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ROAD DESIGN USING GEOCOMP, SDR Map, ROADENG, and LUMBERJACK

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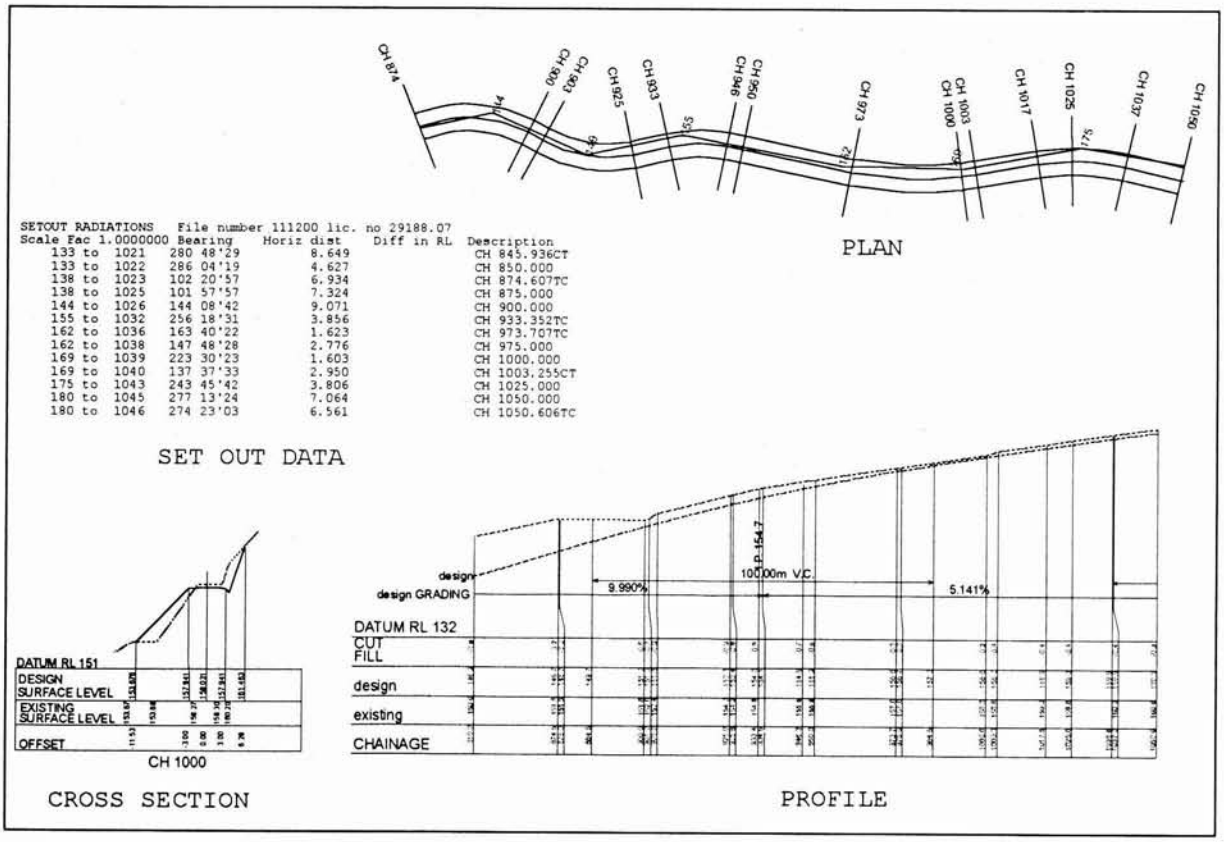

Figure 1 - Plot of plan, profile and set out data produced in GEOCOMP

SUMMARY

Forest roads should be properly designed, so that the grades and corners can be negotiated successfully, without the need for an assist vehicle. ROADENG, GEOCOMP, SDR Map, and LUMBERJACK are computer programmes that may make the design of forest roads more efficient and cost-effective.

