

**DECISION SUPPORT SYSTEM FOR PLANNING IRRIGATION
SYSTEM IN LARGE AREAS.**

DISSERTATION

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IN

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By

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DEDICATION

DEDICATED

TO

MY BELOVED

PARENTS AND MY IDEAL TEACHER DR.H.S.ACHARYA

CANDIDATE'S DECLARATION

I, hereby declare that the dissertation
or part there of has not been previously submitted
by me to any other University or Institution for a
degree or diploma.

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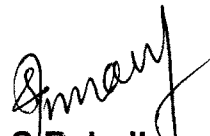
CERTIFICATE - II

This is to certify that the dissertation entitled "**Decision Support System for Planning Irrigation System in Large Areas**" submitted by **Miss. Tagade Kavita Mahadeo** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **Master of Technology (Agril. Engg.)** in the subject of **Irrigation and Drainage Engineering** has been approved by the students advisory committee after oral examination in collaboration with external examiner.

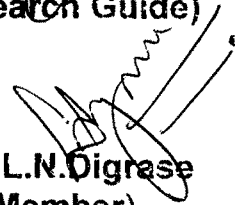


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"There always area in the world a few inspired men whose acquaintance is beyond price"

- Plato

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ABBREVIATIONS

| | | |
|----------------|---|---|
| % | - | Per cent |
| ^ | - | Square |
| ^o E | - | Degree east |
| ^o N | - | Degree north |
| ^o S | - | Degree south |
| abs | - | Absolute |
| Agril. | - | Agricultural |
| Ann | - | Annual |
| ASAE | - | American Society of Agricultural Engineers |
| B.M | - | Bench mark |
| B.S. | - | Back Site |
| BSCT | - | Basic science and computer technology |
| cov | - | Covariance |
| CAET | - | College of Agricultural Engineering and technology |
| c.p | - | change point |
| cpp | - | C plus - plus |
| dept. | - | Department |
| div. | - | Divergence |
| DSS | - | Decision support system |
| estz | - | estimated Z |
| <i>et al.</i> | - | And others |
| F.S. | - | Fore site |
| FAO | - | Food and Agriculture Organization |
| Fig. | - | Figure |
| H.I | - | Height of instrument |
| ha | - | Hectares |
| I. S. | - | Inter Site |

| | | |
|-----------|---|---|
| IDE | - | Irrigation and drainage engineering |
| irrig. | - | Irrigation |
| J | - | Journal |
| M | - | Meters |
| M. A. U. | - | Marathwada Agricultural University |
| N.S. | - | North - south |
| obsz | - | Observed Z |
| P.C. | - | Personal |
| Pvt. Ltd. | - | Private limited |
| R.L | - | Reduced levels |
| rmse | - | Root mean square error |
| S.W.C.E | - | Soil and water conservation Engineering |
| sci. | - | Science |
| soc. | - | Society |
| sq. | - | Square |
| sqrt | - | Square root |
| Trans. | - | Transactions |
| var | - | Variance |
| Vol. | - | Volume |

INTRODUCTION

CHAPTER I

INTRODUCTION

Water constitutes one of the several inputs for crop production, which feeds human being. Although irrigation increases production, it can create the problem of sustainable productivity if not used properly. An adequate water supply is important for plant growth. When rainfall is not sufficient, the plant must receive additional water from irrigation. Various methods can be used to supply irrigation water to the plants. These should be taken into account when choosing the method, which is best suited to local circumstances.

To choose irrigation policies over a large area, consulting engineer must know the nature of the land and its topography. Here by large area we mean area to the order of thousands of hectares, which is generally the area under watershed development project. The area under watershed development project varies from 10 hectares to thousands of sq. kms. The organizations, which take development work generally, have an area about 300-500 ha. for one watershed for convenience in interaction with people. Traditionally, engineers and managers of irrigation system have tried to cope with the compilation of field information that was manually processed. The number of users in a medium sized irrigation system runs in the order of thousands and manual processing of information becomes a lengthy and costly exercise. As a consequence, relevant information is often not available on time or is incomplete and many adhoc decisions have to be taken.

The engineer must know which method suits the topographical conditions best. The slope of land and undulations are very important factors, which have to be considered while designing the irrigation method applicable to the particular field. Concept of slope of land is

well defined, but we find that the methods of quantifying undulations are unsatisfactory in literature.

The irrigation method selected should provide uniform distribution of water to the crop in a field, and should suite structural layouts required for the irrigation setup.

The first step in any irrigation planning exercise is to prepare a good topographic map. Currently, after surveying the land, the consulting engineer converts the field book into grid points and reduced levels for drawing a contour map. He draws contour map manually, and classifies the land according to slope and undulations for selecting appropriate method of irrigation, and subdivides the land into smaller areas suitable for different activities. Generally the land is classified as flat, undulating, non-undulating land, saucer like area etc. It takes quite a bit of time when the area is large.

Hence a computer based decision support system is necessary. An irrigation decision support system should generally help the engineer in scrutinizing the topography of the land and help him in identifying the sub regions suitable for each method. After identifying the sub regions, tools to compute design details are also needed to assist practicing engineers. With these needs in mind current project is taken up to develop a computer program for land mapping and then to suggest a suitable irrigation method depending upon the topography, soil type, drainability and the infiltration rate of the soil.

Use of computer assisted planning can lead to optimal solutions, which, considering the huge size of the data may reduce manual efforts and avoid possible erroneous decisions based on adhoc policies.

The specific objectives of the study are:

1. To define, scientifically, the important parameters describing the topography of land.
2. To develop computer programs, which can calculate these parameters using the survey data.
3. To write and develop a computer program for the demarcation of land as per the topographic classification.
4. To develop a DSS (decision support system), which will suggest the best possible irrigation method suitable to each piece of land.
5. Verify and validate these programs on real data from Marathwada Agricultural University watershed.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the review of research work carried out for suggestion and design of irrigation systems. Comprehensive reviews of literature directly or indirectly relevant to the objectives of the study are included in this chapter.

2.1 Surface irrigation

Cuenca (1989) developed irrigation system design. Parameters necessary in the design, installation and operation of various types of irrigation system were discussed. Fundamental principles of economic analysis, soil physics, soil chemistry and crop water requirements were considered and the design of surface, sprinkler and trickle systems was detailed with examples. Pump systems, pipeline system design, groundwater, wells and open channel flow were also discussed.

Clemmens (1990) suggested feedback control for surface irrigation management. The paper summarized the state-of-the-art for using feedback control in surface irrigation, and described the results of applying feedback control to a field-scale 32 ha level-basin irrigation system. Methods for the control of runoff rates from furrows had been successfully used with feedback control when measurements have comprised either: inflow rate and advance time and distance, or runoff.

Dahmen (1990) suggested design criteria for hydraulic networks in irrigation systems. The paper discussed the basic objectives of irrigation schemes and examines the planning and construction stages in the development of irrigation networks. It argued that recent designs have become complex, sometimes too complex, due to the large amount of information now available about the farming systems that irrigation supports. Furthermore, planners have tended to over-design irrigation networks so that they can cater for a wide range of demands. The paper calls for designs to be based on more realistic demands.

Lyle *et al.* (1990) suggested irrigation system design for multiple cropping operations. Development of moving truss irrigation machines capable of performing every function necessary to produce a crop could revolutionize agricultural production systems. Large powerful tractors and multiple pieces of equipment would be replaced. A multifunction irrigation system was designed and developed for the purpose of applying both water and chemicals through separate nozzle systems from the same basic moving pipe and tower structure.

Makadho *et al.* (1990) suggested the design of farmer managed irrigation systems: experiences from Zimbabwe. Efforts have been made to involve Zimbabwean farmers in a scheme where they participate in the process of planning, designing and implementing their irrigation projects and where they meet the costs for infield infrastructural development, operation and maintenance. Initially, farmers' willingness to irrigate was assessed. They were able to indicate their preferred crops and methods of irrigation. They were also involved physically by providing labour during construction. At the same time, engineers and extension officers from Zimbabwe's Department of Agricultural, Technical and Extension services held discussions with the farmers' alternative irrigation methods and cropping patterns. This involvement had a beneficial effect on the farmers' enthusiasm for irrigation developments being introduced, and had minimized many of the problems that often occur.

Sonune *et al.* (1991) suggested estimation of crop water requirement for planning and design of irrigation systems in India. Crop water requirements, estimated by modified Penman technique, were presented for major and medium irrigation projects in India's Maharashtra State, located in different agro-climatic zones. The information was used to provide design parameters in planned irrigation projects.

Magdalina *et al.* (1995) presented a new concept for the use and design of irrigation systems taking into account the present land property structure in Romania, after the 1989 revolution. Under the land stock law, 14 million ha of agricultural land, and ten million ha of arable lands were distributed to 6,2 million owners, one million more than the number of owners after the 1948 reform. The majorities of farms were less than 3 ha and fragmented.

Pira (1997) published a book on golf course irrigation system design and drainage. This book contains 13 chapters which serves as a course outline that will assist students in preparing for careers as golf course superintendents and provides them an understanding of the principles of irrigation system design and operation. Topics covered include pipe layout, pipe size selection, two-row system, electric fundamentals, pump selection, remote control valves, automatic controllers, irrigation scheduling, and guidelines for basic surveying of tile drainage systems. Appendices provide standard irrigation system symbols, conversion charts, glossary, and details of various irrigation equipment.

Zerihun *et al.* (1997) developed generalized dependent surface irrigation parameter prediction functions for use in design and management. The paper reviewed the major drawbacks of currently available surface irrigation mathematical models. A methodology for developing irrigation parameters in surface irrigation systems design and management has been defined. Information from the modeling of surface irrigation process, dimensional analysis, experimental design and management equations was collected. The potential uses of these equations include optimal system design and automatic feedback control.

Nimah *et al.* (2000) developed furrows irrigation design parameters as affected by soil compaction. The objectives of this

paper were to determine the impact of furrow compaction on the furrow design parameters. Five treatments were implemented: (1) control, no compaction; (2) one tractor pass; (3) two tractor passes; (4) three tractor passes; (5) four tractor passes. All treatments were followed by three successive irrigations. Advance time and cumulative intake rate decreased with one pass, and thereafter didn't change. Manning's roughness coefficient decreased by 9% with one pass and after the first irrigation; while, soil compaction increased at 7.5 cm depth and no change was recorded at 22.5 cm depth.

Zerihun *et al.* (2000) developed optimal design of furrow irrigation system using an enumeration algorithm. A furrow irrigation system design problem was formulated in a minimum cost design setting. The design problem was formulated as a function of three integers valued decision variables. A simple exhaustive enumeration based model was used to solve the design problem. The model was simple (required only about 40 lines of code), robust, and capable of finding a globally optimal solution to the design problem.

Meissner *et al.* (2001) suggested precision planning for irrigation of vegetables - an Australian approach. An integrated approach to match vegetable crops, irrigation system design, and management to the most appropriate soil types in Australia, was presented. The essential components of the methodology were: (1) describing the soils; (2) designing an appropriate irrigation system to match the soil and crop combination; (3) maintaining the irrigation system to industry standards; and (4) measuring the use of water by the crop to apply the right amount of water at the right time.

2.2 Drip and sprinkler irrigation

Wu and Gitlin (1974) developed design procedure for submain slopes less than 0.5% and also for submain slopes greater than or equal to 0.5%.

Wu and Gitlin, (1975) developed a simple design procedure for lateral line design on non-uniform slopes.

Wu and Gitlin, (1977) developed design charts, which can be used to design submain, size very quickly. Separate charts were prepared for line slope of which were less than 0.5% and greater than 0.5%.

Wu (1985) developed a uniplot technique for drip irrigation internal and sub main design. The design was made by using line slope and an allowable pressure variation to form a reference area and then fitting the energy gradient curve into the reference area. If energy gradient line can be fitted into the area design, which has a maximum pressure variation less than allowable pressure variation was accepted. He recommended that the uniplot method could be used for either uniform and non-uniform slope situations and for a single size of multi size lateral and sub main design.

Anyoji and Wu (1987) developed a design technique for drip lateral design using a statistical approach. This technique was based upon coefficient of variation of pressure head along a lateral line and variation of emitter flow caused by manufacturer. Collecting the values of pressure head at different points of the lateral may be laborious. So instead of following the statistical approach, the pressure

2.3 Computer models

Aikeng (1988) developed a model to design micro-irrigation systems. The theoretical background was presented for a mathematical model of friction loss in a micro-irrigation pipe network

containing pipes of different sizes and cascades of outlets. Allowance was made for the mode of water discharge from multiple outlets.

Blair (1989) suggested surface irrigation design and evaluation software. A user manual for a surface irrigation design and evaluation software system for use on an IBM-PC is presented. The software system was menu driven with graphical display of simulation results. The program can be used to determine surface irrigation efficiency and optimal system parameters.

Pleban (1989) developed JACK - the irrigation system design program. JACK was a toolbox for designing agricultural trickle and sprinkler irrigation systems. It included tools for selecting emitters, designing laterals, manifolds, irrigation units and mainlines, analyzing existing lines, managing inventory and preparing a list of materials.

Madsen *et al.* (1990) reported mapping of irrigation need based on computerized soil and climate data. A nationwide mapping of irrigation need based on a computerized soil and climatic soil database was carried out in Denmark. Based on the Danish soil classification and on pedological investigations, approximately 36000 profiles have been constructed, and the root zone capacities for grass and barley have been calculated. Based on an empirical model with daily values of potential evapotranspiration and precipitation as driving variables, the relationship between root-zone capacity and irrigation need for different climatic zones has been outlined and a map of irrigation needs constructed.

Maheshwari *et al.* (1990) developed sensitivity analysis of parameters of border irrigation models. Six models of border irrigation, (Jobling-Turner, Strelkoff, Walker, Jaynes, Schmitz and Ross) were evaluated for their sensitivity to the input parameters. The parameters selected were (i) solution parameters: time step and grid size and (ii) field parameters: longitudinal slope, the Manning ' n ', parameters of the

infiltration equation and inflow rate. The values of the solution parameters were varied between -90 and +233% of the values in the control simulation and those for the field parameters between -50 and +50%. The analysis showed that, for the variation of the parameters considered, the models were not sensitive to the solution parameters but were sensitive to the field parameters.

Teixeira *et al.* (1991) suggested irrigation scheduling with limited water supply using a simulation model. The ISAREG simulation model was used to plan and schedule irrigations in Mediterranean climates under limited water availability for two cases: summer irrigation of forage maize and supplemental irrigation of winter wheat. The model was used to simulate maize irrigation with the following strategies: maximal yield, restricted water during the peak irrigation month, using an allowable water deficit, limited water volume for the irrigation season, rigid delivery schedule, negotiable delivery schedule. Several strategies for supplemental irrigation of wheat were also investigated for different irrigation depths, volumes and schedules. Such irrigation schedule models were of particular use during periods of drought or limited water availability.

Anonymous (1994) developed the software package available that provides the user with user-friendly and well-supported functions for DTM, CAD and irrigation design in one package. The system operates independent of other commercial software and provides its own plotting and reporting facilities. It is committed to development of highest quality software in the fields of surveying, engineering, mining, town planning, landscaping, quantity survey, irrigation design and construction.

Bellostas (1994) developed application of linear programming models to irrigation systems using the databases of SIMIS. This paper illustrated how a complex linear programming (LP) model could be run

on a normal PC with a commercial software package to solve a problem of optimizing water allocation. It also explained how information stored in SIMIS (Scheme Irrigation Management Information System) could be prepared for use in the LP decision model.

Kumbhakern and Das (1996) developed a modular computer program, which can perform greenhouse design computations, provides structural specifications and compute the capacity and sizes of control equipments.

Anonymous (1998) developed an IRRI MAKER Computer Software System that incorporates the manipulation of survey data, surface modeling, drafting and irrigation design in one integrated package, Whether you are generating contour plans, drafting detail layout plans, designing small or major irrigation systems.

Goncalves *et al.* (1998) developed Decision support system for surface irrigation design. The interactive DSS software SADREGA was developed to assist designers and managers in the design of on-farm surface irrigation, including the selection of the irrigation method. The DSS included models for land levelling and on-farm water supply structures, and applied the simulation model SIRMOD for calculating furrow, level basin and border irrigation. Computing models were developed for the determination of alternative attributes characterizing the impacts of surface irrigation systems on financial, economic, crop yield, and soil and water quality aspects.

