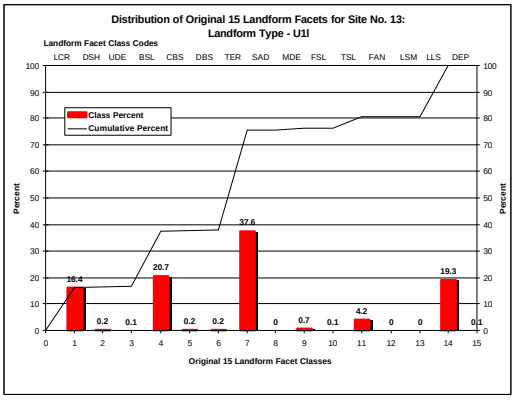
d) Effective relief (cell to pit) (m)



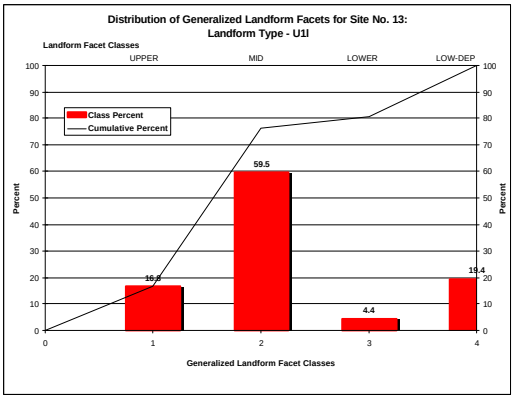
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



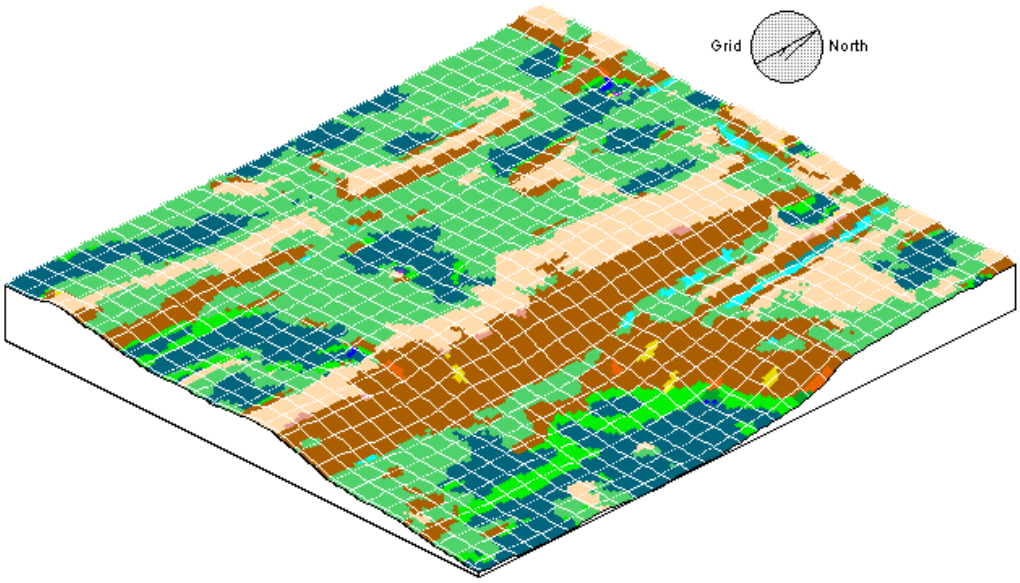
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

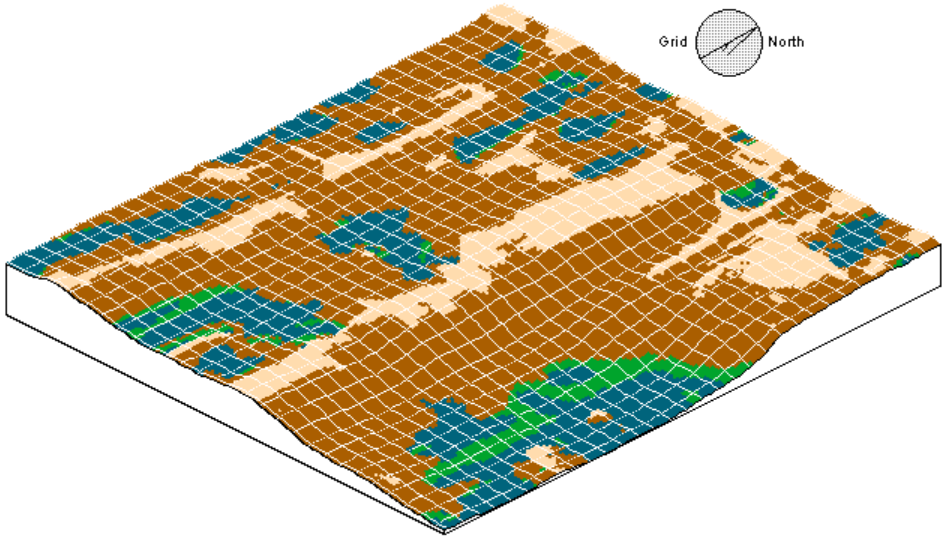
Site No: 13 **Peace River Site** **Landform Type: Ll**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
16.4	0.2	0.1	20.7	0.2	0.2	37.6	0.0	0.7	0.1	4.2	0.0	0.0	19.3	0.1



a) 3D view of the Peace River Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		16.8	0.5	0.8	262.4	730.9	6.1
MID		59.5	0.6	1.22	127.0	449.2	3.7
LOW		4.4	1.0	1.2	60.9	230.5	1.1
DEP		19.4	0.4	0.6	36.1	140.4	0.4



b) 3D view of the Peace River Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 14 Landform Type: D1l

Site Identification: Wainwright Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	521058	522068	5826487	5827497

Legal Location	Site Name	Landform Type	Comments
Sec 08-42-05-W4	Wainwright Site	D1l	Selected by AAFC based on air photo suitability

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.6%	4.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	3.1 m	5.0 m	2-5 m	1-2 m
Effective Relief (Cell to Pit) (m)	1.5 m	2.5 m	1-2 m	2-5 m
Descriptive Slope Length (Pit to Peak m)	161.4 m	250 m	100-150 m	150-200 m
Effective Slope Length (Cell to Pit m)	90.0 m	150 m	50-75 m	100-150 m
No. Watersheds per 100 ha	49.0/ 100 ha			
Percent Off-site Drainage	8.7 %			

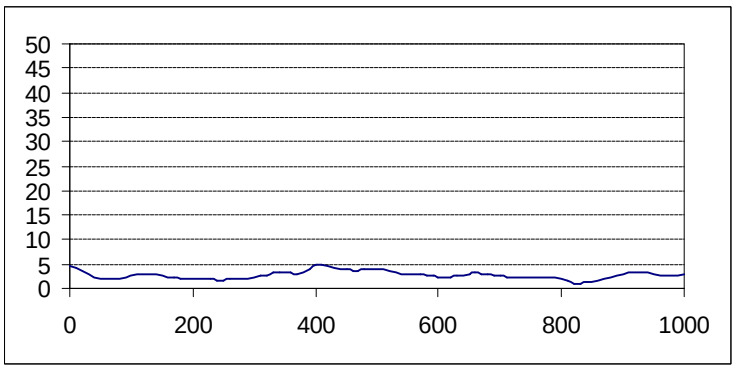
Origin and pre-processing of original DEM X, Y, Z data

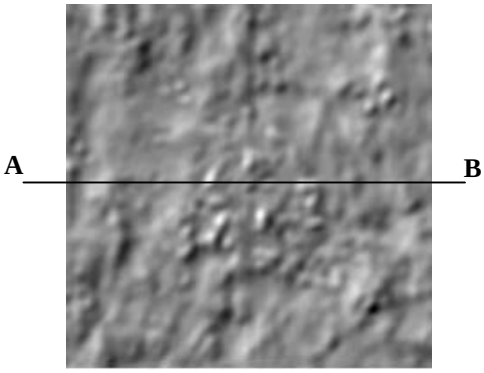
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	4205w4.asc	42,748
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE surface	Qs4205w4.img	42,833
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	C10_m35a.img	10,201

Evolution of the DEM from initial X, Y, Z data to final working surface

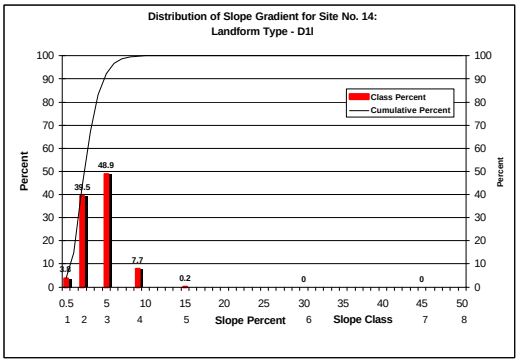
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Qs4205w4.img	521058	522073	5826458	5827513	211	203	5 m	QSURF exact fit DEM
2	Ss4205w4.img	521058	522073	5826487	5827497	202	203	5 m	Window subset of 1
3	Ss4205m3.img	521058	522073	5826487	5827497	202	203	5 m	3x3 mean filter to 2
4	Ss420535.img	521058	522073	5826487	5827497	202	203	5 m	5x5 mean filter to 3
5	Sa420535.img	521058	522073	5826487	5827497	202	203	5 m	ASCII export of 4
6	C10_m35.img	521058	522068	5826487	5827497	101	101	10 m	Aggregate 5 to 10 m
7	C10_m35a.img	521058	522068	5826487	5827497	101	101	10 m	ASCII export of 6

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

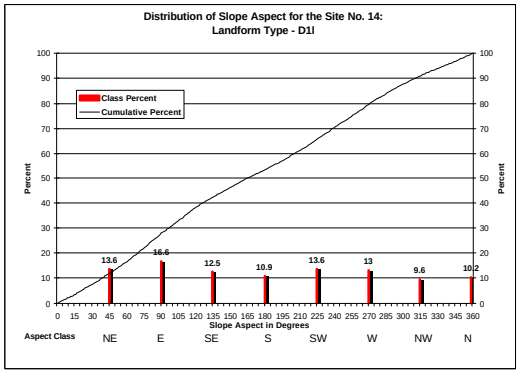




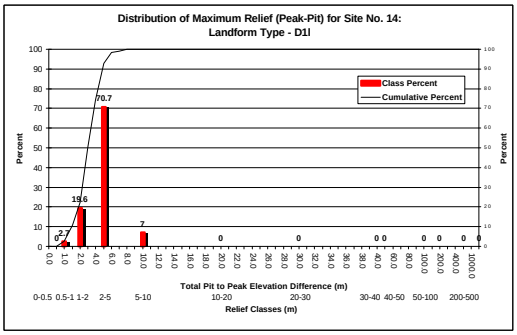
Site No: 14 Wainwright Site Landform Type: D1l



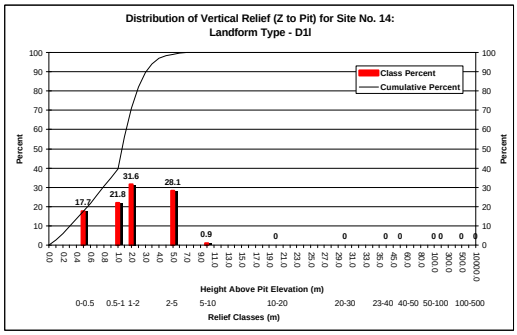
a) Slope gradient (%)



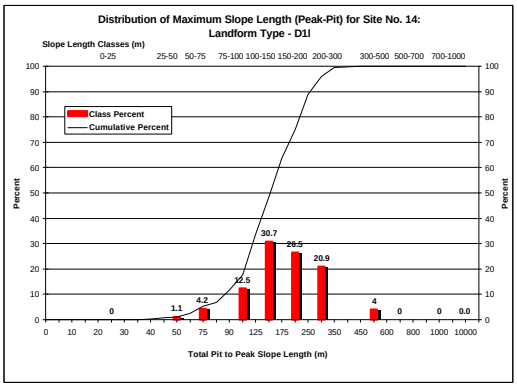
b) Slope aspect (degrees)



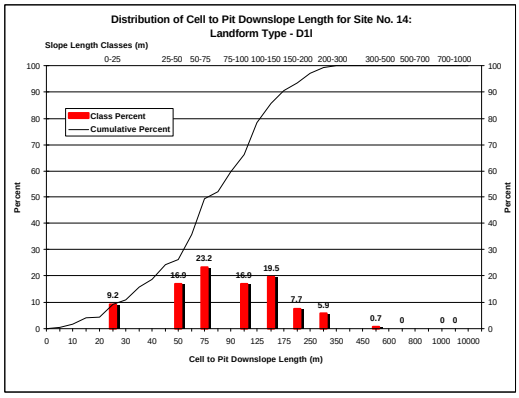
c) Descriptive relief (pit to peak) (m)



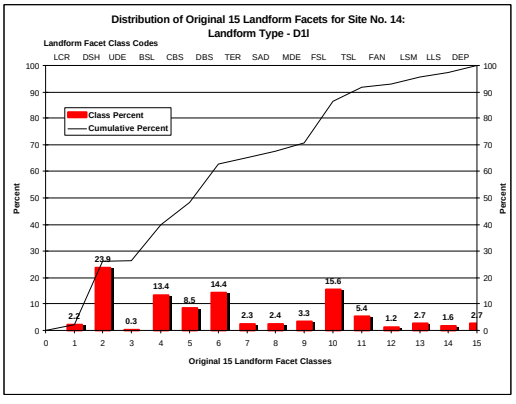
d) Effective relief (cell to pit) (m)



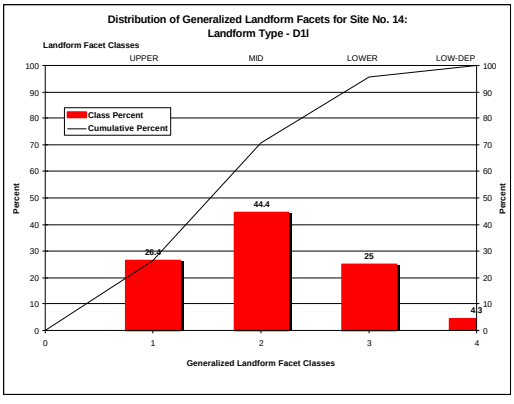
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



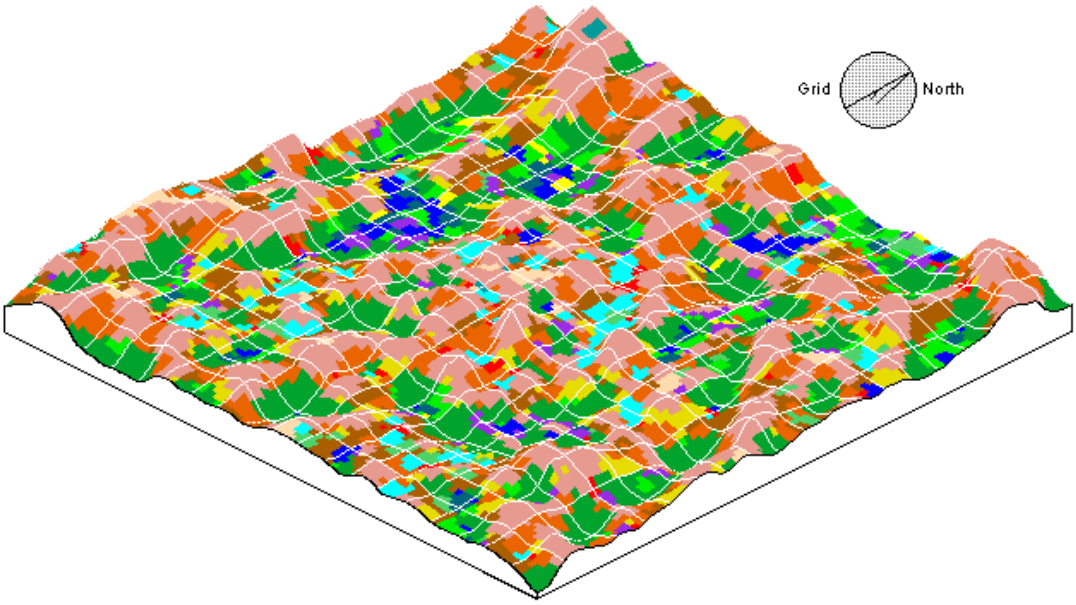
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

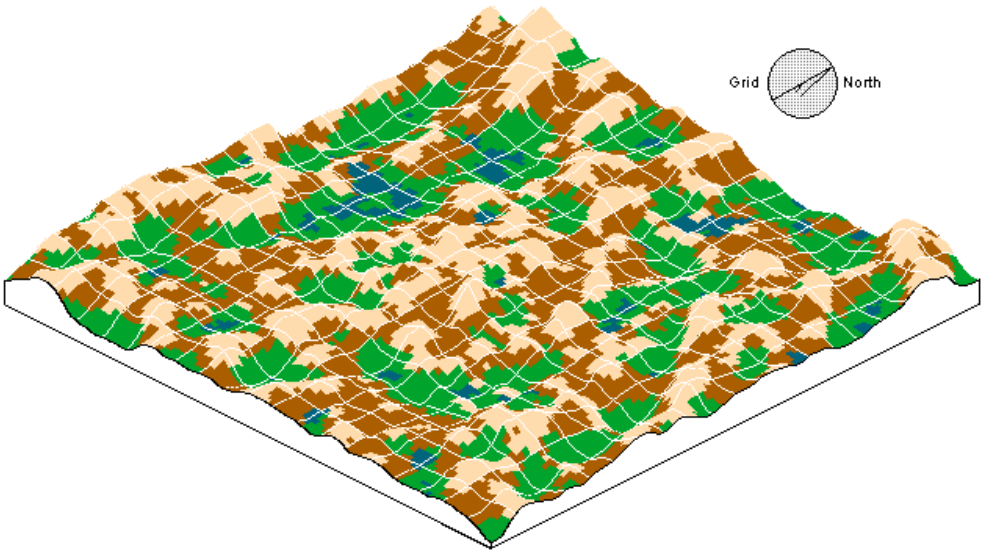
Site No: 14 **Wainwright Site** **Landform Type: D1l**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
2.2	23.9	0.3	13.4	8.5	14.4	2.3	2.4	3.3	15.6	5.4	1.2	2.7	1.6	2.7



a) 3D view of the Wainwright Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		26.4	2.51	4.04	64.5	157.4	3.25
MID		44.4	2.38	3.99	54.3	141.7	2.27
LOW		25.0	2.13	3.25	22.4	71.5	0.90
DEP		4.3	0.71	1.01	20.0	63.3	0.51



b) 3D view of the Wainwright Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 15 Landform Type: FP3

Site Identification: Red Deer River Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	369347	370692	5708248	5709582

Legal Location	Site Name	Landform Type	Comments
Sec 34-29-21-W4	Red Deer River Site	FP3	Selected by AAFC based on air photo suitability

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	8.2%	12.0%	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	65.1 m	100.0 m	50-100 m	30-40 m
Effective Relief (Cell to Pit) (m)	24.5 m	35.0 m	30-40 m	20-30 m
Descriptive Slope Length (Pit to Peak m)	1050.0 m	> 1000 m	>1000 m	700-1000 m
Effective Slope Length (Cell to Pit m)	432.0 m	700 m	300-500 m	500-700 m
No. Watersheds per 100 ha	9.7/ 100 ha			
Percent Off-site Drainage	24.2 %			

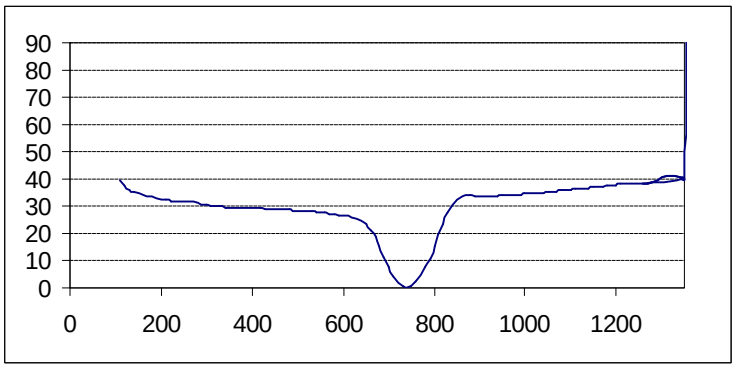
Origin and pre-processing of original DEM X, Y, Z data

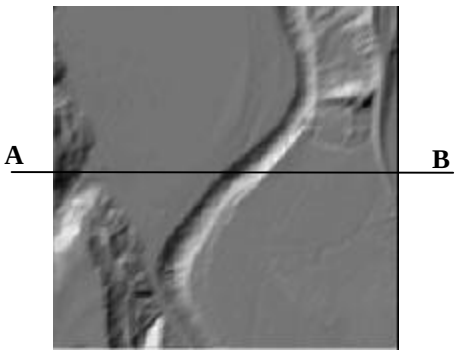
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	2931w4.asc	32,206
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE surface	S2931.img	63,250
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Sa29331m5.img	18,090

Evolution of the DEM from initial X, Y, Z data to final working surface

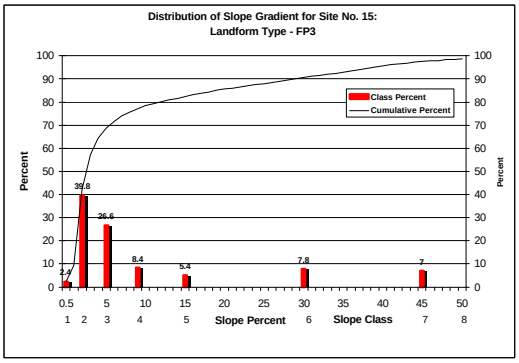
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	2931W4.img	368790	371280	5707680	5710200	253	250	10 m	QSURF exact fit DEM
2	Ss2931w4.img	369347	370692	5708248	5709582	134	135	10 m	Window subset of 1
3	Ss2931a4.img	369347	370692	5708248	5709582	134	135	10 m	ASCII version of 2
4	Ss2931m5.img	369347	370692	5708248	5709582	134	135	10 m	5x5 mean filter to 2
5	Sa2931m5.img	369347	370692	5708248	5709582	134	135	10 m	ASCII export of 4
6	S2931.img	0	1780	0	1850	185	178	10 m	Rotate 1 to N-S block
7	A2931m7.img	0	1780	0	1850	185	178	10 m	ASCII export of 6

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

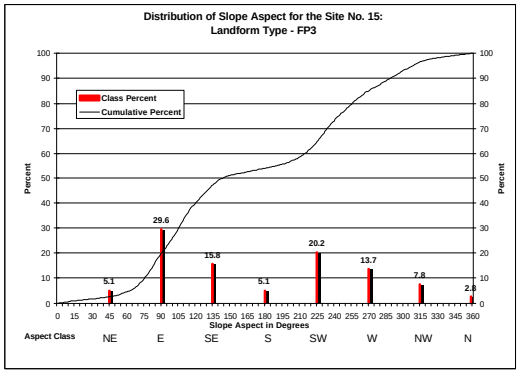




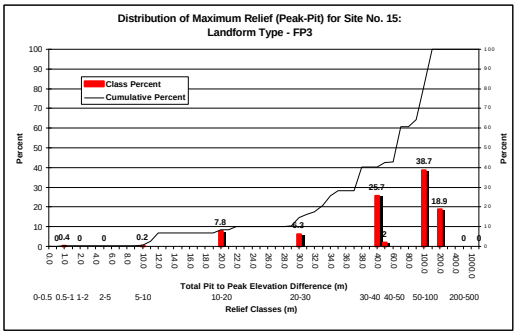
Site No: 15 Red Deer River Site Landform Type: FP3



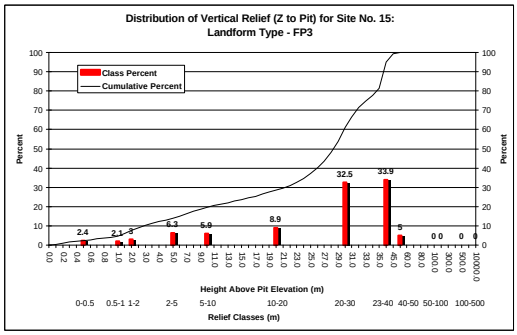
a) Slope gradient (%)



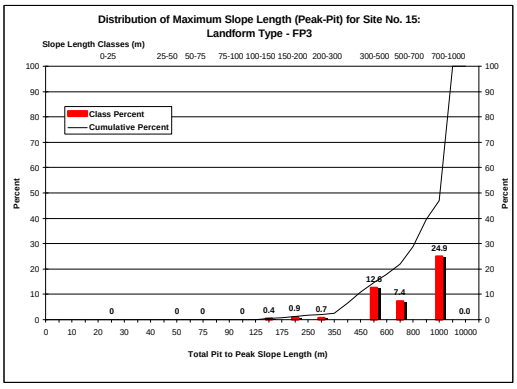
b) Slope aspect (degrees)



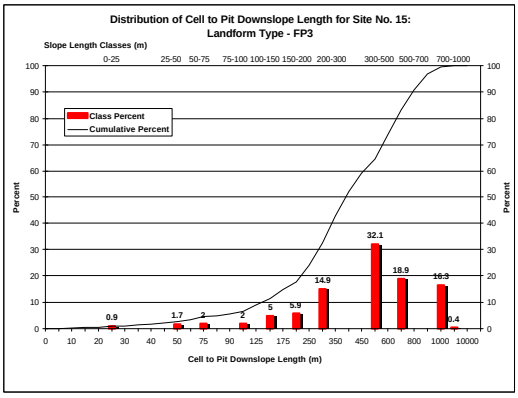
c) Descriptive relief (pit to peak) (m)



