Users Guide to

# GFGEN - Version 4.27

US Army Corps of Engineers
Waterways Experiment Station - Hydraulics Laboratory

# Contents

# Figures and Tables

# Overview

## Introduction

GFGEN's purpose is to create geometry and finite element mesh files for input to the TABS-MD modeling system programs. It performs routine mesh diagnostics, reordering, and plotting (optional). It is the **G**eometry **F**ile **GEN**eration program.

### Origin of the Program

GFGEN is composed of portions of programs written by Resource Management Associates, Lafayette, California, and the Waterways Experiment Station, Hydraulics Laboratory, Vicksburg, Mississippi.

### Capabilities of GFGEN

a. Read node and element data and construct a finite element computational mesh for use by other programs in the TABS-MD modeling system.

b. Identify errors and potential errors in the constructed mesh.

c. Renumber the mesh, omitting unused nodes and/or element numbers.

d. Fit curved element sides to land boundaries and interior element sides may be specified.

e. Develop an elemental solution order that permits the most efficient operation of models using the mesh.

f. Provide a nodal cross reference and statistics summary.

g. Create a binary data file that contains the mesh information and geometry in a format suitable for use by other TABS-MD programs.

h. Create a device independent DISSPLA meta file of one to five mesh characteristics (mesh, node and element numbers, material types, and bathymetric assignments).

# Using GFGEN

## Running GFGEN

GFGEN is presently running on a wide variety of computers, spanning from DOS and UNIX PC's to the Cray Y-MP super computer. It is written in standard FORTRAN-77 source code.

GFGEN may be run in either batch mode or interactive mode by setting the 'IBATCH' variable within the program. Typically GFGEN is set to batch mode for mainframe computational environments and to interactive mode in PC and workstation environments.

The plotting features of GFGEN require a computer with a license to use **DISSPLA** version 11 graphics software. However, the plotting may be easily disabled by editing the source code and removing the call to the **PLTMSH** subroutine and removing all subroutines below PLTMSH (inclusive).

GFGEN is accessibleon the WES Cray Y-MP for validated TABS-MD users simply by running '**proclv**' and selecting the appropriate menu option. Otherwise the program executable runs interactively and queries the user for appropriate files.

GFGEN will support either English or System International (SI) units. However, the user is responsible for appropriately converting or scaling the mesh to be consistent with the 'SI Card' assignment. English units are the default.

## Mesh Characteristics

### Types of Elements

GFGEN is capable of handling many different types of elements within the same computational finite element mesh. The types of elements fit into three basic categories:

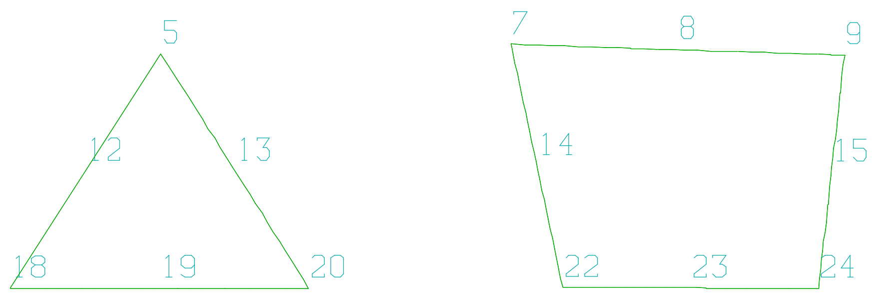
- Two dimensional elements (2D)
- One dimensional elements (1D)
- Special elements (transitions, junctions, and control structure elements).

Elements may have either straight or curved edges.

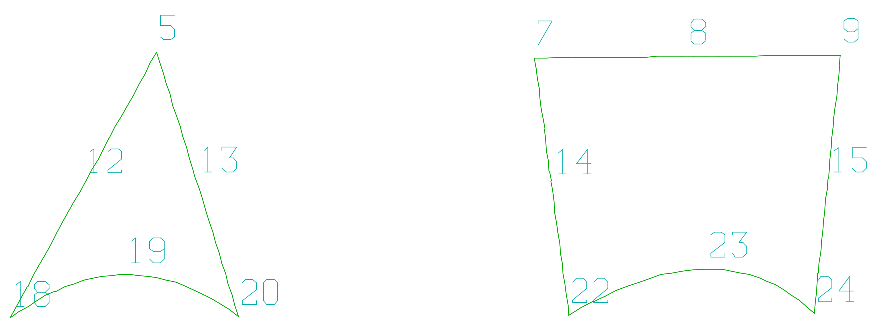
Although it is no longer necessary to prescribe curved external boundaries to prevent *leaking* (releases prior to RMA2 version 4.2), they may be used to achieve aesthetics. Curving is particularly useful for one dimensional elements to achieve the meandering/snaking river effect.

## Two Dimensional Elements

Two dimensional elements may be three sided with six nodes or four sided with eight nodes. Figure 1 illustrates the basic triangle and quadrilateral shapes for two dimensional elements. There are three/four corner nodes at the vertices and three/four mid-side nodes on the sides. If the element is straight, the mid-side node is exactly halfway between the two corners. However, if an edge of the element is curved, the mid-side node of that edge needs to fall within the middle third of the distance between the two corners to meet the criterion of well formed.




*a. Straight 2D elements.*




*b. Curved 2D elements.*

*Figure 1. Well Formed Two Dimensional Elements.*

## How To Curve Two Dimensional Elements

There are several ways to curve a two dimensional element. The newest and simplest technique is to move the location of the mid-side node of the curved edge by explicitly assigning its coordinate value (GNN Card). The second technique is to assign each corner node of a curved edge with a slope assignment (GCN Card), and to include the mid-side node of the curved edge in a mid-side node list (GMN

Card). For this technique there are two semi-automatic ways available in GFGEN to curve the boundary of the mesh.

**Curved 2D Boundary Option 1**

*Option 1 requires use of the GCN, GMN, and possibly the GF cards.*

Slopes are specified at all corner nodes (GCN Card) where curved boundaries are desired and a list of mid-side nodes (GMN Card) for these edges is given. The program calculates the necessary curved boundary to satisfy the specified slopes. If certain slope errors are detected, a warning is printed (see discussion of "Problem Elements" on page 8). If the "fix slope" option is on (IFXSLP=1), the program attempts to modify specified slopes near the error to eliminate it.

**Curved 2D Boundary Option 2**

*Option 2 requires use of the GB and GS cards. After the curved boundary has been created once, change these cards to GCN and GMN cards with slopes inserted to save computer costs.*

A starting corner node, a direction to proceed, and an ending corner node are specified. The program will automatically generate a smooth, curved boundary from the starting node to the ending node. If desired, slopes at some nodes can be pre-specified and the automatic computation will force the curved boundary to meet that specified slope.

