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BANKS : a method of financially assessing banks used to mitigate water erosion in south-western Australia

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“Banks” A Method of Financially Assessing Banks Used to Mitigate Water Erosion in South-Western Australia

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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Summary

Water erosion has been estimated to cost farmers in the <600 mm rainfall zone of south-western Australia about $10 million each year on average. A common method of mitigating water erosion on arable land is the construction of banks which break up long slope lengths and ensure contour cultivation. Grade banks are recommended where waterways can be safely maintained and level- and absorption-banks are recommended elsewhere. These different banks have different costs and benefits.

Water erosion is thought to have three main detrimental effects in south-western Australia:

1. sheet erosion removes soil enriched in nutrients (particularly organic nitrogen);
2. sheet and rill erosion decreases the rooting depth of plants growing on soils with shallow infertile subsoils;
3. gullying results in a decrease in arable and pasture land.

To help determine whether banks for controlling water erosion will be cost-effective in the medium term (20 years), a financial spreadsheet model called BANKS has been developed and is described in this report. The model is quite detailed and incorporates the present knowledge of the effects of water erosion on agricultural soils in south-western Australia. While our present knowledge of water erosion is limited, the model allows the effect of changing different assumptions to be rapidly evaluated. The model can therefore be used to help determine the factors which most influence the cost effectiveness of banks in different parts of the agricultural area. Once these factors have been identified, extra effort should be made to improve their estimates and to concentrate on than when making recommendations in the field. By identifying the factors which most influence the cost of bank systems, bank design may be changed to limit their cost. Several examples on the use of the model are shown in the report.

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Chapter 1

1. Introduction

Water erosion has been estimated to cost farmers in the <600mm rainfall zone of south-western Australia about $10 million each year on average (Carder and Humphry 1983). The long-term effects of water erosion are the complete loss of production from previously arable land and the cost of this has never been estimated.

Water erosion is most severe when run-off waters are allowed to gain depth and momentum while running down long slopes. Constructing banks is a means of breaking up long slope lengths and ensuring contour cultivation. Grade banks are recommended where waterways can be safely maintained and level- and absorption- banks are recommended elsewhere. These banks have different construction and maintenance costs, and take different amounts of land out of production. Banks are commonly installed to prevent rills becoming gullies and to divert water away from infilled gullies.

Water erosion is thought to have three main detrimental effects in south-western Australia:

1. Sheet erosion (which is often insidious) removes soil enriched in nutrients. Marsh (1982) found that the decline in wheat yield following soil loss was directly correlated with the loss of organic nitrogen. In rainfall simulations, run-off was found to contain about five times the concentration of nitrogen and three times the concentration of phosphorus as the uneroded soil.

2. Sheet and nil erosion decreases the rooting depth of plants growing on soil with a shallow subsoil. This decline in soil fertility is permanent (whereas nutrients can be replenished over time by fertilisers and legumes, and gullies can be filled). Shallow subsoils are common in south-western Australia and yields are commonly limited by low plant-available water capacities.

3. Gullying results in a decrease in arable (and to a lessen extent, pasture) land. There are two categories of loss. Initially only the land occupied by the gully is lost. When gullies become numerous or interconnected, the intervening land becomes difficult or impossible to cultivate and large areas are lost to production.

While banks have been recommended by the Soil Conservation Branch as a means of mitigating water erosion for a number of years, there have been no previous attempts to estimate their cost-effectiveness. A recent questionnaire circulated to field-based officers to determine research needs, identified a need for a method of assessing the cost—effectiveness of banks (using existing information) to be the top priority. Napier and Forster (1982) noted that few erosion control practices produce immediate economic returns and that returns on investment are usually relatively low or non-existent. However, a belief that the practices are profitable is a major, if not primary, reason why soil conservation practices are adopted. Even if erosion control practices are found to be unprofitable in the short term, it would be advantageous to know the cost of adopting a conservation approach to farming.

To determine whether banks placed on areas susceptible to water erosion are economic in the medium to long term, a financial spreadsheet program called BANKS has been developed. The program is available to landholders extension and research officers from the Soil Conservation Branch of the Western Australian Department of Agriculture. BANKS is a simulation (evaluation) model rather than an optimisation model (Shapiro 1984). A financial analysis is carried out for specified values of a range of physical, technical and economic parameters. This enables a comparison to be made of the costs and benefits of the banks under various physical, technical and economic assumptions. Given the uncertainty in our current knowledge of water erosion, the ability to test how changing different assumptions affects the cost-effectiveness of installing banks is essential. The model helps identify:

A. the most important factors affecting bank cost-effectiveness (research should then concentrate on quantifying these factors);

B. factors to consider when recommending banks in the field;

C. factors which most influencing the cost of installing different types of banks (which influences bank design).

While BANKS does not optimise bank design, the costs and benefits of alternative designs may be compared. It is not intended that BANKS be used for all cases where banks are being recommended. The model should be used for typical situations encountered in a District to improve recommendations given in the field.

A partial cash flow analysis determines the changes in annual cash flow resulting from the installation of banks to prevent water erosion. The implicit assumption made is that the cropping and livestock carrying capacities of the remainder of the farm land are independent of the mitigation of water erosion on the site. It is the direct costs and benefits associated with mitigating water erosion on the site which are determined.

This report explains how to use BANKS and documents the calculations and sources of data used in the model. Examples of the use of BANKS are given in Section 4. Another spreadsheet model ("DRAINS") has been developed to estimate the cost-effectiveness of installing drains to mitigate waterlogging. There are canton sections to the documentation of both models. It is not necessary to have completely read this report to use BANKS but the documentation should be used when questions arise about any aspects of the method as detailed on the screen and if any changes are attempted.

Chapter 2

Introduction to Lotus 1-2-3

2.1 *Getting started*

BANKS is a financial spreadsheet model developed using Lotus 1-2-3 (Version 1A or higher, Lotus Development Corporation). There are a number of alternative spreadsheet software packages which are compatible with Lotus 1-2-3. These are VP-Planner, Twin and Symphony. BANKS can be used directly by any of these Lotus 1-2-3 compatible spreadsheet programs. These programs use exactly the same commands as Lotus 1-2-3 and the commands outlined in Section 2.2 below are applicable to these packages. To run Lotus 1-2-3 requires a microcomputer which uses either an MS-DOS or PC-DOS operating system. In addition, the computer must have at least 256K of RAM and two disk drives which use double-sided-double-density diskettes. Only one disk drive is necessary if the computer has a hard disk.

To use BANKS, carry out the following steps:

1. Turn the computer on and while the computer self-tests its memory, place the Lotus 1-2-3 system diskette in drive A and the diskette containing BANKS in drive B.
2. Enter the date (if prompted) in the form of dd/mm/yy and press carriage return <or>;
3. Enter the time (if prompted) in the form of hh:mm and press <cr>;
4. Type 123 and press <Cr>. This loads Lotus 1-2-3 into the computer's memory. Lotus 1—2—3 then displays a blank spreadsheet on the screen.

To enable the novice user of BANKS to get started, it is necessary to learn a few basic Lotus commands and features. These are discussed below.

2.2 Menus

The first three lines of the screen (situated above the worksheet) form the control panel. The first line of the control panel contains information about the cell that the pointer (or cursor) is currently occupying. On the right hand side of this line is the mode indicator, which shows the state condition Lotus is currently operating in. The mode states are:

1. READY: Lotus is waiting for the user to perform a task;
2. MENU: Lotus is in menu mode, waiting for the user to select a menu option;
3. WAIT: Lotus is currently performing a task and is unable to accept commands;

4. ERROR: Lotus cannot understand the instruction given. To recover from the error mode and return to ready mode, press the ESC key.

When prompted, the second line of the control displays the menus. It also displays any requests for information that Lotus requires in order to complete a task. When Lotus is in menu mode, the third line of the control panel displays either a submenu or a one line description of the currently highlighted option in the second line of the control panel.

To enter menu mode at the highest level, press the slash (/) key. Lotus responds by displaying the highest menu level. Further submenus are ‘chosen by typing the first letter corresponding to the menu options displayed in the second line of the control panel. To move up from lower menus to higher menus, press the ESC key. Each time the ESC key is pressed, Lotus moves to successively higher menus, and eventually exits menu mode and enters ready mode. The menu commands required to use BANKS are described below.

2.2.1 /FR (Slash File Retrieve)

This command is used to retrieve the BANKS worksheet from the diskette in drive B. After pressing /FR, a list of Lotus worksheet files is displayed on the third line of the control panel. Use the ARROW keys to highlight the file name BANKS, then press <or>. While Lotus retrieves BANKS, the mode indicator displays WAIT. The mode indicator displays READY, when BANKS has been successfully retrieved.

2.2.2 /FS (Slash File Save)

This command is used to save the current worksheet onto the diskette in drive B. After pressing /FS, Lotus displays a list of worksheet files which already exist on the diskette in drive B and the name of the worksheet currently being used. In most situations this worksheet is BANKS because it was previously retrieved from disk. Lotus displays the name of the file to be saved as BANKS. At this point, the version of BANKS on disk can be replaced with the current version in computer memory by pressing <Cr>.

To ensure that you do not accidentally overwrite the previous BANKS file, Lotus requests the user to confirm that BANKS is to be replaced. To replace the BANKS file, type R (or choose menu item replace). To cancel the file save operation, type C (or choose menu item cancel).

To save the current worksheet as an additional file, type /FS, then type the new file name. The first three characters of the file name should consist of B:\ followed by 1 to 8 alpha-numeric characters beginning with a letter (e.g. B:\ RUN1).