Herrera *et al.* (1999) developed computer methodology for the selection and design of microirrigation systems. Two methodologies were developed in this work: the first was to select the system based upon agricultural and topographic factors; the second was a heuristic method used to design the irrigation system. A computer program was developed in C++ language to select and design irrigation systems. It

can be used by engineers to analyse the different project conditions. The program included the following modules: microirrigation system selection, emitter selection, irrigation section design (manifold and lateral), mainline design, and system cost. The program facilitated designing the irrigation system with the maximum discharge uniformity, maximum area, and lowest cost.

Shete *et al.* (1999) developed computer aided design of micro-irrigation laterals for row crops such as cabbage, cotton, groundnut, tomato, etc. and horticultural plants which can be efficiently irrigated by micro-irrigation.

Anonymous (2000) developed a SIMIS. It is decision support software that has been developed for the purpose of facilitating the management tasks of irrigation schemes. The output of SIMIS are crop / plot / irrigation canal water requirement, irrigation planning, scheduling, accounting, water fees, control of maintenance activities and performance indicators.

Jurriens *et al.* (2000) developed SURDEV: a computer package for surface irrigation. The SURDEV (Surface irrigation design, operation and evaluation) model consisting of the BASDEV model for sloping borders and FURDEV model for sloping furrows were discussed. Examples obtained for basin, furrow and border irrigation design and operation were presented.

Kyo *et al.* (2000) developed automatic design of agricultural irrigation structures in IDSAF. Agricultural irrigation structures were designed for the storage, carriage, distribution and drainage of water. Although those structures may have different primary purposes, their technical functions were interrelated systematically. The development of such facilities can be divided into three stages such as irrigation system design-hydraulic design-structural design.

Strelkoff *et al.* (2000) developed ARS software for simulation and design of surface irrigation. ARS surface-irrigation design methodology was based on simulations of irrigation-stream flows over the field surface. One and two-dimensional ARS simulation models were reviewed herein. Computer programs aiding in the design of both layout and operation of level basins and of sloping borders utilized static databases storing thousands of previously obtained simulation results

Andrade *et al.* (2001) developed software for designing and evaluation of furrow irrigation systems. This work presents a software named DimSulco, developed in the Visual Basic language, version 5 for Windows 95, with the objective of helping the user to design and to evaluate furrow irrigation systems from previous knowledge of fundamental project parameters. It was structured in five modules: (I) Without deficit irrigation and defined furrow length; (II) Without deficit irrigation and undefined furrow length; (III) Deficit irrigation and defined furrow length; (IV) Deficit irrigation and undefined furrow length and (V) Reuse of irrigation runoff system. The modules III and I were divided in two sub-modules, which allow the design and performance of the system with and without cutback inflow. The modules II and IV are divided in four sub-modules including the options: (a) Without cutback inflow and advance time (T_a) equal to $1/4$ opportunity time for infiltration of the depth of water at the final end (T_0); (b) With cutback inflow and T_a equal to $1/4 T_0$; (c) Without cutback inflow and T_a equal to T_0 ; and (d) With cutback inflow and T_a equal to T_0 . The module V allowed the design of irrigation runoff reuse systems using any of the previously designed modules, calculating the basic elements of the each set and performance of irrigation variables.

Aujla *et al.* (2002) developed hydraulic model of closed end furrow irrigation. The study was conducted to develop a mathematical

model to simulate the entire closed end furrow irrigation process, by modifying Singh and Fang (1989a) border model, by using shape curves of surface and subsurface water profiles. The field experiment was conducted on the sandy loam soil of Punjab Agricultural University, Ludhiana having a furrow length of 25 m to develop the data for water advance and recession of cropped and uncropped soil to be used for verification of models using four stream sizes viz., 0.72, 1.30, 2.02 and 2.60 l/s. The closed end furrow irrigation models were developed for advance, storage and recession phases of irrigation processes. The models for advance, storage and recession phases were verified with experimental data. The verification of the models using observed data showed that average relative error was less than 10 per cent for both cropped and uncropped soil conditions.

Liu and Pereira (2003) developed optimization of irrigation scheduling considering constraints of surface irrigation technology. In order to research the irrigation scheduling that is appropriate for wheat-maize crop sequence in North China Plain, different irrigation experiments were performed during three consecutive years in Xiongxian, Hebei Province, China. All treatments of the experiment were simulated by the soil water balance model ISAREG. The simulation results showed that the parameters were calibrated and the model was validated well. Several alternative irrigation strategies were simulated with the model for the years corresponding to different probabilities of irrigation requirements. The irrigation times, application depth, water losses both from irrigation and rainfall, and crop yields were compared. The current irrigation scheduling was evaluated. The comparison of the results showed that the current application volume exceed the irrigation requirements. Main reasons were the constraints of the surface irrigation technology, such as uneven basin surface, relative small inflow rate and large basin sizes, which caused difficulty

in controlling the irrigation in a small water volume. In order to get the appropriate application depth for each irrigation that can meet the basic crop water management and lead to minimum water losses, the surface irrigation model SRFR was used to simulate the irrigation in different crop growing periods. From the simulations, the minimum net irrigation depth and the relationships between the application efficiency and the low quarter infiltration depth were obtained for each irrigation and the different inflow rates. Based on the results, improved irrigation scheduling for average, dry and severe dry years were proposed by combining improvement of irrigation models.

Smith (2003) developed a decision support system CROPWAT. It is meant as a practical tool to help irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies and more specifically the design and management of irrigation schemes.

Dechmi *et al.* (2004) developed coupled crop and solid set sprinkler simulation model. I: Model development. The crop model incorporates many of the features developed in the well-known cropwat model. Improvements include the use of thermal time and the input of daily ET_0 . The solid sets sprinkler model applies ballistic theory to determine water distribution resulting from water droplets subjected to wind vector. Regarding the validation of coupled model, the plot of soil available water versus measured and simulated yield reduction resulted in similar features. Adorsim explained 25 per cent of the variability in measured yield reduction. Most of the unexplained variability was due to the effect of non-water related factors affecting crop yield.

Anonymous (2004) developed software to draw contour map. It gives you full control over all map parameters you can accept the surfer intelligent defaults to automatically create a contour map, or

double click a map to easily customize map feature. Display contour maps over any contour range and contour interval, or specify only the contour levels you want to display on the map. And with the surfer software you can add color fill between contours to produce dazzling displays of your maps, or produce gray scale fills for dramatic black and white printouts.

Robertson *et al.* (2004) estimated hydraulic parameters for a surface irrigation model from field conditions. Two experiments were conducted to investigate the relationship between hydraulic parameters of the Analytical Irrigation Model and easily observable field conditions. The field experiments were performed at Tatura, Victoria, on 12 irrigation bays characterized by a Lemnos loam, a red duplex soil, sown to perennial pasture. For each experiment, 3 replicates of 4 treatments were applied. The first experiment found a linear relationship between field soil water deficit, approximated by crop water use less effective rainfall, and the initial infiltration depth. The second experiment found no relationship between pasture height and the model surface roughness parameter. An alternative to estimate the surface roughness parameter was suggested, which involves making an early observation of irrigation advance and solving for the unknown roughness parameter.

Richard Pike (2006) developed a software system named TOPAZ for automated analysis of landscape topography from digital elevation models. The primary objective of TOPAZ was the rapid and systematic identification and quantification of topographic features in support of investigations related to land surface processes, hydrologic and hydraulic modeling, and assessment of land resources and management of watershed and ecosystems.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

This chapter deals with the experimental details, material used and methods followed during the course of investigation.

3.1 Test data

The land survey data of Marathwada Agricultural University Watershed was taken to test the techniques. The data is given in Appendix-III.

3.2 General description of watershed

3.2.1 Location

The watershed is situated geographically between 18.45° and 20.01° N latitude and between 76.13° and 77.09° E longitude at Parbhani in Marathwada Agricultural University.

3.2.2 Area and elevation

The total area of the watershed is 575 acres i.e. 232.70 ha. Elevation of watershed is about 357 m above mean sea level.

3.3 Survey details of watershed

The survey was carried by the department of Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, M.A.U. Parbhani in the year 2005-06. The details of the survey are as follows:

Method - grid survey

Spacing - 60 x 60 m

Levels measured with - Dumpy level

Survey dates - 2005-06

The readings were taken along a north south direction. The sample field book readings are shown in Table.3.1 for reference.

3.4 Irrigation policy

To suggest an appropriate irrigation policy the following parameters were considered as of primary importance:

- Slope of land
- Undulations
- Soil type
- Drainability
- Infiltration Rate

3.4.1 Slope of land

The slope is very important factor to be considered while designing of an irrigation method. The classification of slope is shown in Table 3.2. The land was subdivided according to slope and coded as 1,2,3,4, ----- for convenience.

Table.3.1 Sample field book

| B.S. | I.S. | F.S. | H.I. | R.L. | Remark 1 (R1) | Remark 2 (R2) |
|------|------|------|--------|--------|------------------------------|------------------|
| 0.38 | | | 100.38 | 100.00 | B.M taken on cement stand | NS direction |
| | 0.17 | | | 100.21 | 0 | 0 |
| | 0.49 | | | 99.89 | 30 | |
| | 0.78 | | | 90.60 | 60 | |
| | 0.75 | | | 99.63 | 90 | |
| | 1.81 | | | 98.57 | 120 | |
| | 0.55 | | | 99.83 | 150 | |
| | 0.92 | | | 99.46 | 180 | |
| | 0.63 | | | 99.75 | 30 | C.P. at 1 |
| | 1.02 | | | 99.36 | 60 | |
| | 1.35 | | | 99.03 | 90 | |
| | 1.48 | | | 98.90 | 120 | |
| | 1.52 | | | 98.86 | 150 | |
| | 1.64 | | | 98.74 | 180 | |

Table.3.2 Classification of slope

| Slope (%) | Classification | Code |
|-----------|----------------------|------|
| 0.01-1 | Nearly level | 1 |
| 1 – 3 | Gently sloping | 2 |
| 3 - 5 | Moderate sloping | 3 |
| 5 – 10 | Strongly sloping | 4 |
| 10 – 15 | Moderate steep slope | 5 |
| 15 – 25 | Steep slope | 6 |
| 25 – 33 | Very steep | 7 |
| >33 | Very very steep | 8 |

(Ref. Soil and water conservation engineering by R.Suresh)

3.4.2 Undulations

To define the undulations, a small pilot grid survey on 2-acres of land adjacent to the College of Agricultural Engineering and Technology, Parbhani was carried out. Firstly, undulations were classified on visual basis and then survey was carried out.

The root mean square error (rmserr) was calculated and accordingly the land was classified. Root mean square error (rmserr) is the deviation of plane, which is called an undulation of land in a plane. The classification of undulations is shown in Table.3.3.

3.4.3 Soil Type

Three types of soil namely clay, sand and silt were coded as 1,2 and 3, respectively to suggest an irrigation policy to the land.

Table.3.3 Classification of undulations

| RMSERR (%) | Classification | Codes |
|------------|----------------------|-------|
| 0-5 | No undulations | 1 |
| 5-10 | Gentle undulation | 2 |
| 10-20 | Moderate undulation | 3 |
| 20-30 | Strong undulation | 4 |
| 30-40 | High undulation | 5 |
| > 40 | Very high undulation | 6 |

3.4.4 Drainability

The drainable and non-drainable soil types were coded as 1 and 2, respectively.

3.4.5 Infiltration Rate

An infiltration rate is very important property of surface soil. It was classified and coded as:

| Infiltration | Codes |
|---------------------|--------------|
| Low | 1 |
| Moderately low | 2 |
| Moderately high | 3 |
| High | 4 |

3.5 Decision-making based on all parameter

The notations for different parameters such as slope, undulations, soil type, drainability and infiltration rate are shown in Table 3.4. According to various combinations of these parameters the decision table was prepared, which is shown in Table 4.2 and accordingly suitable irrigation method was suggested.

Table.3.4 Notations in decision table

| Name | Notation in decision table |
|----------------------|----------------------------|
| Slope | a |
| Undulations | b |
| Soil type | c |
| Drainability | d |
| Infiltration rate | e |
| Basin irrigation | B |
| Border irrigation | C |
| Furrow irrigation | F |
| Sprinkler irrigation | S |
| Drip irrigation | D |

Table.3.5 Criteria to decide an irrigation method

| S slope % | Class - slope | Undulations | Class_undulations | Soil class | Drainage | Infiltration rate | Irrigation method |
|-----------|---------------|-------------|-------------------|-----------------------|-------------------------------|--------------------------|--|
| 0.05-2 | 1-2 | No | 1 | Loam Clay Sandy | Drainable | Mod. High Mod. Low | Drip and Sprinkler preferably, Border |
| 2-3 | 1-2 | Strong | 1-4 | Clay Loamy | Non Drainable | Low | Drip and Basin |
| 1-15 | 1-5 | Moderate | 1-3 | Clay Loamy | Drainable | Low | Drip and Furrow |
| 1-33 | 1-7 | Very high | 1-5 | Sandy | Drainable Non drainable | High | Sprinkler |
| 1-33 | 1-7 | Very high | 1-5 | Loam Clay Sandy | Drainable Non Drainable | Low Mod. high | Drip |

3.5.1 Criteria for deciding irrigation method

Table.3.5 shows the specific criteria to decide irrigation method (Ref.Irrigation Theory and Practices by Michael A.M. and Principles of Agricultural Engineering vol. II by Michael and ojha).

3.6 Computer Programs

All the programs required to develop Decision Support System (DSS) were written in C language and compiled along TURBOC on PC. The GNU-C compiler – gcc on Linux machines was also used for compilation of C-programs.

The objective was to classify land according to slope and undulations, to calculate area of land, to subdivide the land and to suggest a suitable irrigation method, which is called as a decision support system.

The following different programs were written to develop a Decision Support System.

3.6.1 Determination of best plane (slope and undulations)

The following formulae were used to calculate slope and undulations.

$$\begin{aligned}\text{Mean (x)} &= \text{sum (x)/n} \\ \text{varx} &= (\text{ssx} - (\text{sx}^2/\text{n})) / (\text{n} - 1) \\ \text{vary} &= (\text{ssy} - (\text{sy}^2/\text{n})) / (\text{n} - 1) \\ \text{varz} &= (\text{ssz} - (\text{sz}^2/\text{n})) / (\text{n} - 1) \\ \text{covxy} &= (\text{sxy} - (\text{sx}^2/\text{n})) / (\text{n} - 1)\end{aligned}$$

Equation of plane to fit the land:

$$\begin{aligned}z &= ax + by + c \\ a &= ((\text{covxz} * \text{vary}) - (\text{covxy} * \text{covyz})) / ((\text{varx} * \text{vary}) - (\text{covxy} * \text{covxy})) \\ b &= ((\text{covxy} * \text{covxz}) - (\text{varx} * \text{covyz})) / ((\text{covxy} * \text{covxy}) - (\text{varx} * \text{vary})) \\ c &= \text{mean (z)} - (a * \text{mean(x)}) - (b * \text{mean(y)}) \\ \text{est z} &= a * x [i] + b * y [i] + c \\ \text{ssez} &= (\text{est. z} - \text{obs. z}) * (\text{est z} - \text{obs. z}) \\ \text{rmserr} &= \text{sqrt (ssez/n)}\end{aligned}$$

3.6.2 Demarcation of land

The program was written to divide the land into smaller pieces and calculate its slope and undulations.

3.6.3 Determination of area (projected and actual) of land

The actual area was determined by dividing it into triangles. The area of triangle was determined by Heron's formula. (Kevin brown, Mathpages, Journal of graphic tools vol.7 (2) 2002)

$$A = \sqrt{s(s-s_1)(s-s_2)(s-s_3)}$$

$$S = (S_1 + S_2 + S_3)/2$$

$$S_1 = \sqrt{(x_2-x_1)^2 + (y_2-y_1)^2 + (z_2-z_1)^2}$$

$$S_2 = \sqrt{(x_3-x_2)^2 + (y_3-y_2)^2 + (z_3-z_2)^2}$$

$$S_3 = \sqrt{(x_3-x_1)^2 + (y_3-y_1)^2 + (z_3-z_1)^2}$$

The actual area of the triangle (land) is always larger than its projected area.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained on the various aspects viz., development of computer program, development of decision support system to suggest the best possible irrigation system and validation of the programs are summarized in this chapter.