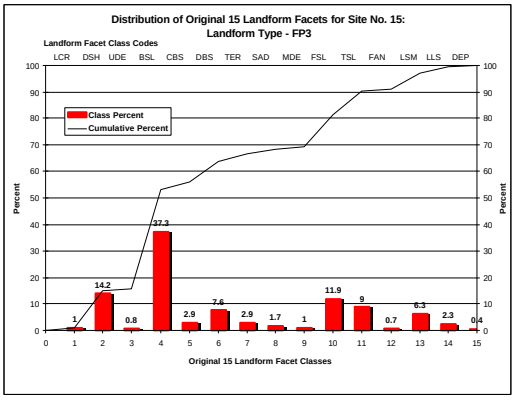
d) Effective relief (cell to pit) (m)



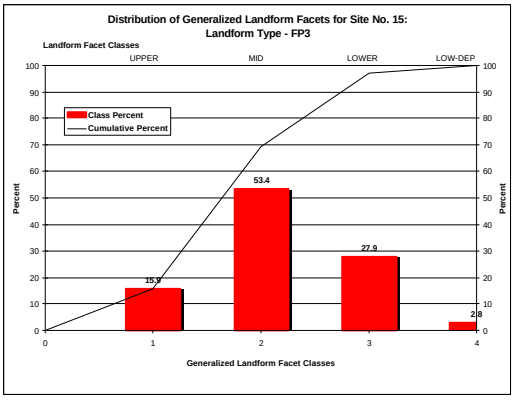
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



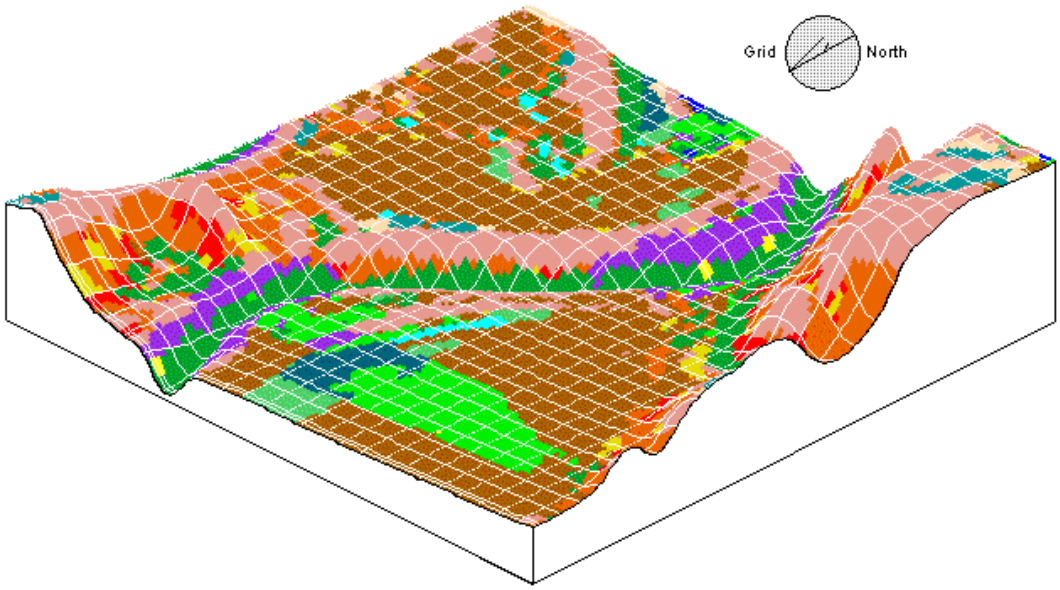
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

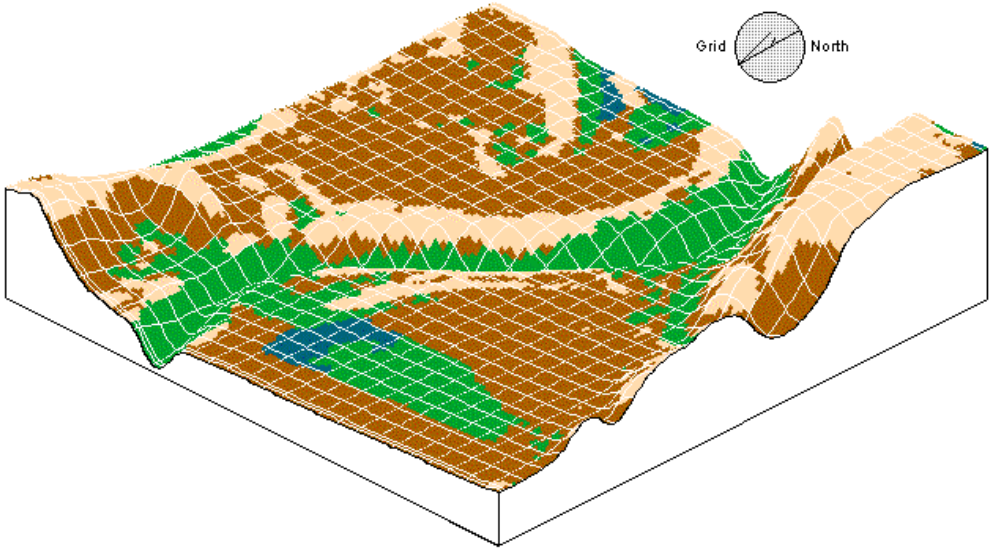
Site No: 15 Red Deer River Site Landform Type: FP3

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
1.0	14.2	0.8	37.3	2.9	7.6	2.9	1.7	1.0	11.9	9.0	0.7	6.3	2.3	0.4



a) 3D view of the Red Deer River Site: 15 unit landform classification - 1 5x5 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		15.9	4.53	14.01	252.0	606.8	32.45
MID		53.4	1.88	3.75	354.3	744.5	36.78
LOW		27.9	6.58	31.91	105.7	370.6	26.34
DEP		2.8	0.59	0.84	53.9	153.0	0.84



b) 3D view of the Red Deer River Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 16 Landform Type: SC1h

Site Identification: Drumheller Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	365625	367025	5710300	5711540

Legal Location	Site Name	Landform Type	Comments
Sec 06-30-21-W4	Drumheller Site	SC1h	Selected by AAFC based on air photo suitability

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	33.4%	70.0%	70.0 -100.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	89.7 m	150.0 m	50-100 m	100-200 m
Effective Relief (Cell to Pit) (m)	44.1 m	90.0 m	50-100 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	1009.8 m	> 1000 m	>1000 m	700-1000 m
Effective Slope Length (Cell to Pit m)	504.8 m	1000 m	700-1000 m	>1000 m
No. Watersheds per 100 ha	18.4/ 100 ha			
Percent Off-site Drainage	3.5 %			

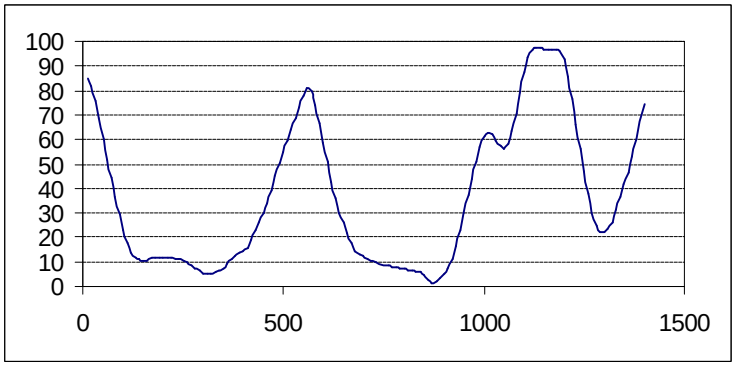
Origin and pre-processing of original DEM X, Y, Z data

Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	3021w4.asc	32,206
DEM Surfacing:	LandMapper	R. MacMillan	QSURF exact fitting MQE surface	3021W4.img	240,100
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Sa10m5.img	17,360

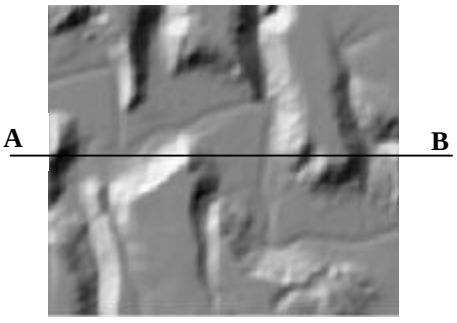
Evolution of the DEM from initial X, Y, Z data to final working surface

DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	3021W4.img	365100	367550	5709670	5712125	491	490	5 m	QSURF exact fit DEM
2	SS3021.img	365625	367030	5710300	5711540	248	281	5 m	Window subset of 1
3	SS3021m5.img	365625	367030	5710300	5711540	248	281	5 m	5x5 mean filter to 2
4	Sa3021m5.img	365625	367030	5710300	5711540	248	281	5 m	ASCII version of 3
5	SS10m5.img	365625	367025	5710300	5711540	140	124	10 m	Contract 3 to 10 M grid
6	SS10m5.img	365625	367025	5710300	5711540	140	124	10 m	ASCII export of 5

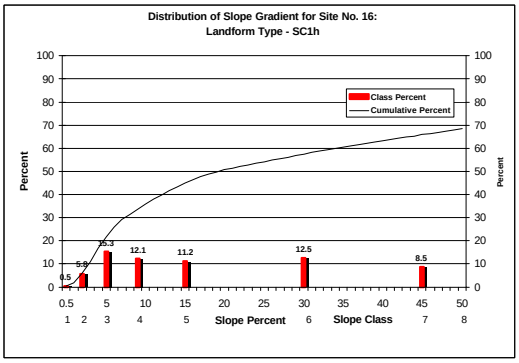
Site Illustration: Schematic Cross Section:



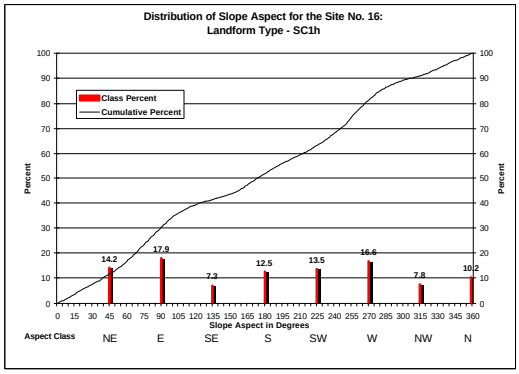
Hillshade of final DEM:



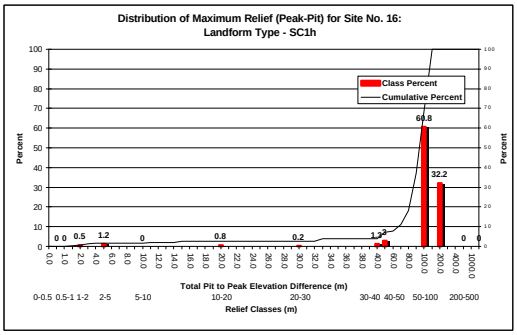
Site No: 16 Drumheller Site Landform Type: SC1h



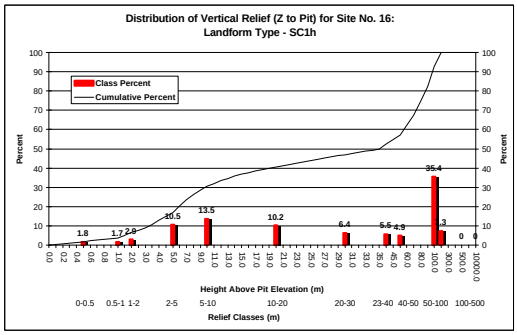
a) Slope gradient (%)



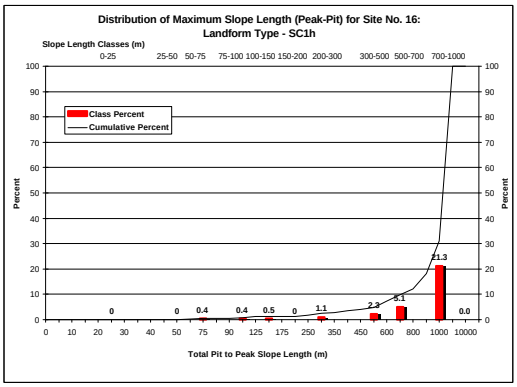
b) Slope aspect (degrees)



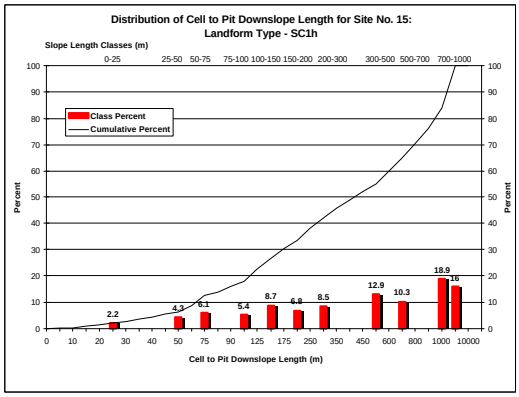
c) Descriptive relief (pit to peak) (m)



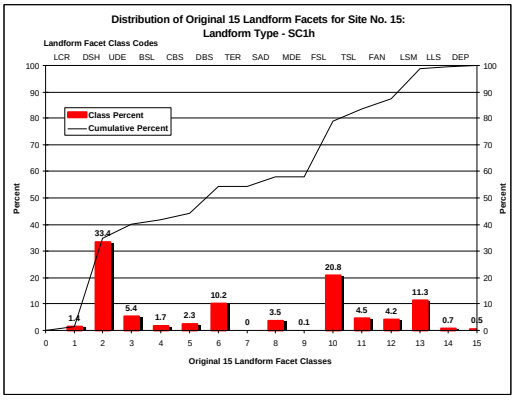
d) Effective relief (cell to pit) (m)



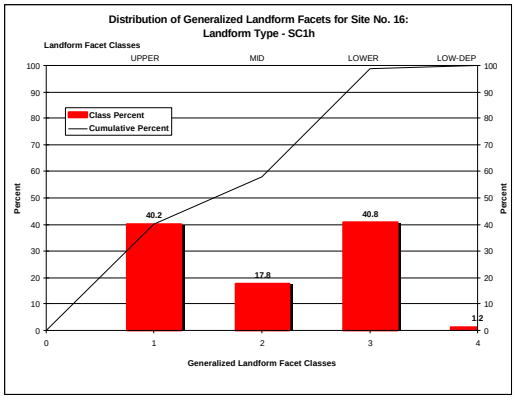
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



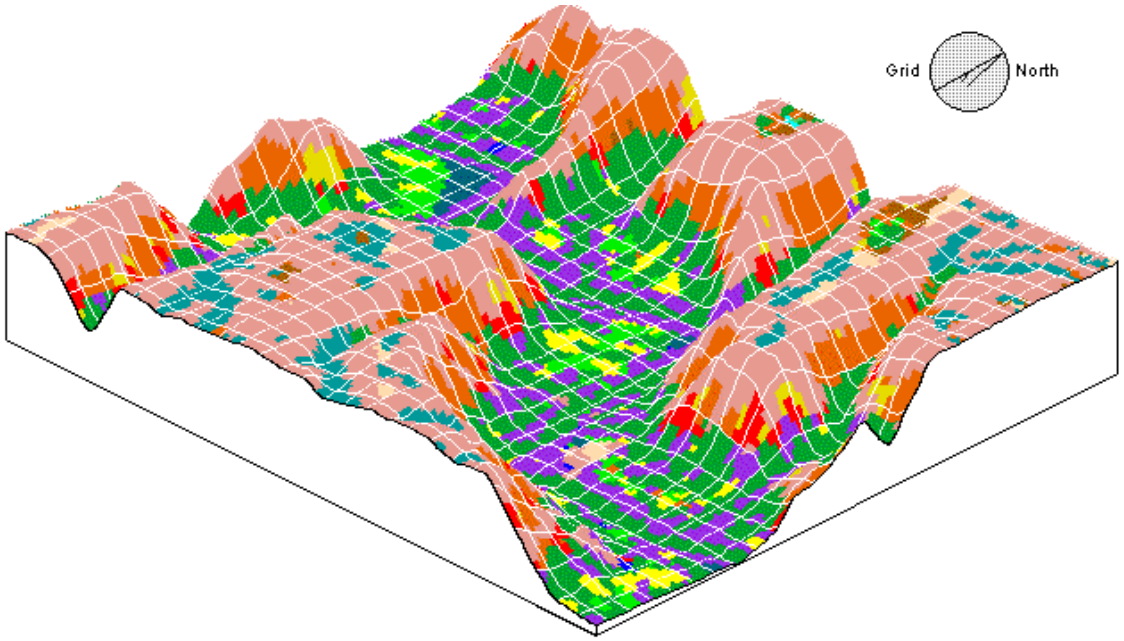
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

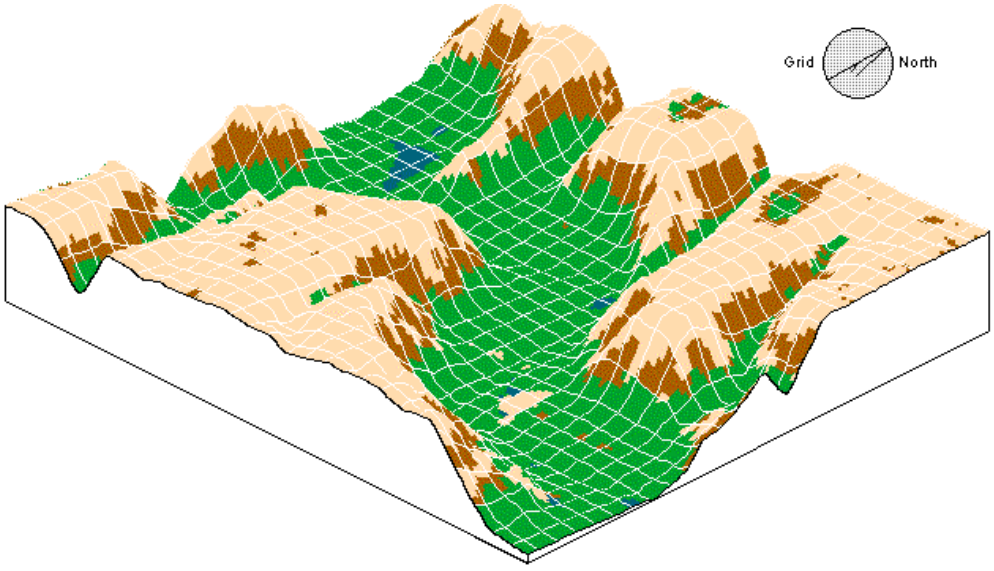
Site No: 16 Drumheller Site Landform Type: SC1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
1.4	33.4	5.4	1.7	2.3	10.2	0.0	3.5	0.1	20.8	4.5	4.2	11.3	0.7	0.5



a) 3D view of the Drumheller Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		40.2	20.44	67.89	661.2	1082.7	99.19
MID		17.8	72.77	87.96	339.3	689.7	63.4
LOW		40.8	11.85	41.17	62.2	234.9	14.8
DEP		1.2	0.74	5.44	53.9	130.8	4.5



b) 3D view of the Drumheller Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 17 Landform Type: U1h

Site Identification: Airdrie 1 Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	695015	696130	5685080	5685975

Legal Location	Site Name	Landform Type	Comments
Sec 11-27-02-W5	Airdrie Site No.1	U1h	Westco research and field trial site #1 near Airdrie

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	1.6%	3.0%	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	5.8 m	11.0 m	2-5 m	10-20 m
Effective Relief (Cell to Pit) (m)	3.0 m	6.0 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	378.6 m	600 m	300-500 m	200-300 m
Effective Slope Length (Cell to Pit m)	168.7 m	300 m	100-150 m	200-300 m
No. Watersheds per 100 ha	31.7/ 100 ha			
Percent Off-site Drainage	36.3 %			

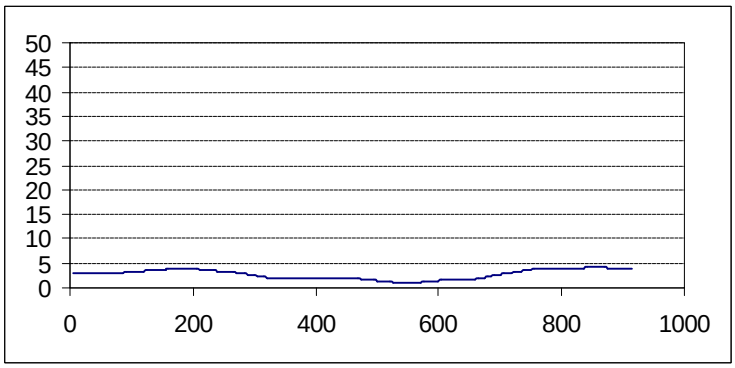
Origin and pre-processing of original DEM X, Y, Z data

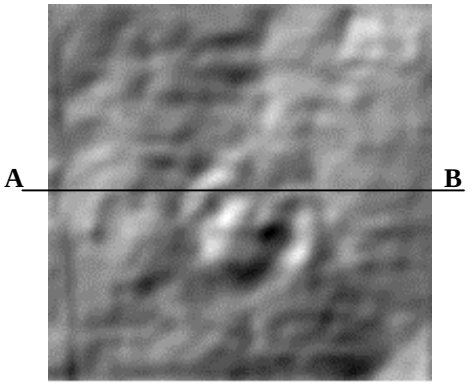
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	112702W5.asc	33,131
DEM Surfacing:	LandMapper	R. MacMillan	ArcView 3 IWD surface (50 m fix)	S11.grd	32,757
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	S11DEM.img	32,757

Evolution of the DEM from initial X, Y, Z data to final working surface

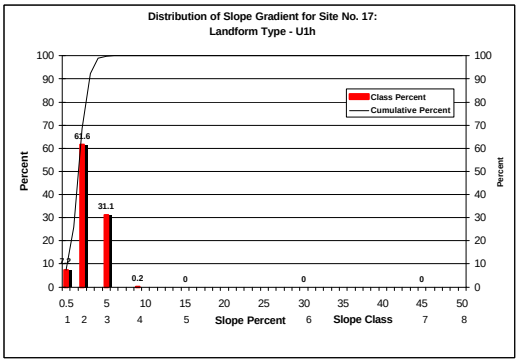
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	S11.grd	696015	696930	5685080	5685975	179	183	5 m	AV3 IWD surface
2	S112702m.grd	696015	696930	5685080	5685975	179	183	5 m	1 3x3 mean filter to 1
3	S112702m.img	696015	696930	5685080	5685975	179	183	5 m	Export of 2 to Idrisi
4	S112702m.asc	696015	696930	5685080	5685975	179	183	5 m	ASCII version of 3
5	S11DEM.dbf	696015	696930	5685080	5685975	179	183	5 m	DBF version of 4
6	Q17DEM.dbf	696015	696930	5685080	5685975	179	183	5 m	Copy of 5 used in QDL

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

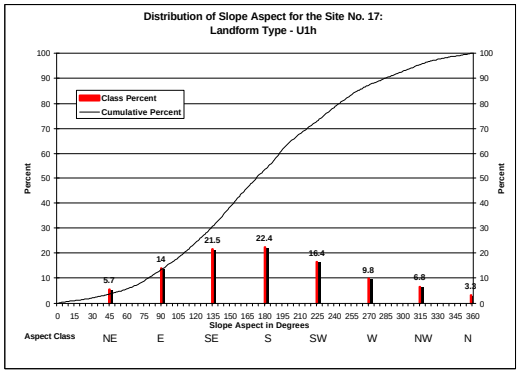




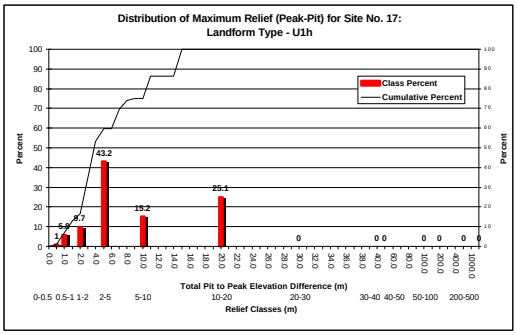
Site No: 17 Airdrie Site 1 Landform Type: U1h



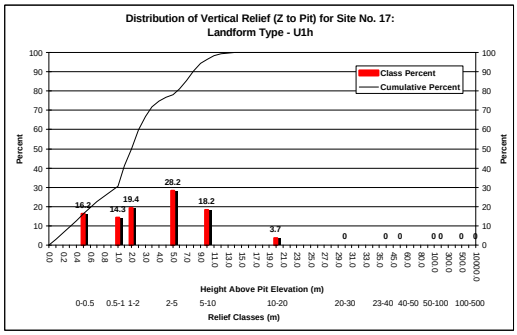
a) Slope gradient (%)



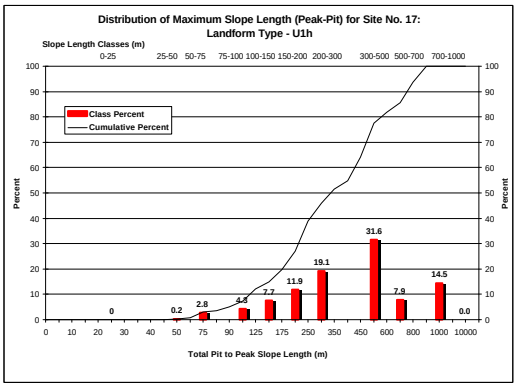
b) Slope aspect (degrees)



