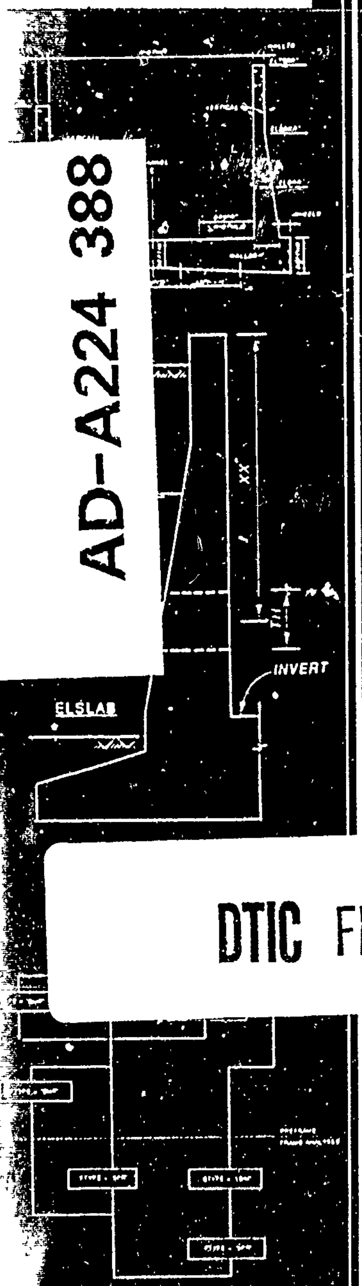
(2)

US Army Corps of Engineers

AD-A224 388



COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

TECHNICAL REPORT ITL-90-3

INVESTIGATION AND DESIGN OF U-FRAME STRUCTURES USING PROGRAM CUFRBC

VOLUME C
USER'S GUIDE FOR CHANNELS

by

Clifford O. Hays, Jr.

1910 SW 43rd Avenue
Gainesville, Florida 32611

and

Clifford Ford

DEPARTMENT OF THE ARMY
US Army Engineer District, Los Angeles
PO Box 2711, Los Angeles, California 90053-2325

DTIC FILE COPY

DTIC
ELECTE
JUL 3 1 1990
S E D

May 1990

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Monitored by Information Technology Laboratory
US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

90 07 31 029

Destroy this report when no longer needed. Do not return it to the originator.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

This program is furnished by the Government and is accepted and used by the recipient with the express understanding that the United States Government makes no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in this program or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made thereof. The program belongs to the Government. Therefore, the recipient further agrees not to assert any proprietary rights therein or to represent this program to anyone as other than a Government program.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

DTIC
ELECTE
JUL 3 1 1990
S E D

(2)

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report ITL-90-3	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION See reverse. 6b. OFFICE SYMBOL *(If applicable)*	7a. NAME OF MONITORING ORGANIZATION USAWES Information Technology Laboratory
6c. ADDRESS *(City, State, and ZIP Code)*	7b. ADDRESS *(City, State, and ZIP Code)* 3909 Halls Ferry Road Vicksburg, MS 39180-6199
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Corps of Engineers 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)* Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
Investigation and Design of U-Frame Structures Using Program CUFRBC;
Volume C: User's Guide for Channels

12. PERSONAL AUTHOR(S)
Hays, Jr., Clifford O.; Ford, Clifford

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final report	FROM ______ TO ______	May 1990	227

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*	
FIELD	GROUP	SUB-GROUP	Channels,	Reinforced concrete,
			Drainage,	Structural design,
			Hydraulic structure,	U-frame

(KR)

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The computer program CUFRBC can be used to investigate or design basins or channels for a variety of load conditions based on a two-dimensional frame analysis of a 1-ft slice of the U-frame.

The soil loading on the walls may be obtained by empirical coefficients, active or passive wedge analyses with corrections for at-rest conditions, or inputing force-deformation curves for the walls. Hydraulic loads are automatically computed from water elevations and drain data. Foundation reaction pressures may be computed using a simple equilibrium approach or a Winkler spring on elastic foundation model.

Design may be by allowable stress or strength design procedures, using American Concrete Institute or Corps criteria. Output includes member pressures, shears, moments, and stress or strength results at discrete points. Graphical output is available. Keywords.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE *(Include Area Code)* | 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

Corps of Engineers, CASE (Computer-Aided ...) Frames ...

90 07 31 029

6a. NAME OF PERFORMING ORGANIZATION (Continued).

Basins and Channels Task Group Computer-Aided Structural Engineering Project

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM Investigation and Design of U-Frame Structures Using Program CUFRBC			PROGRAM NO.
PREPARING AGENCY			
AUTHOR(S)	DATE PROGRAM COMPLETED	STATUS OF PROGRAM	
		PHASE	STAGE
Clifford O. Hays, Jr.	September 1989	Final	

A. PURPOSE OF PROGRAM

The computer program CUFRBC can be used to investigate or design basins or channels for a variety of load conditions based on a two-dimensional frame analysis of a 1-ft slice of the U-frame. Effects of drains and anchors may be included, and the program offers a variety of options concerning the computation of soil pressures. Thus, the program has sufficient versatility to suffice for preliminary designs, final designs, or in-depth investigations.

B. PROGRAM SPECIFICATIONS

Time-sharing FORTRAN Program.

C. METHODS The soil loading on the walls may be obtained by empirical coefficients, active or passive wedge analyses with corrections for at-rest conditions, or inputing force-deformation curves for the walls. Hydraulic loads are automatically computed from water elevations and drain data. Foundation reaction pressures may be computed using a simple equilibrium approach or a Winkler spring on elastic foundation model. For all loadings, a frame analysis is made to generate internal forces and moments at discrete points along the members. Design may be by allowable stress or strength design procedures, using American Concrete Institute or Corps criteria.

D. EQUIPMENT DETAILS

A data entry terminal is required to operate the program in the time-sharing mode. A Techtronix graphics device or emulator is required for obtaining graphical output.

E. INPUT-OUTPUT

Data can be input interactively with the aid of an on-line editor or from a prepared data file with or without line numbers. Output includes member pressures, shears, moments, and stress or strength results at discrete points. Numerical output can be displayed at the terminal or directed to an output file. Graphical output is available using a companion program CUFRMP and the Corps graphics package GCS2D.

F. ADDITIONAL REMARKS

PROGRAM INFORMATION

Description of Program

CUFRBC, called X0095 in the Conversationally Oriented Real-Time Programming System (CORPS) library, can be used to investigate or design basins or channels for a variety of load conditions based on a two-dimensional frame analysis of a 1 ft. slice of the U-frame. Effects of drains and anchors may be included, and the program offers a variety of options concerning the computation of soil pressures. Thus, the program has sufficient versatility to suffice for preliminary designs, final designs, or in-depth investigations. Graphical output is available using a companion program, X0096 (CUFRMP).

Coding and Data Format

CUFRBC is written in FORTRAN and was developed on the Power Computing Company Cyber 865. It will be available in the future on the following systems:

a. WES Honeywell DPS/8

b. Local District Harris 500 Series.

c. Micro Computer IBM PC/XT/AT compatibles.

d. Intergraph workstations.

How to Use CUFRBC

A short description of how to access the program on each of the systems, when the program is available, is provided. It is assumed that the user knows how to sign on the appropriate system before trying to use CUFRBC. In the example initiation of execution commands that follow, all user responses are underlined, and each should be followed by a carriage return.

WES Honeywell System

The user signs on the system and issues the run command.

<u>FRN WESLIB/CORPS/X0095,R</u>

to initiate execution of the program. The program is then executed as described in this user's guide. The data file should be prepared prior to issuing the FRN command. An example initiation of execution is as follows, assuming a data file had previously been prepared:

COEWES HIS TIMESHARING ON 05/10/90 AT 11.612 CHANNEL 2426 TS2

USER ID --<u>ROKACLA</u>
PASSWORD--
<u>XXXXXXXX</u>
#USERS=016 SS=0247K %MEM-USED=046 000-WAIT-000K

*<u>FRN WESLIB/CORPS/X0095,R</u>

Power Computing Company
Computer System

The log-on procedure is followed by a call to the CORPS procedure file

OLD.CORPS/UN=CECELB

to access the CORPS library. The file name of the program is used in the command

BEGIN,,CORPS,X0095

to initiate execution of the program. An example is:

```
CONNECTED TO  (20) 5-2
90/05/10. 11.34.45. AA1D8HA
SN1048 POWER COMPUTING COMPANY          NOS1.4-531-795-A
FAMILY:  KOE
USER NAME: CEROF8
PASSWORD
XXXXXXXX
TERMINAL:      6, NAMIAF
RECOVER/ CHARGE: CHARGE,CEROEGC,CEROF8
$CHARGE,CEROEGC,CEROF8.
/OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,X0095
```

Harris System

The user signs on the system and issues the run command

*CORPS,X0095

to initiate execution of the program.

An example is:

```
"ACOE-WES(H500 V7.1.0)"
ENTER SIGN-ON
1KABC ROKABC
ENTER PASSWORD
XXXXXXXX

** GOOD MORNING CORPS-LIB, IT'S 10 MAY 90 11:34:51
WES HARRIS 500  FOR SYSTEM INFORMATION - ENTER *NEWS
*CORPS,X0095
```

DTIC COPY INSPECTED 6

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

How to Use CUFRMP

Commands for execution of the companion program CUFRMP are similar. The user replaces the program number X0095 in the above examples with X0096.

How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on the WES system is:

```
*FRN WESLIB/CORPS/CORPS.R
ENTER COMMAND (HELP, LIST, BRIEF, EXECUTE OR STOP)
*?LIST
```

On the Power computing Company computer system, the commands are:

```
/OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,CORPS
ENTER COMMAND (HELP, LIST, BRIEF, EXECUTE OR STOP)
*?LIST
```

On the Harris computer system, the commands are:

```
*CORPS
ENTER COMMAND(HELP,LIST,BRIEF,EXECUTE OR STOP)
*?
```

PREFACE

This report, Volume C - "User's Guide for Channels," gives instructions for routine use of the computer program CUFRBC for channel structures. CUFRBC is a program for interactive investigation and design of U-Frame Basin and Channel structures. The program was developed and the report written using funds provided to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, by the Civil Works Research and Development Program of the US Army Corps of Engineers (USACE), US Army, under the Structural Engineering Research Program Work Unit entitled "Computer-Aided Structural Engineering (CASE) Project.

Volume A, "Program Criteria and Documentation," documents and gives the development criteria for the program. Volume B, "User's Guide for Basins," gives instructions for routine use of the program for basin structures.

The program was prepared with criteria developed by the Basins and Channels Task Group of the CASE Project. Members of this group during program development were:

Mr. Byron Bircher, CEMRK-ED-D, Chairman, U-Frame Structures Task Group
Mr. George Henson, CESWT-EC-DT, Chairman, U-Frame Basins and Channels Sub Group
Mr. Frank Coppinger, CENAD-EN-TF
Mr. Edwin Aling, Soil Conservation Service (formerly)
Mr. Donald Dressler, CEEC-ED-D
Mr. Clifford Ford, CESPL-ED-DB
Mr. Lucian Guthrie, CEEC-ED-D
Mr. Bill James, CESWD-ED-TS (formerly)
Mr. Ivar Paavola, CEEC-ED-D (formerly)
Mr. Mike Pace, CEWES-IM-DS
Mr. William Price, CEWES-IM-DA
Mr. Scott Snover, Soil Conservation Service (formerly)
Mr. Tom Wright, CEMRK-ED-DT

The computer program and portions of this document were written by Dr. Clifford O. Hays, Jr., P.E., Gainesville, Florida, under contracts with WES. Mr. William Price, Information Technology Laboratory (ITL), monitored the contract and coordinated the work. Portions of the report were also written by Clifford Ford, member of the U-Frame Structures Task Group, from the Los Angeles District.

The work was managed and coordinated at WES by Dr. N. Radhakrishnan, Chief, ITL, and Mr. Paul K. Senter, ITL. Mr. Donald Dressler was the point of contact with USACE.

COL Larry B. Fulton, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is the WES Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
kips (force)	4.448222	kilonewtons
kips (force)-feet	1355.818	newtons-metres
kips (force) per square inch	6894.757	kilopascals
kips (force) per square foot	47.88026	kilopascals
pounds (force) per cubic foot	0.157087	kilonewtons per cubic metre
pounds (force) per square inch	6.894757	kilopascals
square inches	6.4516	square centimetres

INVESTIGATION AND DESIGN OF U-FRAME STRUCTURES

USING PROGRAM CUFRBC

VOLUME C - USER'S GUIDE FOR CHANNELS

PART I: INTRODUCTION AND OVERVIEW

1. The computer program CUFRBC is a CASE program for interactive investigation and design of U-frame basin and channel structures. The U-frame is modeled as a framed planar structure. CUFRBC is a user friendly interactive program capable of quickly designing or investigating a U-frame structure for a variety of different geometry, load, and foundation conditions. This volume of the report (Volume C) describes the use of the program for U-frame channel structures. Users wishing detailed information about the procedures and algorithms used in the program should refer to Volume A of this report.

Methods and Capabilities

Geometry

2. CUFRBC can be used to design or investigate basins with one, two, or three bays and channels with one or two bays. Separate modules are used for basin and channel configurations. This section briefly describes both the basin and channel geometries. However, the remainder of this volume is specific to channel structures. Users wishing to use the program for U-frame basins must refer to Volume B of this report.

3. In the design mode, the program will compute the required geometry to satisfy design requirements starting from initial values supplied by the designer. The basin and channel modules use slightly different rules for initial geometry and the incrementing of dimensions in the design mode. In the investigation mode, the user prescribes the U-frame geometry to be investigated for the specified loadings.

4. The basin module requires the structure to be symmetric about the center line. The faces of the walls may be sloped, and the fill side of the walls or divider walls may have a vertical face near the top with a break in the wall changing to a sloping face. The top elevation of the slab is held

constant, and the bottom of the slab must be horizontal. The heel may have a sloping top surface and a thickness less than the slab.

5. Channel U-frame structures may be symmetric or nonsymmetric with up to two bays. The channel module will accept a battered wall face on the fill side, but the exterior walls must have vertical channel faces. The top surface of the invert is considered to be a constant elevation, but the bottom surface may be tapered from the heel thickness to a reduced thickness at any point short of the center wall or channel center line. The width of the heel may be different for each side of the structure.

Loading capabilities

6. The self-weight of the U-frame is automatically included in all load cases. Hydraulic loads on all the members are computed within the program from input of water elevations, locations of wall and base slab drains, and drain efficiencies. Earth pressure on the walls and top of heels may be computed by using: (a) an empirical approach with effective lateral soil coefficients, (b) wedge solutions for active or passive loadings including surcharges, or (c) nonlinear lateral force deformation curves. Special loads can also be included as line (concentrated) or distributed loads.

Foundation model

7. CUFRBC is capable of computing foundation reaction pressures using a simple statics approach with a user defined empirical foundation pressure distribution to obtain equilibrium or by a beam on elastic foundation method. Tension only anchors can be used with the elastic foundation method.

Design and investigation modes

8. CUFRBC allows the user to select the design or investigation mode for both basins and channels. Working stress or strength design methods can be used to design or review basins or channels. Corps of Engineers methods for the strength design of hydraulic structures or American Concrete Institute (ACI) methods may be chosen. The user controls allowable stresses in the working stress design and strength reduction and load factors in the strength design.

Input Editor and Program Execution

9. The program is interactive and may be run by preparing a data file in advance or by using an on-line input editor. Due to the many options

offered by the program, the beginning user is strongly urged to use the input editor for data preparation. The interactive input editor is very user friendly and is the easiest way for the novice to become familiar with the program input variables. Appendix A, the Input Guide for Channels, contains a detailed description of the input variables.

10. The ease with which the data files may be modified and the program rerun allows the designer to quickly study the effects of physical parameters that are not well defined. In this way, investigations and designs may be obtained for envelopes of paramaters. The input needed by the frame analysis module is generated by the CUFRBC program from a minimum of input of physical parameters defining the outline of the structure, the soil properties, and the soil and water geometry.

11. The editor automatically takes care of the input data management and asks the user for only the data required for the selected options. For example, if while creating a new file the Working Stress Design (WSD) method is chosen, the user will be asked for only those values appropriate for WSD. If slab drains are to be included but not wall drains, then only the location and effectiveness of the slab drains will be requested by the editor. To avoid being overwhelmed by the number of input items which are omitted for the chosen options, the novice users should elect to utilize the input editor. Details on the use of the input editor are provided later in this report and are also available interactively when running the program.

Display and Output Options

12. Once the editing is complete, an opportunity to display or modify the input file is provided. Then the user has the option to save the file with or without line numbers. Next, the user may stop or continue with the design or investigation. In the design mode, the user may elect to see the design variable interactions with selected factors of safety and stress or strength ratios.

13. When the design or investigation is complete, the user may elect to display the input and output data or store the output and continue the program with new input. The user is also asked if a plot file should be stored for later plots. Graphical output of the results may be obtained allowing the user to quickly verify input data and interpret results.

Disclaimer

14. This program has been developed using criteria supplied by the Basins and Channels Subgroup, U-FRAME Structures Task Group of the CASE Project. This volume describes the criteria and documents the assumptions on which the program is based. The program has been subjected to extensive testing by the author and members of the committee to ensure that it is reasonably error free and will generally provide reasonable investigations or designs for U-frame structures. However, no warranty of the correctness of the results for any particular structure is made or implied by the author. The user of the program is responsible to ensure that the assumptions inherent in the program are applicable to the structure chosen and that the numerical results are reasonable.

Proper Program Usage

15. Considerable efforts have been made to provide the program CUFRBC with extensive capabilities for the design or investigation of U-frame basin or channel structures and still keep the program user friendly. As stated earlier, the on-line input editor is the chief mechanism to allow a new user to learn how to utilize the program rapidly. However, it is essential that the user of any program be thoroughly familiar with the assumptions and limitations of the program in order to apply it correctly. The following procedure is suggested to the new program user as a method of learning the proper way to execute the program in the most efficient manner.

16. After reading this introductory section, the user should know the general capabilities of the program and the distinction between basin and channel geometries. If the user wishes to design or investigate a channel structure, the next section which describes the input variables for the channel geometry in detail should now be read. Then the user should take a look at the first example channel in Appendix B to see how the data may be prepared and the program run for a simple example.

17. Next, the user should read the first part of Appendix A up to the section entitled "Summary of Input by Sections." At this point, the user should try and run the first example in the interactive mode. The user might

then try to change some of the input to see how easy it is to change the data and play "what if" with the program.

18. The user should be convinced that the program has a wide variety of capabilities and should be motivated to read the remainder of this volume to learn the general design and investigation procedures used in the program. The user may of course elect to skim over or omit sections which deal with program options that do not meet particular needs. At that time, the user should be able to properly utilize the program for the design or investigation of most channel structures. If questions arise about some of the assumptions, details of the procedures used in the program, or interpretation of the output, the user should refer to the more complete program documentation in Volume A of this report.

PART II: CHANNEL GEOMETRY

19. The program allows for the investigation or design of channel structures as subsequently described. The user of the program is warned against applying the program to other structures, which might superficially resemble the structures described herein but might be significantly different when loading or behavior is considered.

20. Channels are typically used in floodways. Their criteria generally follow, but are not limited to, EM 1110-2-2400 (Headquarters, Department of the Army 1961a). The program considers structures with either one or two bays as shown in Figures 1 and 2. These figures show the geometric outlines and define the input variables further described in the input guide (Appendix A). The sections may be unsymmetrical as shown in the figures for the investigation mode. However, the section must be geometrically symmetrical for the design mode. Also, there is a symmetrical input option for the investigation mode which is described in Appendix A.

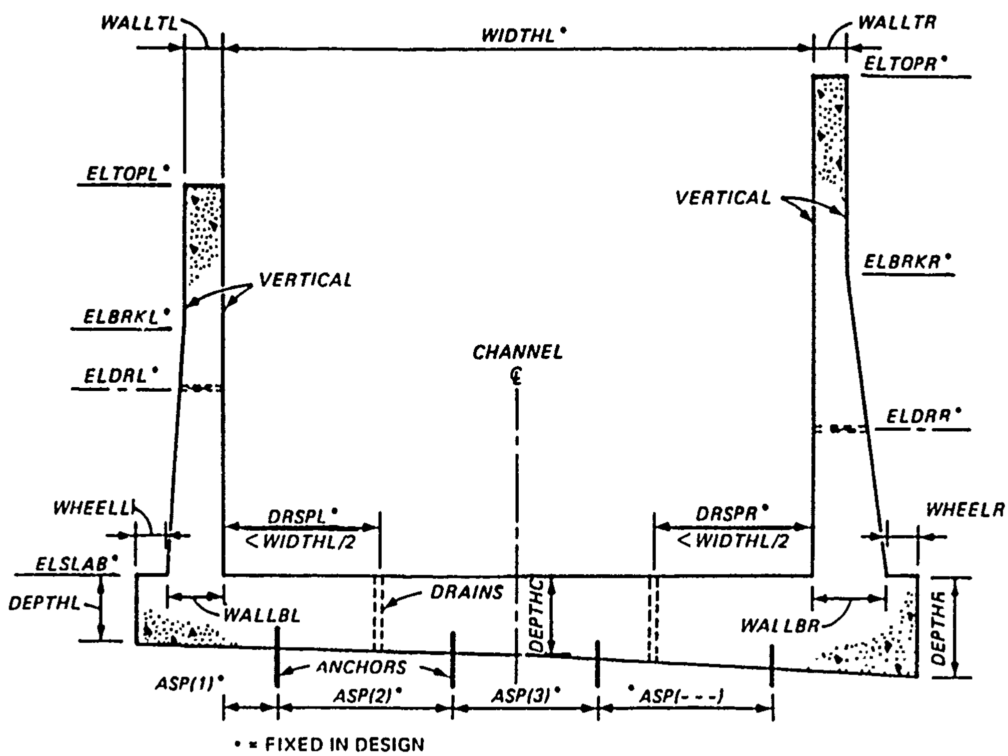


Figure 1. Single-bay channel structure

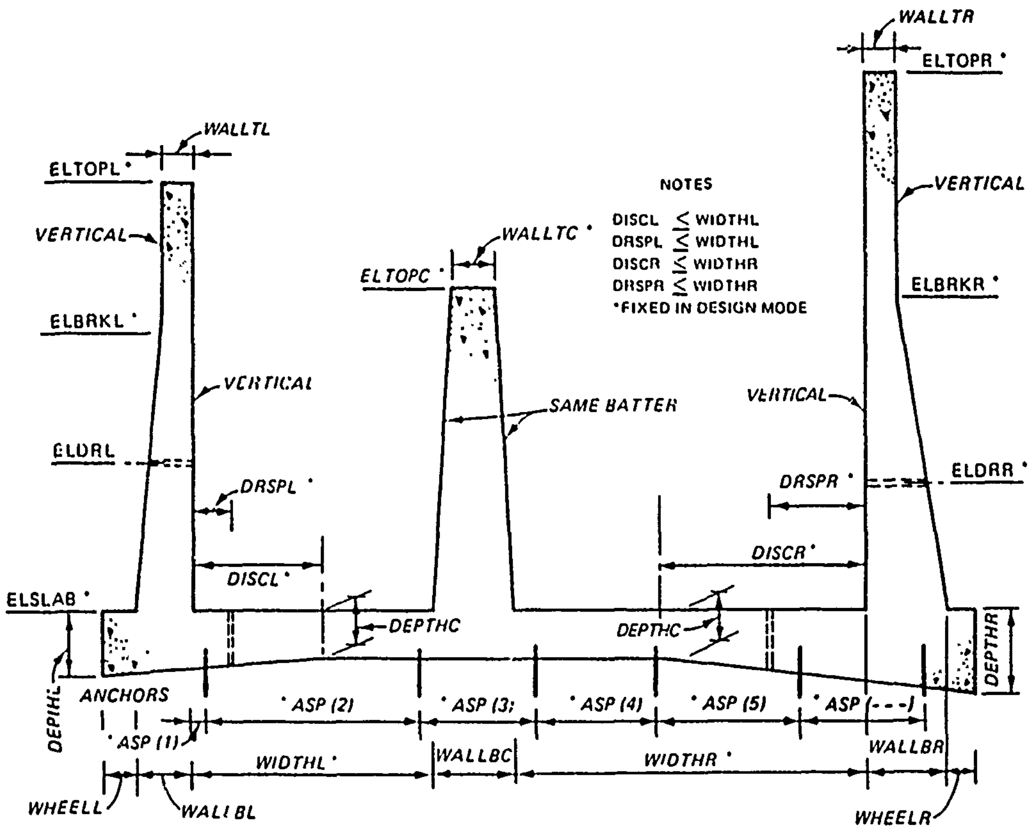


Figure 2. Double-bay channel structure

21. The input values define the cross section for the investigation mode. However, in the design mode these values define the initial cross section. Input variables shown with an asterisk are kept constant in the design mode. The cross-section variables not shown with an asterisk are incremented as necessary for the final design. The details of the design procedure are given later in this report.

22. The variables describing the locations of drains and anchors are shown in the figures defining the geometric outlines of the channel. The use of these variables is discussed in subsequent sections; however, several points should be noted about the locations of the anchors by the user. First, the leftmost anchor is located by giving the distance from the inside face of the left wall. This distance may be negative, as long as the anchor remains under the slab. Subsequent anchors are located by giving a positive distance from the previous anchor.

23. For symmetrical channels, including all channels being designed by the program, only data for the left half of the channel are input. Thus, only the anchors on the leftside of the channel are specified, and equal

symmetrical anchors are created by the program on the right-half. However, any anchor located within one-tenth of a foot* of the center line is treated as a "center-line anchor" and does not cause the creation of an additional anchor. Also, it should be noted that for the design mode the widths of the walls may increase. Thus, the relative positions of the anchors may shift slightly during the design process. If the walls increase significantly during the design of the walls, the user of the program may respecify the locations of the anchors and rerun the program. Note, however, that the anchor located at the center line using the original minimum wall thickness will remain at that center line location in spite of the changes in the wall thicknesses.