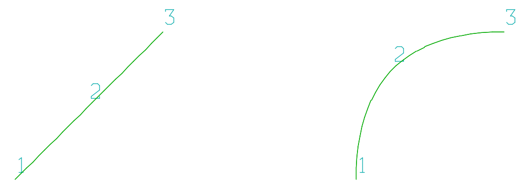
## *One Dimensional Elements*

*The one dimensional element is presently not available in the sediment transport code.*

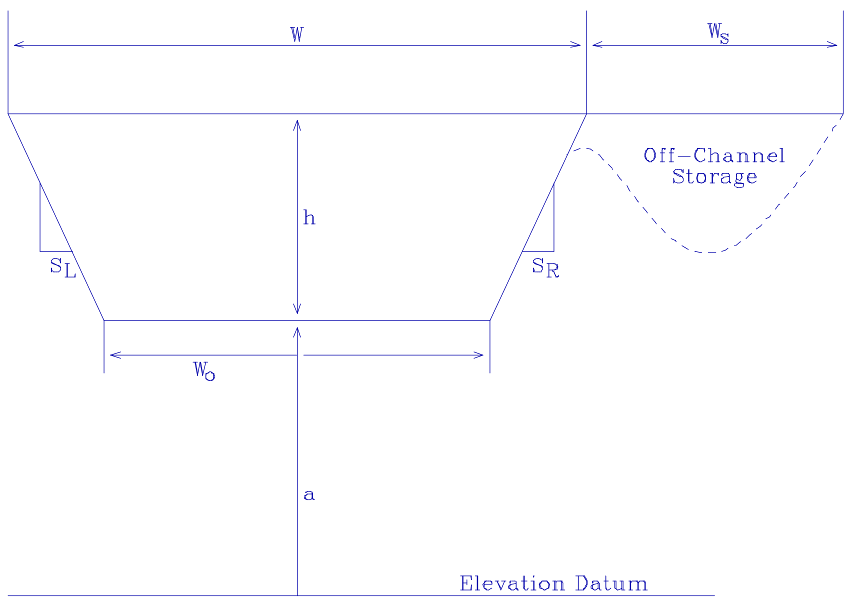
The basic one dimensional element is composed of two corners and one mid-side node. Parts *a* and *b* of Figure 2 illustrate a basic straight and curved one dimensional element. As depicted in part *c* of Figure 2, the numerical model's governing equations for 1D elements are based on a trapezoidal cross-section with side slopes and off-channel storage. The user may assign the width (W), slopes ($S_L$ and $S_R$), and off-channel storage ($W_s$) within GFGEN (GNN or GWN cards) or wait and include that information within the numerical model run.

## *How To Curve One Dimensional Elements*

The 1D element is conceptually easier to curve than the 2D element. A 1D element is curved simply by changing the (*x*, *y*) coordinate of the mid-side node number to the desired location (GCN Card).




*a. Straight 1D element* *b. Curved 1D element*




*c. 1D Trapezoidal cross-section diagram*

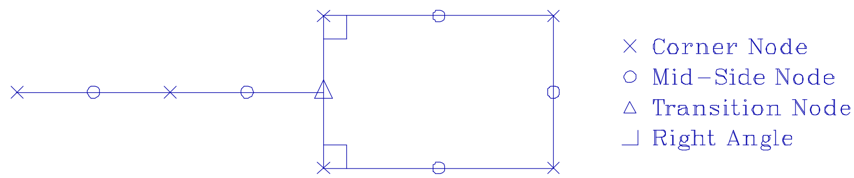
*Figure 2. Well Formed One Dimensional Elements.*

# Special Elements

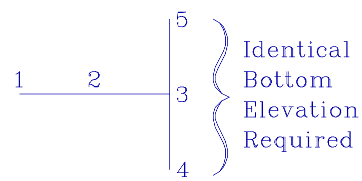
## *Transitional Element*

A transitional element is a special 1D element that is required for connecting a 2D element with a 1D element. Part *a* of Figure 3 illustrates a 1D element transition to a 2D element. The transition element has 5 nodes and is shaped like the letter **T**. The order of the nodal connection (GE Card) is very specific, as shown in part *b* of

Figure 3. The first three nodes must be from the 1D side of the transition, the last nodes of the transition element are the corner nodes of the adjacent 2D element. Note that the transition node 3 requires coordinates and bottom elevation (GNN Card) though it will look like a mid-side node to the adjoining 2D element. The angles between the transition side of the 2D element and the adjacent 2D element sides should be close to 90 degrees, otherwise leakage will occur along those sides. In addition, the bottom elevations of nodes 3, 4, and 5 of the transition element must be identical to conform to the trapezoidal channel assumption.




*a. Function of a transition element.*




*b. The nodal connection of a transition element.*

*Figure 3. Transition Element.*

## *Junction Element*

A junction element is a special 1D element that is used to describe the proper characteristics where three or more 1D elements intersect. GFGEN is capable of handling from three to eight *branching channels* within a junction. A junction element is composed of collocated corner nodes at the junction end of all 1D elements that connect into the junction. Figure 4 illustrates a junction formed by nodes 3, 4 and 7. The IMAT (GE Card element material type) of a junction element must be either 901, 902, or 903.

## Material Types for Junction Elements

a. IMAT = 901 Equal water surface elevation junction

b. IMAT = 902 Equal energy head at all nodes of junction

c. IMAT = 903 Preservation of Momentum along the two primary channels (defined by the first two nodes listed in the junction)

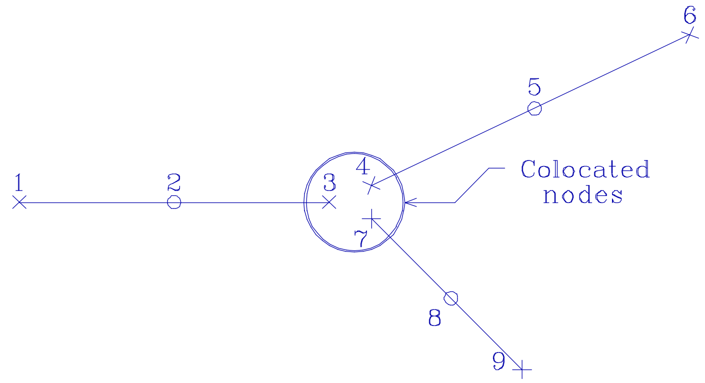



*Figure 4.  Junction Element.*

### *Control Structure Element*

A control structure element is a special 1D element that is used to simulate weirs, gates, etc.  The control structure has two collocated corner nodes connecting two 1D elements.  This element must have an IMAT (GE Card element material type) greater than or equal to 904.  Figure 5 illustrates a control structure element.

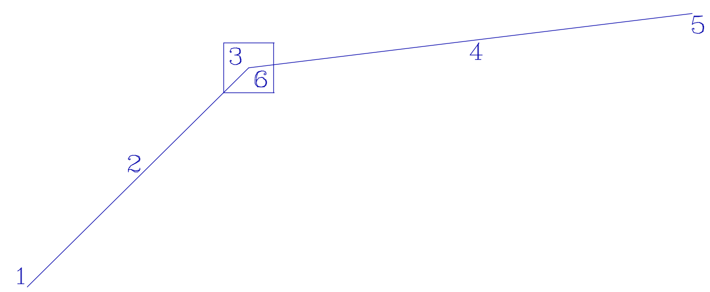



*Figure 5.  Control Structure Element.*

## Problem Elements

There are several categories of issues which lead to problem elements.