While Lotus saves the current worksheet on disk, the mode indicator displays WAIT. Upon successful completion, Lotus returns to READY mode.

2.2.3 /WGRM and /WGRA (Slash Worksheet Global Recalculation Manual/Automatic)

These two commands are used to control when Lotus recalculates (updates) the spreadsheet. The default setting is automatic. This means that whenever a parameter is changed, Lotus recalculates the entire spreadsheet. In a large spreadsheet model, continual recalculation is time consuming and it may be best to wait until all the parameters have been changed before recalculating.

To prevent automatic recalculation, type /WGRM. In this mode, a recalculation is only performed when requested. The user performs a recalculation by pressing the F9 function key. If there are many numbers to be altered, it is more efficient to set recalculation mode to manual. Remember, however, to recalculate the spreadsheet when the new answer is required. To remind the user that a number has been altered since the last recalculation, Lotus displays the message CALC on the lower right hand side of the screen. To revert to automatic recalculation mode, type /WGRA.

2.2.4 /RE (Slash Range Erase)

To erase the contents of a cell, trove the cursor to the cell containing the number to be erased. Then type /RE. Lotus responds by asking the user to specify the range of cell in the spreadsheet to be erased. By pressing <Cr>, the user selects the cell where the cursor is currently located.

BANKS permits the user to change data only in highlighted cells. If the user attempts to alter any other cell, Lotus goes into ERROR mode. A bell sounds and the message PROTECTED CELL is displayed at the bottom of the screen. To return to READY node, press the ESC key.

2.3 Special keys

The user of *BANKS* needs to be familiar with the position of a few special keys on the keyboard. These are:

1. ALT key;
2. HOME key;
3. PgUp (Page Up) key;
4. PgDn (Page Down) key;
5. ARROW (Vector) keys;
6. RETURN (Enter or Carriage Return <or>) key;
7. F9 function key;
8. / (Slash) key.

Chapter 3

Banks

After retrieving the BANKS worksheet, it is ready to be used to evaluate the economics of installing banks to mitigate water erosion.

3.1 Main Menu

BANKS initially displays the main menu (Table 1). This menu identifies the sections comprising the model. Using the instructions displayed at the bottom of the menu, the user may proceed to any section. It is suggested that first-time users proceed sequentially through the sections until familiar with the structure and layout of the spreadsheet model. The next section is displayed by pressing the "page down" (PgDn) key.

3.2 Physical Structures

Section A (Table 2) deals with the specification of physical parameters relating to the site where the banks are to be installed. This may be a whole paddock or the erosion-prone section of a paddock. The numbers which the user is allowed to change are highlighted on the screen by a contrasting color. A plan of the paddock used in the example (before and after bank construction) is shown in Figure 1.

On Screen 1 of Section A, the following parameters may be specified:

1. the area of the site to be influenced by the banks, including the planned waterway;
2. the width of the banks (i.e. the width lost to cropping);
3. the length of the proposed waterway;
4. the width of the proposed waterway;
5. whether or not the planned waterway was originally cropped;
6. the area of land (if any) which prior to gully reclamation could not be cropped;
7. the area of land (if any) which prior to gully reclamation could not be used for pasture production and grazing.

Table 1: The main menu of BANKS

BANKS – Main Menu

BANKS is a financial spreadsheet model developed by John Salerian and Don McFarlane at the Western Australian Department of Agriculture (Copyright) to evaluate the economics of installing banks to mitigate water erosion.

The model consists of the following sections:

A	Physical Structures	H	Prevented Yield Loss
B	Bank Construction Costs	I	Prevented Area Loss
C	Additional Cropping Costs	J	Cash Flow
D	Commodity Prices and Costs	K	Post-tax Cash Flow
E	Rotation Sequence	L	Discounted Cash Flow
F	Probability of Erosion	M	Hardcopy
G	Organic N Balance		

Table 2: Section A of BANKS

A Physical Structures **Section A**
Screen 1

This section defines the area of the erosion site, the area removed from crop and pasture production due to the banks and the area of reclaimed gullies.

Initial paddock area including waterway and reclaimed land (ha)	120
Width of banks (m)	5
Length of waterway (m)	1000
Width of waterway (m)	35
Waterway originally cropped? (1=Y, 0=N)	1
Initial area of reclaimed crop land (ha)	2
Initial area of reclaimed pasture land (ha)	2

Individual Bank Statistics **Section A Screen 2**

Bank No	Length (m)	Bank No	Length (m)	Bank No	Length (m)
1	965	5	965	9	
2	965	6		10	
3	965	7		11	
4	965	8		12	

Total length of banks	4825		
Non-gullied crop area (ha)	112.08	Forgone crop area (ha)	-5.912
Non-gullied past area (ha)	115.58	Forgone pasture area (ha)	-2.412

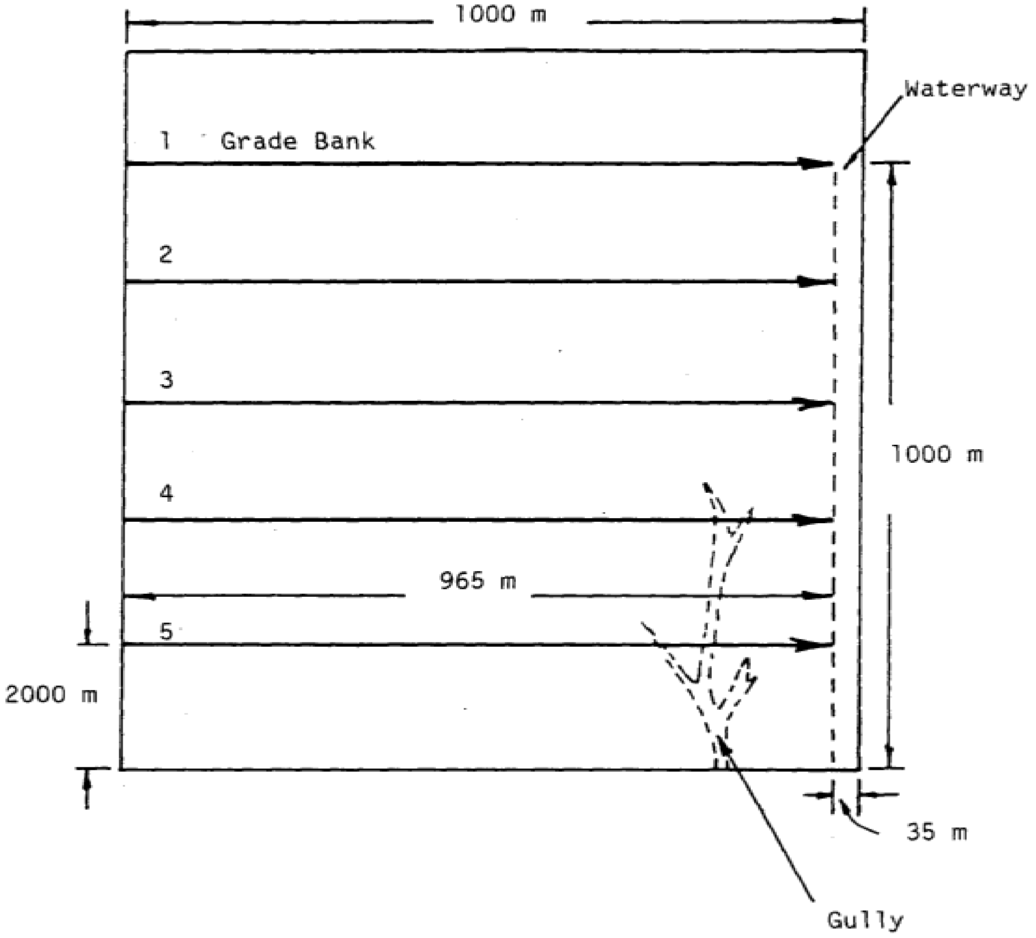


Figure 1: Eroding area (whole paddock) and proposed banking system.

On Screen 2 of Section A, the number of planned banks and their lengths are specified. To eliminate a bank, erase its length using the /RE command as explained in subsection 3.1.4. To add a bank, move the cursor to the cell corresponding to the banks length, enter its length and press <Cr>.

The physical data of Section A are used to determine:

1. the total length of banks built;
2. the area of the site which can be used for cropping and pasture after the banks are built (but excluding the gully infill area which is treated separately);
3. the reduction in the areas of crop and pasture land due to the use of land by the banks and waterway;
4. the increase in the area of land which can be cropped because of gully reclamation.

In the example shown in Table 2, there are five banks each 965 m in length. In this case, the total length of banks is 4825 m. If the number of banks is changed, BANKS recalculates the total length. In the example, two hectares of gullies are infilled and run-off is diverted, to a waterway which was originally cropped (Figure 1).

The non-gullied crop area is the initial area of the site less the area occupied by the banks, the waterway and any gullies which may have been infilled. The area of the waterway is subtracted only if the waterway could originally be cropped. For the example given in Table 2, non-gullied crop area is given by:

(1) Non-gullied crop area

= site area — area of banks - area of waterway - reclaimed crop area

= 120 — 4825*5/10000 — 1000*35/10000 — 2

= 112.08 hectares

The foregone crop area is given by:

(2) Foregone crop area

= - area of banks - area of waterway

= — 4825*5/10000 — 1000*35/10000

= - 5.962 hectares

If the waterway was not previously cropped, then the non—gullied crop area is given by:

(3) Non-gullied crop area

= site area — area of banks — reclaimed crop area and the foregone crop area is given by:

(4) Foregone crop area = - area of banks

The non—gullied area of the site which can be used for pasture production in the example shown in Table 2 is given by:

(5) Non-gullied pasture area

= site area — area of bank — reclaimed pasture area

= 120 — 4825*5/10000 — 2

= 115.53 hectares

The foregone pasture area is given by:

(6) Foregone pasture area

= — area of banks

= — 4825*5/10000

= - 2.412 hectares

3.3 Bank Construction Costs

In Section B (Table 3) bank construction and maintenance costs, the frequency of maintenance and the total gully reclamation cost are specified. A maintenance frequency of five years means that maintenance costs occur in years 6, 11 and 16 of a 20 year planning horizon.