24. Input and output for the channels are keyed to the members as defined in Figure 3. The details of the frame model are discussed subsequently. However, it is important to note here that the frame analysis considers a frame of relatively flexible vertical and horizontal members connected at essentially rigid joints of finite size. The rigid joints are shown within

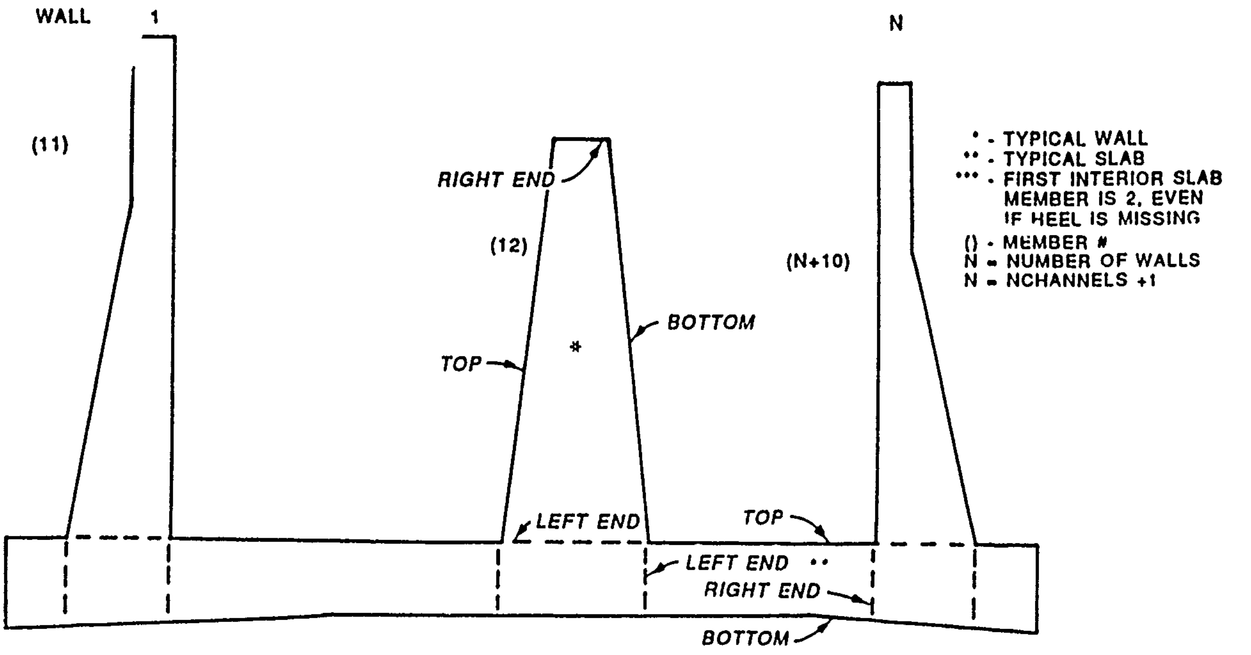


Figure 3. Channel geometry model

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

dashed lines in the figure. Base slab members including heels are numbered from left to right from 1 to N + 1, where N is the number of walls. The heels may be omitted; however, if the left heel is omitted, the first slab member will still be member number 2. The number of channels is NCHANNELS and

$$N = NCHANNELS + 1$$

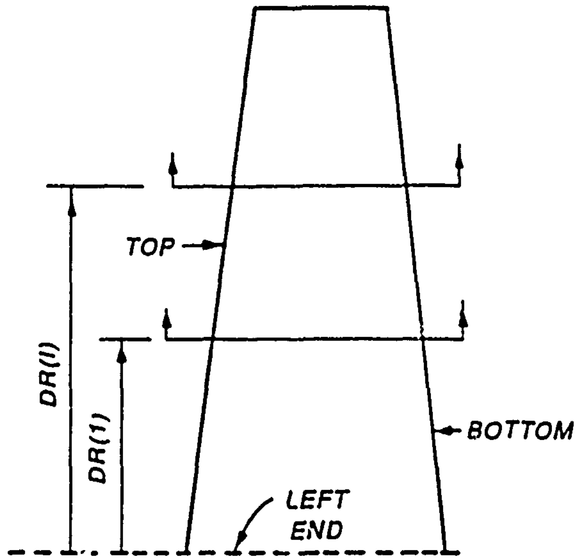
The leftmost wall is numbered 11, and then the remaining walls increase in number from left to right as shown in the figure. Input of reinforcing and special loads and the all member output are keyed to these member numbers and the "left-right" - "top-bottom" orientation of the members as shown in the figure. Distances along the member are always specified from the "left" end of the member.

25. Section behavior may be reviewed at up to five points per member in the investigation mode. The locations of the review points are specified as shown in Figure 4. The distance to the review point is always measured from the "left" end of the member as defined in Figure 4. Up to three layers of reinforcing may be specified for the "top" and "bottom" of a member. As many of the members as desired may be reviewed, NMINV is the total number of members being reviewed. Thus, if all members of a single channel structure with heels were reviewed, NMINV would be five (two walls, two heels, and the center slab).

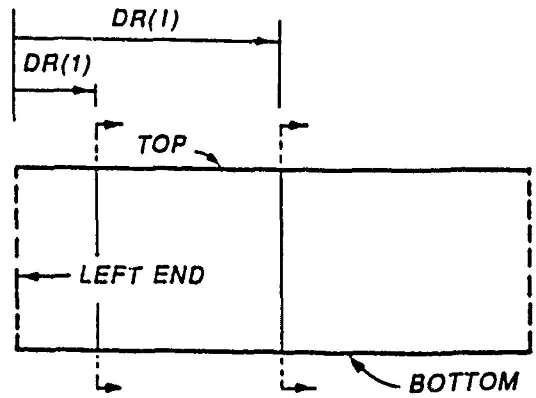
26. It should be noted by the user that the program will compute stresses or evaluate strength design criteria in the heel in the investigation mode. However, the depth-span ratio of the heels in channels may often exceed that for which the computations are valid. Thus, the user of the program should ensure that the depth-span ratio is sufficiently small for the calculations to be valid.

27. The "top" layers of steel are not considered effective in resisting tension on the "bottom" side of the member. Thus, the user should ensure that steel is located in the proper face for all load conditions. Details on the calculations of elastic stresses and strength design procedures are discussed subsequentlv.

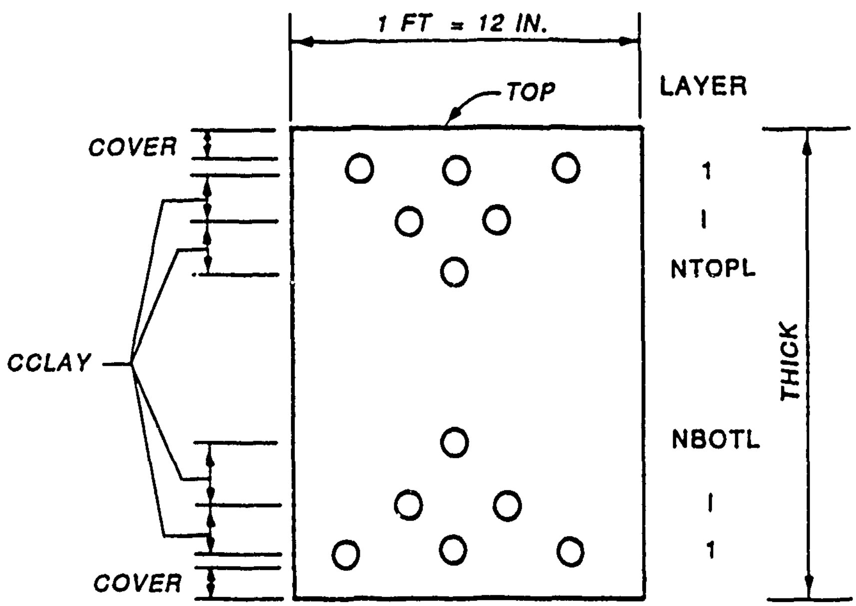
28. NTOPL and NBOTL are the number of layers in the "top" and "bottom" of the section, respectively. Layers are numbered from the exterior of section to the interior as shown in the figure. The steel within the layers



a. Typical wall member



b. Typical slab member



c. Typical cross section

Figure 4. Description of reinforcement/analysis option

may be specified by two different bar options. For 'REOPT' = "BAR," the steel within each layer is specified by the bar size (number of nominal one-eighth-in. increments in diameter) and the spacing in inches within the layer. For 'REOPT' = "ARE," the steel is specified by giving the area in square inches per foot of the steel in each layer and the nominal diameter of the steel in the outer layer. This nominal diameter is only used in computing the location of the centroid of the outer steel layer.

29. The variable COVER is the clear cover from the outer edge to the first steel layer and is specified for four different conditions as defined in the input guide (Appendix A). The center-to-center distance between steel layers, CCLAY, is constant at all locations.

PART III: FRAME ANALYSIS

Frame Analysis Module, FRAME55

30. In order to incorporate limited soil-structure interaction capabilities into the program, it was decided that the frame analysis module should permit frame members to have nonlinear soil support characteristics, i.e. beam on nonlinear elastic foundation. FRAME54 previously developed by the author permits general nonlinear soil supports for members through the use of nonlinear force deformation (q-w) curves describing the lateral and axial forces developed along the length of members. Similar support curves may be specified at the frame joints. Nonlinear stress-strain behavior and nonlinear geometric behavior (buckling and beam-column action) are also modeled in the FRAME54 program.

31. FRAME55 is a modified version of the earlier program eliminating the nonlinear stress-strain and nonlinear geometric models and with other minor modifications to facilitate the specific nature of the U-frame structures. FRAME55 was then made the analysis module of the U-frame analysis program CUFRBC.

32. CUFRBC consists of this frame analysis module, a preprocessor to prepare the voluminous data required by FRAME55 describing the U-frame geometry and loading, and a postprocessor to present the results in a convenient manner, including graphical output. The frame analysis module is described in Volume A.

Frame Model

33. Both basin and channel structures have many common features, and either can be modeled as a general multiple wall U-frame as described in Volume A of this report. Thus, it was decided to write one program that would handle both structure types. However, this volume only describes the details for the channel structures. Further, once the user of the program specifies that a channel is being analyzed or investigated, the program blocks out all references to input for basins. Likewise, if the person using the program is working with a single-bay channel, input references and output for portions of two-bay channels will be omitted.

34. The frame members are taken as essentially vertical and horizontal. The idealized axis for all the horizontal members is .ken at the middepth of the central portion of the slab. Similarly, the idealized axis of all wall members are taken at the center of the walls at the elevation of the top of the slab. The eccentricity of the centroid of the cross section from the idealized axis is however considered. The maximum number of walls permitted is three.

35. The slab and wall members shown in Figure 3 are treated as flexible members in the frame solution. The essentially rigid blocks between these members are treated as semirigid members internally in the frame analysis. However, member input and output are keyed to the flexible members as described throughout the report.

36. Frame geometry data for the frame analysis module (joint coordinates and member incidences) are automatically generated by the program from the channel input variables. The modulus of elasticity, EC, of all members is taken as that of the uncracked concrete section and is expressed as

$$EC = 33.*WCEFF^{1.5}*FPC^{0.5}$$

where FPC is the compressive strength in pounds per square inch, and WCEFF is the effective unit weight of the concrete in pounds per cubic foot. WCEFF is computed by subtracting 6 pcf from the input unit weight of the concrete to account for the weight of the steel reinforcement.

37. Gross section properties are used throughout the analysis, since generally stresses are kept low enough in channel structures to avoid significant cracking. If the stresses should be high enough to cause cracking, the deflections computed by the program would be too low. Likewise, no allowance for creep is made in the analysis for deflections.

PART IV: PROGRAM LOADING OPTIONS

Nature of Loading

38. The U-frame channel structure must function in a variety of flow conditions from drought to flood. The exact nature of the loading or the physical parameters on which the loadings are based are never known precisely. Thus, the designer is forced to look at extreme ranges of possibilities and determine a range of loadings which control the size of the U-frame cross section and the reinforcing at various points within the section.

Active and Reactive Loading

39. For the planar models of analysis, it is convenient to subdivide the loadings on the structure into two primary classifications, active and reactive loads. Active loadings are primarily those that tend to move the U-frame structure, and reactive forces are those that are developed to counteract or oppose that motion.

40. The program CUFRBC computes the different types of active forces and pressures to be developed against the surfaces of the U-frame. Then, in general, a frame analysis is made for the frame subjected to these loadings to find the reactive forces and the internal force distributions of shear, axial force, and moment for design.

41. The program provides for a wide variety of different ways of specifying the loadings in order to allow different design practices to be followed using the same program. Thus, the program can be used to make important parameter studies comparing various design approaches. Also, while the program is quite comprehensive, the input is still simple enough such that a designer will be able to use the program efficiently for routine designs that may involve only a small portion of the allowed program options. However, it is recommended that anyone planning to use the program read the descriptions of all the possible loadings before attempting to apply the program.

Description of Geohydraulic Loac

42. Figure 5 shows soil, water, and rock elevations and surcharge data

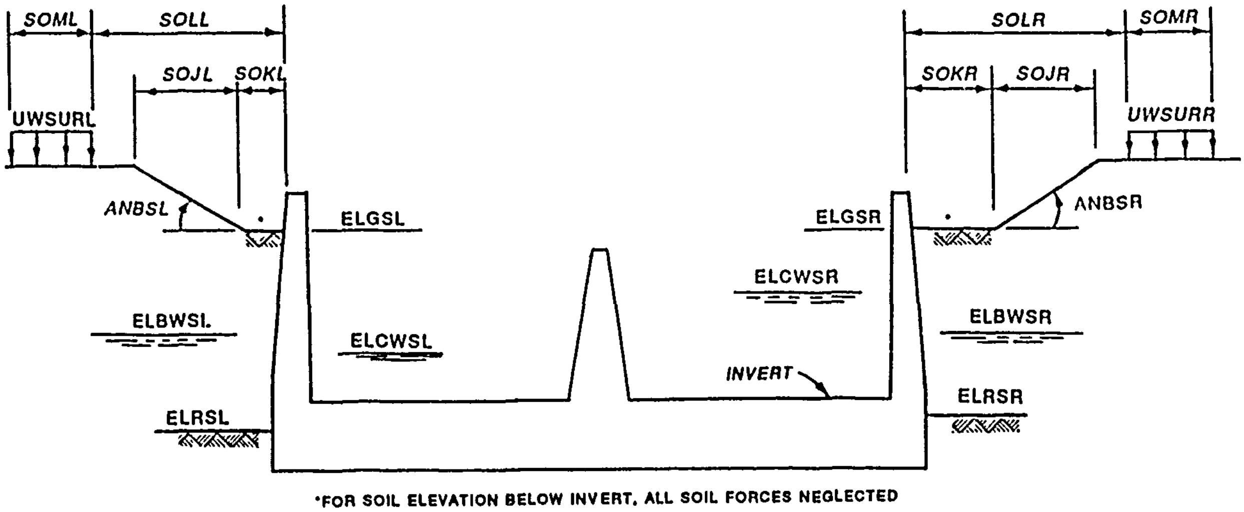


Figure 5. Ground profile, water elevations, and surcharge

which are input for a general U-frame structure. The input guide in Appendix A specifies which of these items are required for the particular structure geometry.

43. The various types of active and reactive loadings are next briefly reviewed. Then the loadings are described in detail. Some of the loadings described cannot be used simultaneously in the program. For instance, either empirical wall pressures or wedge solutions may be used but not both within the same computer solution. Thus, after all loadings are described, the various program options concerning loading are discussed in the section entitled "Program Loading Combinations." Certain of the loading options are not permitted in the design mode. The design loadings are generally restricted to symmetrical cases. Details on the loadings for the design mode are covered subsequently in detailed discussions of the design mode.

Summary of Active Loadings in Investigation Mode

44. The CUFRBC program allows for the following types of active loading in the investigation mode:

a. Self-weight of concrete U-frame automatically generated from the geometry of the section and the input unit weight for all load conditions.

b. Hydraulic loading wherein all hydraulic pressures are automatically computed from the input water elevations, drain locations, and specified drain efficiencies.

c. Active earth pressure by wedge solution. A wedge solution may be performed to give active earth pressures for symmetrical soil loadings. For unsymmetrical situations, the pressure on the active side may be obtained by an active wedge solution.

d. At-rest pressures by multiplying input coefficient times active earth pressures.

e. Vertical surcharge loads as part of wedge solution.

f. Empirical wall and heel pressures computed from input soil elevations and lateral pressure coefficient.

g. User specified special loads. General concentrated and distributed loads and at any points along the section. These loads may be used to represent types of loadings other than those generated directly by the program. Also, the special loads can be used to "correct" any loading that the program computes in a different manner than that normally done by the user. The special loads may be combined with any of the other active and reactive loads.

Summary of Reactive Loadings in Investigation Mode

45. The CUFRBC program allows for the following types of reactive loading in the investigation mode:

a. Base slab pressures computed using compression only beam on elastic foundation model, i.e., distributed vertical elastic springs acting only in compression.

b. Vertical tiedown forces computed as tension only elastic spring forces.

c. Base slab pressures computed by statics with user specified shape. This method is similar to a "P/A" $\pm$ "Mc/I" approach except the shape of the "P/A" portion can be specified.

d. Base shears computed to satisfy horizontal equilibrium from having all active forces be either uniformly distributed over the base or on the basis of distributed horizontal springs on the base slab.

e. Lateral wall pressures on both active and passive sides computed using nonlinear force-deformation curves and the compatibility of deformation with wall deflection. These so-called q-w curves may be input to range from the full active to passive states.

f. Base shears and earth pressures on the passive side of U-frame based on the proportional distribution of potential maximum passive values, primarily for nonsymmetric loadings.

Hydraulic Loading

46. The hydraulic loading on the structure is automatically computed with the assumptions described herein. The calculations do not follow the line of creep theory as outlined in EM 1110-2-2502 (Headquarters, Department of the Army 1961b). However, the pressures will not differ much from the line of creep calculations, and the users may adjust the computed pressures or give their own hydraulic pressures by including the special loads option.

47. The hydraulic pressures acting on the U-frame are computed in terms of the effective water elevations, ELW(I), adjacent to each wall as shown in Figure 6. The actual water elevations are input as ELBWSL, ELCWSL, ELCWSR, and ELBWSR, shown in the figure. The actual elevations are input as necessary for the particularly channel and with consideration of symmetry as described in the input guide.

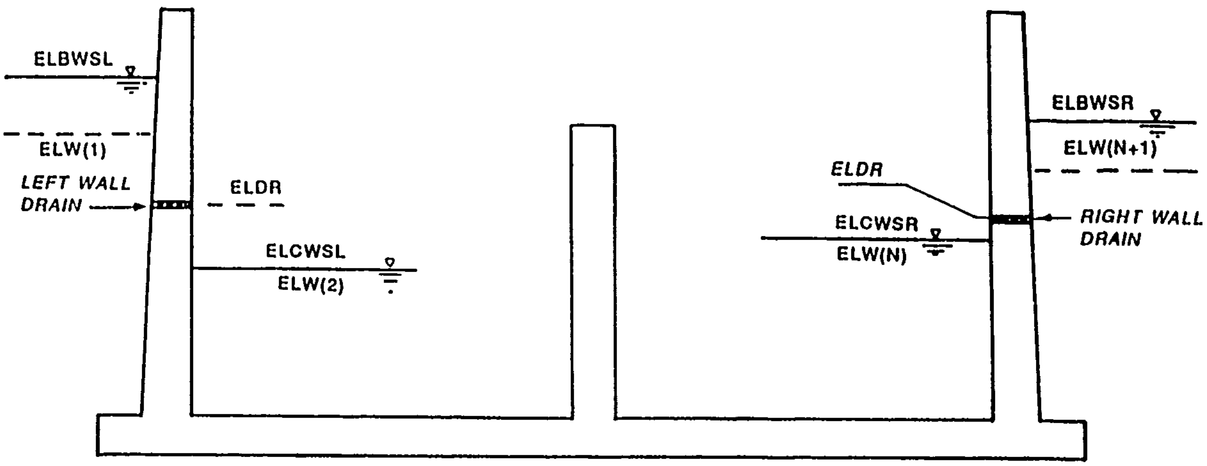


Figure 6. Input and effective water elevations

48. The effective interior water elevations are simply the corresponding input values. However, the effective exterior water elevations, ELW(1) and ELW(N+1), are computed considering the percent effectiveness for the exterior wall drains. The exterior wall drains are only considered effective in draining water into the U-frame and thus only affect the exterior effective water elevations. The interior water elevations are not affected by the wall drains.

49. It should be noted that since the wall drain option in effect only lowers the exterior wall elevations, the same results as using the wall drain

option could be cbtained by simply setting the exterior water elevations at their effective values. However, the wall drain option was included to allow automatic reduction of the exterior elevations based on input values of drain effectiveness. The percent effectiveness operates on the smaller of the difference in head between the exterior water elevation and the wall drain or the exterior and interior water elevations. It should be noted that the effective elevations for the exterior wall are used in computing not only wall pressures but also uplift pressures on the base in conjunction with slab drains.

50. Hydraulic forces on the wall members are computed at the center of each of the 10 discrete elements used for the wall by finding the hydraulic pressure at the middle of the element. The resultant hydraulic force acts normal to the wall, and the vertical and horizontal components of the force and the moment of the vertical component are computed. Similar computations are made for both sides of the wall, and the forces summed to obtain the net hydraulic forces.

51. The hydraulic forces acting on the base slab are computed in a similar manner. However, first, the effective head along the bottom of the slab must be found with due consideration of the drains. The procedure for computing the effective head at each of the drains is illustrated in Figure 7.

52. First, the reference head, EHB, is computed at each of the drains. EHB is the head that would be acting assuming no drain effectiveness and a linear variation of head across the base. The head on the top of the slab, EHT, and the head from the water on top of slab projected to the bottom of the slab, EHTP, are next found from the water elevations ELW(I). Then the effective head at drain J, EH(J), is found by applying the percent effectiveness to the difference between EHB and EHTP. The head on top of the slab is not adjusted for the effectiveness of the slab drains; however, if EHTF is greater than EHB, and the drain is considered, the water pressure on the base will be increased.

53. If a drain is specified as 100 percent effective, then the head on the bottom of the slab at the drain will be EHTP with the head on top of the slab based on EHT. If the drains are specified as being 0 percent effective, then they have no effect on the hydraulic forces. Further, a drain option is specified which allows the user to avoid all input of slab drain data.

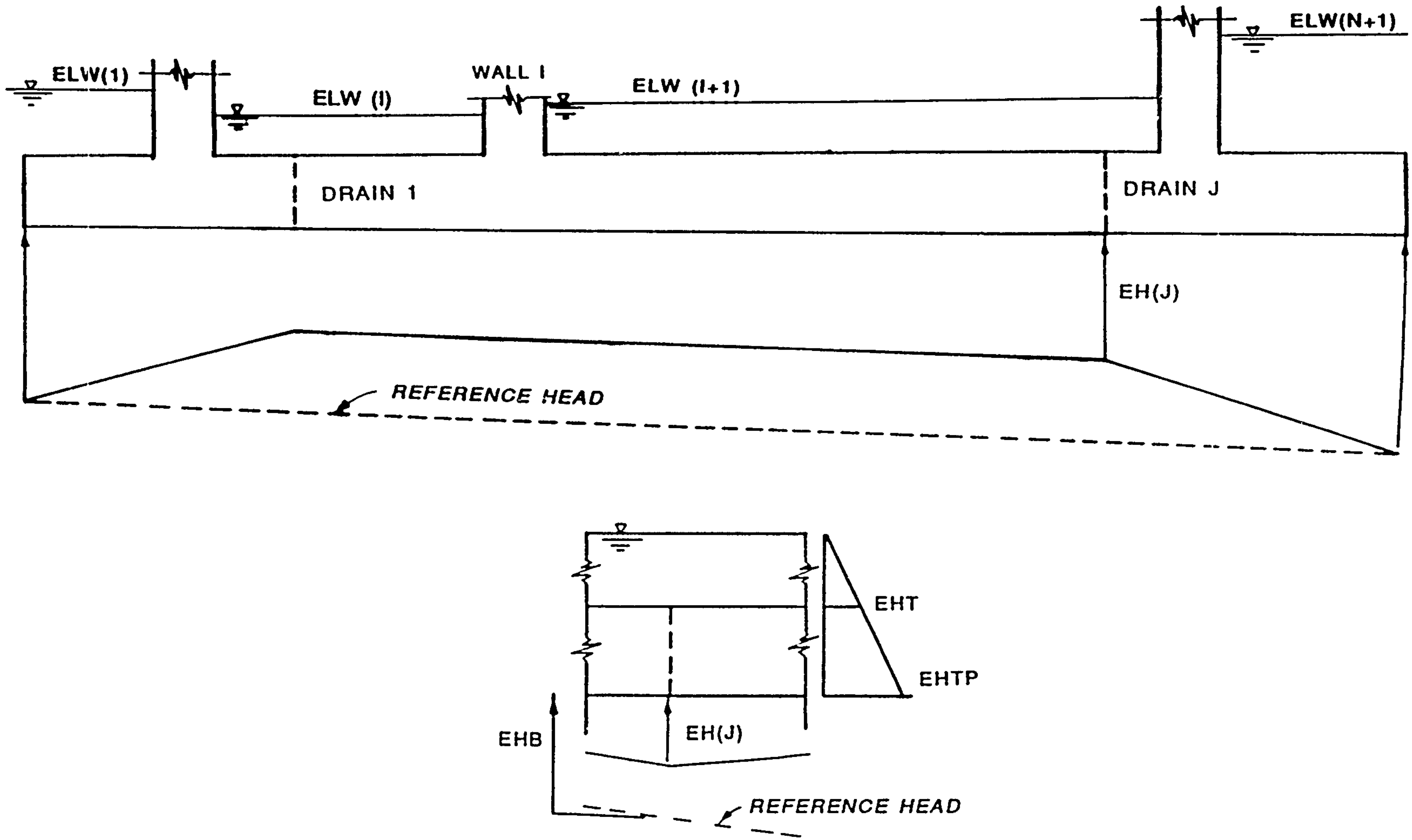


Figure 7. Hydraulic forces on base slab

Active Pressures Using Wedge Solution

54. Active pressure is based on a condition of limit equilibrium. The soil forces acting on the faces of the walls and the top of the base slab are obtained from an active wedge solution. The solution differs slightly from that used in standard stability analysis because it was formulated to give the distribution of forces acting on the faces of the U-frame.

55. The wedges are solved incrementally as described in Volume A of this report to give the required force distribution. Up to 10 different wedges are taken along the face of the wall with the bottom of each wedge corresponding to the tenth points, vertically from the top to the bottom of the wall. The force on each wall segment is found by statics on the corresponding wedge and is assumed acting at the midpoint of the segment.

56. The wall friction angle δf may be considered if desired. The surcharge weight WSUR is included in solving the wedge. Both a soil friction angle ϕ and soil cohesion c can be specified.

57. The wedges are solved by trial and error to obtain the maximum value of forces acting on the wall, and they are broken up into horizontal and vertical components of force because of wall pressure. Next, a similar wedge solution is made to solve for the forces on the vertical face of the wall below the invert elevation. Then 10 wedge solutions are made for forces on the top face of the heel, and finally a wedge solution is made to find the force on the vertical face of the heel. All the wedge solutions follow the same procedure as described for the wall. However, if a wall friction angle is specified, it is not used for the wedges solved for the heel. As indicated in Figure 5, if the soil elevation is below the invert, any nominal soil pressures are neglected.

58. In order to account for cracking of cohesive soils, the force on the wall found for each incremental wedge is tested to see if it is positive (compression). If the force is negative, it is set equal to zero and the next incremental wedge below is solved. The program does not apply any hydraulic forces for water which might accumulate in the crack. However, the user may specify appropriate forces as special loads.

59. The forces from the wedge solution are used in the frame analysis module. However, for output purposes they are converted to an approximate pressure by dividing by the length of the wall or heel surface over which they

act. The wedge solution was tested by verifying against a number of standard cases. For the cases where the simplifying assumptions were satisfied, the pressure distributions were in good agreement. Also, the wedge solution was tested against other wedge solutions where applicable. Again the agreement was quite good.

60. At-rest forces may be approximated by specifying an appropriate at-rest factor. This factor is multiplied by the horizontal forces from the active wedge solution. If the at-rest factor is specified as one, then the forces obtained will correspond to the active case.

61. Figure 5 shows that the exterior rock elevations are input items. These input elevations are considered in the wedge solutions. The wedge solutions start as usual and proceed down the wall. However, the last incremental wedge solution is made with the bottom of the wedge taken at the top of the rock elevation. For U-frames with no actual rock contact, the rock elevation should be set at or below the bottom of the base slab.

Passive Wedge Solution

62. Passive pressure is also based on a condition of limit equilibrium. However, the soil mass is assumed to be resisting the movement of the wall. Thus, the passive wedge solution is similar to the active one, except that the direction of the soil forces is reversed from the direction for the active wedge and the direction of the wall friction angle is changed.

63. The results of the passive wedge solution are not used directly. However, if the user selects an appropriate loading option, the horizontal forces from the passive wedge solution will be scaled along with the shear force on the base slab to provide horizontal equilibrium as described subsequently. The user should note that this procedure may result in forces on the wall on the passive side which are less than those for the at-rest case. Thus, for a U-frame that is only slightly unsymmetrical, it would be wise to run too separate solutions. Use the active solution for both walls for one run and the passive solution for one wall in another run. Then the critical design values can be selected from the two analyses. Of course, this problem does not occur in the design mode since all loadings are symmetrical in the design mode.

Empirical Wall Pressures

64. As an alternate to the wedge solutions previously outlined, an empirical wall pressure option is provided. In general, the wedge solution is more accurate, and even though the hand calculations for the wedge solution may be lengthy, the computer time is not greatly increased by using the wedge procedure. However, some economy may be found if preliminary solutions are run with the empirical procedure. Also, it may be desirable to match existing solutions with the empirical procedure.

65. The empirical procedure assumes that the groundline is horizontal as shown in Figure 8, and the horizontal pressure at a point is found by multiplying the effective vertical stress, PRESS, by an empirical factor, EKF, input by the user. The effective vertical stress is found considering the following: (a) UWD - the drained unit weight of the soil, (b) UWS - the saturated unit weight, and (c) GAMMAW - the unit weight of water.