### *Causes of Problem Elements*

Poor aspect ratio

Erroneous element connections

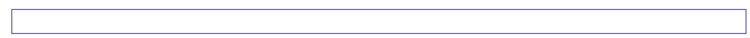
Mid-side nodes violating the middle third rule

Slope rule error

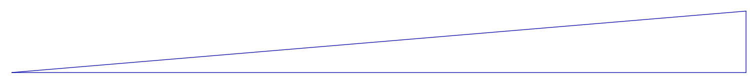
Needle-like corners

Element edge overlap

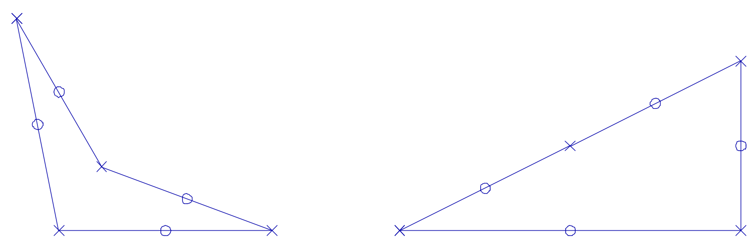
Parts *a* through *c* of Figure 6 illustrate some of the problems which may occur with straight elements.  Figure 7, parts *a* through *c*, illustrates problems which may occur with curved elements.



*a.  Poor length to width aspect ratio.*

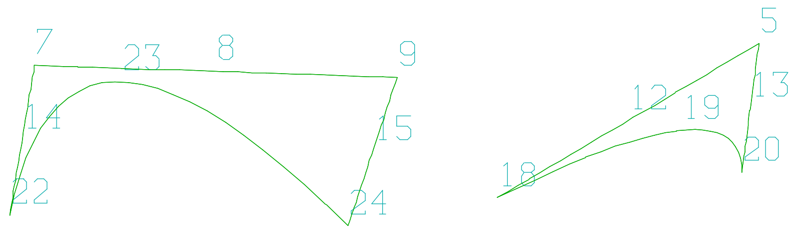


*b.  Needle-like corner.*

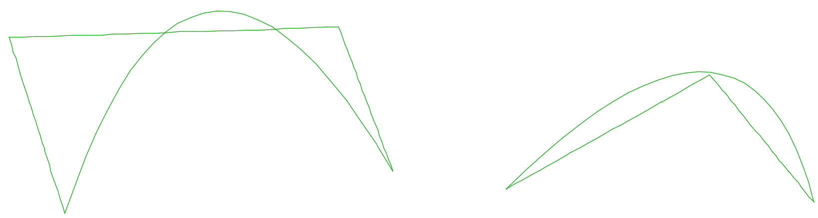


*c.  Boomerang or 4-sided triangle shapes.*

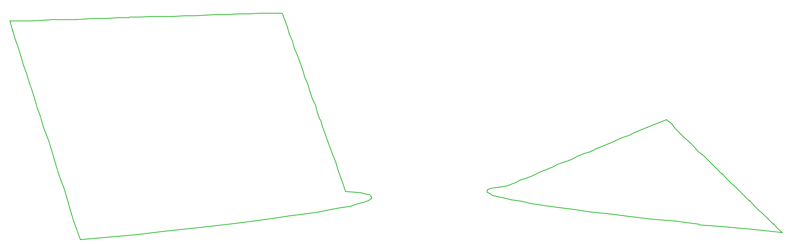
*Figure 6.  Problem Straight Elements.*




*a. "Middle third rule" violation.*



*b. Curved side overrun.*



*c. "Slope rule" violation.*

*Figure 7. Problem Curved Elements.*

*Middle third rule violations that are close to a fraction of either 0.333 or 0.666 can usually be tolerated by the models. Fractions less than 0.2 or more than 0.8 usually lead to model inaccuracy and even instability.*

The shape described by a curved element side is that of a second order curve. It can contain only one inflection point between two corner nodes. If a boundary is curved very sharply, as shown in part *a* of Figure 7 then the mid-side node will fall quite close to one of the adjacent corner nodes. Hence the mid-side node falls outside of the middle third of the curved arc length, producing what GFGEN will designate as a "middle third rule" violation and GFGEN will print the fraction of the arc length at which the mid-side falls.

## Reordering

The simultaneous equation solver used by the models runs more efficiently (and thus, considerably more economically) if the solution sequence is optimized by reordering the mesh. Reordering does not change any element or node numbers; it changes the sequence in which the elemental equations are assembled.

The program will attempt various reordering schemes as directed and present the matrix characteristics (bandwidth, band sum and front width) for each scheme. It will automatically select the ordering scheme that minimizes the front width. The cost savings associated with reordering are large enough that it is strongly recommended that the user spend some time carefully generating the optimum reordering scheme. Once reordering is complete, only the best list should be used in subsequent runs so that computation costs are minimized.

Two options are available for reordering, however, only one option per GFGEN execution is allowed. Reordering Option 1 is for a fully two-dimensional mesh. Option 2 permits both 1D and 2D elements within the mesh. Either Option 1 or Option 2 may be used if the mesh does not include 1D elements.

### Reordering Option 1

Option 1 requires that the GO card be used to give a starting list of ***nodes*** (corner and mid-side nodes), as opposed to a list of elements, to begin the reordering process. Several starting lists should be tried.

**When using Option 1 reordering, consider the following points.**

*Try inflow or outflow boundaries as reordering lists.*

In general, choose reordering lists that make up a continuous line along one end of the mesh. Try lists on several edges of the mesh and of varying length. Be warned that a very short list (less than five nodes) may cause the front width (number of equations assembled simultaneously) to become too large for program dimensions.

When the starting node list leading to the smallest front width is found, try multiple versions of that list, including slightly shorter and slightly longer lists. Try reversing the order that the nodes are listed (left to right instead of right to left, etc.).

### Reordering Option 2

The rules for the reordering list for Option 2 are similar to that given for Option 1 with the exception that a starting list of ***elements***, as opposed to a list of nodes, is given on the GO card for Option 2. As in Option 1, it is recommended that several lists be tried to find which gives the smallest front width given in the GFGEN job output listing.

## Input Options

*A geometry file may be copied to logical unit 08 when running GFGEN in Batch mode. Normally,* ***proclv*** *would be used which handles this automatically.*

Input consists of run control data which are in card image and may be either on cards or in a disk file identified as logical unit 08. Briefly, each card image begins with a two or three character identification string followed by the data. Data may be formatted in column fields or free format separated by spaces or commas.

Another input option allows the user to read in a previously generated binary GFGEN geometry file on logical unit 04. This is a very efficient way to request additional plots, etc.

## Output

Output consists of user selectable printed results, a plot file, a collapsed geometry file, and a binary geometry file.

### *What's in the Output*

- Echo prints of input data
  - A list of elements
  - Associated nodes
  - Element types
- Slopes at the nodes
- A list of boundary nodes
- High and low element and node numbers
- Unused elements and node numbers
- A list of special elements
- A nodal cross reference table (GF Card Option 2)

A collapsed file (GF Card option 4) is created after collapsing the mesh to eliminate unused nodes and elements and becomes a new GFGEN input file.

## Error Messages

Messages showing mesh errors are printed if switched on by the GF card. Three primary error messages are given.

**Middle Third Rule violation** — A mid-side node on a curved boundary has been calculated to lie outside the middle third of the arc forming the element side. As discussed in "Problem Elements" on page 8, middle third rule violations need not always be fixed.

**Slope Rule Error** — The slopes given at two adjacent corner nodes will cause the boundary to reverse directions between the nodes as shown in part *c* of Figure 7. If a user is tempted to use exotic slopes in an attempt to define complex shoreline boundaries, be warned that experience has proven that greater resolution (higher numbers of elements) is a better strategy.

**ILL-defined elements** — Identified if an element has:

a. Any number of nodes other than 3, 5, 6, or 8 (unless it is a junction element or control structure)

b. A node list containing a zero

c. A node list that does not alternate corner and mid-side node numbers

# Keeping Track of Runs

*Supply accurate information on the banners when executing* ***proclv***.