3.4 Additional Working Costs

In Section C (Table 4) the additional cropping costs caused by the construction of the banks are specified. Banks divide the paddock into smaller sections. This increases the number of corners to be negotiated by machinery, which can increase the tine required to sow and harvest crops and increases the load on machinery. Overall, the banks are likely to increase the fuel, labour and maintenance costs of sowing and harvesting. If it is thought that working on the contour will actually result in less fuel being used in a particular case the increase in fuel consumption can be entered as a negative number.

Table 3: Section B of BANKS

B Bank Construction Costs Screen 1	**Section B**
This section defines the bank construction and maintenance costs, and the frequency maintenance is required.	
Bank construction cost ($/km)	120
Bank maintenance cost ($/km)	40
Frequency of maintenance (years)	5
Initial gully reclamation cost ($)	1000

Table 4: Section C of BANKS

C Additional Working Costs Screen 1	**Section C**
This section defines the additional working costs caused by the partitioning of the paddock into smaller subsections.	
Fuel	
Fuel price (c/L)	45
Original fuel consumption for seeding (L/ha)	10.5
Increase in fuel consumption for seeding (%)	5
Original fuel consumption for harvesting (L/ha)	5
Increase in fuel consumption for harvesting (%)	2
Increase in fuel cost ($/ha)	0.28
Labour	**Section C Screen**
Wage rate ($/hr)	8
Original seeding rate (hrs/ha)	0.2
Decrease in seeding rate (%)	2
Original harvesting rate (hrs/ha)	0.1
Decrease in harvesting rate (%)	2
Increase in labour cost ($/ha)	0.048

Machinery maintenance	**Section C Screen**
Original seeding equipment maintenance cost ($/ha)	2.5
Increase in seeding equipment machinery cost (%)	2
Original harvesting equipment maintenance cost ($/ha)	1.5
Increase in harvesting equipment maintenance cost (%)	2
Increase in equipment maintenance cost ($/ha)	0.08

The default values provided by BANKS are based on a farm case study in the Narrogin area (Negus and Barrett 1979). The case study suggests that the division of a paddock into small subsections causes only a small increase in the fuel and labour requirements to sow crops.

In the example shown in Table 4, the increase in fuel cost per hectare is given by:

(7) Fuel cost increase

= fuel price * change in fuel consumed during sowing and harvesting

= 45/100 * (10.5*5/100 + 5*2/100)

= $0.28 per hectare

The increase in labour costs is given by:

(8) Labour cost increase

= wage rate * change in labour required during sowing and harvesting

= 8 * (0.2*2/100 + 0.1*2/100)

= $0.048 per hectare

Similarly, the increase in maintenance cost is given by:

(9) Maintenance cost increase

= change in sowing maintenance cost + change in harvesting maintenance cost

= 2.5*2/100 + 1.5*2/100

= $0.08 per hectare

The limited evidence available suggests that the additional cropping costs following the working of smaller lands are relatively small (only $0.41/ha in the above example) and therefore do not need to be accurately estimated.

3.5 Commodity Prices and Costs

In Section D (Table 5) the prices and variable costs of production for five alternative crops and pasture are defined. The revenue from crops is expressed in dollars per tonne. The revenue from pasture production (sheep) and all variable costs are expressed in dollars per hectare. Revenue from production within a single year can be received over a three year period. For sane commodities, the landholder only receives the guaranteed minimum price in the year of production. Further payments (second and third advances) are received over the next two years.

In Table 5, wheat receives $75/t in the year of production and $I6/t the following year. The total price received for profit and taxation purposes is $9I/t in the year of production. The variable cost of production for wheat is taken as $57/ha. Variable cost of production includes the cost of machinery, fuel, fertiliser, seed and chemicals used in the production of the crop.

The planning horizon in BANKS is 20 years. The prices and costs used over the planning horizon are those specified in Section D.

The assumption is that commodity prices and costs only change according to the inflation rate. The reasons for this simplified approach to future commodity prices and costs are:

1. The difficulty in correctly forecasting relative changes in future prices and costs;

2. Provided that relative commodity prices and costs are unchanged, changes in prices over time will reflect inflation. These changes can be corrected for by using real discount rates in the calculation of net present value in Section J.

BANKS allows for only five crop activities and one pasture activity. It is possible to include a crop which is not listed. For example, if rape is to be grown and triticale is never to be grown, simply use the heading TRI and crop—pasture code 4 as if it represents rape. All data relevant to rape can be entered in the triticale locations. The pasture prices and costs are used to estimate the losses due to removing grazing land from production by constructing the banks, and to estimate the gains due to reclaiming gullies.

Table 5: Section D of BANKS

D Commodity Prices and Costs **Section D Screen 1**

This section defines the farm gate prices for crops, average variable costs of crop production, and the returns and costs of pasture production. Returns from annual production may be distributed over 1 to 3 years to reflect first, second and third advances. Crop returns are in $/t, pasture returns and crop and pasture costs are in $/ha. Average variable costs are the costs used in calculating gross margins for various farm enterprises.

	Wht	**Oat**	**Bar**	**Tri**	**Lup**	**Pas**
Crop or pasture code	1	2	3	4	5	6
Return in year of production	75	70	70	80	102	22.7
Return delayed 1 year	16		10		18	
Return delayed 2 years						
Total Return	91	70	80	80	120	22.7
Average variable cost	57	58	60	58	50	7

3.6 Rotation Sequence

In Section E (Table 6) the sequence of crops and pasture over the planning period are specified.

The year which commences the planning period is specified. Then under each year of the planning horizon, a number corresponding to the crop-pasture code is entered. In the example shown, wheat is grown in 1987 and pasture in 1988 which is the beginning of a 1 in 2 rotation.

3.7 Probability of Water Erosion

In Section F (Table 7) the annual and cumulative soil loss levels over the planning horizon are estimated. Given the paucity of data on soil loss rates under different management conditions, several different scenarios may be tried here (eg. to find the soil loss rate which makes the banks economic). A soil loss of 1mm represents about 14 tonnes/ha and would not be expected to occur very frequently in many situations. However when rilling occurs on cultivated paddocks it is common to lose soil to the depth of cultivation (80mm?) from the rilled area and an unspecified amount from the inter-rill areas. Given the selective removal of nutrients from eroding soils, it may not be necessary to remove a large tonnage of soil to have a significant effect on the yield of subsequent crops. In most areas of south-western Australia, mean soil losses will be low but variances high, reflecting the episodic nature of water erosion.

The first number under each year is the soil loss (mm) accruing in the year. The second number under each year is the cumulative soil loss (mm) up to and including the year. The sequence of annual soil loss levels can be determined using two methods:

1. entering the individual levels for each year. This method is preferrable if you want to indicate that soil loss is likely to be infrequent but severe;

2. randomly, using the mean/variances of the poison distributions of soil erosion levels specified and a random number generator.

To generate a random sequence of erosion levels, ensure that the means/variances of the poison distributions of soil erosion under crop and pasture are correctly specified. Then hold down the ALT key and type W. BANKS then assigns a random level of soil loss to each year, using the appropriate mean/variance, depending upon whether a crop or pasture is grown. Different sequences of soil loss with the same means and variances can be generated by retyping ALT W to assess the stability of any result.

The method used to calculate the random levels of soil erosion based on a poison discrete probability distribution is outlined in Appendix 1.

Table 6: Section E of BANKS

E Rotation Sequence	**Section E Screen 1**
This section defines the rotation sequence over the planning period.	
Length of the planning period (years)	20
The date of the first year (I9xx)	1987
Crop-pasture code : Wht=I Bar=2 Oat=3 Thi=4 Lup=5 Pas=6	

Rotation sequence

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	6	1	6	1	6	1	6	1	6
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	6	1	6	1	6	1	6	1	6

Table 7: Section F of BANKS

F Probability of Soil Erosion							**Section F Screen 1**		
This section defines the annual and cumulative levels of soil erosion prevented by banks. To generate a new series of random erosion levels based on the poison distributions specified, hold down the ALT key and type W. Alternatively, enter your own sequence.									
Mean/variance of soil erosion under crop (mm)								3	
Mean/variance of soil erosion under pasture (mm)								2	
Annual and cumulative soil loss (mm)									
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
2.00	0.00	5.00	1.00	1.00	1.00	1.00	3.00	6.00	1.00
2.00	2.00	7.00	8.00	9.00	10.00	11.00	14.00	20.00	21.00
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2.00	0.00	2.00	0.00	2.00	2.00	3.00	3.00	3.00	0.00
23.00	23.00	25.00	25.00	27.00	29.00	32.00	35.00	38.00	38.00

3.8 Organic Nitrogen Balance

In Section G (Table 8) the deficiency in organic nitrogen that occurs in the absence of banks is calculated. Marsh (File 3512 EX) found that water erosion selectively removes nutrients from the topsoil and that cereal yield declines were linearly correlated with the loss in organic nitrogen. Organic nitrogen is most concentrated near the soil surface under pasture and the loss of the top few millimetres has a larger effect on yield than does the loss of soil lower in the profile. Under cultivation however, organic nitrogen is mixed evenly throughout the cultivation layer. Due to previous erosion or particular management practices (e.g. multiple cultivation), the site may already have a reduced level of organic matter at the commencement of the analysis. This initial deficiency is specified in Section G.