4.1 Computer Programs

The different computer programs required to develop decision support system have been written and tested. The programs are as follows:

4.1.1 Program to fit the bestplane (*bestplane.cpp*)

A function *bestplane* was written which computes slope, undulations of any piece of land using grid points and levels. The function *bestplane.cpp* is as follows:

```
/*The following function is used to fit the bestplane & compute the
root*/
/*mean square of z,in which*/
/*coef[0]=a=slope along x-axis*/
/*coef[1]=b=slope along y-axis*/
/*coef[2]=c=intercept*/
/*rmserr=root mean square error of z*/
# include <stdio.h>
# include <math.h>
float bestplane(int n,float *x, float *y,float *z ,float coef[3])
{
int i;
float sx=0.0,sy=0.0,sz=0.0,ssx=0.0,ssy=0.0,ssz=0.0,sxy=0.0,syz=0.0,
sxz=0.0; float mx,my,mz,varx,vary,varz,covxy,covyz,covxz,a,b,c;
```

```

float estz,obsz,sserz=0.0,rmserr;
for(i=0;i<n;i++)
{
    sx=sx+ *(x+i);
    sy=sy+ *(y+i);
    sz=sz+ *(z+i);
    ssx=ssx+ *(x+i)* *(x+i);
    ssy=ssy+ *(y+i)* *(y+i);
    ssz=ssz+ *(z+i)* *(z+i);
    sxy=sxy+ *(x+i)* *(y+i);
    syz=syz+ *(y+i)* *(z+i);
    sxz=sxz+ *(x+i)* *(z+i);
}
mx=sx/(float)n;
my=sy/(float)n;
mz=sz/(float)n;
varx=(ssx-(sx*sx)/((float)n))/((float)(n-1));
vary=(ssy-(sy*sy)/((float)n))/((float)(n-1));
varz=(ssz-(sz*sz)/((float)n))/((float)(n-1));
covxy=(sxy-(sx*sy)/((float)n))/((float)(n-1));
covyz=(syz-(sy*sz)/((float)n))/((float)(n-1));
covxz=(sxz-(sx*sz)/((float)n))/((float)(n-1));
a=((covxz*vary)-(covxy*covyz))/((varx*vary)-(covxy*covxy));
b=((covxy*covxz)-(varx*covyz))/((covxy*covxy)-(varx*vary));
c=mz-(a*mx)-(b*my);
coef[0]=a;
coef[1]=b;
coef[2]=c;
for(i=0;i<n;i++){
    estz=(coef[0]* *(x+i)+ coef[1]* *(y+i)+ coef[2] );
}

```

```

obsz= *(z+i);
//printf(" %i %f %f \n ", i, estz, obsz);
ssez=ssez+((estz-obsz)*(estz-obsz));
}
rmserr= sqrt(ssez/(float) n);
return (rmserr);
}

```

4.1.3 Program to classify land into smaller pieces (*classification.cpp*)

The program *classification.cpp* reads the grid points and levels of complete land. It scans through the field determines slope and undulations at point i, j enclosed by 60×60 m of land. (According to classification given in Table 3.2 and 3.3). The program further clusters similar land pieces with minimum size of land of 1 hectare and maximum size of 25 hectares.

Fig.4.1 shows the land with grid points. The data x_i, y_i and L_i have been read to determine m_x, M_x, m_y, M_y .

where,

m_x = minimum value of $x[i]$

M_x = maximum value of $x[i]$

m_y = minimum value of $y[i]$

M_y = maximum value of $y[i]$

The next step is to initialize $L [i] [j]$ with -1.0, i.e. $L [i][j] = -1$ if the point is not in the field and $L [i][j] = z [i]$, if the point is in the field. Then the slope and undulation are calculated for whole land. After calculating slope and undulations of complete land, dividing the same field into smaller pieces of size 60×60 m and 120×120 m. It covers all the field undulation of each piece of land is calculated. Using overlapping

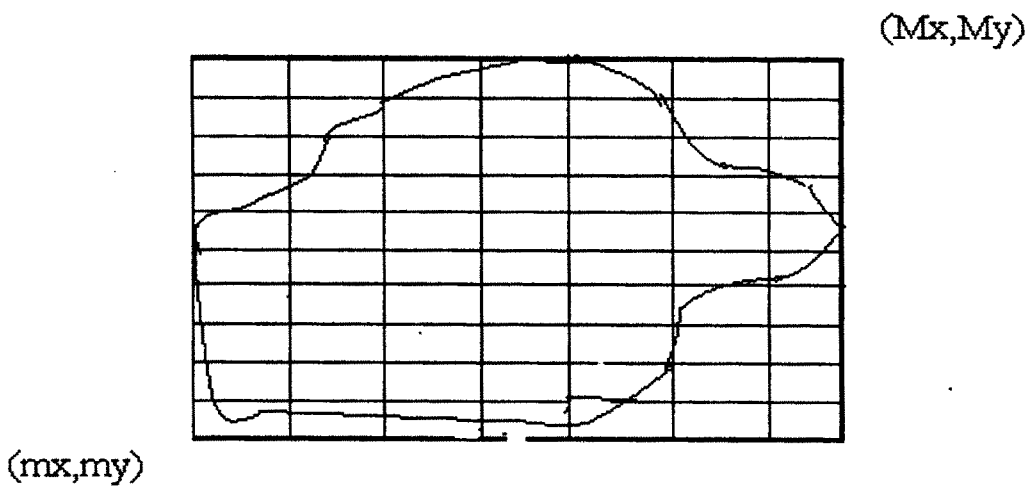


Fig.4.1 Land with grid points

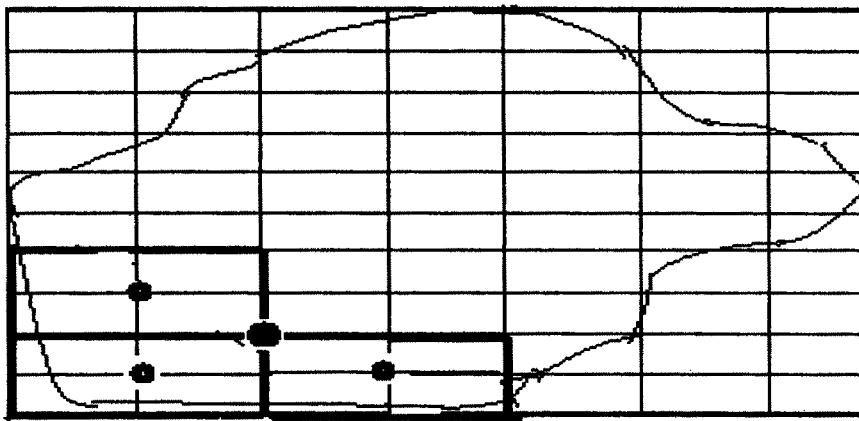


Fig.4.2 Division of land into smaller pieces of size 60*60m

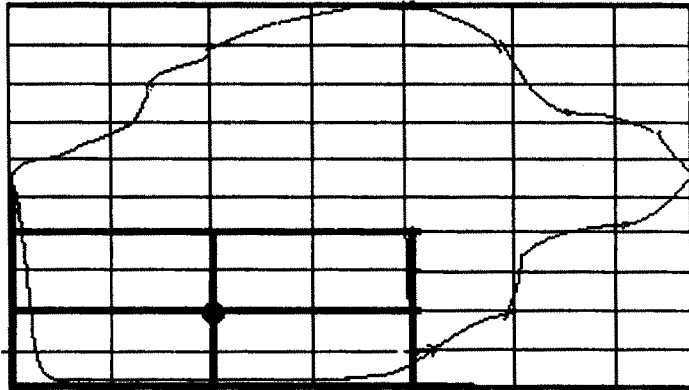


Fig.4.3 Division of land into smaller pieces of size 120*120m

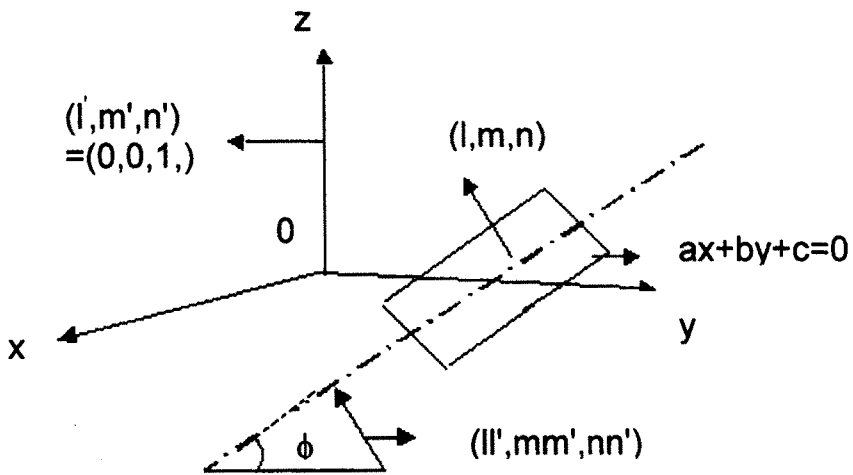


Fig. 4.4 Plane p with direction cosines of normals

square pieces as shown in Fig.4.2 and Fig.4.3, the slope and undulations for each piece of land are calculated. The program is given in Appendix- I.

4.1.4 Program to calculate actual area and projected area (area.cpp)

The areas computed are both horizontal projections and actual inclined areas. This program gives total actual area and projected area of smaller piece of land. The program is given as follows:

```
/*program to compute max. and min. values of x & Y */
#include <stdio.h>
main()
{
int i,j,n=0;
int x[1000],y[1000],mx,my,Mx,My;
/* where Mx=max. value of x */
/* My=max. value of y */
/* mx=min. value of x */
/* my=min. value of y */
float L[100][100],z[1000],a;
FILE* inp;
inp=fopen("survey.txt","r");
for(i=0;i<=1000;i++){
    x[i]=0;y[i]=0;z[i]=0.0;
    }
mx=100;
Mx= 0;
my= 100;
My= 0;
fscanf(inp,"%i",&n);
printf("%i\n",n);
```

```

for(i=0;i<n;i++){
fscanf(inp,"%i%i%f",&x[i],&y[i],&z[i]);
    }
for(i=0;i<n;i++){
    if(x[i] < mx) mx = x[i];
    if(x[i] > Mx) Mx = x[i];
    if(y[i] < my) my = y[i];
    if(y[i] > My) My = y[i];
    }
/* initialization of L*/
for(i= 0;i<= Mx;i++)
    for(j= 0;j<= My;j++){
        L[i][j]= -1.0;
        }
for(i=0;i<n;i++){
    L[x[i]][y[i]] = z[i];
}
printf("mx=%i , Mx=%i , my=%i , My=%i\n",mx,Mx,my,My);
/*program to determine the projected area of field is as follows*/
/*if level of three points in a grid is -1 then a=0,*/
/*if level of two points either x or y are same is -1 then a=0,*/
/*if level of one point in a grid is -1 then a=1/2,*/
/*if there is no any point in grid with -1 then a=1 */
for(i=0; i< Mx; i++)
    for(j=0;j< My;j++){
        printf("%i %i %f %f \n",i,j,L[i][j]);

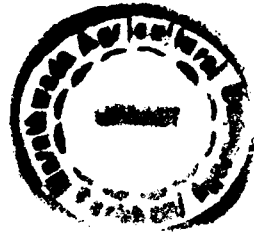
if(L[i][j] == (-1.0) && L[i][j+1]> 0 && L[i+1][j] > 0 && L[i+1][j+1] > 0)
        a=a+0.5;
else

```

```

if(L[i][j] > 0 && L[i][j+1] == -1.0 && L[i+1][j] > 0 && L[i+1][j+1] > 0)
    a=a+0.5;
else
if(L[i][j] >0 && L[i][j+1]> 0 && L[i+1][j] ==-1.0 && L[i+1][j+1] > 0)
a=a+(0.5);
else
if(L[i][j] >0 && L[i][j+1]> 0 && L[i+1][j] > 0 && L[i+1][j+1]==-1.0)
a=a+(0.5);
else
if(L[i][j] >0 && L[i][j+1] >0 && L[i+1][j] > 0 && L[i+1][j+1] > 0)
a= a+1.0;
    printf(" %f %f %f %f %f \n " ,
        L[i][j], L[i][j+1], L[i+1][j], L[i+1][j+1], a);
}
printf("projected area of field,a=%f\n",a);
return 0;
}

```



4.1.5 Program to calculate slope of plane (*planeslope.cpp*)

The program *planeslope.cpp* was written by using following formulae:

By using *bestplane* function *a*, *b* and *c* is calculated.

`coef [0] = a`

`coef [1] = b`

`coef [2] = c`

Fig.4.4 shows plane *p* with direction cosines of normals.

Given a plane *p* is $ax + by + c = z$

which can be written as,

$$ax + by - z + c = 0$$

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The direction cosines of the normal to the plane p can be computed as,

$$d = \sqrt{a^2 + b^2 + (-1)^2}$$

$$(l, m, n) = (a/d, b/d, -1/d)$$

Normal to the xy-plane is given by,

$$(l', m', n') = (0, 0, 1)$$

angle between the normal = $\cos t$

$$= ll' + mm' + nn' = 0 + 0 + (-1/d)$$

Slope of the plane p = $\tan t = \sin t / \cos t$

$$\cos t = \text{abs}(-1/d)$$

Where,

$$d = \sqrt{a^2 + b^2 + 1}$$

we know that,

$$1 + \tan^2 = \sec^2$$

$$1 + \tan^2 = d^2 \quad (\cos = 1/\sec)$$

$$\tan^2 = d^2 - 1$$

$$\tan = \sqrt{d^2 - 1}$$

We have,

$$d^2 = a^2 + b^2 + 1$$

$$\tan = \sqrt{a^2 + b^2 + 1}$$

$$\tan = \sqrt{a^2 + b^2}$$

By using this formula for slope using a and b, the program is written to determine the slope of land. The function to determine plane slope is as follows:

```
/*program to determine the slope of a plane.*/
```

```
#include "my.h"
```

```
#include <stdio.h>
```

```
#include <math.h>
```

```
main()
```

```
{
```

```

int n=0, i;
float x[1000],y[1000],z[1000],coef[3],slope;
FILE *inp;
inp = fopen("survey.txt","r");
for(i=0;i<1000;i++)
    { x[i]=0.0 ; y[i]=0.0; z[i]=0.0; }
fscanf(inp,"%i",&n);
printf(" %i \n", n);
for(i=0;i<n;i++)
{
fscanf(inp,"%f%f%f",&x[i],&y[i],&z[i]);
printf(" %f %f %f \n", x[i], y[i], z[i]);
}
bestplane(n,x,y,z,coef);
printf("coef[0]=a=%f\n,coef[1]=b=%f\n,coef[2]=c=%f\n",coef[0],coef[1],
        coef[2]);
slope=sqrt(((coef[0]*coef[0])+(coef[1]*coef[1])));
printf("plane slope=tant=%f\n",slope);
fclose(inp);
return 0;
}

```

4.1.6 Program to form complete DSS (*dspila.c*)

The complete Decision Support System (DSS) was programmed by name *dspila.c*, which calls all above functions together to identify small pieces of land according to slope class and undulations. It also gives the total (actual) area of land as the output. The program is given in Appendix-I.

4.1.7 Program to draw a map (*landmap.cpp*)

The program *landmap.cpp* draws a map for visualization of land pieces according to classification of slope and undulations given in

Table 3.2 and Table 3.3. The different colors i.e. red color was used to identify the undulating land and green was used to identify land with slope class 1-2 and no undulations. The program is given in Appendix-II.

4.2 Validation of the program

The four sample test data were used to test the validity of the program dspila.c.

Table.4.1 Test data with file name

| Sr.no. | File name | Type of land |
|--------|------------|------------------------|
| 1 | dummy 1 | Flat land |
| 2 | dummy 2 | Hilly and flat land |
| 3 | dummy 3 | Mixed undulating land |
| 4 | dummy 4 | Undulating land |
| 5 | survey.txt | real data of watershed |

The contour maps of flat land (dummy1), hilly and flat land (dummy2), mixed undulating land (dummy3), undulating land (dummy4) and MAU watershed (survey.txt) are shown in Fig. 4.5, Fig.4.8, Fig.4.11, Fig.4.14 and Fig. 4.17, respectively. The contours were drawn at 0.25m interval and at 60m grid. The program dspila.c was used to calculate average slope and undulations of complete land and then land was divided into small pieces of size 60X60m and 120X120m according to different slope class 1-2, 2-3, 3-4 and no undulations. The total (actual) area of each identified piece of land, can also be calculated by this program.