Keeping track of runs is made easier by use of consistent file naming conventions, a file management system, and job tracking sheets as illustrated in "Figure 8. GFGEN Job Sheet." on page 13.

## GFGEN JOB SHEET

JOB EXECUTED _________ DATE OF RUN _________ TIME OF RUN_________

JOB PRINTED _________ SUBMITTED BY ________ CPU ____ PRI______

* * * * * * * * * * * * REVISION NO. = ________ * * * * * * * * *

NODES = ___________ REORDERED? YES OR NO

ELEMENTS = ___________ MESH CHECK = 0, 1, 2 OR 3

CURVED BOUNDARY = ___________

PLOT = NO or ALL or PARTIAL (if partial, give limits = ____,____,____,____)

ROTATION = _________ DEGREES

ELEM HGHT = _________

NODE HGHT = _________

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

PURPOSE =

*Figure 8. GFGEN Job Sheet.*

# GFGEN Data File Format

## Input Instructions

The following pages provide instructions for preparing card image run control input to GFGEN. Table 1 summarizes the input data types. The order of the cards is the order in which they should appear when used in a GFGEN geometry data file.

### GFGEN Data Cards

*Table 1. GFGEN Version 4.27 Data Card Sequence.*

| Card | Content | Required ? | Page |
|---|---|---|---|
| T1–T3 | Titles | Yes | 20, 20 |
| SI | Specifies English or Metric units | No | 20 |
| $L | Input/output files | No | 21 |
| GB | Boundary for automatic curve fitting to sides | No | 22 |
| GC | Corner nodes and slopes for specified curve fitting to sides | No | 23 |
| GM | Mid-side nodes on specified curve-fitted boundaries | No | 27 |
| GF | Mesh debug controls | No | 25 |
| GG | Automatic mesh generator controls | No | 26 |
| GW | Node descriptions | Yes, for 1D | 29 |
| GO | Mesh reordering controls | No | 30 |
| GR | Mesh refining controls | No | 31 |
| GS | Specified corner node slopes to override automatic slope computation | No | 32 |
| GX | Geometry scales | No | 33 |
| PO | Plot controls | No | 34 |
| PP | Partial plot controls | No | 35 |
| GE | Element arrays | Yes, if GG not used | 24 |
| GN | Node descriptions | Yes, if GG not used | 28 |

# Example-Card Image Input Data

Table 1 on page 15 lists the card image input data needed for GFGEN instructions. An example listing of the card image input data file for GFGEN is shown in Figure 10 on page 17. The T3, $L, GE, GNN cards are the only cards required to generate a mesh. However, other cards are usually desired for such user options as generating a plot, adding curved boundaries, reordering, etc.

The majority of the GFGEN input files will consist of GE cards (one card for each element which gives the element/node connection table, the element type, and its orientation in the mesh) and GNN cards (one for each corner node in the mesh giving its (*x*, *y*, *z*) location in that sequence). For example, the GNN card at the bottom of the sample listing in Figure 10 on page 17 shows (1100.00, 5300.00, and 95.00) for the (*x*, *y*, *z*) coordinates, respectively.

A plot of the finite element network is shown in Figure 11 on page 17. It is the first of five plot files requested on the PO card. The second plot file produced has the same image as the first plus element numbers and the third plot file has that same image but node numbers are displayed rather than element numbers. The fourth plot has the same image as the first plus element material numbers (IMAT's). The fifth plot has the same image as the first plus corner node elevations and 1D element width information. It is this plot which may be requested, at map scale, to code the *z* coordinate for each corner node.

```
T3      GENERIC ESTUARY 1–D 2–D  208 ELEMENTS  629 NODES
$L      3  0  6  0
GF      2
GO      2    1    2    3    4    -1
PO      3    3    0.    30.  0.    0.    0.   .14   .07
GX      5.    5.
GE      1    1    2    3    21    32    31   30   20   2   0.0
GE      2    3    4    5    22    34    33   32   21   2   0.0
GE      3   34   22    5     6     7    23   36   35   3   0.0
GE      4   36   23    7     8     9    24   38   37   3   0.0
        .
        .
        .
GE      205     622     618     611     612     613     619     0       0       2       0.0
GE      206     622     619     613     614     615     620     624     623     3       0.0
GE      207     624     620     615     616     617     621     0       0       3       0.0
GE      208     622     623     624     626     629     628     627     625     2       0.0
GNN     1       400.00    900.00        60.00
GNN     3       1100.00   200.00        60.00
GNN     5       1800.00   0.00          60.00
GNN     7       1860.00   0.00          60.00
        .
        .
        .
GNN     622     1000.00  4900.00    95.00
GNN     624     1200.00  5000.00    95.00
GNN     627     900.00   5200.00    95.00
GNN     629     1100.00  5300.00    95.00
```