The organic nitrogen level is expressed in units called Pasture Soil loss Equivalents (PSLE' s). PSLE is measured in mm. The reason for adopting PSLE as a measure of organic nitrogen deficiency is because the soil loss -productivity relationship used is estimated for soil loss occurring in the pasture phase of a rotation. The data used is from swept plot trials (Marsh, File 3512EX). To use the yield-soil loss relationship, soil loss occurring under cropping needs to be converted to an equivalent level of soil loss under pasture which results in the same level of organic nitrogen and yield decline.

The effect of soil erosion on the organic nitrogen levels is assumed to be reversible. Organic nitrogen levels increase under a lupin crop or a pasture.

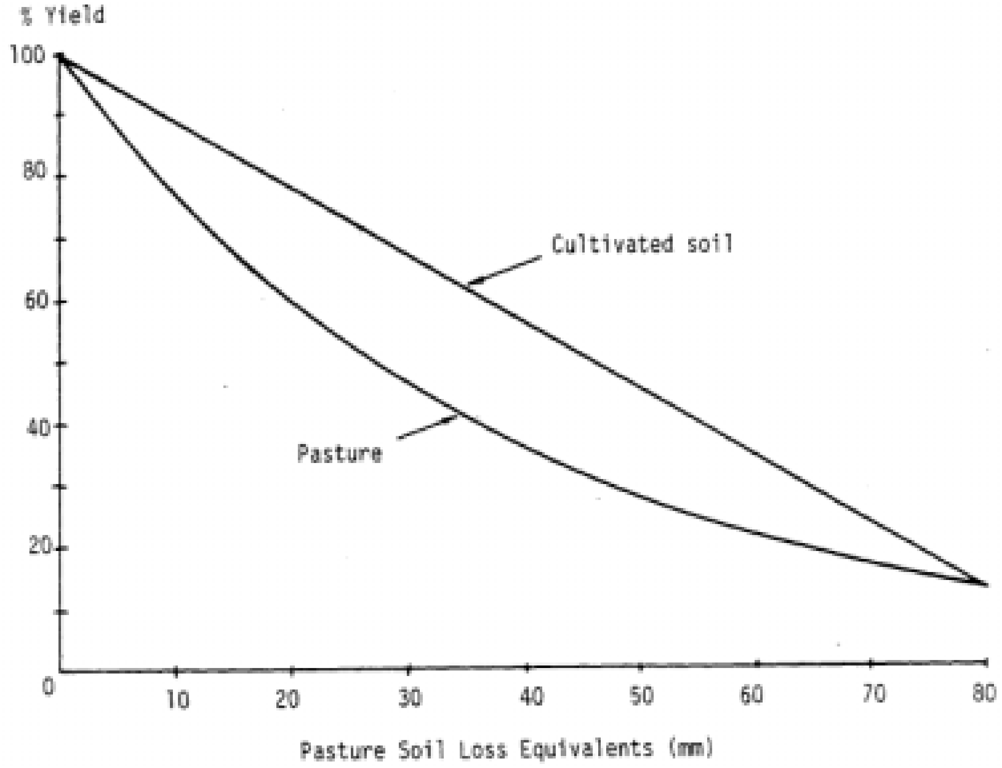
The rate of recovery is specified in Section G.

Table 8: Section G of BANKS

G Organic Nitrogen Balance							**Section G Screen 1**		
This section defines the organic nitrogen deficiency (expressed in mm of Pasture Soil Loss Equivalent) occurring with and without banks.									
Pasture soil loss equivalent nitrogen deficiency (mm)							0		
Pasture soil loss equivalent recovery: pas or lup (0<R<l)									0.5
Cumulative pasture soil loss equivalent with and without banks									
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.86	0.43	2.61	1.80	2.23	1.62	2.04	2.52	5.15	3.08
1997	1998	1999	2000 ‘	2001	2002	2003	2004	2005	2006
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.93	1.97	2.82	1.41	2.27	2.14	3.43	3.21	4.51	2.25

Figure 2 shows the relationship between soil loss and crop yield for soil loss under pasture and under cropping. As nitrogen is concentrated at the top of the soil profile under pasture, this relationship is curvilinear

Figure 2: Soil loss-yield for organic nitrogen loss



The relationship between cereal yield and soil loss under pasture is given by:

(10) Y = Y(PSLE=0) * EXP(a*PSLE)

where Y (PSLE=0) is the maximum cereal yield when organic nitrogen is not limiting yield, and "a" is a parameter which controls the rate of yield decline with soil loss. Using the swept plot data (Marsh, File 3512EX), a is estimated to be -0.0257 with a Student's t—test value of -11.4 ($P < 0.01$). However, soil loss only explained 20.7 per cent of the variation in yield in the trial ($R^2 = 0.207$).

The amount of organic nitrogen lost from erosion to the depth of cultivation (which is common in rills) is assumed to be identical under pasture and crop conditions. BANKS assumes that the cultivation depth is 80 mm. The decline in yield as a proportion of maximum yield is (1-EXP(a*80)) and the change in soil loss is —80. With erosion under crop, this yield decline is assumed to be linear over the 80mm range of soil loss. Therefore, the yield equation for soil loss under crop conditions is given by:

(11) $Y = Y(SL_c=0) * (1 + (1-EXP(a*80)) / —80 * SL_c)$

where SL_c is the level of soil loss under crop. This equation is only valid for soil loss levels less than the cultivation depth.

While the initial swept plot data have been extrapolated beyond the measured range in Figure 2, for all rotations except continuous cropping, it is unlikely that the PSLE' s will go beyond the measured range.

To convert SL_c to an equivalent level of soil erosion under pasture (PSLE), equations 13 and 14 have been equated and the terms rearranged:

(12) $Y(0)*EXP(a*PSLE) = Y(0)*(1+(1-EXP(a*80))/-80*SL_c)$

$PSLE = 1n(1+(1-EXP(a*80))/-80*SL_c)/a$

Consider the example shown in Tables 7 and 8. In 1987, the level of soil erosion in a cereal crop year is 2mm. The PSLE of this level of soil is given by:

(13) $PSLE = 1n(1+(l-exp(-0.0257*80))/-80*2)/-0.0257$

$= 0.86mm$

This means that 2mm of soil erosion under crop has an equivalent effect on cereal crop yield to 0.86mm of soil erosion under pasture. These values can also be read off Figure 2 by taking a horizontal line from the curved relationship for pastures to the straight relationship with cropping.

To estimate any initial deficiency, refer to Figure 2. If the initial yield of the site is thought to be only 90 per cent of uneroded yields, this is the sane as having a pasture soil loss equivalent of 4.5mm.

Cultivation is assumed not to decrease the concentration of organic nitrogen in the soil. This simplification is made to prevent the spreadsheet model from becoming unnecessarily large and complicated. The objective of the analysis is to identify the relative costs and benefits between soil erosion and its prevention using banks. For any given rotation sequence, any decline in organic nitrogen due to cultivation adjusts cereal yields under both erosion and banks by the same proportion. However, it does change the absolute yield differences, and this affects the economic benefits of preventing soil loss.

Cereal yield is assumed to be a function of cumulative PSLE and soil depth. The loss of soil depth is assumed to be irreversible. In Screen 1 of Section H, the (effective) soil depth (defined later) at the beginning of the planning horizon is specified. The soil depth in any year is the initial soil depth less the cumulative soil loss up to and including the specific year.

In BANKS, it is assumed that:

1. cereal crop yields are affected by soil loss (PSLE) and soil depth;

2. lupin crop yields are only affected by soil depth;
3. pasture production is unaffected by soil loss and soil depth.

Cereal crop yields are responsive to the level of organic nitrogen in the soil whereas lupins and pasture are not. Crops are deep rooting compared with pasture and are likely to exhibit yield decline due to declining soil depth before pastures.

The cereal yield equation is specified as:

(14) $Y = Y(CPSLE=0:SD) * EXP(a*CPSLE) *$

$(1-bEXP(c*Sd_{max}))^{-1} * (1 - b*EXP(c*SD))$

SD is the soil depth occurring in the specific year, SD_{max} is the maximum (initial) soil depth and "b" and "c" are parameters relating to the soil depth component of the yield responses function.

Under lupins and pasture, the organic nitrogen deficiency is assumed to recover. This is achieved by reducing the cumulative PSLE (CPSLE) at the rate specified in Section G (see Table 8). In the example, 1988 is a pasture year. The level of soil loss (PSLE) occurring in 1988 is 0.0mm. This level of soil loss is added to the cumulative PSLE in 1987. Then the cumulative PSLE recovers at rate of 0.5. The cumulative PSLE in 1988 is given by:

(15) CPSLE(1988) = (CPSLE(1987) + PSLE(l988)) * (1—recovery rate)

= (0.86 + 0) * (1 — 0.5

= 0.43mm

3.9 Prevented Yield Loss

In Section H (Table 9) the crop yields that occur with and without banks, and the crop yield gains attributed to banks are calculated.

The parameters relating to the yield equation (a, b and c) are defined in Section H. The a parameter controls the rate at which yield declines as CPSLE increases (the curve for a = -0.0257 was shown in Figure 2). The small value of a (-0.0257) indicates that yield declines slowly as CPSLE increases.