66. The force on the vertical face above the heel, 10 vertical and horizontal forces on the top of the heel, and the force on the vertical face on

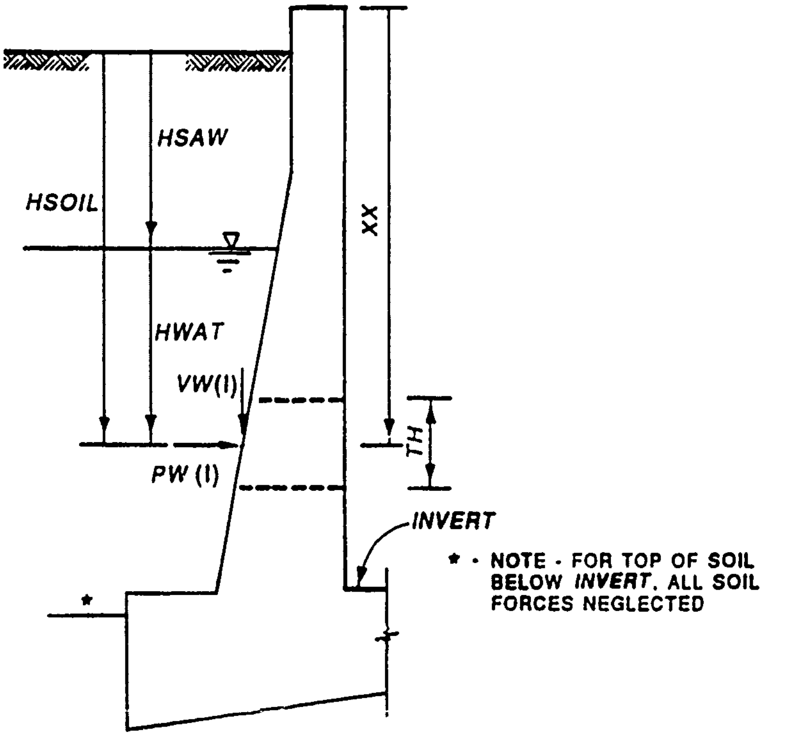


Figure 8. Empirical soil forces

the end of the heel are computed using the same assumptions as just described for the wall. However, as in the wedge solution, if the soil elevation is below the invert elevation, then all soil forces are neglected.

67. For simple cases, the empirical solution can be made to give identical solutions with the wedge procedure and the corresponding Coulomb solution. For sloping walls or heel tops, the results of the wedge solution and the empirical solution will be slightly different since the wedge solution assumes that the resultant force is normal to the surface, if no friction angle is specified.

68. No at-rest factor is input for the empirical wall pressure solution. Thus, the EKF coefficient should include the at-rest correction when appropriate. Also, it will be observed by the user that the empirical factor is the same for all load cases. Thus, the user cannot adjust the horizontal forces for movement into and away from the soil as may be done with different at-rest factors for different load cases in the wedge solutions.

69. No empirical solution is given for sloping or irregular backfills. However, the user can either specify the wedge solution or estimate an approximate empirical coefficient to handle the irregular ground surface. In a manner similar to the wedge solution, no backfill force is found below the rock elevation input for the wall or heel adjacent to the rock. If there is no rock contact with the U-frame, the rock elevation should be set at or below the elevation of the bottom of the base slab.

User Specified (Special) Loads

70. The user may specify a large number of "special" distributed and concentrated loads in a simple format as illustrated in Figure 9. As described subsequently, these loads may be combined with the geohydraulic forces automatically computed if so desired. This combination feature greatly extends the capability of the program. If the users do not agree with any of the default procedures for computing the geohydraulic forces acting on the structure, they may either input the desired forces directly or add corrective forces to the ones automatically computed. In addition, forces to represent wind, earthquake, or 3-D correction forces may be applied and combined with the standard solution.

71. Since the program has nonlinear soil features, superposition of

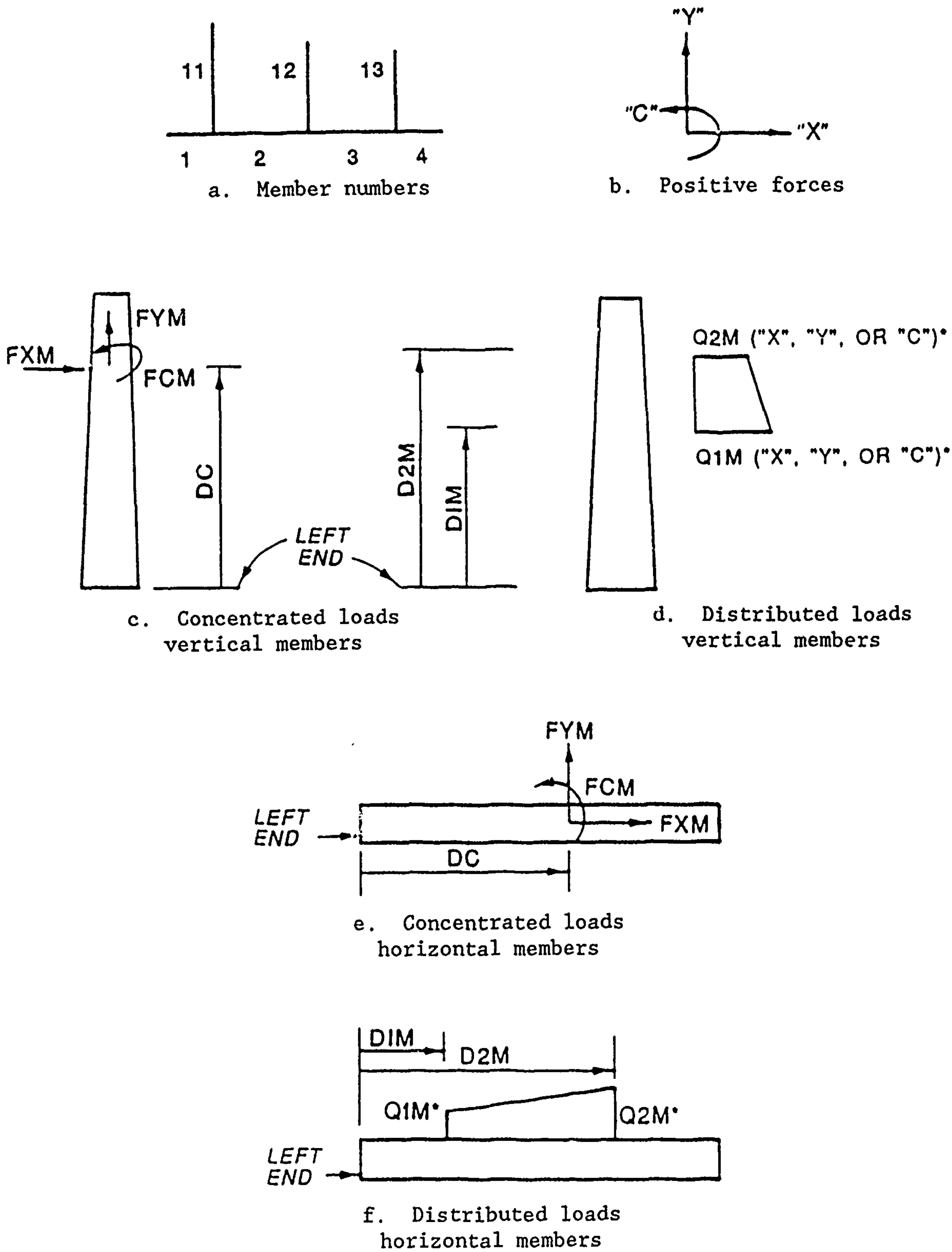


Figure 9. Input description of special loads

results of different load cases should not be done in general. If the special loads are combined with other loads, the loads are combined before the analysis is made. The results of two separate solutions are not superimposed. Also, the user should not try to superimpose the results of any of the load cases because of the possibility of nonlinear response and the fact that the self-weight of the frame is automatically included in each analysis.

72. Figure 9 shows the manner in which the special member loads are described. The member numbering sequence discussed previously is shown in the figure. All forces input are keyed to one of these members. All forces acting above the invert should be referenced to the appropriate wall member. Forces acting below the invert may be referenced to any of the members of the base slab.

73. It should be noted that while concentrated and distributed forces are discussed, the units of the concentrated force are kips per foot of wall and the units of distributed force are kips per foot per foot of wall or kips per square foot. Similarly, the units of concentrated couples will be kips and distributed couples kip per foot. The positive direction of all forces on either wall or slab members are shown in the figure to be to the right for horizontal forces, up for vertical forces, and counter-clockwise for couples. This coordinate system is global even though the loads are referenced to the individual members. Thus, horizontal loads are "X" loads whether they are applied to vertical or horizontal members. Similarly, "Y" loads are always vertical.

74. Forces parallel to a member are assumed applied at the centroid of the member (centroid at point of application). If the force is actually acting on a face of the member, then a couple or "C" force should also be input equal to the moment of the force about the member centroid.

75. The position of the loads are always referenced to the "left" end of the members as defined previously in Figure 3. Note that the distances used for inputting special loads are referenced to the left end of the members as done to specify reinforcement locations and for output of member forces. As shown in Figure 9, concentrated loads are specified by giving the distance from the left end of the reference member to the concentrated load, DC, and the value of the concentrated load, FXM, FYM, or FCM for horizontal forces, vertical forces, and couples, respectively.

76. For convenience, any load below the base slab may be referenced to

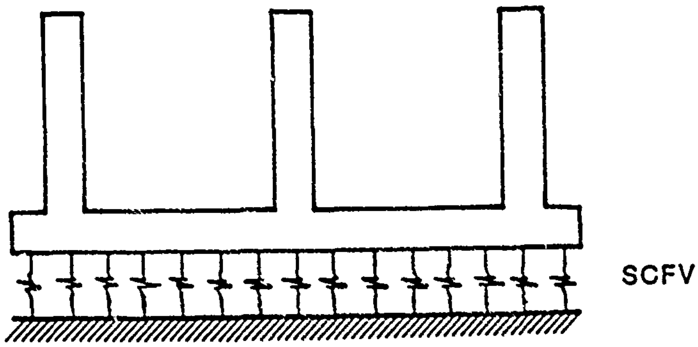
any of the slab members. Thus, the user could reference all of the loads to member one, if the left heel is present. Thus, the horizontal distance locating all loads can be specified for the left end of member one, which is the left end of the U-frame base slab. Internally, the program will compute the proper horizontal distances to locate the forces within the proper members. However, if a heel is absent, slab loads may not be referenced to the missing member. It should be remembered that the numbering of the members in the base slab is the same whether or not the heels are present. Thus, the first slab member will be member two when the left heel is omitted.

77. Distributed forces are specified by describing them as "X" forces, "Y" forces, or couples "C." Then the distances to the beginning and end of the distributed forces D1M and D2M are specified and measured from the left end of the member. Now, the values of the distributed forces at the start and end points Q1M and Q2M are input. Since all slab loads may be referenced to a single member, a linearly varying distributed load extending the entire width of the foundation may be specified as a single distributed load, with the user giving the distance to the start of the loading and the end of the loading for the chosen reference member.

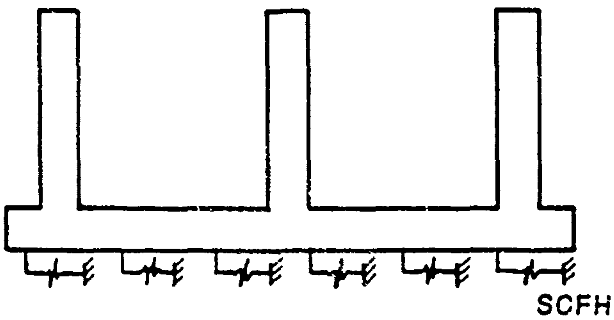
Winkler Spring Foundation

78. The Winkler assumption that the soil beneath the base acts as a series of independent elastic springs is normally used in a beam on an elastic foundation analysis. Figure 10 shows that the base is assumed to be supported by a Winkler foundation of compression only springs with a constant stiffness or spring constant SCFV. The units of SCFV are pressure per unit of deflection (kips per square inch or kips per cubic inch). The choice of SCFV can have a significant, although usually not dominating, effect on the distribution of internal forces in the U-frame. Thus, some care should be exercised in the selection of the appropriate spring constant. The availability of the program will facilitate the bracketing of significant design variables by varying the input value of SCFV.

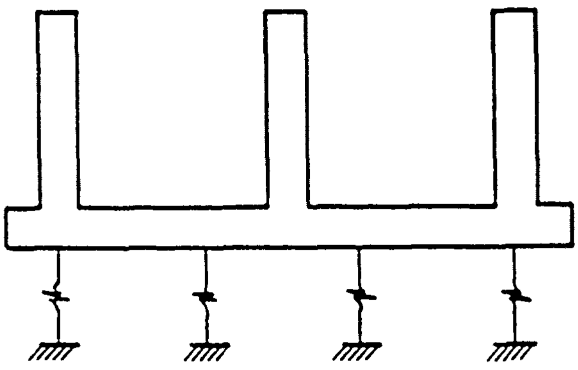
79. Distributed horizontal springs with springlike stiffness SCFH, as shown in Figure 10, are also used when the spring foundation option is selected. The horizontal shear springs are applied at the base of the slab and have the units of kips per cubic inch. The use of horizontal shear springs is



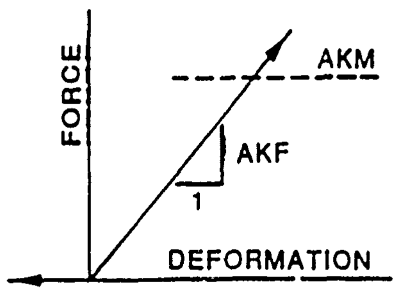
a. Vertical compression only spring foundation



b. Horizontal shear spring foundation



c. Vertical tension only anchor springs



d. Anchor response

Figure 10. Foundation spring restraints

not as common as vertical compression springs. However, it is important to note that for symmetrical cases the value of shear spring chosen has only a very minimal effect on the distribution of forces in the U-frame. It primarily affects the distribution of axial force in the base slab, and even this effect on the axial forces is quite small. It should be noted that for the spring foundation option the only thing providing lateral stability in the frame analysis is the stiffness of the horizontal shear springs, unless the force-deformation solution is being used for the walls. Thus, some positive value of shear spring stiffness is required.

80. In the absence of detailed recommendations on horizontal shear stiffnesses, they should be taken on the order of magnitude of the vertical compression springs. The user will find that major changes in the actual input value will have a minimal change in the solution for symmetrical loadings. For unsymmetrical loads put in equilibrium with the load-deformation method for wall loading, the value of base shear spring stiffness has a more pronounced effect since it interacts with the stiffness of the springlike wall forces in providing horizontal equilibrium.

81. The vertical and horizontal base springs are assumed to be interdependent. Thus, if there is any uplift at a point along the foundation, and the compression only spring no longer provides any hold down force, the shear spring at that location is also assumed ineffective. If uplift is a problem, then vertical anchors can be modeled as tension only springs with spring constants as shown in Figure 10. The units of the anchor spring stiffnesses, AKP, are kips per foot of U-frame per foot of deflection. The locations of the anchors are specified as described earlier in the geometry sketches for the particular channel under consideration.

82. A maximum spring force, AKM, in kips per foot of U-frame is also input. However, it is important to note that as shown in the force-deformation response curve of Figure 10d, the program may compute a force that exceeds this value, i.e., elastic-plastic response is not modeled in the program. The input anchor spring maximum force is used only in computing the factor of safety for the spring and the factor of safety against uplift. The factor of safety for the spring is computed by dividing the force found in the spring into the input maximum force. Thus, a number less than one means that the anchor could not provide the force indicated by the analysis.

83. The fact that the base shear springs are assumed to be ineffective

at points where the foundation has lost contact means that if vertical anchors are used, the U-frame would lose lateral stability if contact is lost along the entire width of the base slab. In reality, some lateral stability would be provided by the force-deformation response of the soil against the sides of the U-frames. It is probably best to use a force-deformation solution for the walls for such cases. However, if the loading is close to symmetrical, it is acceptable to simply artificially stabilize the U-frame with fictitious lateral springs of small stiffness. The fictitious lateral springs are automatically provided for in the program whenever the user specifies vertical anchors.

84. In spite of the generally highly nonlinear response of the frame when uplift is a problem, the solutions generally converge with little difficulty. The few cases where convergence has not occurred were generally associated with excessive uplift and having only a minimal number of anchors effective in resisting uplift.

Empirical Foundation Pressures

85. The active loads may be put in equilibrium by an empirical foundation procedure rather than by the Winkler spring foundation model just described. The Winkler spring foundation is considered the more rational approach. However, some small economy in computer time may be obtained in using the empirical procedure, and the empirical approach may be convenie. for matching existing design calculations.

86. Figure 11 illustrates the empirical procedure for satisfying vertical and rotational equilibrium. SUMFY is the sum of all active vertical forces, and SUMM is the resultant moment of all active forces about the center of the base slab at the bottom of the slab. The empirical procedure is based on a "P/A $\pm$ Mc/I" approach except that the "P/A" distribution may be nonuniform. The dashed line distribution in Figure 11 shows the assumed distribution if the sum of the moments, SUMM, was zero. The user specifies the ratio, PRAT, of the inner pressure Pb to the outer pressure Pa. Input of the distances XUNIF and XSLOP as defined in the figure are also required. Then the pressure Pa is computed such that the dashed line pressure distribution will put the force SUMFY in equilibrium. Then based on rotational equilibrium and assuming a rigid foundation, the additional pressure Pc due to the moment is

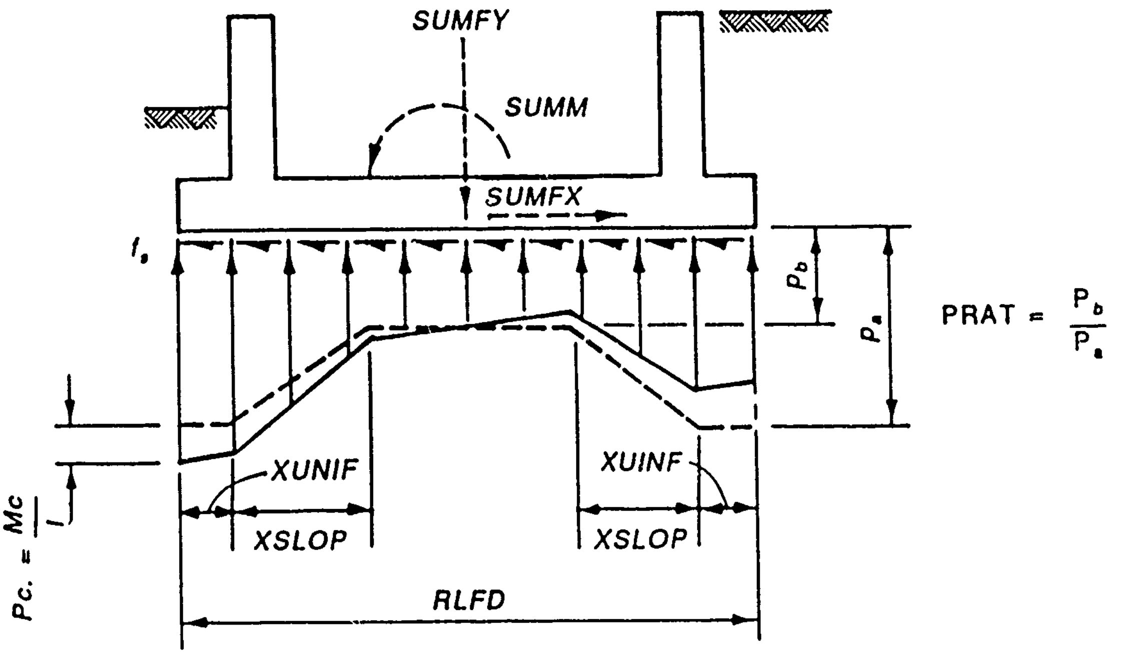


Figure 11. Empirical foundation pressures

found. The total pressure at any point is easily found by summing the pressure from the "P/A" and "Mc/I" solutions.

87. The foregoing solution was developed assuming contact between the soil and the U-frame across the full width of the foundation. If contact is lost, an incorrect tension (negative) foundation pressure will be calculated and the program will output a warning message. It would be possible to develop an empirical solution for the case where contact is lost. However, this step was not taken since the elastic spring foundation procedure should be used for such cases. The resultant horizontal force, SUMFX, is put in equilibrium by the uniformly distributed pressure, fs, across the bottom of the slab.

88. When the empirical foundation option is used, then the total forces applied to the U-frame module will be in equilibrium prior to going to the frame solution. However, rigid body restraints must be provided to allow the frame solution to proceed. Rigid body motion is prevented by one horizontal and two vertical springs. While these springs develop no force and do not effect the distribution of internal forces in the U-frame, they do prevent rigid body motion in an arbitrary manner. Thus, the deflections computed in

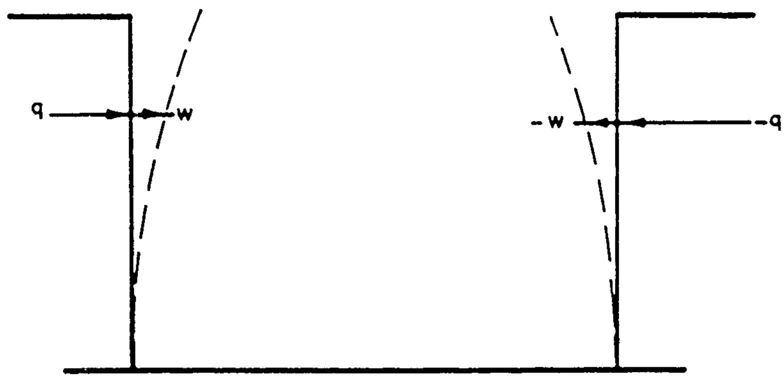
the frame module are meaningless and are not output for the empirical foundation option.

Load-Deformation Solution for Wall Loading

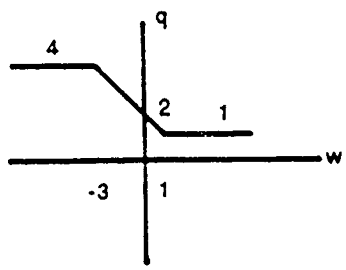
89. The active and passive states of soil pressure are limit states of the more general nonlinear load-deformation response of soil to the motion of the wall. If the wall moves sufficiently into the soil, an upper limit of passive pressure is reached. When the wall moves far enough away from the soil, a lower limit of active pressure is reached. In between these states the soil pressure acting on the wall is a nonlinear function of the displacement of the wall. The exact nonlinear relationship is quite complex and depends on the soil parameters, the wall friction, and the construction technique.

90. Haliburton (1972) has given rules for a simple elastic-plastic relationship between the active and passive states. More detailed studies are needed with correlations with testing and rigorous finite element solutions to develop force-deformation relationships that are precise. Meanwhile, the program can be used to aid in such studies and to allow the designer to see the effect of the interaction of wall deflection and soil pressure on the forces developed in a U-frame structure.

91. Force-deformation curves are described as q-w curves herein. The general nature of the curves for a symmetrical U-frame is illustrated in Figure 12. The curves shown in the figure are of the elastic-plastic type. However, the curves may be input by a series of up eight points. The units of q are pressure (kips per square foot), and the displacements are in feet. Positive pressure and displacement are to the right. Thus, the signs of curves for the left and the right wall will be reversed as shown in the figure. Also, the order the points are input will be reversed. The program allows, however, for the description of these symmetrical and reversed curves through the input of a negative curve number. If the curve number input is negative, then the values used for the negative curve are obtained by reversing the order of the input points and changing the signs of the curve with the same absolute value as the negative curve number. Also, the curves may be scaled by giving basic curves and then multipliers of the basic curves at different locations along the walls.

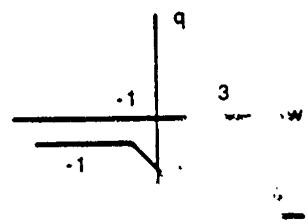


a. U frame symmetrically loaded



W	-	-3	0	1	+
q	4	4	2	1	1

b. Left wall curve



W	-	-1	0	3	+
q	-1	-1	-2	-4	-4

c. Right wall curve

Figure 12. Input description of force-deformation curves

92. Curves may be used to represent soil or rock force-deformation response on any of the walls of the U-frame. However, the rock elevations shown in Figure 5 are not input for the force-deformation option. The user must specify appropriate q-w curves at various elevations to model the soil and/or rock stiffnesses.

93. The force-deformation response is only in the horizontal direction for the walls. Thus, no vertical forces are developed on the wall and no forces below the bottom of the wall members (the invert elevation). Any vertical wall forces or active soil forces on the heel must be input as special forces. Of course, the reactive forces on the base slab and heel may be obtained from the spring foundation solution.

Program Loading Combinations

94. The various program options for active and reactive loadings have already been described. In this section, the ways in which they may be combined are described. Section 7 in the input guide is the loading control section. Here the user specifies the following control parameters. As mentioned earlier, there are certain restrictions on the loading for the design mode which will be discussed later.

95. NEM is the number of "EM-like" load cases (1-10). These load cases are governed by water and fill elevations using the various options described earlier. However, if the load-deformation solution is used for the wall loading, then fill elevations are not used and the program has the following restrictions. For load-deformation solutions, only one EM-like load case is permitted and there must be one special load case (NSPEC = 1). All active loads (U-frame weight, hydraulic loads, and special loads) are combined before the frame analysis is made; the frame analysis puts these loads in equilibrium with the wall loading generated by the force-deformation curves and the foundation reaction pressure developed using the spring foundation option.

96. NSPEC is the number of special load cases (1-3). These load cases are specific loadings described with the various members of the frame being considered. However, except when using the load-deformation solution for lateral wall pressures, the user may combine the special load cases with any one of the previously defined EM-like load cases, if desired, by giving the reference number of the EM-like load case.

97. For instance, suppose three EM-like load cases are run followed by two special load cases, and the first special load case references the third EM-like load case while the second special load case does not reference an EM-like load case. The fourth load case would be for the combined active loads of the third EM-like load case and special load case one. The fifth load case would be for the active loading of special load case two only plus the self-weight of the U-frame. All load cases have reactive loadings computed with the options exercised and automatically include the weight of the U-frame using the input concrete unit weight.

98. BTYPE is the type of analysis for the backfill including divider fill if present. For BTYPE = "WEDA," the backfill pressure is computed using active wedge solutions for all walls with backfill. For BTYPE = "WEDPL," a passive solution is made for the left wall and an active solution for the right wall. For BTYPE = "WEDPR," a passive solution is made for the right wall and an active solution for the left wall. When a passive solution is made for either wall, it is adjusted to provide the equilibrium of all horizontal forces in conjunction with the horizontal base shear as described subsequently.

99. For all active wedge solutions the at-rest factor will be multiplied times the value of horizontal forces and pressures originally obtained. Thus, if no at-rest correction is desired, then the at-rest factor should be specified as 1.0. For BTYPE = "EMP," the backfill pressure is computed using the empirical procedure previously described. For BTYPE = "LDM," a load-deformation solution is made for the horizontal loading on the walls.

100. FTYPE is the type of foundation analysis used to compute the reactive loading to provide equilibrium. For FTYPE = "EMP," the active loads are put in equilibrium through the empirical procedure previously described. For FTYPE = "SPR," the active loads are put in equilibrium using the beam on elastic foundation procedure. If the load-deformation option is used for the wall loading (BTYPE = "LDM"), then the foundation type must be beam on an elastic foundation (FTYPE = "SPR"). This restriction is necessary since the wall loading must be known in advance for the empirical foundation option.

Horizontal Equilibrium Factor

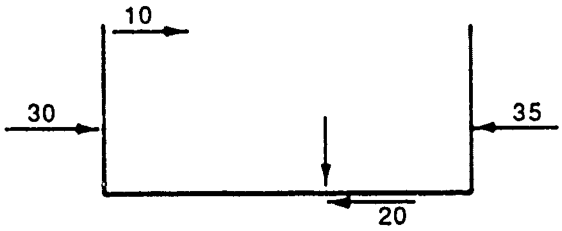
101. For BTYPE = "EMP" or "WEDA," a horizontal equilibrium factor, HEF,

is computed as illustrated in Figure 13. The 20-kip foundation force shown is the maximum shear capacity of the base computed by multiplying the input cohesive stress times the full width of the base slab and adding the product of the resultant vertical force on the base slab (if upwards) times the tangent of the input base friction angle. The base shear force required for equilibrium is 5 kips as shown in the figure. Thus, the horizontal equilibrium factor is four. If the horizontal equilibrium factor is less than one the solution may still proceed at the discretion of the user. However, if the solution continues, then the computer will be using a base shear larger than the maximum capacity computed for the foundation.