*Figure 10. Example Input for GFGEN.*

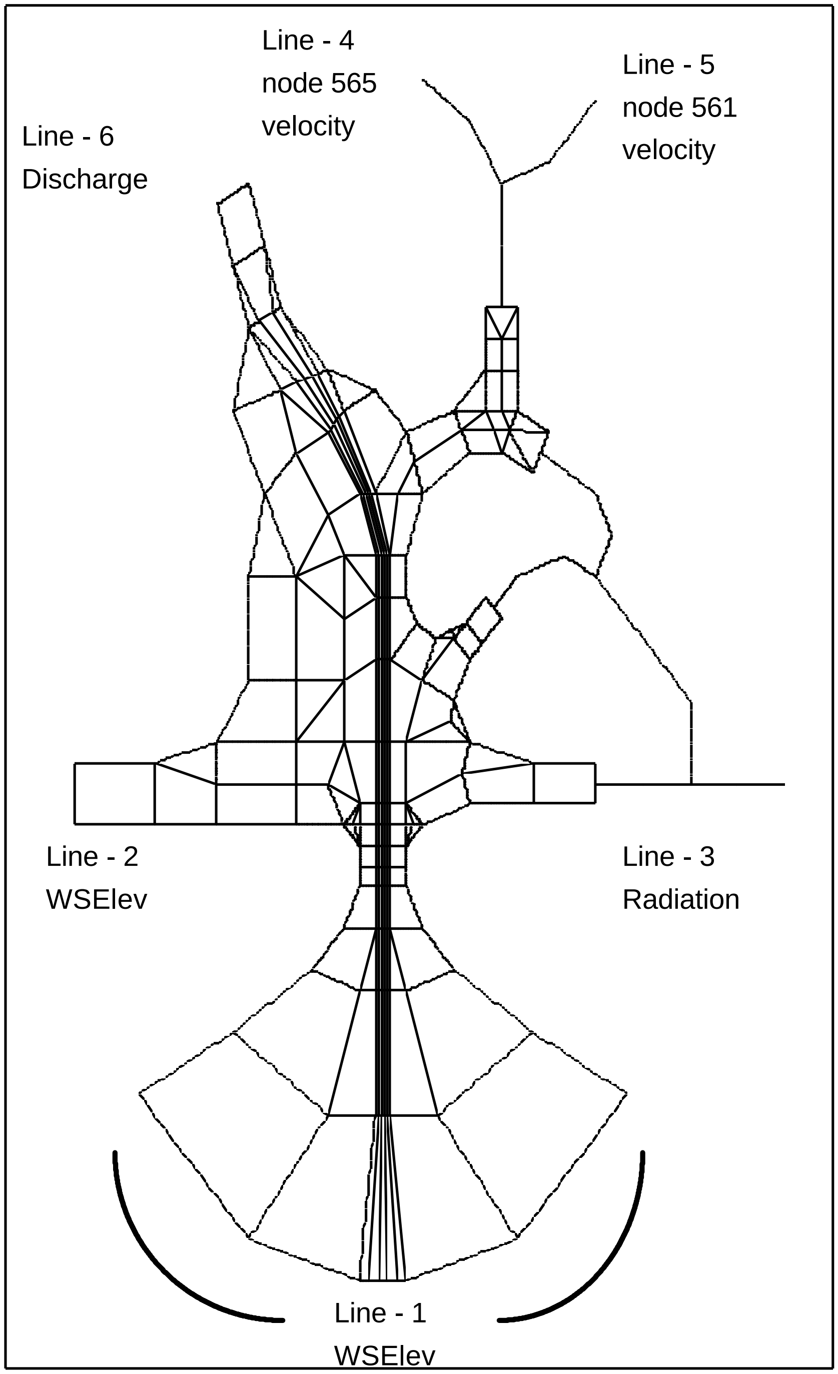



*Figure 11. Example Mesh Plot Produced by GFGEN.*

# Data Card Syntax

The information presented in this section is intended as reference material for use when constructing a GFGEN data file.

## Discription of Card Data Table Format

The table headings are as shown in Figure 12.

| Field | Variable | Value | Description |
| --- | --- | --- | --- |

*Figure 12. Card Data Table Heading*

## T1 or T2 Card Title Cards

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | T | Card group identifier |
| Col 2 | IDT | 1, 2 | |
| 2-10 | TITLE | Any text | Title information |

## T3 Card Title Cards

**One required**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | T | Card group identifier |
| Col 2 | IDT | 3 | |
| 2-10 | TITLE | Any text | Title information |

**Note**: If T1 and T2 cards are used, the T3 card must be the last of the **T** cards.

## SI Card System International Units

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 - 2 | IC1 | SI | Card group identifier |
| Col 3 | METRIC | 0 | English units are applied (default). |
| | | 1 | Metric units are expected as input and used for output. |

**Note**: If no SI card is present, English units are used.

The SI card must be placed early in the card line-up in the data file (before the $L card).

## $L CARD Input/Output Data Logical Unit Numbers

**Required**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | $ | Card group identifier |
| Col 2 | IDT | L | |
| 1 | LUNIT | + | **Logical Unit Number** (LU) on which results of the network generation are to be written. This file will serve as input to the models or to another GFGEN run. Usually LU 03. |
| | | 0 | No output file will be written. |
| 2 | IGIN | + | LU for an existing network which is to be read in and revised. If, IGIN <0, only the reordering list will be read. Usually LU 04. |
| | | 0 | No existing network will be read. |
| 3 | LP | + | LU for standard printed output. |
| | | 0 | Default to LU 7. |
| 4 | NRPT | + | If an existing network is to be refined and it is desired to interpolate velocities and depths at the refined nodes: NRPT is the LU on which interpolation information is written by program REFINE. |
| | | 0 | No interpolation needed. |

## GB CARD Boundary to be Automatically Fit with Curved Sides

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | B | |
| Col 3 | ISI | ƀ | |
| 1 | $LOC_1$ | + | Corner node at which curved boundary computation is to begin. |
| 2 | $LOC_2$ | + | Next corner node in curved boundary computation (indicates direction that computation is to go). |
| 3 | $LOC_3$ | + | Last corner node in curved boundary computation. |

**Note**: Repeat fields 1-3 on additional GB cards to complete the lists of curved boundary computation. Continuation cards are coded the same as the first card.

## GC CARD Corner Nodes on Curved Sides

**Optional**

| Field | Variable | Value | Description |
| --- | --- | --- | --- |
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | C | |
| Col 3 | ISI | N | |
| 1 | $LOC_1$ | + | Corner node number for $ALPHA_1$ |
| 2 | $ALPHA_1$ | + | Slope at node $LOC_1$ |
| 3 | $LOC_2$ | + | Corner node number for $ALPHA_2$ |
| 4 | $ALPHA_2$ | + | Slope at node $LOC_2$ |
| 5 | | | Continue coding until all corner nodes with slopes are listed. Continuation cards are coded the same as the first card. Do not break a node-slope pair between cards. |

**Note**: This card is not needed for boundaries where Option 2 is used.

## GE CARD Element Arrays

**Optional**

**Use one card per element.**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | E | |
| 1 | JELE | + | Element number |
| 2-9 | NOP | + | 2 to 8 element node numbers beginning with any corner and going counter-clockwise around the element. For triangular elements, the last two nodes must be entered as zero. |
| 10 | IMAT | + | Element type** |
| 11 | TH | + | Direction of eddy viscosity tensor for this type element. The direction of TH should generally be oriented along the primary flow direction measured in radians counterclockwise from the positive x-axis (east). Note that this value is ignored for 1D elements. |

**Note**: For formatted reads this card is read as (2A1,6X,I8,8I4,I8,F8.0)

** Element types are used by the RMA2 model to define eddy viscosity coefficients, roughness coefficients, etc.

## GF CARD Mesh Debug Controls

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | F | |
| 1 | IDEBUG | 1 | Print high and low element and node numbers, ill-defined elements, unused elements and nodes bad slope specifications, and all boundary nodes. |
| | | 2 | Perform all of optional 1 plus generate node cross-reference list. |
| | | 3 | Perform all of options 1 and 2 plus eliminate all unused nodes. |
| | | 4 | Perform all of option 3 plus eliminate undefined elements and write a new GFGEN input file on logic unit 98. |
| 2 | IFXSP | 1 | Attempt to correct slope rule errors at listed nodes. |
| | | 0 | No slope corrections. |
| 3 | NODA | + | List of mid-side nodes between corner nodes that can be adjusted to correct slope rule errors. Limit of 100. Continue coding on additional cards if needed, starting with field 1. |

## GG CARD Automatic Mesh Generator

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | |
| Col 2 | IDT | G | |
| 1 | NY | + | Number of element panels in x-direction |
| 2 | NY | + | Number of element panels in y-direction |
| 3 | XL | + | Mesh length in x-direction |
| 4 | XY | + | Mesh length in y-direction |
| 5 | XR | + | x-direction geometric spacing (usually 1) |
| 6 | YR | + | y-direction geometric spacing (usually 1) |

## GM CARD Mid-side Nodes on Curved Sides

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | M | |
| Col 3 | ISI | N | |
| 1 | $LOC_1$ | + | Mid-side node for which location and slope are to be computed. |
| 2 | $LOC_2$ | + | Mid-side node for which location and slope are to be computed. |
| 3 | | | Continue coding until all mid-side nodes which are to have location and slope computed are listed. Continuation cards are coded the same as the first card. |

**Note**: This card is not needed for boundaries where Option 2 is used.

## GN CARD Nodal Descriptions

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | |
| Col 2 | IDT | N | |
| Col 3 | ISI | | Coding options |
| | | b̸ | Constant value to be used at all nodes of number J and higher |
| | | N | Values to be assigned to node J only (insert all ISI = b̸ cards before first N card) |
| 1 | J | + | Node number |
| 2 | CORD(J,1) | + | x-coordinate of node J |
| 3 | CORD(J,2 | + | y-coordinate of node J |
| 4 | WD(J) | + | Bed elevation at node J |
| 5 | WIDTH | + | Channel width at zero depth |
| 6 | SS1 | +,- | Left side slope |
| 7 | SS2 | +,- | Right side slope |
| 8 | WIDS | + | Storage width associated with node at zero depth |