The b parameter represents the responsiveness of crops to soil depth. It defines the proportion of maximum yield occurring when soil depth is zero. A value of -1 means that when soil depth is 0, crop yield is 0. A value of b greater than -1 means that a yield is possible when soil depth is 0. The initial default value for b is -1. By specifying b as -1, the soil depth asked for in Section H is the soil depth at which yield becomes 0. For a duplex soil or a wodgil soil with subsoil acidity, the effective soil depth is the depth of topsoil that can be removed before a crop will no longer set seed.

Table 9: Section H of BANKS

H Prevented Yield Loss **Section H Screen 1**

This section calculates the crop yields that occur with and without banks and the crop yield gains attributed to banks. Yield is given by:

y(CPSLE=0) EXP(aCPSLE)/(1+b*EXP(c*SD))

where CPSLE is the cumulative pasture soil loss equivalent of organic nitrogen deficiency, SD is the soil depth, and SD(max) is initial soil depth. Parameters relating to soil depth, the yield equation and base yields are defined.

Initial soil depth — SD(max) (mm): 250

Yield equation parameters:	a	b	c
	-0.025	-1	-0.01

Maximum yields (t/ha):	wht	bar	oat	tri	lup
(Y(CPSLE=0,SD=max))	1	1.1	1.6	1.2	0.9

Section H Screen 1

Crop yields with and without banks (t/ha)

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0	1	0	1	1	1	0	1	0
0/976	0.000	0.929	0.000	0.96	0.939	0.939	0.000	0.859	0.000
1997	1998	1999	2000	2001	2003	2003	2004	2005	2006
1	0	1	0	1	1	1	0	1	0
0.883	0.000	0.906	0.000	0.917	0.885	0.885	0.000	0.854	0.000

Crop yield gains with banks (t/ha)

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0.024	0.000	0.071	0.000	0.064	0.000	0.061	0.000	0.141	0.000
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
0.117	0.000	0.094	0.000	0.083	0.000	0.115	0.000	0.146	0.000

On deep soils, setting b = -1 but specifying a deep (e.g. > 500 rim) soil, effectively results in soil depth not affecting the economics of bank construction. In such cases only organic nitrogen losses and gullying are affected.

The c parameter controls the rate at which yield declines as soil depth declines. It affects the shape of the yield-soil depth response function. It is analogous to the a parameter. An initial value of c is -0.01. Figure 3 shows the decline in relative yield for a soil with a 300mm thick topsoil and c values of -0.001, -0.005, -0.01, -0.025 , -0.05 and -0.1. In Figure 3, it is assumed that yield is 0 (ie a crop cannot be grown on the area) when there is no more topsoil left. Choosing a more negative c value (eg -0.1) results in there being little effect of soil loss on yield until there is almost no topsoil left. The closer c is to 0 (eg -0.001), the more linear the effect of soil loss on yield. Choosing a c value greater than 1, would indicate the rate of yield decline is initially high but decreases as the depth of topsoil decreases. This is not thought to be the case.

To date, it has not been possible to estimate the soil depth parameters, b and c, because of the lack of data.

Also in Section H, the maximum yields for cereal crops and lupins are defined. These are the yields that occur when there is no organic nitrogen deficiency and the soil depth is at its initial value (SD_{max}).

Using the information in Sections E, F, G and H, crop yields with and without banks, and the crop yield gains attributed to banks are calculated in Screen 2 of Section H. It is assumed that with banks, no soil loss occurs. However, yield may still be reduced due to reduced organic nitrogen levels from soil lost before the analysis commences.

In the example shown in Table 9, a wheat crop is grown in 1987. The yield with banks is given by:

$$\text{(16)} \quad \text{wheat yield (banks)} = \text{yield(max)} * \text{EXP}(a*\text{CPSLE})$$

$$= 1 * \text{EXP}(-0.0257*0)$$

$$= 1 \text{ t/ha}$$

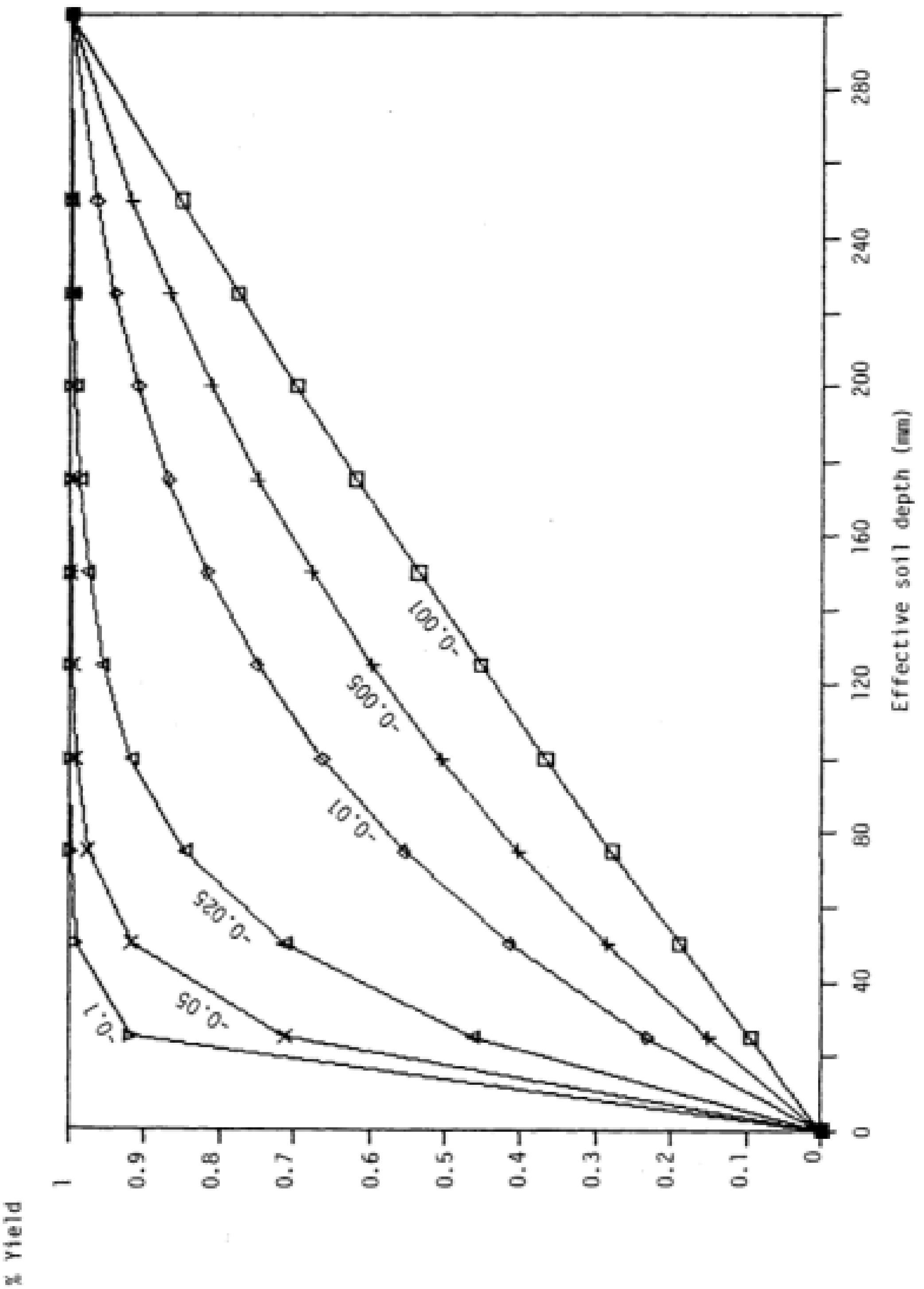


Figure 3: Yield versus soil depth for various c values

If lupins are grown, the yield is equal to the maximum yield because their yield is independent of CPSLE. In 1988, no crops are grown and yield is set to 0.

The wheat yield without banks in 1987 is given by:

(17) Wheat yield (no banks)

= yield(max) * EXP(a*CPSLE) * 1/(1-bEXP (cSD_{max})*(1-b*EXP(c*SD))

= 1 * EXP(-.0257*0.86) * l/(1-EXP(-.01*250)*(1-EXP(-.01*(250-2))

= 0.976 t/ha

In the case of a lupin crop being grown in the absence of banks, the yield is given by:

(18) Lupin yield (no banks)

= yield(max) * 1/(1-b EXP(cSD_{max}) * (1-b*EXP(c*SD))

In 1988 no crop is grown and the crop yield without banks is set to 0.

Crop yield gains attributed to banks are calculated as the yield with banks less the yield without banks. For example, the crop yield gain attributed to banks in 1988 is given by:

(19) Crop yield gain = crop yield (banks) - crop yield (no banks)

= 1 - 0.976

= 0.024 t/ha

3.10 Prevented Area Loss

In Section I (Table 10) the annual increases in the areas of land which cannot be cropped or are unavailable for pasture are specified.

In the absence of banks, erosion is likely to lead to further gullying, resulting in increasing areas of land lost to:

1. gullies;
2. areas becoming inaccessible to machinery and sheep.

Table 10: Section I of BANKS

I Prevented Area Loss							**Section I Screen 1**		
This section calculates the area that is made unavailable for cropping and pasture, if banks are not installed. The annual change in the area lost from crop and pasture production are defined.									
Annual increment in crop area lost (ha)									
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1997	1998	1999	2000	2002	2002	2003	2004	2005	2006
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Annual increment in pasture area lost (ha)									
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
							Section I Screen 2		
Crop area loss (ha)									
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0
Pasture area loss (ha)									
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0

At this stage it is not possible to quantify the relationship between erosion and the spread of gullies. It is left to the user to use local knowledge of the site to specify the rates of growth of gullies and the area lost. In estimating the increases in the area of land lost to gullying, the annual levels of soil erosion specified in Section F should be noted.

