SEDCON: A MODEL OF NUTRIENT AND HEAVY METAL LOSSES IN SUSPENDED SEDIMENT

by

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INTRODUCTION

A prototypical computer simulation model has been developed to aid watershed managers in estimating impacts of alternative land management practices on nutrient and heavy metal losses due to transported sediment on forested watersheds of the southwestern United States. The model, called SEDCON, allows users at remote locations with modest computer terminal equipment and commonly available data to obtain reliable estimates of nutrient and heavy metal concentrations in suspended sediment originating on uniformly-stocked, forested watersheds in the Southwest. SEDCON has been structured in an interactive mode to facilitate its use by persons not familiar with computer operations. Written in FORTRAN IV computer language, the model requires approximately 5000 words of core. SEDCON is operative on a DEC-10 computer at the University of Arizona.

FORMULATION OF SIMULATION TECHNIQUE

A study by Gosz, White, and Ffolliott (1979a, 1979b, 1980) found that combinations of given geologic and vegetative types (other factors of the physical environment were assumed to be reflected by the vegetative type) produce characteristic weathering regimes that influence the physical and chemical characteristics of transported sediment. Using the source data base collected in this study and other appropriate background sources, SEDCON was formulated to estimate nutrient and heavy metal loss by suspended sediment concentrations derived from ponderosa pine and mixed conifer forested watersheds in the southwestern United States (Gabbert, 1982). Geologies evaluated included basalt, sandstone, limestone, and granite. Most of the study areas have been utilized as watershed research areas (Figure 1).

In formulating SEDCON, it was important to select data sets representative of sediment transported during stream flow. Chemical compositions of transported sediments collected in settling tanks on a control watershed (Beaver Creek Watershed Number 19) were compared with sediments taken from the stream channel on one of the study areas (Beaver Creek Watershed Number 13). This comparison was made to determine whether the data used in the computer model were representative of sediment actually transported during stream flow. Geology and vegetation were similar on both watersheds (Gosz, White, and Folliott, 1979a, 1979b, 1980; Gabbert, 1982).

Overall, the results of the above-mentioned comparison support the hypothesis that representative values of transported sediment concentrations can be obtained by sampling channel sediments (Gosz, White, and Ffolliott, 1979a, 1979b, 1980; Gabbert, 1982). As a result, stream channel data were used in the formulation of SEDCON (Gabbert, 1982).

Gosz, White, and Ffolliott (1979a, 1979b, 1980) found that concentrations of chemical constituents varied among soils: under the forest canopy, on stream banks, and in stream channels. Thus, it is important to remember that errors could result when using SEDCON to simulate nutrient and metal loss by transported sediment on disturbed or geologically unstable areas (which could result in bank and surface erosion). Likewise, the model should not be used to simulate losses caused by extreme runnoff events (which also result in bank and surface erosion), as the data could prove to be unrepresentative (Gabbert, 1982).

Chemical constituents transported by suspended sediments in a mixed-conifer forest (Thomas Creek) and a ponderosa pine forest (Beaver Creek) were compared to determine whether the effects of vegetation on nutrient and metal content of sediment could be separated from the effects of geology. Both watersheds were located on similar bedrock. The results of this comparison indicated that it would be difficult to quantify the effects of vegetation. Thus, SEDCON should only be used to estimate nutrient and heavy metal loss on watersheds comprised of: ponderosa pine forests on basalt, granite, sandstone, or limestone; and mixed conifer forests on basalt (Gabbert, 1982).

