# 1. Class Exercise Using the ANSWERS-GRASS Integration

**Note:** *This exercise was used as part of a class assignment for the Spring, 1992 AGEN 526 Class in Agricultural Engineering, Purdue University. The exercise was ostensively part of the class instruction about watershed modeling, but also served as test of the programs created for the ANSWERS-GRASS integration. Map names used herein are references to layers existing in the sample mapbase for the Indian Pine Natural Resource Laboratory.*

## Introduction

This exercise introduces the use of the ANSWERS watershed simulation program integrated with GRASS. ANSWERS (Areal Nonpoint Source Watershed Environmental Response Simulation) is an event oriented, distributed parameter model that was developed to simulate the behavior of watersheds having agriculture as their primary land use. Its primary applications are watershed planning for erosion and sediment control on complex watersheds, and water quality analysis associated with sediment associated chemicals.

Because ANSWERS is a distributed parameter model that divides the watershed area into a series of grid elements, one of the primary inputs to the model are spatial data, since each element requires input describing land use, soil type, slope and flow direction. Other spatial input data used by the model include the area of the watershed, the location of its outlet, elements containing channels, Best Management Practices (BMPs), and subsurface drainage. The ANSWERS-GRASS integration uses GRASS map layers for these spatial ANSWERS inputs.

Other data required by ANSWERS include physically-descriptive parameters for each soil and land use type, the size (in meters) to be used for dividing the watershed into grid elements, and data describing the storm event(s) to be modeled.

You will be using a tool called `r.answers` for this exercise. The `r.answers` program is central to the integration of ANSWERS with GRASS by providing organization and management of simulation scenarios. When the inputs have been collected and prepared using `r.answers`, it can then run the simulation and capture the results, which include maps of sediment loss and deposition for the watershed, as well as data about the runoff and sediment leaving the watershed.

Before you use `r.answers`, some preparations map layers to be used as ANSWERS input data are necessary. This will be described below. It is also recommended that you refer to the GRASS manual entry for more specific information about the `r.answers` program. For information about ANSWERS, refer to the *ANSWERS User's Manual* (1991) by David Beasley and Larry Huggins, that is available from Dr. Bernard Engel, Agricultural Engineering, Purdue University, West Lafayette, Indiana, 47906-1146.

**Input data description**

I. Watershed mask

A layer is required to serve as a watershed mask. All cell values in the map that are greater than zero will be considered by `r.answers` to be part of the watershed. Note that the current region and mask will be ignored. Use the map *a.wshd*.

II. Slope and aspect

Your current mapset may include prepared maps of slope and aspect, but they cannot be used unless they were prepared as described here. (For instance, maps produced by the regular GRASS program, `r.slope.aspect` will contain values in the wrong format as required by ANSWERS).

To prepare slope and aspect maps for ANSWERS, the starting point is an elevation surface layer, otherwise known as a Digital Elevation Map (DEM). Elevation values should be in meters. Use the map *a.elevation*.

a. Creating ANSWERS slope input from a DEM

ANSWERS requires slope map with slope values in percent multiplied by 10. (Thus, a cell value of 15 would represent a slope of 1.5%). The slope map is produced from the elevation map. The program to do this with is called `r.slope`.

Usage:
`r.slope elevation=`*name* `slope=`*name*
(i.e. `r.slope elevation=`a.elevation `slope=`*name*)

Parameters:
elevation Raster elevation file name
slope Output slope filename

b. Creating ANSWERS aspect input from a DEM

ANSWERS requires an aspect map with flow directions for each cell in the watershed. The aspects for ANSWERS are given values from 1-360. Cells where flow direction is east are given a value of 360, south east are 315, south are 270, south west are 225, and so on in 45 degree increments. A flow direction map is produced from the elevation map using the `r.direct` program.

Usage:
`r.direct input=`*name* `output=`*name* `type=`*name*
(i.e. `r.direct input=`a.elevation `output=`*name* `type=`answers)

Parameters:

input Name of existing raster map containing elevation surface
output Output direction raster map
type Output direction type (GRASS, AGNPS, or ANSWERS)

c. Inspection and editing of the aspect map

Currently, the algorithms available are not able to create flawless flow direction maps. Thus manual inspection and editing is required. When editing the aspect map, pay careful attention to 1) cells on the watershed border, which all must flow *into* the watershed; 2) cells that will be declared as "channels" must flow directly *from one to another*; 3) flow from two cells must not point directly to each other (-><-) or otherwise form circuitous routes. In the final flow map, one should be able to start at any cell in the watershed and follow the flow directions from cell to cell until arriving at the outlet cell.