102. If a passive solution is specified for either the left or the right wall, then the appropriate passive solution is accomplished with an active solution made for the other exterior wall. Then the horizontal equilibrium factor is computed as shown in Figure 14. Again, the maximum capacity of the base shear is computed and now added to the full passive wall force in computing the horizontal equilibrium factor as illustrated by the example in the figure. Then the passive wall force is divided by the horizontal equilibrium factor to yield the wall force acting on the passive side under equilibrium conditions. The base shear force is then actually found in the solution of the base for equilibrium (either the empirical or spring foundation solution). However, the result will always be the same value as simply dividing the maximum base shear possible by the horizontal equilibrium factor.

103. As for the empirical and active backfill options, the solution should be allowed to continue only if an adequate horizontal equilibrium factor is obtained. Since the load-deformation solution is an equilibrium solution based on compatible displacements, no horizontal equilibrium factor is computed for the load-deformation solution.

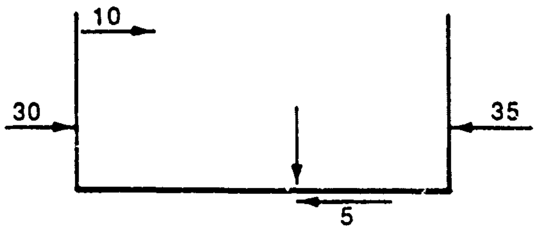
104. If any portion of the base slab uplifts then the portion of the maximum horizontal force computed for the base slab will be in error, since the entire width of the base slab was multiplied times the maximum foundation cohesion. No correction was made in the program for this uplift because the amount of contact at the time of potential sliding is not known. If the elastic foundation module is used, the locations at uplift under the nominal loading would be known. However, the uplift may be different under conditions in which the maximum foundation force would be acting. Thus, in cases where



a. Active forces/maximum base shear

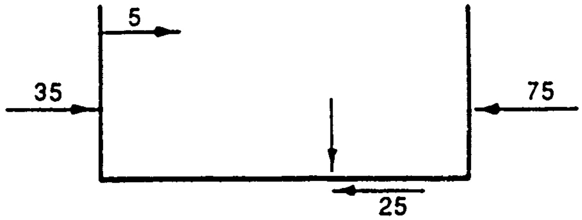
$$HEF = \frac{20}{30 + 10 - 35}$$

$$HEF = 4$$



b. Active forces/equilibrium base shear

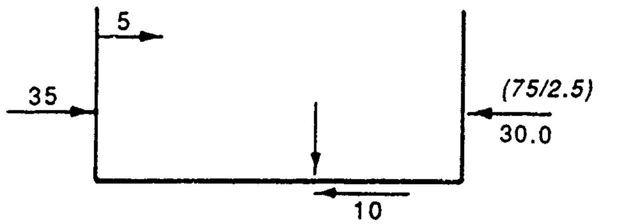
Figure 13. Horizontal equilibrium for BTYPE = "WEDA"



a. Active forces/maximum passive forces

$$HEF = \frac{(75 + 25)}{(35 + 5)}$$

$$HEF = 2.5$$



b. Active forces/equilibrium passive forces

Figure 14. Horizontal equilibrium for BTYPE = "WEDPR"

uplift occurs or is impending, the value of cohesion input for the base slab should be a conservative value.

105. It will be noted by the user familiar with sliding stability calculations that the horizontal equilibrium factor is somewhat like the factor of safety with respect to sliding. However, the procedure used is not the same as and will yield values different from those found using the procedure outlined in ETL-1110-2-256, "Sliding Stability For Concrete Structure" (Headquarters, Department of the Army 1981). The primary purpose of the U-frame program is to find the forces acting on the walls under the design loading condition. If the sliding stability is in question, then a separate sliding stability analysis should be made.

Uplift Factor of Safety

106. The factor of safety against uplift, FSUP, is computed as follows. WUF is the weight of the U-frame, and WSOIL is the sum of all the vertical components of the soil forces acting on the U-frame. WSPEC is the sum of all the vertical components of the special forces acting on the U-frame. FHOLD is the sum of the maximum anchor forces input for all anchors, and WWATI is the sum of the weight of all the water contained within the U-frame. All of these forces react against the total uplift force UWAT to provide stability. UWAT is the algebraic sum of the uplift forces on the bottom of the base slab and the weight of the water on the external walls and heel. Thus,

$$FSUP = (WSOIL + WUF + WSPEC + WWATI + FHOLD) / UWAT$$

A factor of safety against uplift is computed for all load options except for that of special loads only, since there would be no hydraulic forces specified for that case.

107. If a factor of safety against uplift less than 1.0 is obtained, equilibrium cannot be maintained within the conditions specified by the data and generally the problem should be terminated. However, the program does allow the user to continue, because for the foundation with anchors a solution would still be possible. However, one or more of the anchors would have forces in excess of the input maximum values. If the spring foundation is used and there are no anchors present, then equilibrium is not possible for an

uplift factor of safety less than 1.0. In fact, numerical problems may occur if the factor of safety against uplift is less than about 1.01.

108. For the empirical foundation solution, a nonsensical solution involving tension between the base slab and the soil would be obtained for a case with an uplift factor of safety less than 1.0. If the user allows such a solution to proceed, then a warning message will be included in the output.

PART V: RESULTS OF ANALYSIS

Description of Program Output Options

109. The program allows a variety of output options involving partial, detailed, and graphical output. A complete listing of the input data, with appropriate headings, will be generated with the output file. For the design mode, original and final values are shown for the design variables. Also, a sketch of the frame geometry, water elevations, and ground profile, as shown in Figure 15, may be obtained. The figure shows a two-bay structure with two heels and both wall and slab drains. Note that the member numbers used in describing the member loads, reinforcing, and output are shown on the sketch. The ground profile and rock elevations are plotted and the water elevations are shown for the EM-like load cases.

110. For the investigation mode, no pass-fail decisions are made by the program; all results are presented, and the user makes the decision of the adequacy of the structure. For example, if the SD option is used, the strength and ductility ratios are computed and output at the various sections requested by the user. However, no messages are printed if these values exceed 1.0. Further, no strength checks are made at any section not requested by the user.

111. In the design mode, either the section selected satisfies all the criteria checked by the program, or appropriate warning messages will be issued. The user should review the output for such messages, as well as the complete output and the assumptions and limitations of the program, before accepting the results of the program as an acceptable design.

112. The remainder of this part of the report is devoted to the output for the investigatic- mode. Much of this output is also available in the design mode. Part VI of this report describes in detail the design mode and the special output for the design mode.

Factors of Safety

113. The factor of safety concerning uplift is computed as described earlier. The factor of safety against excessive bearing pressure is computed by dividing the maximum foundation pressure developed in either the empirical

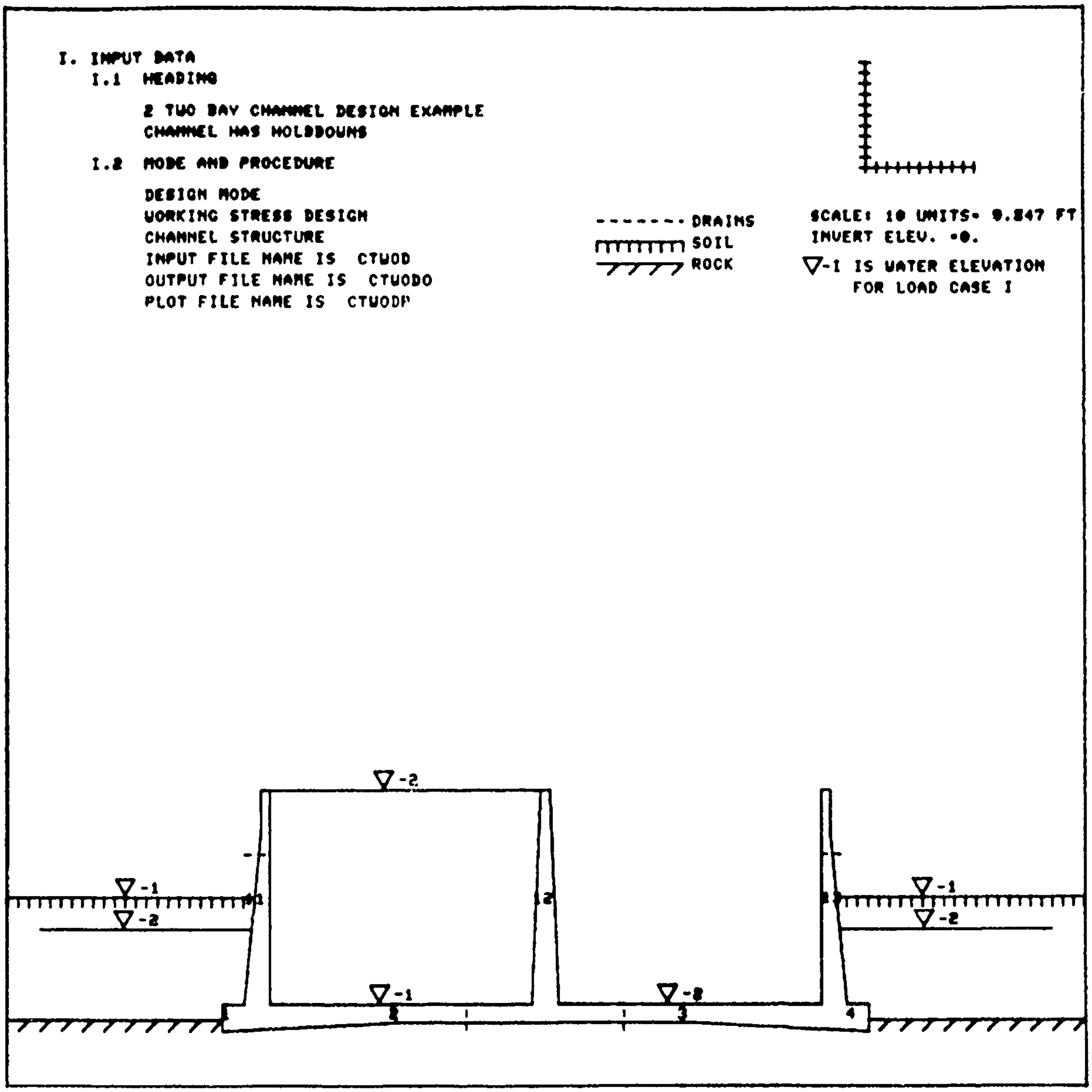


Figure 15. Geometry plot for two-bay U-frame channel

or the spring foundation option into the maximum foundation pressure specified for the foundation. The horizontal equilibrium factor described earlier is output with the factors of safety concerning uplift and bearing. However, it should not be considered to be a factor of safety in sliding according to ETL-1110-2-256 (Headquarters, Department of the Army 1981).

114. Depending on the loading options exercised, some of the above factors may not be known prior to the frame analysis solution. Generally, the program will output the factors, and the user has the option of stopping the

analysis before going to the frame solution if any of the factors are not satisfactory. For the load-deformation solution, no horizontal equilibrium factor is computed.

Output of Member Pressures

115. Output of pressures along the faces of the U-frame are organized in terms of the members used for describing the frame. The signs used for all pressures are the same as that used for loads; horizontal pressures are positive to the right, and vertical pressures are positive if up. All of these directions refer to the direction of the pressure on the U-frame, regardless of the member or face on which the pressure acts. Thus, the horizontal water pressure shown on the right of the wall in Figure 16 would be negative.

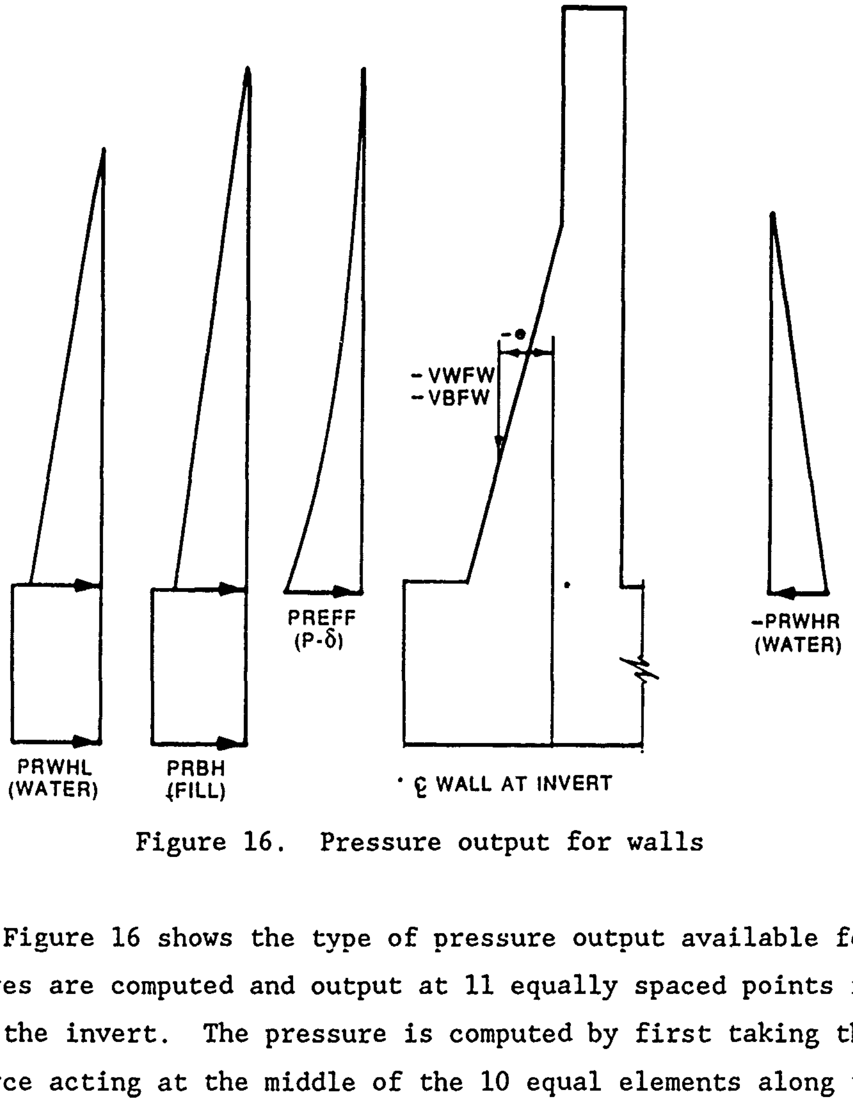


Figure 16. Pressure output for walls

116. Figure 16 shows the type of pressure output available for a wall. Wall pressures are computed and output at 11 equally spaced points from top of the wall to the invert. The pressure is computed by first taking the corresponding force acting at the middle of the 10 equal elements along the wall

used in the frame solution and dividing by the vertical length of the element. This computation gives the approximate pressure at the middle of the elements. Then the pressures at the nodes at the ends of the elements are obtained by interpolation for the interior nodes and by extrapolation for the end nodes. This procedure may sometimes give a slight pressure with the wrong sign at a node close to the point of zero pressure. As a result, the program will output a zero pressure at that node. However, it should be remembered that these pressures are computed only for convenience in the output. The correct forces were used in the frame solution.

117. The output pressures available for the wall members are as follows:

a. PRBH is the horizontal component of the backfill pressure.

b. PRWHL is the horizontal component of the water pressure acting on the left side of the wall.

c. PRWHR is the horizontal component of the water pressure acting on the right side of the wall.

d. PREFF is the horizontal pressure from the nonlinear force deformation solution.

The net lateral pressure which is the sum of all pressures acting on the wall is also available. However, that output is included with the member force output and will be described later.

118. For external walls, values for water pressure and backfill pressure will be also be available below the invert as shown in the figure. While the pressures are given at 11 equally spaced points above the invert, the values below the invert are only given at the centers of the vertical face of the heel.

119. In addition to the lateral pressures, vertical resultant forces on the wall are also output for the backfill and water, VWFW and VBFW, respectively. The signs of these resultant forces are the same as for the pressures. The units of the forces are kips per foot of wall. The eccentricities of these forces from the center of the base of the wall are also listed. The eccentricities are positive if to the right. Thus, the vertical wall forces and eccentricities are all negative as shown in Figure 16, as would normally be the case for the leftmost wall.

120. Numerical values of these output pressures and resultant forces are placed in the output file for all wall members. Also, the horizontal

components of backfill and water pressure may be plotted for the wall members as shown in Figure 17. The sample plot shows the output for an external wall of the U-frame presented in Figure 15. The direction of the pressures are indicated in addition to the sign. Note that the backfill pressure plotted for the bottom face of the heel is lower than the pressure on the wall at higher elevation. This lower output pressure is due to the fact that the rock elevation was set along the lower vertical face of the heel as shown in Figure 15. The correct horizontal force was computed for the wedge taken with its lowest point on top of the rock surface. The pressure output is an "average" over the full height of the vertical surface of the heel.

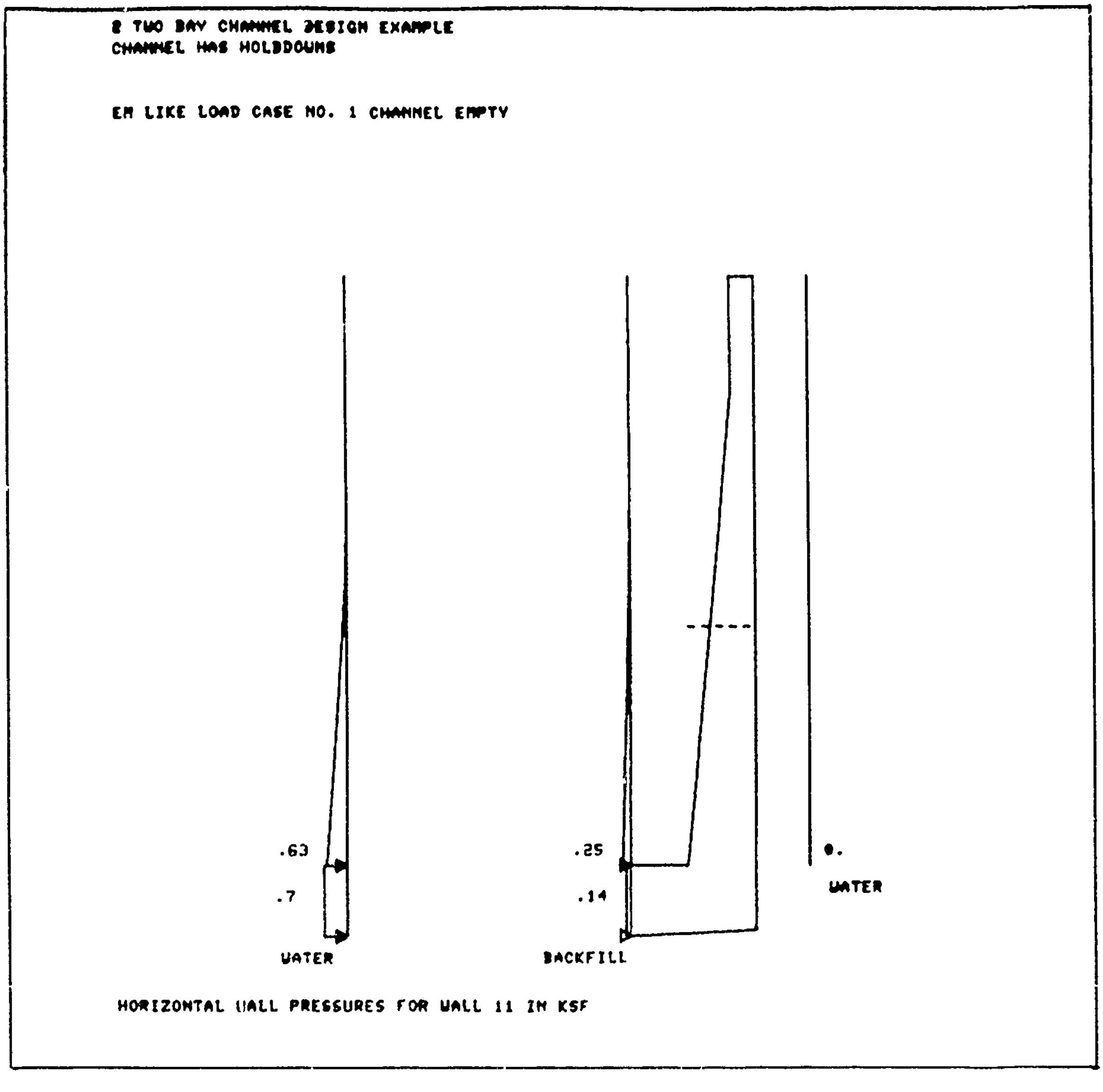


Figure 17. Sample wall pressure plot

121. Figure 18 shows the pressures and resultant forces which are stored in the output file for the members of the base slab, including the heel. The same sign convention is used as for the walls. The following pressures are available:

- a. PRBV is the vertical component of the backfill pressure.
- b. PRWDV is the vertical component of the water pressure on top of the slab.
- c. PRWUV is the vertical component of the water pressure on the slab bottom.
- d. PREFF is the vertical effective foundation pressure from either the spring or the empirical foundation solution.

122. Numerical values are given at 11 equally spaced nodal points for all the interior slab members. Values are given for the heels at the ends and midpoint. Also, values are given for the rigid blocks under the walls at their ends. Pressures for output at these nodal points are computed from the forces acting at the center of the elements in a manner similar to the procedure described for the walls.

123. In addition to the pressures listed, the values of the resultant forces as shown in the figure are stored in the output file.

- a. HBFH is the horizontal force from the backfill acting on the vertical face on the end of the heel.
- b. HWFH is the horizontal hydraulic force acting on the same face.
- c. HWFHB is the horizontal hydraulic force acting on the bottom of the slab.
- d. HEFFB is the horizontal effective foundation force acting on the bottom of the slab.

Numerical values of the above forces and their eccentricities from the centroids of the left end of the member or end block are given for the slab members and rigid blocks under the walls as indicated in the figure.

124. The vertical pressures acting on the base slab may also be plotted as shown in Figure 19. The outline of the base slab is seen with the water pressure on the top and the bottom of the slab plotted adjacent. The effective foundation pressure is seen at the bottom of the figure, while at the top of the figure the vertical component of the fill pressure is plotted.

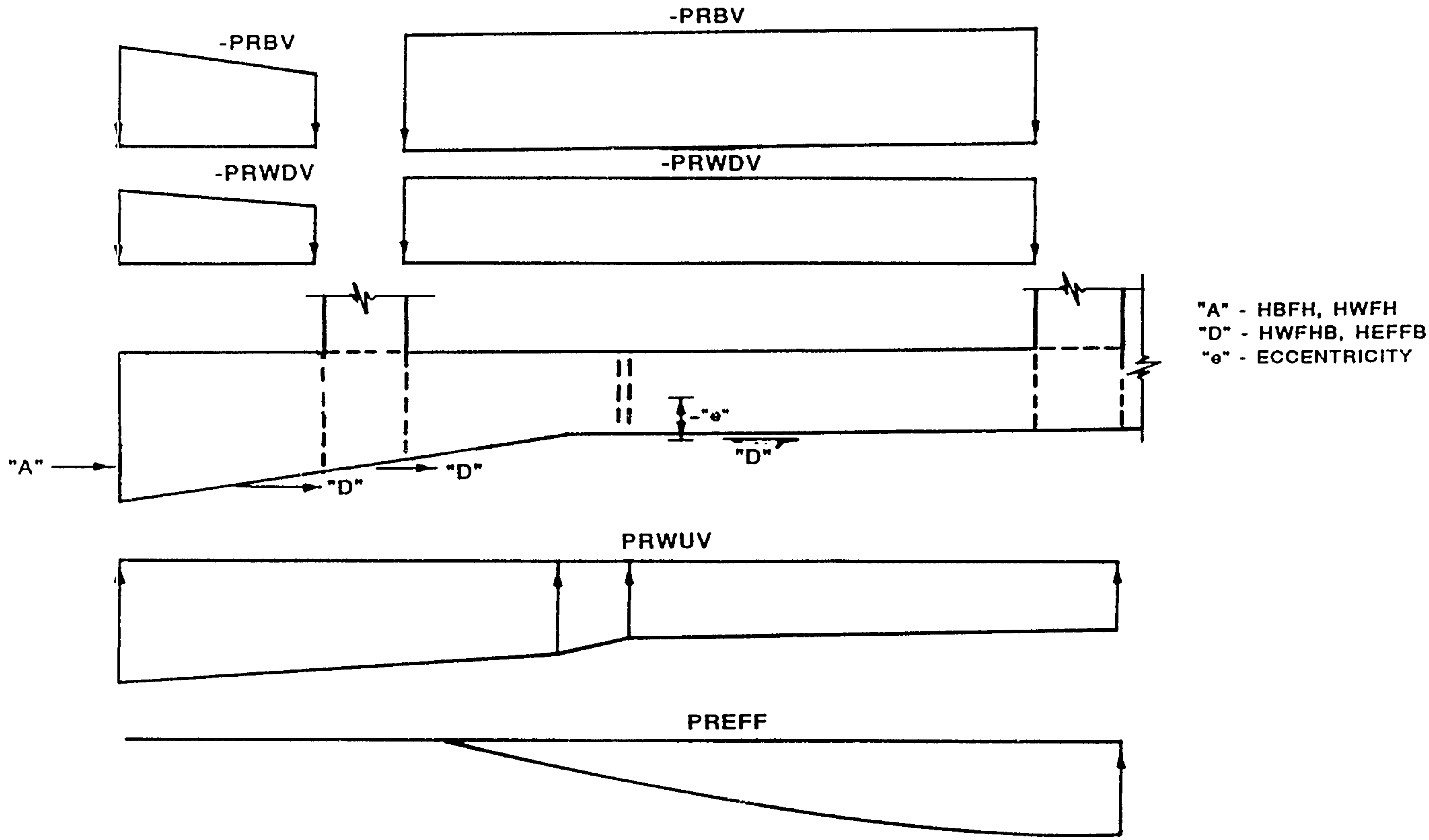


Figure 18. Pressure output for base slab

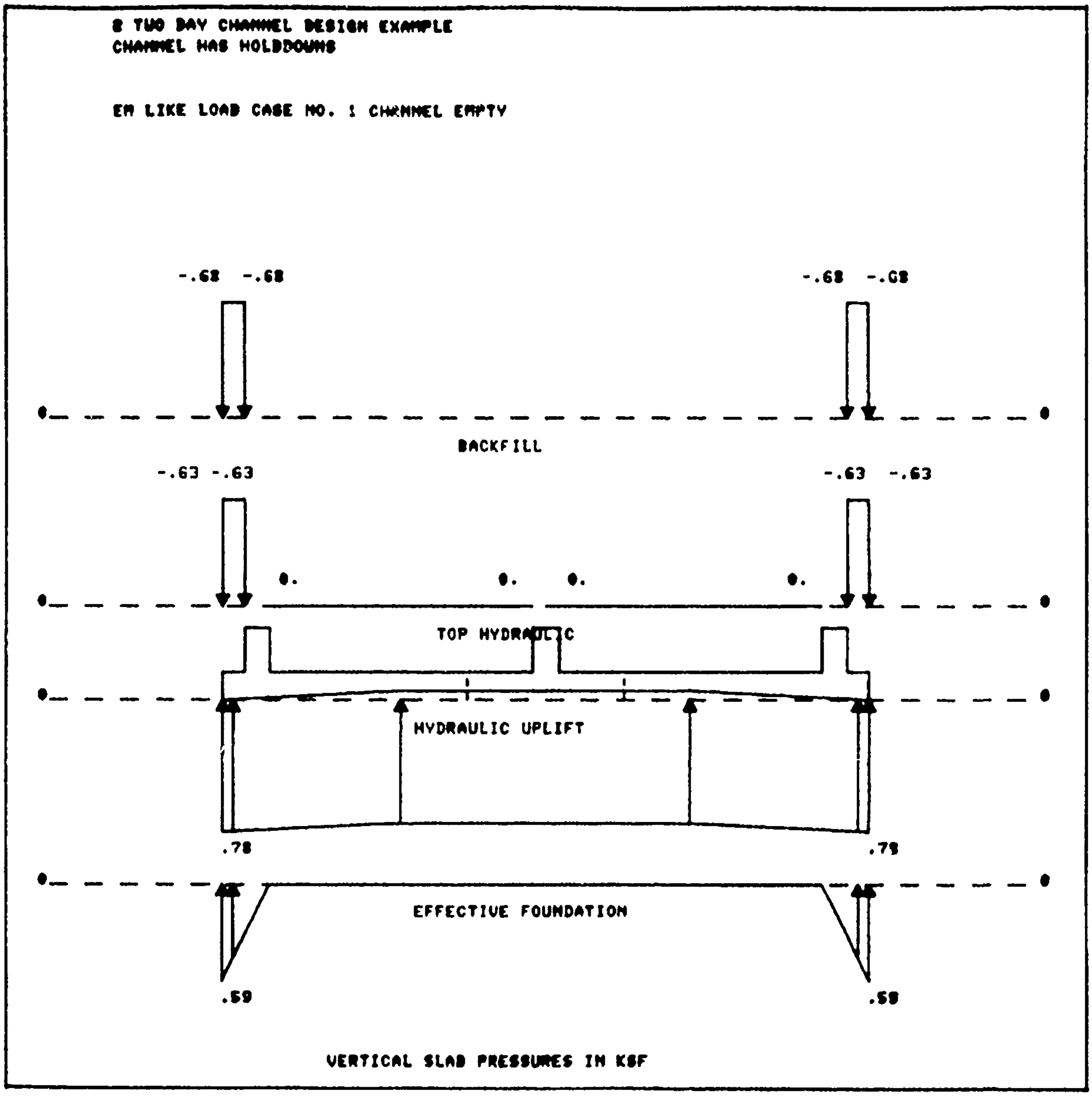
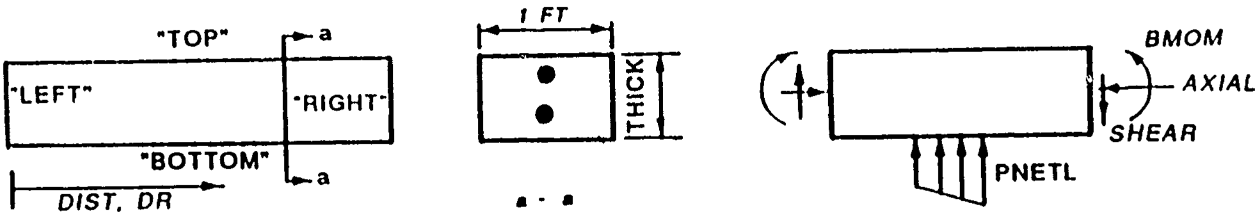