Designing road alignment by computer has many advantages, including: accurate road costing, minimising cut and fill depths, confidence that the road alignment will work, minimising the number of trees felled in the roadline and more efficient processing of Resource Management Act (RMA) consent applications.

ROADENG and LUMBERJACK were developed specifically for designing forest roads. They are simple, easy to use and operate within Microsoft Windows™. This allows for interactive road design as the cross-sections, earthwork quantities, plan and profile can all be displayed simultaneously. When changing the road alignment, the changes in cross-sections and earthworks are shown immediately on the screen. ROADENG and LUMBERJACK enable forest road designs to be produced quickly and easily. However, they are less sophisticated than GEOCOMP and SDR Map.

GEOCOMP and SDR Map are capable of a wide range of surveying and civil engineering applications, with many features available, including importation of a digital terrain model (DTM) created in a Geographic Information System (GIS). These packages are commonly used by engineering consultants for designing highway alignments and for large earthwork projects like land reclamation for airport construction or mining. Their sophistication enables flexibility for use in other applications. However, designing forest road alignments can be time-consuming for the occasional user. There are some difficulties in inputting standard forest road survey data and getting the required set-out-data for simple set-out of earthworks for forest roads.

This report aims at those familiar with road design principles and who are considering the purchase of a road design software package.

INTRODUCTION

Traditionally, the process of road design is carried out by producing on paper: a plan, a longitudinal section and cross-sections. When combined with earthwork quantities and mass haul diagrams, a complete cost estimate of the construction work can be completed. The time involved in this design process has meant that full road design and drawings are seldom produced in the forest industry, except for major roads (Robinson, 1990).

Recent advances in the power of computer software and hardware make designing forest roads more efficient and cost-effective. Design activities which were once laborious and time-consuming can now be rapidly accomplished by the forest engineer. The result is improved road design and construction. GEOCOMP, SDR Map, ROADENG and LUMBERJACK are only a few examples of computer software packages for computer-aided road design. They were assessed to determine their usefulness in forest road design.

ACKNOWLEDGMENTS

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WHY DESIGN FOREST ROADS?

The proper engineering design of forest roads reduces costs and the risk of road failure. The forest owner does not need to rely on the skill of the bulldozer driver to ensure that the road reaches the required destination at an acceptable grade, and that trucks can negotiate the corners. In addition, design and setting out forest roads has the following advantages:

- A critical grade (for example, 10%) can be sustained over the whole length of the road
- Road costing is more accurate
- Detailed plans allow fixed price contracts
- The responsibility to build the road as set out is placed on the contractor

- Set-out pegs will aid the contractor in road construction, with minimal supervision required
- A mistake in the final road construction can be checked against the set-out pegs to determine whether the fault lies with the contractor or with the designer (surveyor/engineer)
- Decisions can be made on marginal road locations
- Cut and fill depths can be minimised
- A full engineering design aids in obtaining RMA consents
- Where the road corridor is pegged accurately, no trees are felled unnecessarily
- Road location is optimised within the surveyed strip.

Road design software packages perform the large quantity of calculations required for road design and earthworks, but the location of the road is still decided by the user. The final design is only as good as the user's expertise in geometric road design. An understanding on how the combination of grades and curve radii influence a truck's manoeuvrability is required. If the user does not know the maximum grade for various curve radii, then it is quite possible to design a road that trucks will be unable to negotiate.

PROFESSIONAL SURVEYING AND ENGINEERING SOFTWARE

GEOCOMP, SDR Map and CIVILCAD are three software packages commonly used by professional surveyors and engineers in New Zealand. These have similar capabilities and are primarily used for surveying and civil engineering applications, such as geometric road design for highway alignments. GEOCOMP and SDR Map were evaluated.

Road Design Process

Adequate survey data of the existing terrain is required before any road design. GEOCOMP and SDR Map readily accept data collected using a Total Station (theodolite and electronic distance measurer as one unit) and recorded electronically on a data recorder. Survey data collected manually using a cloth tape, clinometer and magnetic compass is difficult to input into these programs.