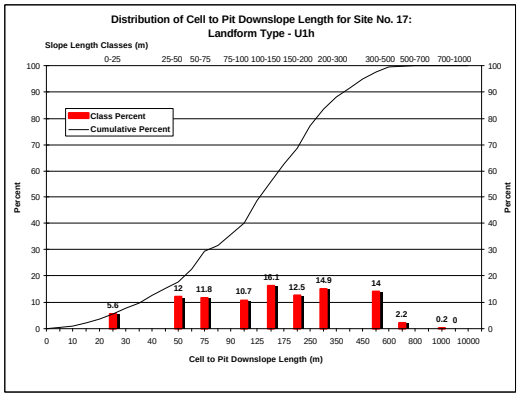
c) Descriptive relief (pit to peak) (m)



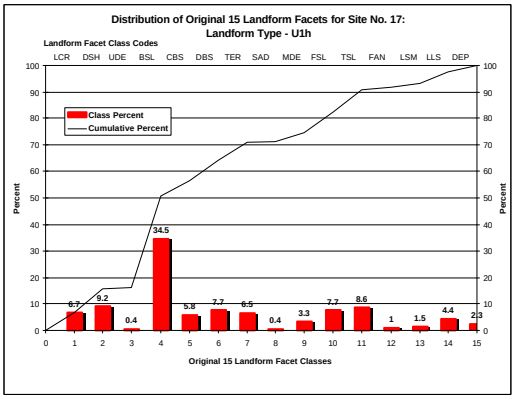
d) Effective relief (cell to pit) (m)



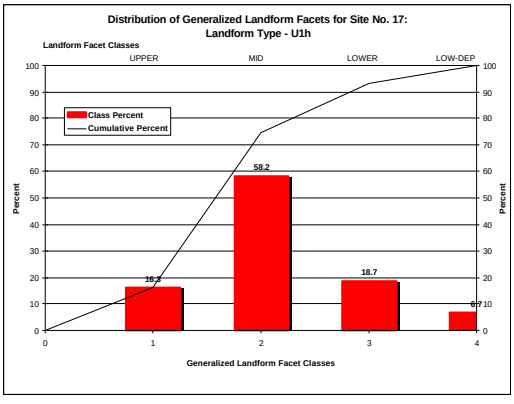
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



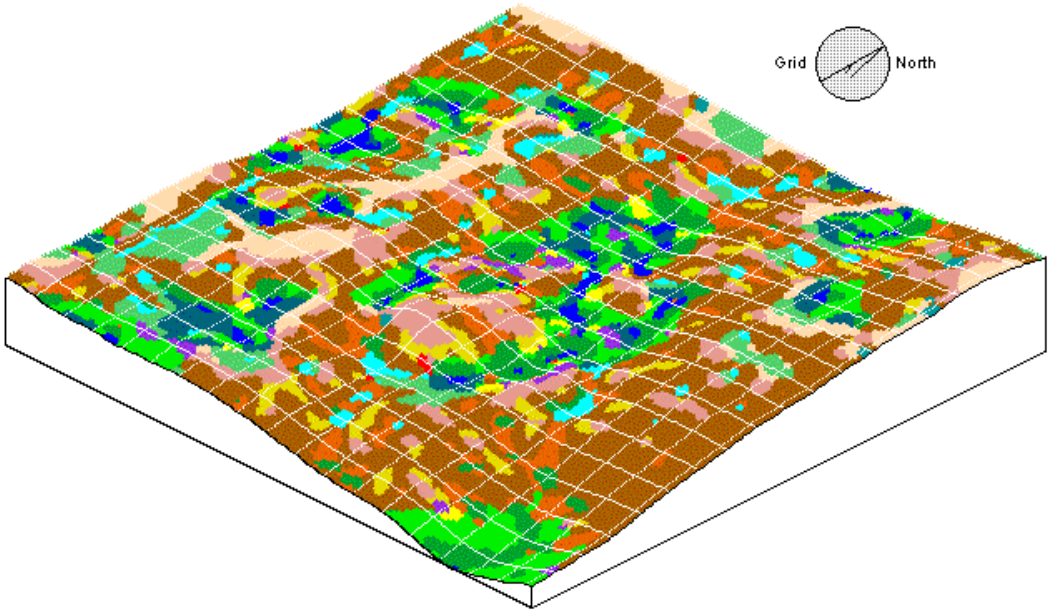
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

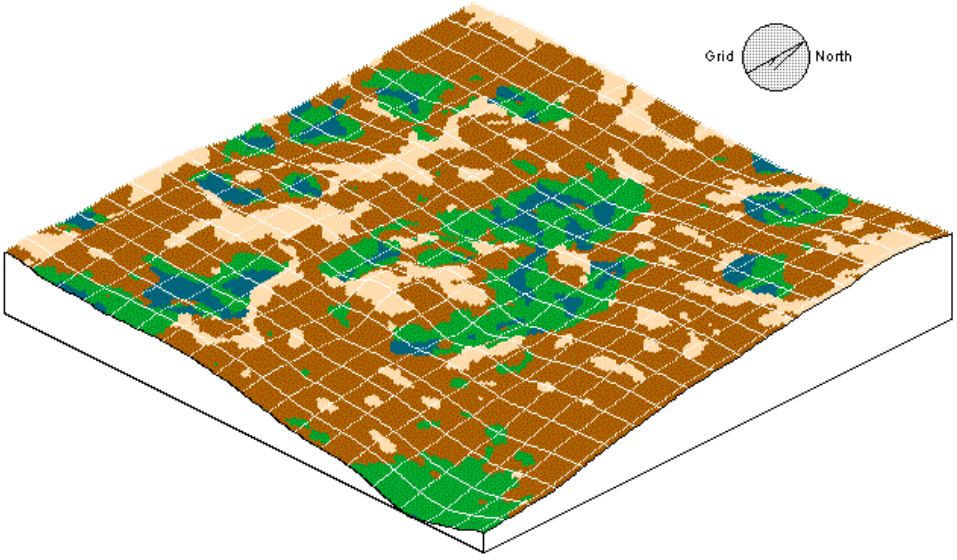
Site No: 17 Airdrie Site 1 Landform Type: U1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
6.7	9.2	0.4	34.5	5.8	7.7	6.5	0.4	3.3	7.7	8.6	1.0	1.5	4.4	2.3



a) 3D view of the Airdrie 1 Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		16.3	1.19	1.98	105.8	347.6	7.37
MID		58.2	1.65	2.40	86.2	305.7	6.85
LOW		18.7	1.76	2.70	27.0	89.5	1.20
DEP		6.7	0.63	0.88	15.8	70.2	0.51



b) 3D view of the Airdrie 1 Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 18 Landform Type: U1h

Site Identification: Airdrie 2 Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	694435	695335	5684211	5685126

Legal Location	Site Name	Landform Type	Comments
Sec 03-27-02-W5	Airdrie2 Site	H5m	Westco research and field trial site #2 near Airdrie

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	3.4%	5.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	8.1 m	13.0 m	10-20 m	5-10 m
Effective Relief (Cell to Pit) (m)	4.2 m	8.0 m	2-5 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	312.5 m	450 m	300-500 m	200-300 m
Effective Slope Length (Cell to Pit m)	164.7 m	300 m	200-300 m	100-150 m
No. Watersheds per 100 ha	37.6/ 100 ha			
Percent Off-site Drainage	28.7 %			

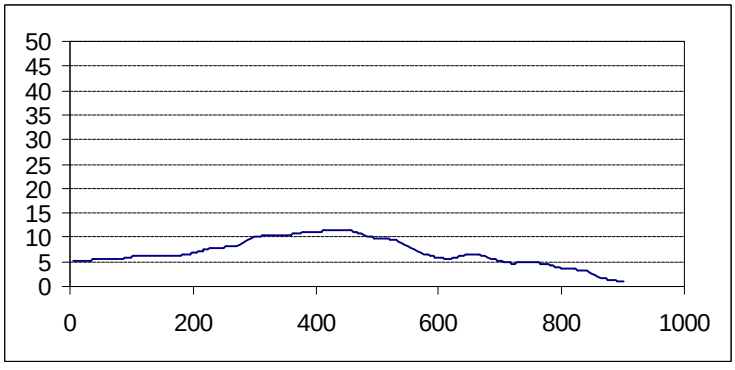
Origin and pre-processing of original DEM X, Y, Z data

Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	32702W5.asc	31,501
DEM Surfacing:	LandMapper	R. MacMillan	ArcView 3 IWD surface (50 m fix)	S032702.grd	40,572
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Q18DEM.img	32,940

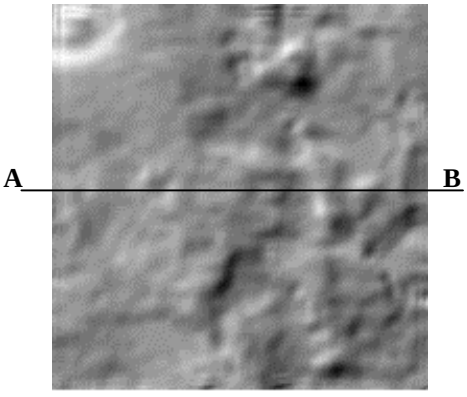
Evolution of the DEM from initial X, Y, Z data to final working surface

DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	S032702.grd	694365	695400	5684181	5685161	196	207	5 m	AV3 IWD surface
2	S032701m.grd	694365	695400	5684181	5685161	196	207	5 m	1 5x5 mean filter to 1
3	S32702m.asc	694365	695400	5684181	5685161	196	207	5 m	Export of 2 to Idrisi
4	S032701w.img	694434	695334	5684211	5685126	183	180	5 m	Window subset of 3
5	S03DEM.dbf	694434	695334	5684211	5685126	183	180	5 m	DBF version of 4
6	Q18DEM.dbf	694434	695334	5684211	5685126	183	180	5 m	Copy of 5 used in QDL

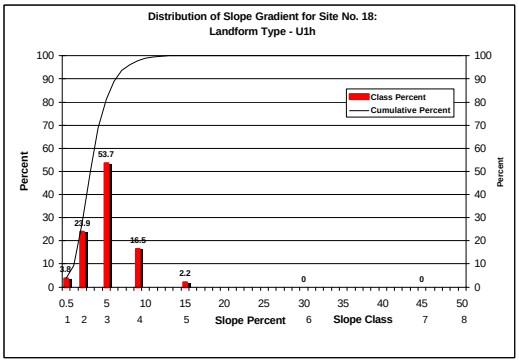
Site Illustration: Schematic Cross Section:



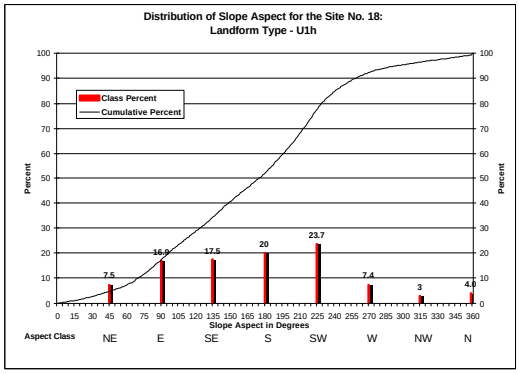
Hillshade of final DEM:



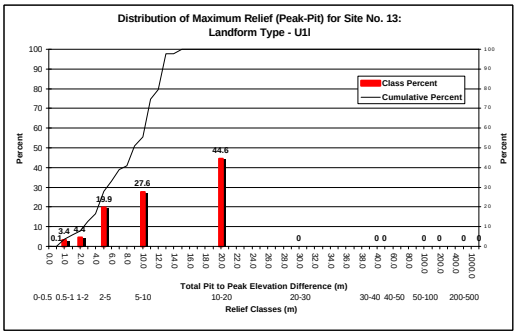
Site No: 18 Airdrie Site 2 Landform Type: U1h



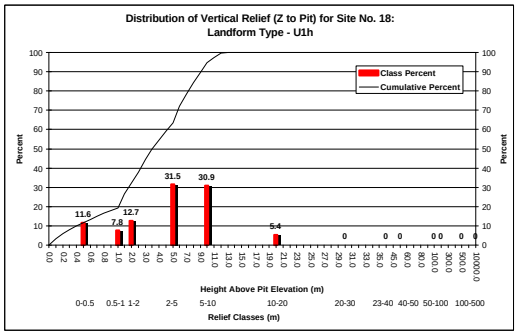
a) Slope gradient (%)



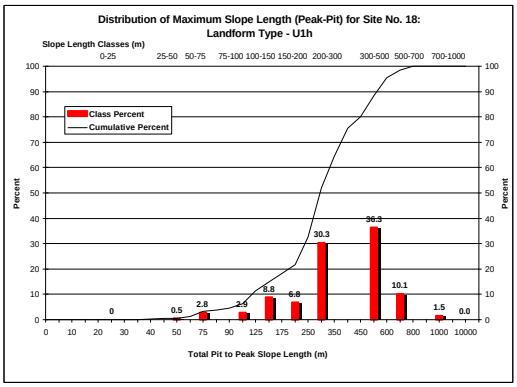
b) Slope aspect (degrees)



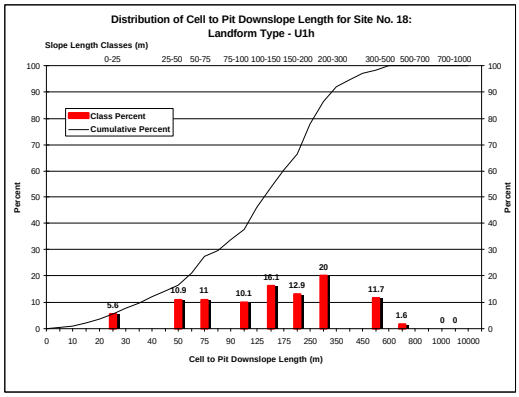
c) Descriptive relief (pit to peak) (m)



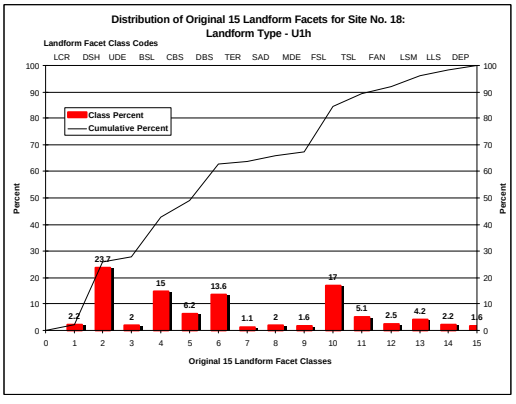
d) Effective relief (cell to pit) (m)



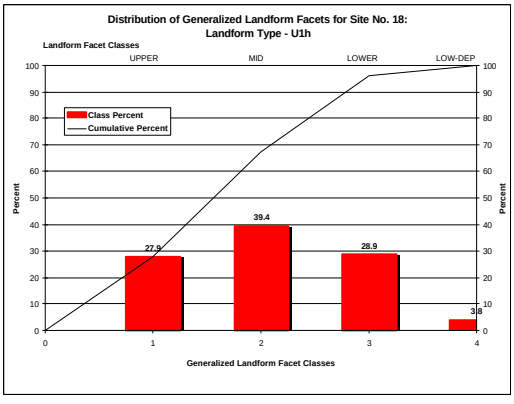
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



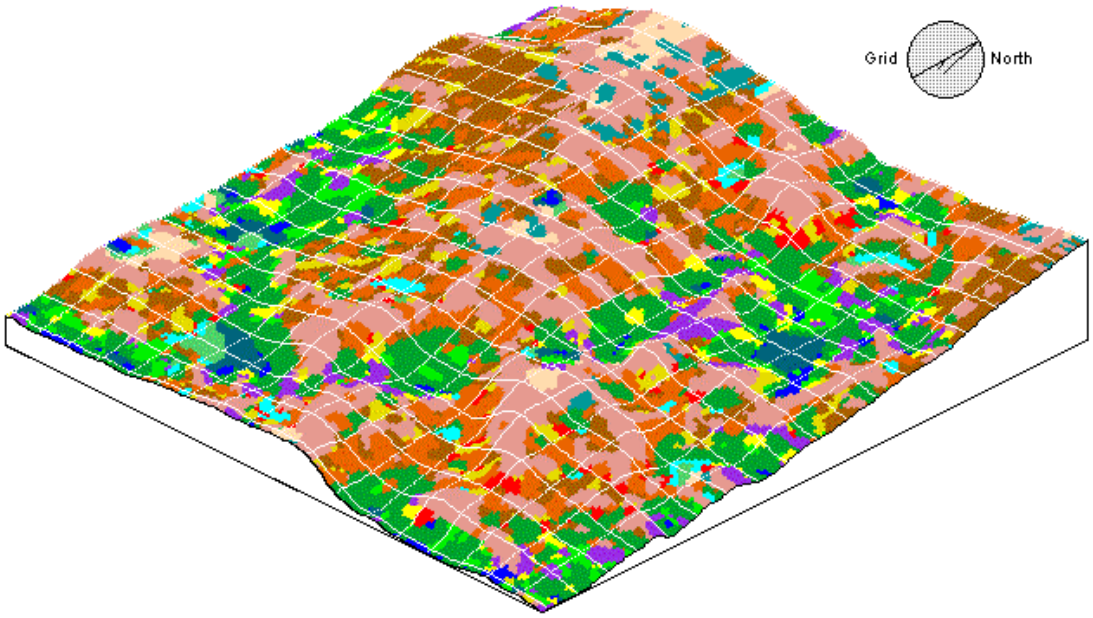
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

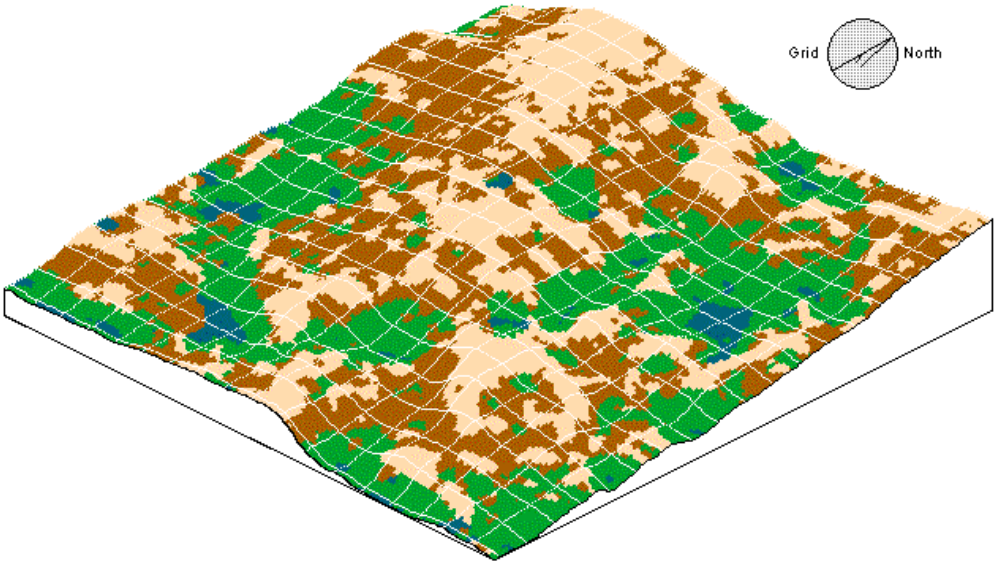
Site No: 18 Airdrie Site 2 Landform Type: U1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
2.2	23.7	2.0	15.0	6.2	13.6	1.1	2.0	1.6	17.0	5.1	2.5	4.2	2.2	1.6



a) 3D view of the Airdrie 2 Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		27.9	3.01	4.96	92.3	335.0	9.57
MID		39.4	3.18	5.14	96.7	274.8	7.14
LOW		28.9	2.98	4.67	31.7	138.0	2.56
DEP		3.8	0.47	0.78	15.0	60.4	0.39



b) 3D view of the Airdrie 2 Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 19 Landform Type: M1h

Site Identification: Airdrie 3 Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	700880	701880	5683860	5684990

Legal Location	Site Name	Landform Type	Comments
SW-05-27-01-W5	Airdrie Site No. 3	M1h	AAFRD weed research site (L. Hall & T. Faechner)

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	4.7%	7.0%	2.0 -5.0%	5.0 -9.0%
Descriptive Relief (Pit to Peak) (m)	32.5 m	50.0 m	40-50 m	30-40 m
Effective Relief (Cell to Pit) (m)	18.0 m	29.0 m	10-20 m	20-30 m
Descriptive Slope Length (Pit to Peak m)	908.9 m	>1000 m	>1000 m	700-1000 m
Effective Slope Length (Cell to Pit m)	558.6 m	900 m	700-1000 m	300-500 m
No. Watersheds per 100 ha	3.5/ 100 ha			
Percent Off-site Drainage	100.0 %			

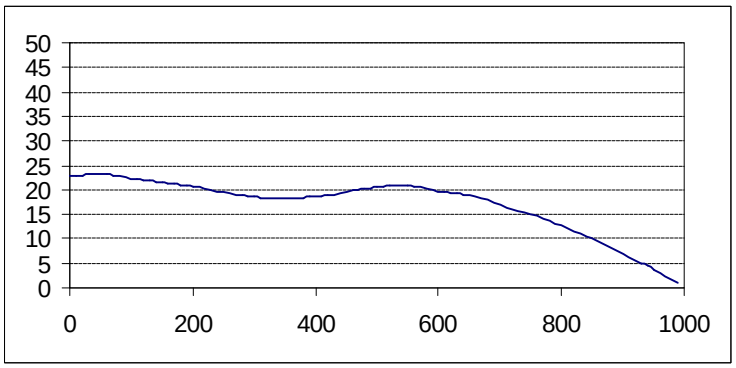
Origin and pre-processing of original DEM X, Y, Z data

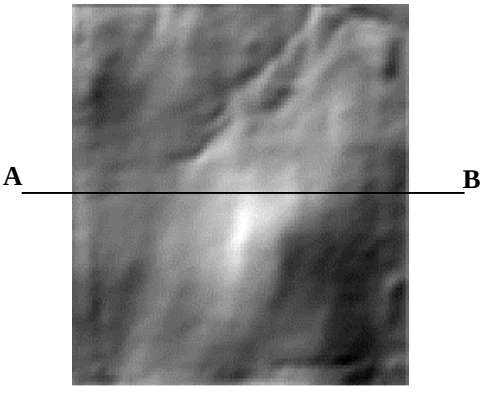
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	5-27-1as.asc	35,473
DEM Surfacing:	LandMapper	R. MacMillan	ArcView3 IWD 40 m fixed radius	As_iwd1.grd	32,025
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	SW5dema.img	11,300

Evolution of the DEM from initial X, Y, Z data to final working surface

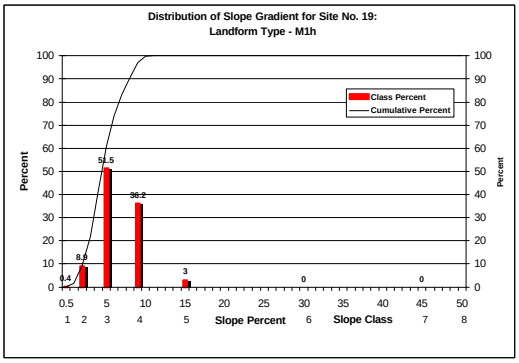
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	As_iwd1.grd	700880	702630	5683860	5685690	183	175	10 m	AV3 IWD surface
2	As_iwd3x3.grd	700880	702630	5683860	5685690	183	175	10 m	3x3 mean filter to 1
3	Asiwd3x3.img	700880	702630	5683860	5685690	183	175	10 m	Convert to Idrisi format
4	iwd3x3a.img	700880	702630	5683860	5685690	183	175	10 m	ASCII export (section)
5	Sw5dem.img	700880	701880	5683860	5684990	113	100	10 m	Window subset of 3
6	Sw5dema.img	700880	701880	5683860	5684990	113	100	10 m	ASCII export of 5 (1/4)

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

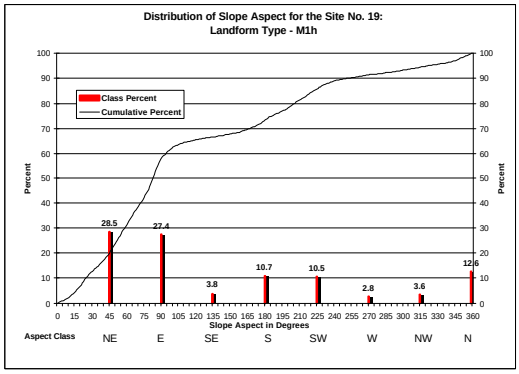




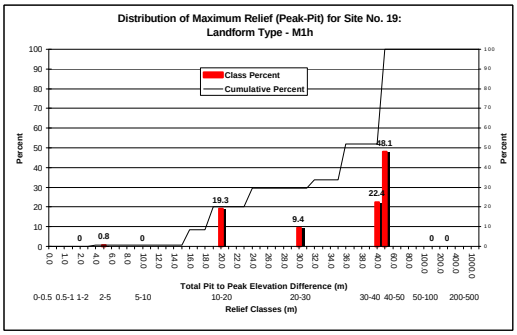
Site No: 19 Airdrie Site 3 Landform Type:M1h



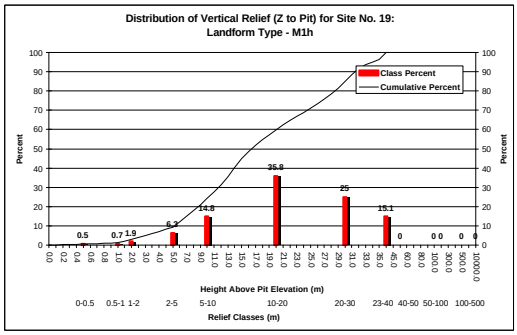
a) Slope gradient (%)



