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A summary of techniques for measuring soil erosion

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(N.Z.)

For the Ministry for the Environment
and Regional Councils' Land
Monitoring Group

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Signposts for sustainability

A SUMMARY OF TECHNIQUES FOR MEASURING SOIL EROSION

**Prepared for the Ministry for the Environment and the Regional
Councils' Land Monitoring Group**

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INTRODUCTION

In October 2000 the Ministry for the Environment commissioned Dr. N. C. Lambrechtsen and Dr. D. L. Hicks to prepare a literature review of techniques for monitoring soil erosion. The literature review encompassed:

- * Surface erosion (windblow, sheetwash, and rilling),
- * Streambank erosion (scour and collapse),
- * Gullies (tunnel, shallow and deep-seated),
- * Mass movements (slips, earthflows and slumps),

Though it was restricted to publications or reports which gave specific instances of the techniques' use under New Zealand conditions. In February 2001 the review was printed for distribution to regional councils' land monitoring staff, as a guide to the information locally available for monitoring soil erosion, as part of state-of- environment monitoring pursuant to Section 35 of the Resource Management Act 1991. The reference is Lambrechtsen, N.C. and Hicks, D.L., Soil intactness/erosion monitoring techniques: a literature review, Technical Paper 62, Ministry for the Environment.

The regional councils' Land Monitoring Group met in mid-March to discuss amongst other matters the literature review and how it may assist their design of a soil intactness/soil erosion monitoring programme. While they acknowledged that the literature review was a useful aid, they saw value in summarising the main methods in a cross-referenced document. In response, the Ministry has commissioned this summary, and proposes that the work contribute to a technical best practice manual for designing and implementing regional monitoring programmes for soil erosion.

CONTENTS

To aid comparisons the summary is set out in tabular format, with a consistent description supplied for each of the following techniques:

	Page Number	
1	Field measurement with survey instruments	4
2	Field measurement with global positioning systems	6
3	Approximate field measurement with various devices	8
4	Field measurement with tracers	12
5	Field measurement by soil profile description	14
6	Field measurement by soil probe or auger	16
7	Aerial photographic measurement with stereoplotters	18
8	Aerial photographic measurement by digital techniques	20
9	Approximate aerial photographic measurement by various methods	22
10	Point sample measurement from aerial photographs	24
11	Interactive measurement from satellite images	26
12	Digital classification of satellite images	28
13	Measurement from runoff plots	30
14	Measurement from stream discharge	32
15	Measurement from vegetation	34

The framework chosen for description, is the one suggested to the Ministry for the Environment by the Land Monitoring Group; though the author has made minor modifications to its wording, so as to facilitate concise table layout.

Each descriptor in the framework has been ranked, using the ordinal rankings suggested by the Land Monitoring Group.

Relevant references in Lambrechtsen's and Hicks' literature review are cited. To facilitate cross-reference with that document, the citations are divided according to type of erosion, with utility of each reference indicated.

Author's note: Doing this has reinforced my view that Lambrechtsen and Hicks 2001, though formatted as per request of the Land Monitoring Group in February, is difficult for readers to find their way around. It would be easier to use if re-printed in the draft format i.e. a single list arranged by authors' names.

The citations in this summary seem an easy way for people to ascertain a document's subject matter and utility. If further details are required, they could then just look it up in a single alphabetic listing, instead of hunting through nine separate lists.

1 FIELD MEASUREMENT WITH SURVEY INSTRUMENTS

Description

Levels and theodolites which measure horizontal or vertical angles by optical sighting onto targets, with distance measurement by chain or band; as well as instruments modified to measure distances by electronic means e.g. infrared or laser beam reflection from targets.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	lim	lim
Streambank	yes	yes	yes
Gully	yes	yes	yes
Mass movement	yes	yes	yes

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Method is based on optics and electronics.
Able to identify?	1	Erosion types are viewed in field.
Statistically valid?	1	Provided erosion is sampled at sufficient locations.
Interpretable?	2	Depends on sample size. Large quantity of data may be difficult to process.
Sensitive (time)?	1	If geomorphic process operates, method can detect change in short time.
Sensitive (space)?	1	If geomorphic process operates, method can detect change over short distance.
Repeatable?	1	Possible to relocate measurement points.
Responsive (set-up)?	1	Provided staff can be assigned at short notice.
Responsive (execution)?	3	Measurement and data analysis take long time.
Historical information?	2	Comparable with old survey data where it exists.
Acceptable impacts?	2	Some vegetation clearance may be needed.
Cost-effective?	3	High instrument cost; high staff cost.

NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- *** Basher 1989
- * Owens 1967

Streambank erosion

- ** Grant 1982
- ** Grant 1985
- ** Hayward 1980
- ** Pain 1968
- ** Pain and Hosking 1970
- ** Pearce and Watson 1983
- * Pearce and Hodgkiss 1987
- ** Petch 1985

Gullies

- * Gage and Black 1979
- * Selby 1972, 1973

Mass movement

- * Blong 1971, 1973a, 1973b
- * Gage and Black 1979
- ** McConchie 1986
- ** Owen 1979, 1981
- * Pearce et al 1987
- * Trotter 1992
- ** Zhang et al 1991a
- ** Zhang et al 1991b
- ** Zhang et al 1993

2 FIELD MEASUREMENT WITH GLOBAL POSITIONING SYSTEMS

Description

Instruments which fix position and elevation by receiving electronic signals from three or more navigation satellites. Includes use of a single mobile receiver for approximate measurement (standard); and use of two receivers, one mobile and one fixed, for precise measurement (differential).

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	lim	lim
Streambank	yes	yes	yes
Gully	yes	yes	yes
Mass movement	yes	yes	yes

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Method based on electronics.
Able to identify?	1	Erosion types are viewed in field.
Statistically valid?	1	Provided erosion is sampled at sufficient locations
Interpretable? to process.	2	Depends on sample size. Large quantity of data may be difficult
Sensitive (time)?	1	If geomorphic process operates, method can detect change in short time.
Sensitive (space)?	1	If geomorphic process operates, method can detect change over short distance.
Repeatable?	1	Possible to relocate measurement points.
Responsive (set-up)?	1	Provided staff can be assigned at short notice.
Responsive (execution)?	2	Measurement and data analysis take moderate time.
Historical information?	2	Comparable with old survey data where it exists.
Acceptable impacts?	1	Slight vegetation clearance may be needed.
Cost-effective?	2	Moderate instrument and staff costs

NZ examples *** Extensive data and/or detailed discussion of technique
 ** Useful data and/or modest discussion of technique
 * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

None found by Lambrechtsen and Hicks

Streambank erosion

*** Kelly 2001

Gullies

None found by Lambrechtsen and Hicks

Mass movement

None found by Lambrechtsen and Hicks

3 APPROXIMATE FIELD MEASUREMENT WITH VARIOUS DEVICES

Description

Optical instruments or mechanical devices used by explorers, geologists or engineers for approximate measurement of distances e.g. tapes; bearings e.g. compasses; vertical angles e.g. clinometers; and elevations e.g. altimeters. Also includes simple survey techniques e.g. plane table survey with a goniometer or similar optical sighting instrument.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	lim	lim
Streambank	yes	yes	yes
Gully	yes	yes	yes
Mass movement	yes	yes	yes

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	2	Optical or mechanical measuring devices, with limited precision.
Able to identify?	1	Erosion types are viewed in field.
Statistically valid?	1	Provided erosion is sampled at sufficient locations.
Interpretable?	2	Depends on sample size. Large quantity of data may be difficult to process.
Sensitive (time)?	2	If geomorphic process operates method can detect change, though measurement devices limit accuracy.
Sensitive (space)?	2	If geomorphic process operates method can detect change, though measurement devices limit accuracy.
Repeatable?	2	Relocation of measurement points will not be as accurate as by survey or gps.
Responsive (set-up)?	1	Provided staff can be assigned at short notice.
Responsive (execution)?	2	Measurement and data analysis take moderate time.
Historical information?	3	Comparable data rarely available.
Acceptable impacts?	2	Minimal impacts on soil, vegetation and wildlife.
Cost-effective?	1-2	Low instrument cost; moderate staff cost.

NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- *** Basher 1989
- *** Basher 1997
- ** Bryan et al 1985
- ** Campbell 1951
- * Cuff 1974
- ** Cuff 1980
- *** Eyles 1985
- * Gradwell 1960
- *** Hunter and Lynn 1990
- ** McMahon 1995
- ** Murphy et al 1984
- ** Owens 1967, 1969
- * Perkins 1972
- *** Selby 1966, 1970
- * Stevenson 1945

Streambank erosion

- * Anonymous 1975
- ** Baillie 1998
- ** Basher 1986
- * Bridson 1981
- ** Campbell 1951
- * Cuff 1974
- ** Cuff 1980
- * Edwards 1993
- *** Eyles 1985
- * Grant 1983
- *** Hicks 1992a
- * Jessen et al 1997
- * Luckman et al 1999
- * Marden 1979
- ** Moseley 1978, 1980
- * Page et al 1999
- *** Page et al 1994
- ** Page and Trustrum 1997
- ** Pain 1968
- ** Pain and Hosking 1970
- ** Pearce and Watson 1983
- *** Petch 1985
- * Trustrum and Page 1991