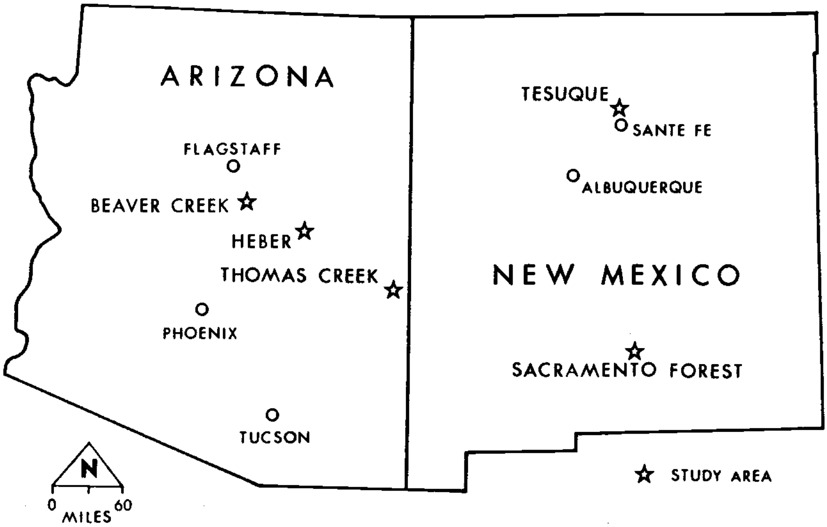

Figure 1. Location of study areas.

Predictive equations were developed for each of the above-listed vegetative types and geologies. These equations, which were incorporated into SEDCON, compute 90 percent confidence intervals. General forms of the equations were:

<u>Lower Limit</u>

$$Y_1=a_1X_s + b_1X_f$$

where Y_1=lower limit (ppm) of constituent concentration.

a_1=lower limit coefficient for sand fraction.

b_1=lower limit coefficient for fine fraction.

X_s=percent sand in the sediment.

X_f=percent fines in the sediment.

<u>Upper Limit</u>

$$Y_2=a_2X_s + b_2X_f$$

where Y_2=upper limit (ppm) of constituent concentration.

a_2=upper limit coefficient for sand fraction.

b_2=upper limit coefficient for fine fraction.

In the above equations, it is important to note that there are separate predictive coefficients for the sand (0.061 mm to 2.0 mm) and fine (less than 0.061 mm) fractions of sediment. This separation was essential since Gosz, White, and Ffolliott (1979a, 1979b, 1980) found that constituent concentrations of sediment vary between sands and fines.

APPLICATION OF MODEL

To encourage use of SEDCON, a readily understandable framework was constructed. An illustration of this framework, a simplified flowchart of activities executed in the model, is presented in Figure 2.