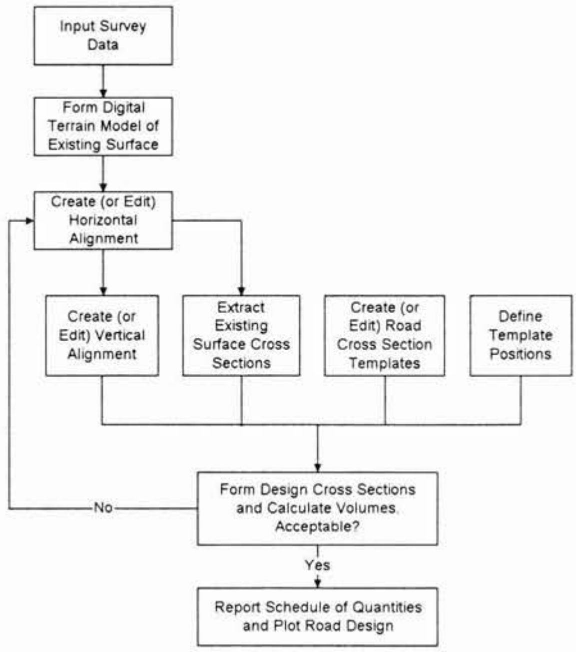

Figure 2 - Road design process using professional surveying and engineering software

Road design is an iterative process, where a series of steps are repeated until a satisfactory design is obtained (Figure 2). Firstly, the horizontal alignment is designed (plan, Figure 1) by locating intersection points (intersection of two lines) and assigning a curve radius to these points. Cross-sections are then extracted along this horizontal alignment from the DTM created. Following this, the vertical alignment is created (profile, Figure 1) along the existing surface profile by dragging points with the mouse. The grade is displayed on the screen.

Finally, standard road cross-sections (templates) are created and assigned a position on the road alignment for generating the design cross-sections. The earthwork quantities are calculated and the design cross-sections are checked. If the resulting design is unsatisfactory, the road design process is repeated from the beginning.

A special feature of SDR Map is the ability to partially automate the horizontal and vertical alignment design. For a specified vehicle design speed, maximum gradient and minimum allowable sight distance, horizontal curves and vertical alignment are automatically designed.

On completion of the design, detailed engineering drawings can be plotted as shown in Figure 1.

FOREST ENGINEERING SOFTWARE

ROADENG and LUMBERJACK are two commercially available software packages developed specifically for basic forest road design. They readily accept standard forest road survey data collected with a cloth tape, compass and clinometer. Designing the road alignment is relatively easy, producing set-out data in a useable format. There are other forest engineering software packages available but ROADENG and LUMBERJACK were considered most suitable for evaluation.

