DESIGN AND SIMULATION OF SOIL SAVING DAMS IN THE MOUNTAINOUS AREAS BY USING GIS WITH DIGITAL ELEVATION MAP

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ABSTRACT

Landslide, debris flow, snow-slide arise every year in Japan, and precious property and life have been lost. Ministry of Construction and local government of Japan hurry up the installation of the sand control facilities ,for example soil saving dam, by the sand control plan in order to prevent the disaster. However, it is also necessary to consider the natural environment, when soil saving dam is constructed.

The purpose of the research is that management and sand control plan of the sand control facilities simulates by using the Geographic Information System(GIS). On the simulation, digital map data which could cheaply and simply obtain was used. Enormo us funds are required they in that 1/500 vector data (contour line) are made. It is one of the reason why we starts the rescerch. In the study, the following data were used. There are digital map data of 50m mesh (elevation) and 1/25000 raster maps. One of the reasons for utilizing digital data is because there is a prediction that will come to be able to utilize the high resolution satellite data in the near future.

As a result of the simulation using the 50m mesh data (elevation), transferable sediment and transportable sediment were more dangerous than actual plan. Sedimentary depth of the average calculated by the 50m mesh was very small value. By this receiving result, we made 10m mesh data from 50m mesh data. The most remarkable result of the research is to obtain vector data of the contour line from 50m mesh and original 10m mesh digital data. It is possible to estimates that number of soil saving dam and constructing place automatically decide using the geographic information system, when developed algorithm is used.

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Figure 1. The landslide disaster which local severe rain caused. (July 11,1995 Nagano Pref. Japan)

Figure 2. Soil saving dam (SABO dam)