**Note:** Fields 5 thru 8 a re required only if the node is one dimensional (see Figure 2 on page 6).

## GW CARD Nodal Descriptions

**Required for 1D**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 - 2 | IC | GW | Card identifier |
| Col 3 | IC3 | blank | Option 1: Universal assignment for all nodes >= NODE |
| | | N | Option 2: Individual node assignment |
| 1 | NODE | + | Node number (one dimensional) |
| 2 | WIDTH | + | Channel width at zero depth |
| 3 | SS | -,+ | Left side slope |
| 4 | SS2 | -,+ | Right side slope |
| 5 | WIDS | + | Storage width associated with NODE at zero depth |

**Note:** See Figure 2 on page 6.

# GO CARD Mesh Reordering

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | O | |
| 1 | IRO | 1 | Reorder a fully 2D mesh using lists of starting node numbers. |
| | | 2 | Reorder either a 1-D and/or 2-D mesh using list of starting element number. |
| 2 | LISTN | + | For IRO=1, provide a list of nodes (corners and mid-sides) in sequence to be used as starting line in reordering.<br>For IRO=2, provide a list of elements in sequence to be used as starting line in reordering.<br>The last value in each list must be a negative number. |

**Note**: For continuation cards, LISTN begins in the first field.

Do not repeat IRO for subsequent lists.

You cannot attempt multiple values of IRO with a single GFGEN execution. Reordering is strongly recommended as a last step before running the models. See documentation for suggestions.

## GR CARD Mesh Refining

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | R | |
| 1 - 4 | LISTR | + | 3 or 4 node numbers on the existing mesh that will be used to form a new element using the cited nodes as corner nodes in the new element. |

**Note:** One new element per card.

## GS CARD Fixed Boundary Slopes

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | Card group identifier |
| Col 2 | IDT | S | |
| 1 | $LOC_1$ | + | Corner node at which automatic slope computation will be forced to use specified slope |
| 2 | $SLOPE_1$ | | Specified slope |

**Note**: Repeat fields 1 and 2 as needed or insert additional GS cards to complete the list. Do not break a location-slope pair between cards.

## GX CARD Geometry Scales

**Optional**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | G | |
| Col 2 | IDT | X | |
| 1 | XFACT | + | Scale factor to multiply input x-coordinates by to get model distances |
| | | 0 | Default is 1 |
| 2 | YFACT | + | Scale factor to multiply input y-coordinates by to get model distances |
| | | 0 | Default is 1 |

## PO CARD Plot Controls

**Optional**

**Presence of this card indicates that at least one plot is to be drawn.**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICG | P | Card group identifier |
| Col 2 | IDT | O | |
| 1 | IPNN* | 0 | Plot the mesh without numbers. |
| | | 1 | Node numbers will be plotted. |
| | | 2 | Corner node elevations will be plotted. |
| | | 3 | Both nodes and corner node elevations will be plotted. |
| 2 | IPEN* | 0 | Plot the mesh without numbers. |
| | | 1 | Element numbers will be plotted. |
| | | 2 | Element types (IMAT) will be plotted. |
| | | 3 | Both element numbers and IMAT's will be plotted. |
| 3 | HORIZ | + | Maximum horizontal size of plot |
| | | 0 | Use XSCALE and YSCALE |
| 4 | VERT | + | Maximum vertical size of plot |
| | | 0 | Use XSCALE and YSCALE |
| 5 | XSCALE | + | Scale factor for x-dimensions |
| | | 0 | Use HORIZ and VERT |
| 6 | YSCALE | + | Scale factor for y-direction |
| | | 0 | Use HORIZ and VERT |
| 7 | AR | + | Plot rotation in degrees clockwise from x-axis |
| 8 | HITEL | + | Height in inches of element numbers on plot |
| | | 0 | Default is .21 |
| 9 | HITNN | + | Height in inches of node numbers on plot |
| | | 0 | Default is .21 |

**Note**: Plot information is written to logical unit 99.

*Each plot option produces a separate plot. Thus, IPNN = 3, IPEN=0 will produce three plots--one with the mesh only, one with node numbers, and one with corner node elevations.

At the Waterways Experiment Station, plotting is available only on the following mainframe computers:

Cray Y-MP (larry)

VAX at HL (bubba)

## PP CARD Partial Plot Options

**Optional**

**Presence of this card indicates that at least one plot is to be drawn.**

| Field | Variable | Value | Description |
|---|---|---|---|
| Col 1 | ICT | P | Card group identifier |
| Col 2 | IDT | P | |
| 2 | NXPMIN | + | Node number of minimum x location in partial plot |
| 3 | NXPMAX | + | Node number of maximum x location in partial plot |
| 4 | NYPMIN | + | Node number of minimum y location in partial plot |
| 5 | NYPMAX | + | Node number of maximum y location in partial plot |

**Note**: Windowing is performed after any requested plot rotation specified by the PO card. The choices of maximum and minimum coordinates should be in terms of the rotated plot.

# Glossary of Terms

## 1D

The geometry is defined by cross section (a straight bottom line between corner nodes) and reach length. The calculated velocity is averaged over the cross section.

## 2D

The geometry is defined in two space coordinates and averages over the third space coordinate. In a 2 Dimensional *Horizontal* model, the averaging occurs over depth. In a 2 Dimensional *Vertical* model, the averaging occurs over width. Several 2 Dimensional Horizontal elements aligned side by side may accurately define the bottom elevation of a navigation channel.

## Alternate boundary condition file

(Supplemental BC file)

A formatted file which contains the boundary specifications for an RMA2 run.

## Aspect ratio

An element's length to width ratio. Long, slender elements with an aspect ratio greater then 15 may cause stability problems.

## Band sum

The summation of the bandwidths for each node (equation) of the mesh.

## Bandwidth

The span between the minimum and maximum node (or equation) numbers in elements common to the that node (equation). The bandwidth can be defined either by simple nodal assoication or by taking into acount the number of equations at each node.

Of particular interest to the modeler will be the average and maximum bandwidths.

## Banner

An alphanumeric set of information appended to all TABS binary output files which describes the flow of data between GFGEN, RMA2, RMA4, and STUDH.

## Base to Plan comparisons

The process of identifying differences in numerical model results between existing conditions and revised conditions, usually a change in geometry.

## Batch mode

The opposite of interactive. A job is typically submitted via proclv and is put in a job queue and will execute as CPU time and memory become available on the mainframe computer.

## Boundary condition specifications

There are several ways to specify BC's: slip flow, velocity, discharge per unit width, water surface elevation (exit head or exact head), non-reflecting, etc.

## Boundary conditions

Water levels, flows, concentrations, stage/discharge relationships, etc., that are specified at the boudaries of the area being modeled. A specified tailwater elevation and incoming upstream discharge are typical boundary conditions.

## Boundary effect

A consequence of dissimilarities between the model boundary conditions and the conditions occurring in the prototype at the location of the model boundaries. This effect may be minimized if the model's boundaries are far from the area of interest.

## Branching channel

A point in the mesh where two or more channels meet.