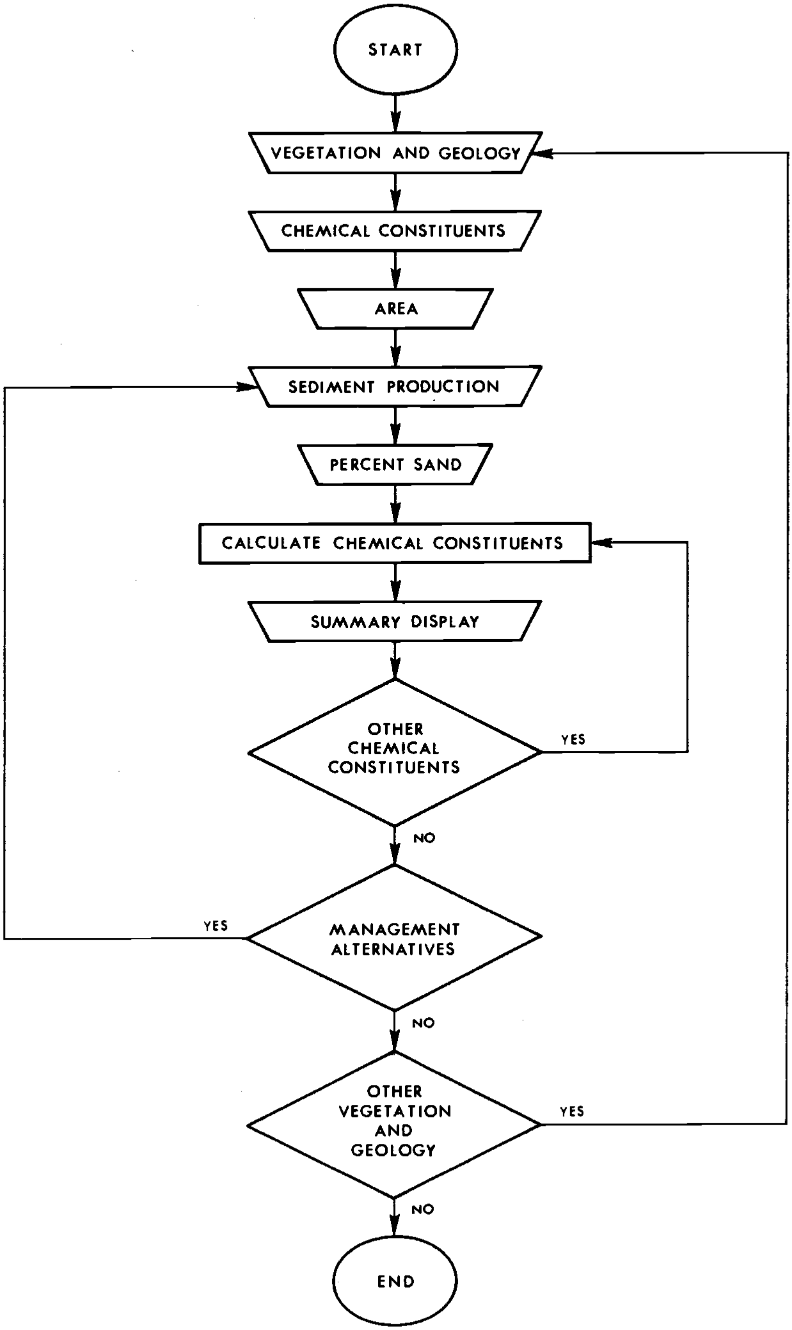

Figure 2. Flowchart of SEDCON.

Application of SEDCON can best be demonstrated with a hypothetical example (Figure 3). Operation begins with a question as to which VEGETATIVE TYPE AND GEOLOGY is to be considered. In this example, ponderosa pine forest on basalt was selected.

Next, a list of available TRANSPORTED CHEMICAL CONSTITUENTS is presented. In the example, the terminal operator chose to evaluate all of the constituents. WATERSHED AREA (ACRES), 400 acres, was input next (Figure 3).

The user must then specify whether WINTER OR SUMMER SEDIMENT is to be evaluated. Winter sediments are those that orginate from runoff produced by snowmelt or rain-on-snow events. Summer sediments originate from runoff produced by thunderstorms. Winter sediments were evaluated in this example. Next, SEASONAL SEDIMENT PRODUCTION (POUNDS PER ACRE) was input at 40 pounds per acre (Figure 3).

SEDCON is not designed to predict sediment production. Instead, this information must be obtained through use of on-site inventory data, appropriate predictive equations, or other simulation models.

An interactive model designed to simulate suspended sediment yields on forested watersheds in central Arizona is available on a DEC-10 computer at the University of Arizona (Rasmussen and Ffolliott, 1979). If desired, this model, called SED, can be linked to SEDCON to provide input data on seasonal sediment production (Gabbert, 1982).

Since concentrations of constituents vary between sands and fines, PERCENTAGE OF SAND in the sediment is requested (Figure 3). Limits have been placed on values that should be selected for PERCENTAGE OF SAND.

Hansen (1966) reported that sands account for 35 to 65 percent of winter suspended sediments. Additionally, he found a mean concentration of 55 percent of the sediments were sand. As a result, 35 and 65 percent have been incorporated into SEDCON as the range for PERCENTAGE OF SANDS in winter sediment.

A default value of 55 percent sands in winter suspended sediments is available. Acceptance of the default value allows simulation to continue when specific knowledge of the input requested is limited. However, the user has the option of overriding the default value. Since winter sediments were evaluated in the example, the default value of 55 percent sands was utilized (Figure 3).

Hansen (1966) found summer suspended sediment samples varying from 0 to 20 percent sand. Thus, 0 and 20 percent sand in summer suspended sediments were used as limits. A default value of 10 percent sand is available.

At this point, SEDCON will calculate and display estimated values of nutrient and heavy metal transport capacity of suspended sediment. The summary display presents values as acid digestable (primary chemical composition of sediment) and extractable (absorbed to the sediment) nutrients and heavy metals (Figure 3).

At this point, the terminal operator can request another value for percent sand, input a different value for seasonal sediment production, evaluate another season, request to have other constituents evaluated, or select another vegetative type. Anywhere in these steps, the operator can exit the model by answering with a -1. In the example, SEDCON was exited when asked if another value for percent sand was desired (Figure 3).