3.11 Pre-tax Cash Flow

In Section J (Table 11) the changes in annual pre-tax cash flow are derived for the parameters specified above. Installing banks to prevent water erosion causes expenditure and receipts of the farm business to change compared to those that occur in the absence of banks. There are two methods available to compare the two situations. One is to estimate the annual cash flow budgets that occur in each situation. This requires financial and technical details for the entire farm business. The two cash flows can then be compared.

The alternative approach is to calculate the changes in annual cash flow. The advantage of this approach is that less information is required. Instead of preparing two whole farm budgets, a partial budget is prepared. Only the difference between the two whole farm budgets is required. Subtracting one whole farm budget from the other cancels out data that is unchanged.

BANKS does not optimise cash flow or bank design. It simply simulates changes in annual cash flow for a specific set of assumptions regarding the parameters of the model.

The implicit assumption of BANKS is that the major costs and benefits of mitigating water erosion depend upon the direct effects of the banks on the site. The interactions between the mitigating of water erosion on a site and other farm activities are assumed to be insignificant. This assumption may be inappropriate when comparing evaluations derived from different rotation sequences. For example, changing from a pasture dominant rotation to a crop dominant rotation on the site (due to the banks enabling an erosion-prone area to be cropped) may alter the gross margins for cropping and pasture activities. The gross margins need to adjusted to include the interactive effects between crops and between crops and pasture.

Table 11: Section J of BANKS

J Cash Flow			**Section J Screen 1**		
Income	1987	1988	1989	1990	1991
Production increases: current year	237	38	640	44	585
Production increases: delayed 1 yr		77	0	168	0
Production increases: delayed 2 yrs			0	0	0
Outgo					
Bank/gully reclamation cost	1579				
Bank maintenance cost	0	0	0	0	0
Additional cropping cost	47	0	47	0	47
Production losses: current year	96	38	75	38	78
Production losses: delayed 1 yr		92	0	88	0
Production losses: delayed 2 yrs			0	0	0
Change in annual cash flow	-1484	-15	518	86	86

			Section J Screen 1		
Income	1992	1993	1994	1995	1996
Production increases: current year	50	568	57	1238	63
Production increases: delayed 1 yr	161	0	162	0	310
Production increases: delayed 2 yrs	0	0	0	0	0
Outgo					
Bank/gully reclamation cost					
Bank maintenance cost	193	0	0	0	0
Additional cropping cost	0	47	0	47	0
Production losses: current year	38	79	38	44	38
Production losses: delayed 1 yr	89	0	89	0	81
Production losses: delayed 2 yrs	0	0	0	0	0
Change in annual cash flow	-108	441	92	1147	254

	Section J Screen 3				
Income	1997	1998	1999	2000	2001
Production increases: current year	1040	69	852	75	768
Production increases: delayed 1 yr	0	273	0	238	0
Production increases: delayed 2 yrs	0	0	0	0	0
Outgo					
Bank/gully reclamation cost					
Bank maintenance cost	193	0	0	0	0
Additional cropping cost	48	0	48	0	48
Production losses: current year	55	38	65	38	70
Production losses: delayed 1 yr	0	84	0	86	0
Production losses: delayed 2 yrs	0	0	0	0	0
Change in annual cash flow	745	221	739	189	650

	Section J Screen 4				
Income	2002	2003	2004	2005	2006
Production increases: current year	82	1036	88	1292	94
Production increases: delayed 1 yr	225	0	287	0	346
Production increases: delayed 2 yrs	0	0	0	0	0
Outgo					
Bank/gully reclamation cost					
Bank maintenance cost	193	0	0	0	0
Additional cropping cost	0	48	0	48	0
Production losses: current year	38	55	38	42	38
Production losses: delayed 1 yr	87	0	84	0	81
Production losses: delayed 2 yrs	0	0	0	0	0
Change in annual cash flow	-11	933	253	1202	322

The planning horizon in BANKS is 20 years. The sources of benefit from preventing water erosion are derived from additional crop yield and additional productive land.

In the example, the increase in revenue generated in 1987 (a cropping year) is given by:

(20) Production increase: current year

= (original site area - foregone crop area - cumulative prevented crop area loss) * yield gain * revenue: current year + cumulative prevented crop area loss * (return in year of production * yield with banks - variable cost)

= 112.08 * 0.024 * 75 + 2.2 * (75*1 - 57)

= $237

In 1988, pasture is grown and there are no yield gains. Therefore the increase in revenue from production increases is given by:

(21) Production increase: current year

=cumulative prevented pasture area loss * (return in year of production - variable cost)

= 2.4 * (22.7 - 7)

= $38

In 1988, revenue is received from the wheat crop grown in 1987. The increase in revenue from production in the preceding year is given by:

(22) Production increases :delayed 1 year

= (original site area - foregone crop area - cumulative prevented crop area loss) * yield gain * return: delayed 1 year + cumulative prevented crop area loss * return:delayed 1 year * yield with banks

= 112.08 * 0.024 * 16+2.2 * 16 * 1

= $77

In the example, there are no delayed receipts from pasture production. However, when there are delayed returns from pasture, they are given by:

(23) Production increases :delayed 1 year

= cumulative prevented pasture area loss * return :delayed 1 year

In 1989 there are no delayed returns received from increased crop production in 1986.

The increase in revenue in 1989 from production in 1987 is given by:

(24) Production increases :delayed 2 years

= (original site area - foregone crop area - cumulative prevented crop area loss) * yield gain * return:delayed 2 years +cumulative prevented crop area loss * return :delayed 2 years * yield with banks

=112.08 * 0.024 * 0+2.2 * 0 * 1

=$0

Increases in costs relating to the use of banks are:

1. bank construction and gully reclamation;
2. maintenance;
3. variable costs;
4. production losses.

Bank construction and gully reclamation costs are assumed to occur in the first year of the planning period. In the example in Table 11, bank construction and gully reclamation cost is given by:

(25) Bank/gully reclamation cost

= total length of banks * unit construction cost + gully reclamation cost

=4825/1000 * 120 + 1000

=$1579

Bank maintenance occurs periodically according to the frequency specified in Section B (Table 3). In this example, maintenance is carried out in 1992, 1997, and 2002. The maintenance cost shown in Table 11 is given by:

(26) Bank maintenance cost

=total length of banks * unit maintenance cost

=4825/1000 * 40

=$193

The third component of costs are the increases in variable costs of cropping. These only occur in a cropping year. In the example shown in Table 11, the first cropping year is 1987 and the increase cropping cost is given by:

(27) Increase cropping cost

= (area of site - area of banks and waterway + prevented cumulative crop area loss) * (increase in unit fuel cost + increase in unit labour cost + increase in unit maintenance cost)

= 112.08 * (0.28+0.048+0.08)

= $47

The last category of cost is the value of production lost because the area occupied by the banks is completely unproductive and the area of the waterway cannot be cropped. If the waterway originally could not be cropped (as in the example shown in Table 11) then the cost of production losses in a cropping year, such as 1987, is given by:

(28) Production losses : current year

= area of banks and waterway * (yield with no banks * return in year of production - variable costs

= 5.912 * (0.976 * 75 — 57)

= $96

If the waterway were not originally arable, then the change in crop area would be equal to the area of the banks only.

A delayed payment for wheat produced in 1987 is received in 1988. The value of production losses: delayed one year in 1988 is given by:

(29) Production losses :delayed 1 year

= area of banks and waterway * yield with no banks * return: delayed 1 year

= 5.912 * 0.976 * 16

= $92

In 1989, no delayed return from the wheat crop grown in 1987 is received. The value of the delayed returns for production losses is given by:

(30) Production losses :delayed 2 years

= area of banks and waterway * yield with no banks * return: delayed 2 years

= 5.912 * 0.976 *

= $0

In 1988, pasture is grown and, the value of the production losses in the year of production is given by:

(31) Production losses: current year

= area of banks * (return in year of production - variable cost)

= 2.412 * (22.7 - 7)

= $38

In 1989, the production losses delayed 1 year from pasture grown in 1988 are received and is given by:

(32) Production losses: delayed 1 year

= area of banks * return delayed 1 year.

= 2.412 * 0

= $0

The same calculation is performed for the value of production losses delayed 2 years by substituting the return delayed 1 year for pasture with that delayed 2 years.

The annual changes in pre-tax cash flow in each year are calculated as:

(33) Annual change in pre—tax cash flow

= (production increases : current year + production increases :delayed 1 year + production increases :delayed 2 years) - (bank/gully reclamation cost + bank maintenance cost + additional cropping cost + production losses: current year + production losses:delayed 1 year + production losses :delayed 2 years)

3.12 Post-tax Cash Flow

The installation of banks and the mitigation of water erosion causes changes to the annual farm profits. In addition, recent changes to the Taxation Act make capital expenditure to prevent land degradation fully tax deductible in the year of expenditure.

The annual changes in tax payable depend upon:

1. the general level of farm profits;
2. the changes in farm profits due to the construction of the banks and the mitigation of water erosion;
3. the number of partners sharing the farm profits.

Taxation affects cash flow as the farm business either pays more tax or less tax because the mitigation of water erosion alters annual farm profits. The tax liability in any year is based on the farm business profitability of the preceding year because the completion of financial accounts and the assessment of tax liability take approximately 6 to 12 months. A recent review of taxation measures and their effects on soil conservation was conducted by the Bureau of Agricultural Economics (BAE, 1985).

In Screen 1 of Section K (Table 12) the marginal tax rates and the number of partners sharing in the profits of the farm business are specified. In Screens 2 to 5 of Section K, the expected levels of annual taxable income in the absence of banks are specified.