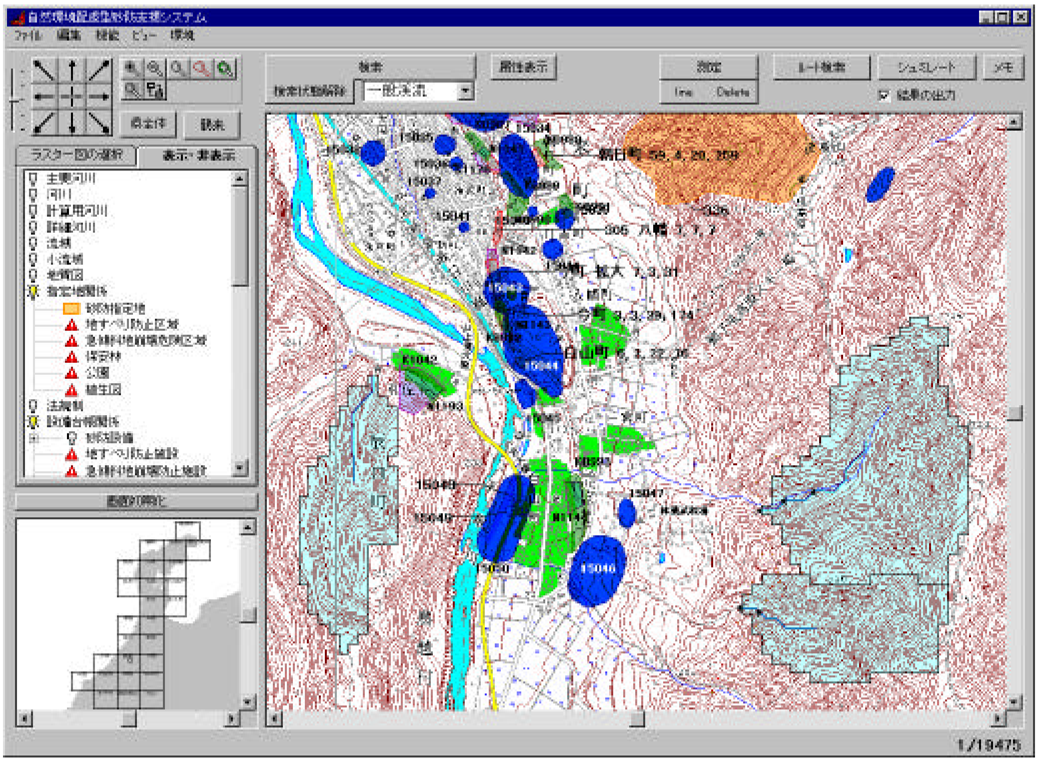


Figure 3. Main Frame of Pilot System

1. OUTLINE OF SYSTEM

Figure. 1 shows houses run in the local severe rain. Figure.2 shows the soil saving dam (SABO dam) in the