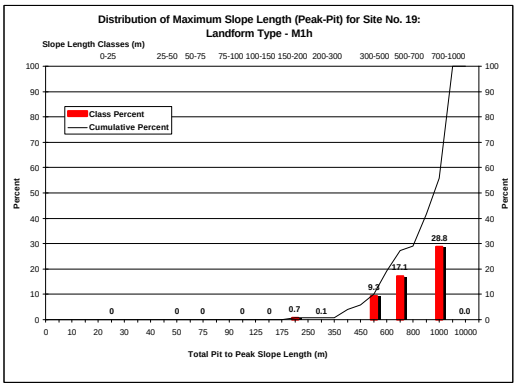
b) Slope aspect (degrees)



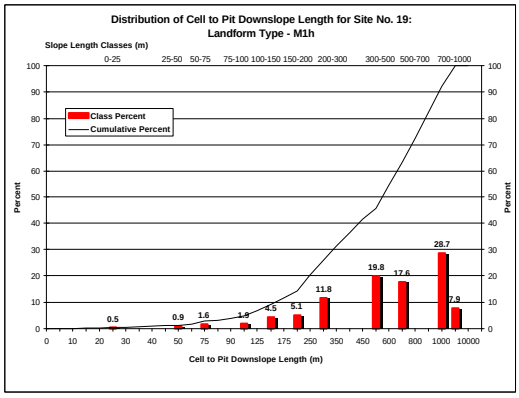
c) Descriptive relief (pit to peak) (m)



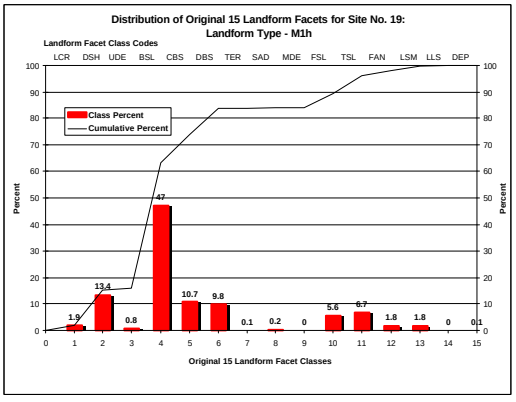
d) Effective relief (cell to pit) (m)



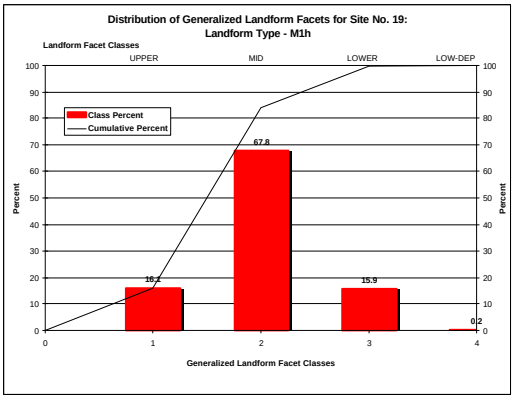
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



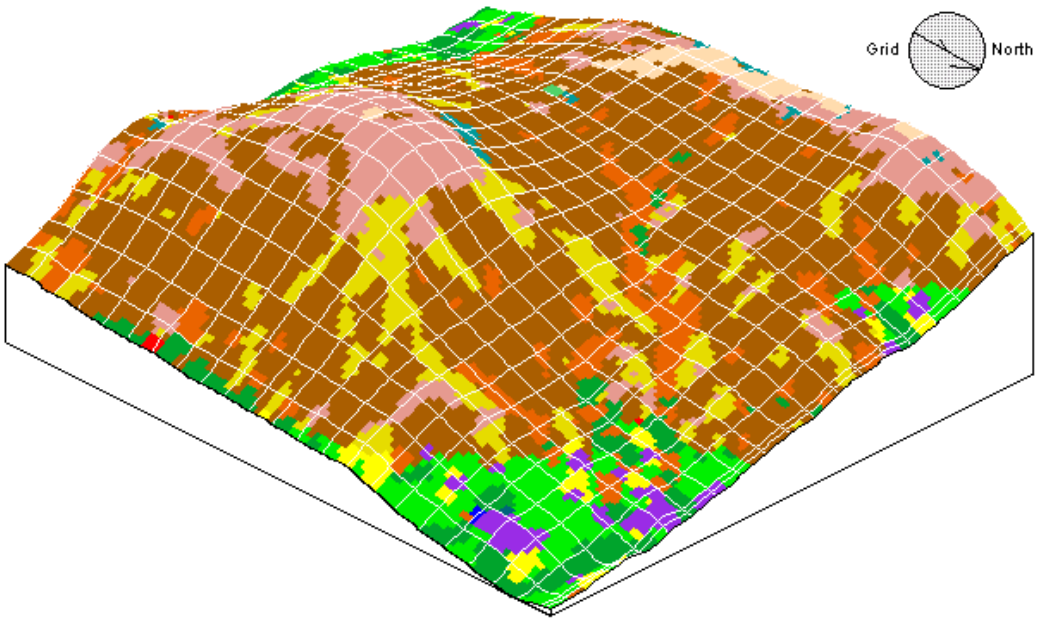
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

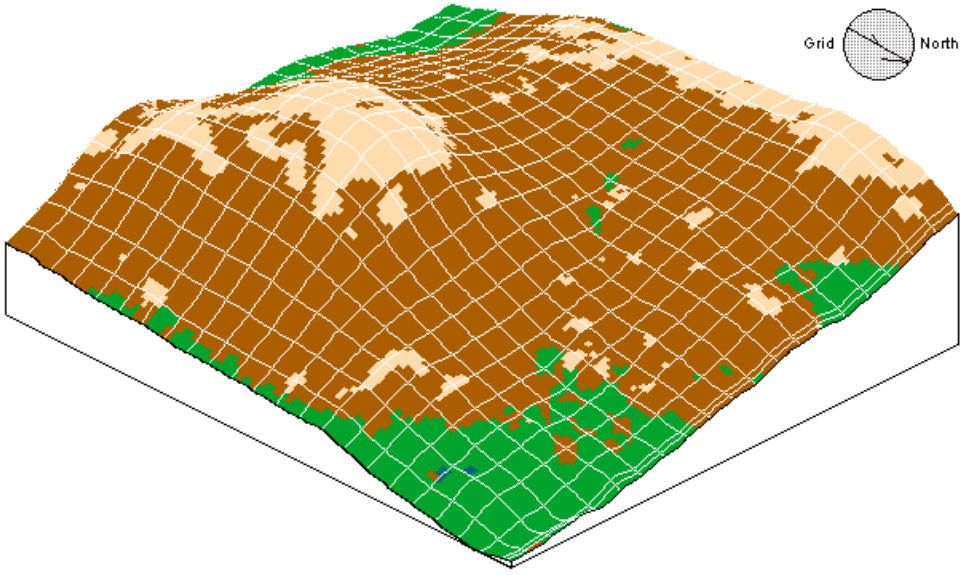
Site No: 19 Airdrie Site 3 Landform Type: M1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
1.9	13.4	0.8	47.0	10.7	9.8	0.1	0.2	0.0	5.6	6.7	1.8	1.8	0.0	0.1



a) 3D view of the Airdrie 3 Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		16.1	4.21	6.67	385.0	998.0	34.84
MID		67.8	4.58	6.93	326.0	886.3	39.42
LOW		15.9	4.00	5.76	82.6	308.1	8.63
DEP		0.2	1.35	4.62	74.8	170.5	6.37



b) 3D view of the Airdrie 3 Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 20 Landform Type: IUh

Site Identification: Olds North Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	703365	706871	5738404	5739200

Legal Location	Site Name	Landform Type	Comments
N 1/2 24-32-01-W5	Olds North Site	IUh	AAFRD Precision Farming Research Site near Olds

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	1.5%	3.0%	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	8.1 m	13.0 m	5-10 m	2-5 m
Effective Relief (Cell to Pit) (m)	4.2 m	8.0 m	2-5 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	482.9 m	700 m	300-500 m	500-700 m
Effective Slope Length (Cell to Pit m)	281.7 m	450 m	300-500 m	200-300 m
No. Watersheds per 100 ha	18.2/ 100 ha			
Percent Off-site Drainage	21.9 %			

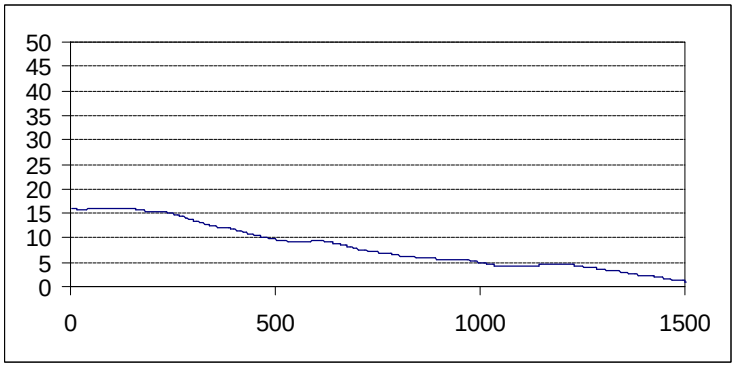
Origin and pre-processing of original DEM X, Y, Z data

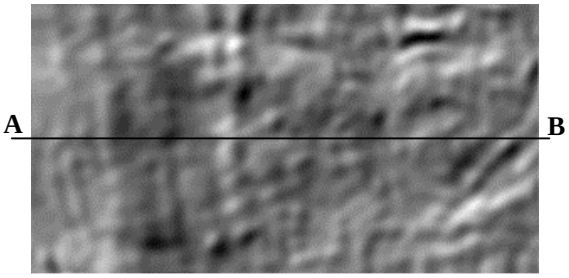
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	L.Kryzanowski	Unknown		
DEM Surfacing:	AAFRD	S. Nolan	GRASS Thin Plate Spline (TPS)	Tg0420.txt	53,694
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	A18DEM.img	48,320

Evolution of the DEM from initial X, Y, Z data to final working surface

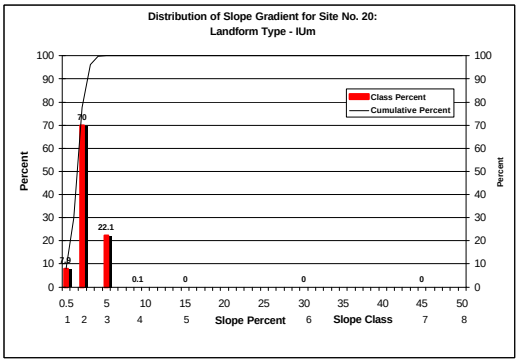
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Tg0420.txt	705336	706901	5738380	5739230	171	314	5 m	AAFRD TPS Surface
2	Mf0420as.img	705336	706901	5738380	5739230	171	314	5 m	1 7x7 mean filter to 1
3	Mf0420ss.img	705365	706871	5738404	5739200	160	302	5 m	Window subset of 2
4	as0420ss.img	705365	706871	5738404	5739200	160	302	5 m	ASCII export of 3
5	Q20DEM.dbf	705365	706871	5738404	5739200	160	302	5 m	4 input into LSM
6	Mf042010.img	705365	706871	5738404	5739200	80	151	10 m	10 m contraction of 3

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

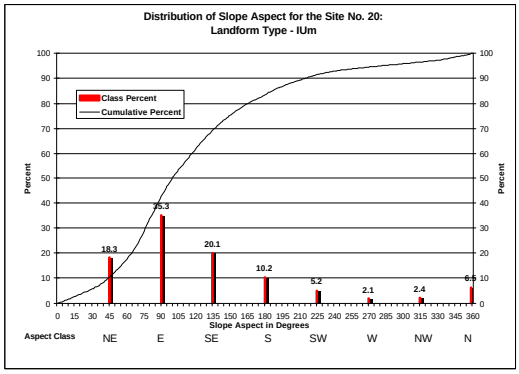




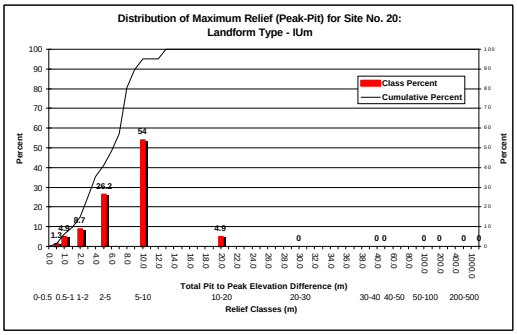
Site No: 20 Olds North Site Landform Type: IUh



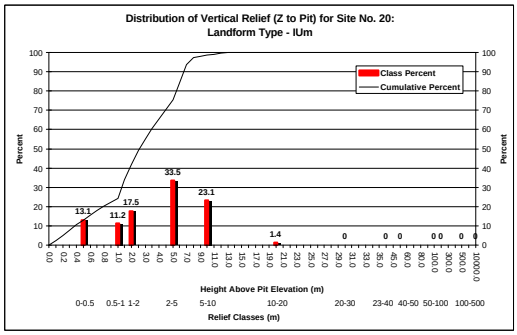
a) Slope gradient (%)



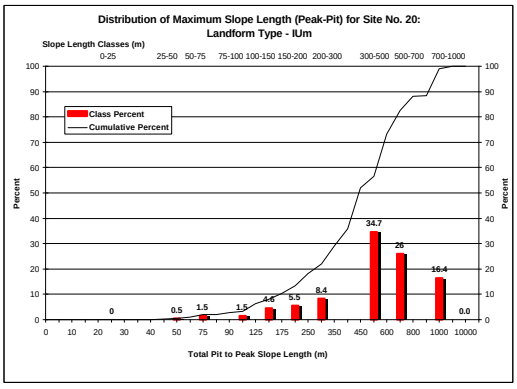
b) Slope aspect (degrees)



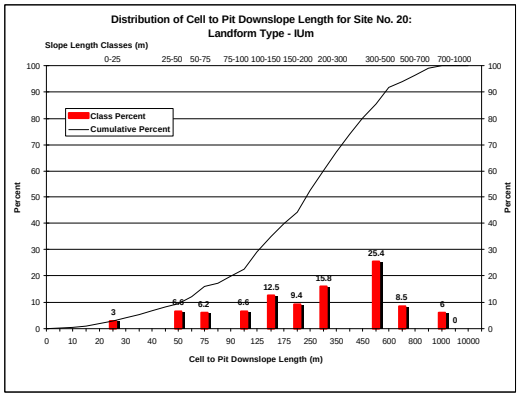
c) Descriptive relief (pit to peak) (m)



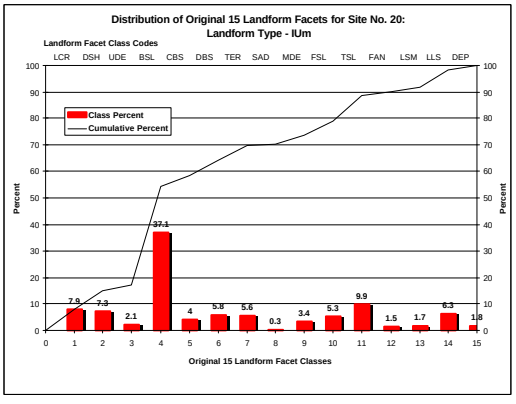
d) Effective relief (cell to pit) (m)



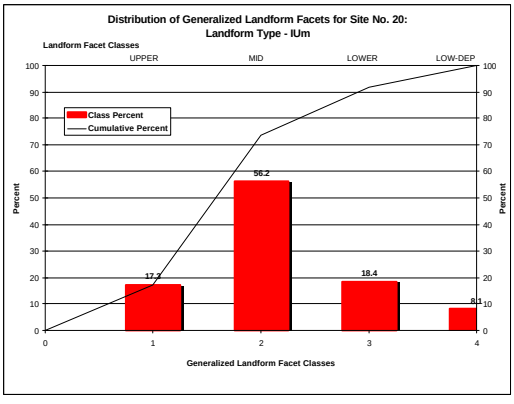
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



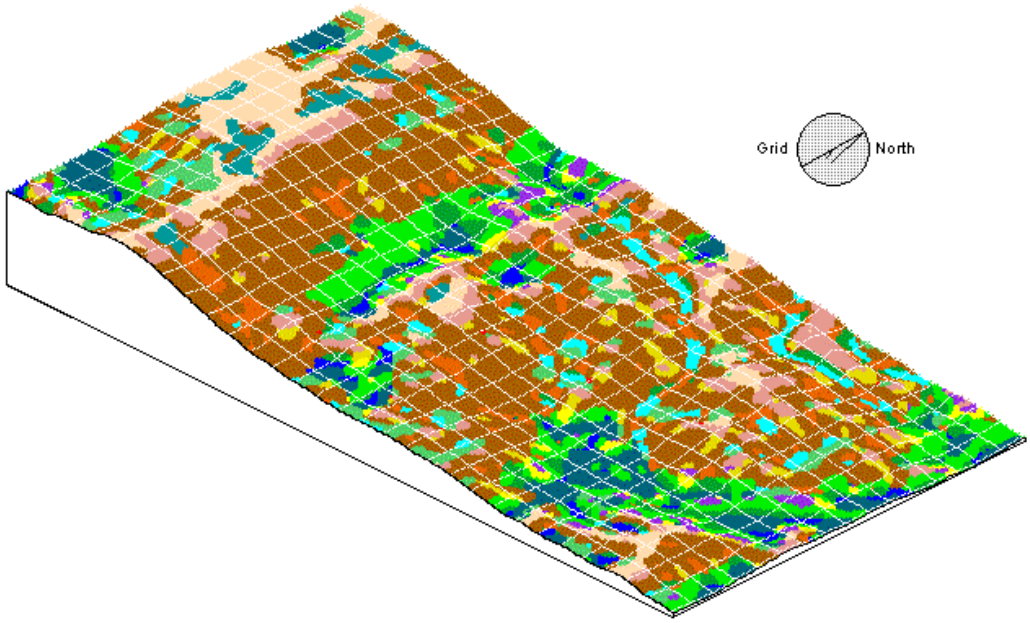
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

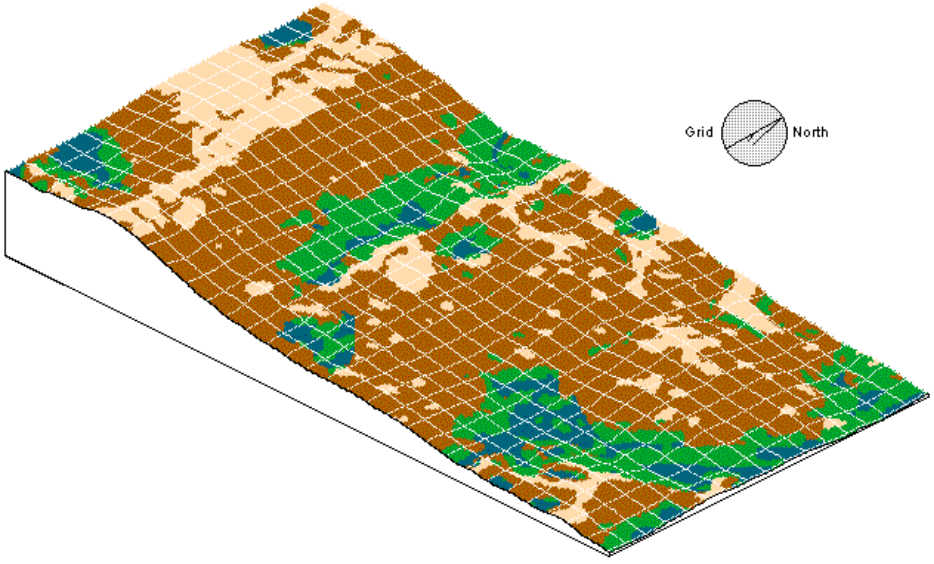
Site No: 20 Olds North Site Landform Type: IUh

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
7.9	7.3	2.1	37.1	4.0	5.8	5.6	0.3	3.4	5.3	9.9	1.5	1.7	6.3	1.8



a) 3D view of the Olds North Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		17.3	1.01	1.71	262.7	558.7	6.98
MID		56.2	1.52	2.23	152.3	475.7	5.34
LOW		18.4	1.51	2.13	43.1	147.8	1.40
DEP		8.10	0.63	0.85	25.0	114.2	0.77



b) 3D view of the Olds North Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 21 Landform Type: IUh

Site Identification: Olds South Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	705359	709937	5737585	5738435

Legal Location	Site Name	Landform Type	Comments
S 1/2 24-32-01-W5	Olds South Site	IUh	AAFRD Weed Research Site near Olds

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	1.8%	3.0%	1.0 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	5.4 m	10.0 m	2-5 m	5-10 m
Effective Relief (Cell to Pit) (m)	2.8 m	5.0 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	450.4 m	600 m	300-500 m	500-700 m
Effective Slope Length (Cell to Pit m)	244.6 m	400 m	200-300 m	300-500 m
No. Watersheds per 100 ha	27.6/ 100 ha			
Percent Off-site Drainage	16.8 %			

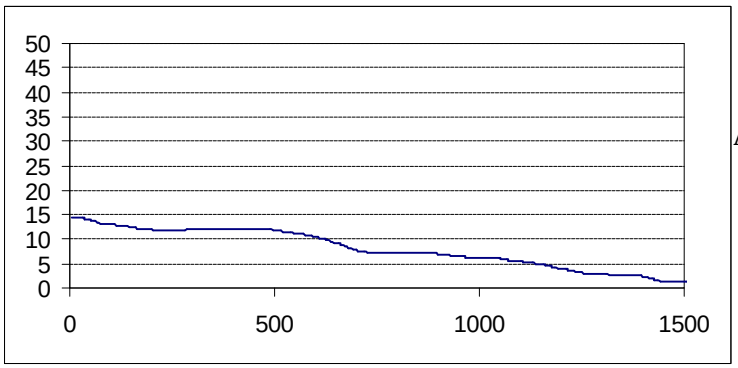
Origin and pre-processing of original DEM X, Y, Z data

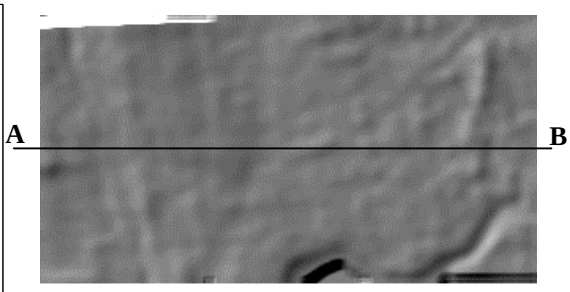
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	L. Hall	Vehicle mounted DGPS survey	Nielsentopo.txt	161,390
DEM Surfacing:	LandMapper	R MacMillan	ArcView3 IWD, 50 m fixed radius	Jeff1.grd	53,550
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	JE2_DEM.img	53,550

Evolution of the DEM from initial X, Y, Z data to final working surface

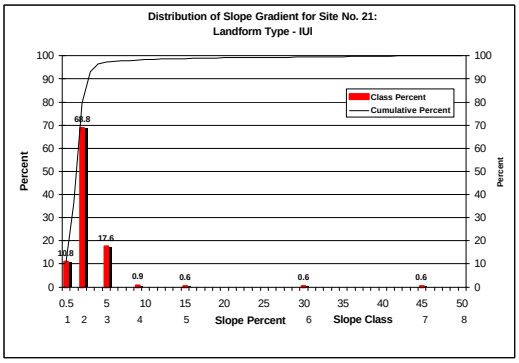
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Jeff1.grd	705359	706937	5737585	5738435	170	315	5 m	AV3 IWD surface
2	Jeff2.grd	705359	706937	5737585	5738435	170	315	5 m	1 5x5 mean filter to 1
3	JE1_5m.img	705359	706937	5737585	5738435	170	315	5 m	Export 2 to Idrisi
4	JE1_asc.txt	705359	706937	5737585	5738435	170	315	5 m	ASCII export of 3
5	JE2_7x7.img	705359	706937	5737585	5738435	170	315	5 m	7x7 mean filter to 3
6	JE2_7x7.img	705359	706937	5737585	5738435	170	315	5 m	ASCII export of 5
7	Q21DEM.dbf	705359	706937	5737585	5738435	170	315	5 m	Import 6 into DBF

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

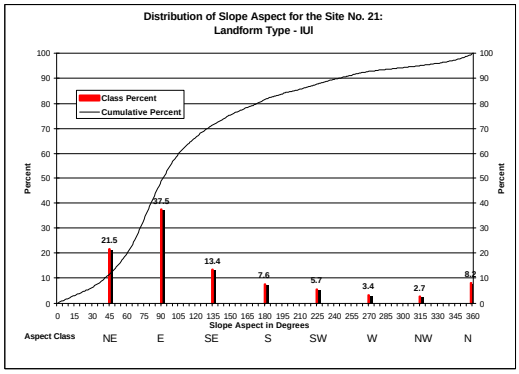




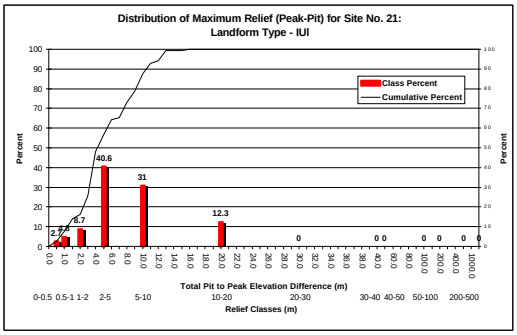
Site No: 21 Olds South Site Landform Type: IUh



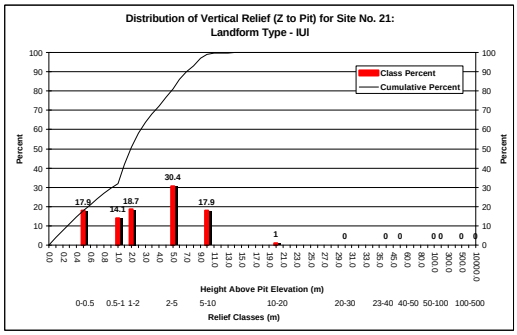
a) Slope gradient (%)