Gullies

- * Anonymous 1975
- ** Basher 1986
- * Brundall 1966
- * Cuff 1974
- ** Cuff 1980
- *** Eyles 1985
- * Gage and Black 1979
- * Haylock and Trotter 1983
- ** Hicks 1989
- * Hosking 1962
- * Hughes 1972
- * Laffan and Cutler 1977
- *** Luckman and Thompson 1992
- ** McSaveney and Whitehouse 1988
- * Owens et al 1994
- *** Page et al 1994
- ** Page and Trustrum 1997
- *** Petch 1985
- * Scott 1963
- *** Selby 1972, 1973
- * Sutherland et al 1974
- * Trustrum and Page 1991
- * Ward 1966a, 1966b
- * Waters 1980
- ** Whitehouse and McSaveney 1992

Mass movement

- * Anonymous 1975
- ** Campbell 1951
- ** Coker and Fahey 1993
- ** Crozier 1970, 1973
- * Cuff 1974
- ** Cuff 1980
- *** Crozier et al 1982, 1983
- ** Eyles 1971
- *** Eyles et al 1978
- *** Eyles 1985
- ** Fahey and Coker 1989
- * Gage and Black 1979
- ** Harmsworth et al 1987
- *** Hawley and Dymond 1988
- ** Haylock and Trotter 1983
- ** Hicks 1990
- ** Hicks 1991a
- ** Hicks 1991b
- *** Hicks 1992b, 1992c
- ** Hicks et al 1993
- *** Luckman and Thompson 1992

* Marden 1979
*** McConchie 1977, 1980, 1981
*** McGlinchy 1987
** McSaveney and Whitehouse 1988
** Moseley 1978, 1980
** O'Loughlin et al 1982
** Owen 1979, 1981
* Owens et al 1994
*** Page et al 1999
*** Page et al 1994
** Page and Trustrum 1997
** Pain 1969, 1971
** Phillips 1988, 1989
** Phillips et al 1990
** Reid and Page 2000
** Rogers 1978, 1980
** Selby 1967
** Selby 1976
* Smith 1974
* Sutherland 1974
** Thorn 1994
* Trustrum and Page 1991
* Waters 1980
*** Willis 1995
** Whitehouse and McSaveney 1992
** Bergin et al 1995

4 FIELD MEASUREMENT WITH TRACERS

Description

Mobile substances which can be entrained by water or wind, if added to soil. Measuring their dilution/concentration over time, enables volumetric rates of surface erosion or deposition to be calculated. An enormous variety of substances have been tried; soluble dyes and radionuclides with greater success than others. The technique includes use of radionuclides added to soil by atomic bomb tests 1940s-1960s, notably caesium.

Applications

(yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	yes	yes	yes
Streambank	lim	lim	lim
Gully	lim	lim	lim
Mass movement	no	no	no

Ratings

(1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Method based on physics (radionuclides) or chemistry (dyes).
Able to identify?	1	Detects re-located soil particles in field.
Statistically valid?	2	Provided sample is carefully taken at sufficient locations; and stratified for soil type or landform.
Interpretable?	2	Depends on sample size. Small sample may be misleading.
Sensitive (time)?	1	If geomorphic process operates, method can detect change in short time.
Sensitive (space)?	1	If geomorphic process operates, method can detect change over short distance.
Repeatable?	1	Possible to return, if measurement points are marked.
Responsive (set-up)?	3	Advance set-up and calibration needed.
Responsive (execution)?	1	Measurement and data analysis take short time.
Historical information?	3	Comparable data unlikely to exist.
Acceptable impacts?	2-3	Whether hazardous, depends on tracer selected.
Cost-effective?	3	High instrument and staff costs.