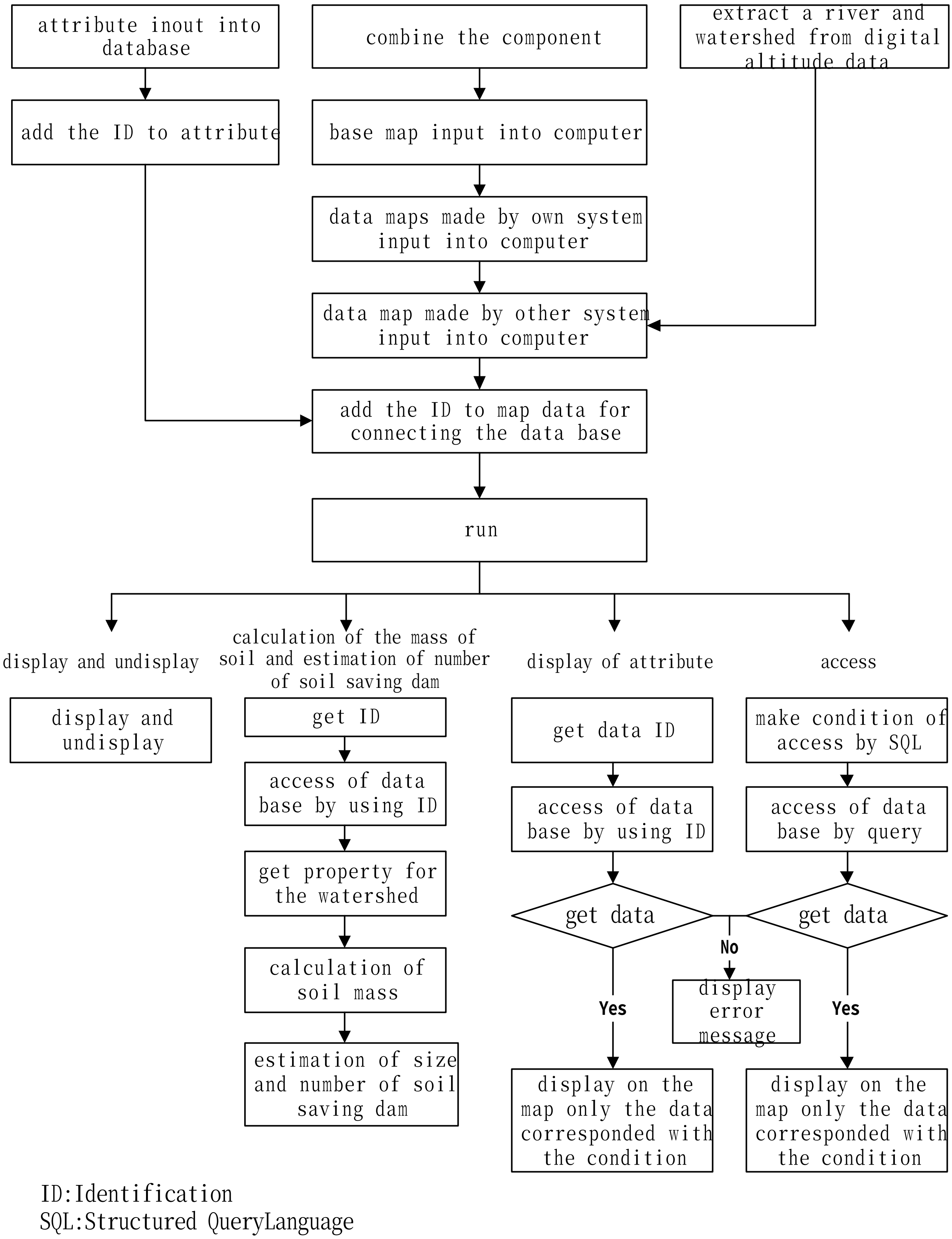


Figure 4. Flow of developed simulation system

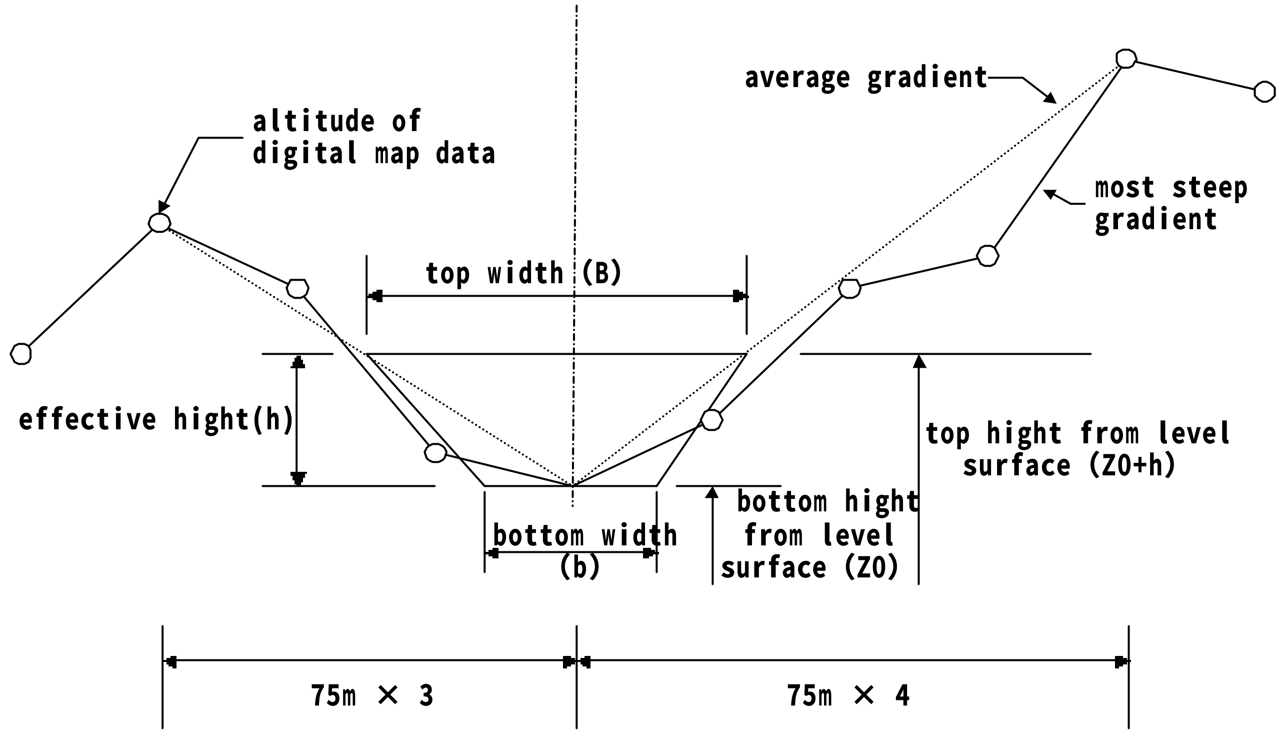


Figure 5. Cross section of Sabo dam calculated from 50m DTM

mountainous area. The system uses for administration of Sabo dam, extraction of environmental information and support of Sabo planning by estimating the mass of earth and location of the Sabo dam. In developed system, the first Sabo dam would be set in SP. It is repeated, until the maintenance rate becomes 100% for the calculation of the facilities effect quantity for the upstream.. Simulation adopted a mountain stream of TSURUGI district where have many disasters such a landslide as an example areas. The system needs about 1/500 digital elevation data on the simulation . In the mountainous region ,however, it has a lot of cost to produce digital map. We use digital map data (DEM) of 50m mesh and 25000-raster map that are easy to obtain. These simulations make those parameters for Sabo dam by using 50m mesh. Parameters are