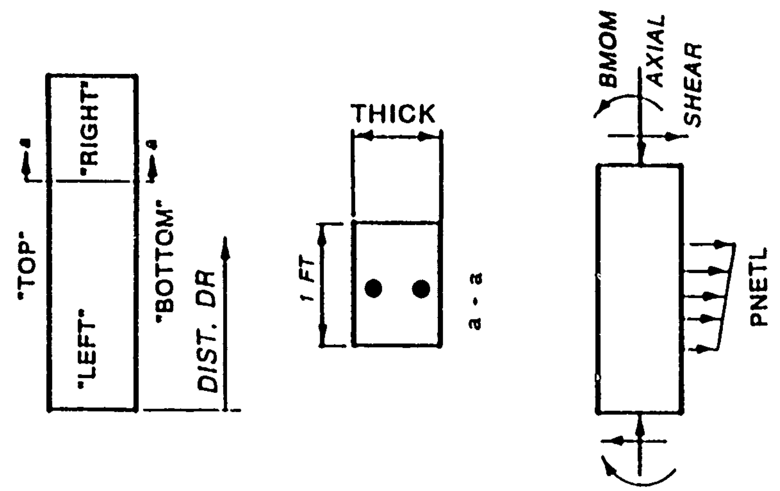
Figure 19. Sample base pressure plot

Output of Member Forces

125. Member forces are computed in the frame analysis module at 11 equally spaced points along the vertical and horizontal members. However, for the heels, the forces are only output at both ends and the middle of the heels. These forces may be obtained in both tabular and graphical form. The force quantities available are the axial force, AXIAL, shear force, SHEAR, and bending moment, BMOM. Positive values of these forces are shown in Figure 20



a. Member output - horizontal members



b. Member output - vertical members

Figure 20. Positive member output quantities

for both horizontal and vertical members. The sign convention used is a designer's convention rather than a frame convention. Thus, a positive moment produces tension on the "bottom" of the member, a positive shear produces a clockwise couple on the element, and a positive axial force is in compression. The distance to the output point from the "left" end of the member, DIST, is included in the tabular output along with the thickness of the member at the output node, THICK.

126. Simultaneously with the force output, the net lateral pressure, PNETL, is output. This net lateral pressure is simply the sum of all the acting pressures and is useful for checking the equilibrium of the members. The corresponding lateral deflections of the member, LATD, are also tabulated except for the empirical foundation option. The signs for the pressure and deflections are the same as for all the other pressures, i.e. to the right and up are positive.

127. Graphical output of all these quantities may be obtained, member by member, for each load case as illustrated by Figures 21 and 22 for a typical slab and wall member, respectively. The results for the wall show that the wall has a net pressure to the right. Thus, a positive shear and negative moment situation on the member whose "bottom" is at the far right was created. The deflections were so small for this load case with the very low soil and water elevations that the deflections did not plot for the wall.

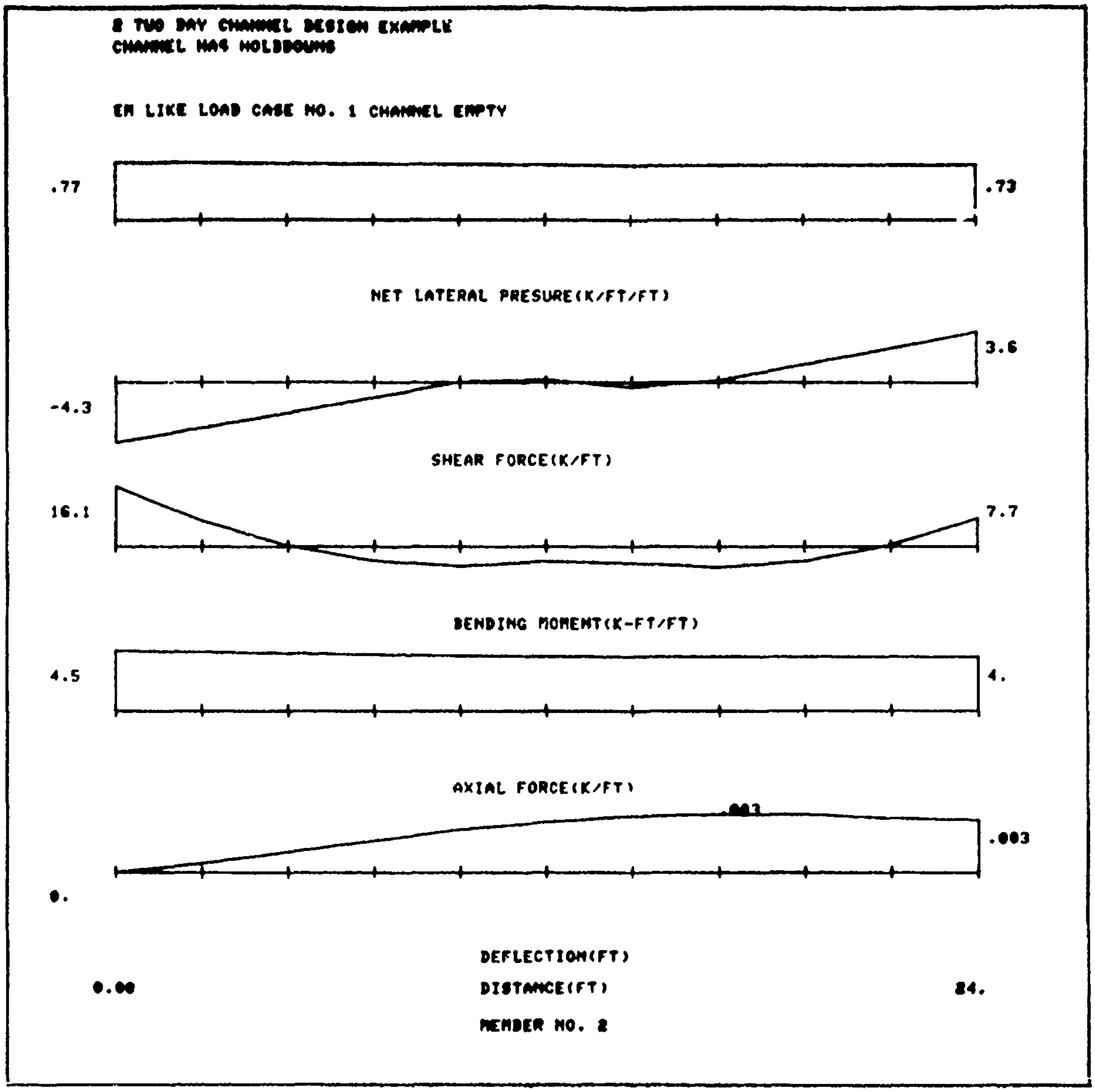


Figure 21. Sample member force plot for slab member

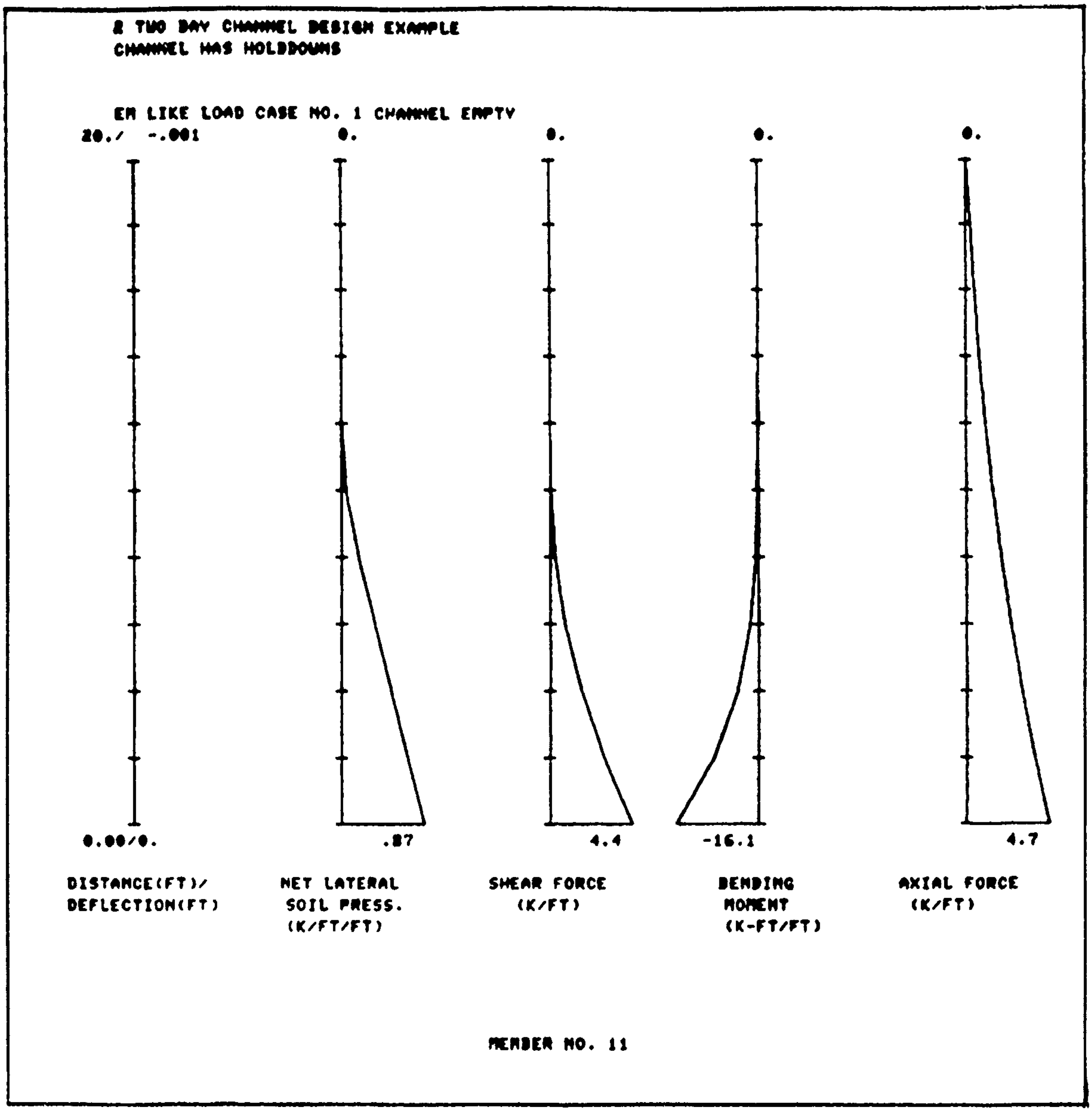


Figure 22. Sample member force plot for wall member

Output of Member Stresses in Investigation Mode - WSD Option

128. Stresses can be computed by traditional formulae associated with allowable stress design, as described subsequently, at up to five points per member. The locations of these points and the reinforcing at the locations of the points must be specified by the user as shown in Figure 4. The user specifies steel reinforcing for the sections at the "top" and "bottom" faces as previously described. A warning message is output whenever the user fails to

specify steel on the "tension" side of the section. Stress output is only provided for members for which it is requested. The stress output is listed for each load case following the other member output for those members for which it is requested.

129. The axial force, shear, and moment at the section being investigated are found by linear interpolation of the member forces at the output points as described in previous section. Interpolation for the heels of the U-frame is accomplished in the same manner as for the other member since internally the member forces are always computed at 11 points, although member force output is only given at 3 points for the heels.

130. The details of the stress calculations are described in the next section. However, the output stresses and their sign convention are summarized here. First, the stresses due to axial force and bending moment are output as follows. The maximum compressive stress in the concrete (compression positive) is computed on the side of the member in which the moment induces compression. The maximum stress in the outer layer of compressive reinforcement (compression positive) is computed if compressive reinforcement is specified. The maximum tension stress in the steel (tension positive) is computed in the outer layer of tension steel specified.

131. If no tension steel is specified, the maximum tension stress in the concrete (tension positive) is computed on the side of the member in which the moment induces tension. A warning message is also printed if no tension steel is specified at the section to ensure that the user has placed the steel on the intended side. The user should thoroughly review the stress situation if it is intended to omit steel on the tension face for any loading. The concrete shear stress is always output as a positive quantity. If the direction of the shear stress is desired, the user can refer to the output of member shear forces.

132. In addition to the stress output described above for the individual members, the maximum stresses at each section investigated by the user are saved and summarized in Section 0.2 of the output. Stresses are output for evaluation of the user. No comparisons of the computed stresses are made with the allowable stresses in the investigation mode. The input allowable stresses have no effect on the program solution in the investigation mode.

Working Stress Calculations

133. Stresses due to flexure and axial forces are computed using the simple equations traditionally used for the working stress design option. More details on the calculation procedures are available in Volume A of this report.

134. For combinations of axial force and moment that do not produce tension, the gross transformed section properties are used. For cases involving tension, the cracked transformed section properties are used. Up to three layers of steel may be on both the tension and compression sides. It is initially assumed that the entire section is in compression as shown, and the gross transformed section is be used for the simple "P/A + Mc/I" calculation of stress. If no tension steel was specified on the tension side of the member, then the maximum tension stress in the concrete is computed and output along with a warning message that no tension steel was specified.

135. If all the steel layers are in compression, then the stresses computed as described above are assumed correct. If any of the steel layers are in tension, the solution is repeated assuming the section is cracked. The normal cracked section solution assumes some compression exists in the concrete. However, for larger values of axial tension, the concrete is completely ineffective. For this case, only the steel in the section is effective in resisting stresses, and at least two layers are required for a solution. For large values of axial tension and only one layer of steel, the program outputs a steel stress of 999.99 ksi.

136. The nominal shear stress as a measure of diagonal tension is computed by dividing the shear force by B*DSH, where B is 12 in. and DSH is the depth to the centroid of the tension steel. However, for sections without tension steel, DSH is taken as 80 percent of the total depth of the section. It should be noted that stresses computed are nominal at best and that shrinkage effects have been ignored. Thus, cases without tension steel specified should be thoroughly reviewed, and appropriate action take to prevent possibly excessive tension stresses.

Review of Member Strengths in Investigation Mode - SD Option

137. Using the strength design option, section strength capacities may

be reviewed at the predetermined locations described earlier. The flexural-axial capacities are calculated using the procedures outlined in ETL 1110-2-312 (Headquarters, Department of the Army 1988) or ACI 318-83 (1983). Actual calculations for section strength are made using subroutines taken from the CASE program CSTR (Hamby and Price 1984).

138. The primary input for the strength design option is as follows:

a. FPC = standard ultimate concrete strength in compression.

b. WTCONC = unit weight of the concrete in pounds per cubic foot.

c. FY = yield stress of the steel in tension and compression. (A limit may be placed on this value depending on the design criteria chosen.)

d. PBRAT = ratio of steel permitted to that associated with a balanced condition. (A limit may be placed on this value depending on the design criteria chosen.)

e. 'DCRIT' = design criteria. 'DCRIT' = "HYD" for Corps Hydraulic Concrete Structure design criteria.

f. 'DCRIT' = "ACI" for ACI Code design criteria. 'DCRIT' = "INP" to input the parameters defining the design criteria.

If the program user chooses the "HYD" or "ACI" options, then it is not necessary to specify the parameters that define the design criteria. The design criteria are described in Volume A of this report.

139. It is anticipated that the user of the program will normally use the "HYD" or "ACI" criteria depending on whether or not crack control is essential. It should be noted that if the "ACI" option is chosen, the ACI crack control criteria are not considered. The "INP" option is included primarily for possible parameter studies on the effects of the design criteria on the results.

140. Load factors are input separately for each EM-like load case and any special load case that may exist. A single load factor is input for each load case and is applied to the results of the analysis for all loads. Thus, no distinction is made between dead and live loads. This approximation is slightly conservative. However, the loading which governs the design of U-frame structures is so predominantly live, in nature, that this approximation will have very little if any affect on the final results. It is anticipated that the user of the program will use the normal live load factor as the load factor.

141. It should be noted that the basic frame analysis is made for the

nominal or unfactored load level. Where nonlinear response is important, such as for investigations made specifying the nonlinear force-deformation solution for wall pressures, this use of unfactored load levels may not be appropriate.

142. A primary output of the program is the ratio of the flexural-axial capacity required based on the factored axial force and bending moment at the section to the flexural-axial capacity provided by the section. A value of 1.0 indicates that 100 percent of the section's capacity is utilized. The appropriate phi factors are considered. Thus, a value of 1.0 or less indicates the strength of the section is satisfactory.

143. For sections with significantly more tension steel than compression steel, the normal case for design of U-frame structures, the shape of the interaction curve for axial force and moment is such that in addition to the strength ratio being less or equal 1.0, a certain minimum eccentricity is required for axial loadings in tension. The program checks for the required minimum eccentricity, when required. If this condition is not met, the value of the strength ratio is set equal to 99.99 that is well in excess of the maximum limit of 1.0.

144. In addition to the strength ratio at the section, a ductility ratio is also output. The ductility ratio is computed to give an indication of whether or not the section has sufficient size such that the amount of tension steel is less than the amount for a balanced failure and should be less than or equal to one. The value of ductility ratio computed in the investigation mode is the ratio of the moment acting on the section to the moment capacity of a section with PBRAT times the area of tension steel corresponding to the balanced conditions. The balanced conditions are defined by having the strain in the tension steel equal to its yield value simultaneously with the attainment of a compression strain in the concrete of 0.003.

145. If, for any load condition, no steel is specified on the tension side of the member, a warning message will be indicated. It is possible that for small values of moment, the strength and ductility requirements may be satisfied. However, the user of the program is cautioned that such a condition could imply very large strains, and hence excessive cracking is possible.

146. The nominal shear capacity VCN of the section is computed for members with compressive forces Pu by

$$VCN = 2[1. + Pu/(2000*AG)]*12*DSH*FPC^{0.5}$$

and for member in tension by

$$VCN = 2[1. + Pu/(500*AG)]*12*DSH*FPC^{0.5}$$

where AG is the gross concrete section, and DSH is generally the flexural depth at the section. However, if the program user does not specify any steel on the tension face, DSH is taken as 80 percent of the total depth. The user is warned that the application of the above equations to cases with no tensile steel is not guaranteed to produce adequate results since shrinkage and other tension producing factors are not considered. Pu is take as positive in compression.

Omission of Symmetrical Output

147. Detailed pressure and member force output are listed only for the members on the left side of symmetrical U-frames under symmetrical EM-like loadings. However, if the loading involves special load cases or the load-deformation option for wall pressures, detailed output will be given for all members. Likewise, investigation results of stress or strength criteria are available for right-side members of symmetrical U-frames only for unsymmetrical EM-like load cases, special load cases, or when using the load-deformation option for wall pressures.

PART VI: DESIGN MODE

General Description

148. It is possible to design by a trial and correction process using the investigation mode. However, this method is often tedious and time-consuming. Thus, it is desirable to have a design mode for the program. The design module was developed with the guidance of engineers experienced with the design of channels and could be considered to be something akin to an "expert system." However, it should be noted that any automated design procedure will have a large number of design decisions programmed. Such decisions, while generally providing a safe and reasonable structure, will not always guarantee the most economical structure. In addition, designers must be certain that any limitation of the program, which may be insignificant for most U-frame structures, will not affect the validity of the design of their particular structure. Thus, it is essential that the user of the program understand the design algorithm included in the program. In addition, it is necessary that the user of the program in the design mode be familiar with the investigation features of the program previously described. The design mode is simply a specified procedure of executing a series of analyses and checks to arrive at a final solution.

149. The program requires that the designer specify a minimum cross section of the U-frame. This decision by the user can obviously have a considerable effect not only on the final design but also on the computer cost of the computer-aided design. If the designer specifies a larger section than needed, then the program will simply select reinforcing for that size structure. On the other hand, if the user specifies too small an original section, then a design solution may not be reached. The program does not allow an unlimited amount of incrementing sizes, which could cause excessive computer costs. However, if the design criteria cannot be satisfied within the iteration limits permitted, the program will allow the user to obtain output which will give pressures, forces, and stresses, or a review of the strength criteria for the last design attempted. This procedure will allow the user to make a better selection for the next design run. The limits which are placed on the design iterations are described subsequently.

Design Mode Restrictions

150. The program is structured such that the data input and procedures are as close as possible for the design and investigation modes. However, several restrictions were placed on the design mode to avoid unnecessary complications of the design algorithm for cases rarely encountered. These restrictions also tend to simplify the input for the design mode. The restrictions on the design mode are listed below.

151. The geometry of the channel must be completely symmetrical for the design mode. Next, input dimensions are either fixed or else the minimum for design iterations.

152. Active loadings, with only one exception (see paragraph 153b), must be symmetrical EM-like load cases in the design mode. Loads permitted include some but not all of the loads allowed in the investigation mode, described previously. Loads allowed in the design mode are given below.

Active Loading for Design Mode

153. The types of active loading allowed include:

a. Self-weight of concrete U-frame automatically generated from geometry of section (updated during design) and input unit weight.

b. Hydraulic loading wherein all hydraulic pressures are automatically computed from the input water elevations, drain locations, and specified efficiencies of the drains. All water elevations must be symmetric; except for two-bay channels, the internal water elevations may be unsymmetrical. This exception was made to allow for the design the internal wall. However, it should be noted that the program still only designs the left "half" of the structure. The designer is responsible for ensuring that sufficient load conditions are specified if the unequal internal water elevations control the design of any member other than the central wall.

c. Active earth pressure by wedge solution.

d. At-rest pressures by modification of active wedge pressures by input coefficient.

e. Vertical surcharge loads as part of wedge solution.

f. Empirical wall and heel pressures computed from input soil elevations and lateral pressure coefficient.

Reactive Loading for Design Mode

154. The types of reactive loading allowed include:

   a. Base slab pressures computed using compression only beam on elastic foundation model, i.e. distributed vertical elastic springs acting only in compression.

   b. Vertical anchor forces computed as tension only elastic spring model. (See subsequent discussion of uplift.)

   c. Beam slab pressures computed by statics with user specified shape. This procedure is similar to a "P/A" + "Mc/I" approach except the shape of the "P/A" portion can be specified.

   d. Base shears computed to satisfy horizontal equilibrium from all active forces uniformly distributed either over the base or on the basis of distributed horizontal springs on the base slab.

Reinforcement by WSD or SD Options

155. The sections are sized and reinforcement is selected based on shear, flexure, and axial force effects as described herein, and no consideration is given to bond, anchorage, or detailing requirements. The ACI strength design criteria for cutting off steel in a tension zone, the minimum amount of tension steel needed to avoid a possible flexural cracking failure, and distribution of steel to avoid oversize cracks are not checked. Also, it is assumed that the depth-span ratios are such that consideration of the deep beam theory is not required. Channel heels are normally very short in length and should be designed with due consideration of their high depth-to-span ratio. Thus, no consideration is given to the design of channel heels by the program.

156. In the investigation mode, the stresses are computed or strengths are evaluated at user specified points. However, the design mode computes the required areas of steel at certain predetermined points (usually the tenth points of members). Consequently, user input is reduced considerably in the design mode. Figure 23 illustrates the reinforcement input for the design mode of channels. This figure shows that for channels, clear cover is generally specified in four locations, (COVER (I),I = 1,4). The center-to-center spacing between parallel layers of steel, CCLAY, is constant.

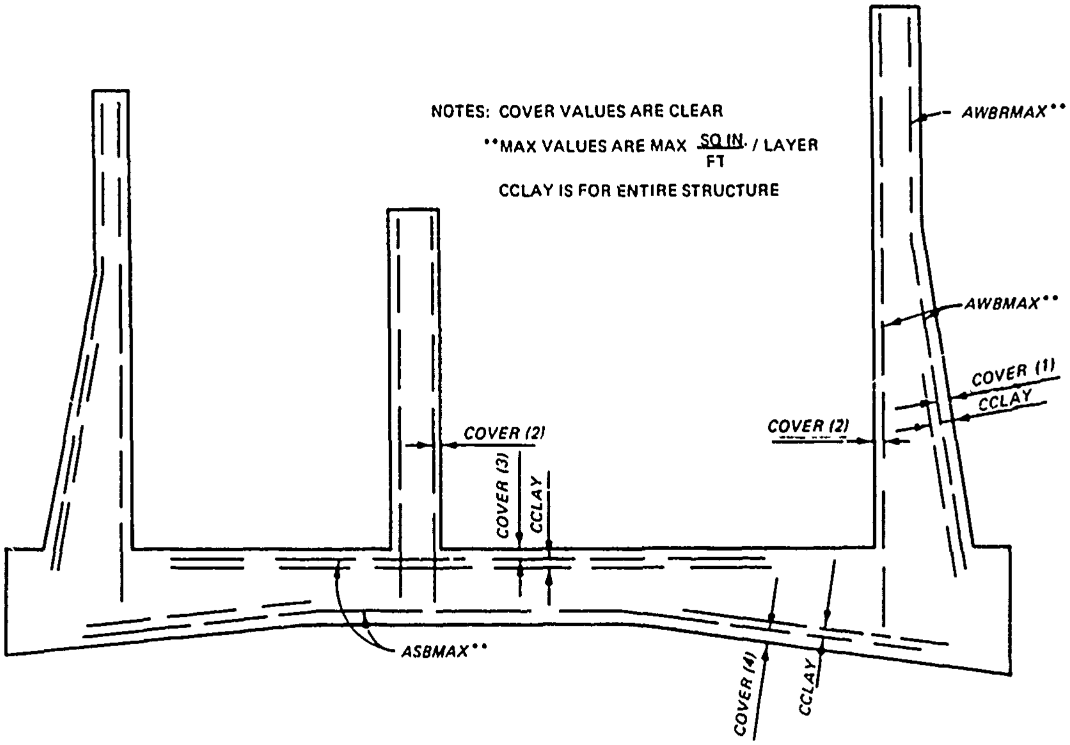


Figure 23. Reinforcement description for design mode, channels

157. The maximum number of layers of tension reinforcement are specified for the walls and slab, NOLAYW and NOLAYSB, respectively. The maximum number of layers above the break in the wall is limited to one. Then the maximum amount of steel per layer is specified by giving the area in square inches per foot using the variables AWBRMAX, AWBMAX, and ASBMAX for the walls above the break, below the break, and base slab, respectively, as shown in Figure 23. The maximum diameter must also be given in these same locations by specifying DWBRMAX, DWBMAX, and DSBMAX. Details on required input are included in the input guide (Appendix A).