## Card

A term which comes from the 1960-1980's when computers recieved data on punched cards. Each card supplied the computer with a line of data.

The TABS programs use cards in the same way. The difference is that the card data are stored in a disk file and not in a filing cabinet.

## Card image

An ASCII line of data for the computer to read.

## Coastal Engineering Research Center

The US Army Corps of Engineers, Waterways Experiment Station, Coastal Engineering Research Center (CERC) focuses on coastal engineering, including waves, winds, water levels, tides, currents, and their interactions with coastal sediments and structures. Projects include shore and beach erosion control, coastal flood and storm protection, sand bypassing, dredging, navigation improvement, and harbor design and maintenance.

## Cold start

A model run using initial conditions that are not expected to be close to conditions as solved by the model, i.e., a level water surface elevation and velocity values of zero.

## Collapsed geometry file

All unused nodes and elements have been eliminated from the mesh.

## Compiler

A special computer program which converts a higher level language (such as FORTRAN) to a coded set of machine dependent instructions (fetch the contents of REGISTER 1). All TABS programs are written for the FORTRAN-77 compiler.

## Control structure element

A special 2-node element with an IMAT $\geq$ 904. The first node in the element connection table should be the side of the structure with the typical higher elevation.

## Corner node

Defines a vertex of an element. A point within the mesh that has an ($x$, $y$) coordinate and $z$ depth.

If an element has three sides, then it has three corner nodes.

## Curved boundary

An optional aesthetic means to outline key landmarks within the computational domain. A quadratic curved side is created by assigning ($x$, $y$) coordinates to the mid-side node of an element. Curving can help conserve mass in the transport models.

Curved boudaries may be created within the FastTABS program by unlocking the nodes and moving the mid-side node.

## Curved element side

An optional aesthetic means to outline key landmarks within the computational domain. A quadratic curved side is created by assigning ($x$, $y$) coordinates to the mid-side node of an element.

## Datum offset reference

An arbitrary constant from which all depths are subtracted in order to obtain a positive value for a bottom elevation.

Example: If the deepest section of the mesh is 125 feet *below* NGVD, then 200.0 would be a good arbitrary constant; and hence the bottom elevation for that corner node would be 75. If the highest section of the mesh is +2 feet above NGVD, then the bottom elevation would be 202.

## Datum reference (NGVD)

National Geodetic Vertical Datum. Vertical datum plane reference that has replaced mean sea level.

## Depth variation along an element (gradient)

The difference between the bottom elevation of any two corner nodes of an element. Large depth gradients along short distances are unstable. The general guideline is $\leq$ 20% depth variation.

## Digitize

The process of converting data from a map or graphical form to a digital form for use by computer programs. Data points are selected with a pointing device on a digitizing tablet which defines an ($x$, $y$) coordinate system. The ($x$, $y$) location of the pointing device is stored in a file for each point that is selected, possibly including a $z$ value at that point.

## Discretization

The procedure of representing a continuous variable by discrete values at specified points in space and/or time.

## DISSPLA

A comercial software plotting package. DISSPLA is distributed by Computer Associates, headquarters in Garden City, New York.

## DISSPLA meta file

A file generated by DISSPLA plot routines called by GFGEN which can be downloaded to a plotting device.

## Eddy viscosity

**Turbulent exchange coefficient**.

A coefficient used to relate the turbulent exchange of momentum (which occurs at space and time scales smaller than those being simulated) to the local derivative of the velocity. Its units in RMA2 are (lb sec/sq ft), and generally determines the freedom of a velocity vector to affect the velocities at adjacent nodes. Although it is difficult to establish its value, it is influenced by water depth, element size, and flow speed.  Therefore, as an element size increases, or as the velocities increase, so should the eddy viscosity.

For a fixed geometric mesh, running the model with oil as a fluid would require a higher coefficient, and with water a relatively lower coefficient.

## Element

A segment, triangle, or quadrilateral shape composed of corner nodes and mid-side nodes.  An element must be ‘connected’ to a neighboring element.

An element is composed of a list of nodes in a counterclockwise fashion and may define a 1, 2, or 3 dimensional problem.  A line segment defines a 1-D area, a triangle or quadrilateral defines a 2-D area, while the 3-D area is defined by adding layers to an element.

## Element connection table

The set of GE cards which define the nodes contained in each element

## Element connections

A counterclockwise sequential list of nodes that defines each element.

## Element edge overlap

Occurs when an element’s edge encroaches upon the area of an adjacent element, such as with improperly curved elements.

## Elemental solution order

A numerically efficient reordering of the mesh.

## Environmental Laboratory

US Army Corps of Engineers, Waterways Experiment Station, Environmental Laboratory research covers many broad areas, including predicting the effects of both natural and man-induced activities on the environment, developing and demonstrating methods for mitigating adverse effects, and providing many diverse technologies for environmental enhancement.

## FastTABS

A computer program that provides a graphical, point and click means for performing pre- and post-processing for surface water numerical models.

Developed at the Waterways Experiment Station and Bringham Young University. Contact the Waterways Experiment Station at (601) 634-3339 for more information.

## Field

A specific location on a record (card in TABS programs) in a data file where a data value occurs.

## Finite element

A method of solving the basic governing equations of a numerical model by dividing the spacial domain into elements in each of which the solution of the governing equations is approximated by some continuous function. This method lends itself well to the river/estuarine environments because of its diversity in computational mesh (element size, shape, orientation), flexibility of boundary conditions, and continuity of the solution over the area.

## Fixed format

An input structure that requires a preset sequence and column dependent location of data.

## Free field format

An input structure that requires a preset sequence of data with freedom in regard to location of data. Free field input variables may be separated by commas or spaces.

## Front width

The number of equations in the numerical model's solution matrix that are assembled simultaineously.

## Gate

A movable barier, such as a tide gate, in a river or stream.

## Geotechnical Laboratory

The Geotechnical Laboratory, Waterways Experiment Station, is actively engaged in research, development, testing, and evaluation projects in soil and rock mechanics, foundation design, embankment design, slope stability, seepage analysis, earthquake engineering, engineering geology, geophysics, pavement technology, expedient surfacing dust control, vehicle mobility, and trafficability.

It is the lead laboratory for Airfields and Pavements and for Sustainment Engineering as identified by the Tri-Service Project RELIANCE Civil Engineering Science and Technology Plan.

## GFGEN

Geometry File GENeration program used to create the computational mesh for all TABS applications.

## Gradient

The difference between the bottom elevation of any two corner nodes of an element. Large depth gradients along short distances are unstable.

## HEC format

A naming convention for the style of run control input derived by Hydrologic Engineering Center (HEC) in which each line of input is defined by a ‘Card Type in field 0’ and the data follows in fields 1 thru n.

Example,  GNN card:

| Field 0 | Field 1 | Field 2 | Field 3 | Field 4 |
|---|---|---|---|---|
| **GNN** | **node** | **x coordinate** | **y coordinate** | **bottom elevation** |

## Hydraulics Laboratory

The US Army Corps of Engineers, Waterways Experiment Station, Hydraulics Laboratory, Vicksburg, Mississippi, is the principal Corps agency for engineering research and experimentation in hydraulics and hydrodynamics and is one of the largest hydraulics laboratories in the world.

The Hydraulics Laboratory provides TABS Numerical Model maintenance and support for Army Corps installations.  Contact the Hydraulics Laboratory at (601) 634-3339 to find out about availability and support for the TABS modeling system.