4.2.1 Sample data of flat land

The results of the program are shown in Fig. 4.6. From the program results it is seen that total area of 14.58 ha (60X60m) and 15.52 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 7.47 ha (60X60m) and 7.74 ha

(120X120m). It is also revealed that the average slope of the land and undulations were found to be 0.1250 percent and 0.41 percent, respectively. The graphic results for slope class 1-2 is shown in Fig.4.7.

4.2.2 Sample data of hilly and flat land

Fig. 4.9 shows the program results of hilly and flat land. From the results it is seen that total area of 13.10 ha (60X60m) and 14.81 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 6.52 ha (60X60m) and 7.83 ha (120X120m). It is also revealed the average slope of the land and undulations were found to be 0.259 percent and 0.49 percent, respectively. The graphic results for slope class 1-2 is shown in Fig.4.10.

4.2.3 Sample data of mixed undulating land

The program results and graphic results are shown in Fig.4.12 and Fig.4.13, respectively. From the program results it is seen that total area of 14.76 ha (60X60m) and 15.21 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 5.99 ha (60X60m) and 7.25 ha (120X120m). It is also revealed that the average slope of land and undulations were found to be 0.251 percent and 0.4229 percent, respectively.

4.2.4 Sample data of undulating land

Fig. 4.15 and Fig.4.16 shows the program results and graphic results, respectively. From the program results it is seen that the total area of 15.30 ha (60X60m) and 15.39 ha (120X120m) was found to be slope class 1-2. The area under slope class 2-3 was found to be 7.24 ha (60X60m) and 7.56 ha (120X120m). It is also observed that the average slope and undulations are 0.2495 and 0.462 percent, respectively.

Finally real data of M.A.U. watershed was tested and it is clear that the software identifies slope and undulations correctly. It also determines area of small piece correctly. Hence it is reliable for use in any decision support system (DSS).

4.2.5 Real data of M.A.U. watershed

Fig.4.18 shows the program results for M.A.U. watershed data and Fig.4.19 shows the graphic representation of the M.A.U. watershed. From the output results it is seen that average slope of watershed is 0.424% and it belongs to slope class 2. The undulations are 1.41% in the watershed and it also belongs to the class 2. It is also revealed that the total area of 21.64 ha (60X60m) and 26.95 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 14.84 ha (60X60m) and 20.91 ha (120X120m).

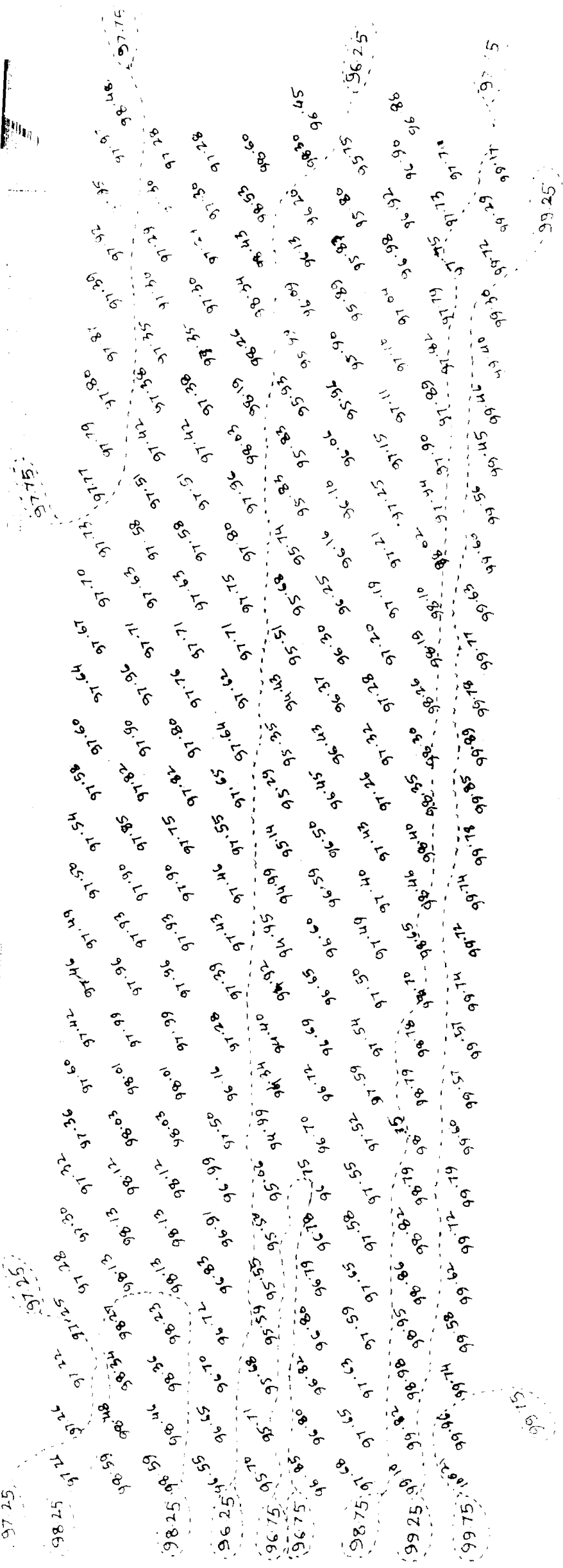
4.3 Advice of irrigation method

The decision making based on all various combinations of parameters such as slope, undulations, soil type, drainability and infiltration rate is shown in Table 4.2. From this table it is revealed that the best possible irrigation system depending upon slope class and undulations for various combinations can be suggested.

From the decision table it can be concluded that all the irrigation methods i.e. basin irrigation, border irrigation, furrow irrigation, sprinkler and drip irrigation are found to be suitable for lands with slope class 1-2 (0.03-1%) and with no undulations.

The lands with slope class 2-3 (3-5%) and 3-4 (5-10%) and no undulations three methods of irrigation i.e. furrow, sprinkler and drip irrigation are found to be suitable.

In undulating land for any slope class only drip and sprinkler method of irrigation can be recommended.



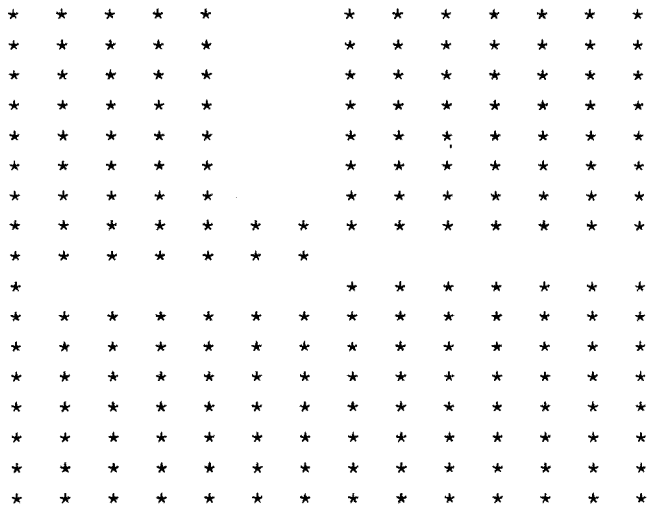
DUMMY-1-CONTOUR MAP FOR FLAT LAND

CONTOUR INTERVAL - 0.25m. SCALE - 1cm = 60m

DUMMY-1

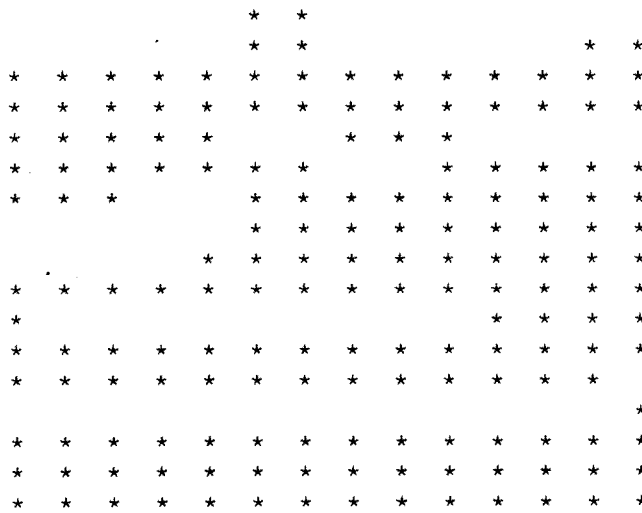
Fig.4.6 Output results of program for flat land

slope class 1 - 2



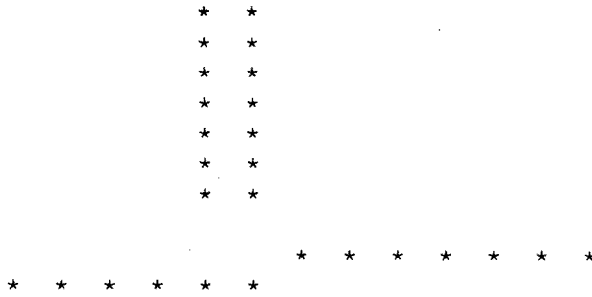
total area(actual) 14.582594 ha

slope class 2 - 3



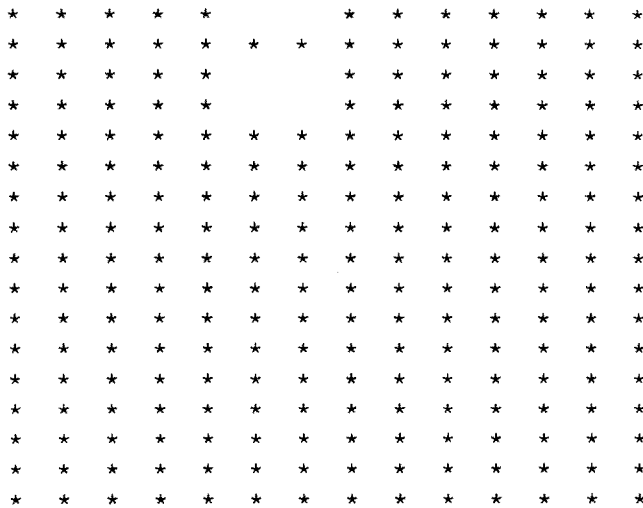
total area(actual) 7.471900 ha

slope class 3 - 4



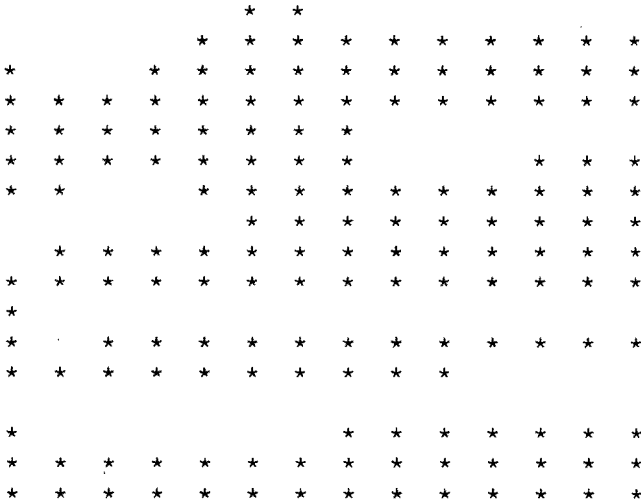
total area(actual) 0.000000 ha

current size is 1
next size please ? 0 to stop 2
slope class 1 - 2



total area(actual) 15.529327 ha

slope class 2 - 3



total area(actual) 7.743298 ha

slope class 3 - 4



total area(actual) 0.000000 ha

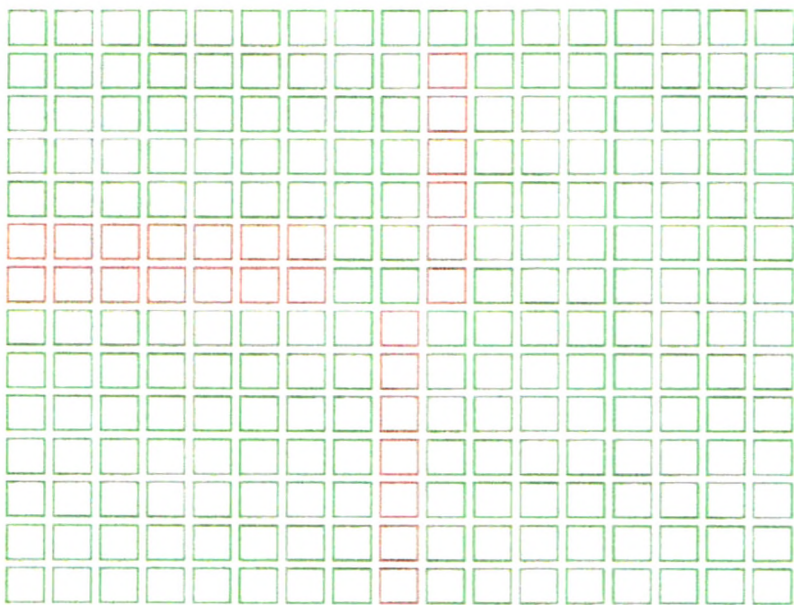
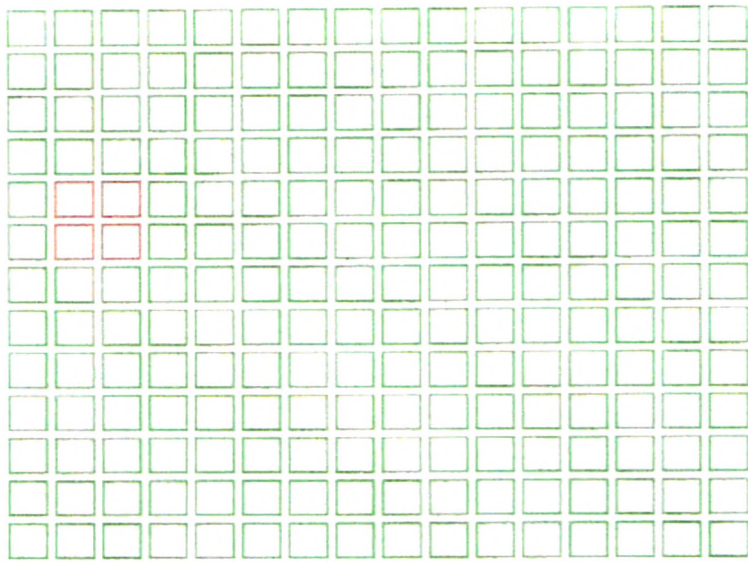
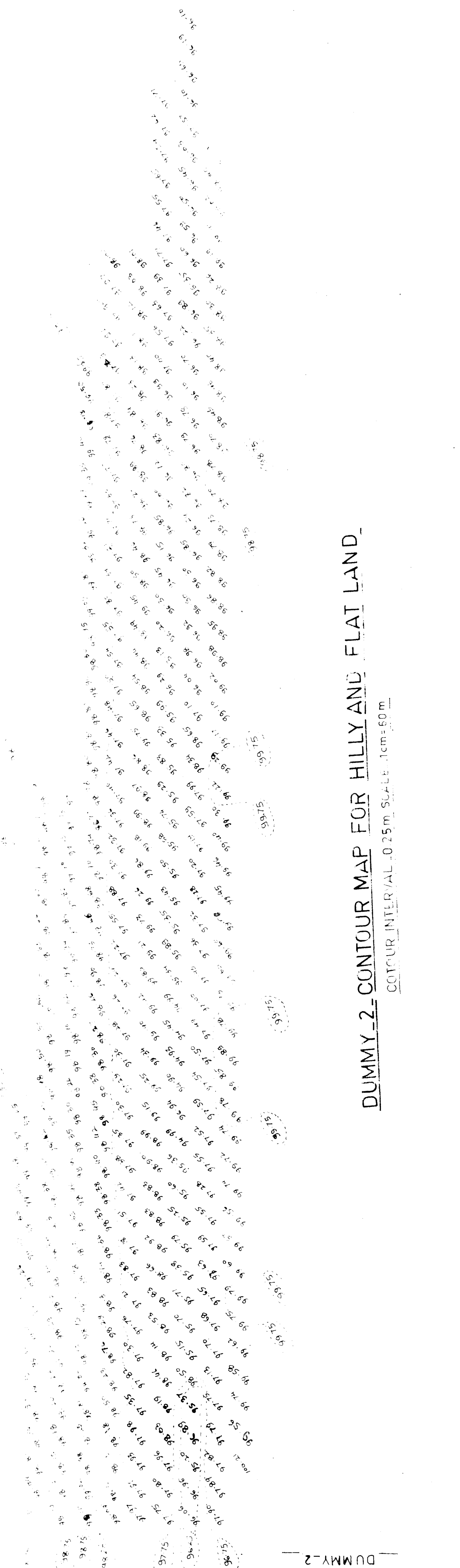


Fig.4.7 Graphic representation of flat land according to slope and undulations.