- NZ examples**
- *** Extensive data and/or detailed discussion of technique
 - ** Useful data and/or modest discussion of technique
 - * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- *** Basher 1989
- ** Basher and Matthews 1993
- *** Basher 1997
- ** Basher et al 1995
- ** Basher et al 1997
- *** Basher and Ross 1997

5 FIELD MEASUREMENT BY SOIL PROFILE DESCRIPTION

Description

Observation of different horizons' appearance and depth in the soil profile. Provided changes are not attributable to other causes, erosion/deposition may be inferred by interpreting change in a single profile over time; or by interpreting differences between profiles for the same soil at two sites; or by statistical analysis of variation in horizons' depth for the same soil at numerous sites.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	no	yes	no
Streambank	no	yes	no
Gully	no	yes	no
Mass movement	no	yes	no

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on pedology.
Able to identify?	2	Soil profiles viewed in field, though horizon depth can be difficult to discern.
Statistically valid?	2	Provided many profiles are sampled; with stratification by soil type and landform.
Interpretable?	2	Depends on sample size. Small sample will be misleading.
Sensitive (time)?	2-3	Other factors which change soil profile can make it hard to tell whether change is due to erosion.
Sensitive (space)?	2-3	Natural variability over short distances can make it hard to tell whether change is due to erosion.
Repeatable?	1	Possible to return, if measurement points are marked.
Responsive (set-up)?	1	Provided staff can be assigned at short notice.
Responsive (execution)?	3	Profile excavation and measurement take time.
Historical information?	2	Comparison with reference soil profiles may be possible.
Acceptable impacts?	2	Soil is disturbed but holes are filled in.
Cost-effective?	1-2	Low instrument cost; moderate staff cost.

NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- ** Basher 1986
- ** Basher and Tonkin 1985
- *** Benny and Stephens 1985
- * Cuff 1981
- *** Espie 1998
- ** Francis et al 1998
- * Gillingham 1966
- * Hayward 1969
- ** Parminter and Orr 1997
- * Raeside and Baumgart 1947
- * Watt 1972

Streambank - nothing found by Lambrechtsen and Hicks

Gullies - nothing found by Lambrechtsen and Hicks

Mass movements

- *** Blaschke 1989 unpub
- *** Blaschke 1990
- ** Laffan 1982
- ** Vincent 1984

6 FIELD MEASUREMENT BY SOIL AUGER OR PROBE

Description

Measurement of total depth to bottom of soil profile, by inserting an auger or graduated steel probe. Erosion or deposition may be measured by repeat observation at a single site; or by comparison of depth for the same soil at two sites, one known to be eroded and one not; or statistical analysis of depth variation for the same soil at numerous sites where extent of erosion is unknown.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	no	yes	no
Streambank	no	yes	no
Gully	no	yes	no
Mass movement	no	yes	no

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on pedology.
Able to identify?	2	Soil augered or probed in field, though soil depth can be difficult to measure accurately.
Statistically valid?	2	Provided many points are sampled; with stratification by soil type and landform.
Interpretable?	2	Depends on sample size. Small sample will be misleading.
Sensitive (time)?	2-3	Other factors which change soil depth can make it hard to tell whether change is due to erosion.
Sensitive (space)?	2-3	Natural variability over short distances can make it hard to tell whether change is due to erosion.
Repeatable?	1	Possible to return, if measurement points are marked.
Responsive (set-up)?	1-2	Depends whether staff can be assigned at short notice.
Responsive (execution)?	2	Augering and probing take moderate time.
Historical information?	3	Unlikely to exist in comparable format.
Acceptable impacts?	1	Minimal soil disturbance.
Cost-effective?	1-2	Low instrument cost; moderate staff cost.

- NZ examples**
- *** Extensive data and/or detailed discussion of technique
 - ** Useful data and/or modest discussion of technique
 - * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- *** Benny and Stephens 1985
- * Gillingham 1966
- * Hayward 1969
- * Raeside and Baumgart 1947
- * Watt 1972

Streambank

- * Edwards 1994
- *** Gomez et al 1998
- *** Gomez et al 1999
- ** Grant 1982, 1985
- *** Marutani et al 1999

Gullies - nothing found by Lambrechtsen and Hicks

Mass movements

- *** De Rose et al 1991
- *** De Rose et al 1993
- *** Marutani et al 1999
- *** Smale et al 1997
- * Thorn 1994
- *** Trustrum and de Rose 1988
- *** Willis 1995

7 AERIAL PHOTOGRAPHIC MEASUREMENT WITH STEREOPLOTTERS

Description

Optical-mechanical instruments for stereoscopic observation of aerial photographs. Positions and heights can be measured precisely and maps can be plotted by an observer, provided at least three surveyed ground control points are available for each stereo-pair.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	yes	lim	lim
Gully	yes	lim	lim
Mass movement	yes	lim	lim

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on physics (remote sensing) combined with optical-mechanical measuring devices.
Able to identify?	2	Erosion types identifiable, provided aerial photos are good scale and quality.
Statistically valid?	1	If many points/areas are measured.
Interpretable? software is unavailable.	2	Large data volume may be difficult to process, if computer
Sensitive (time)?	1	If geomorphic process operates, method can detect change in short time.
Sensitive (space)?	2	If geomorphic process operates, method can detect change over short distance; reliable depths/volumes can only be obtained as area-weighted averages.
Repeatable?	1	If measurement points are marked on aerial photo.
Responsive (set-up)?	3	Takes time to organise ground control and aerial photography.
Responsive (execution)?	3	Photogrammetry takes time.
Historical information?	1	Old aerial photos generally available.
Acceptable impacts?	1	Minimal disturbance.
Cost-effective?	3	High instrument and staff costs.