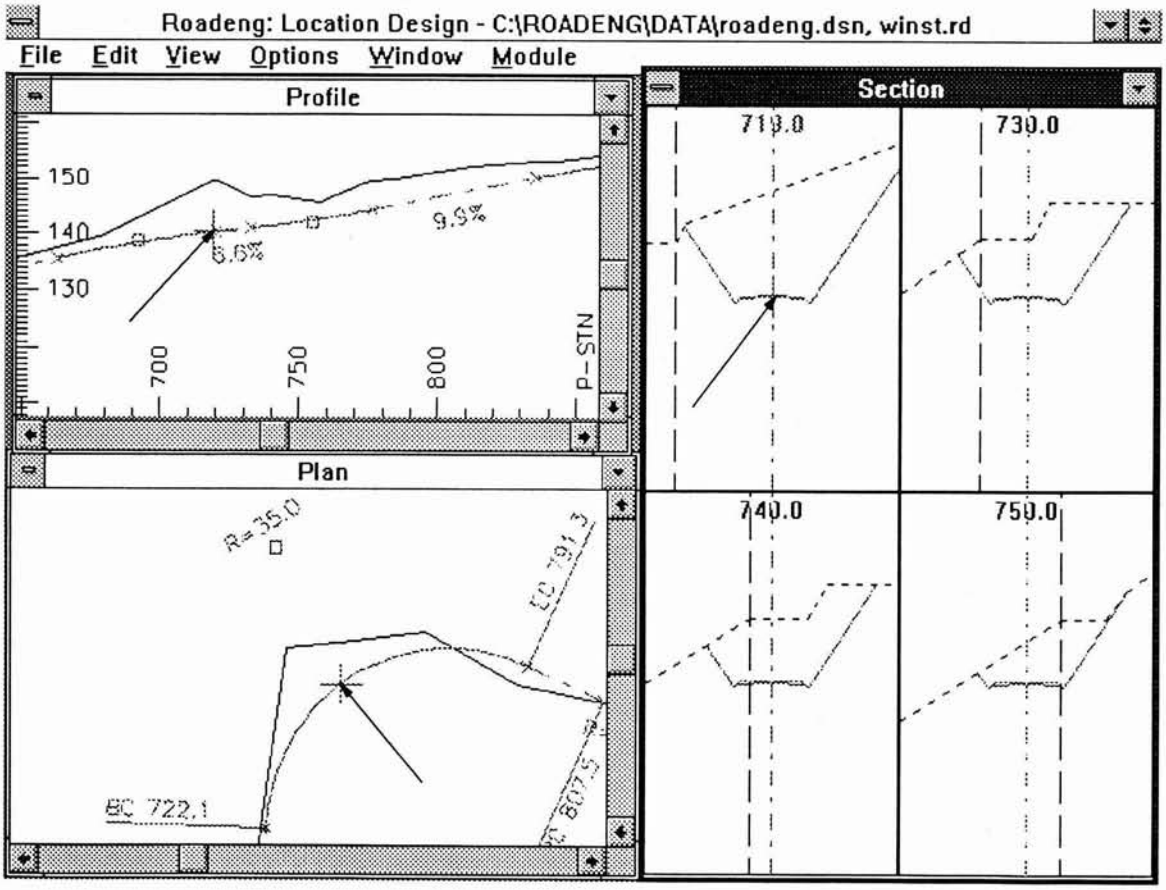

Figure 3 - Interactive road design within ROADENG

ROADENG

ROADENG is a forest engineering software system developed by Softree in Canada specifically for forestry use. Because of its simplicity, the occasional user can design a forestry road, producing drawings, earthwork quantities and set-out data in very little time. Facilities include: field note entry, map generation, digitising, digital terrain modelling, contouring, road design and cable logging analysis. These facilities are available in five modules: Survey Notes, Map View, Terrain, Cable Analysis, and Location Design.

Road Design Process

The Location Design module provides facilities for detailed road design. Cross-sections, plan, and profile can be printed, and set-out data and earthwork quantities are calculated. The Location Design module consists of five windows: plan, profile, cross-section, status and data. These can be displayed in any combination by sizing, moving and turning windows on and off with the mouse. This feature allows for interactive design. By modifying the alignment, the change in cross-sections can be viewed simultaneously (Figure 3).

LUMBERJACK

LUMBERJACK is a forest road design software program developed by Alternatech in Washington. Version 5 operates in Microsoft Windows, and is easy to use and learn. Because of its simplicity, the occasional user can design a forestry road, producing drawings, earthwork quantities and set-out data in very little time. Four integrated modules (Input/Edit, Template, Export and Design) are used for the design.