1) Watershed
2) Drainage area
3) Stream
4) Length of river channel
5) Width of river bed
6) Slope of river bed
7) Width of bottom for dam body

By using the parameter from 1 to 7, sediment load and number of the necessary dam calculate it. The system shows location and sectional plan of dam. System decides the values of parameter which was estimated by expert engineers. The result seems to be not different, even if the human whom it calculates using the system changes on this system. To use standardized digital maps, system can adopt anywhere in Japan. Figure 3 shows the main frame of the system. Figure 4 shows the flowchart of the system. Figure 6 shows topographic feature of simulation condition.

2. DETAILED CALCULATION OF PARAMETERS

1)Le:Length of River Channel, A:Drainage Area

・Le and A estimate from digital elevation map using GIS software.

2) θ :Slope of River Bed

・ θ is changed to the gradient between upstream 225m from SP and SP.

・The line is pulled from SP in the manual, and it is moved to the upstream along the line.

3) Crown Width

・Crown width is calculated as a variable for calculating the width of the river bed.

・The average gradient of right bank and left bank is calculated.

・An elevation of SP is calculated.

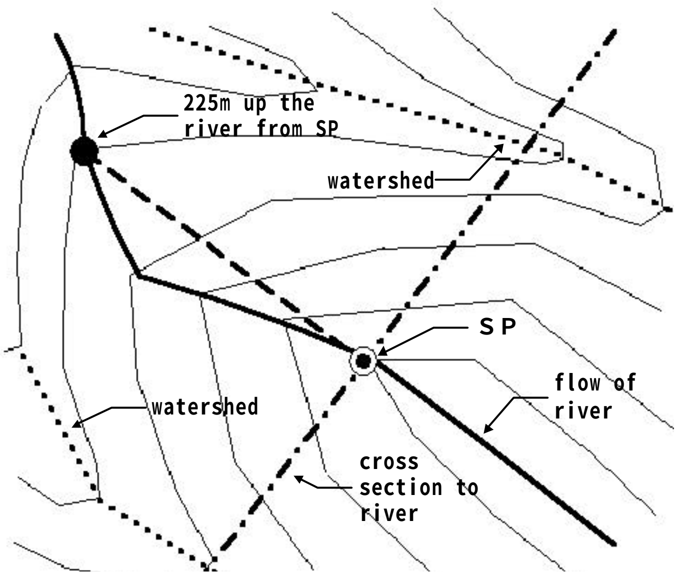


Figure 6 Topographic Feature

・ Top width is shown by the intersection point between right bank at the altitude of Z and altitude of left bank average gradient and altitude.

4)Left and Right Bank Slope

・The gradient of the mountainside is normal line gradient which is right-angled for the direction of the flow.

・The normal line is made to be intersection point with boundary line of watershed.

・SP becomes an origin for the gradient, and it calculates it to boundary line of watershed .

5)Width of Bottom for Dam Body

・By using the result from 1 to 4, Width of Bottom calculates it.

・Width of Bottom is required in the intersection point between largest gradient and altitude in SP.

6) Iteration of Calculation

・Calculation of Q (Q is sediment Load)

・Calculation of V2 at SP (V2 is Sediment volume at the design slope)

・If (Q-V2) is plus, SP move to upper stream (L2*1.2m) and continue iteration.

・The iteration is stopped, when (Q-V2) becomes following Xth.

(Q-V2) < 0 : Iteration is stopped at Xth.