Annual farm income exhibits variability due to variations in commodity prices and yields. In addition, taxable income can vary due to interest repayments on loans. Expected taxable farm income is farm specific. While it is difficult to estimate future levels of taxable income with any certainty, it is necessary to make some estimates.

The marginal tax position of the farm business can have a significant effect on the post-tax changes in annual cash flow. The effect of taxation on cash flow is lagged one year and there are no tax effects on changes in annual cash flow in the first year of the planning period. It should also be noted that the change in taxable income is not equal to the change in cash flow because profit from production in a given year includes returns which are not received until future years.

Table 12: Section K of BANKS

K Post-Tax Cash Flow		**Section K Screen 1**	
This section calculates the post-tax cash flow. The number of partners sharing profits, the tax schedule, and expected annual income can be can be modified.			
Number of partners sharing taxable income		3	
Taxation Schedule			
Upper Limit	Tax Rate	Farm Limit	Tax Payable
4595	0	13785	0
12095	0.24	36285	5400
18995	0.29	56985	11403
27495	0.43	82485	22368
34495	0.46	103485	32028
infin	0.55		

	Section K Screen 2				
	1987	1988	1989	1990	1991
Expected annual farm taxable income	30000	30000	30000	30000	30000
Expected tax payable	3892	3892	3892	3892	3892
Taxable income with banks	28501	30000	30598	30006	30532
Tax payable with banks	3532	2892	4035	3893	4019
Change in annual tax payable	-360	-0	144	1	128
Post-tax annual cash flow	-1484	345	518	-57	85

	Section K Screen 3				
	1992	1993	1994	1995	1996
Expected annual farm taxable income	30000	30000	30000	30000	30000
Expected tax payable	3892	3892	3892	3892	3892
Taxable income with banks	29819	30515	30019	31376	30025
Tax payable with banks	3848	4015	3896	4222	3898
Change in annual tax payable	- 43	123	4	330	6
Post-tax annual cash flow	- 236	484	-31	1142	-76

	Section K Screen 4				
	1997	1998	1999	2000	2001
Expected annual farm taxable income	30000	30000	30000	30000	30000
Expected tax payable	3892	3892	3892	3892	3892
Taxable income with banks	30935	30031	30891	30037	30788
Tax payable with banks	4116	3899	4105	3901	4081
Change in annual tax payable	224	7	214	9	189
Post-tax annual cash flow	739	-4	732	-24	641

	Section K Screen 5				
	2002	2003	2004	2005	2006
Expected annual farm taxable income	30000	30000	30000	30000	30000
Expected tax payable	3892	3892	3892	3892	3892
Taxable income with banks	29851	31136	30050	31467	30056
Tax payable with banks	3856	4164	3904	4244	3905
Change in annual tax payable	-36	273	12	352	14
Post-tax annual cash flow	-201	969	-20	1190	-30

In Table 12, taxable income after the installation of banks in 1988 is given by:

(34) Taxable income with banks

=expected income:l987 + change in pre—tax cash flow:l987 + production increases :delayed 1 year :1988 + production increases :delayed 2 years :1989 - production losses :delayed 1 year:l988 - production losses:delayed 2 years:l989

=30000 + (-484) + 77 + 0 -92 -0

= $29819

BANKS calculates the taxes payable before and after the installation of banks based on the profit sharing arrangements and marginal tax rates specified.

Using the data in Table 12 as an example, the tax payable in 1987 before the installation of banks is given by:

(35) Tax payable before banks

= 0*13785 + 0.24*(30000_l3785)

= $3892

The tax payable after the installation of banks is given by:

(36) Tax payable after banks

= 0*13785 + 0.24*(298l9_l3785)

= $3532

The change in tax payable in 1987 is given by:

(37) Change in tax payable

= tax payable with banks - tax payable without banks

= 3892 - 3532

= $-360

This means that in 1988, taxation affects the changes in annual cash flow. The post-tax change in cash flow in 1988 is given by:

(38) Change in post-tax cash flow

= change in pre—tax cash flow:l988 - change in tax payable:1987

= -15 - (-360)

= $345

3.13 Discounted Post-tax Cash Flow

In the previous section the annual changes in annual post-tax cash flow were estimated; these changes occur over a number of years. To compare values between different time periods, the values need to be adjusted to reflect the opportunity cost (time value) of money. Money has an opportunity cost because of the risk and uncertainty associated with receiving an amount in the future.

If a person has to wait to receive a future sum versus receiving it now, they require compensation for the risks involved in postponing the receipt of the money.

The adjustment process is termed discounting. Discounting should not be confused with the indexation of values to allow for inflation. If money is invested, upon maturity the investor receives the original amount, plus compounded interest. If money is borrowed, upon maturity the borrower must repay the amount, plus compounded interest.

Consider the example in Table 13 where the sum of the annual changes in cash flow for three situations are positive and equal.

Assume that the individual can simultaneously borrow and lend funds at 10 percent interest at the beginning of the planning period. Future receipts are equivalent to investing now and earning compound interest. Future costs are equivalent to borrowing now and paying back the sum in the plus compound interest.

For example, spending $1000 in five years time is equivalent to borrowing $620.92 now and repaying it with interest compounded in five years time. Similarly, receiving $1000 in five years time is equivalent to 'receiving $620.92 now and investing it for five years. The values of Future Values (PV) expressed in today' values are called Present Values (PV).

The PV of a future sum is given by:

(39) $PV = FV(1+i)^{-n}$

where i is the rate of interest and n is the number of time periods over which the rate of interest is applied.

In the BANKS discounted cash flow (Table 14) all changes in post-tax cash flow are converted to their present values. In BANKS, the real rate of discount is used. The nominal rate of interest is adjusted for inflation. The future values (returns and costs) are expressed in today’ s prices. However, inflation will cause these to grow at the rate of inflation. The inflated future prices are then discounted. Inflating and discounting can be achieved by using the real rate of discount as the opportunity cost of money (Baumnol 1977).

(40) Real discount rate

= ((1+rate of interest)/(1+rate of inflation)) - 1

= ((1+0.18)/(1+0.08)) - 1

= 0.0926 or 9.26 percent

In using a constant rate of real discount across all time periods, the assumption made is that the nominal rate of interest and the rate of inflation over the planning horizon are constant. This assumption is likely to be violated. However, at the time the analysis is conducted, the current rate of inflation and interest rate are considered acceptable estimates for future levels. To incorporate variable rates of interest and inflation would increase the complexity of the analysis and requires forecasting.

The PV of the change in annual post-tax cash flow for 1987 is given by:

(41) Present value

= change in annual post-tax cash flow * $(1 + \text{real rate of discount})^{1}$

= $-1484 * (1+00926)^{-1}$

= -$1359

Similarly, the pci of the annual change in post-tax cash flow in 2003 is given by:

Table 13: Comparison of NPV for alternative cash flows

	Year 1	Year 2	Year 3	Year 4	Year 5	Sum	NPV
Cash Flow 1	-1000	1000	-1000	1000	1000	1000	470
Cash flow 2	-1000	-1000	1000	1000	1000	1000	320
Cash Flow 3	1000	1000	1000	10001	-1000	-1000	1183

Table 14: Section J of BANKS

L Discounted Cash Flow **Section L Screen 1**

This section discounts the annual changes in post-tax cash flow using the real rate of discount provided. In addition, the Net Present Values and Equivalent Annual Values for each year are calculated. The Internal Rate of Return (over 20 years) can be calculated by holding down the ALT key and typing Y.

Nominal rate of discount 0.1800 Real discount rate 0.0925

Inflation rate 0.0800

Discounted annual changes in cash flow

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
-1359	289	397	-40	54	-139	261	-15	515	-31
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
279	-1	231	-7	170	-49	215	-4	221	-5

Cumulative NPV's and EAV's **Section L Screen 2**

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
-1359	-1070	-673	-713	-658	-797	-536	-552	-37	-69
-1484	-610	-267	-221	-170	-179	-108	-101	-6	-11
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
211	209	441	434	603	555	770	766	987	982
31	30	60	57	76	68	92	89	112	110

IRR over 20 years 0.1741

(42) Present value

= 969 * (1+0.0926)17

= $215

Net Present Value (NPV) is the summation of the discounted annual changes in post—tax cash flows. NPV allows the comparison of projects with different cash flows over a given time horizon. Consider Table 13, where the three cash flows have the same sum. Note that the NPV for each cash flow is different. If NPV is positive, the cash flow is earning a return in excess of the discount rate used. The larger the NPV, the higher is the rate of return. The project with the highest NPV is preferred (Tisdell, 1972). Although the three cash flows shown have identical suns in Table 13, cash flow 3 is superior using the NPV criterion. This illustrates the importance of discounting.

In Table 14, NPV is calculated by:

(43) NPV

= the cumulative sum of the discounted annual changes in post-tax cash flow for the planning horizon.

The NPV of $211 in 1997 means that the installation of banks is earning a return in excess of the real discount rate of 9.25 per cent. The NPV of $-69 in 1996 means that the installation of banks is earning a return less than the real discount rate. Investing in banks is economic for planning horizons in excess of 10 years.

In comparing projects with different economic lives, the NPV criterion is inappropriate. In these cases, the Equivalent Annual Value (EAV) criterion is used. The EAV is defined as a constant value occurring in each time period. The sun of the discounted values of this constant in each time period must equal the NPV (Fabrycky et al, 1984). The EAV is the constant post-tax change in cash flow occurring in each year of the planning horizon which, when discounted and summed, yields the NPV.