NZ examples *** Extensive data and/or detailed discussion of technique
 ** Useful data and/or modest discussion of technique
 * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion - nothing found by Lambrechtsen and Hicks

Streambank erosion

*** Dymond and Hicks 1986
** Hicks unpubl
** Jowett unpubl
** Stephens unpubl

Gullies

*** Dymond and Hicks 1986

Mass movements

** Owen 1979, 1981
** McSaveney 1989

8 AERIAL PHOTOGRAPHIC MEASUREMENT BY DIGITAL TECHNIQUES

Description

Encompasses stereoplotters modified to digitise photo co-ordinates and pass them to a computer; devices fitted to computer screens so that scanned aerial photographs may be viewed in stereo to match photo co-ordinates; and software which matches photo co-ordinates by automated pattern recognition. The common element is rectification of photo co-ordinates to cartographically correct positions by computer software. Includes rectification of photo co-ordinates corresponding to features of interest, to produce a line map; and rectification of all scanned photo co-ordinates, to produce an orthophoto.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	yes	lim	lim
Gully	yes	lim	lim
Mass movement	yes	lim	lim

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on physics (remote sensing) combined with optical-electronic measuring devices.
Able to identify?	2	Erosion types identifiable, provided aerial photos are good scale and quality.
Statistically valid?	1	If many points/areas are measured.
Interpretable?	1	Large data volume can be processed by computer software.
Sensitive (time)?	1	If geomorphic process operates, method can detect change in short time.
Sensitive (space)?	2	If geomorphic process operates, method can detect change over short distance; reliable depths/volumes can only be obtained as area-weighted averages.
Repeatable?	1	If measurement points are marked on aerial photo.
Responsive (set-up)?	2	Takes time to organise aerial photography; ground control may also be needed.
Responsive (execution)?	1-2	Digital techniques though automated still take time to set up and run.

Historical information?	1	Old aerial photos generally available.
Acceptable impacts?	1	Minimal disturbance.
Cost-effective?	2	Moderate instrument and staff costs.

NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- ** Dymond 2001
- *** Jessen et al 2000
- ** Stephens 1985
- ** Wilde 1990

Streambank erosion - nothing found by Lambrechtsen and Hicks

Gullies

- *** Betts and De Rose 1999
- ** De Rose et al 1998

Mass movements

- * Dymond et al 1999
- * Fransen 1998
- *** Jessen et al 2000
- *** Stephens et al 1995
- *** O'Leary et al 1996
- ** Pain and Stephens 1990

9 APPROXIMATE AERIAL PHOTOGRAPHIC MEASUREMENT BY VARIOUS METHODS

Description

Simple techniques for measuring from aerial photographs, used by geomorphologists, soil scientists and ecologists. Includes monoscopic measurement of area with dots, grids or planimeter (mechanical or electronic); monoscopic measurement of length with rulers, wheels or line-meters (mechanical or electronic); and stereoscopic measurement of height with parallax bars.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	yes	no	no
Gully	yes	no	no
Mass movement	yes	no	no

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	2	Based on physics (remote sensing) combined with simple optical or mechanical measuring devices, of limited precision and accuracy.
Able to identify?	2	Erosion types identifiable, provided aerial photos are good scale and quality.
Statistically valid?	1	If many points/areas are measured.
Interpretable?	2	Large data volume may be difficult to process.
Sensitive (time)?	1	If geomorphic process operates, method can detect area change in short time.
Sensitive (space)?	2	If geomorphic process operates, method can detect area change over short distance; instruments are too imprecise to obtain reliable depths or volumes.
Repeatable?	2	If measurement points are marked on aerial photo, though re-location will not be as accurate as by stereo or digital techniques.
Responsive (set-up)?	1-2	Takes time to organise aerial photography, though no ground control needed.
Responsive (execution)?	2-3	Faster than stereo, slower than digital techniques.