DUMMY-2- CONTOUR MAP FOR HILLY AND FLAT LAND

CONTOUR INTERVAL - 0.25m SCALE - 1cm = 60m

DUMMY-2

96.06

96.31

96.56

96.81

97.06

97.31

97.56

97.81

98.06

98.31

98.56

98.81

99.06

99.31

99.56

99.81

100.06

96.31

96.56

96.81

97.06

97.31

97.56

97.81

98.06

98.31

98.56

98.81

99.06

99.31

99.56

99.81

100.06

96.56

96.81

97.06

97.31

97.56

97.81

98.06

98.31

98.56

98.81

99.06

99.31

99.56

99.81

100.06

96.81

97.06

97.31

97.56

97.81

98.06

98.31

98.56

98.81

99.06

99.31

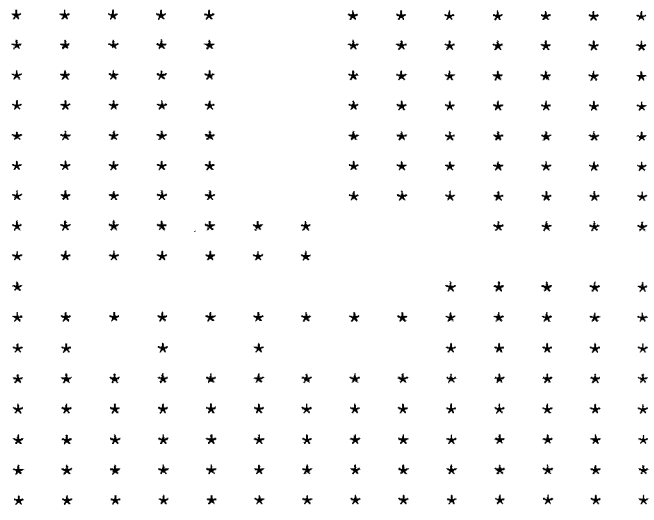
99.56

99.81

100.06

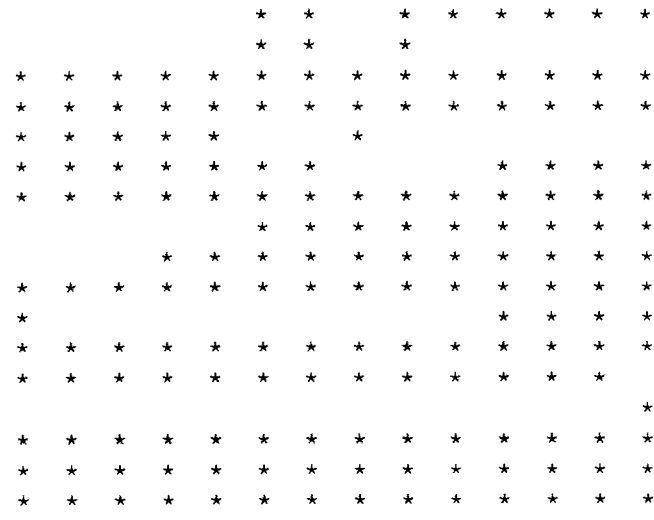
Fig.4.9 Output results of program for hilly and flat land

slope class 1 - 2



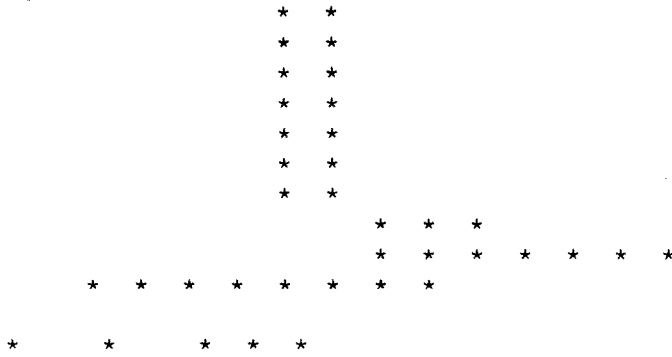
total area(actual) 13.100285 ha

slope class 2 - 3



total area(actual) 6.528676 ha

slope class 3 - 4

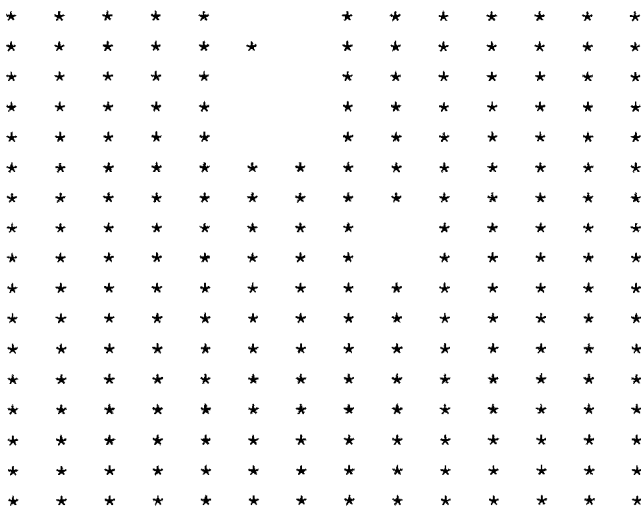


total area(actual) 0.000000 ha

current size is 1

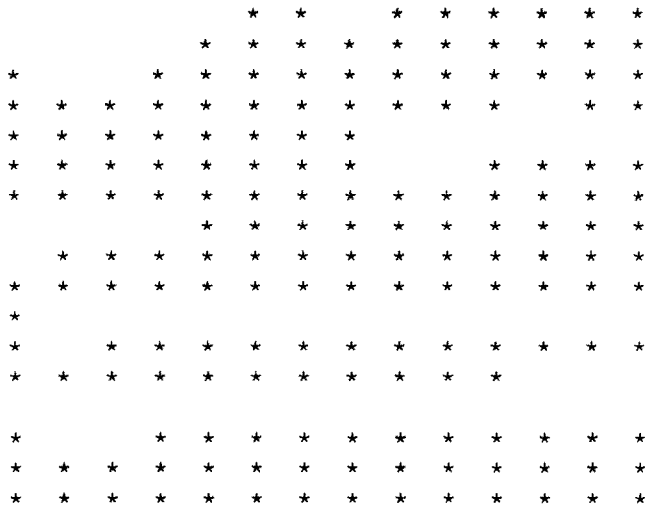
next size please ? 0 to stop 2

slope class 1 - 2



total area(actual) 14.811860 ha

slope class 2 - 3



total area(actual) 7.837518 ha

slope class 3 - 4



total area(actual) 0.000000 ha

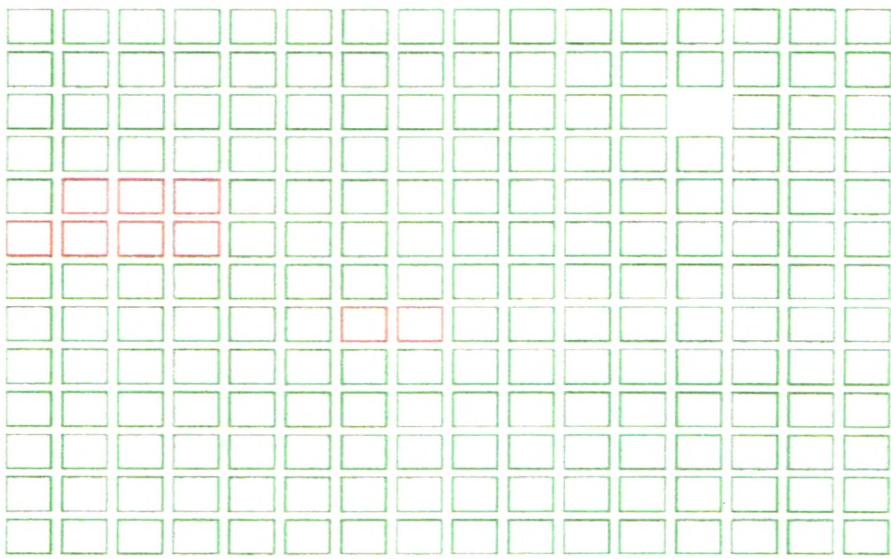
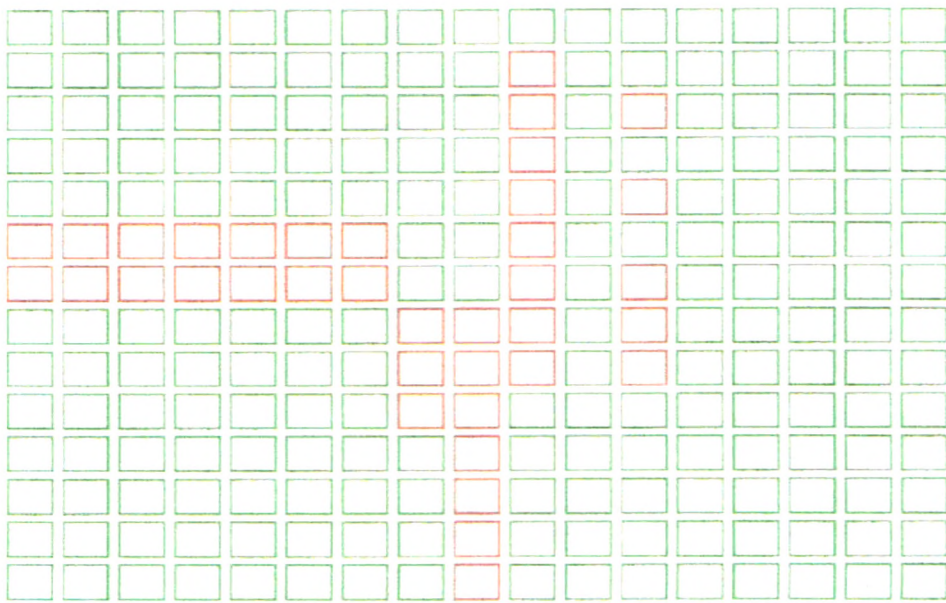
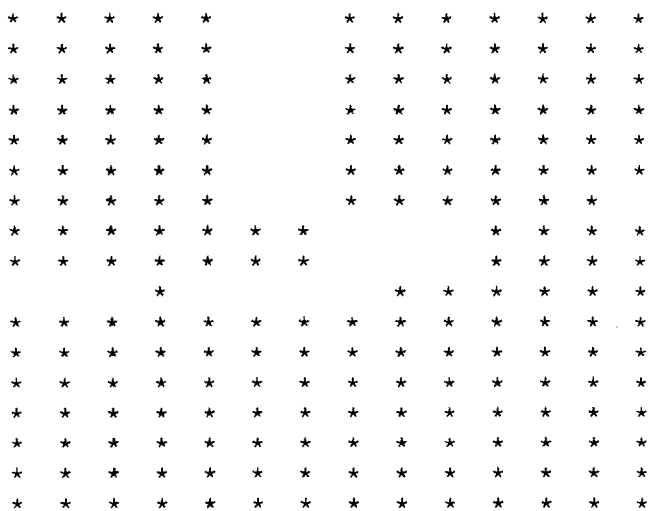


Fig.4.10 Graphic representation of hilly and flat land according to slope and undulations

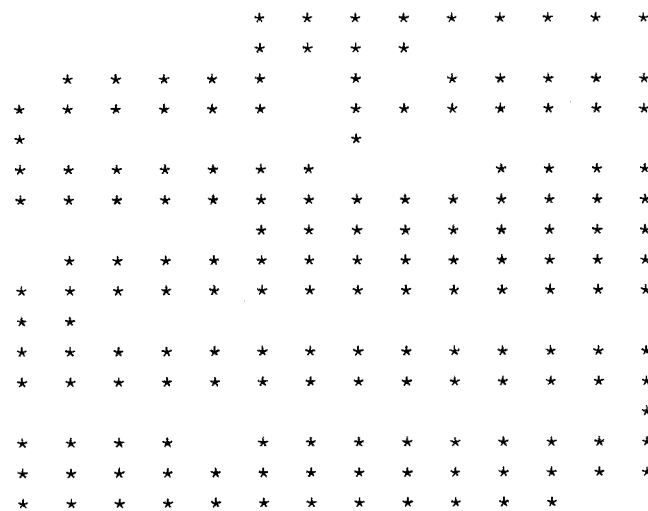
Fig.4.12 Output results of mixed undulating land

slope class 1 - 2



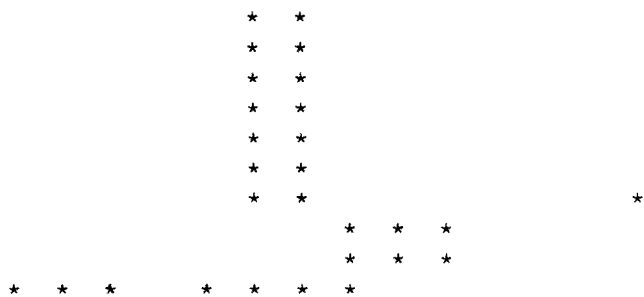
total area(actual) 14.765671 ha

slope class 2 - 3



total area(actual) 5.992788 ha

slope class 3 - 4

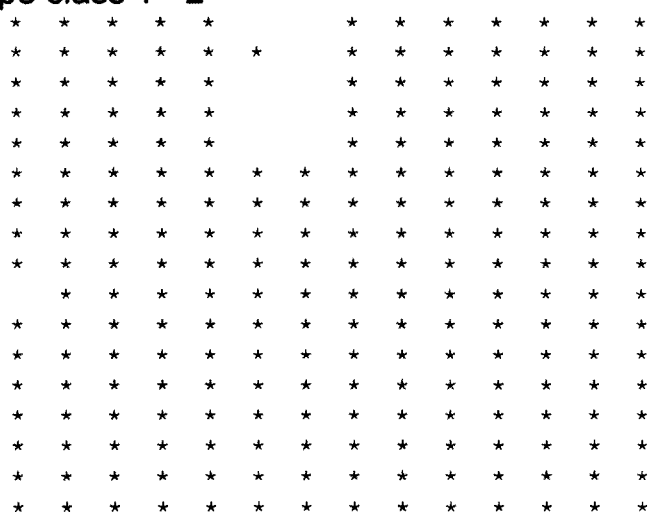


total area(actual) 0.000000 ha

current size is 1

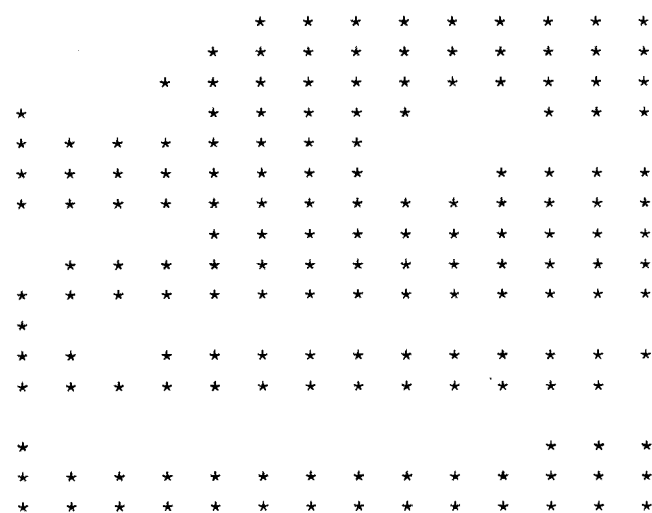
next size please ? 0 to stop 2

slope class 1 - 2



total area(actual) 15.216638 ha

slope class 2 - 3



total area(actual) 7.251151 ha

slope class 3 - 4

* *
* *
* *
* *

*

total area(actual) 0.000000 ha

. . . .