(Q-V2) < 0.1*Q : Iteration is stopped at (X+1)th.

3. DISPOSITION OF SABO DAM BY THE SIMULATION

Figure.7 shows the automatically extracted watershed from 50m DTM by GIS software at that of pre-processing. For example, results of these simulation shows the figure 8. Left figurer shows watershed area, location of simulated Sabo dam and elevation data got from digital map. Right figurer shows cross section model of mountain

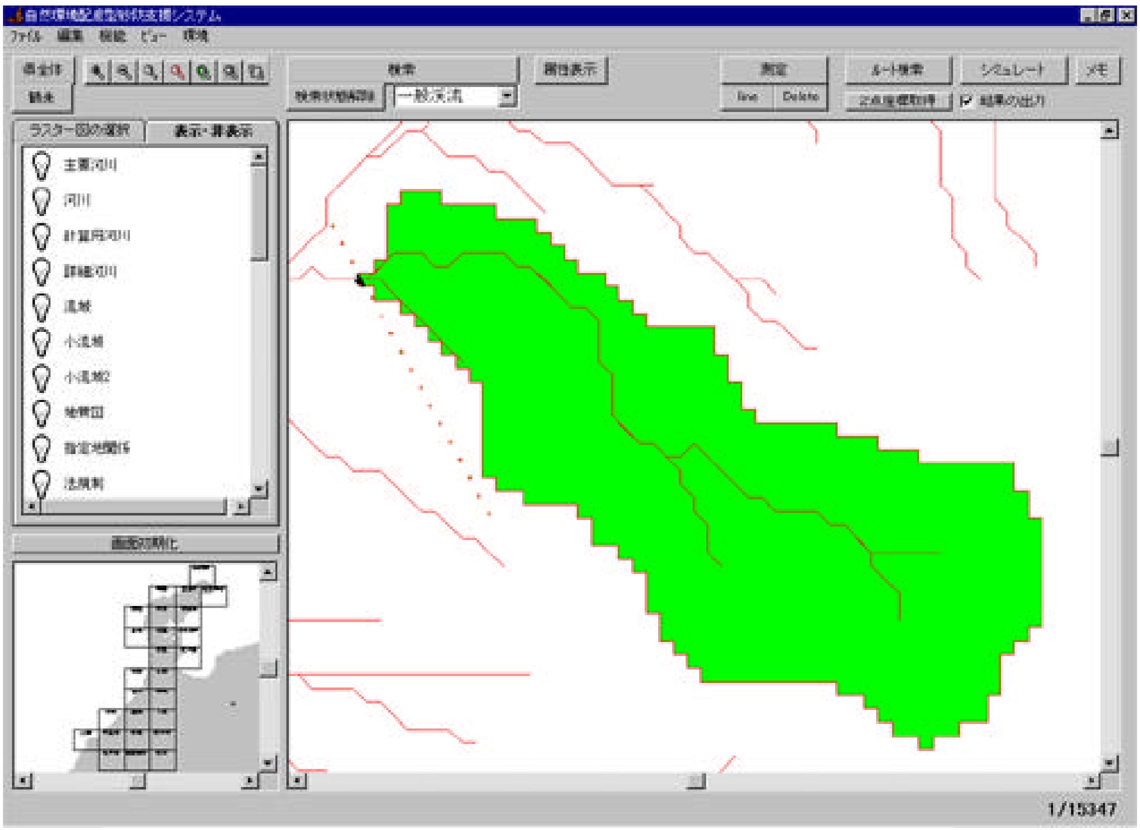


Figure.7 Watershed area calculated from 50m DTM

stream which was simulated at point SP.