Historical information?	1	Old aerial photos generally available.
Acceptable impacts?	1	Minimal disturbance.
Cost-effective?	1-2	Low instrument cost, moderate staff cost.

NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- ** Basher 1986
- *** Basher 1989
- *** Benny and Stephens 1985
- *** Eyles 1983, 1985
- ** Firth et al 1984

Streambank erosion

- ** Basher 1986
- *** Eyles 1983, 1985
- *** Page et al 1994
- * Page et al 1999
- * Trustrum and Page 1991
- ** Page and Trustrum 1997

Gullies

- ** Basher 1986
- *** Eyles 1983, 1985
- * Gage and Black 1979
- *** Hicks 1992b, 1992c
- *** Page et al 1994
- * Page et al 1999
- ** Page and Trustrum 1997
- * Trustrum and Page 1991
- * Waters 1980

Mass movements

- ** Basher 1986
- ** Black 1989
- ** Crozier 1970, 1973
- ** Crozier et al 1980
- *** De Rose 1994
- *** Eyles et al 1978
- ** Eyles and Eyles 1982
- *** Eyles 1983, 1985
- ** Fransen and Brownlie 1996
- * Gage and Black 1979
- *** Hicks 1992b, 1992c
- *** Marden and Rowan 1993
- ** McConchie 1986
- ** O'Loughlin et al 1982
- *** Omura and Hicks 1992
- ** Owen 1979, 1981
- *** Page et al 1994
- *** Page et al 1999
- ** Page and Trustrum 1997
- ** Phillips 1988, 1989
- ** Phillips et al 1990
- ** Reid and Page 2000
- ** Russ 1984
- ** Salter et al 1983
- ** Stephens 1975
- ** Stephens et al 1983
- *** Thomas and Trustrum 1984
- * Trustrum and Page 1991
- ** Trustrum et al 1984
- * Waters 1980
- ** Whitehouse and Griffiths 1983

10 POINT SAMPLE MEASUREMENT FROM AERIAL PHOTOGRAPHS

Description

Simple technique for recording soil erosion/deposition at numerous points overlaid on aerial photographs. The overlay pattern may be irregular, regular, or stratified for particular soil types and landforms. If enough points are sampled, the proportion of points with erosion or deposition equates to the percentage of soil area disturbed.

Applications

(yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	yes	no	no
Gully	yes	no	no
Mass movement	yes	no	no

Ratings

(1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on physics (remote sensing) combined with statistical techniques.
Able to identify?	2	Erosion types identifiable, provided aerial photos are good scale and quality.
Statistically valid?	1	If many points are measured.
Interpretable?	2	Large data volume may take time to process.
Sensitive (time)?	1	If geomorphic process operates, method can detect change over short time.
Sensitive (space)?	2	If geomorphic process operates, method can detect change over short time; though point sampling technique necessitates area-averaged analysis.
Repeatable?	2	If measurement points are marked on aerial photo, though re-location will not be as accurate as by stereo or digital techniques.
Responsive (set-up)?	1-2	Takes time to organise aerial photography, though no ground control needed.
Responsive (execution)?	1	Faster than approximate aerial photo measurements.
Historical information?	1	Old aerial photos generally available.

Acceptable impacts?	1	Minimal disturbance.
Cost-effective?	1-2	Low instrument cost, moderate staff cost.
NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

- ** Crippen 1999b
- ** Hicks 1998b
- ** Hicks 2000b
- *** Hicks 2000c

Streambanks

- ** Crippen 1999a
- ** Hicks 1998a
- ** Hicks 2000a
- *** Hicks 2000c

Gullies

- ** Crippen 1999a
- * Hicks 1995, 1999
- ** Hicks 1998a
- ** Hicks 2000a
- *** Hicks 2000c

Mass movements

- ** Crippen 1999a
- * Hicks 1995, 1999
- ** Hicks 1998a
- ** Hicks 2000a
- *** Hicks 2000c

11 INTERACTIVE MEASUREMENT FROM SATELLITE IMAGES

Description

Identification of erosion/deposition either by viewing hardcopy prints of satellite images, or viewing computer screen displays. Boundaries are delineated by hand with drawing instruments (hardcopy) prior to manual area measurement, or cursor (screen) prior to digital area measurement.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	lim	no	no
Gully	lim	no	no
Mass movement	lim	no	no

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on physics (remote sensing) combined with optical interpretation techniques.
Able to identify?	2	Difficulty discriminating some erosion types e.g. streambanks, gullies, earthflows.
Statistically valid?	1	Provided image is well-interpreted.
Interpretable?	2	Interactive measurements are more difficult to obtain and process, than digital ones.
Sensitive (time)?	1	If geomorphic process operates, change can be detected in short time.
Sensitive (space)?	2	If geomorphic process operates, change can be detected over short distance; though detection may be limited by spatial resolution of satellite sensor.
Repeatable?	1	Possible to re-measure, if areas are marked on satellite image.
Responsive (set-up)?	2	Takes time to obtain and process image.
Responsive (execution)?	2	Interactive interpretation is slower than digital.
Historical information?	2	Old satellite images are usually available, though may be difficult to compare due to differences in resolution.
Acceptable impacts?	1	Minimal disturbance.