current size is 2

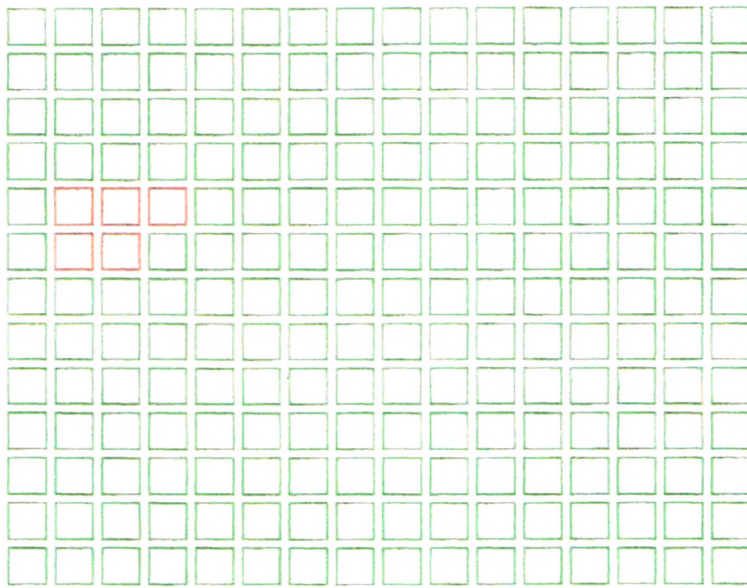
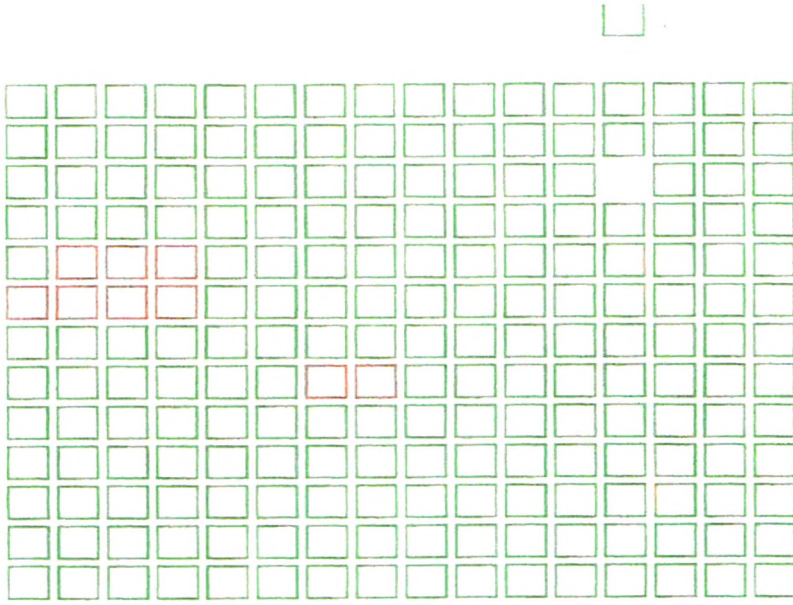
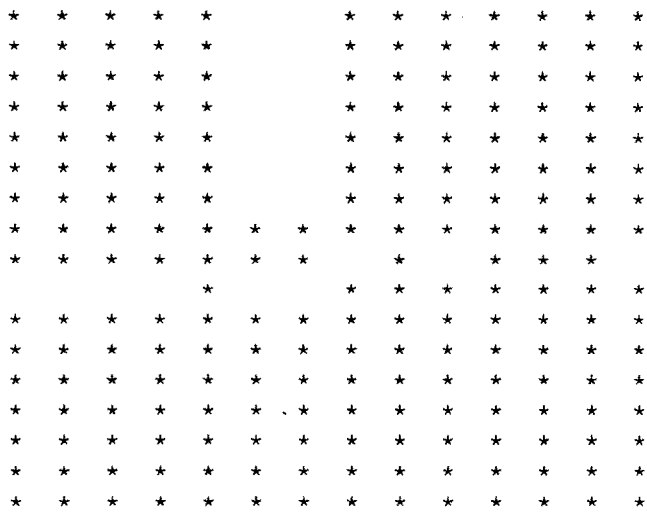


Fig.4.13 Graphic representation of mixed undulating land according to slope and undulations.

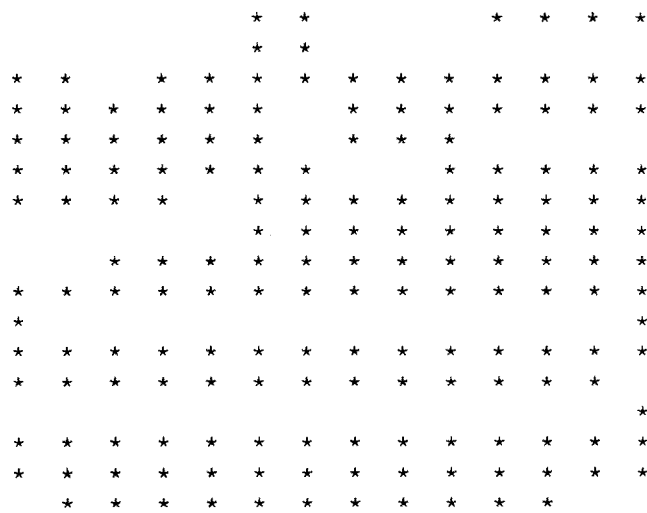
Fig.4.15 Output results of program for undulating land

slope class 1 - 2



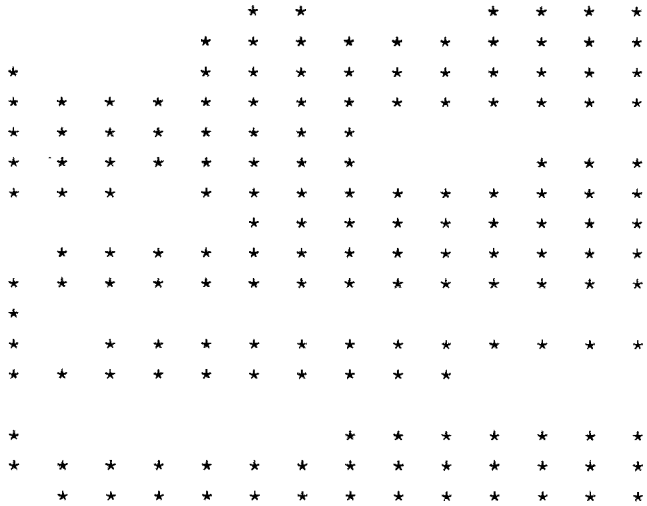
total area(actual) 15.303745 ha

slope class 2 - 3



total area(actual) 7.248422 ha

slope class 2 - 3



total area(actual) 7.563423 ha

slope class 3 - 4



*

total area(actual) 0.000000 ha

current size is 2
next size please ? 0 to stop 0

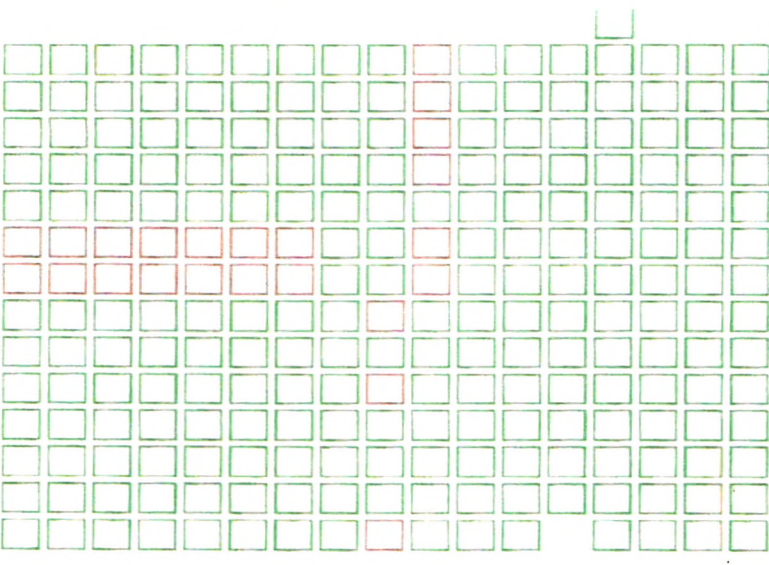
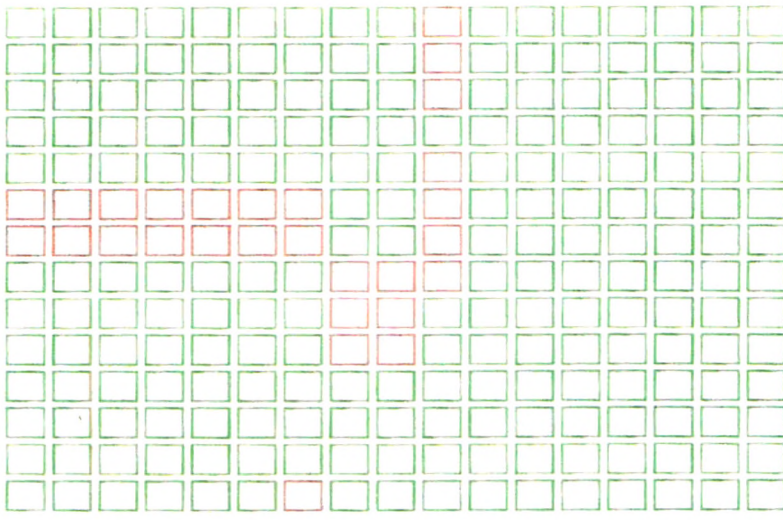
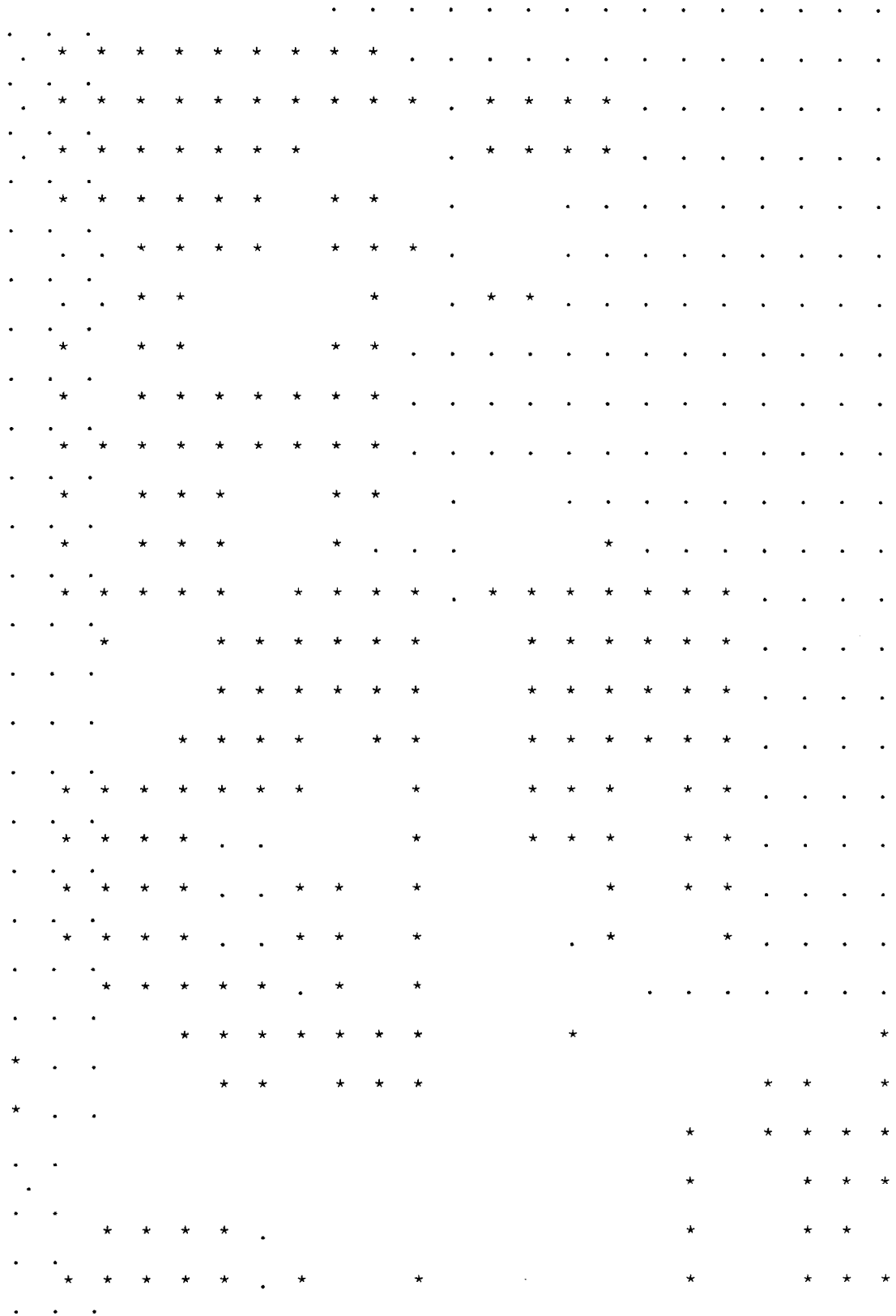


Fig.4.16 Graphic representation of undulating land according to slope and undulations.