## ill-defined elements

Identified if an element has any number of nodes other than 3, 5, 6, or 8 (unless it is a junction element or control structure), a node list containing a zero, or a node list that does not alternate corner and mid-side node numbers.

## IMAT

**Material Type**.  A variable name used in TABS programs to specify a number representing the type of material within an element.  The IMAT is located on the GE card and is used to aid in assigning modeling coefficients.

IMAT=0 is equivalent to assigning a land boundary around the element.

## Information Technology Laboratory

The US Army Corps of Engineers, Waterways Experiment Station, Information Technology Laboratory (ITL) supports the missions of WES, other Corps activities, the Army, DoD, and other agencies by conceiving, planning, managing, conducting, and coordinating R&D in computer-aided and interdisciplinary engineering, computer science, and information technology.

Through a balanced program of R&D and demonstration, ITL advances the Corps’ knowledge and ability to use advanced information technology to address a wide range of engineering and scientific challenges.

## Interactive mode

Opposite of  Batch mode.  The program requires the user to respond to questions.

If the program is running on a mainframe computer, the program is time sharing the CPU with other jobs, which can cause delays in some cases.

## Junction element

A special 3 to 8 noded element which defines the intersection of 3 to 8 one dimensional elements.

## Leaking

A description of the inability of a mesh to properly hold water. Some modelers refer to a 'leak test' as a means to check out a mesh.

Leaks, or "oozes", are a result of poor element shapes, large boundary break angles, and/or erroneous boundary condition specifications.

## Logical unit

Computer lingo used to associate a device number with a data file. In this FORTRAN statement, **10** is the logical unit number:

```
READ(10,*) DATA
```

## Map scale

Relates a real distance to a map distance, such as **1:20,000** means 1 inch = 20,000 feet.

## Material type

A number representing the type of material within an element.

See the definition of IMAT and the GE card for more information.

## Mesh

A collection of nodes and elements which defines the domain of the study area.

## Mid-side node

A node between two corner nodes in an element. TABS models require mid-side nodes.

## Mid-side node list

A list of all mid-side nodes, generated by GFGEN.

## Middle third rule

When using a curved element side, the point at which the smallest radius of the curved side is located must lie between the middle third of the distance between the two corner nodes of the element side.

**See also:**

Middle third rule violation

## Middle third rule violation

Occurs when a mid-side node on a curved boundary has been calculated to lie outside the middle third of the arc forming the element side. As discussed in "Problem Elements" on page 8, middle third rule violations need not always be fixed.

## Needle-like corners

Elements which have an interior angle of less than approximately 6 degrees.

An element of this shape will likely cause stability problems in RMA2.

## NGVD

National Geodetic Vertical Datum. Vertical datum plane reference that has replaced mean sea level.

## Nodal cross reference table

Shows the relationships between a node and any element with which it is connected. For each node in the mesh there is a cross reference to every element to which that node is associated, along with its designation (corner, mid-side, juction, or transition).

## Node

A point containing an *x*, *y*, and *z* coordinate which defines a location in space. Mid-side nodes (*x*, *y*, *z*) are linearly interpolated from adjacent corner nodes, unless the element side is curved.

## Off-channel storage

A one dimensional element feature. The storage width associated with the node at zero depth, as specified on GNN or GWN cards.

## One dimensional element

A line segment composed of two corner nodes and one mid-side node. The geometry is defined by cross section (a straight bottom line between corner nodes) and reach length. The calculated velocity is averaged over the cross section.

## PLTMSH subroutine

A subroutine within GFGEN which calls DISSPLA specific subroutines.

## Proclv

The user friendly interactive procedure on mainframe computers which permits users to access the library versions of the TABS system.

## REFINE

A subroutine in GFGEN which will increase mesh resolution in the *x* and *y* directions automatically (this routine is no longer necessary due to the capabilty of FastTABS to perform the task).

## Renumber

A reorder option within GFGEN to make the mesh computationally efficient for the Finite Element code.

## Resource Management Associates

The TABS numerical models were initially developed by Dr. Ian King at Resource Management Associates, (RMA), in Lafayette, California. An RMA representative can be reached at (707) 864-2950.

## RMA2

The 1-D/2-D depth averaged hydrodynamic Finite Element numerical model within TABS.

## RMA4

The 1-D/2-D depth averaged water constituent transport Finite Element numerical model within TABS.

## Run control data

Information that is to be read by a program and is used to specify the input parameters for a program run.

## Sediment Transport code

The STUDH program.

## Slope Rule Error

Occurs when the slopes given at two adjacent corner nodes cause the boundary to reverse directions between the nodes as shown in “Figure 7. Problem Curved Elements.” on page 10 of GFGEN Users Guide. If a user is tempted to use exotic slopes in an attempt to define complex shoreline boundaries, be warned that experience has proven that greater resolution (higher numbers of elements) is a better strategy.

## Source code

The US Army Corps of Engineers, Waterways Experiment Station, Hydraulics Laboratory, Vicksburg, Mississippi, provides TABS Numerical Model maintinance and support for Army Corps installations. Contact the Hydraulics Laboratory at (601) 634-3339 to find out about availability and support for the TABS modeling system.

## Special elements

Junction element, transition element, or control structure element.

## Structures Laboratory

The US Army Corps of Engineers, Waterways Experiment Station, Structures Laboratory carries out research, development, testing, and evaluation work in the fields of weapons effects, earth dynamics, structural design, structural behavior, and construction materials. This work is performed by designing and analyzing structures to resist static and dynamic loadings; defining effects of detonations and explosives; evaluating material properties, applications, and behavior in service; and defining the state of stress in soil and rock masses, especially as associated with transient loadings.

## STUDH

The TABS-2 model for sediment transport.

One dimensional elements are not supported in STUDH.

## System International

(SI) Formally named in 1960 by an international general conference on weights and measures. This system provides exact definitions of the metric system units for the fields of science and industry.

## TABS

The TABS-MD Modeling System is comprised of three main programs: GFGEN, RMA2, and RMA4.

## Transition element

A special ‘T’ shaped 5 node element which makes the transition between a 1-D element and a 2-D element.

## Two dimensional element

A triangle (3 corners and 3 mid-side nodes) or quadrilateral (4 corners and 4 mid-side nodes) shape which defines the geometry in two space coordinates and averages over the third space coordinate. In a 2 Dimensional *Horizontal* model, the averaging occurs over depth. In a 2 Dimensional *Vertical* model, the averaging occurs over width. Several 2 Dimensional Horizontal elements aligned side by side may accurately define the bottom elevation of a navigation channel.

## Waterways Experiment Station

The U.S. Army Engineer Waterways Experiment Station (WES), located in Vicksburg, Mississippi, is the principal research, testing, and development facility of the U.S. Army Corps of Engineers. Its mission is to conceive, plan, study, and execute engineering investigations and research and development studies in support of civil and military missions of the Chief of Engineers and other federal agencies.

**WES is composed of the following 6 laboratories:**

Coastal Engineering Research Center

Environmental Laboratory

Hydraulics Laboratory

Geotechnical Laboratory

Information Technology Laboratory

Structures Laboratory

## Weir

An obstruction placed in a stream, diverting the water through a prepared aperture for measuring the rate of flow.

## Well formed element

An element with the proper aspect ratio, shape, angle, plane, and depth variation along an element (gradient).

# Index

**W**