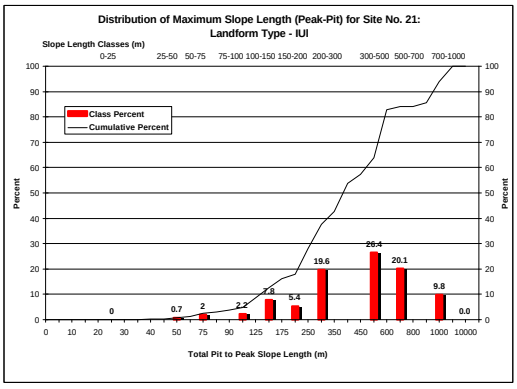
b) Slope aspect (degrees)



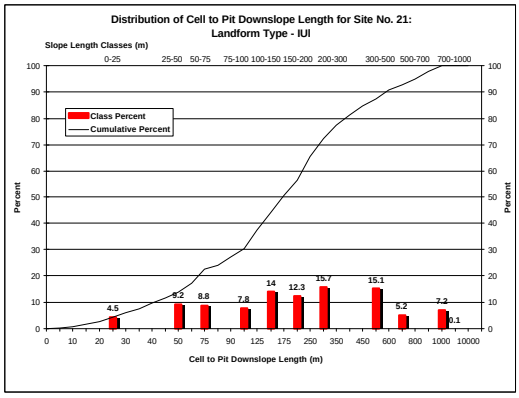
c) Descriptive relief (pit to peak) (m)



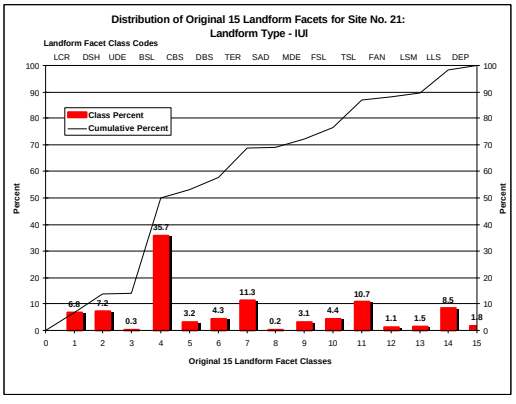
d) Effective relief (cell to pit) (m)



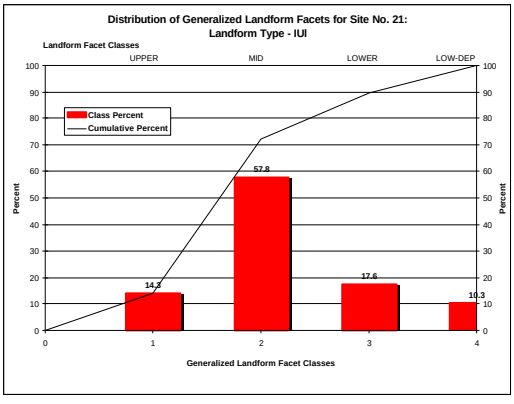
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



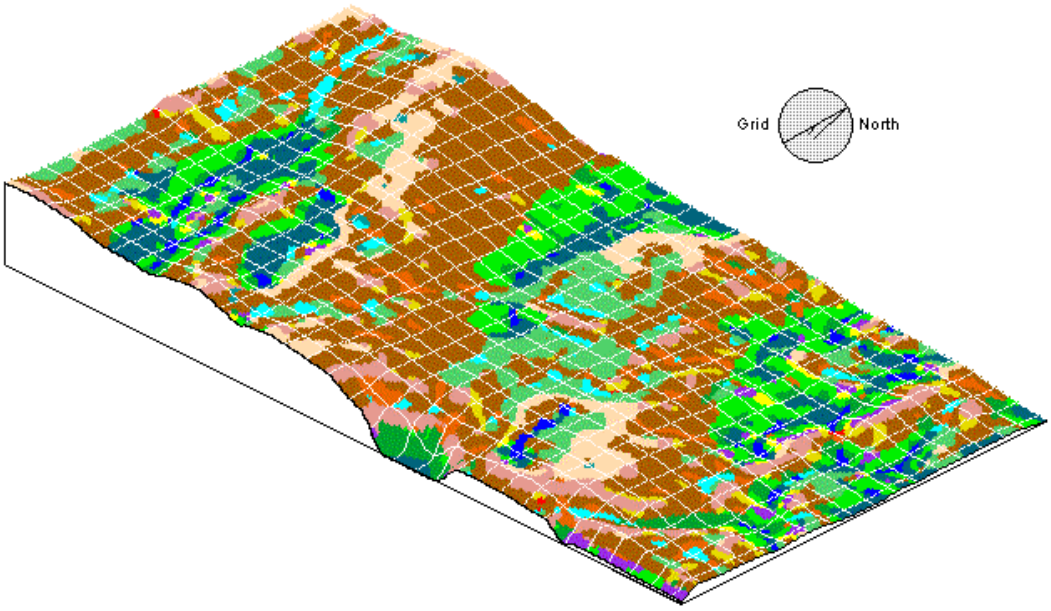
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

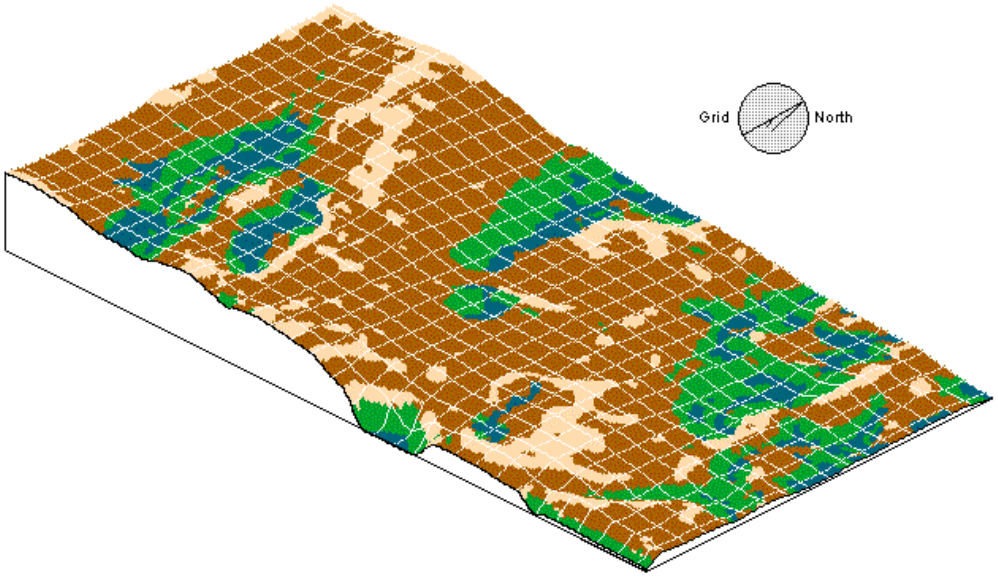
Site No: 21 **Olds South Site** **Landform Type: IUh**

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
6.8	7.2	0.3	35.7	3.2	4.3	11.3	0.2	3.1	4.4	10.7	1.1	1.5	8.5	1.8



a) 3D view of the Olds South Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		14.3	1.13	2.26	124.7	444.2	7.69
MID		57.8	1.33	2.09	123.7	467.6	5.50
LOW		17.6	1.40	2.12	35.4	130.5	1.12
DEP		10.3	0.57	0.81	21.2	91.3	0.52



b) 3D view of the Olds South Site: 4 unit landform element generalization - 1 3x3 post classification modal filter

SITE NO. 22 Landform Type: U1l

Site Identification: Leduc AAFRD Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	705359	709937	5737585	5738435

Legal Location	Site Name	Landform Type	Comments
SW-18-49-24-W4	Leduc Abman Site	U1l	AAFRD Weed Research Site near Leduc

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	0.8%	2.0%	1.0 -2.0%	0.0 -1.0%
Descriptive Relief (Pit to Peak) (m)	1.9 m	3.0 m	2-5 m	1-2 m
Effective Relief (Cell to Pit) (m)	0.9 m	2.0 m	0-1 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	263.6 m	400 m	300-500 m	200-300 m
Effective Slope Length (Cell to Pit m)	121.2 m	200 m	100-150 m	50-75 m
No. Watersheds per 100 ha	42.6/ 100 ha			
Percent Off-site Drainage	12.2 %			

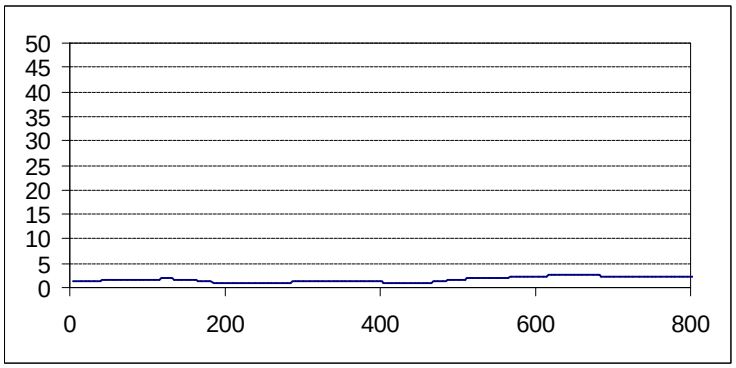
Origin and pre-processing of original DEM X, Y, Z data

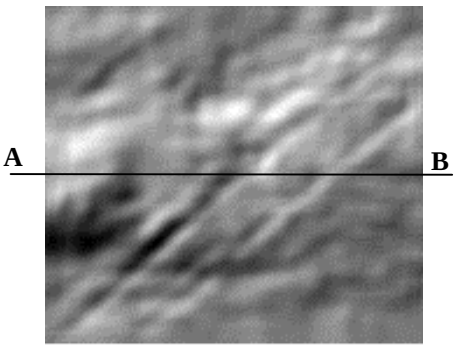
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	L. Hall	Vehicle mounted DGPS survey	AbmaGPS1,2,3	25,000
DEM Surfacing:	LandMapper	R MacMillan	ArcView3 IWD, 50 m fixed radius	Ab3IWD.grd	26,490
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Ab3IWD73.img	26,490

Evolution of the DEM from initial X, Y, Z data to final working surface

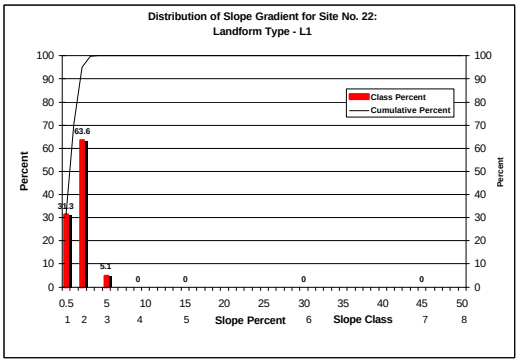
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	AB3IWD.grd	332311	333121	2901540	5902265	145	162	5 m	AV3 IWD surface
2	Ab3iwdm7.img	332311	333121	2901540	5902265	145	162	5 m	1 7x7 mean filter to 1
3	AB3iwd73.img	332311	333121	2901540	5902265	145	162	5 m	1 3x3 mean filter to 2
4	AB3asc73.img	332311	333121	2901540	5902265	145	162	5 m	ASCII export of 3
5	Q22DEM.dbf	332311	333121	2901540	5902265	145	162	5 m	Import 4 into DBF
6									
7									

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

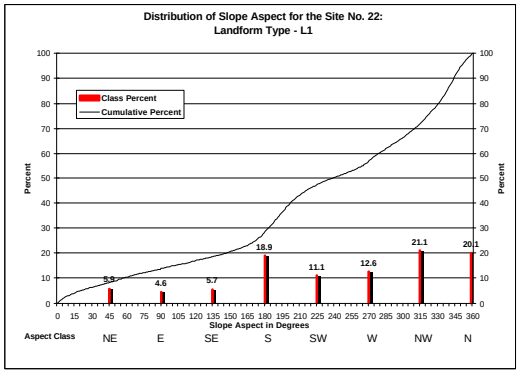




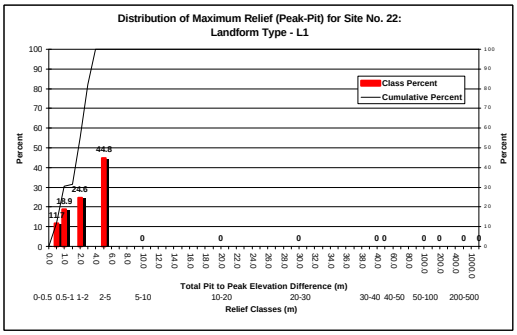
Site No: 22 Leduc AAFRD Site Landform Type: U1l



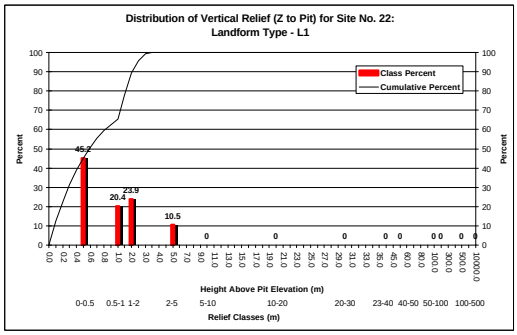
a) Slope gradient (%)



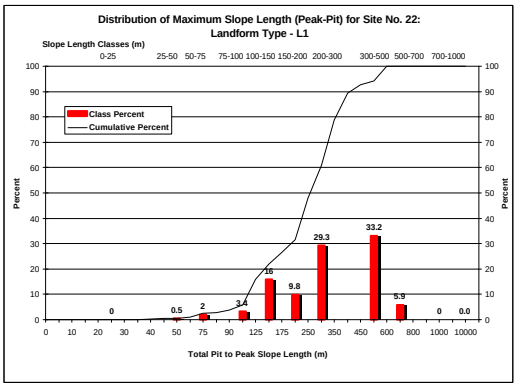
b) Slope aspect (degrees)



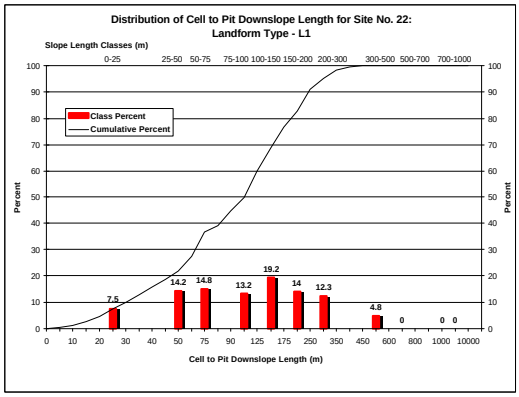
c) Descriptive relief (pit to peak) (m)



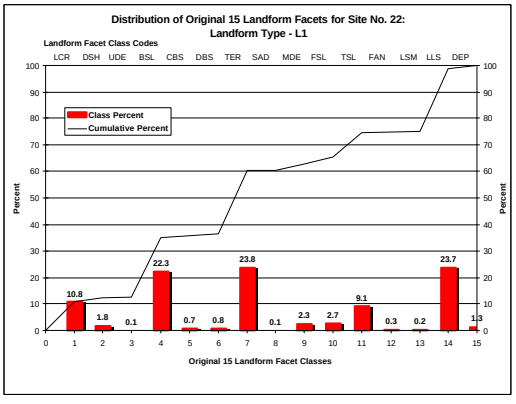
d) Effective relief (cell to pit) (m)



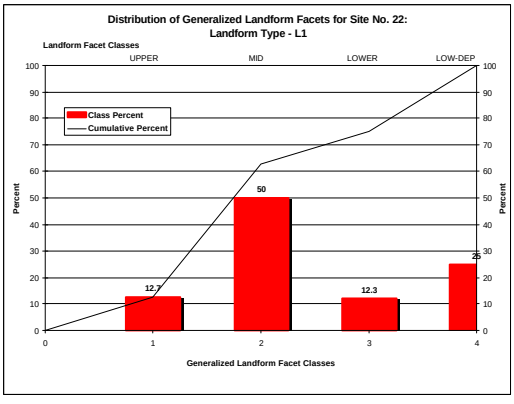
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



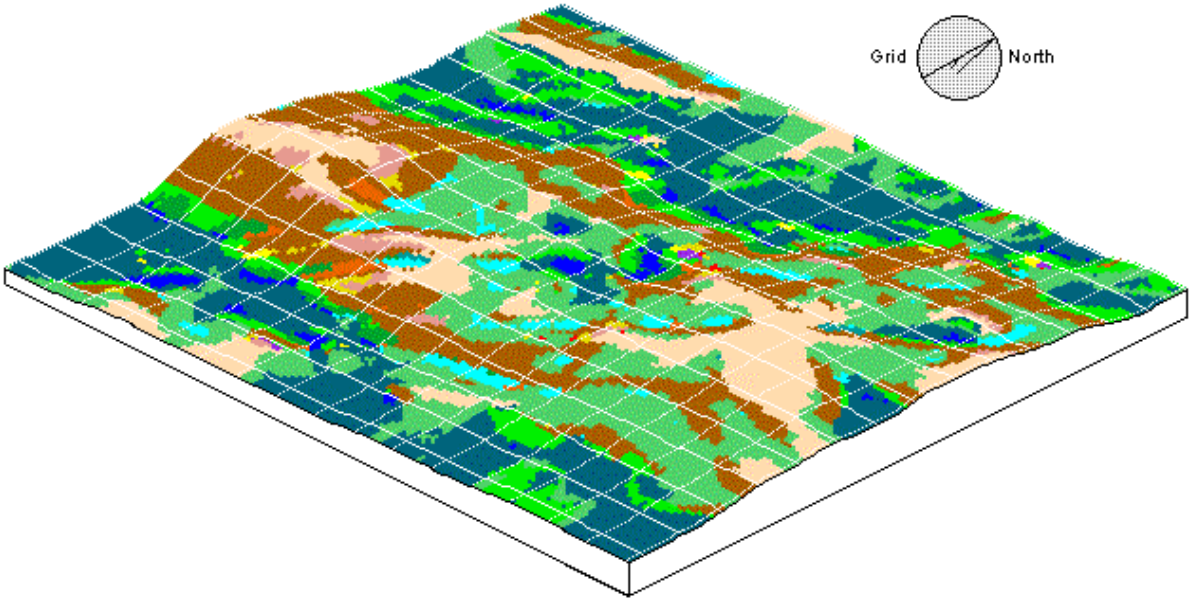
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

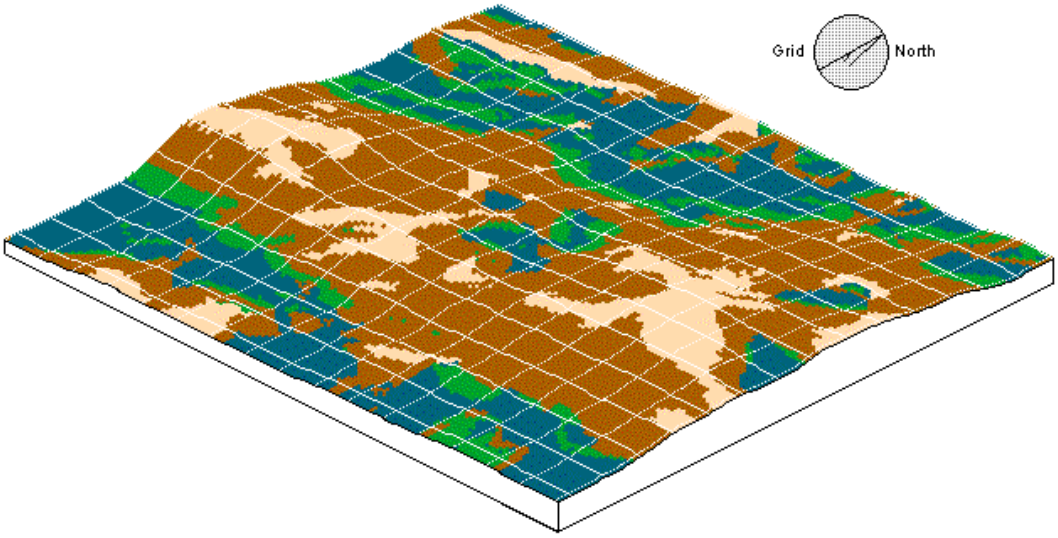
Site No: 22 Leduc AAFRD Site Landform Type: U1l

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
6.8	7.2	0.3	35.7	3.2	4.3	11.3	0.2	3.1	4.4	10.7	1.1	1.5	8.5	1.8



a) 3D view of the Leduc AAFRD Site: 15 unit landform classification - no post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		14.3	1.13	2.26	124.7	444.2	7.69
MID		57.8	1.33	2.09	123.7	467.6	5.50
LOW		17.6	1.40	2.12	35.4	130.5	1.12
DEP		10.3	0.57	0.81	21.2	91.3	0.52



b) 3D view of the Leduc AAFRD Site: 4 unit landform element generalization - no post classification modal filter

SITE NO. 23 Landform Type: IUl

Site Identification: Didsbury AAFRD Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	705359	709937	5737585	5738435

Legal Location	Site Name	Landform Type	Comments
SW5-31-27-W4	Didsbury Conrad Site	IUl	AAFRD Weed Research Site near Leduc

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.3%	3.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	18.3 m	20.0 m	10-20 m	5-10 m
Effective Relief (Cell to Pit) (m)	8.9 m	14.0 m	10-20 m	5-10 m
Descriptive Slope Length (Pit to Peak m)	906.2 m	>1000 m	700-1000 m	>1000 m
Effective Slope Length (Cell to Pit m)	447.4 m	700 m	300-500 m	500-700 m
No. Watersheds per 100 ha	6.5/ 100 ha			
Percent Off-site Drainage	100.0 %			

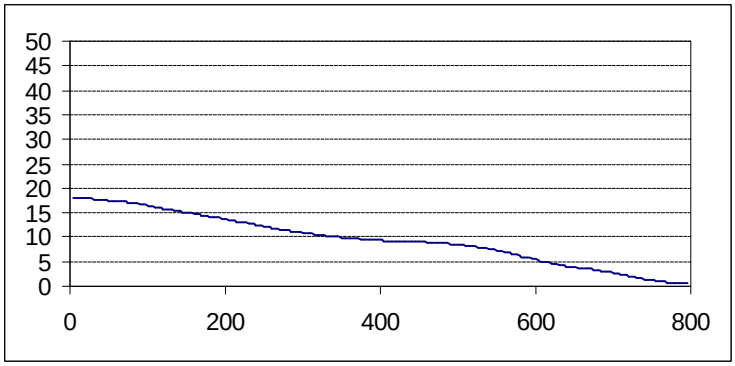
Origin and pre-processing of original DEM X, Y, Z data

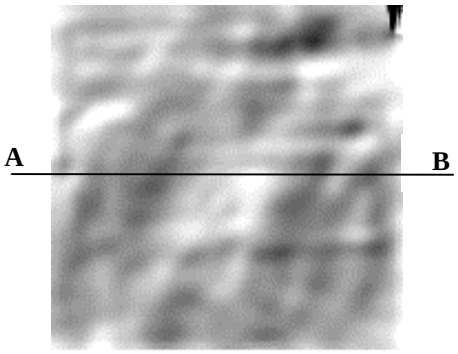
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	L. Hall	Vehicle mounted DGPS survey	Conradtopo.txt	34,249
DEM Surfacing:	LandMapper	R MacMillan	ArcView3 IWD, 50 m fixed radius	Co1_IWD1.grd	24,804
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Co1_3377.img	24,804

Evolution of the DEM from initial X, Y, Z data to final working surface

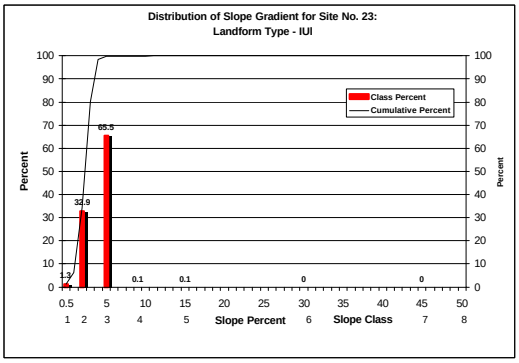
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Co1_IWD1.grd	676040	676835	5734875	5735655	156	159	5 m	AV3 IWD surface
2	Co1_IWD1.img	676040	676835	5734875	5735655	156	159	5 m	Export 1 to Idrisi
3	Co1_3377.img	676040	676835	5734875	5735655	156	159	5 m	1 5x5 mean filter to 2
4	Co2_7x7.img	676040	676835	5734875	5735655	156	159	5 m	1 7x7 mean filter to 3
5	Co2_asc.img	676040	676835	5734875	5735655	156	159	5 m	ASCII export of 4
6	Q23DEM.dbf	676040	676835	5734875	5735655	156	159	5 m	Import 5 into DBF
7									

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

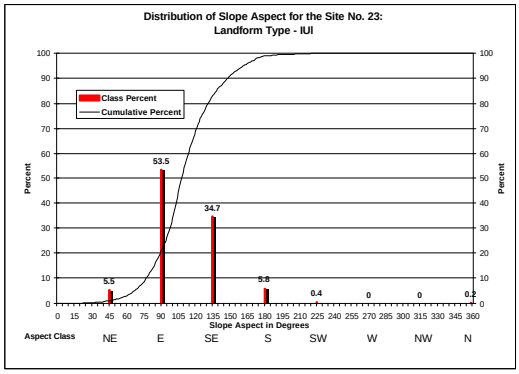




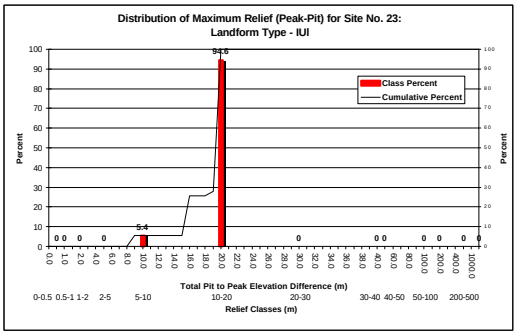
Site No: 23 Didsbury AAFRD Site Landform Type:IUl