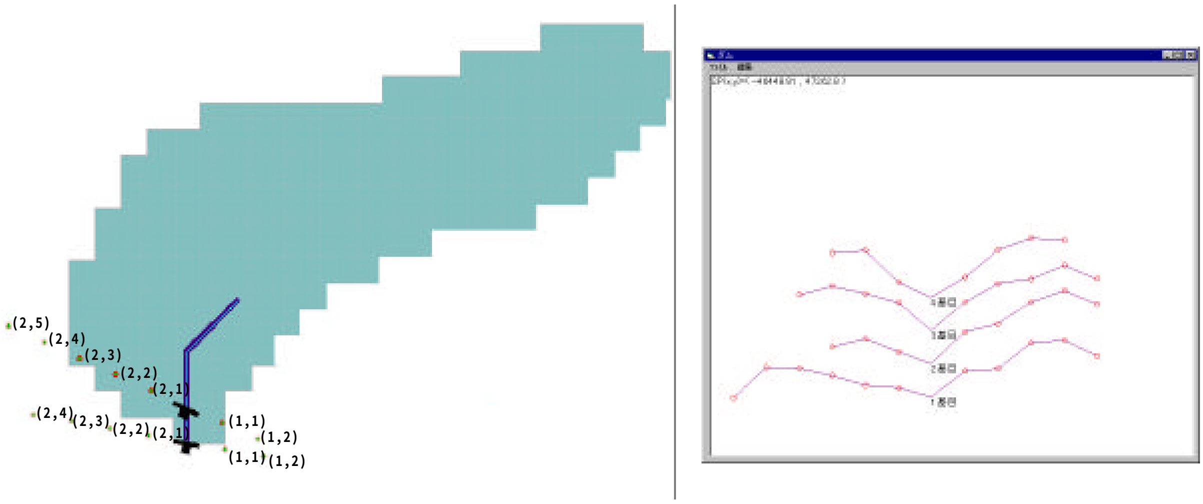


Figure 8. Results of Simulation

4. ADOPT 10M MESH DATA

Digital elevation maps which was published by Geographical Survey Institute of Japan is only 250m and 50m mesh data. We used 50m mesh data. However, there was a problem in order to use the data of the 50m mesh. The problem is like the following.

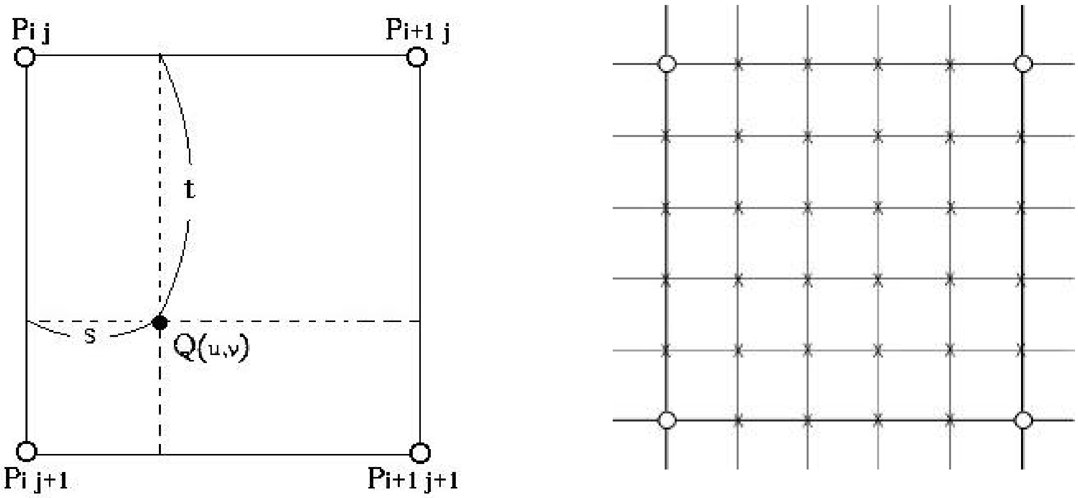
a. The width can not design the dam of 50m or less.

b. The value of the parameter which is correct, since the interval of the elevation data is wide, is not obtained.

We take note of utilization of High Resolution Satellite which was launched in the September 1999. The purpose of this research is to confirm whether it can solve the problem by improving the mesh data.