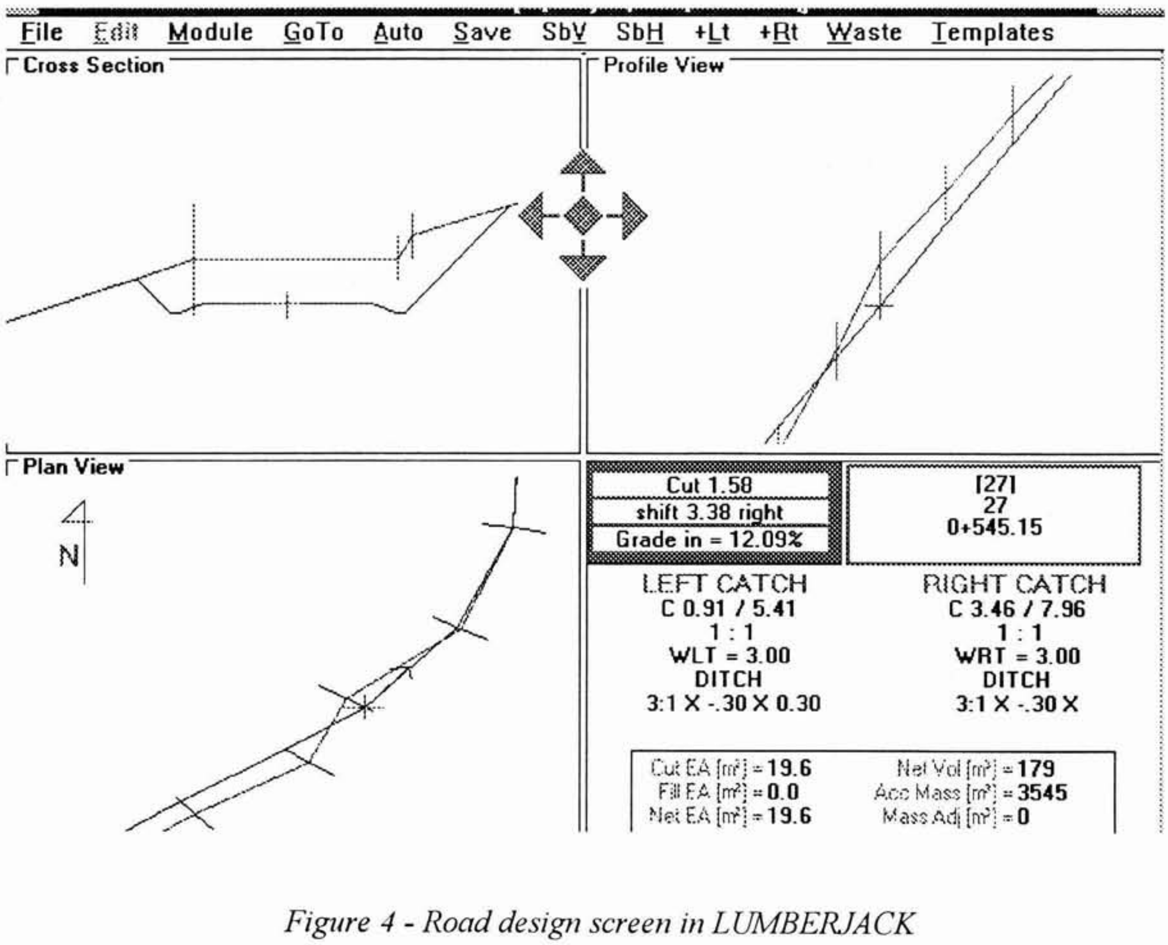

Figure 4 - Road design screen in LUMBERJACK

Road Design Process

The main LUMBERJACK design screen is divided into four windows. These windows show the cross-section, profile view, plan view, quantity and catch information (Figure 4). All windows are usually displayed, although for fine adjustments either the profile, cross-section or plan window can be displayed separately.

To design the alignment, the arrows in the middle of the screen are clicked with the mouse. For moving the road up or down, the up and down arrows are activated. Similarly, to move the road left or right, the left or right arrows are activated. Each section is adjusted one at a time to achieve a satisfactory alignment. Circles can be drawn in the plan view to act as a guide for drawing curves but most of the alignment is judged by "eye". If required, this module can automatically adjust a road alignment to balance cuts and fills by moving the road either vertically or horizontally.