Fig.4.18 Output results of program for watershed

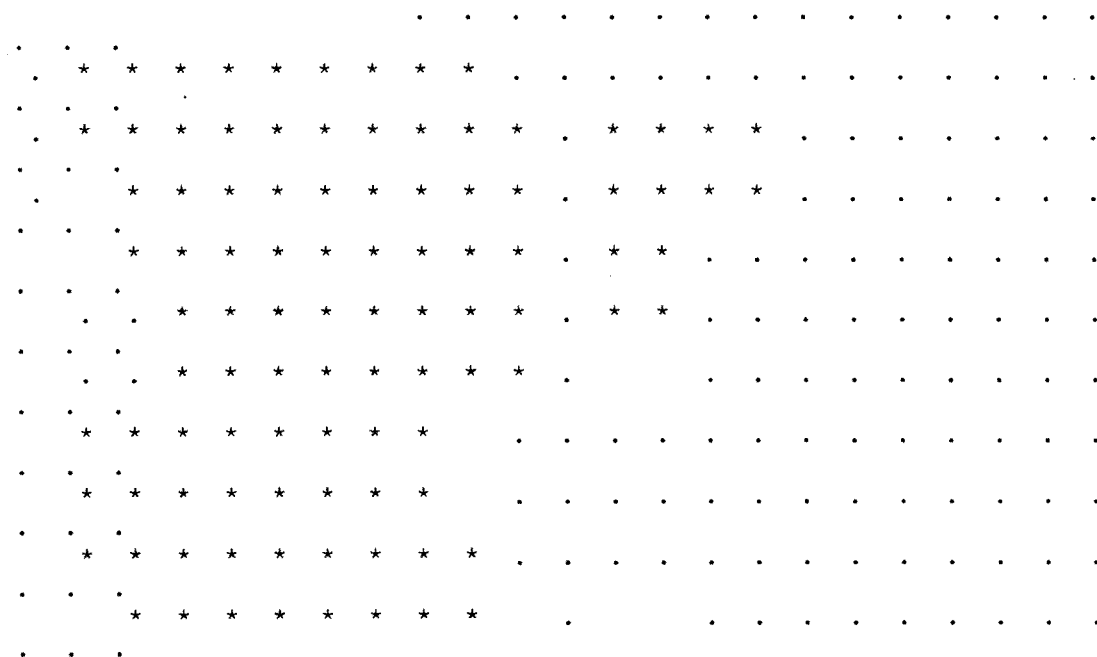
slope class 1 - 2

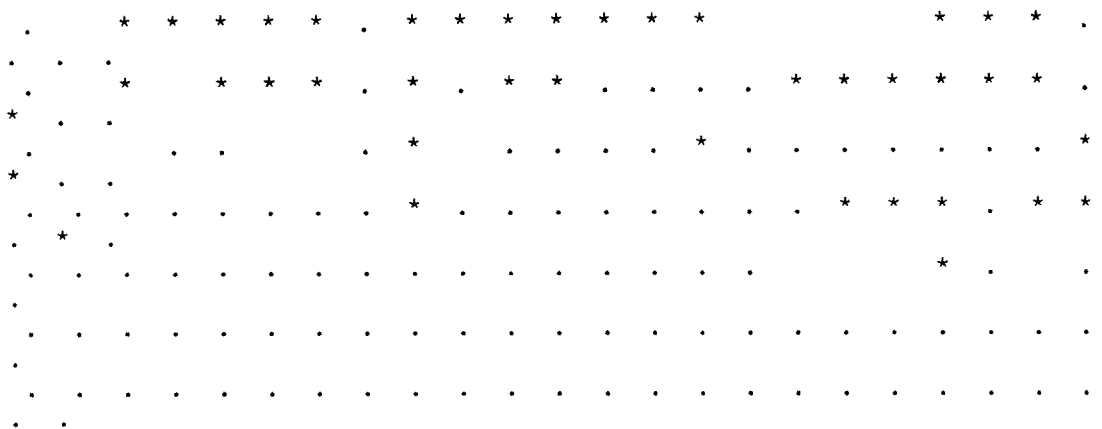




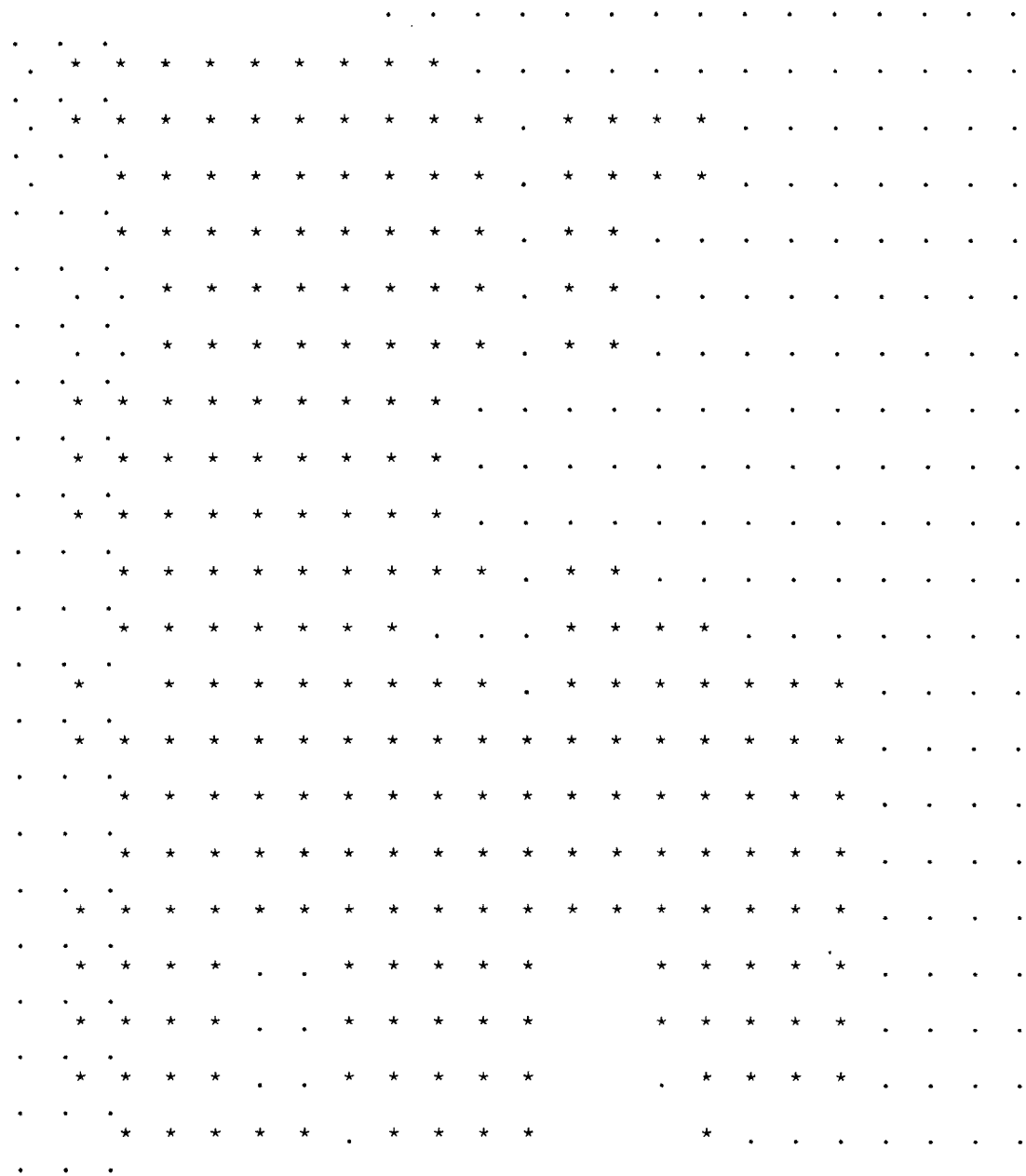
total area(actual) 21.642527 ha

slope class 2 - 3





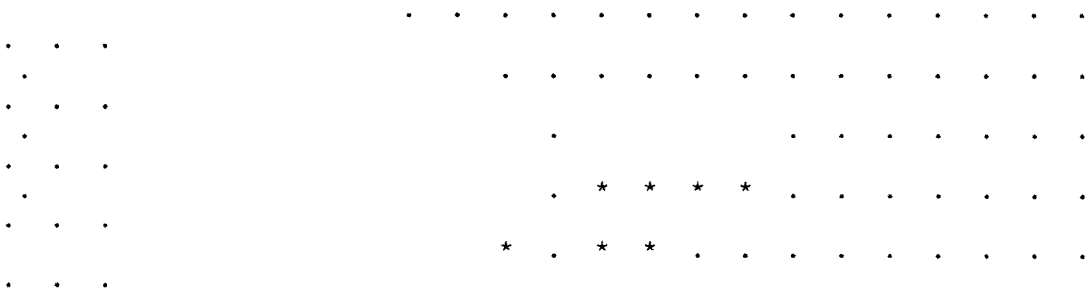
total area(actual) 26.956785 ha
 slope class 2 - 3





total area(actual) 20.918205 ha

slope class 3 - 4





total area(actual) 0.000000 ha

current size is 2

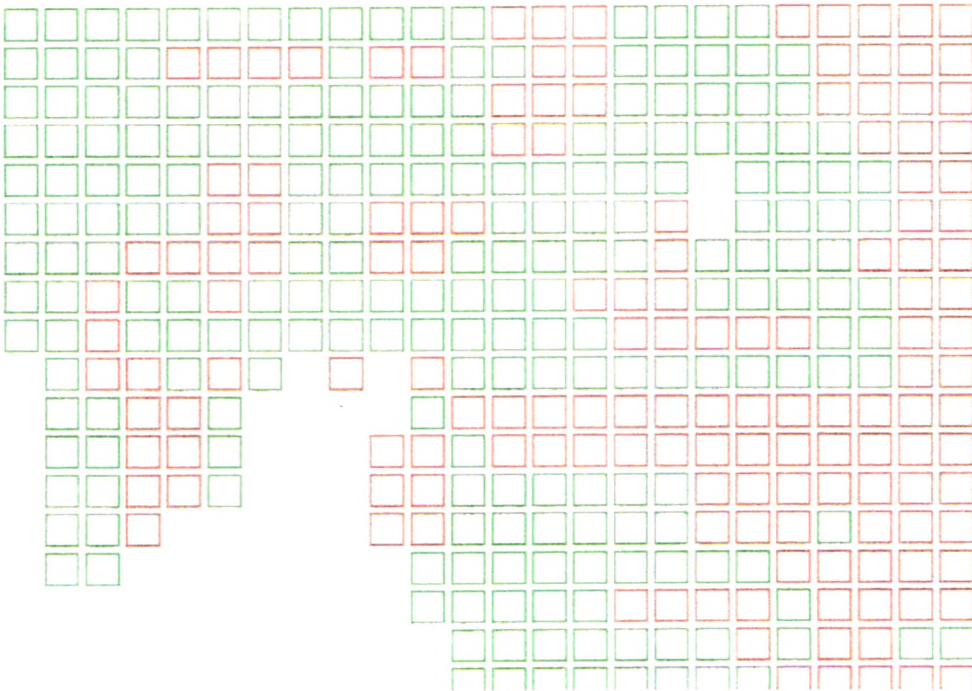
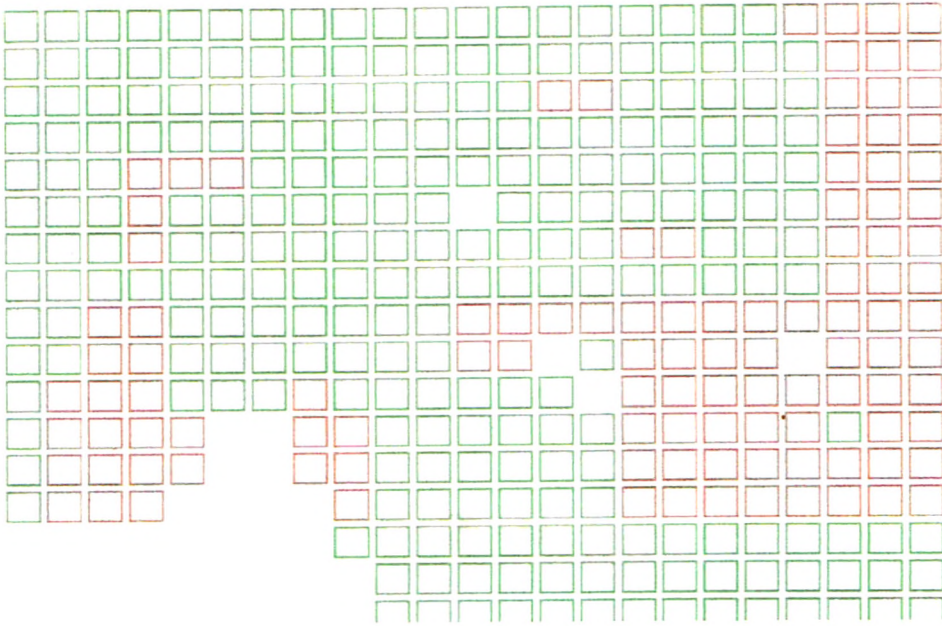


Fig. 4.19 Graphic representation of M.A.U. Watershed according to slope and undulations.

Table.4.2 Decision Table

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|------------|
| 1111100111 |
| 1111201011 |
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| 1112110011 |
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| 1112301011 |
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| 1122300011 |
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| 1131100111 |
| 1131201011 |
| 1131301011 |
| 1131400011 |
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| 1231100111 |
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| 1232110011 |
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| abcdeBCFSD |
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| 1431400011 |
| 1432110011 |
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| 1432300011 |
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SUMMARY AND CONCLUSIONS

Chapter V

SUMMARY AND CONCLUSIONS

To choose all irrigation policies over a large area, consulting engineer must know the nature of the land and its topography. A topographic map is necessary to classify land according to slope and undulations and it takes quiet bit of time in case of large areas. With these needs in mind current project is taken up to develop a computer program for land mapping and to classify land according to slope and undulations. According to slope and undulations appropriate irrigation method is recommended i.e. an irrigation decision support system has been developed.

The different computer programs such as program to fit the bestplane (*bestplane.cpp*), program to classify land into smaller pieces (*classification.cpp*), program to calculate actual area and projected area (*area.cpp*), program to calculate slope of the plane (*planeslope.cpp*) and program to form complete Decision Support System (*dspila.c*) were written separately. For the validation of the program four sample test data i.e. dummy1 (flat land), dummy2 (hilly and flat land), dummy3 (mixed undulating land) and dummy4 (undulating land) were used.

The separate flowcharts were prepared before writing each program. Each program was written separately in C-language according to flowchart and compiled along TURBOC on PC.

The GNU-C compiler -gcc on Linux machines was also used for compilation of C-programs. All the programs then linked together to form an integrated software.

The survey data of Marathwada Agricultural University watershed was used to test the software. The contour map was drawn manually.

The highlights of important findings are summarized in the form of following conclusions.

1. The software is user friendly and it saves much time required for classification of land.
2. The developed Decision Support System (DSS) can be favorably used to classify land according to slope and undulations.
3. From tested results it is clear that the software identifies slope and undulations correctly and also calculates total area of each piece of land.
4. The average slope and undulations of flat land were found to be 0.1250 per cent and 0.41 per cent, respectively. The average slope and undulations of hilly and flat land were found to be 0.259 per cent and 0.49 per cent, respectively.
5. For mixed undulating land, the average slope and undulations were found to be 0.251 per cent and 0.4229 per cent, respectively. The average slope and undulations of undulating land were found to be 0.2495 per cent and 0.462 per cent, respectively.
6. The average slope and undulations of real data of MAU watershed were found to be 0.424% and 1.41%, respectively.
7. For flat land, the total area of 14.58 ha (60X60m) and 15.52 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 7.47 ha (60X60m) and 7.74 ha (120X120m).
8. The total area of 13.10 ha (60X60m) and 14.81 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 6.52 ha (60X60m) and 7.83 ha (120X120m) for hilly and flat land.
9. The total area of 14.76 ha (60X60m) and 15.21 ha (120X120m) was found to be under slope class 1-2 for mixed undulating land.

The area under slope class 2-3 was found to be 5.99 ha (60X60m) and 7.25 ha (120X120m).

10. For undulating land, the total area of 15.30 ha (60X60m) and 15.39 ha (120X120m) was found to be slope class 1-2. The area under slope class 2-3 was found to be 7.24 ha (60X60m) and 7.56 ha (120X120m).
11. The total area of 21.64 ha (60X60m) and 26.95 ha (120X120m) was found to be under slope class 1-2. The area under slope class 2-3 was found to be 14.84 ha (60X60m) and 20.91 ha (120X120m) in real watershed data.
12. For slope class 1-2 i.e. lands having slope 0.01 - 3% and non-undulating, all irrigation methods basin, border, furrow, sprinkler and drip are recommended.
13. The land with slope class 2-3 (1-5%) and 3-4 (5-10%) and no undulations, three methods of irrigation i.e. furrow, sprinkler and drip irrigation methods are found to be suitable.
14. For remaining slope class and undulating land only drip and sprinkler irrigation is found to be suitable.