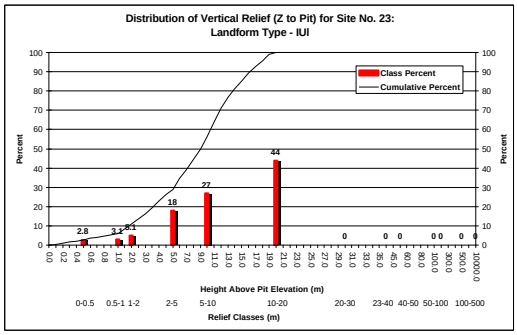
a) Slope gradient (%)



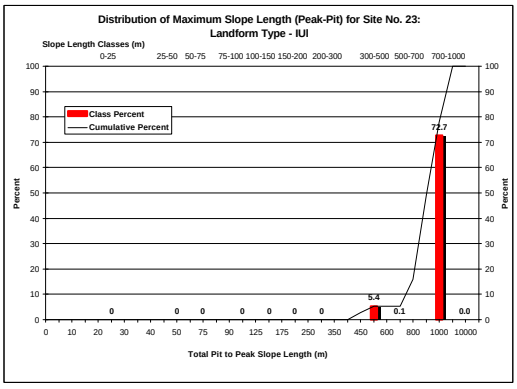
b) Slope aspect (degrees)



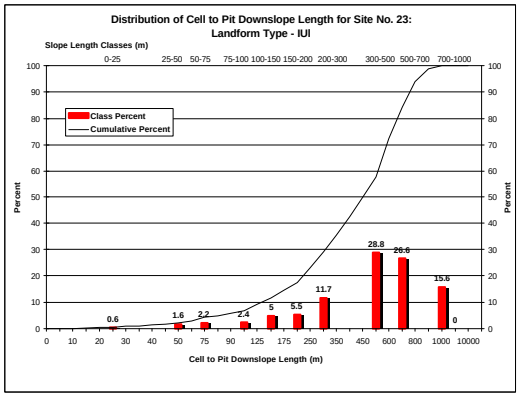
c) Descriptive relief (pit to peak) (m)



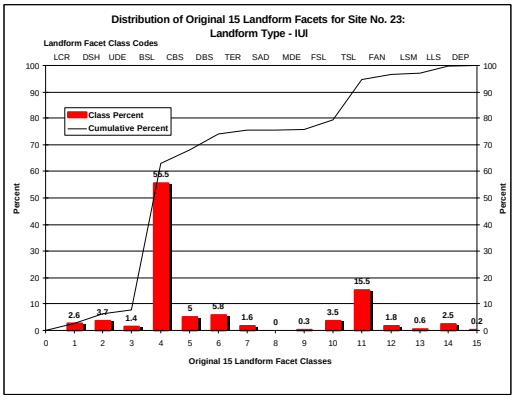
d) Effective relief (cell to pit) (m)



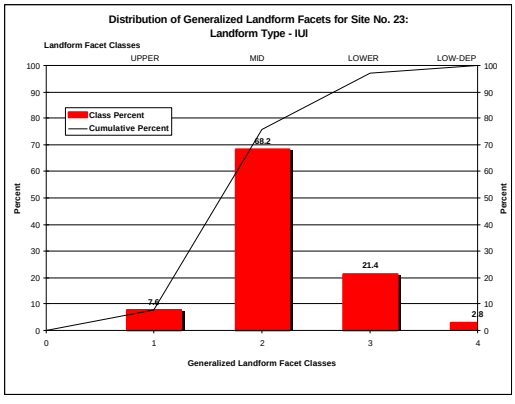
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



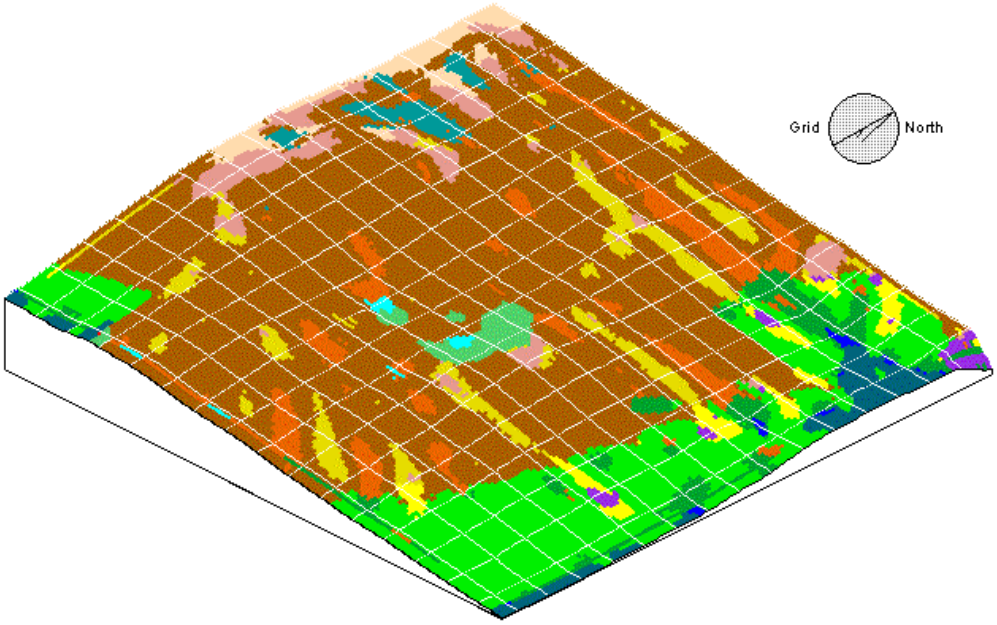
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

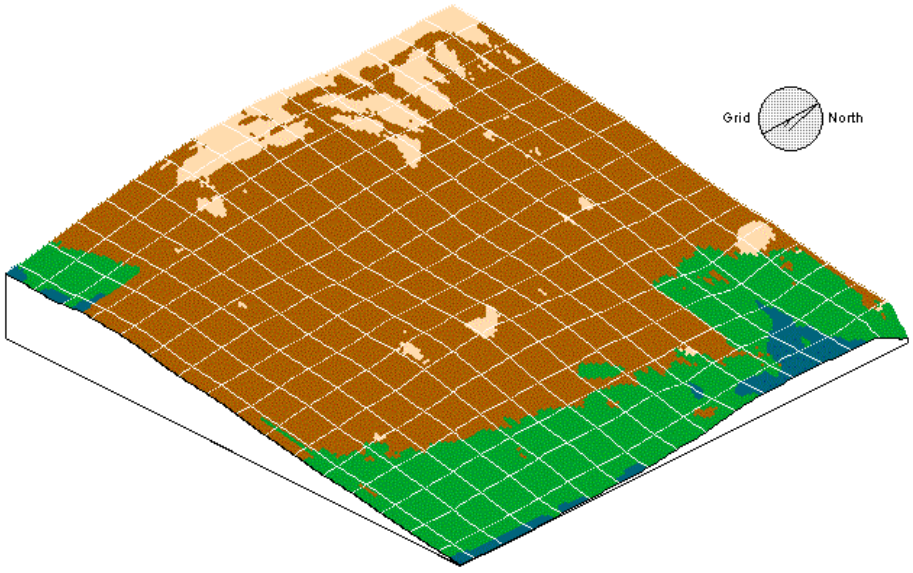
Site No: 23 Didsbury AAFRD Site Landform Type: IUl

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
2.6	3.7	1.4	55.5	5.0	5.8	1.6	0.0	0.3	3.5	15.5	1.8	0.6	2.5	0.2



a) 3D view of the Didsbury AAFRD Site: 15 unit landform classification - no post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		7.6	1.62	2.28	711.4	870.8	18.8
MID		68.2	2.40	3.04	343.2	657.8	13.7
LOW		21.4	2.46	3.05	91.6	291.5	3.77
DEP		2.8	0.66	0.87	43.0	440.8	3.53



b) 3D view of the Didsbury AAFRD Site: 4 unit landform element generalization - no post classification modal filter

SITE NO. 24 Landform Type: U1h

Site Identification: Stony Plain - AAFRD Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	300066	300031	5932547	5933537

Legal Location	Site Name	Landform Type	Comments
NE-24-52-01-W5	Stony Plain Site	U1h	AAFRD Weed Research Site near Stony Plain (Hennig)

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	2.9%	5.0%	2.0 -5.0%	1.0 -2.0%
Descriptive Relief (Pit to Peak) (m)	4.1 m	6.0 m	2-5 m	5-10 m
Effective Relief (Cell to Pit) (m)	1.8 m	3.0 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	182.1 m	250 m	150-200 m	200-300 m
Effective Slope Length (Cell to Pit m)	77.6 m	125 m	25-50 m	50-75 m
No. Watersheds per 100 ha	70.1/ 100 ha			
Percent Off-site Drainage	14.5 %			

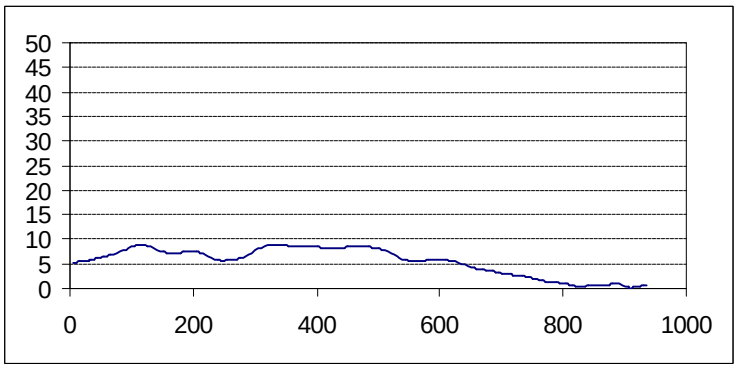
Origin and pre-processing of original DEM X, Y, Z data

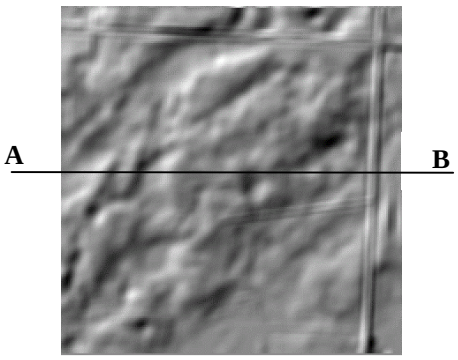
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	Land Data	P. Seeley	Floating dot photogrammetry	52-01-05.asc	42,221
DEM Surfacing:	LandMapper	R MacMillan	ArcView3 Spline with tension	Spline_ver1.grd	38,214
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Ty_spl55.img	38,214

Evolution of the DEM from initial X, Y, Z data to final working surface

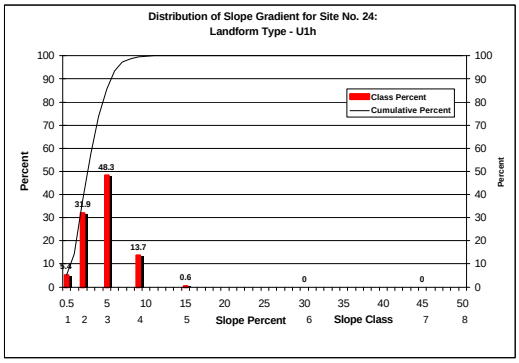
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Spline_ver1.grd	300066	301031	5932547	5933537	198	193	5 m	AV3 TPS surface
2	Spline_v1.img	300066	301031	5932547	5933537	198	193	5 m	Export 1 to Idrisi
3	Spline55.img	300066	301031	5932547	5933537	198	193	5 m	1 5x5 mean filter to 2
4	Ty_spl55.img	300066	301031	5932547	5933537	198	193	5 m	ASCII export of 3
5	T52DEM.dbf	300066	301031	5932547	5933537	198	193	5 m	Import 5 into DBF
6									
7									

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

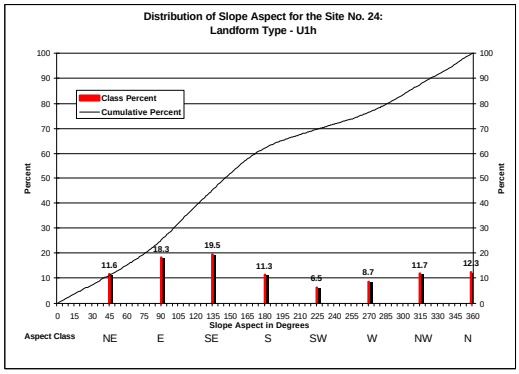




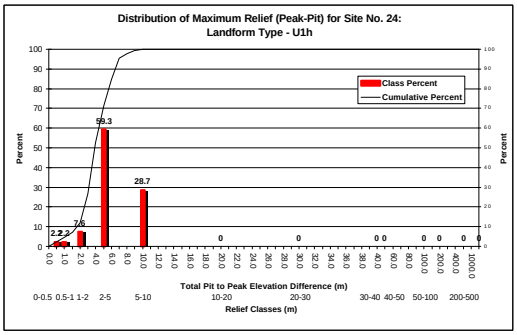
Site No: 24 Stony Plain AAFRD Site Landform Type: U1h



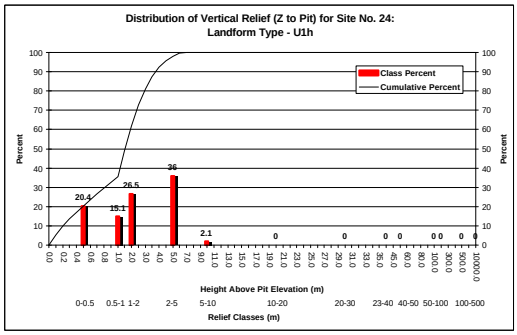
a) Slope gradient (%)



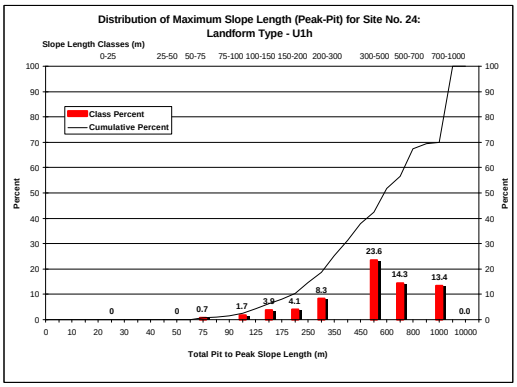
b) Slope aspect (degrees)



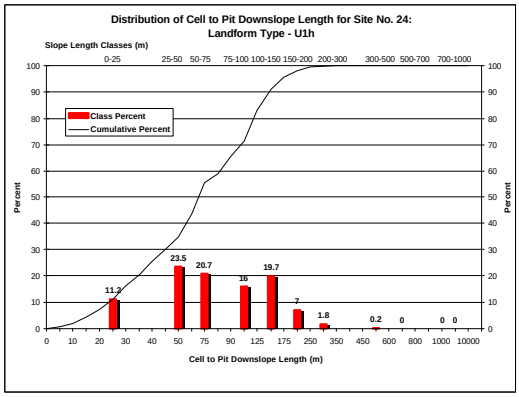
c) Descriptive relief (pit to peak) (m)



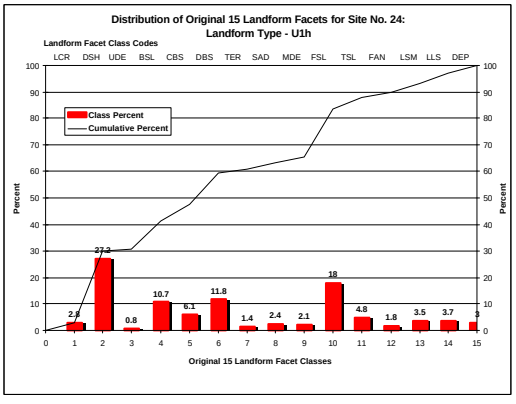
d) Effective relief (cell to pit) (m)



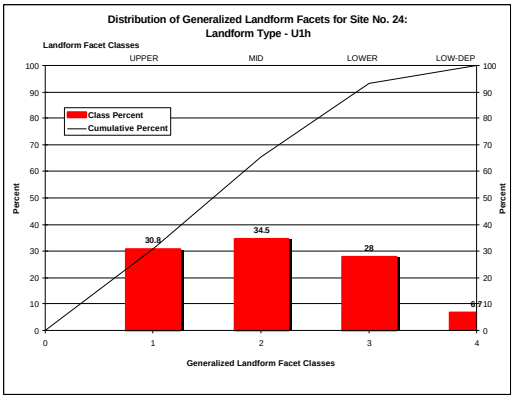
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



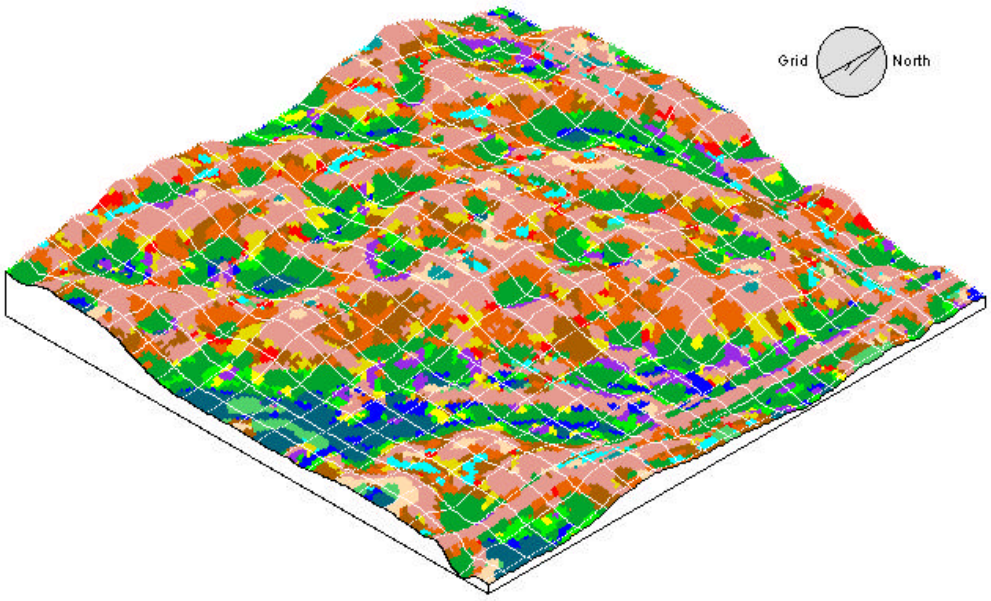
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

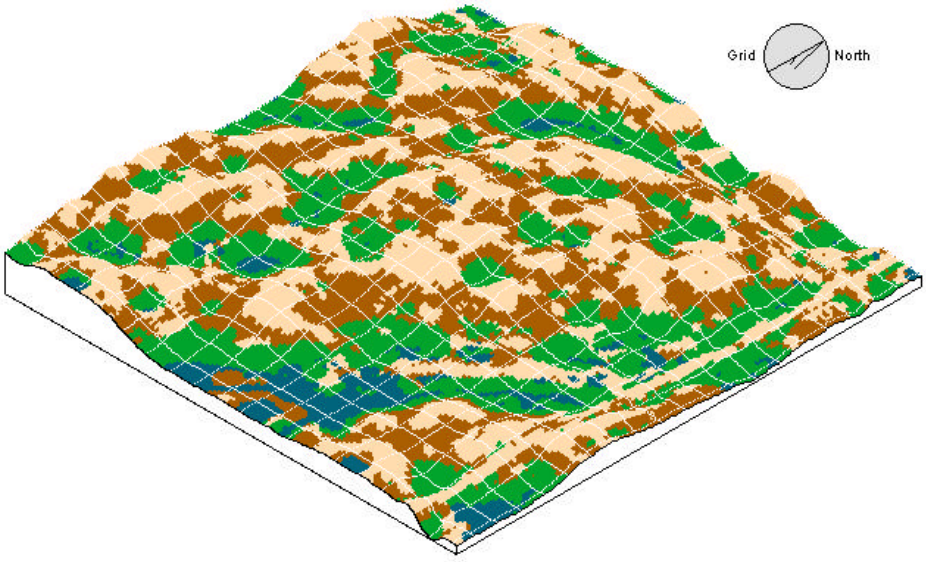
Site No: 24 Stony Plain AAFRD Site Landform Type: U1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
2.8	27.2	0.8	10.7	6.1	11.8	1.4	2.4	2.1	18.0	4.8	1.8	3.5	3.7	3.0



a) 3D view of the Stony Plain AAFRD Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		30.8	2.6	4.4	56.7	142.6	3.97
MID		34.5	3.05	5.03	51.1	125.6	2.89
LOW		28.0	2.65	4.18	20.7	64.3	1.04
DEP		6.7	0.58	0.91	15.0	50.0	0.33



b) 3D view of the Stony Plain AAFRD Site: 4 unit landform element generalization - 1 3x3 post modal filter

SITE NO. 25 Landform Type: H1m

Site Identification: Viking - AAFRD Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	449850	450680	5877542	5878442

Legal Location	Site Name	Landform Type	Comments
SE13-48-13-W4	Viking AAFRD Site	H1m	AAFRD Weed Research Site near Viking (B. Leech)

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	5.6%	9.0%	2.0 -5.0%	5.0 -9.0%
Descriptive Relief (Pit to Peak) (m)	5.5 m	8.0 m	5-10 m	2-5 m
Effective Relief (Cell to Pit) (m)	2.4 m	4.5 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	131.5 m	175 m	100-150 m	150-200 m
Effective Slope Length (Cell to Pit m)	65.8 m	100 m	25-50 m	50-75 m
No. Watersheds per 100 ha	79.0/ 100 ha			
Percent Off-site Drainage	8.3 %			

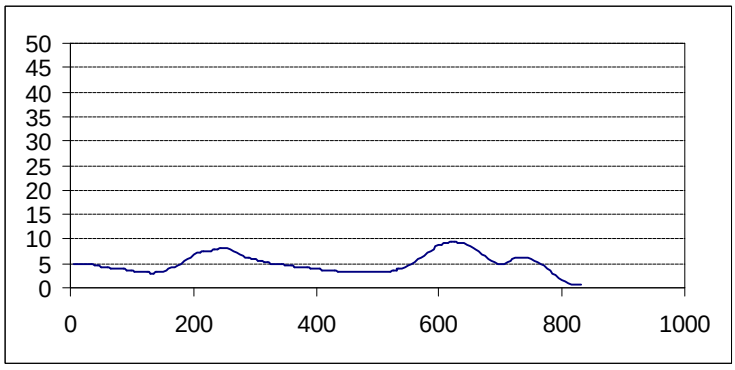
Origin and pre-processing of original DEM X, Y, Z data

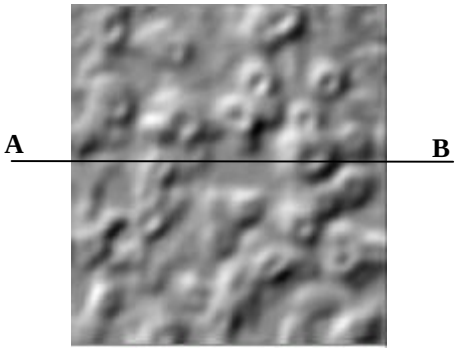
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	L Kryzanowski	Differential GPS Field Survey	Bleech.xyz	unknown
DEM Surfacing:	AAFRD	S. Nowlan	GRASS TPS with tension	V03_DEM1.grd	29,880
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	V03DEM5a.img	29,880

Evolution of the DEM from initial X, Y, Z data to final working surface

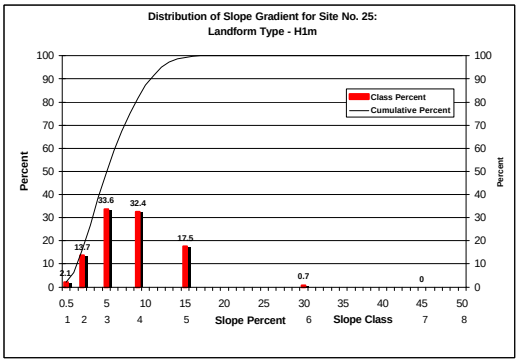
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Vik_DEM1.grd	449850	450680	5877542	5878442	180	166	5 m	GRASS TPS surface
2	V03dem1.img	449850	450680	5877542	5878442	180	166	5 m	Export 1 to Idrisi
3	V03DEM55.img	449850	450680	5877542	5878442	180	166	5 m	1 5x5 mean filter to 2
4	V03DEM5a.img	449850	450680	5877542	5878442	180	166	5 m	ASCII export of 3
5	V03DEM.dbf	449850	450680	5877542	5878442	180	166	5 m	Import 5 into DBF
6									
7									