10m mesh data created by Bi-Linear from 50m mesh data. The equation of Bi-Linear as be shown in the following.

$$Q(u,v)=(1-s)(1-t)P_{i\,j}+(1-s)tP_{i\,j+1}+s(1-t)P_{i+1\,j}+stP_{i+1\,j+1} \tag{12}$$



○ - 50m mesh data × - 10m mesh data

Figure 9. Interpolation of Mesh Data

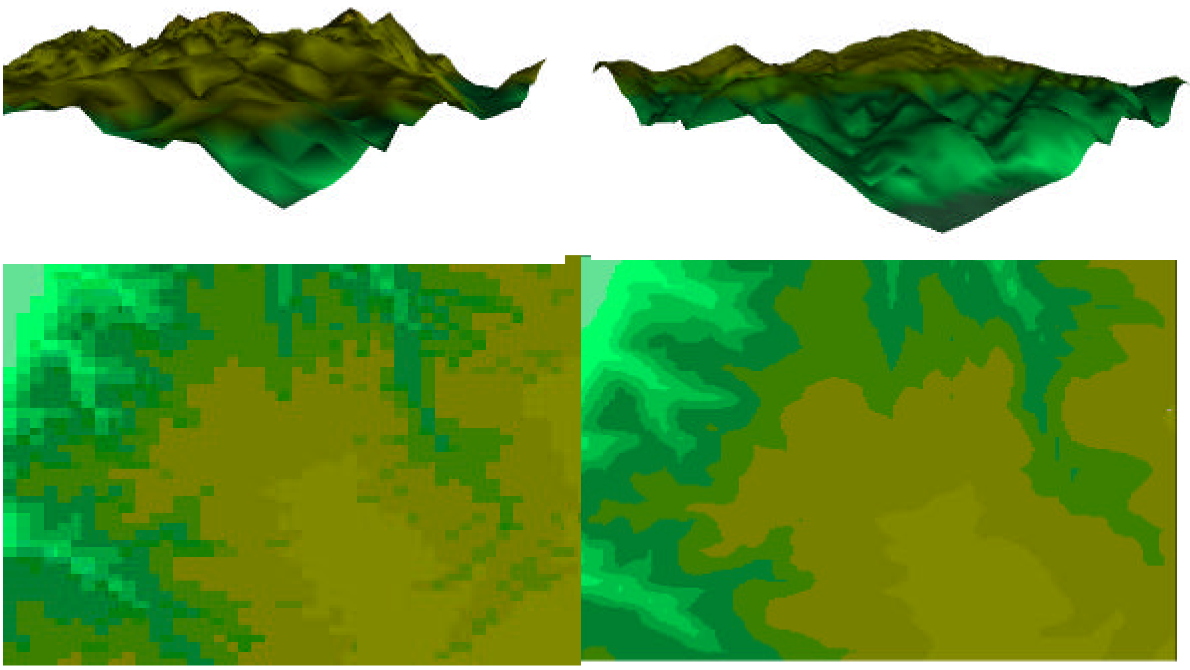


Figure 10. Comparison of 50m and 10m DTM data

Table 1. Comparison of calculated parameters among practice 50m mesh and 10m mesh

			Practice	50m mesh	10m mesh
Drainage area	A	km^2	1.430	1.410	1.430
length of river channel	Le	m	3,400	3,528	3,955
Slope of river bed	θ	°	7.600	4.500	10.000
Width of river bed	B	m	5.000	1.500	12.221
Depth of sediments	De	m	1.400	6.422E-02	1.024
Coefficient of discharge	f		0.613	0.326	0.329
Sediment concentration	C_*		0.600	0.137	0.356
Design daily rainfall	R_{24}	mm	237.000		
Angle of internal friction	Φ	°	30.000		
Voids in total mix	λ		0.400		
Unit weight of debris flow	ρ_n	tf/m^3	1.200		
Unit weight of gravels	σ	tf/m^3	2.600		
Suspended load	Ve	m^3	30,400	353	49,485
Bed load	Vec	m^3	53,300	29,280	103,562

5. COMPARISON OF 50M AND 10M MESH DATA

Space of elevation data change from 75m to 15m. Distance of 75m is more than 50m* √2 to get different elevation data which adjoined mesh point. Because the used system treats mesh data as grid. Distance of 15m is more than 10m* √2.