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APPENDICES

APPENDIX- I

```
/*program to develop a complete decision support system*/
#include <stdio.h>
#include <math.h>
#include <stdlib.h>
#include "my.h"
main()
{
int i,j,l,k,n=0,np=0,u,v;
int *x,*y, mx, my, Mx, My, size, p;
/* where mx, Mx, my, My are max and min of x , y */
float L[100][100],*z,*tx,*ty,*tl,coef[3],rmserr,sl,slope,w,A,PA,a,pa;
float TL[100][100];
int slp[100][100],und[100][100];
int class_s(float);
int class_u(float);
//int map(int,int,int,int,*int,*int );
FILE *inp,*outp1,*outp2;
inp=fopen("survey.txt","r");
outp1=fopen("cland","w");
outp2=fopen("class_su","w");

for(i=0;i<100;i++)
for(j=0;j<100;j++){
L[i][j] = -1; slp[i][j]=0; und[i][i]=0;
TL[i][j] = -1;
}
for(i=0;i<3;i++)
coef[i]=0;
```

```
mx=1000;
Mx= 0;
my= 1000;
My= 0;
fscanf(inp,"%i",&n);
printf("%i\n",n);
if ( (x = (int *) malloc ( n*sizeof(int))) == NULL ) {
printf(" no adequate memory \n");
exit(0); }
if ( (y = (int *) malloc ( n*sizeof(int))) == NULL ) {
printf(" no adequate memory \n");
exit(0); }
if ( (z = (float *) malloc ( n*sizeof(float))) == NULL ) {
printf(" no adequate memory \n");
exit(0); }
if ( (tx = (float *) malloc ( n*sizeof(float))) == NULL ) {
printf(" no adequate memory \n");
exit(0); }
if ( (ty = (float *) malloc ( n*sizeof(float))) == NULL ) {
printf(" no adequate memory \n");
exit(0); }
if ( (tl = (float *) malloc ( n*sizeof(float))) == NULL ) {
printf(" no adequate memory \n");
exit(0); }
u=0;v=0;
w=0.0;

for(i=0;i<n;i++){
fscanf(inp,"%i%i%f",&u,&v,&w);
*(x+i) = u;
```

```

*(y+i) = v;
*(z+i) = w;
L[u][v]= w;
}
for(i=0;i<n;i++){
if(*(x+i) < mx) mx = *(x+i);
if(*(x+i) > Mx) Mx = *(x+i);
if(*(y+i) < my) my = *(y+i);
if(*(y+i) > My) My = *(y+i);
}
fprintf(outp1," %i %i %i %i \n", mx, Mx, my, My);
for(i=mx; i<= Mx; i++)
for(j=my; j<= My;j++){

fprintf(outp1,"%i %i %f \n",i,j, L[i][j]);

}

np =0;
for(i=0; i<= Mx; i++)
for(j=0; j<= My; j++) {

if(L[i][j] != -1.0 {
*(tx+np) = (float) i;
*(ty+np) = (float) j;
*(tl+np) = L[i][j];
fprintf(outp1,
" seleted %i %f %f %f \n", np, *(tx+np), *(ty+np), *(tl+np));
np++;
}
}
}

```

```
}  
}
```

```
rmserr = bestplane(np,tx,ty,tl,coef)/30.0;  
sl = sqrt(coef[0]*coef[0]+coef[1]*coef[1]);  
slope = sl/(float) 30;
```

```
fprintf(outp1,  
"complete land: coef[0] = %f,coef[1]= %f,sl =%f,slope= %f,rmserr =%f",  
coef[0],coef[1],rmserr,sl,slope);  
if ( coef[2] < 0 ) fprintf(outp1,"negative slope\n");  
else    fprintf(outp1,"postive slope\n");  
fprintf(outp1,"class_s  
=%i,class_u=%i\n",class_s(slope),class_u(rmserr));
```

```
size=1;
```

```
while(size) {
```

```
/* now processing for smaller land pieces */
```

```
fprintf(outp2,"\n ----- %i m * %i m---- \n", 60*size , 60*size);
```

```
np=0;
```

```
for(i=size;i< Mx; i++)
```

```
for(j=size;j< My; j++){
```

```
np=0;
```

```
for(l=i-size;l<=i+size;l++)
```

```
for(k=j-size;k<=j+size;k++){
```

```
if(L[l][k]!= -1.0)
```

```
{
```

```
*(tx+np)= (float)l;
```

```
*(ty+np)= (float) k;
```

```

*(tl+np)= L[i][k];
//printf("selected %i, %f, %f, %f\n",np,tx[np],ty[np],tl[np]);
np++;
}
}
if(np > 2*size+1){
fprintf(outp2," %i %i ", i, j );

```

/* z is measured in meters whereas x , y are measured in grid units 1 unit = 30 m, Hence it is necessary to normalize rmserr so that it is dimensionless by converting it to the same unit in which x and y are measured hence we use rmserr = rmserr as returned by bestplane/30 */

```

rmserr=bestplane(np,tx,ty,tl,coef)/30.0;
sl=sqrt(coef[0]*coef[0]+coef[1]*coef[1]);
slope= sl/30;

```

```

fprintf(outp2,"%f %f ",slope, rmserr );
fprintf(outp2," %i %i",
(slp[i][j]=class_s(slope)),(und[i][j]=class_u(rmserr)));
if ( coef[2] < 0 ) fprintf(outp2,"negative slope\n");
else      fprintf(outp2,"postive slope\n");

```

```

}
}

```

```

for(i=size;i< Mx; i++)
for(j=size;j< My; j++)
TL[i][j] = L[i][j];
for(p=2;p<5;p++) {
printf(" slope bracket %i - %i \n", p-1, p);

```

```

for(i=0; i<= Mx; i++){
for(j=0; j<= My;j++)
if (L[i][j] != -1.0)
if ( (slp[i][j] == p || slp[i][j] == p-1)&&(und[i][j]==1))
printf(" * ");
else { printf(" "); TL[i][j] = -1; }
else printf(" . ");
printf("\n");
}
A =0.0; PA=0.0;
/* Now calculating area */
for(i=0; i<= Mx; i++)
for(j=0; j<= My;j++) {
a = 0.0; pa=0.0;
if(TL[i][j] > 0 && TL[i][j+1] > 0 && TL[i+1][j] > 0 && TL[i+1][j+1] > 0){
a = area((float)i,(float)i,(float)(i+1),(float)j,(float)(j+1),
(float) j, TL[i][j],TL[i][j+1],TL[i+1][j])
+area((float)(i+1),(float)i,(float)(i+1),(float)j,(float)(j+1),
(float)(j+1),TL[i+1][j],TL[i][j+1],TL[i+1][j+1]);
pa = 1.0; }
else
if(TL[i][j] > 0 && TL[i][j+1] > 0 && TL[i+1][j] > 0)
{ a = area((float)i,(float)i,(float)(i+1),(float)j,(float)j,
(float) j+1,TL[i][j],TL[i][j+1],TL[i+1][j]);
pa = 0.5;}
else
if(TL[i][j] > 0 && TL[i][j+1]> 0 && TL[i+1][j+1] > 0 ){
a= area((float)i,(float)i,(float)(i+1),(float)j,(float)(j+1),
(float)(j+1),TL[i][j],TL[i][j+1],TL[i+1][j+1]);
pa = 0.5;}

```

```

else
if(TL[i][j]> 0 && TL[i+1][j] > 0 && TL[i+1][j+1]> 0 ){
a= area((float)i,(float)(i+1),(float)(i+1),(float)j,(float)j,(float)(j+1),
TL[i][j],TL[i+1][j],TL[i+1][j+1]);
pa = 0.5; }
else
if(TL[i][j+1] > 0 && TL[i+1][j] > 0 && TL[i+1][j+1] >0){
a=area((float)i,(float)(i+1),(float)(i+1),(float)(j+1),(float)j,
(float)(j+1),TL[i][j+1],TL[i+1][j],TL[i+1][j+1]);
pa = 0.5; }
A = A + a;
PA = PA + pa;}
printf(" total area(actual) %f ha total projectd area %f ha\n",
A, PA*0.09);
getchar();
}
printf(" current size is  %i \n", size);
printf(" next size please ? 0 to stop ");
scanf("%i",&size);
}
free(x);
free(y);
free(z);
free(tx);
free(ty);
free(tl);
ifclose(outp2);
fclose(outp1);
fclose(inp);
return 0;

```

```
}  
/*the following function is used to classify land according to slope*/  
/*1=nearly level land */  
/*2=gently sloppy */  
/*3=modrately sloppy */  
/*4=strongly sloppy */  
/*5=moderately steep */  
/*6=steep slope */  
/*7=very steep */  
/*8=very very steep */  
int class_s(float slope)  
{  
if(slope <= 0.01)  
return(1);  
if(slope <=0.03)  
return(2);  
if(slope <=0.05)  
return(3);  
if(slope <=0.10)  
return(4);  
if(slope <=0.15)  
return(5);  
if(slope <=0.25)  
return(6);  
if(slope <=0.33)  
return(7);  
if(slope >0.33)  
return(8);  
return 0;  
}
```

```

/*the following function is used to classify land according to
undulations */
/*    1=no undulations */
/*    2=gently undulating */
/*    3=moderately undulating */
/*    4=strongly undulating */
/*    5=highly undulating */
/*    6=very highly undulating */
int class_u(float rmserr)
{
if(rmserr <=0.05)
return(1);
if(rmserr <=0.10)
return(2);
if(rmserr <=0.20)
return(3);
if(rmserr <=0.30)
return(4);
if(rmserr <=0.40)
return(5);
if(rmserr > 0.40)
return(6);
return 0;
}
/*program to determine the triangle area is as follows*/
/*if level of three points in a grid is -1 then a=0,*/
/*if level of two points either x or y are same is -1 then a=0,*/
/*if level of one point in a grid is -1 then a=1/2,*/
/*if there is no any point in grid with -1 then a=1 */
/* area formula */

```

```
float area(float x1, float x2, float x3,  
float y1, float y2, float y3,  
float z1, float z2, float z3)  
{  
float s1, s2, s3, s, a=0.0;  
s1=sqrt(((x2-x1)*(x2-x1)+(y2-y1)*(y2-y1))*900.0+(z2-z1)*(z2-z1));  
s2=sqrt(((x3-x2)*(x3-x2)+(y3-y2)*(y3-y2))*900.0+(z3-z2)*(z3-z2));  
s3=sqrt(((x3-x1)*(x3-x1)+(y3-y1)*(y3-y1))*900.0+(z3-z1)*(z3-z1));  
s=(s1+s2+s3)/2.0;  
a=sqrt(s*(s-s1)*(s-s2)*(s-s3))/(10000.0);  
return a;  
}
```

APPENDIX- II

```
/*program to represent land with colors*/
#include <graphics.h>
#include <stdlib.h>
#include <stdio.h>
#include <conio.h>
sint main(void)
{
/* request auto detection */
int gdriver = DETECT, gmode, errorcode;
int i,j,p,s,t,mx,Mx,my,My,n;
float u,v;
FILE *inp;
inp = fopen("class_su","r");
fscanf(inp,"%i%i%i%i",&mx,&Mx,&my,&My);
printf("%i%i%i%i\n",mx,Mx,my,My);
fscanf(inp,"%i",&n);
printf("%i\n",n);
getch();
/* initialize graphics and local variables */
initgraph(&gdriver, &gmode, "");

/* read result of initialization */
errorcode = graphresult();
if (errorcode != grOk) /* an error occurred */
{
printf("Graphics error: %s\n", grapherrormsg(errorcode));
printf("Press any key to halt:");
getch();
}
```

```

exit(1); /* terminate with an error code */
}
setcolor(15);
rectangle((mx+1)*25,(my+1)*25,(Mx+1)*25,(My+1)*25);
getch();
for(i=0; i<n ; i++) {
fscanf(inp, "%i%i%f%f%i%i",&j,&p,&u,&v,&s,&t);
if((s== 2|| s== 1)&&(t==1))
{ setcolor(2);
// printf("***");
rectangle( (j+1)*25 -10,(p+1)*25-10,(j+1)*25+10, (p+1)*25+10) ;}

else{ setcolor(4);
rectangle( (j+1)*25-10, (p+1)*25-10,(j+1)*25+10,(p+1)*25+10);
}

}
printf("graphic representation of land according to slope &
undulations.");
getch();
closegraph;
return 0;
}

```

APPENDIX-III

Survey data of M.A.U. Watershed

| |
|------------|
| 0 0 100 |
| 4 0 98.78 |
| 5 0 98.66 |
| 6 0 98.10 |
| 7 0 98.38 |
| 8 0 98.38 |
| 9 0 98.42 |
| 10 0 98.0 |
| 11 0 96.30 |
| 12 0 96.37 |
| 13 0 95.60 |
| 14 0 95.12 |
| 15 0 94.31 |
| 16 0 93.97 |
| 17 0 93.8 |
| 18 0 92.94 |
| 19 0 92.15 |
| 20 0 92.05 |
| 21 0 88.11 |
| 22 0 88.54 |
| 23 0 87.46 |
| 24 0 -1 |
| 25 0 86.44 |
| 26 0 86.22 |
| 27 0 86.71 |
| 28 0 86.0 |
| 29 0 84.50 |
| 30 0 84.37 |
| 31 0 84.32 |
| 32 0 84.59 |
| 33 0 84.04 |
| 34 0 84.59 |
| 35 0 84.75 |

| |
|------------|
| 36 0 81.05 |
| 0 1 100.21 |
| 1 1 99.60 |
| 2 1 99.57 |
| 3 1 99.46 |
| 4 1 99.79 |
| 5 1 -1 |
| 6 1 -1 |
| 7 1 98.38 |
| 8 1 98.82 |
| 9 1 97.78 |
| 10 1 97.43 |
| 11 1 99.18 |
| 12 1 99.22 |
| 13 1 97.70 |
| 14 1 96.82 |
| 15 1 96.39 |
| 16 1 95.58 |
| 17 1 94.78 |
| 18 1 94.14 |
| 19 1 93.74 |
| 20 1 93.25 |
| 21 1 92.59 |
| 22 1 92.18 |
| 23 1 91.63 |
| 24 1 89.36 |
| 25 1 88.25 |
| 26 1 87.11 |
| 27 1 86.92 |
| 28 1 86.69 |
| 29 1 86.98 |
| 30 1 85.55 |
| 31 1 84.77 |

| |
|------------|
| 32 1 84.20 |
| 33 1 84.34 |
| 34 1 83.90 |
| 35 1 84.49 |
| 36 1 83.93 |
| 37 1 84.36 |
| 38 1 84.62 |
| 39 1 80.62 |
| 0 2 99.56 |
| 1 2 99.17 |
| 2 2 98.68 |
| 3 2 98.42 |
| 4 2 98.99 |
| 5 2 -1 |
| 6 2 -1 |
| 7 2 97.26 |
| 8 2 97.61 |
| 9 2 97.01 |
| 10 2 96.41 |
| 11 2 97.93 |
| 12 2 97.35 |
| 13 2 97.20 |
| 14 2 99.99 |
| 15 2 96.12 |
| 16 2 95.12 |
| 17 2 94.55 |
| 18 2 93.90 |
| 19 2 93.48 |
| 20 2 92.97 |
| 21 2 92.39 |
| 22 2 90.05 |
| 23 2 91.65 |
| 24 2 89.04 |

| |
|------------|
| 25 2 88.34 |
| 26 2 87.59 |
| 27 2 87.14 |
| 28 2 86.87 |
| 29 2 86.39 |
| 30 2 85.77 |
| 31 2 84.95 |
| 32 2 84.33 |
| 33 2 84.20 |
| 34 2 84.04 |
| 35 2 84.13 |
| 36 2 83.93 |
| 37 2 84.13 |
| 38 2 84.57 |
| 39 2 81.06 |
| 0 3 99.74 |
| 1 3 99.30 |
| 2 3 99.10 |
| 3 3 98.31 |
| 4 3 98.33 |
| 5 3 97.73 |
| 6 3 96.69 |
| 7 3 96.82 |
| 8 3 96.66 |
| 9 3 95.90 |
| 10 3 96.95 |
| 11 3 96.58 |
| 12 3 96.20 |
| 13 3 99.47 |
| 14 3 96.02 |
| 15 3 95.58 |
| 16 3 95.08 |
| 17 3 94.49 |

| | |
|------|-------|
| 18 3 | 93.99 |
| 19 3 | 93.35 |
| 20 3 | 92.77 |
| 21 3 | 92.25 |
| 22 3 | 91.50 |
| 23 3 | 89.19 |
| 24 3 | 88.36 |
| 25 3 | 87.83 |
| 26 3 | 87.20 |
| 27 3 | 87.35 |
| 28 3 | 86.70 |
| 29 3 | 85.75 |
| 30 3 | 84.70 |
| 31 3 | 84.20 |
| 32 3 | 84.10 |
| 33 3 | 84.17 |
| 34 3 | 84.19 |
| 35 3 | 84.39 |
| 36 3 | 84.04 |
| 37 3 | 84.63 |
| 38 3 | 80.71 |
| 0 4 | 99.59 |
| 1 4 | 98.94 |
| 2 4 | 98.23 |
| 3 4 | 97.76 |
| 4 4 | 97.34 |
| 5 4 | 97.44 |
| 6 4 | 97.03 |
| 7 4 | 96.09 |
| 8 4 | 96.05 |
| 9 4 | 95.88 |
| 10 4 | 95.23 |
| 11 4 | 96.67 |
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| 15 4 | 95.26 |
| 16 4 | 95.16 |

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| 4 5 | 96.57 |
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| 6 5 | 96.25 |
| 7 5 | 95.38 |
| 8 5 | 95.18 |
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| 13 5 | 95.26 |
| 14 5 | 94.96 |
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| 38 5 | 83.74 |
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| 7 6 | 94.59 |
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| 10 6 | 94.00 |
| 11 6 | 95.63 |
| 12 6 | 94.92 |
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| 37 6 | 83.76 |
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| 39 6 | 81.61 |
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| 4 7 | 95.31 |
| 5 7 | 95.09 |
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| 8 7 | 93.79 |
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| 26 7 | 87.24 |
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| 21 8 | 90.45 |
| 22 8 | 90.20 |
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| 13 15 | 90.59 |
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| 15 15 | 89.00 |
| 16 15 | 88.65 |
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| 18 15 | 88.48 |
| 19 15 | 88.33 |
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| 25 19 | 88.02 |
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