FEATURES AND LIMITATIONS

The features and limitations of the four programs evaluated are summarised in Table 1.

GEOCOMP and SDR Map

GEOCOMP and SDR Map were developed specifically for the design of civil engineering projects, where a high level of accuracy is required. Designing unsealed forest roads can be cumbersome and time-consuming using GEOCOMP and SDR Map. Survey data collected using a compass, clinometer (must record slope in degrees) and a cloth tape is difficult to input into GEOCOMP and SDR Map. Before entering the data, all slope measurements need to be converted to true vertical angles (horizontal is 90°).

Both GEOCOMP and SDR Map produce set-out-data at set intervals only, which do not often fall exactly on a measured cross-section. For interpreting cross-sections at the set intervals, a DTM is required. Forming the DTM from imprecise forest road survey data is inaccurate. Very large inaccuracies occur around corners as the extent of two measured cross-sections can overlap.

Cross-sections can be generated at the survey station locations by specifying each survey station as an intersection point. The alignment is then manually adjusted by moving the points left or right with the mouse. Using this method, the cross-sections will be more accurate than those formed by interpolation. Setting out the road design will also be easier as the points are simply offset a known distance left or right from an existing survey station. However, this method is more time-consuming.

GEOCOMP and SDR Map are compatible with GIS and so may be used to aid in planning the locations of roads and landings. The DTM created in a GIS can be imported into GEOCOMP or SDR Map for the design of roads and landings (Arnold, 1995). The earthwork quantities for different road locations can be compared.

LUMBERJACK and ROADENG

ROADENG and LUMBERJACK readily accept survey data collected using a tape, compass and clinometer. The alignment can be "eyeballed" rather than by specifying a curve radius or a vertical curve length. This allows an experienced roading person to design a road that looks right, rather than having to obtain measurements of minimum radii and vertical curve lengths. The main advantage of both ROADENG and LUMBERJACK is ease of use. Occasional users can quickly design a road producing drawings and earthwork quantities.

Table 1 - Subjective ratings of software capabilities (where, 1 is the highest and 5 is the lowest)

	SDR Map	GEOCOMP	ROADENG	LUMBERJACK
Flexibility to accept electronic survey data in a wide range of formats. (for example, data collectors, GPS, GIS, Survey Lasers, digitised maps)	1	2	4	4
Ease of entering standard forest road survey data collected using a tape, compass and clinometer	4	4	1	1
Ease of drawing additional features such as fences and streams	2	2	NA	NA
Ease of editing cross-sections graphically	2	2	NA	NA
Ease of forming a digital terrain model and displaying contours	2	2	3	NA
Suitability for designing a sealed road, where transition curves and a high level of accuracy is required	1	1	5	5
Suitability for designing unsealed forest roads	4	4	1	1
Ease of calculating stockpile and quarry volumes	2	2	3	4
Ease of displaying 3D perspective views of the terrain and road alignment	1	2	NA	NA
Ease of designing more than one road alignment (for example, intersecting roads)	2	2	NA	NA
Ease of compiling map data from GIS, photogrammetric or other sources	2	2	5	NA
Ease of displaying the plan, profile and cross sections simultaneously for interactive design	NA	NA	2	3
Ease of automatically designing a horizontal curve and vertical alignment by specifying a design speed, minimum allowable sight distance and maximum gradient	3	NA	NA	NA
Ease and time to learn the software	4	5	2	1
Ease of "driving" the software (for example, pull down menus that are self explanatory)	3	4	1	2
Current level of software support within New Zealand	1	4	2	5
Suitability of output for setting out unsealed forest roads	4	4	2	1
Suitability of output for setting out high standard sealed roads	2	2	4	5
Flexibility to customise the output (for example, drawings, quantities and set-out data)	1	1	3	5
Approximate cost for purchasing the minimum requirement for geometric road design (NZ$ excluding GST)	$11,230	$11,800	$6,000	$2,700

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