The inspection and editing of the aspect map is facilitated by the `d.rast.edit` program. This program allows you to display a raster map and edit individual elements. It also includes several GRASS programs as internal functions to help with this process, namely the `d.rast.zoom` program what provides a means to "zoom" in to areas for close inspection; the `d.rast.arrow` program that reads the aspect map value for each element and draws an arrow over the displayed element on the screen to indicate the flow direction; the `d.rast.num` program that displays the element value over the displayed cell on the screen; and the `d.vect` program that can be used to display vector maps over the aspect map being edited (this is useful to indicate locations of channels).

III. Soils and land use layers

Maps will be required for both soils and land use classes to be represented in the watershed. No special pre-processing of these layers is required, however, the `r.answers` program will prompt for parameter values describing each category of the maps found in the watershed. Use the maps *a.soils* and *a.cover*.

IV. Preparing rainfall data

In this exercise you will prepare four storm events. Using methods covered in the class earlier this semester, you will create files of simulated design storm data. The storms will be of a 2 hour duration with 1, 2, 5, and 10 year return periods. For each storm event you design, create a file with two columns of numbers, such as in the following example:

```
0     0
6     2
12    4
18    3
24    10
.     .
```

```
.      .
.      .
120    0
```

In this example, the first column is time (minutes) and the second column is rainfall intensity (mm/hour). This is the basic format of the input file `r.answers` will expect as rain gauge data. The program will ask how many gauges you are using in the watershed. We will only use one, however, if more are used, a map layer will be required to indicate the groups of elements that represented by each gauge.

## V. **Building an** `r.answers` project

When you run `r.answers` it will first ask about a project. A project is a collection of all the information, maps, and data needed to run an ANSWERS simulation scenario in GRASS. Initially, you will create a new project. Once a project is created and progress is made toward its completion, `r.answers` will automatically save the project's current status in your GRASS workspace so you can quit at any point and later return to the same state by starting `r.answers` and giving the name of the existing project.

The primary operation of `r.answers` is through the main menu (shown below):

ANSWERS on GRASS Project Manager Main Menu
Project Name: <*sample*>

Status Option Description
-------------------------------------------------------
0 Quit
1 Set mask, region, and resolution
2 Catalogue soils parameters
3 Catalogue land use and surface parameters
4 Identify elevation-based input layers
5 Prepare rain gauge data
6 Identify outlet cell
7 Specify areas with subsurface drainage
8 Catalogue channel parameters
9 Define channel slopes
10 Specify BMP's in watershed
11 Prepare ANSWERS input and run simulation
12 Miscellaneous Command Menu

Option: 0__

The following is a description of what you will need to do for each step to complete your ANSWERS project.

**Step 1**
This step is initiated automatically when a new project is started. It will ask for a layer to use as a project mask (use *a.wshd*), project resolution (use 100 meters) and will then

establish a project region. This step will create a new map with a name <*project name*>.ELEMENT; This map will act as a reference to ANSWERS' methods of referring to raster cells. Raster values of the element map will indicate element number, with the category description giving row and column numbers.

**Step 2 - Soils**
Use the map *a.soils* for this exercise. Each soil category found in the watershed will require 8 parameters. This step will provide a worksheet for entering the parameters as shown below:

| Map Category | Total Porosity (TP) | Field Capacity (FP) | Infiltration Constants (FC) | (A) | (P) | Zone Depth (DF) | Antecedent Moisture (ASM) | USLE (K) |
|---|---|---|---|---|---|---|---|---|
| 29 | 54% | 87% | 21 mm/h | 24 mm/h | 0.63 | 133 mm | 60% | 0.28 |
| 51 | 47% | 93% | 21 mm/h | 24 mm/h | 0.56 | 108 mm | 60% | 0.33 |
| 79 | 46% | 74% | 7 mm/h | 14 mm/h | 0.60 | 96 mm | 60% | 0.28 |
| 103 | 47% | 68% | 7 mm/h | 14 mm/h | 0.55 | 57 mm | 60% | 0.32 |
| 105 | 48% | 96% | 21 mm/h | 24 mm/h | 0.55 | 95 mm | 60% | 0.32 |
| 106 | 47% | 93% | 21 mm/h | 24 mm/h | 0.55 | 108 mm | 60% | 0.32 |

After entering the above parameters, two other inputs are requested by step 2; complete them as shown:

- Tile drainage coefficient: 8.20 mm/day

- Groundwater release fraction: .001

**Step 3 - Land cover**
Use the map *a.cover* for this exercise. For each land cover class found in the watershed, ANSWERS requires 6 parameters. Fill out the table in this step with the values as shown:

| Category | (CROP) | (PIT) | (PER) | (RC) | (HU) | (N) | (USLE C) |
|---|---|---|---|---|---|---|---|
| 1 | pasture | 3.4 mm | 97% | 0.52 | 25 mm | 0.115 | 0.50 |
| 2 | corn | 0.1 mm | 5% | 0.47 | 75 mm | 0.099 | 0.45 |

**Step 4 - elevation-based layers**
Enter the names of the slope and aspect files you created previously.

**Step 5 - rain gauge data**
Use the names of the four rain data files (that you created previously) to enter the storm data under different event names.