Since SEDCON calculates seasonal losses of nutrients and heavy metals transported by sediments, it is necessary to execute the model twice, once for winter losses and once for summer losses, to obtain an annual loss. This procedure must be followed for each level management alternative to obtain an estimate of the annual loss of nutrients and heavy metals associated with each alternative.

CONCLUSIONS

SEDCON was developed to aid watershed managers and land use planners estimating the loss of sediment transported nutrients and heavy metals. The model accepts basic watershed data on bedrock geology, vegetative type, and seasonal sediment production. By evaluating management alternatives through the seasonal sediment production function and having an understanding of the significance of a change in site productivity, SEDCON can be used by the land manager to estimate the expected consequences of particular management options.

REFERENCES CITED

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Figure 3. Hypothetical example of SEDCON.

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EXECUTE SEDCON


LINK:   Loading
[LNKXCT SEDCON execution]

VEGETATIVE TYPES AND GEOLOGIES ARE:

     1. PONDEROSA PINE FOREST ON BASALT
     2. PONDEROSA PINE FOREST ON SANDSTONE
     3. PONDEROSA PINE FOREST ON LIMESTONE
     4. PONDEROSA PINE FOREST ON GRANITE
     5. MIXED CONIFER FOREST ON BASALT

ENTER NUMBER OF VEGETATIVE TYPE AND GEOLOGY TO BE EVALUATED.
1

TRANSPORTED CHEMICAL CONSTITUENTS ARE:

                              ACID DIGESTABLE

     1. CALCIUM                                      7. COPPER
     2. MAGNESIUM                                    8. MAGANESE
     3. SODIUM                                       9. LEAD
     4. POTASSIUM                                   10. CADIUM
     5. ZINC                                        11. TOTAL NITROGEN
     6. IRON                                        12. TOTAL PHOSPHORUS

                                EXTRACTABLE

    13. CALCIUM                                     16. CATION EXCHANGE CAPACITY
    14. MAGNESIUM                                   17. ORGANIC MATTER
    15. POTASSIUM

    18. ALL ACID DIGESTABLE AND EXTRACTABLE CONSTITUENTS

ENTER NUMBER OF CONSTITUENT(S) YOU WISH TO EVALUATE.
18

WHAT IS WATERSHED AREA IN ACRES?
400

DO YOU WANT TO EVALUATE WINTER(1) OR SUMMER(2) SEDIMENT?
1

WHAT IS WINTER SEDIMENT PRODUCTION IN POUNDS PER ACRE?
40

WHAT IS PERCENT SAND IN SEDIMENT (RANGE:35-65,<CR> GIVES:55)?
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CONSTITUENT	CONCENTRATION (PPM)	VOLUME (POUNDS)
ACID DIGESTABLE		
CALCIUM	3885.- 5910.	62.16- 94.56
MAGNESIUM	18090.- 29440.	289.44- 471.04
SODIUM	381.- 658.	6.10- 10.52
POTASSIUM	895.- 1342.	14.32- 21.47
ZINC	71.- 90.	1.14- 1.43
IRON	57300.- 87050.	916.80- 1392.80
COPPER	58.- 81.	0.94- 1.29
MANGANESE	1018.- 4610.	16.30- 73.76
LEAD	6.- 15.	0.10- 0.24
CADIUM	0.26- 0.26	0.00- 0.00
TOTAL NITROGEN	335.- 766.	5.36- 12.25
TOTAL PHOSPHORUS	542.- 1138.	8.66- 18.21
EXTRACTABLE		
CALCIUM	1413.- 2260.	22.60- 36.16
MAGNESIUM	378.- 1016.	6.05- 16.26
POTASSIUM	126.- 202.	2.02- 3.23
ORGANIC MATTER	46250.- 80200.	740.00- 1283.20
CEC(MEQ/100G)= 8.78- 46.45		

DO YOU WANT TO EVALUATE OTHER CONSTITUENTS?
(1=YES, 2=NO, -1=EXIT)
2

DO YOU WANT TO EVALUATE ANOTHER PERCENT SAND VALUE?
(1=YES, 2=NO, -1=EXIT)
-1

STOP

END OF EXECUTION
CPU TIME: 0.27 ELAPSED TIME: 2:8.28
EXIT