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

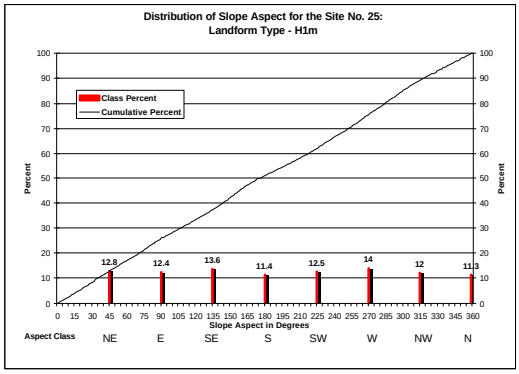




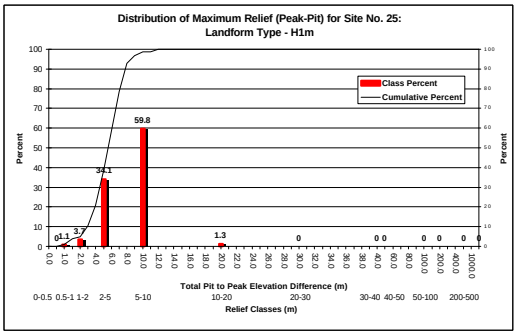
Site No: 25 Viking AAFRD Site Landform Type: H1m



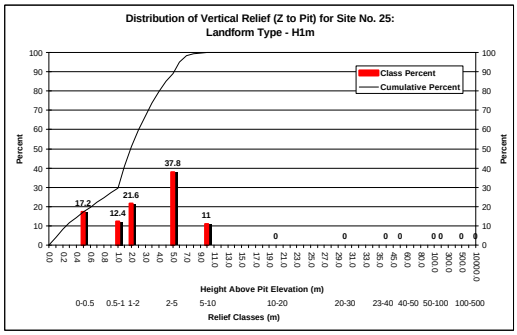
a) Slope gradient (%)



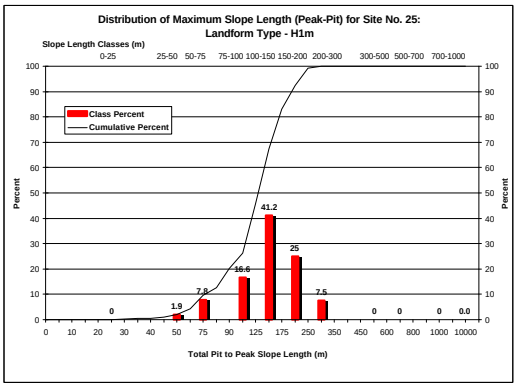
b) Slope aspect (degrees)



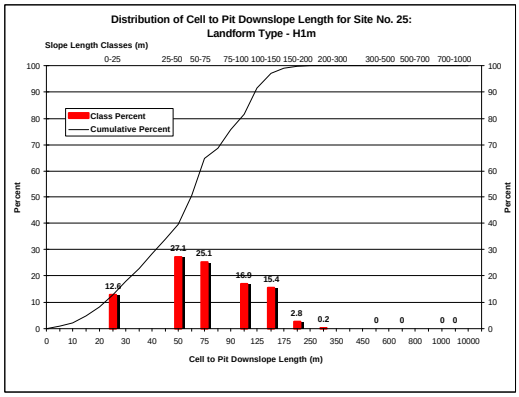
c) Descriptive relief (pit to peak) (m)



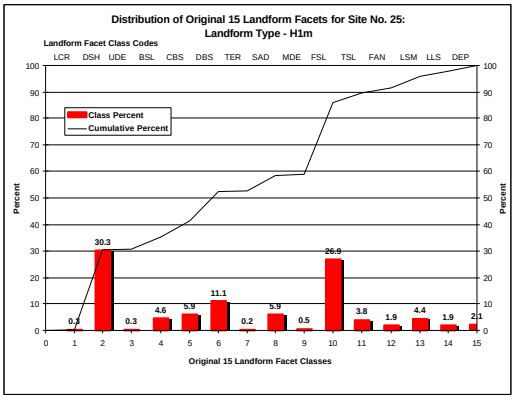
d) Effective relief (cell to pit) (m)



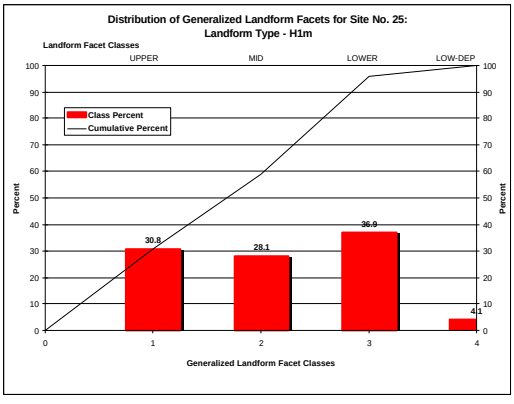
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



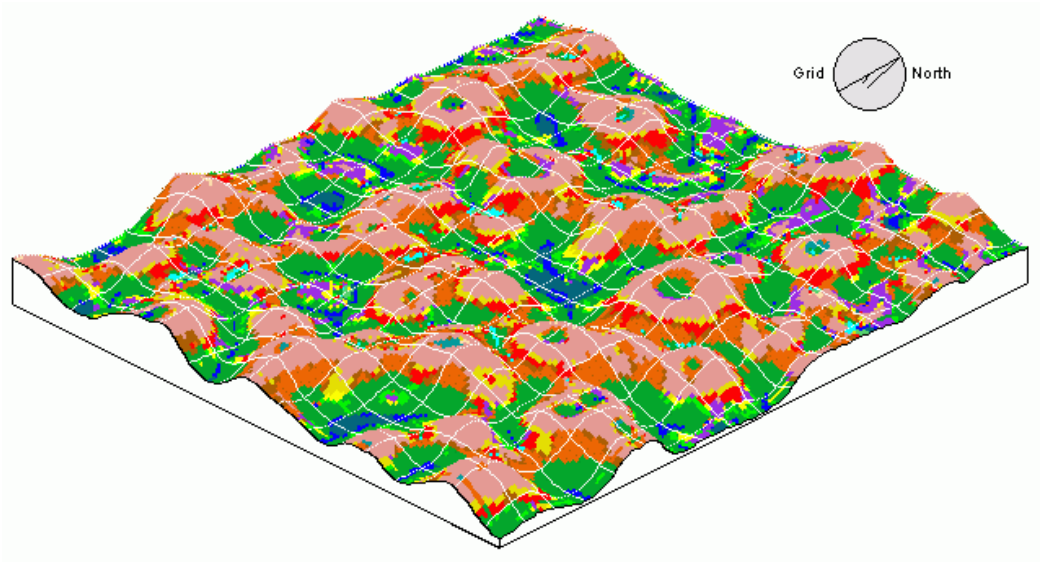
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

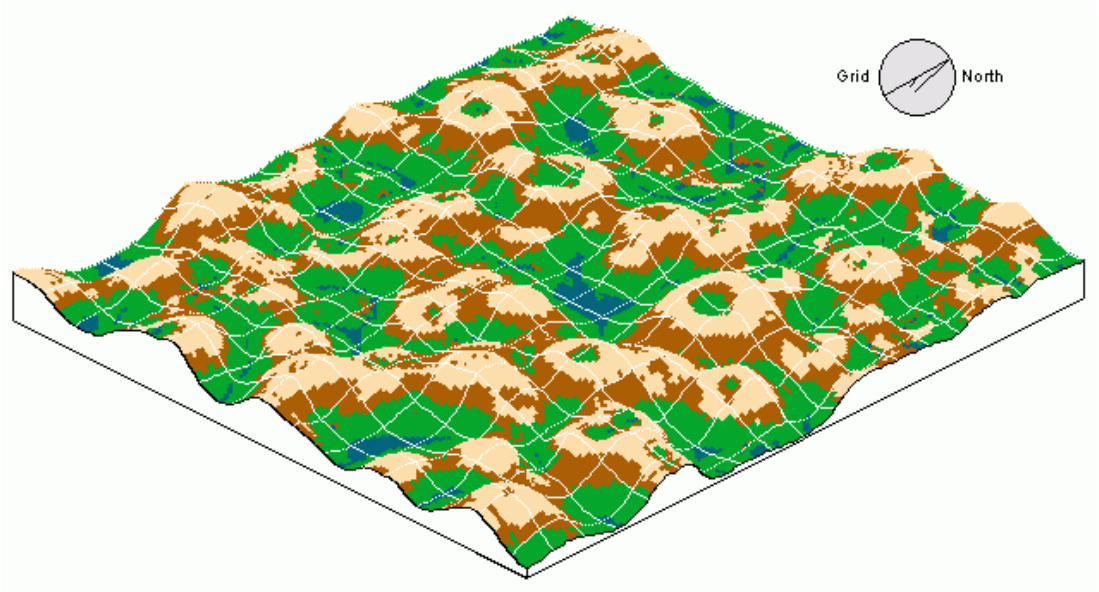
Site No: 25 Viking AAFRD Site Landform Type: H1m

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
0.3	30.3	0.3	4.6	5.9	11.1	0.2	5.9	0.5	26.9	3.8	1.9	4.4	1.9	2.1



a) 3D view of the Viking AAFRD Site: 15 unit landform classification - no post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		30.8	5.66	9.32	53.4	177.1	5.63
MID		28.1	6.73	10.25	47.5	109.8	3.69
LOW		36.9	4.11	6.98	20.9	62.7	1.34
DEP		4.1	0.59	0.81	11.2	42.7	0.25



b) 3D view of the Viking AAFRD Site: 4 unit landform element generalization - no post classification modal filter

SITE NO. 26 Landform Type: U1h

Site Identification: AAFRD Bow Island Site

UTM Location	Min Easting	Max Easting	Min Northing	Max Northing
6°UTM - NAD83	481664	482399	5527839	5528604

Legal Location	Site Name	Landform Type	Comments
SW-03-11-10-W4	Bow Island Site	U1h	AAFRD Precision Farming Site near Bow Island

Landform Description

Main Landform Characteristics	Mean Value	80% Value	Dom-1 Value	Dom-2 Value
Slope Gradient (%)	1.9%	2.0%	0.5 -2.0%	2.0 -5.0%
Descriptive Relief (Pit to Peak) (m)	4.8 m	8.0 m	2-5 m	5-10 m
Effective Relief (Cell to Pit) (m)	2.3 m	4.0 m	2-5 m	1-2 m
Descriptive Slope Length (Pit to Peak m)	352.4 m	600 m	500-700 m	300-500 m
Effective Slope Length (Cell to Pit m)	201.4 m	350 m	300-500 m	100-150 m
No. Watersheds per 100 ha	24.9/ 100 ha			
Percent Off-site Drainage	52.1 %			

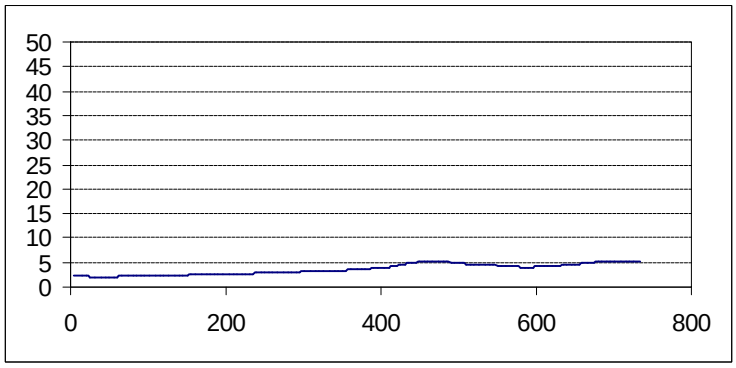
Origin and pre-processing of original DEM X, Y, Z data

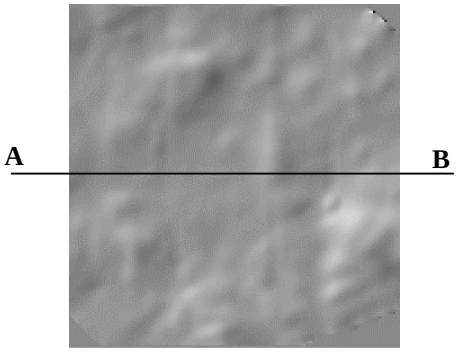
Action	Source	Individuals	Method	File Name	No. Points
Data Collection:	AAFRD	S. Nolan	Differential GPS Field Survey	Bi9596z.txt	46,568
DEM Surfacing:	LandMapper	R MacMillan	ArcView IWD 50 m Fixed	BiIWD50.grd	22,491
Classification:	LandMapper	R MacMillan	LSM Model: April 1999 version	Bi1DEM.img	22,491

Evolution of the DEM from initial X, Y, Z data to final working surface

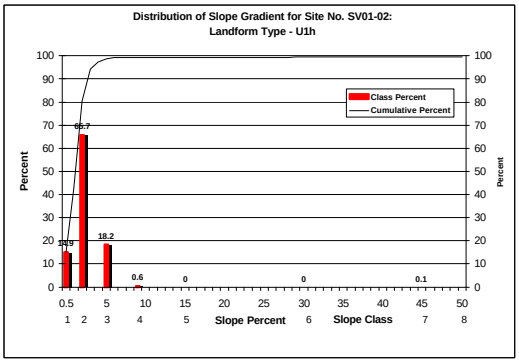
DEM No.	DEM File Name	Min X	Max X	Min Y	Max Y	No. Rows	No Cols.	Grid Size	Actions Taken or Comments
1	Bi_IWD50.grd	481664	482399	5527839	5528604	153	147	5 m	AV3 IWD Surface
2	Bi_IWD33.img	481664	482399	5527839	5528604	153	147	5 m	1 3x3 mean to 1
3	Bi_IWD35.img	481664	482399	5527839	5528604	153	147	5 m	1 5x5 mean filter to 2
4	aBiIWD35.img	481664	482399	5527839	5528604	153	147	5 m	ASCII export of 3
5	BiDEM.dbf	481664	482399	5527839	5528604	153	147	5 m	Import 4 into DBF
6									
7									

Site Illustration: Schematic Cross Section: Hillshade of final DEM:

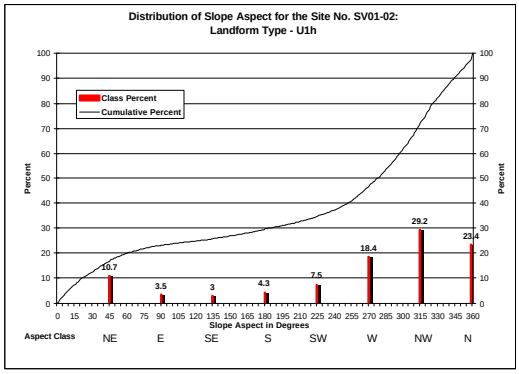




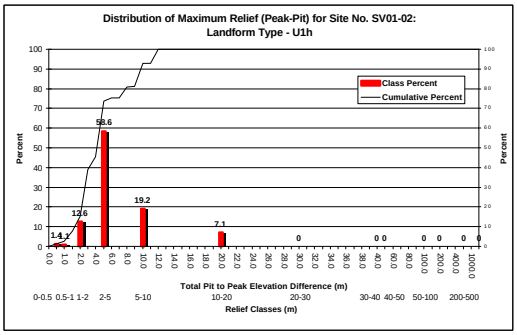
Site No: 26 AAFRD Bow Island Landform Type: U1h



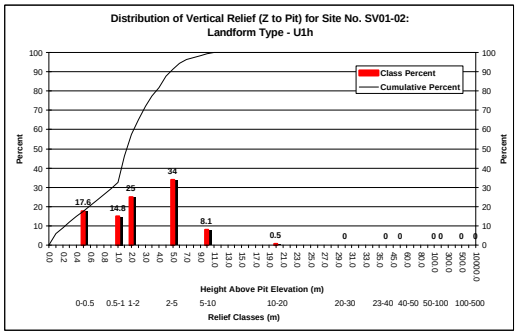
a) Slope gradient (%)



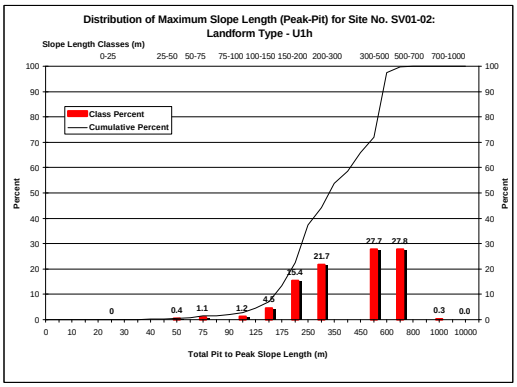
b) Slope aspect (degrees)



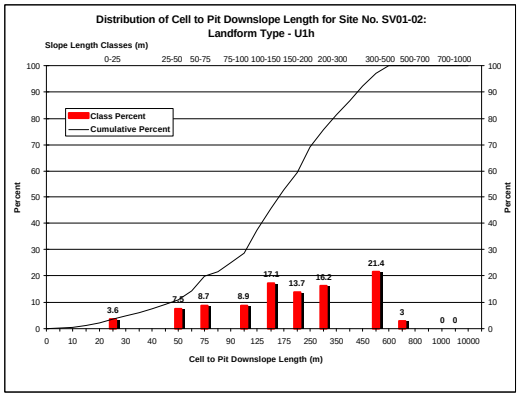
c) Descriptive relief (pit to peak) (m)



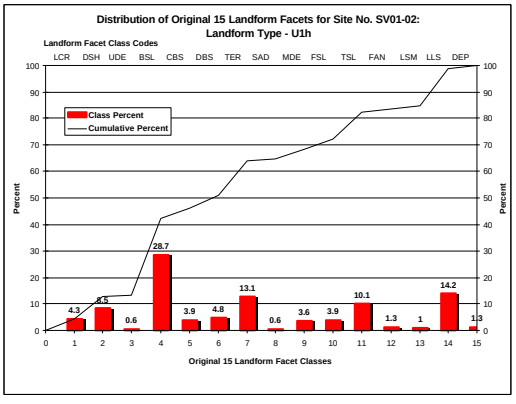
d) Effective relief (cell to pit) (m)



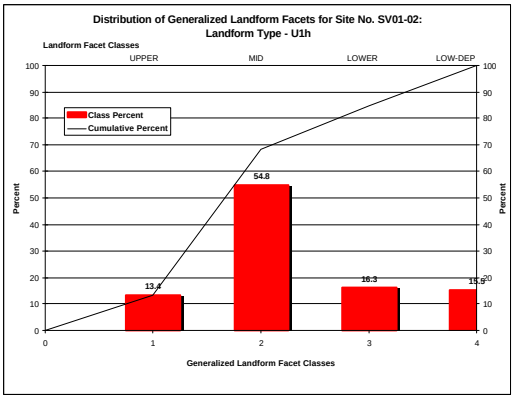
e) Descriptive slope length (pit to peak) (m)



f) Effective slope length (cell to pit) (m)



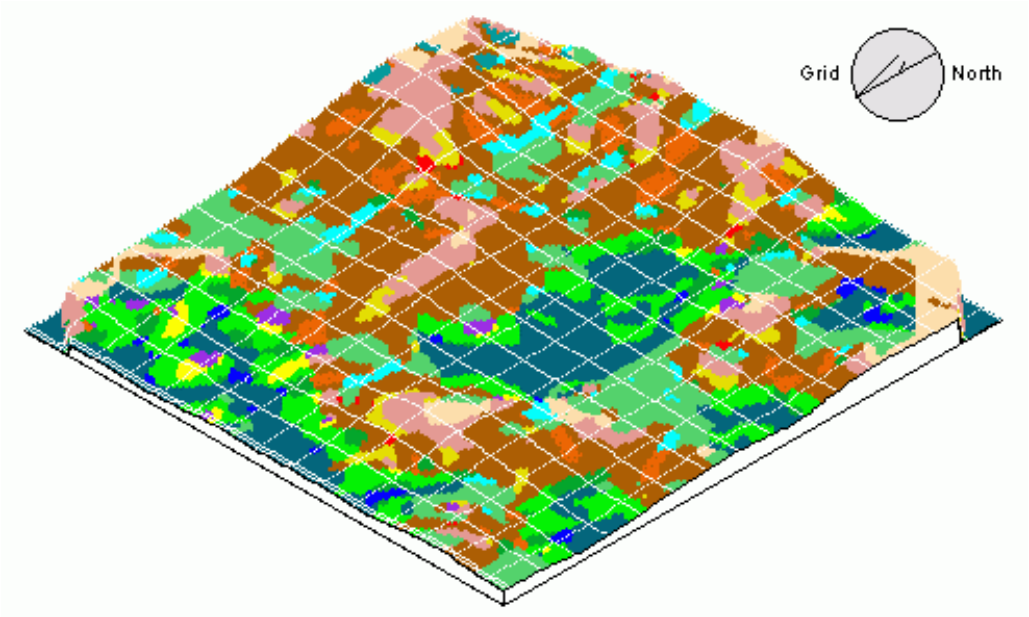
g) Landform classification into 15 facets



h) Landform classification generalized into 4 segments

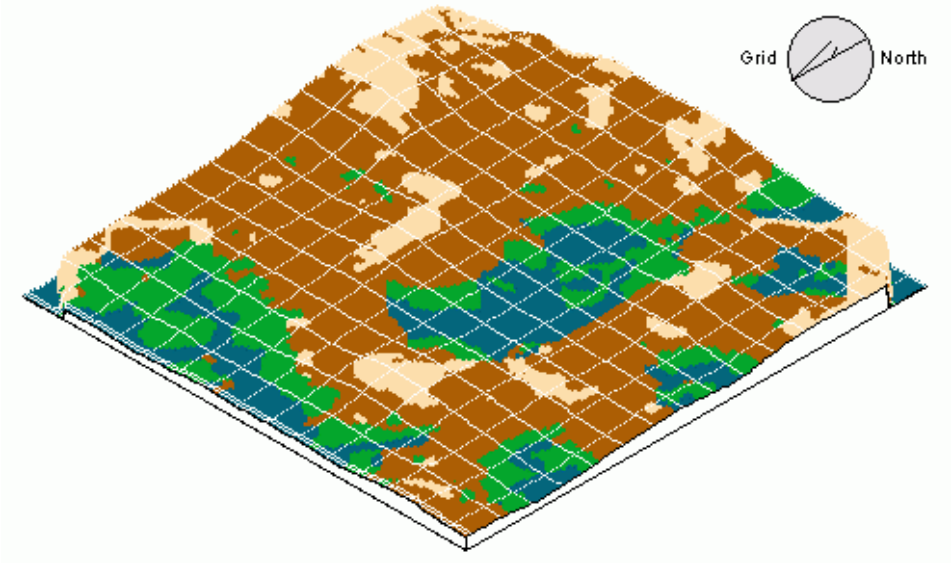
Site No: 26 AAFRD Bow Island Landform Type: U1h

LCR	DSH	UDE	BSL	DBS	CBS	TER	SAD	MDE	FSL	TSL	FAN	LSM	LLS	DEP
4.3	8.5	0.6	28.7	3.9	4.8	13.1	0.6	3.6	3.9	10.1	1.3	1.0	14.2	1.3



a) 3D view of the Bow Island AAFRD Site: 15 unit landform classification - 1 3x3 post classification modal filter

UNIT	COLOR	AREA (%)	SLOPE 50	SLOPE 80	LENGTH 20	LENGTH 80	RELIEF 80
UPS		13.4	1.44	2.49	115.0	437.6	7.16
MID		54.8	1.25	2.14	126.3	383.1	4.04
LOW		16.3	1.35	1.83	51.6	167.8	1.34
DEP		15.5	0.54	0.80	25.5	109.8	0.63



b) 3D view of the Bow Island AAFRD Site: 4 unit landform element generalization - 1 3x3 post modal filter

APPENDIX 2.