**Step 6 - outlet cell**
To find the row and column of the outlet cell, display the <*project name*>.ELEMENT on the GRASS graphics monitor, then `d.vect` the *a.channel* map. Use the program `d.what.rast` to click on the cell at the outlet of the watershed (which you can tell by

the vector map of channels). The output of `d.what.rast` will give you the row and column of the outlet.

**Step 7 - subsurface drainage**
Complete this step by indicating all of the watershed has subsurface drainage installed.

**Step 8 - channels and their parameters**
Use the raster channel map *a.channel*. There are 2 categories of channels, the parameters are to be filled in as follows:

| | | |
|---|---|---|
| Category: 1 | Width: 2.0_ meters | Roughness: 0.060 |
| Category: 2 | Width: 1.5_ meters | Roughness: 0.070 |

**Step 9 - channel slopes**
Run this step to tell it you do not wish to input channel slopes.

**Step 10 - Best Management Practices**
We will only simulate one of the four possible BMPs, Grassed Waterways. Use the map *a.waterway*, and when you are prompted for the width of the waterway, use 20 meters.

VI. **Test inputs by running ANSWERS**

**Step 11** will compile the inputs from Steps 1 through 10 to create ANSWERS input, then will run the simulation and capture and process the output. Because of the complexity of the simulation and its inputs, it is quite possible the simulation does not run without error on the first attempts. (The most common problems typically stem from the aspect map routing runoff in directions the program cannot follow).

Some errors may be captured and displayed to the screen by `r.answers`, while others may be buried in the answers output file created when the simulation is run. This means you may have to use the facilities in **Step 12** to read file *answers_output* in the project database. (The project database is where all data files used by `r.answers` are stored).

VII. **Run scenarios**

You will run four simulations using the each of the design storms you create (as described above). Once you are successfully getting results with your first scenario, use the "copy an existing project" function on the initial menu of `r.answers`. Create three copies of your original project, so that you have a total of four. Now you can modify the new scenarios to simulate different conditions of the watershed. The initial inputs for the project gave land cover inputs for corn at the beginning stage of its growth. In the other three projects you will simulate the corn at later stages of growth. For each of the stages of corn growth, model the four design rain storms.

To simulate the changing land cover conditions of the different stages of corn growth, you will run step 3 again in each of the copied projects. Use the same cover map (*a.cover*, and edit the existing parameters from the earlier simulation as shown below (note, only corn values are shown, pasture values will remain the same as before):

| Category | (CROP) | (PIT) | (PER) | (RC) | (HU) | (N) | (USLE C) |
|---|---|---|---|---|---|---|---|
| | | | Crop Stage 2 | | | | |
| 2 | corn | 0.5 mm | 20 % | 0.40 | 70 mm | 0.12 | 0.30 |
| | | | Crop Stage 3 | | | | |
| 2 | corn | 1.0 mm | 55 % | 0.37 | 65 mm | 0.15 | 0.20 |
| | | | Crop Stage 4 | | | | |
| 2 | corn | 1.4 mm | 80 % | 0.35 | 63 mm | 0.18 | 0.14 |

Thus you will have 4 projects for the 4 stages of corn growth. Each project will model 4 design storms, so you will have a total of 16 simulations. Note that running sequential simulations in a given project will overwrite previously created output files... so you will want to use the facilities of Step 12 to copy files you want to keep to another place before running another simulation with that project (or you can create a different project for each simulation).

VIII. **Analyze results**

Now generate a summary of what happened by analyzing the results.

ANSWERS output includes data for sediment movement for watershed elements. The `r.answers` program will use this output to create new maps of net sediment loss, net sediment deposition, and channel deposition in your GRASS workspace. You can use GRASS raster map tools to generate reports comparing the results of the outputs; plus you can look at the input maps to correlate to the results. You may also wish to use the `d.answers` shell script to view a summary of input and output maps. `d.answers` provides an option to use the `d.linegraph` program to display graph plots of the outlet hydrograph data.

Another place to look are the project database files, accessible via the Miscellaneous Command Menu (Step 12 of the `r.answers` Main Menu. See the appropriate section of the `r.answers` manual handout under the description for Step 12 and the "FILES" section.) The data files of the output which you will want to focus on will be the files in the project database starting with "out_". Hydrograph data will be stored in the file "out_hydro". This file is processed to be used as input to the `d.linegraph` program in the files "hydro_time", "hydro_rain", "hydro_runoff", "hydro_sed1", and "hydro_sed2". A shell script is available called `d.hydro_graph` which demonstrates the use of the `d.linegraph` program to graph hydrograph data. To use, type `d.hydro_graph` *project name* (where project name is the name of the project where an ANSWERS simulation has been successfully ran). These data can also be imported to other programs, such as your favorite spreadsheet, statistical analysis, or plotting package, for analysis and display.