Cost-effective? **1-2** Low instrument cost, moderate staff cost.

NZ examples *** Extensive data and/or detailed discussion of technique
 ** Useful data and/or modest discussion of technique
 * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

*** Dymond et al 2000
** Stephens 1985
** Wilde 1990

Streambank erosion - nothing found by Lambrechtsen and Hicks

Gullies - nothing found by Lambrechtsen and Hicks

Mass movements

** Stephens and Trotter 1989
** Stephens et al 1988
** Trotter et al 1989

12 DIGITAL CLASSIFICATION OF SATELLITE IMAGES

Description

Uses automated classification software. Entails initial training of software to identify targets, by interactive identification of small known areas of erosion/deposition on computer screen display. Subsequent identification, boundary delineation and area measurement are performed automatically by software.

Applications

(yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	lim	no	no
Gully	lim	no	no
Mass movement	lim	no	no

Ratings

(1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on physics (remote sensing) combined with optical-electronic interpretation techniques.
Able to identify?	3	Substantial difficulty discriminating some erosion types e.g. streambanks, gullies, earthflows.
Statistically valid?	1	Provided image is well-classified.
Interpretable?	1	Large volume of data can be easily processed.
Sensitive (time)?	1	If geomorphic process operates, change can be detected in short time.
Sensitive (space)?	2	If geomorphic process operates, change can be detected over short distance; though detection may be limited by spatial resolution of satellite sensor.
Repeatable?	1	Possible to re-measure, if areas are stored on digital file in computer.
Responsive (set-up)?	2	Takes time to obtain and process image.
Responsive (execution)?	1-2	Digital classification though automated still takes time.
Historical information?	2	Old satellite images are usually available, though may be difficult to compare due to differences in resolution.

Acceptable impacts? **1** Minimal disturbance.
Cost-effective? **2-3** Moderate instrument cost, high staff cost.

NZ examples *** Extensive data and/or detailed discussion of technique
 ** Useful data and/or modest discussion of technique
 * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

Surface erosion

*** Dymond et al 2000
** Stephens 1985
** Wilde 1990

Streambanks - nothing found by Lambrechtsen and Hicks

Gullies - nothing found by Lambrechtsen and Hicks

Mass movements

** Stephens and Trotter 1989
** Stephens et al 1988
** Trotter et al 1989

13 MEASUREMENT FROM RUNOFF PLOTS

Description

Hydrological technique. Entails establishing bounded plots to collect surface runoff, with flow-collecting device at outlet. Can be modified to trap sediment and calculate depth or volume of surface erosion.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	lim	yes
Streambank	no	no	no
Gully	no	no	no
Mass movement	no	no	no

lim = indirectly by extrapolation backwards from measured volume

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on hydrology combined with sediment-trapping devices.
Able to identify?	2	Methodological problems. May not trap all sediment.
Statistically valid?	2	If large number of measurements are collected and carefully interpreted.
Interpretable?	2	Large number of measurements may take time to process.
Sensitive (time)?	1	Detects change over short durations.
Sensitive (space)?	1	Detects change within small areas.
Repeatable?	1	Plots can be maintained or re-established.
Responsive (set-up)?	2	Requires advance set-up and calibration.
Responsive (execution)?	3	Continuous monitoring is needed for lengthy period, to obtain enough data.
Historical information?	3	Comparable data rarely available.
Acceptable impacts?	2	Some soil and vegetation disturbance at plot site.

Cost-effective?

2-3 High instrument cost; moderate staff cost.

NZ examples

- *** Extensive data and/or detailed discussion of technique
- ** Useful data and/or modest discussion of technique
- * Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

- *** Basher 1989
- *** Basher 1997
- *** Campbell 1945
- * Cathcart 1980
- * Coker et al 1993
- * Fahey and Coker 1992
- *** Hayward 1968
- * Read 1986
- * Soons 1967
- ** Smith 1989
- ** Smith 1992
- ** Smith and Fenton 1993
- * Tan 1983
- ** Watt 1968

14 MEASUREMENT FROM STREAM DISCHARGE

Description

Hydrological technique. Entails collecting suspended sediment and/or bedload with sampler; alternatively indirect measurement e.g. turbidity meter or bedload plate, calibrated so that readings can be converted to sediment concentrations. Provided streamflow is also recorded, sediment concentrations may be converted to volumes eroded from upstream catchment.