The EAV in each year is given by:

(44) Equivalent Annual Value

$$= \text{NPV*real rate of discount/ (1- (1+real rate of discount)}^{-\text{time}}\text{+1)}$$

where time is the number of years (planning horizon) to which the NPV applies and for the number of years being greater than or equal to three.

If the planning horizon is for one year only, the EAV is given by:

(45) Equivalent Annual Value

$$= \text{NPV/(1 + real rate of discount)}^{-1}$$

and if the planning horizon is for two years, the F.AV is given by:

(46) Equivalent Annual Value

$$= \text{NPV/((1 + real rate of discount)}^{-1} + \text{(1 + real rate of discount)}^{-2}\text{).}$$

If the FAV is positive, the project is earning a real rate of return in excess of the specified real rate of discount. If the EAV is negative, the project is earning a real rate of return less than the specified real rate of discount. However, the real rate of return may still be greater than zero. This can be demonstrated by lowering the nominal discount rate, causing the real discount to fall. This will cause the NPV and EAV to become positive in a shorter period of time.

It is useful to determine the real rate of return being earned by the project. This rate of return is called the Internal Rate of Return (IRR). The IRR is defined as the rate of discount which makes the NPV of a project equal to zero. The IRR is difficult to calculate, and it is possible that it does not exist (i.e. there may be no real discount rate which makes NPV equal to zero). If the IRR does not exist, BANKS displays NA (Not Available).

The method for calculating the IRR is described in Appendix 2.

Chapter 4

Example Simulations

In this section, BANKS is applied to a variety of simulation exercises. The methodological approach used in BANKS allows the user to evaluate the sensitivity of the analysis to various parameter specifications. Sane examples are illustrated in the following subsections.

4.1 Monte Carlo Simulation of Water Erosion Years

In this simulation the parameters of the model are identical to those in the above example. However the random number generator is used to generate six sequences of water erosion amounts (with the same mean and standard deviation but with a varying sequence). This type of analysis shows how the cost-effectiveness of grade banks may vary due to random variation in the amounts of water erosion over the planning period. In many analyses, stochastic variables are assumed to be equal to their mean values. In the long term (over 30 years or more) this is a reasonable assumption. However, in the short term there is no guarantee that the farm will actually experience the expected values. In this case, over a planning period of 20 years, it is unlikely that the mean amount of water erosion will occur. Using Monte Carlo simulation, it is possible to generate statistically possible sequences of water erosion amounts. These are shown in Table 15 below.

In summary, for a given set of parameters, the three factors affecting the cost-effectiveness of banks are:

(i) the mean amount of water erosion;

(ii) the distribution of the water erosion events over the planning horizon;

(iii) the amount of erosion during pasture years (given the greater concentration of organic nitrogen in the top few millimetres of the soil profile).

4.2 Probability of Water Erosion

In the preceding subsection, it is shown that there can be sane variability in the amount of water erosion observed for a given probability of annual water erosion. However, as the probability of annual water erosion increases, the probabilities of observing a larger amount of water erosion increase. This increases the benefits of the banks.

The sequence of water erosion amounts in each case is randomly determined. The results are shown in Table 16.

The cost-effectiveness of banks increases as the probability of high annual water erosion amounts increases.

4.3 Rotation Sequence

In Table 17, two rotation sequences are evaluated with all other parameters as described in Section 3. The rotation sequences are WPWP and WWW, where W and P stand for wheat and pasture respectively.

As the frequency of crop in the rotation increases, the cost-effectiveness of banks increases. This is because of the prevented decline in organic nitrogen, as shown in Table 17.

4.4 Taxation

The general level of farm profitability affects the cost-effectiveness of banks because marginal tax rates modify the effects of expenditure and benefits on cash flow. This is illustrated in Table 18, where the model described in Section 3 is simulated for three levels of expected annual farm taxable income.

Banks provide the greatest financial benefit to landholders who are paying the least amount of tax. This is only true if the banks have a positive NPV. When banks are profitable, landholders on low marginal tax rates retain more of the profits. However if banks are unprofitable, it is landholders with high marginal tax rates who obtain a reduction in tax liability. In the situation where banks are profitable, it is the landholder with low marginal tax rates who has the greatest incentive to install banks. Unfortunately, it is this landholder who may be least able to afford the banks.

Table 15: Monte Carlo simulation of water erosion amounts.

Cumulative soil loss (mm) (20 years)	NPV $	EAV $
50 (expected value)	1797	200
38	982	110
56	2521	281
50	1598	178
52	1432	160
44	1128	126

Table 16: Effect of water erosion probability on NPV and EAV

Probability distribution of water erosion		Prevented	NPV	EAV
Crop Mean/variance (mm)	Pasture Mean/variance (mm)	Soil loss (mm) (20 years)	($)	($)
1	1	16	-184	-20
3	2	38	982	110
5	3	67	3169	354

Table 17: The effect of rotation sequence on NPV and EAV

Rotation Sequence	Prevented soil loss (mm) (20 years)	CPSLE after 20 years	NPV ($)	EAV ($)
WPWP	38	2.25	982	110
WWWW	38	16.41	9133	1010

4.5 Grade— Versus Level-Banks

In certain situations, there may be alternative structures which can be used to mitigate water erosion. In this simulation, grader-built grade banks are compared with bulldozer-built level banks. The model tests whether it is more economical to install "maintenance—free" level banks with no waterway rather than grade banks requiring maintenance every five years. The model for the level banks is the same as defined in Section 3 with the exceptions that:

1. the banks are 15 m wide (i.e. they remove 15m from cropping);
2. the construction cost of banks is 600 $/ha;
3. banks require no maintenance;
4. there is no waterway removed from cropping.

The comparison of the cost-effectiveness of the two methods of mitigating water erosion are shown in Table 19.

In this case grade banks are profitable and level banks are not profitable in mitigating water erosion. Level banks provide the same yield gains in prevented soil erosion and have lower maintenance costs. However, they take more land out of production and have higher construction costs. The net effect is that level banks, in this case, are less cost-effective in mitigating water erosion.

Table 18: Taxation affects on NPV and EAV

Expected annual taxable income	NPV	EAV
($)	($)	($)
12000	1335	149
21000	982	110
40000	908	101

Table 19: The NPV FA for grade- and level-banks.

Structure	NPV	EAV
	($)	($)
Grade banks	1697	189
Level banks	-897	-100

Conclusion

BANKS provides a flexible quantitative method to help landholders, extension-and research-workers evaluate the cost-effectiveness of installing banks to mitigate water erosion. As with all analyses, it is not possible to include all aspects of the problem into a quantitative economic analysis. Those aspects not covered should be noted by the user. The results of the BANKS analysis should be used in conjunction with any other relevant information when the decision is being made. It should be stressed that BANKS is an aid to decision making and is not meant to reduce the decision-making role of the farmer.

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Appendix 1

Method Calculating Random Levels of Soil Loss

BANKS uses the Poisson discrete probability distribution to generate random levels of annual soil erosion. The probability function is given by:

(47) $p(SL) = (e^{-m} m^{SL}) / SL!$

where p(SL) is the probability of an integer value of soil loss occurring, m is the mean (and variance) of annual soil loss, and SL is the integer value of soil erosion.

Using the means supplied by the user in Section F, cumulative probability tables are set up for crops and pasture for levels of soil erosion between 0 and 9 inn, shown in Table 20.

For each year, a uniformly distributed random number is generated. The uniformly distributed random number is then compared with the appropriate cumulative probability table, depending upon whether it is a cropping or pasture year. The level of erosion is set equal to that level for which the random number is less than its cumulative probability and greater than the cumulative probability of the adjacent lower level. For example, if the random number is 0.5, then the level of erosion in a cropping year is 3mm.

Table 20: Probability tables to determine random levels of soil loss (mm) under crops and pasture.

	Crops (m=3)		**Pasture (m=2)**	
	P(SL)	Cumulative P(SL)	P(SL)	Cumulative P(SL)
0	0.0497	0.0497	0.1353	0.1353
1	0.1493	0.1991	0.2706	0.4060
2	0.2240	0.4231	0.2706	0.6766
3	0.2240	0.6472	0.1804	0.8571
4	0.1680	0.8152	0.0902	0.9473
5	0.1008	0.9160	0.0360	0.9834
6	0.0504	0.9664	0.0120	0.9954
7	0.0216	0.9880	0.0340	0.9989
8	0.0081	0.9961	0.0008	0.9997
9	0.0027	0.9988	0.0001	0.9999

Appendix 2

Estimation of Internal Rate of Return

NPV equation is a polynomial as shown by:

$NPV = C_1X^{-1} + C_2X^{-2} + . . . + C_ox^{-n}$

C is the change in annual post-tax cash flow, and X is the discount equal to 1+r. The IRR is equivalent to finding that value of X which NPV is equal to zero. Using the first two terms of the Tailor series equation, an improved estimate of the value of x which makes NPV= 0 is given as

Xk+1 = Xk – (C1Xk-1 + … + CnXk-n-1) / (-C1Xk-2 - … (-n-1)*CnXk-n-2)

The initial value of X, r is set equal to the real rate of discount used in the calculation of NPV. Unfortunately, in version 1 of Lotus, any recalculation of a portion of the spreadsheet requires the recalculation of the entire spreadsheet. This means that each iteration of the algorithm to calculate IRR takes some time. Although Lotus has a built-in function to calculate IRR, this has proved to be unreliable. This is because the annual changes in cash flow do not conform to the classic examples shown in text books. The changes in cash flows change sign repeatedly throughout the horizon, and the absolute magnitude of the cash flows changes. This means that there can be no solution to equation 30 when NPV = 30. If the algorithm detects that there is no solution, it displays NA (Not Available) in the area of the IRR.