158. The steel is assumed to fill up the outer layers first in computing the effective depth of the member. Figure 24 illustrates this procedure. The figure shows partial input and output for a channel. As seen in input section I.5, the base slab can have a maximum of two layers (NOLAYSB = 2) with a maximum area of steel of 2.00 sq in./ft in each layer (ASBMAX = 2.00). Output Section 0.2 shows that member number 2, which is the base slab, requires two layers near the left end (DISTANCE = 0,2.4) and near the center of the symmetrical member (DISTANCE = 9.6,12.0).

I.5 REINFORCEMENT FOR DESIGN OPTION

NUMBER OF LAYERS

WALL NOLAYW	SLAB NOLAYSB
2	2

CLEAR COVER AND CL TO CL LAYER DISTANCE(CCLAY)

COVER (IN)				CCLAY(IN)
COVER(1)	COVER(2)	COVER(3)	COVER(4)	CCLAY
2.50	3.00	3.00	3.50	4.00

MAXIMUM AREAS PER LAYER AND DIAMETERS

WALL BELOW BREAK		SLAB	
AREA AWBMAX (SI/FT)	DIAM. DWBMAX (IN)	AREA ASBMAX (SI/FT)	DIAM. DSBMAX (IN)
2.37	1.00	2.00	1.13

O.2 SUMMARY OF STEEL REQUIREMENTS BY MEMBER

************* MEMBER 2 *************

********** TOP STEEL **********
NONE REQUIRED FOR STRENGTH

********** BOTTOM STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00	1.128	2.00	.51		.0076	27.57
2.40	1.128	2.00	.15		.0070	25.45
4.80	1.128	1.95			.0070	23.32
7.20	1.128	1.94			.0076	21.19
9.60	1.128	2.00	.32		.0101	19.06
12.00	1.128	2.00	1.75		.0184	16.94

************* MEMBER 11 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
20.00					0.0000	7.00
18.00					0.0000	8.60
-	-	-	-	-	-	-
4.00	1.000	1.50			.0063	19.80
2.00	1.000	2.30			.0090	21.40
0.00	1.000	2.37	2.15		.0164	23.00

Figure 24. Sample design mode reinforcement input/output

159. The selected output for member 11 (wall) shows that no steel is required based on stress or strength calculations at the top of the wall, and two layers are required at the base. Again, it should be emphasized that the steel areas shown are those based on stress or strength calculations for flexure and axial force at the indicated section. The steel has to be extended past the points shown to ensure proper anchorage, and good detailing practice should be followed.

160. The user is also reminded that the program does not specify minimum areas of steel based on temperature, shrinkage, or prevention of a cracking failure (ACI 318, paragraph 10.5.1). However, the program will output a nominal value of 0.01 sq in. on the side, or sides, of a section for which an applied moment tends to cause tension, even if the stress or strength calculations show that no steel is required on that face.

161. Figures 25 and 26 show graphical output of the required areas of steel for a base slab and a wall member, respectively. The required areas are plotted on the sides of the member for which steel is needed based on axial-flexural requirements. Both the slab and the wall show that steel is required on both sides of the members because of the nature of the two EM-like load cases considered.

Design Criteria - WSD Option

162. When designing by the WSD option, basic allowable stresses are input, and then an allowable stress multiplier is input for each EM-like load case. For instance, to allow a 100 percent stress increase in the allowable stresses for a certain EM-like load case, an allowable stress multiplier of 2.0 would be input for that EM-like load case.

163. Design for flexure and axial force is based on actual computed stresses being less than allowable stresses at critical sections described subsequently. Actual stresses are computed using allowable stress equations described in the earlier investigation discussion. Stresses computed and their corresponding allowables are concrete compression (FC and FCA), steel (FS and FSA), and shear (VC and VCA).

164. For economy, it is generally desirable that the total amount of steel be less than that corresponding to balanced conditions. To ensure this condition is satisfied, the minimum depth required for balanced conditions,

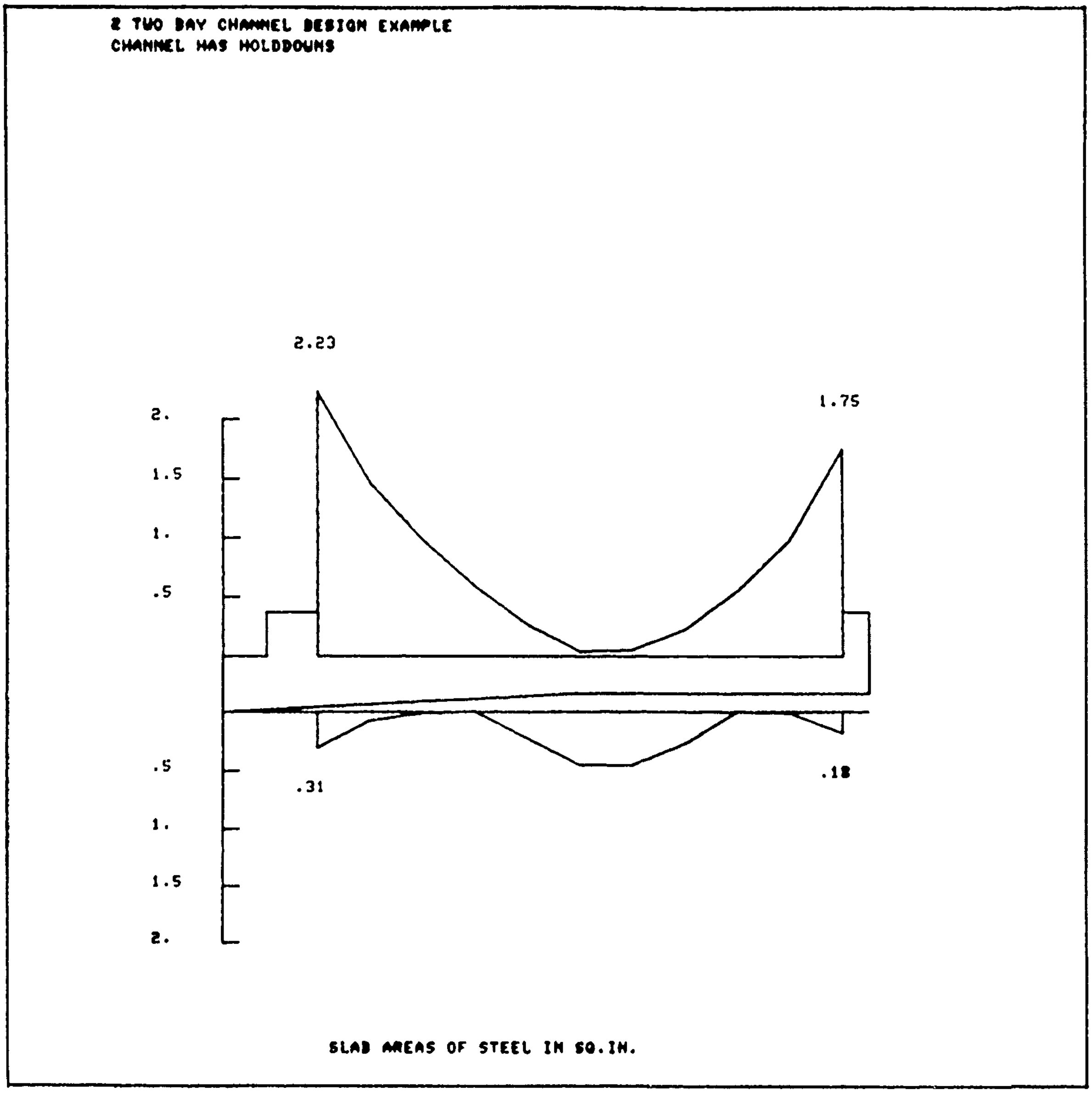


Figure 25. Sample area of steel plot for base slab

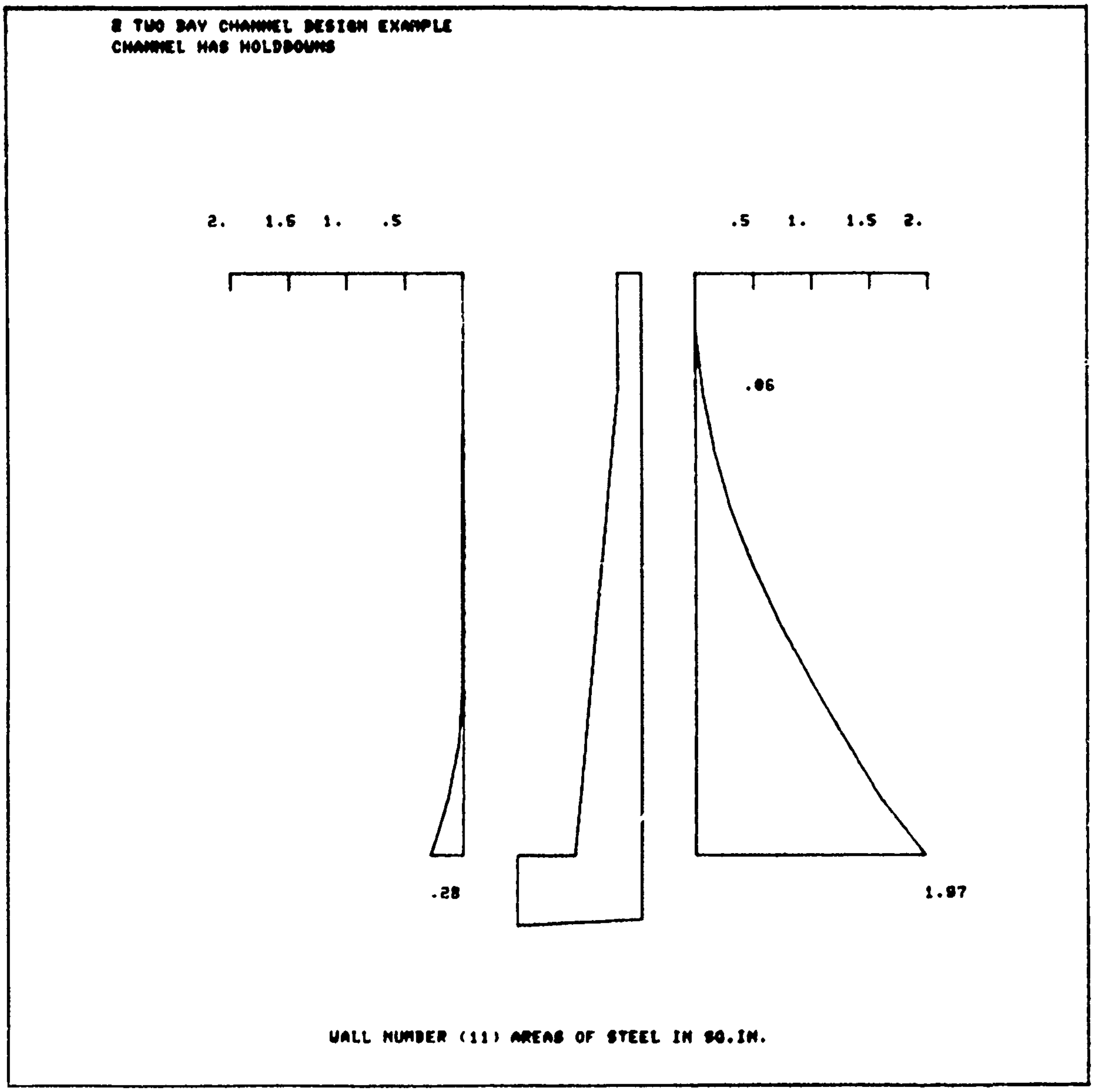


Figure 26. Sample area of steel plot for wall

DBAL, (including effect of axial force) is computed as described subsequently, and the actual value of D is kept at least as large as DBAL.

165. In addition to checking that FC does not exceed FCA and FS is less than or equal to FSA, the program checks short-column capacity by requiring the axial force, P, not to exceed the axial force corresponding to a stress of FCA on the extreme compression side and 0 on the tension side. This condition defines PO where

$$PO = .5*FCA*AG$$

where AG is the gross concrete area. If FCA is equal to .45*˜ ˛, the result is

$$PO = .225*FPC*AG$$

which is almost identical to the limiting axial force specified by ACI 318-56 (1956). Long-column effects are ignored.

166. Design for shear is by allowable stress provisions of ACI 318-83 (1983) for reinforced concrete members of normal depth-span ratios. Consequently, no design is done for heels of channels. The allowable shear stress, VCA, is computed by the following equations where P is the axial force.

If P is in compression (> 0.), then

$$VCA = 1.1*(1. + .0006*P/AG)*(FPC)^{0.5}$$

If P is in tension (< 0.), then

$$VCA = 1.1*(1. + .004*P/AG)*(FPC)^{0.5}$$

167. The nominal shear stress is computed as in the investigation mode, except that if the design shows no steel is needed for axial-flexural affects, DSH is computed based on one layer of steel. Thus, some minimum steel should be provided in any region of significant shear.

168. The ratios FC/FCA, FS/FSA, VC/VCA, P/PO, and DBAL/D should be less than one at all points to satisfy allowable stress criteria. The program makes these checks at the critical points, subsequently described. Also, when the user exercises the option to output the design variables during the iteration process, the values of these ratios will displayed. This option allows the designer to be much more involved with the design process than simply taking the final results as a "black-box" solution.

Design Criteria - SD Option

169. When design for concrete and steel is by the SD option, the load

factor is input for each EM-like load case as described earlier. Axial forces, moments, and shears computed at sections are multiplied times the specified load factor to check the adequacy of the sections. Design for flexure and axial force is based on the strength and ductility ratios being less than one at critical sections described subsequently. Strength and ductility ratios are computed as described earlier for investigation of section strength.

170. For cases which calculations for axial-flexural effects show no steel is required, the effective depth for shear strength calculations, DSH, is computed assuming a single layer of steel. Thus, minimum steel should be provided at all locations of significant shear. No considerations are given to long-column effects since the axial forces in U-frames are generally quite small and the soil offers restraint against long-column effects.

171. The detailed output for the SD option shows the critical strength and ductility ratios at the output locations for all load cases. Also, the user may elect to obtain interactive output of these ratios, at critical locations, during the iterations to determine the required size of the members.

General Design Procedure

172. Permitted factors of safety for uplift and bearing are input only once per run and are constant throughout design for all EM-like load cases. Foundation size is increased to try and satisfy minimum uplift requirements. However, if the specified minimum bearing factor of safety is not achieved, no resizing of members is attempted. A warning message is displayed, and the user has the option of continuing or stopping. In general, if the criteria cannot be satisfied, the user has the option of continuing the program in order to obtain output or an immediate termination.

173. The designer should probably be generous, but reasonable, in the number of layers permitted. If the number of layers are kept low, then the total amount of steel permitted may be too low resulting in a larger concrete section than really necessary. The designer should remember that the program will automatically limit the amount of steel to the value corresponding to DBAL using the WSD option, or it will ensure the ductility requirement is satisfied when using the SD option, regardless of the maximum amount input by

the designer. The user of the program may wish to experiment with varying the amount of steel permitted to do some economic parameter studies.

174. The modified half-interval procedure was developed to avoid the many wasted iterations that would occur using a simple incrementing procedure when the initial guess was well below the correct solution and still not overly penalize the experienced designer whose initial estimate is very close to the final solution. The modified half-interval iterative procedure is described in detail in Volume A of this report. The program sets an upper limit for a design variable at twice the initial value.

175. A brief flowchart for the design module is shown in Figure 27.

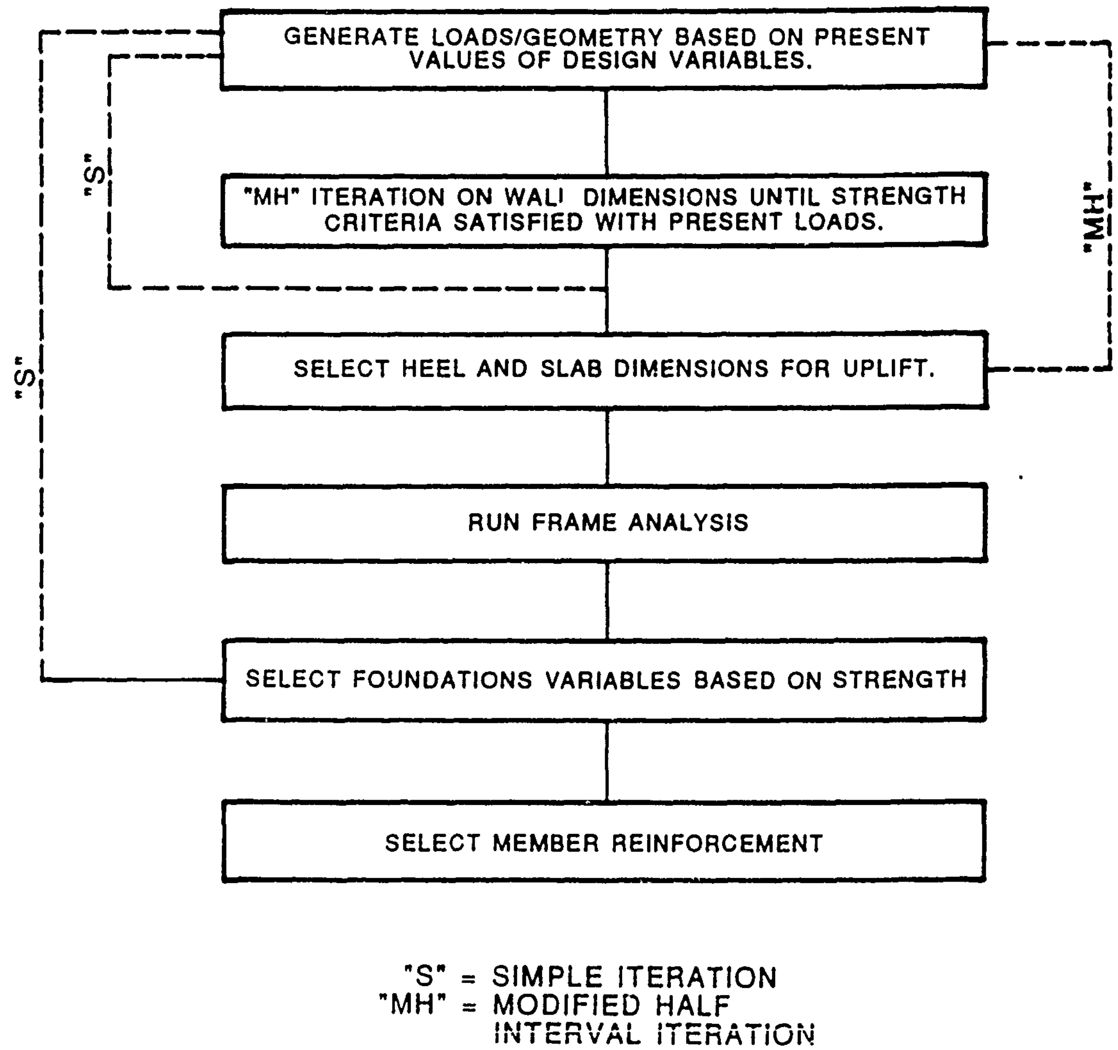


Figure 27. Design module flowchart

The first step in the design module is to generate the structure geometry and loads using the present value of the design variables. The present values are the initial input values at the start of the program. However, these initial values are updated as appropriate during the solution. The loads generated have been described earlier and include those due to hydraulic pressure and soil pressure.

Selection of Wall Thicknesses

176. Next, the wall members are sized based on stress or strength criteria. The loading is assumed to remain constant, and a modified half-interval iteration solution is made on the wall variables shown in Figure 28. WALLT is the thickness of the top wall, and WALLB is the bottom thickness. These design variables for the wall are restricted to less than two times their initial input values. Stress or strength criteria for axial force and moment are checked at sections A-A and C-C. Shear is checked at A-A and B-B

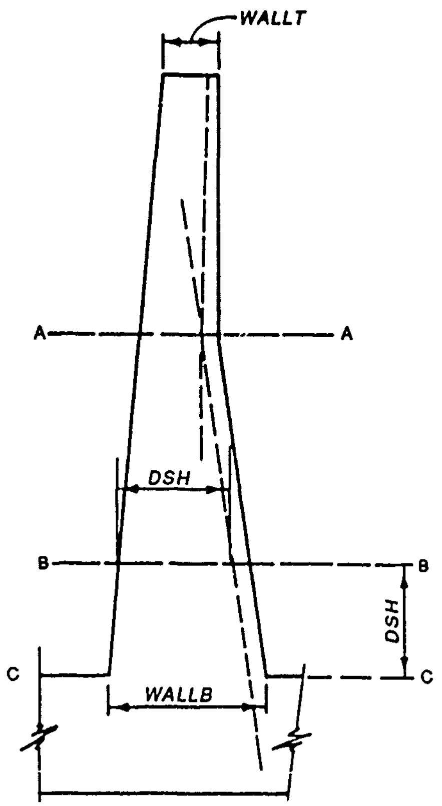


Figure 28. Incrementing wall size for strength

where B-B is at a distance equal to the effective flexural depth, DSH, up from the base of the foundation unless the slab provides tension support for the wall. For the rare case where the slab is in tension, the critical section for shear is at the top of the base slab. The thickness WALLT is incremented to satisfy the appropriate criteria at A-A, and then the thickness WALLB is incremented to satisfy the appropriate conditions at C-C and/or B-B.

177. After the walls have been sized, the solution returns to the origin of the design module and recomputes the wall geometry and loads. Then the wall dimensions are checked with the new loads. Since the loads usually change only slightly as the wall dimensions increase, a simple iteration is used here (the wall dimensions are simply incremented by an appropriate increment, if necessary). An increment of 1 in. is used for channels.

Design For Uplift

178. Next, the slab dimensions are increased as shown in Figure 29 to provide the minimum desired factor of safety for uplift. If the heel dimensions are being increased, then the program returns to the start of the design module to recompute soil, water, and self-weight loads following the modified

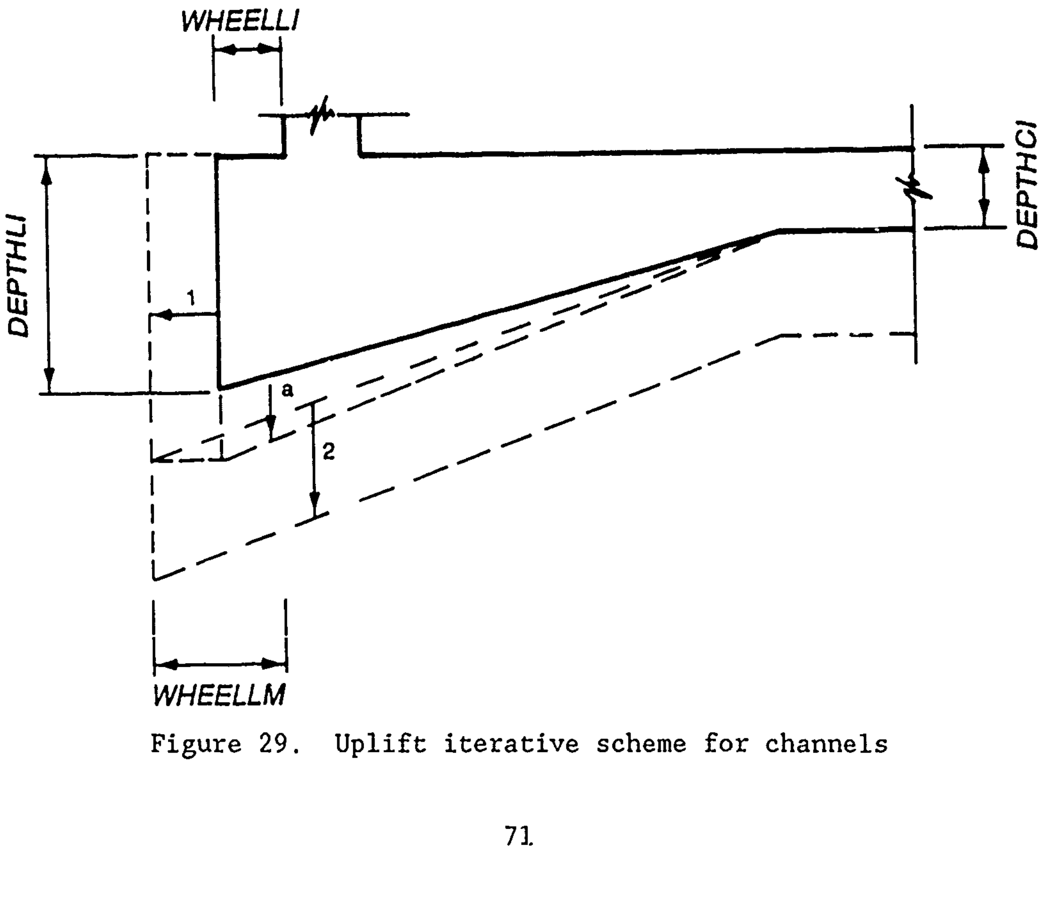


Figure 29. Uplift iterative scheme for channels

half-interval procedure as indicated in the flowchart of Figure 27. However, if only the slab thickness is being incremented, then the changes in hydraulic pressure and self-weight are computed locally during the iterations using a simple iteration procedure.

179. The input variables which vary during the design have an I suffix, DEPTHCI, DEPTHLI, and WHEELLI indicating these are the initial values of the corresponding variable names without the I suffix. During the wall iteration described earlier, the slab depth at the outer end, DEPTHL, may have already been increased because of the increase in the wall dimension, as indicated in Figure 29 by step "a."

180. The procedure for the initial "a" increase in the outer thickness of the base slab b is as follows. If the wall thickness in the outer wall is increased during the design cycles for wall strength, then the initial value of DEPTHL will generally be increased by a thickness of about 75 percent of the increase in wall thickness. However, the increase will be limited such that the initial estimate of the outer base slab thickness does not exceed twice the value of the minimum input value. Also, the initial guess for the outer base slab thickness will not be increased if the wall thickness is less than the input minimum value of DEPTHLI.

181. If uplift is not satisfactory, the value of WHEELL is incremented using the modified half-interval procedure as described earlier subject to the upper limit of WHEELLM. If the uplift requirement is still not satisfied, the base slab is incremented uniformly in 1-in. increments as shown in step "2" until the uplift criteria are satisfied, DEPTHL reaches twice DEPTHLI, or DEPTHC reaches twice DEPTHCI.

182. During the uplift iteration, the effects of anchors are considered. The anchors were described earlier in the investigation mode. The design considering anchors is somewhat limited, because the number and capacity of the anchors must already have been input. Thus, the designer must have already anticipated the need for the anchors prior to the design run. It is likely that the designer would first attempt a solution without the anchors, decide that they were needed, and do a revised run including the anchors. The iterative design procedure is identical in every respect whether or not anchors are used. However, the maximum capacity of all the anchors are included in computing the factor-of-safety for uplift. The user should refer to the earlier discussion of maximum anchor force for the investigation mode.