Descriptive tables related to landform segmentation

Table A 2.1 Terrain derivatives computed from the DEM for each site

No.	Abbr.	Description	Reference
1	Upslope	Upslope Area Count as per the single flow direction (D8) algorithm	Jenson & Dominique, 1988
2	DS_Area	Upslope area count for the inverted DEM as per the D8 algorithm	Jenson & Dominique, 1988
3	ShedNo	ID Number for initial watershed (with no pits removed)	MacMillan et al., 2000a
4	ShedNow	ID Number for the current watershed after small pits removed	MacMillan et al., 2000a
5	Upshed	ID Number for the current watershed for the inverted DEM	MacMillan et al., 2000a
6	Crest	Identifies cells considered to be located at a crest or divide location	MacMillan et al., 2000a
7	Channel	Identifies cells considered to be located at a channel location	MacMillan et al., 2000a
8	Edge	Identifies cells located at the edge of the data matrix	MacMillan et al., 2000a
9	Slope	Slope gradient (%) by finite difference method	Eyton, 1991
10	Aspect	Slope azimuth (aspect in degrees) by the finite difference method	Eyton, 1991
11	Prof	Profile Curvature (degrees per 100 m) by the finite difference method	Eyton, 1991
12	Plan	Plan Curvature (degrees per 100 m) by the finite difference method	Eyton, 1991
13	Qarea	Upslope area count using a multiple descent algorithm	Quinn et al., 1991
14	Qweti	Wetness index (also called compound topographic index)	Quinn et al., 1991
15	Z2cr	Vertical distance (m) from cell upslope to the nearest crest cell	MacMillan et al., 2000a
16	N2cr	Flow path distance (as cell count) from each cell to the nearest divide cell	MacMillan et al., 2000a
17	Z2st	Vertical distance (m) from cell downslope to the nearest stream channel cell	MacMillan et al., 2000a
18	N2st	Flow path distance (as cell count) from each cell to the nearest channel cell	MacMillan et al., 2000a
19	Z2pit	Vertical distance (m) from each cell downslope to a flow terminating pit cell	MacMillan et al., 2000a
20	N2pit	Flow path distance (as cell count) from each cell to a flow terminating pit cell	MacMillan et al., 2000a

Table A 2.1 (continued) Terrain derivatives computed from the DEM for each site

No.	Abbr.	Description	Reference
21	Z2top	Vertical distance (m) from each cell upslope to the highest cell in the data set	MacMillan et al., 2000a
22	Z2peak	Vertical distance (m) from a cell upslope to the closest peak cell (along a flow path)	MacMillan et al., 2000a
23	Pmin2max	Relative relief as percent elevation relative to min and max elevation	MacMillan et al., 2000a
24	PctZ2st	Relative relief computed as (Z2st/(Z2st+Z2cr))*100	MacMillan et al., 2000a
25	PctZ2pit	Relative relief computed as (Z2pit/(Z2pit+Z2peak))*100	MacMillan et al., 2000a
26	PctZ2top	Relative relief computed as ((Z2pit)/(Z2Pit+Z2Top))*100	MacMillan et al., 2000a
27	Pit2PeakZ	Total vertical elevation difference (m) of the flow path through a cell from peak to pit	MacMillan et al., 2000a
28	Top2PitZ	Total vertical elevation difference (m) of watershed in which a cell is located	MacMillan et al., 2000a
29	Cr2StZ	Total vertical elevation difference (m) of the flow path through a cell from divide to channel	MacMillan et al., 2000a
30	L2Pit	Horizontal distance (m) from a cell to its associated pit	MacMillan et al., 2000a
31	L2Peak	Horizontal distance (m) from a cell to its asociated peak	MacMillan et al., 2000a
32	Lpit2Peak	Horizontal distance (m) of line through a cell from its associated peak to pit	MacMillan et al., 2000a
33	Ppit2PeakL	Relative slope position in terms of slope length computed as (L2Pit/(L2Pit+L2Peak))*100	MacMillan et al., 2000a
34	L2Str	Horizontal distance (m) from a cell to first downslope cell classed as a channel	MacMillan et al., 2000a
35	L2Div	Horizontal distance (m) from a cell to first upslope cell classed as a divide	MacMillan et al., 2000a
36	Lstr2div	Total horizontal distance (m) of a flow line from a divide to a channel through a cell	MacMillan et al., 2000a
37	PctStr2DivL	Relative slope position in terms of slope length computed as (L2Str/(L2Str+L2Div))*100	MacMillan et al., 2000a

Table A 2.2 Fuzzy landform attributes derived from 10 basic terrain derivatives

No.	Input Terrain Derivative	Output Fuzzy Landform Attribute	Description of Fuzzy Landform Attribute	Standard Index (*b*)	Dispersion Index (*d*)
1	PROF	CONVEX_D	Relatively convex in profile (down)	5.0	2.5
2	PROF	CONCAVE_D	Relatively concave in profile (down)	-5.0	2.5
3	PROF	PLANAR_D	Relatively planar in profile (down)	0.0	2.5
4	PLAN	CONVEX_A	Relatively convex in plan (across)	5.0	2.5
5	PLAN	CONCAVE_A	Relatively concave in profile (across)	-5.0	2.5
6	PLAN	PLANAR_A	Relatively planar in profile (across)	0.0	2.5
7	SLOPE	NEAR_LEVEL	Nearly level slope gradient	0.5	0.5
8	SLOPE	REL_STEEP	Relatively steep slope gradient	2.0	1.0
9	QWETI	HIGH_WI	Relatively high wetness index	7.0	3.0
10	QWETI	LOW_WI	Relatively low wetness index	0.5	3.0
11	PMIN2MAX	NEAR_MAX	Relatively near maximum elevation	90.0	15.0
12	PCTZ2TOP	NEAR_TOP	Relatively near top of the watershed	90.0	15.0
13	PCTZ2ST	NEAR_DIV	Relatively near to a local divide cell	90.0	15.0
14	PCTZ2PIT	NEAR_PEAK	Relatively near to a local peak cell	90.0	15.0
15	PCTZ2PIT	NEAR_MID	Relatively near pit-to- peak mid-slope	50.0	25.0
16	PCTZ2PIT	NEAR_PIT	Relatively near to pit relative to peak	10.0	15.0
17	Z2PIT	HI_ABOVE	Relatively high above a pit cell (in m)	2.0	1.0
18	PMIN2MAX	NEAR_MIN	Relatively near to minimum elevation	10.0	15.0
19	PCTZ2TOP	NEAR_BOT	Relatively near to pit relative to the maximum elevation in the watershed	10.0	15.0
20	PLAN PROF	PLANAR_2X	Relatively planar in profile and plan	NA	NA

Table A 2.3 Rules for the fuzzy landform classification

FACET NAME	CODE	FUZZY ATTRIBUTE	WT
Level Crest	LCR	NEAR-LEVEL	20
	LCR	NEAR_TOP	20
	LCR	NEAR_DIV	10
	LCR	PLANAR_2X	5
	LCR	LOW_WI	5
	LCR	HIGH_ABOVE	5
Divergent Shoulder	DSH	REL_STEEP	20
	DSH	CONVEX_D	20
	DSH	CONVEX_A	20
	DSH	NEAR_DIV	10
	DSH	NEAR_TOP	10
	DSH	HI_ABOVE	5
	DSH	LOW_WI	5
Upper Depression	UDE	NEAR_TOP	20
	UDE	NEAR_MAX	10
	UDE	HIGH_WI	10
	UDE	CONCAVE_D	10
	UDE	CONCAVE_A	10
	UDE	NEAR_LEVEL	10
	UDE	HI_ABOVE	5
Back-slope	BSL	PLANAR_D	20
	BSL	PLANAR_A	20
	BSL	NEAR_MID	20
	BSL	REL_STEEP	10
	BSL	HI_ABOVE	5
Divergent Back-slope	DBS	PLANAR_D	20
	DBS	CONVEX_A	20
	DBS	NEAR_MID	20
	DBS	REL_STEEP	10
	DBS	HI_ABOVE	5
	DBS	LOW-WI	5
Convergent Back-slope	CBS	CONCAVE_A	20
	CBS	PLANAR_D	20
	CBS	NEAR_MID	20
	CBS	REL_STEEP	10
	CBS	HIGH_WI	5
	CBS	HI_ABOVE	5
Mid-slope Terrace	TER	NEAR_LEVEL	20
	TER	NEAR_MID	20
	TER	PLANAR_D	10
	TER	PLANAR_A	10
	TER	HI_ABOVE	5

FACET NAME	CODE	FUZZY ATTRIBUTE	WT
Saddle	SAD	CONCAVE_D	20
	SAD	CONVEX_A	20
	SAD	NEAR_MID	20
	SAD	HI_ABOVE	10
	SAD	HIGH_WI	5
	SAD	NEAR_LEVEL	20
Mid-slope Depression	MDE	NEAR_MID	20
	MDE	CONCAVE_D	10
	MDE	CONCAVE_A	10
	MDE	HIGH_WI	20
	MDE	NEAR_LEVEL	20
	MDE	HIGH_ABOVE	5
Foot-slope	FSL	NEAR_BOT	20
	FSL	CONCAVE_D	20
	FSL	HIGH_WI	20
	FSL	CONCAVE_A	10
	FSL	REL_STEEP	5
Toe-slope	TSL	PLANAR_A	20
	TSL	NEAR_BOT	20
	TSL	REL_STEEP	10
	TSL	PLANAR_D	10
Lower-slope Fan	FAN	NEAR_BOT	20
	FAN	PLANAR_D	20
	FAN	CONVEX_A	20
	FAN	REL_STEEP	10
Lower-slope Mound	LSM	CONVEX_D	20
	LSM	CONVEX_A	20
	LSM	REL_STEEP	20
	LSM	NEAR_BOT	20
	LSM	LOW_WI	10
	LSM	NEAR_DIV	10
Level Lower-slope	LLS	NEAR_BOT	20
	LLS	NEAR_LEVEL	20
	LLS	NEAR_PIT	10
	LLS	PLANAR_D	5
	LLS	PLANER_A	5
	LLS	HIGH_WI	5
Lower-slope Depression	DEP	NEAR_PIT	20
	DEP	CONCAVE_A	10
	DEP	CONCAVE_D	10
	DEP	NEAR_LEVEL	10
	DEP	NEAR_BOT	10
	DEP	HIGH_WI	10

Explanation of codes in Table A 2.3

A= across slope;
D = down slope;
WI = wetness index;
HI = high;
REL = relatively;
BOT = bottom

Please note: All the basic data and intermediate calculations associated with the DEM descriptions and segmentation are archived with

Alberta Land Resource Unit
Research Branch, Agriculture and Agri-Food Canada
Edmonton, Alberta

APPENDIX 3.

Procedural issues and methodological concerns

Development and application of the procedures described in this document raised a number of concerns related to procedural issues. Many of these were related to questions of the most appropriate way to represent a landform of interest using raster digital elevation models (DEMs). Procedures followed to obtain, generate and process the digital elevation models involved considerable operator intervention and choice. This raised a question of the manner and degree to which operator choices may have influenced the final results

Systematic errors in the DEM data

It is critically important to produce a working DEM that faithfully represents the terrain surface at levels of resolution and abstraction appropriate for the intended use. All results and classifications rely on use of appropriate input data and the production of an appropriate DEM for a given site is probably the single most difficult part of the exercise. The issue is compounded by the fact that there are no widely accepted guidelines or protocols to follow to ensure the production of a DEM with minimal noise and maximum fidelity in its representation of the terrain at the scale of interest.

Many of the terrain derivatives of interest are computed by assessing the relationship of the elevation of a cell with respect to its 8 immediate neighbors. Therefore, it is often more critical that the DEM properly capture these cell to cell relationships than that it accurately reflect absolute elevation at each grid site. These relative (point to point) relationships need to capture variation in the terrain at the scale of interest. In many cases, a significant component of the variation between adjacent points in high resolution gridded DEMs consisted of high frequency, short wavelength, noise arising from error in the original x, y, z input data. In many cases, the error associated with the original x, y, z input data was retained,by algorithms used to surface the x, y, z input data to a regular raster grid (Figure 3).

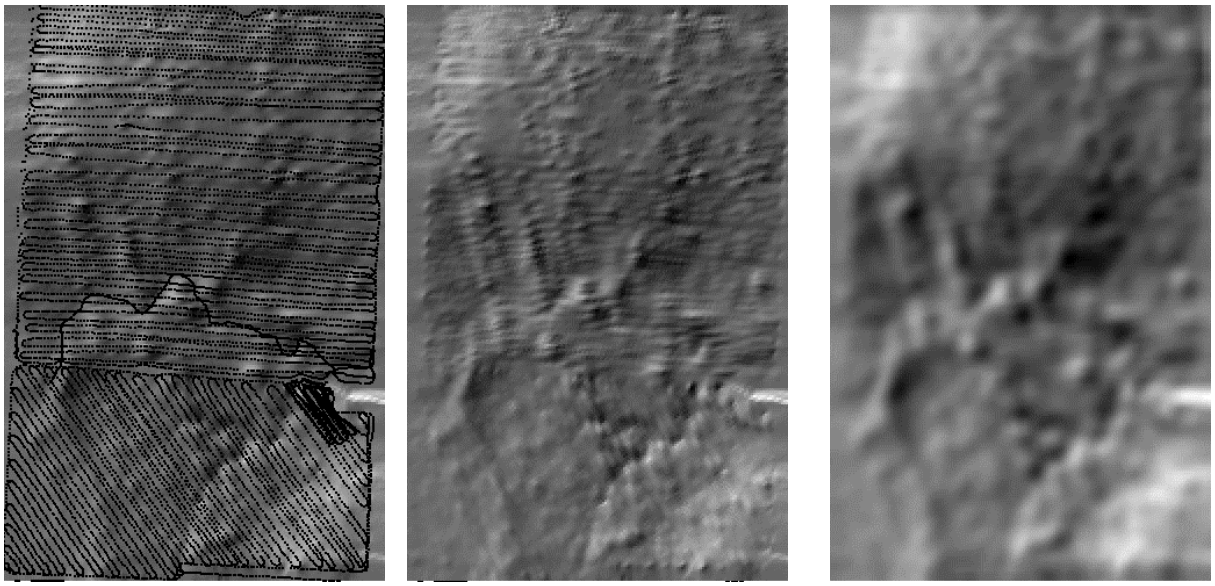


Figure 3. Illustration of the relationship between GPS sampling pattern and systematic patterns in the DEM

When the original x, y, z input points for most of the DEMs were overlaid on a suitable representation of the DEM (e.g. a relative radiance light model or a gray scale image of profile curvature), a clear relationship was often evident between systematic patterns in the routes followed to collect the original x, y, z input data and regular patterns (error) exhibited by the surfaced DEM (Figure 3). The severity of this problem was related to a number of factors including the method used to collect the x, y, z data (GPS vs. floating dot photogrammetry), the method used to surface the data to a regular grid (TPS vs. MQE vs. IWD) and the characteristics of the terrain.

Both GPS and floating dot x, y, z data tend to be collected using a series of more or less parallel transects or field traverses. In both cases, both systematic and random error was evident in the initial x, y, z input data (Figure 3). The systematic error tended to be expressed in terms of one line or transect of points being consistently higher or lower than its adjacent line. When this pattern was repeated by alternating lines, the result was a repeating pattern of subdued ridges and troughs in the surfaced DEM. In some cases, the pattern was repeated in orthogonal directions, resulting in a checker board pattern of intersecting ridges and troughs. This regular variation is a characteristic of the data collection process; it is not a characteristic of the terrain. Because it tends to occur along adjacent rows of data, the error is strongly reflected in any derivatives that are computed from consideration of relationships between a cell and its 8 surrounding neighbors.

The application of the GRASS thin plate spline (TPS) interpolation procedures with selective thinning of points and use of a suitable tension produced raster surfaces with the least obvious expression of high frequency noise and systematic patterns. This was not unexpected, since the TPS procedure incorporates a smoothing function into the interpolation process via the tension factor. The multi-quadric equation (MQE) surfacing approach (using QSURF) retained, and sometimes even amplified, systematic patterns arising from periodicity in the input data. This was also not unexpected, since an MQE surface is computed to exactly pass through each and every original input data point and must therefore reflect any systematic patterns in the original input data. Surfaces produced using an inverse weighted distance (IWD) linear interpolation algorithm retained most original systematic error and introduced an additional component of semi-random error. The additional error was associated with noise caused by sudden changes in the local weighted average elevation arising from one regular row of data dropping outside the search radius to be suddenly replaced with another row of data with a systematic difference in elevation values.

The third controlling factor appeared to be the shape of the terrain, especially its degree of curvature. We noticed less systematic error in DEMs produced for strongly hummocky landforms than for smoother undulating or rolling landforms. Hummocky landforms tend to exhibit rapid and significant changes in elevation over short distances along with strong and continuous terrain curvature. The magnitude of systematic data collection error appears to be relatively small in comparison with actual changes in elevation between data points. This reduces the strength and degree of expression of systematic input error. In contrast, landforms with subtle changes in topography were more susceptible to confusion arising from systematic input error. The more planar the actual terrain surface the more likely accurate representation of it was to be confounded by minor, but systematic, input error. Thus systematic error was strongly evident in DEMs produced for both low relief, low gradient undulating landforms and high relief, high gradient rolling or inclined landforms.

In the present project, systematic error was identified by examining visualizations of the raster surface using relative radiance light models and 3D drapes. A trial and error procedure was followed in which surfaces displaying obvious systematic patterns were smoothed using one of a 3x3, a 5x5 or a 7x7 mean filter. The smoothed surface was assessed after each filtering by producing and examining a light model for the filtered surface. The process continued using various combinations of mean filters, until the visualized surface was deemed to be free of most obvious systematic patterns. This approach is very subjective and is sub-optimal, but it was necessary to adopt in the absence of any formal alternatives.

Matching the resolution of the DEMs to the scale of the landform

It is apparent that, while low resolution DEMs (25–100 m grids) are often inadequate for capturing the variation in terrain in subtle agricultural landscapes, use of high resolution DEMs (5-10 m) also poses some problems. A significant consideration is that, while high resolution (5 m) DEMs may be needed to accurately capture subtle changes in slope gradient or slope position and to delineate small, but important, landform features such as depressions and peaks, noise in the high resolution DEMs may mask features of interest. Most noise is characterized by high frequency and short wavelength (e.g. it occurs and repeats over short distances). For most studies of landform shape and orientation it is unlikely that very small features of less than 0.25 – 0.50 m height and 10-20 m length are of interest. A problem that therefore needs to be addressed is how to define the level of abstraction (generalization) best suited to capturing the terrain features and characteristics of interest and how to produce a DEM that is capable of representing the terrain at this required level of abstraction.

It was apparent that application of successive mean filters not only removed unwanted noise from the DEM data sets, it also generalized the DEMs into successively more idealized abstractions of the actual terrain surface. This is not necessarily a bad thing. These generalized DEMs may have actually been better suited for representing the terrain at the level of abstraction appropriate for use with soil survey information collected at a scale of 1:100,000. In a few cases, it was clear that the abstracted DEMs increasingly represented highly idealized, almost cartoon-like portrayals of the true landscape. It was also clear that this cartoon-like portrayal was conceptually in step with the level of abstraction of the landscape appropriate for soil-landform models as described for 1:100,000 scale soil surveys.

This conundrum is best illustrated using an example from one of the selected sites. Site 3 was originally processed to compute terrain derivatives and define landform facets with no smoothing of the DEM. The resulting landform element classification (Figure 4 left) was quite highly fragmented due to strong and rapid changes in slope curvature arising from high frequency noise in the original DEM. This noise produced values for profile and plan curvature that were more reflective of the noise (5 m) than of the broader scale (10-50 m) landscape features of interest.

Application of a 7x7 mean filter to the original DEM data for the Lunty site produced a very idealized representation of the terrain surface (Figure 4 right). The idealized terrain surface was clearly less accurate in its portrayal of the landscape (note how the N-S road down the centre of the site is no longer visible). However, the classification produced by analyzing this generalized DEM was more coherent and more accurately reflected the expected distribution of soil-landform elements at the scale of interest.

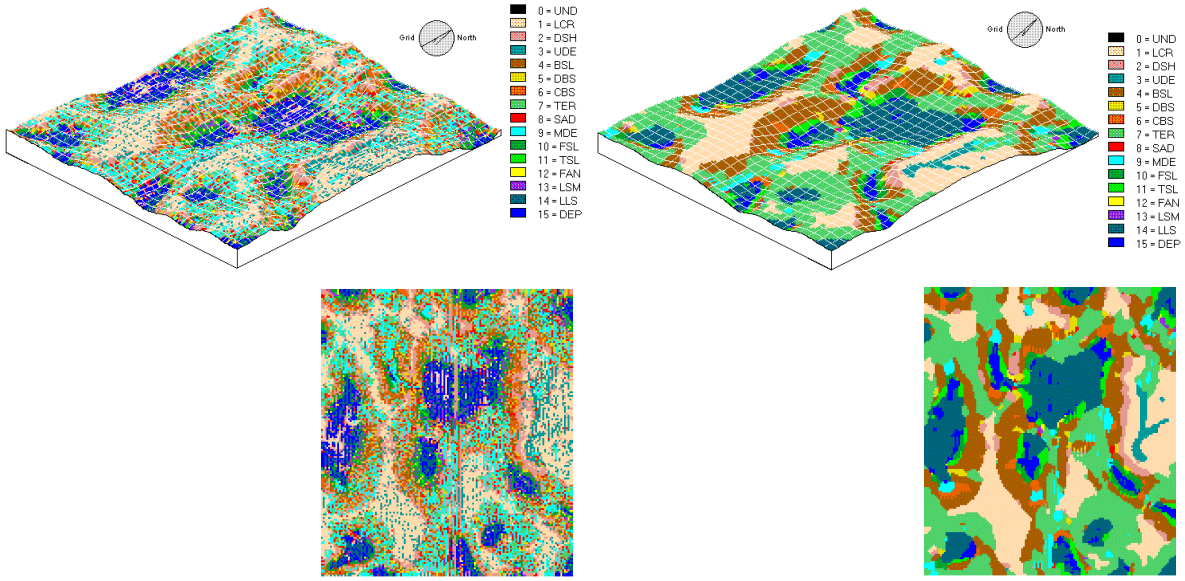


Figure 4. Effect of filtering the DEM on the 15-element classification (no filter on the left vs. 7x7 mean filter on the right)

Application of the landform classification procedures

Most of the problems encountered in applying the landform segmentation procedures to the DEMs for the selected type landforms were related to the previously discussed issues of systematic error and appropriate level of abstraction of the DEM data. Some remaining problems were related to the rule base used to define landform elements or to decisions taken for particular sites on what threshold values to use to define channels or divides or to remove pits.

Some problems were encountered that were specific to undulating landforms, particularly undulating landforms that were also inclined (IUl). In these landforms, application of procedures for removing small or spurious depressions with the initially recommended threshold value of 0.50 m resulted in the removal of virtually all local depressions. This was partly due to the fact that the undulating topography was very subtle. Very shallow depressions and very low mounds that were of significance in terms of the local distribution of soils were regarded as artificial relicts of the DEM sampling process and were removed.

The problem was compounded in inclined undulating landforms where the long range tilt of the land surface caused depressions that would have been regarded as significant in level terrain to be treated as too shallow for retention and to be removed. Removal of all (or most) local depressions in these inclined undulating landforms resulted in definition of integrated drainage systems. This had a profound effect on calculation of derivatives for slope length and relative relief and hence, landform position. These derivatives are calculated by following flow paths downslope and upslope from every grid cell until the flow path reaches a peak or divide or a pit or channel. With completely integrated drainage in inclined undulating landforms, all cells belonged to flow paths that ran from the top and bottom of the regional slope respectively. Thus the relative slope position of all cells was assessed in terms of the same two points, namely the highest and lowest points in the DEM. The local context of all cells in terms of small, local depressions or rises was not computed because the depressions and peaks were considered to be too small to warrant recognition and retention.

A further complication in areas of low relief and undulating landforms was that the initial rule base for defining landform facets was not designed to separate very low gradient slopes from level flats and terraces. Cells were originally only classified as sloping if their slope gradient exceeded 2%. All other cells were classified into level landform elements. This was not a major concern in landforms with high relief and strong slope gradients. In more subtle, undulating landforms however, it was often desirable to differentiate gently sloping and raised portions of the landform from truly level flats and terraces. The distinctions were subtle, but were often meaningful in terms of observed patterns of distribution of water and soils.

The problems of low relief and compound landforms were both addressed by reducing the threshold values of several key attributes. The depth of pits identified for removal from the DEM was reduced from 0.5 m to 0.15 m. The threshold values for differentiating planar from curving surfaces were reduced from 10°/100 m to 5°/100 and thresholds for differentiating level from sloping surfaces were reduced from 2% to 1%. These procedural modifications, in combination with additional smoothing of DEMs as previously described, resulted in improved landform classifications for these more subtle landform types. The effect on more strongly sloping and more strongly curved landform types was minimal.

The definition of closed depressions

Depressions are presently defined as nearly level in terms of slope gradient and strongly concave in both profile and plan. They are then further differentiated into upper, mid and lower depressions based on relative slope position. However, it is clear that depressions are not consistently delineated using criteria based on slope gradient and surface form (curvature). Some closed depressions may have low gradients, but others may display steeper gradients, particularly around the margins of the depression. Similarly, not all depressions are strongly concave in profile and plan. Many true depressions may exhibit planar surfaces in their central portions and strongly convex surfaces at their rims or margins. Many cells classified as belonging to depressions using the current classification procedure belonged, in fact, not to closed depressions, but rather to relatively level swales which were strongly concave in both profile and plan, but which were part of an open, integrated drainage path rather than a closed depression.

A classification of cells as depressions might be more effective and consistent if it incorporated new criteria to assess the likelihood that a given cell might be inundated by surface water that accumulates in a closed depression. A previously developed terrain derivative called “mm-to-flood” (MacMillan, 1994) might provide an effective measure of potential for inundation, but was not implemented or tested in this project.

Effects of smoothing DEMs on the calculation of derivatives

It was necessary to apply smoothing filters to the DEM data in order to remove local high frequency noise and produce acceptable landform classifications. The effect of this smoothing on the values computed for the various terrain derivatives of interest must be acknowledged. Smoothing lowers high points and raises low points in the DEM. This reduces the range of slope gradients computed for any given site and lowers the value of slope gradient computed for almost all grid cells in a DEM. Smoothing also lowers the values computed for slope curvature for most cells and affects the value of aspect computed for any cell. Smoothing also tends to remove many small, shallow depressions in a DEM. As depressions were used as important tie points in the procedures used to compute relief and slope length, removing depressions by smoothing alters the values computed for slope

length and relief for any given cell. In general, smoothing produces higher values for slope length and relief for a given landform. A test of the effect of smoothing confirmed the trends noted but single filter passes resulted in only minor changes in absolute values. As discussed earlier, this must be balanced against unwanted noise and fragmentation.

All values for terrain derivatives reported in this document were computed from DEMs that had been filtered at least once with a 3x3, 5x5 or 7x7 mean filter. The values for slope gradient and curvature are therefore conservative estimates of the actual slopes for any given site.

Effects of removing depressions from the DEM

The LSM procedures were designed to remove small or spurious pits from the DEMs used for landform analysis and classification. An important consequence of removing pits was the effect this had on calculations of relief and slope length. Pits (and peaks) were used as tie points in the procedures used to compute slope length and relief. Removing pits increased the distance (and elevation difference) from many cells to the nearest depression or peak. This produced values for slope length and relief that were larger than would have been computed had the pits (and peaks) not been removed. In the same vein, had larger pits been removed, the values computed for slope length and relief for any given site would have been larger.

Reducing the threshold value for removing pits from 0.5 m to 0.15 m had a rather significant effect on the values computed for drainage characteristics. The decision to retain very small pits (0.15 – 0.50 m depth) as legitimate landform features resulted in computation of more, small local internal watersheds. Each watershed drained to an internal depression located at the center of a depression in the DEM. This improved the ability of the landform classification procedures to assess the local landform context of cells and to produce more effective and relevant landform classifications. On the negative side, it tended to over-estimate the amount of internal surface drainage and under-estimate the size and density of watersheds for the processed DEMs.