Table 1 shows the parameters which can get values of the existing dams and simulated dams by using 50m mesh and 10m mesh data respectively. As a results parameters which was calculated from 50m mesh data has dangerous value compare with actual data. Suspended load and bed load are proportional to each parameters. It is a cause on the value of sediment load becoming dangerous. Depth of sediments at 50m mesh has very small value. In the system, depth of sediments estimated from crossfall. DEM with the high accuracy are necessary in order to accurately express the topographic feature.

6. CONCLUSIONS

In this paper our purpose focused to evaluate the place where the soil saving dam will construct in valley. First objection of the research is to estimate the number and the place of soil saving dam. Costs can be reduced, if the Sabo dam is simulated by this system, and the design considered in the environment is also possible. The result which the simulation using 10m altitude data was more correct than the simulation using 50m altitude data was obtained. 10m data was also closer to the value of the actuality on the calculated value of sediment volume. Therefore, it was proven that the calculation of the sediment volume of the Sabo dam could be preliminarily carried out by GIS system. Next stage will consider to use remote sensing data of high resolution. It will be possible to also easily carry out the analysis concerning the environment, if the satellite image is utilized.

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REFERENCES

1) J. Yamashita and M. Shikada et al.,”Erosion Control and Environmental Assessment by Using GIS”,Proc. of the Thirteenth International Conference on Applied Geologic Remote Sensing, p.II89-II96,March 1999.

2) M. Shikada and J. Yamashita et al., “An Application of GIS Information and Remotely Sensed Data for Valley Areas,” In International Symposium on Resouce and Environmental Monitoring, p.607-614, August 1998.

3) T.Kusaka,M.Otsuka and M.Shikada,”Discrimination of Landslide Ares Using Satellite Imagery and the Spatial Features of Watershed, Journal of Natural Disaster Science, Vol.20,No.1,1998,pp33-40.

4) M.Shikada,Y.Suzuki,T.Kusaka et.al.,An Application of GIS Information and Remotely Sensed Data for Extraction of Lanslide,IEEE Proc. of IGARSS'97, Vol.1, pp.210-212,1997

5) M.Shikada,T.Kusaka et al.,International Archives of Photogrammetry and Remote Sensing,Vol.16,PartB4,(786/791), Application of GIS and Remote Sensing to Extraction of Landslide Areas.1996

6) M.Shikada,N.Muramatu,T.Kusaka and S.Goto,Extraction of Landslide Areas Using Satellite Remote Sensing and GIS Technology,IEEE Proc. of IGARSS'95, Vol.1, pp.377-379,1995

7) T.Kusaka and M.Shikada, 1993. Inference of Land-slide Areas Using Spatial Features and Surface Temperature of Water- sheds, SPIE Int.Sympo. on Optical Eng. and Photonics Aerospace and Remote Sensing, pp241-246.

8) M.Shikada,T.Kusaka and K.Miyakita, 1992. Extraction of Landslide areas Using MSS Data and Thematic Map DatabaseSystem, International Archives of Photogrammetry and Remote Sensing, Vol.16. Part B4Com.4,pp.386- 391.

9) T.Kusaka,M.Shikada and Y.Kawata, 1992.Extraction of Landslide Areas Using Spatial Features of Topographic Basins,Proc.of IGARSS'92.

10)] A.Takei, 1993 SABO Engineering, BUNEIDO Co,.LTD

11) Japan Society of Civil Engineering, 1980 SABO,Landslide and Dangerous areas for steep Slope, GHIHOUDO Book Company Co,.LTD

12) ESRI, 1991. ARC/INFO Command References