Applications (yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	no	lim	yes
Streambank	no	lim	yes
Gully	no	lim	yes
Mass movement	no	lim	yes

yes = not individually, but as integrated yield for all four

lim = indirectly by extrapolation backwards from measured volume

Ratings (1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	1	Based on hydrology combined with sediment-sampling devices.
Able to identify?	2	Methodological problems. May not detect all sediment.
Statistically valid?	2	If large number of measurements are collected and carefully interpreted.
Interpretable?	2	Large number of measurements may take time to process.
Sensitive (time)?	1	Detects change over short durations.
Sensitive (space)?	1-3	Changes are area-averaged over catchments which range from small to large.
Repeatable?	1	Recorder sites can be maintained or re-established.
Responsive (set-up)?	2	Requires advance set-up and calibration.
Responsive (execution)?	3	Continuous monitoring is needed for lengthy period, to obtain enough data.

Historical information?	2	Comparable sediment yields sometimes available.
Acceptable impacts?	2	Some channel disturbance at recorder site.
Cost-effective?	2-3	High instrument cost; moderate staff cost.

NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

- *** Gomez et al 1999
- ** Griffiths 1982, 1983
- ** Hayward 1980
- *** Hicks (D.M.) and Griffiths 1992
- ** Hicks (D.M.) et al 1997
- ** Hicks (D.M.) et al 2000
- * Jones and Howie 1970
- ** McSaveney 1978
- * Page et al 2000
- * Pearce 1986
- * Schouten 1976
- ** Strachan 1977
- ** Van Roon 1983a, 1983b
- ** Whitehouse 1986
- * Williams 1976

15 MEASUREMENT FROM VEGETATION PATTERNS

Description

Ecological techniques which infer soil disturbance from plant cover e.g. canopy disturbance, indicator species, and species succession. Requires field calibration i.e. examination of soil beneath a sample of different vegetation covers to confirm whether disturbance is due to erosion/deposition, or other causes. Provided this is done, the technique can be used to measure areas of eroded/deposited soil.

Applications

(yes = useable, lim = limited, no = inapplicable)

	area	depth	volume
Surface erosion	lim	no	no
Streambank	lim	no	no
Gully	lim	no	no
Mass movement	lim	no	no

Ratings

(1 = excellent, 2 = good, 3 = poor)

Scientifically defensible?	2	Based on plant ecology and pedology, though correlation between plant succession and erosion is poorly defined.
Able to identify?	2	Can be done in field or from aerial photos. Problems discriminating some erosion types e.g. surface or streambank erosion beneath tree canopy.
Statistically valid?	2	If large number of measurements are collected and carefully interpreted.
Interpretable?	2	Large number of measurements may take time to process.
Sensitive (time)?	2	Depends on pace of geomorphic process. Works where erosion severe enough to disturb vegetation.
Sensitive (space)?	2	Depends on variability of geomorphic process. Works where erosion severe enough to disturb vegetation.
Repeatable?	1	Provided measurement points are marked in field or on aerial photos.
Responsive (set-up)?	1-2	Fast if done from aerial photos, slower if done in field.
Responsive (execution)?	1-2	Fast if done from aerial photos, slower if done in field.

Historical information?	2-3	Comparable data often available from old aerial photos, but rarely from field surveys.
Acceptable impacts?	1-2	Minimal, unless trees are cored or cut to count growth rings.
Cost-effective?	1-2	Low instrument cost; moderate staff cost.
NZ examples	***	Extensive data and/or detailed discussion of technique
	**	Useful data and/or modest discussion of technique
	*	Limited data and/or minimal discussion of technique

(See Lambrechtsen and Hicks bibliography for full reference and summary)

- *** Blaschke 1989, 1990
- * Bosch et al 1996
- * Dick 1952, 1975
- ** Dick 1978
- *** Espie 1998
- *** Gibson and Bosch 1996
- ** Grant 1982, 1983
- ** Grant 1991
- ** Hunter 1986
- ** Jane 1973
- ** Mark et al 1964, 1989
- * Schweinfurth 1966
- * Sheppard 1973
- *** Smale et al 1997
- * Williams 1975
- ** Wright and Miller 1952