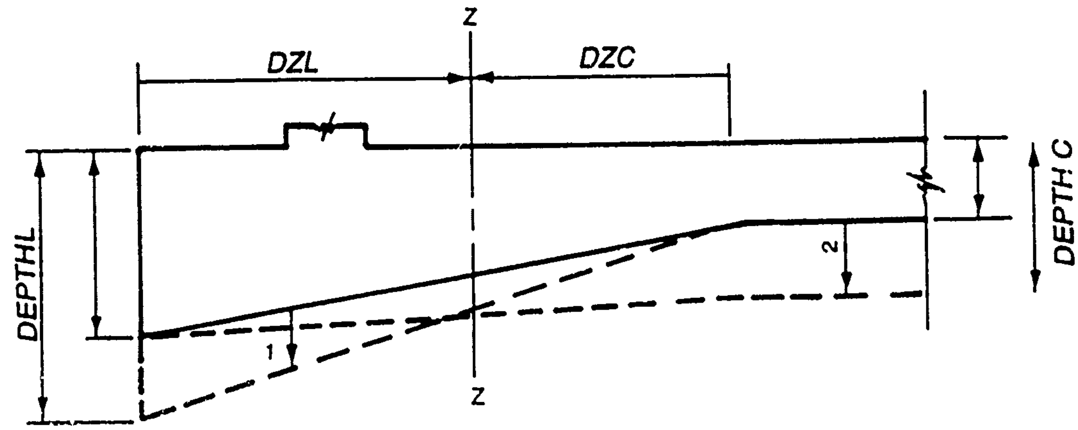
Checks of Bearing Pressure

183. Bearing pressure is checked prior to the frame solution for the empirical foundation option and afterwards for the beam on elastic foundation option. However, the foundation dimensions are not revised if the bearing criteria are not satisfied. The factors of safety concerning bearing are simply reported and a message is output if the required factor of safety is not achieved. Bearing is seldom a problem for U-frame structures, and the iterative scheme to eliminate the bearing overstress would make the program unduly more complicated. Also, it should be noted that as the iterations for other criteria occur, the status of the bearing check will change and be duly reported.

Design of Base Slab for WSD or SD Criteria

184. Next, the foundation variables are increased as appropriate until stress or strength criteria are satisfied. Since the slab has possibly already been incremented in size because of wall thickness increases or to help satisfy uplift, the simple iteration procedure is used in incrementing the slab thicknesses for stress. The slab iteration involves the most recalculations of any of the design steps because the entire solution including the frame analysis is repeated during each iteration. Thus, the program user is warned that inputing an initial value of slab thickness greatly thinner than the walls could cause excessive computer costs. As discussed for the walls, the amount of steel permitted by the user may also influence the size of the section selected by the program.

185. The iterative scheme to satisfy stress or strength criteria for the channel base slab is shown in Figure 30. The procedure may increment the heel depth, DEPTHL, or the center slab depth, DEPTHC, separately or together according to the following criteria. If DZL is less than 50 percent of DZC, increment DEPTHL; if DZC is less than 50 percent of DZL, increment DEPTHC; if both cases are not true, then increment both DEPTHL and DEPTHC. DZL is the distance from the extreme left edge of the base slab to the location of the overstress, and DZC is the distance from the overstress to the location of the central depth. The user is reminded that the program has an option to output



0. Stress iterative scheme for channels

...tion steps and that exercising this option may be he... ...tanding the iteration process.

186. For base slabs the stress or strength criteria are checked internally at the tenth points. The shear check is made at the face of the walls rather than some distance away since the wall support for the slab is not a well-defined condition for being a tension or compression support. No stress or strength is checked for the channel heel.

187. The checks on shear are made initially with the depth DSH computed assuming the maximum number of steel layers are acting. However, if the shear is critical and flexure is not, this solution is slightly conservative. Thus, for this case, an approximate solution is made to find the required area of steel that is used to compute the value of DSH with which to recheck shear. The user who elects to output the design variable iterations may occasionally see more than one value of the shear stress ratio output for a particular load case (the first value greater than one and a subsequent value less than one). This result indicates that the procedure just described allowed the trial section to satisfy the shear requirement. A similar adjustment based on the required area of steel being less than the maximum input by the user is made for the DBAL/D ratio with the WSD option and in the ductility ratio for the SD option.

188. During the iterative process, the members are sized such that they ensure the appropriate stress or strength criteria will be satisfied with an amount of steel less than the maximum prescribed by the user or less than that

to make the DBAL/D ratio or the ductility ratio equal to one. If any of the criteria cannot be satisfied, the user has the option to get the complete output of the results for detailed study before trying another design. Such outputs contain appropriate warnings when any criteria are not satisfied.

Design Mode Output

189. The output file will contain all the original input values of the design variables and the final incremented values. The final values are clearly distinguished to reduce the possibility of the smaller initial value being accidentally mistaken for the final value. Pressures and member forces are output generally for the analysis mode except this output and the detailed output described below are limited to members on the left side of the channel.

190. After all iterations are completed, the final steel requirements are computed as described subsequently and given at the tenth points for all members except heels. Channel heels will not show any steel requirements. Walls with breaks will also have the areas required at the breaks output.

191. After all areas of steel are found and stored for both sides of a section if needed, the final stresses or the section strength and ductility ratios are computed using these areas and output by load case. If a reversal of the moment at a section requires tension steel on both faces, there would in fact be some compression steel. However, compression steel is not considered in computing the final stresses or making the final strength checks. The only case in which compression steel is taken into account is in the investigation mode. The steel required on the nominal compression face is of course considered in computing stresses for cases with significant axial tension.

192. Because of the iterations involved in both the design and investigation equations using the WSD option, some stresses may be nominally higher than their allowable values. The final stresses are printed for each load case, and if any flexural stress exceeds one-half percent over the corresponding allowable value, a warning message is printed.

193. The procedure used for the SD module should ensure that the final strength and ductility ratios for axial-flexural effects are all less than or equal to one. However, if any of these values exceed 1.005 at the output points, a warning message will be output.

194. The shear stress or strength ratios output for the walls may

exceed 1.0 at the base because the wall is usually sized for shear at a distance DSH above the base slab. As usual, the user of any complex design program should thoroughly review the output.

Steel Selection

195. In the WSD option, the selection of steel is made after the sections have been reviewed and found to satisfy all allowable stress criteria with the steel less than or equal to the maximum amount permitted by the user.

196. In the SD option, the selection of steel is made after the sections have been reviewed and found to satisfy all strength and ductility criteria with the steel less than or equal to the maximum amount permitted by the user. Details on the steel selection procedures are available in Volume A of this report.

PART VII: TERMINAL EXECUTION OF PROGRAM

197. The program executes in a terminal control mode. The user may prepare a data file in advance or prepare the data file using an on-line editor which will guide the user in preparing data by only asking for the data required for a particular problem. For example, once the user specifies that the channel has only one bay, the on-line editor will only prompt for input related to a single-bay channel. However, users should have read this report and will occasionally need to refer to the input guide (Appendix A) and the associated sketches even if preparing the data file with the aid of the on-line editor. Beginning users are strongly urged to utilize the on-line editor to prepare their input files.

198. Once the data file is prepared, it may be displayed, edited, saved, and executed during the terminal run. Thus, the on-line editor could be used to create several data files during one program run, and these files saved for later execution. Likewise, output obtained may be viewed and/or stored for later printing. A plot file may be prepared to be used later with the plotting program CUFRMP which uses the Corps Graphics Compatibility System 2D (C 2D) (US Army Engineer Waterways Experiment Station and West Point Mil .y Academy 1982).

Creating and Modifying Data Files Using On-line Editor

199. The on-line editor portion of the program which displays the prompts for editing and creating data is very user friendly. Input is requested by section, using the section numbers found in the input guide. However, input is not requested for sections which are not required for the user's particular problem.

200. When a line of input is requested for a section, the editor displays the variable description as well as the program variable name. Values are input on the line below the variable names and must be input in order with one or more spaces placed between values. If a value is not placed on the input line for each variable or if too many values are placed on the input line, the editor will ignore the values and redisplay the variable names when the return key is struck.

201. When editing an existing file, the editor asks the user to decide

whether or not to modify each input section one by one, ignoring redundant sections. A "No" response will move the editor to the next required section. A "Yes" response will prompt the editor to display the required variables with the variable descriptions, variable names, and the current value of each variable. A carriage return by the user is an indication of acceptance of all the current values, and the editor moves to the next required line of input variables within the current section or on to the next section to be edited.

202. The user may accept the current value of any variable within the line by placing an "S" (for same) in the appropriate space. New values for an individual variable may be input by placing the new value in the appropriate space. For example, for a data line with five variables required, the user might respond

2 s s 15.53 eMP

This input would keep the second and third variables at their same or existing value, and redefine the first, fourth and fifth variables. Floating point data such as a dimension of 15.53 must be entered with the decimal point, but scientific notation is not permitted. However, the decimal point is optional for whole floating point numbers. Integer data such as the number of EM-like load cases should be entered without a decimal point. Key words such as "EMP" are input without quotes and may be upper or lowercase.

203. It is generally a good idea to input the data sections in numerical order. However, an option is provided such that the experienced user can move directly to a particular data section with the on-line editor. When prompted for a "Yes" or "No" response regarding modifying a particular section, the user may respond "GJ," where J is any integer from 1 to 14. The G should be followed by the value of J without any spaces. This response will cause the on-line editor to move to section J for data modification. This option to move to a particular section is very convenient when only one or two sections need to be modified. However, the user is warned that if a section is skipped, the program will not request any data for that section, even if other changes in the data require some change in the skipped section. Users may also elect to exit the on-line editor anytime when prompted for a "Yes"/"No" response to modify a particular section by responding "Q" for quit.

204. Finally, the users are reminded that there will be no prompting for variables that are not needed by the program for a particular problem.

Thus, while the input guide may describe eight values of input for a line in the most general case, if only five values are needed because of the options selected, the users will only be prompted for those five values (i.e. USE THE ON-LINE EDITOR!).

Program Execution

205. Figure 31 presents a summary flowchart of the terminal execution of the program. The flowchart shows that an early response requested from the user is to indicate whether or not an existing data file is to be input. Such responses will be either "YES" or "NO" ("YE", "Y", and "N" are also acceptable responses). If a previously prepared data file is to be used, then the name of the data file must of course be input. If the user responds "YES," indicating an old file is to be input, the program will read the data file named and prompt for another "YES"/"NO" response indicating whether or not the data file is to be displayed on the terminal. If the data file is displayed at this time, it will be shown as a raw data file without any accompanying headings.

206. Next, as seen in the flowchart, the user will be asked to indicate whether it is necessary to modify the data file as input or if a new data file is to be created. If the "MOD" option is selected, then the user will be given the necessary prompts by the on-line editor to edit the existing data file. If the "CRE" option is selected, the on-line editor user will provide the prompts to prepare a new data file. The user will be given the option to see a summary of instructions on how to apply the on-line editor if the on-line editor is selected. Then as seen in the flowchart, the program control returns to the portion where the user is prompted to indicate if the data file should be displayed.

207. Eventually, the user will be satisfied with the data file and respond "NO" to the query on creating or modifying the data file. At that time, the flowchart indicates that the user has the option of storing the data in a permanent data file. Data files that are stored may or may not have line numbers. If line numbers are chosen, they are numbered such that the first two digits of the line number are the data section number.

208. Next, assuming an investigation problem is being run, the decision is made by the user whether or not the data file now active in the program is

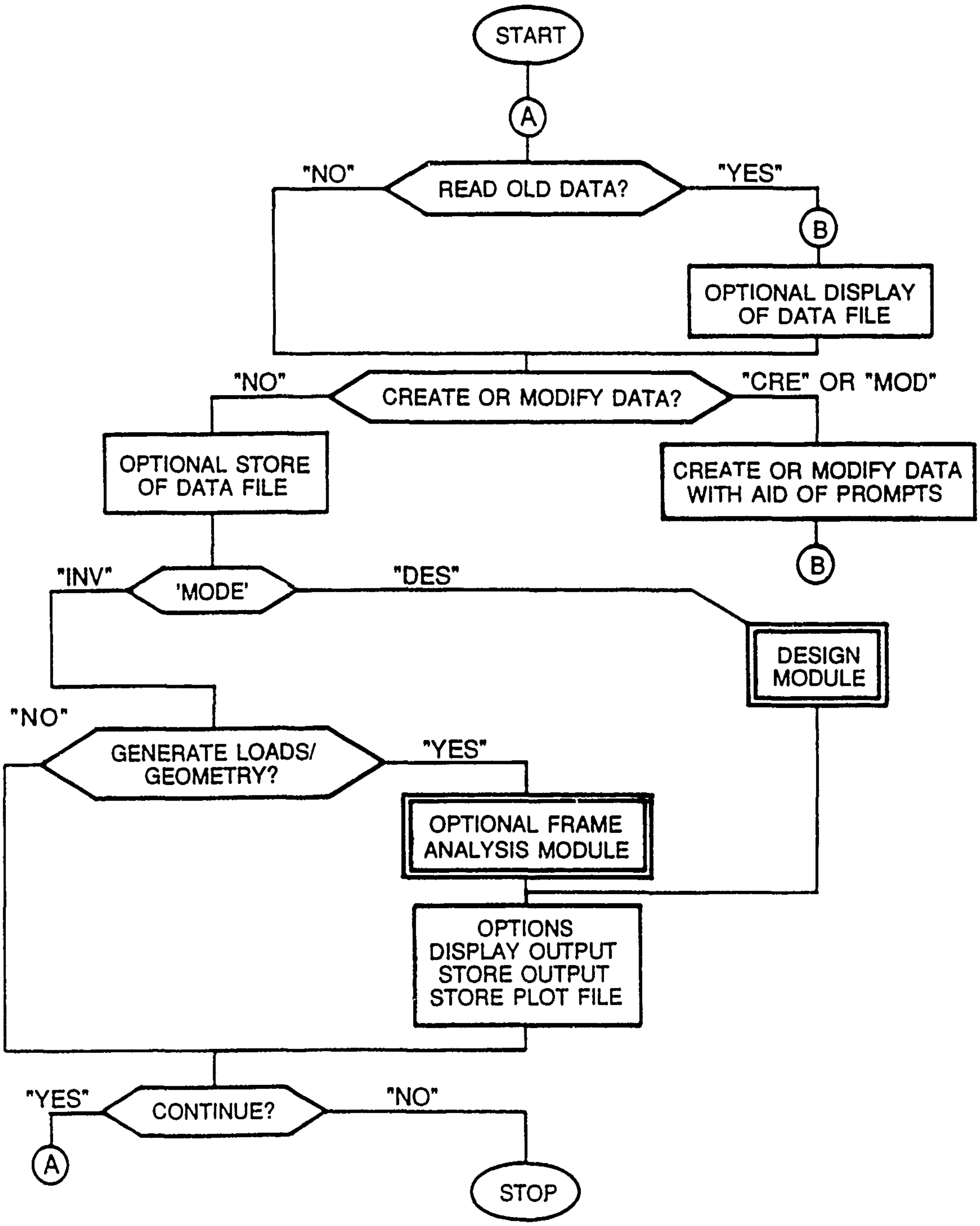


Figure 31. Summary flowchart for terminal execution

ready to be executed. The execution is broken up into two phases. First, the loads are generated and the frame geometry defined. After the first phase, the user has the option of continuing on to the detailed frame analysis or not. The terminal will display factors of safety and the horizontal equilibrium for the appropriate load cases prior to prompting for the decision on whether or not to do the detailed frame analysis.

209. At this point, an output file is now created with either the results of the preliminary analysis or the complete analysis. It also contains the input with appropriate headings. This output file may be displayed at the terminal and/or stored for future listing. Also, the option is provided for storing the necessary plot data, such that the user may obtain plotted output in a later execution of the CUFRMP graphics program. Instructions on using the CUFRMP program to obtain the plots are in the input guide.

210. Now, the user may stop the run or continue the program. If the program is continued, the user may modify the existing data file in the program, create a new one, or input any other existing data file. This flexibility allows the user to perform a variety of investigations varying important parameters or to iterate to a design that has acceptable output very quickly.

211. If the run is made using the design option, the flow is slightly different. After the data file is ready, the program branches to the DESIGN MODULE as shown on the flowchart. Here the user is asked whether or not the design should be continued. Assuming the user continues, the program follows the design algorithm flowchart previously discussed until the output and plot files are prepared. From that point on, the flow is identical to the investigation mode. During the design, the intermediate values of the design variables and the corresponding stress or strength ratios can be displayed at the terminal if requested by the user.

Semibatch Mode

212. The above described procedure gives the user maximum control over the program at the cost of a few minutes of time. However, after several runs of the same problem or runs of several problems with previously prepared data files, a semibatch mode is available to reduce the interaction time. If the

semibatch mode is selected, the user is only required to give the name of the input file, whether or not it is a line-numbered file, and whether or not the response is to continue on to a new problem. Depending on the type of terminal being used, it may even be possible to stack a series of problems by inputing these three responses to a series of problems on the terminal screen during pauses in the response from the host computer.

213. If the semibatch mode is selected, then the user must be prepared to accept the consequences of the loss of control of the process. In the semibatch mode, the program generally takes the more complete, longer, and more costly of the options that would be available to the user in the terminal control mode. However, intermediate values of the stress or strengths ratio are not output for the semibatch mode.

File Conventions

214. The data file, output file, and plot file are all given unique file names of up to six characters by the user. The data file will in fact contain all of these names. It should be noted that while the output file will always contain the information in the input file, it is still desirable to maintain the input file for documentation purposes or possible later modification. Also, the data file that is used is the one that exists at the time of the execution of the solution. Thus, it is possible to execute the program with a data file that is not stored as a permanent file.

215. Experienced users may wish to prepare the data files in advance of the program execution using their own editor. Such files must be in the American Standard Code for Information Interchange (ASCII) format and optionally may have line numbers of up to six integers at the extreme left of the file. The data file is free format with input items either numbers or alphanumeric data. The items are separated by one or more spaces. Floating point and integer data should be typed as described earlier for the on-line editor.

216. The data are structured sequentially in sections and lines. The sections are numbered as indicated in the input guide. Each section asks for a certain number of lines of data, and each line should contain a certain number of data items. However, as indicated in the input guide, certain lines and data items on lines are omitted depending on the options selected. As a data file is read, it is checked for the correct number of items in each

sequential line. If a line has an incorrect number of items, a message is displayed indicating the section number of the erroneous line, and the program terminates to allow the user to correct the data file. When entering the input directly with the on-line editor, if the wrong number of items are input for a line, the user is reprompted for the data line.

217. Since free format input is used, it is possible that some very small values could be input and used in the program. However, the input file and the output file contain only a finite number of places after the decimal point. Thus, a very small input number could conceivably be lost in the input and output files. For writing most input quantities to the input or output file, the program generally uses three places after the decimal point in order to represent all reasonable data to satisfactory accuracy.

218. A limited number of checks are made on the acceptability of program data by the on-line editor. For instance, water elevations are not permitted to exceed the height of an adjacent wall. The data checks are made just prior to the solution of the program. If any unacceptable data are encountered, the user will be allowed to either modify the data with the on-line editor, store the data file for future modification, or terminate the run. However, it is not possible to provide checks for all data that might be incorrect, and it is obviously impossible to ensure that the input data will correctly model the user's given problem when applied to the program. Thus, the program user must thoroughly review the program output to ensure that the data selected was appropriate for the particular U-frame.

Plotting Program CUFRMP

219. Because of the large size of the program CUFRBC, it was decided to have a separate program for plotting the results. During the execution of CUFRBC, the user may store request that the results needed for plotting be stored on a permanent file. Then plotted output may be obtained at any later time through the use of the Fortran program CUFRMP.

220. At the start of CUFRMP, the user will be prompted for the name of the file on which the plot information was stored, which was input in Section 2.0 of the data.

221. The entire procedure is interactive, and the user merely responds to simple questions concerning what types of output are desired and for which

load cases the output is needed. Detailed descriptions of the output available for plotting were given earlier in this report. The types of output available are:

a. U-frame geometry including soil and water elevations.

b. Individual wall pressure plots.

c. Base slab pressure plots.

d. Member force and deflection plots.

e. Plots of required areas of flexural steel.

REFERENCES

American Concrete Institute. 1956. "Building Code Requirements for Reinforced Concrete," ACI 318-56, Detroit, Mich.

__________. 1983. "Building Code Requirements for Reinforced Concrete," ACI 318-83, Detroit, Mich.

Haliburton, T. A. 1972 (Feb). "Soil Structure Interaction," Technical Publication Number 14, Oklahoma State University, Stillwater, Okla.

Hamby, C. C., and Price, W. A. 1984 (Sep). "User's Guide for Concrete Strength Investigation and Design (CSTR)," Instruction Report K-84-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Hays, C. O. 1971. "A Nonlinear Analysis of Statically Loaded Plane Frames Using A Discrete Element Model," Ph.D. Dissertation, The University of Texas, Austin, Tex.

__________. 1982 (Aug). "FRAME 54, Nonlinear Analysis of Statically Loaded Plane Frames Using a Discrete Element Model, A User's Guide," University of Florida, Gainesville, Fla.

Hays, C. O., and Matlock, H. M. 1973 (Oct). "Nonlinear Discrete Element Analysis of Frames," Journal of the Structural Division of the American Society of Civil Engineers.

Hays, C. O., and Santhanam, T. K. 1979 (July). "Inelastic Section Response by Tangent Stiffness Method," Journal of the Structural Division of the American Society of Civil Engineers.

Headquarters, Department of the Army. 1961a (May). "Structural Design of Spillways and Outlet Works," Engineering Manual 1110-2-2400, Washington, DC.

__________. 1961b (May). "Retaining Walls," Engineering Manual 1110-2-2502, Washington, DC.

__________. 1981 (June). "Sliding Stability For Concrete Structure," Engineer Technical Letter 1110-2-256.

__________. 1988 (Mar). "Strength Design Criteria for Reinforced Concrete Hydraulic Structures," Engineer Technical Letter 1110-2-312.

Matlock, H. M., and Haliburtion, T. M. 1966 (Sep). "A Finite Element Solution for Linearly Elastic Beam Columns," Research Report 56-1, Center for Highway Research, University of Texas, Austin, Tex.

Shushkewich, K. W. 1983 (Nov - Dec). "Simplified Cracked Section Analysis," Journal of the American Concrete Institute, Detroit, Mich.

Taylor, T. P., and Matlock, H. M. 1968. "A Finite Element Method of Analysis for Composite Reams," Research Report 56-10, Center for Highway Research, University of Texas, Austin, Tex.

US Army Engineer Waterways Experiment Station and West Point Military Academy. 1982 (Revised). "Graphics Compatibility System (GCS) Programmer's Reference Manual," Instruction Report K-82-3, Vicksburg, Miss.

APPENDIX A: INPUT GUIDE FOR CHANNELS

1. The program executes in a terminal control or interactive mode. The user may prepare a data file in advance or prepare the data file using an on-line editor which will guide the user in preparing data by only asking for the data required for the user's particular problem. Beginning users are strongly urged to select the on-line editor to prepare their input files. Once the data file is prepared, it may be displayed, edited, saved, and executed during the terminal run. Output obtained may be viewed and/or stored for later printing. A plot file may be prepared to be used later with the CORPS Graphics Compatibility System (GCS) 2D plot program (US Army Engineer Waterways Experiment Station and West Point Military Academy 1982).*

Terminal Responses

2. Responses to terminal prompts are "YES" or "NO" unless otherwise indicated. "YE", "Y", and "N" are also acceptable. Quote marks are used to indicate a response and should not be entered. Responses may be in upper or lower case.

Creating and Modifying Data Files Using On-line Editor

3. When a line of input is requested for a section, the editor displays the variable description as well as the program variable name and the required units. Values are input on the line below the variable names and must be input in order with one or more spaces between values. If a value is not placed on the input line for each variable or if too many values are placed on the input line, the editor will ignore the values and re-display the variable names when the return key is struck.

4. When editing an existing file, the editor asks the user if he or she wishes to modify each input section one by one, ignoring redundant sections. A "NO" response will move the editor to the next required section. A response of "GJ" will move the user to section J for editing, where J is the desired

* See References at the end of the main text.

section number from 1 to 14. Note that the G should be followed by the section number without a space. The user is warned that skipping around sections may cause the user to forget certain required input items. A "Q" response will end the editing session, and the user may then save the data as modified.

5. A "YES" response will prompt the editor to display, for the current data line, variable descriptions, program names, units, and the current value of each variable. A carriage return by the user is an indication of acceptance of all the current values, and the editor moves to the next required line of input variables within the current section or on to the next section to be edited.

6. The user may enter new values for any or all of the variables on the line by typing in new values in free format with all values separated by one or more spaces. The user may accept the current value of any variable within the line by placing an "S" (for same) in the appropriate position.

7. Floating point data such as a dimension of 15.53 must be entered with the decimal point, but scientific notation is not permitted. However, the decimal point is optional for whole floating point numbers. Integer data such as the number of EM-like load cases should be entered without a decimal point. Key words such as "EMP" are input without quotes and may be upper or lowercase.

Program Execution

8. The standard execution of the program is by terminal control or the interactive mode. The user controls all phases of the program: selecting prepared input files, input or editing input data, and controlling the program solution as described in the report. The output file so created may be displayed at the terminal and/or stored for future listing. The user may selectively display portions of the output file. Also, the option is provided for storing the necessary plot data, such that the user may obtain plotted output in a later execution of the GCS2D graphics program. However, the user will be prompted to indicate whether or not the semibatch mode of operation is to be selected.

9. If the semibatch mode is selected the user is only required to input

the name of the input file, whether or not it is a line numbered file, and whether or not to continue on to a new problem. For the semibatch mode, the program automatically executes the solution for the designated input file and stores the results in the designated output and plot files.

File Conventions

10. The data file, output file, and plot file are all given unique file names of up to six characters by the user. The data file will in fact contain all these names. However, the data used by the program are that which exist in the program at the time of the execution of the solution. Thus, it is possible to execute the program with data that are not stored as a permanent data file.

11. Experienced users may wish to prepare the data files in advance of the program execution using their own editor. Such files must be in ASCII format and optionally may have line numbers of up to six integers at the extreme left of the file. The data file is free format with input items either numbers or alphanumeric data. The items are separated by one or more spaces. Floating point and integer data should be typed as described earlier for the on-line editor. Since free format input is used and all writes to files have a fixed number of decimal digits, it is possible to lose some very small values entered via the terminal. However, the units chosen and the number of decimal digits carried are thought sufficient to represent any meaningful data.

12. The data are structured sequentially in sections and lines. The sections are numbered as indicated in the input guide. Each section asks for a certain number of lines of data, and each line should contain a certain number of data items. A limited number of checks are made on the acceptability of program data by the on-line editor. If any of these checks fail, the user may revise the data or store the data file for later revision.

Obtaining Graphical Output

13. During execution of CUFRBC, the user may request that the results needed for plotting be stored on a permanent file. Then plotted output may

then be obtained at a later time using the Fortran plotting program CUFRMP which uses the Corps graphics package GCS2D.

14. At the start of the program CUFRMP, the user will be prompted for the name of the previously stored plot file. Next, the user responds to several questions concerning which types of output are desired and for which load cases the output is needed.

Summary of Input By Sections

SECTION 1. HEADER.
One to four lines of problem identification.

SECTION 2. PROBLEM DESCRIPTION.
State whether the problem is 'design' or 'investigation', 'Working Stress Design' or 'Strength Design', 'Channel' or 'Basin', number of channels, drain and symmetry options. Names of input and output files are also entered here.

SECTION 3. MATERIAL PROPERTIES AND DESIGN FACTORS.
Input concrete and steel material properties and design criteria for either Working Stress Design or Strength Design procedures.

SECTION 4. GEOMETRY.
Basic channel, slab, and wall dimensions including drain locations.

SECTION 5. REINFORCEMENT DESCRIPTION FOR DESIGN OPTION.
Number of reinforcement layers permitted, concrete cover, maximum area per layer and bar diameter and layer spacing.

SECTION 6. REINFORCEMENT DESCRIPTION FOR INVESTIGATION OPTION.
Input includes number of members to be investigated and locations of sections to be investigated, concrete cover and layer spacing. The reinforcing steel must be described at each section to be investigated using bar numbers and spacing or areas and diameters.

SECTION 7. LOADING.
Number of EM-like load cases governed by fill and water elevations, number of special user defined load cases, types of analysis used for backfill and foundation pressures, and required factors of safety.

SECTION 8. HYDRAULIC AND ALLOWABLE STRESS DATA.
Water elevations in channel and backfill, drain and load or stress factors, repeated for each EM-like load case.

SECTION 9. SOIL LOADING BY WEDGE METHOD.
Input of backfill material properties, backfill geometry, rock elevations and surcharge.

SECTION 10. LOAD - DEFORMATION METHOD.
Input curves describing nonlinear force-deformation response of soil to movement of walls.

SECTION 11. EMPIRICAL SOIL DESCRIPTION.
Backfill material properties and soil and rock elevations

SECTION 12. SPECIAL LOAD CASES.
Allows input of concentrated and uniform loads on any member which may or may not be combined with EM-like load cases.

SECTION 13. BEAM ON ELASTIC FOUNDATION DESCRIPTION.
Input foundation material properties such as crushing strength, Winkler spring moduli, friction angle, and cohesion. Number and capacity of tension anchors are also input here.

SECTION 14. EMPIRICAL FOUNDATION DESCRIPTION.
Input foundation material properties such as crushing strength, friction angle, and cohesion along with parameters defining shape of foundation pressure diagram.

Detailed Description of Input By Sections

SECTION 1. HEADER--ONE (1) TO FOUR (4) LINES ARE PROVIDED FOR IDENTIFYING THE RUN.

A. HEADER LINE 1

A(1) CONTENTS

```
**********************
* NLINES 'HEADING' *
**********************
```

A(2) DEFINITIONS

NLINES = TOTAL NUMBER OF HEADER LINES = INTEGER 1 TO 4.

'HEADING' = ANY ALPHANUMERIC INFORMATION.
TOTAL CHARACTERS ON HEADER LINE 1 INCLUDING NLINES, 'HEADING', AND EMBEDDED BLANKS MUST BE < 70. BLANK 'HEADING' IS NOT PERMITTED.

B. HEADER LINES 2 TO NLINES &&& INCLUDE ONLY IF NLINES > 1 &&&

B(1) CONTENTS

```
***************
*  'HEADING'  *
***************
```

B(2) DEFINITIONS

'HEADING' = ADDITIONAL ALPHANUMERIC INFORMATION.
TOTAL CHARACTERS INCLUDING 'HEADING,' AND EMBEDDED
BLANKS MUST BE < 70. BLANK 'HEADING ' IS NOT PERMITTED.

SECTION 2. PROBLEM DESCRIPTION.

A. GENERAL DESCRIPTION

A(1) CONTENTS

```
*******************************************************************
*  'MODE' 'METHOD' 'TYPE'  NCHANNELS  'INFILE' 'OUTFILE' 'PLTFILE' *
*******************************************************************
```

A(2) DEFINITIONS

'MODE' = DESIGN OR INVESTIGATION.
'MODE' = "DES" OR "INV".
'METHOD' = WORKING STRESS DESIGN
OR
STRENGTH DESIGN.

'METHOD' = "WSD" OR "SD".

'TYPE' = CHANNEL OR BASIN.
'TYPE' = "CHA" OR "BAS".
SEE SEPARATE INPUT GUIDE FOR BASINS.

NCHANNELS= NUMBER OF CHANNELS (1 TO 2).

'INFILE' = NAME OF FILE TO STORE INPUT DATA.
(1 TO 6 CHARACTERS)

'OUTFILE' = NAME OF FILE TO STORE RESULTS.
(1 TO 6 CHARACTERS)

'PLTFILE' = NAME OF FILE TO STORE PLOT INFORMATION
FOR LATER PLOT USING GCS2D. (1 TO 6 CHARACTERS)

B. DRAIN OPTIONS

B(1) CONTENTS

```
**********************************
*  'WDRNOP'  'SDRNOP'  'GEOMOP'  *
**********************************
```

B(2) DEFINITIONS

'WDRNOP' = WALL DRAIN OPTION.
'WDRNOP' = "YES" FOR WALL DRAINS.
'WDRNOP' = "NO" TO OMIT WALL DRAIN DATA.

'SDRNOP' = SLAB DRAIN OPTION.
'SDRNOP' = "YES" FOR BASE SLAB DRAINS.
'SDRNOP' = "NO" TO OMIT BASE SLAB DRAIN DATA.

&&& INCLUDE ONLY IF 'MODE' = "INV" &&&
(SYMMETRY ASSUMED IN DESIGN MODE)
'GEOMOP' = CHANNEL GEOMETRIC SYMMETRY OPTION.
'GEOMOP' = "SYM" FOR SYMMETRICAL CHANNELS.
'GEOMOP' = "NON" FOR NONSYMMETRICAL CHANNELS

SECTION 3. MATERIAL PROPERTIES AND DESIGN FACTORS.

A. STRENGTH DESIGN &&& INCLUDE ONLY IF 'METHOD' = "SD" &&&

A(1) CONTENTS

```
********************************
*  FPC WTCONC FY PBRAT 'DCRIT' *
********************************
```

A(2) DEFINITIONS

FPC = ULTIMATE CONCRETE STRENGTH (KSI).

WTCONC = CONCRETE UNIT WEIGHT (KCF).

FY = REINFORCEMENT YIELD STRENGTH (KSI)
(MAY NOT EXCEED 48.0 FOR 'DCRIT' = "HYD").

PBRAT = RATIO OF MAXIMUM TENSION STEEL ALLOWED TO BALANCED
STEEL RATIO, UNLESS COMPRESSION STEEL IS PROVIDED (0 TO 1)
(MAY NOT EXCEED .25 FOR 'DCRIT' = "HYD")
(MAY NOT EXCEED .75 FOR 'DCRIT' = "ACI").

'DCRIT' = DESIGN CRITERIA.
'DCRIT' = "HYD" FOR CORPS HYDRAULIC STRUCTURE "SD" PARAMETERS
'DCRIT' = "ACI" FOR ACI CODE "SD" PARAMETERS
'DCRIT' = "INP" TO INPUT "SD" PARAMETERS.

```
 &&& INCLUDE ONLY IF "DCRIT' - "INP"          &&&
     (DESIGNS UNDER CORPS HYDRAULIC STRUCTURE
     CRITERIA AND ACI CODE CRITERIA CAN BE
     EXECUTED WITHOUT INPUTING THESE PARAMETERS.
     THE "INP" OPTION IS INCLUDED FOR POSSIBLE
     DETAILED STRENGTH DESIGN STUDIES).
```

A(3) CONTENTS

```
***************************************
*  EPM BETAM FCR PMAXF PHIA PHIF PHIS *
***************************************
```

A(4) DEFINITIONS

```
 EPM - MAXIMUM CONCRETE STRAIN ALLOWED
 (.0015 FOR 'DCRIT' - "HYD")
 (.003  FOR 'DCRIT' - "ACI").

 BETAM - RATIO OF DEPTH OF STRESS BLOCK TO DEPTH UNDER
 COMPRESSION STRAIN (0 TO 1) VARIES WITH FPC (SIMILAR TO
 BETA(1) IN ACI CODE).


 FCR - RATIO OF MAXIMUM STRESS IN STRESS BLOCK TO FPC (0 TO 1)
 (.85 FOR 'DCRIT' = "HYD")
 (.85 FOR 'DCRIT' = "ACI").

 PMAXF - RATIO OF MAX USABLE COMPRESSION STRENGTH TO
 "ZERO ECCENTRICITY" COMPRESSION STRENGTH (0 TO 1)
 (.7 FOR 'DCRIT' - "HYD")
 (.8 FOR 'DCRIT' = "ACI").

 PHIA - STRENGTH REDUCTION FACTOR FOR PURE AXIAL LOAD (0 TO 1)
 (0.7 FOR 'DCRIT' - "HYD")
 (0.7 FOR 'DCRIT' = "ACI").

 PHIF - STRENGTH REDUCTION FACTOR FOR PURE FLEXURAL LOAD (0 TO 1)
 (0.9 FOR 'DCRIT' = "HYD")
 (0.9 FOR 'DCRIT' - "ACI").

 PHIS - STRENGTH REDUCTION FACTOR FOR SHEAR (0 TO 1)
 (.85 FOR 'DCRIT' = "HYD")
 (.85 FOR 'DCRIT' - "ACI").
```

B. WORKING STRESS &&& INCLUDE ONLY IF 'METHOD' = "WSD" &&&

B(1) CONTENTS

```
************************
*  FPC WTCONC FCA FSA  *
************************
```

B(2) DEFINITIONS

FPC = ULTIMATE CONCRETE STRENGTH (KSI).

WTCONC = CONCRETE UNIT WEIGHT (KCF).

FCA = ALLOWABLE UNIT CONCRETE COMPRESSIVE STRESS (KSI).

FSA = ALLOWABLE UNIT REINFORCING STEEL STRESS (KSI).

SECTION 4. GEOMETRY.

A. LEFT EXTERIOR WALL DIMENSIONS

A(1) CONTENTS

```
**********************************************
*  ELTOPL ELBRKL ELSLAB WALLTL WALLBL ELDRL  *
**********************************************
```

A(2) DEFINITIONS

ELTOPL = ELEVATION OF TOP OF LEFT WALL (FT).

ELBRKL = ELEVATION OF BREAK ON FILL-SIDE OF LEFT WALL (FT).
(FOR NO PHYSICAL BREAK ON WALL INPUT ELBRKL = ELTOPL)

ELSLAB = ELEVATION OF CHANNEL SLAB (FT).

WALLTL = WIDTH OF TOP OF LEFT WALL (IN).

WALLBL = WIDTH OF LEFT WALL AT BASE (IN).

&&& INCLUDE ONLY IF 'WDRNOP' = "YES" &&&
ELDRL = ELEVATION OF LOWEST LEFT WALL DRAIN (FT).

B. RIGHT EXTERIOR WALL DIMENSIONS &&&&
&&& INCLUDE ONLY IF 'GEOMOP' = "NON" AND "MODE" = "INV" &&&

B(1) CONTENTS

```
***************************************
*  ELTOPR ELBRKR WALLTR WALLBR ELDRR  *
***************************************
```

B(2) DEFINITIONS

ELTOPR = ELEVATION OF TOP OF RIGHT WALL (FT).

ELBRKR = ELEVATION OF BREAK ON FILL SIDE OF RIGHT WALL (FT).
(FOR NO PHYSICAL BREAK IN WALL INPUT ELBRKR = ELTOPR)

WALLTR = WIDTH OF TOP OF RIGHT WALL (IN).

WALLBR = WIDTH OF RIGHT WALL AT BASE (IN).

&&& INCLUDE ONLY IF 'WDRNOP' = "YES" &&&
ELDRR = ELEVATION OF LOWEST RIGHT WALL DRAIN (FT).

C. SLAB AND HEEL DIMENSIONS

C(1) CONTENTS

```
*****************************************************
*  DEPTHL DEPTHC WHEELL WHEELLM WIDTHL DRSPL DISCL  *
*****************************************************
```

C(2) DEFINITIONS

DEPTHL = DEPTH OF SLAB AT LEFT END (IN).

DEPTHC = DEPTH OF CENTRAL PORTION OF SLAB (IN).

WHEELL = LENGTH OF HEEL AT LEFT END (FT).

&&& INCLUDE ONLY IF 'MODE' = "DES" AND WHEELL > 0. &&&
WHEELLM = MAXIMUM VALUE ALLOWED FOR WHEELL DURING DESIGN ITERATIONS (FT).

WIDTHL = WIDTH OF LEFT CHANNEL (FT).

&&& INCLUDE ONLY IF 'SDRNOP' = "YES" &&&
DRSPL = DISTANCE FROM INSIDE FACE OF LEFT EXTERIOR WALL TO FIRST LINE OF DRAINS (FT).

&&& INCLUDE ONLY IF NCHANNELS = 2 &&&
DISCL = DISTANCE FROM INSIDE FACE OF LEFT WALL TO BREAK UNDER LEFT CHANNEL (FT).

D. RIGHT SIDE SLAB AND HEEL DIMENSIONS &&&
&&& INCLUDE ONLY IF 'GEOMOP' = "NON" AND 'MODE' = "INV" &&&

D(1) CONTENTS

```
*****************************************
*  DEPTHR  WHEELR  DRSPR  WIDTHR  DISCR  *
*****************************************
```

D(2) DEFINITIONS

DEPTHR = DEPTH OF SLAB AT RIGHT END (IN).

WHEELR = LENGTH OF HEEL AT RIGHT END (FT).

&&& INCLUDE ONLY IF 'SDRNOP' = "YES" &&&
DRSPR = DISTANCE FROM INSIDE FACE OF RIGHT EXTERIOR
WALL TO FIRST LINE OF DRAINS (FT).

&&& INCLUDE ONLY IF NCHANNELS = 2 &&&
WIDTHR = WIDTH OF RIGHT CHANNEL (FT).

&&& INCLUDE ONLY IF NCHANNELS = 2 &&&
DISCR = DISTANCE FROM INSIDE FACE OF RIGHT WALL TO BREAK
UNDER RIGHT CHANNEL (FT).

E. INTERIOR WALL DIMENSIONS &&&
&&& INCLUDE ONLY IF NCHANNELS = 2 &&&

E(1) CONTENTS

```
****************************
* ELTOPC  WALLTC WALLBC   *
****************************
```

E(2) DEFINITIONS

ELTOPC = ELEVATION OF TOP OF CENTER WALL (FT).

WALLTC = WIDTH OF CENTER WALL AT TOP (IN).

WALLBC = WIDTH OF CENTER WALL AT BASE (IN).

SECTION 5. REINFORCEMENT DESCRIPTION FOR DESIGN OPTION.
&&&& INCLUDE ONLY IF 'MODE' = "DES" &&&&

A. CONTROL

A(1) CONTENTS

```
********************
* NOLAYW NOLAYSB  *
********************
```

NOLAYW = MAXIMUM NUMBER OF LAYERS OF TENSION STEEL
IN WALL BELOW BREAK (1 TO 3)
(NUMBER OF LAYERS ABOVE BREAK IN WALL IS ONE).

NOLAYSB - MAXIMUM NUMBER OF LAYERS OF TENSION STEEL
IN BASE SLAB (1 TO 3).

B. REINFORCEMENT COVER AND SPACING

B(1) CONTENTS

```
*****************************************************
*  COVER(1)  COVER(2)  COVER(3)  COVER(4)  CCLAY    *
*****************************************************
```

B(2) DEFINITIONS

COVER(1) - CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT ON BACKFILL SURFACES OF WALLS.

COVER(2) - CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT ON CHANNEL SURFACE OF WALLS.

COVER(3) - CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT ON TOP FACE OF SLAB.

COVER(4) - CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT ON BOTTOM FACE OF SLAB .

&&& INCLUDE ONLY IF NOLAYW OR NOLAYSB > 1 &&&
CCLAY - CENTER TO CENTER SPACING (IN) FOR LAYERS OF STEEL.

C. MAXIMUM STEEL DESIGN CRITERIA

C(1) CONTENTS

```
**************************************************
*  AWBRMAX DWBRMAX AWBMAX DWBMAX ASBMAX DSBMAX  *
**************************************************
```

C(2) DEFINITIONS

&&& INCLUDE ONLY IF ELTOPL ABOVE ELBRKL &&&
AWBRMAX - MAXIMUM AREA OF STEEL PER LAYER (SQ.IN./FT.) IN WALL ABOVE BREAK IN WALL.

&&& INCLUDE ONLY IF ELTOPL ABOVE ELBRKL &&&
DWBRMAX - MAXIMUM DIAMETER OF STEEL REINF. (IN) IN WALL ABOVE BREAK IN WALL.

AWBMAX - MAXIMUM AREA OF STEEL PER LAYER (SQ.IN./FT.) IN WALL BELOW BREAK IN WALL

DWBMAX - MAXIMUM DIAMETER OF STEEL REINF. (IN) IN WALL BELOW BREAK IN WALL.

ASBMAX = MAXIMUM AREA OF STEEL PER LAYER (SQ.IN./FT.)
FOR BASE SLAB.

DSBMAX = MAXIMUM DIAMETER OF STEEL REINF. (IN)
FOR BASE SLAB.

SECTION 6. REINFORCEMENT DESCRIPTION FOR INVESTIGATION OPTION.
&&&& INCLUDE ONLY IF 'MODE' = "INV" &&&&&

A. CONTROL

A(1) CONTENTS

```
********************
*  NMINV  'REOPT'  *
********************
```

A(2) DEFINITION

NMINV = TOTAL NUMBER OF MEMBERS TO BE INVESTIGATED.

'REOPT' = REINFORCEMENT DESCRIPTION OPTION.
'REOPT' = "BAR" FOR INPUT OF BAR DATA.
'REOPT' = "ARE" FOR INPUT OF AREA DATA.
('REOPT' REQUIRED ONLY IF NMINV > 0).

B. REINFORCEMENT COVER AND SPACING &&& INCLUDE ONLY IF NMINV > 0 &&&

B(1) CONTENTS

```
*****************************************************
* COVER(1)  COVER(2)  COVER(3)  COVER(4)  CCLAY *
*****************************************************
```

B(2) DEFINITIONS

COVER(1) = CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT
ON BACKFILL SURFACES OF WALLS.

COVER(2) = CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT
ON CHANNEL SURFACE OF WALLS.

COVER(3) = CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT
ON TOP FACE OF SLAB.

COVER(4) = CLEAR COVER (IN) FOR OUTSIDE LAYER OF REINFORCEMENT
ON BOTTOM FACE OF SLAB.

CCLAY = CENTER TO CENTER SPACING (IN) FOR LAYERS OF STEEL.
(CCLAY REQUIRED ONLY IF ONE OR MORE SECTIONS DESCRIBED
BELOW HAVE MORE THAN ONE LAYER)

C. LOCATION CONTROL

```
****** REPEAT  C.,D. AND E. OR F. NMINV TIMES *********************
                                                                  *
C(1) CONTENTS                                                     *
                                                                  *
**************                                                    *
*  MEM NLOC  ******************************************************
**************                                                    *
                                                                  *
C(2) DEFINITIONS                                                  *
                                                                  *
 MEM - THE IDENTIFICATION NUMBER OF THE MEMBER.                   *
                                                                  *
 SLAB MEMBERS ARE NUMBERED FROM LEFT TO RIGHT.                    *
 (FROM 1 TO NCHANNELS + 2)                                        *
 WALL MEMBERS ARE NUMBERED FROM LEFT TO RIGHT                     *
 (FROM 11 TO NCHANNELS + 11)                                      *
 (RIGHT SIDE MEMBERS OF SYMMETRICAL FRAMES MAY NOT BE             *
 INVESTIGATED EXCEPT FOR UNSYMMETRICAL EM-LIKE LOAD CASES,        *
 SPECIAL LOAD CASES, OR WHEN 'BTYPE' - "LDM")                     *
                                                                  *
 NLOC - TOTAL NUMBER OF LOCATIONS TO BE REVIEWED                  *
        THIS MEMBER. (5 MAX)                                      *
                                                                  *
```

D. REINFORCEMENT DESCRIPTION AT EACH LOCATION.

```
                                                                  *
                                                                  *
*********** REPEAT D. AND E. OR F. NLOC TIMES *********************
                                                                  *
D(1) CONTENTS                                                     *
                                                                  *
********************                                              *
*  DR NTOPL NBOTL  ************************************************
********************                                              *
                                                                  *
D(2) DEFINITIONS                                                  *
                                                                  *
DR - DISTANCE (FT) FROM 'LEFT' END OF MEMBER TO                   *
REVIEW POINT ('LEFT' END IS TOP OF SLAB FOR WALLS).               *
                                                                  *
NTOPL = NUMBER OF TOP LAYERS (INTEGER  0 TO 3).                   *
        ('TOP' LAYER IS ON LEFT SIDE OF WALL)                     *
                                                                  *
NBOTL = NUMBER OF BOTTOM LAYERS (INTEGER  0 TO 3).                *
        ('BOTTOM' LAYER IS RIGHT SIDE OF WALL)                    *
                                                                  *
                                                                  *
```

```
E. REINFORCEMENT DESCRIPTION, REPEAT FOR EACH LAYER  ****************
   &&& INCLUDE ONLY FOR 'REOPT' = "BAR" &&&                          *
                                                                     *
                                                                     *
  E(1) CONTENTS                                                      *
                                                                     *
  ***********************  &&& INCLUDE ONLY IF NTOPL > 0  &&&        *
  *  NBAR8(I) SPBAR(I)  ********************************************
  ***********************  REPEAT FOR I = 1 TO NTOPL ON SAME LINE    *
                                                                     *
  ***********************  &&& INCLUDE ONLY IF NBOTL > 0  &&&        *
  *  NBAR8(J) SPBAR(J)  ********************************************
  ***********************  REPEAT FOR J = 1 TO NBOTL ON SAME LINE    *
                                                                     *
  E(2) DEFINITIONS                                                   *
                                                                     *
    I = TOP LAYER NUMBER (I = 1 IS TOP MOST LAYER).                  *
                                                                     *
    J = BOTTOM LAYER NUMBER (J = 1 IS BOTTOM MOST LAYER).            *
                                                                     *
   NBAR8( ) = BAR SIZE IN 1/8 IN (INTEGER 2 TO 11 OR 14).            *
                                                                     *
   SPBAR( ) = BAR SPACING WITHIN LAYER (IN).                         *
                                                                     *
F. REINFORCEMENT DESCRIPTION, REPEAT FOR EACH LAYER  ****************
   &&& INCLUDE ONLY FOR 'REOPT' = "ARE" &&&                          *
                                                                     *
  F(1) CONTENTS                                                      *
                                                                     *
  ****************************** &&&INCLUDE ONLY IF NTOPL > 0  &&&   *
  * DIAMB  AREAB(I),I=1,NTOPL  **************************************
  ******************************                                     *
                                                                     *
  ****************************** &&&INCLUDE ONLY IF NBOTL > 0  &&&   *
  * DIAMB  AREAB(J),J=1,NBOTL  **************************************
  ******************************

  F(2) DEFINITIONS

    I = TOP LAYER NUMBER (I = 1 IS TOP MOST LAYER).

    J = BOTTOM LAYER NUMBER (J = 1 IS BOTTOM MOST LAYER).

    DIAMB = DIAMETER OF BARS IN OUTER LAYER.
            (USED ONLY FOR COMPUTING LOCATION OF STEEL)

    AREAB( ) = AREA OF BARS IN LAYER (SQ.IN./FT.).
```

SECTION 7. LOADING.

A. CONTROL

A(1) CONTENTS

```
************************************************
* NEM 'BTYPE' NSPEC 'FTYPE' FSUPM FSBEARM *
************************************************
```

A(2) DEFINITIONS

NEM = NUMBER OF EM-LIKE LOAD CASES (1 TO 10).
LOADS ARE DEFINED BY
WEIGHT OF ONE FOOT SLICE OF CHANNEL PLUS
!!!! WATER ELEVATIONS INPUT FOR EACH EM-LIKE LOAD CASE
AND FILL ELEVATIONS AND PROPERTIES (CONSTANT)
!!!!OR!!!!
!!!! SEE DISCUSSION BELOW FOR 'BTYPE' = "LDM" !!!!

'BTYPE' = TYPE OF ANALYSIS FOR BACKFILL.
&&&& ONLY 'BTYPE' = 'WEDA' OR 'BTYPE' = 'EMP'
PERMITTED IN DESIGN MODE &&&&
'BTYPE' = "WEDA" FOR ACTIVE WEDGE SOLUTION FOR BOTH WALLS.
'BTYPE' = "WEDPL" FOR LEFT PASSIVE WEDGE SOLUTION FOR LEFT
EXTERIOR WALL AND ACTIVE FOR OTHER WALL.
'BTYPE' = "WEDPR" FOR PASSIVE WEDGE SOLUTION FOR RIGHT
EXTERIOR WALL AND ACTIVE FOR OTHER WALL.
'BTYPE' = "EMP" FOR EMPIRICAL EARTH PRESSURES.
'BTYPE' = "LDM" FOR LOAD DEFORMATION CURVES.
!!!!!! FOR 'BTYPE' = "LDM"
ONLY 1 EM-LIKE LOAD CASE IS ALLOWED WHICH DEFINES
WATER ELEVATIONS AND USES LOAD DEFORMATION CURVES
TO DEFINE LATERAL SOIL PRESSURES ON WALLS.
ALSO A SINGLE SPECIAL LOAD CASE (NSPEC = 1) IS
REQUIRED AND THE SPECIAL LOADS ARE ADDED TO THE
EM-LIKE LOADING INCLUDING WEIGHT OF U-FRAME.!!!!!

&&&& INCLUDE ONLY IF 'MODE' = "INV" &&&&
NSPEC = NUMBER OF LOAD CASES INPUT BY SPECIFYING
LOADS ON THE STRUCTURE (3 MAX
SPECIFIED LOAD CASES MAY BE ' INED
WITH EM-LIKE LOAD CASES OR NC

'FTYPE' = TYPE OF ANALYSIS FOR FOUNDATION.
'FTYPE' = "SPR" FOR BEAM ON ELASTIC FOUNDATION.
'FTYPE' = "EMP" FOR EMPIRICAL FORCE BALANCE.

&&&& MINIMUM FACTORS OF SAFETY FOR DESIGN OPTION
INCLUDE ONLY IF 'MODE' = "DES" &&&&

FSUPM = MINIMUM FACTOR OF SAFETY FOR UPLIFT.

```
  FSBEARM - MINIMUM FACTOR OF SAFETY FOR BEARING.


SECTION 8.  HYDRAULIC AND ALLOWABLE STRESS DATA.
            *******************REPEAT NEM TIMES*********************
                                                                  *
A. CONTROL AND LOAD ID                                            *
                                                                  *
  A(1) CONTENTS                                                   *
                                                                  *
  ***********************************                             *
  * 'SYMTW'  ASMUL SLF  'LOADIDH'   ********************************
  ***********************************                             *
                                                                  *
  A(2) DEFINITIONS                                                *
                                                                  *
   &&&& ALWAYS INCLUDE IF 'MODE' = "INV"  &&&&                    *
   &&&& INCLUDE FOR 'MODE' = "DES" ONLY IF NCHANNELS = 2 &&&&     *
   'SYMTW' = WATER ELEVATION.SYMMETRY OPTION.                     *
   'SYMTW' = "SYM" FOR SYMMETRICAL WATER ELEVATIONS.              *
   'SYMTW' = "NON" FOR NONSYMMETRICAL WATER ELEVATIONS.           *
   WATER ELEVATIONS ARE ASSUMED SYMMETRICAL IN DESIGN MODE;       *
   EXCEPT FOR INTERNAL WATER ELEVATIONS FOR NCHANNELS = 2.        *
                                                                  *
   &&& INCLUDE ONLY IF 'MODE' = "DES"  AND 'METHOD' = "WSD" &&&   *
   ASMUL = ALLOWABLE STRESS MULTIPLIER. THIS FACTOR IS MULTIPLIED *
   BY THE BASIC INPUT ALLOWABLE STRESSES FCA AND FSA AND BY THE   *
   COMPUTED SHEAR STRESS VCA TO OBTAIN REVISED ALLOWABLE STRESSES. *
   INPUT ASMUL = 1.0 TO USE BASIC ALLOWABLE VALUES.               *
                                                                  *
   &&&& INCLUDE ONLY IF 'METHOD' = "SD" &&&&                      *
   SLF = 'SD' LOAD FACTOR FOR ALL LOADS IN THIS EM-LIKE           *
   LOADCASE (>1.).                                                *
                                                                  *
   'LOADIDH' = ALPHA NUMERIC IDENTIFICATION OF LOAD.              *
              (1 TO 20 CHARACTERS INCLUDING EMBEDDED BLANKS)      *
                                                                  *
B. WATER ELEVATIONS                                               *
                                                                  *
  B(1) CONTENTS                                                   *
                                                                  *
  *********************************                               *
  *  ELBWSL ELCWSL ELCWSR ELBWSR  **********************************
  *********************************                               *
                                                                  *
  B(2) DEFINITIONS                                                *
                                                                  *
   ELBWSL - ELEVATION OF BACKFILL WATER SURFACE LEFT SIDE (FT).   *
                                                                  *
   ELCWSL = ELEVATION OF CHANNEL WATER SURFACE LEFT SIDE (FT).    *
                                                                  *
   &&&& INCLUDE ONLY IF 'SYMTW' = "NON" AND NCHANNELS = 2 &&&&    *
```

```
   ELCWSR - ELEVATION OF CHANNEL WATER SURFACE RIGHT SIDE (FT).      *
                                                                     *
   &&&& INCLUDE ONLY IF 'SYMTW' - "NON" AND 'MODE' - "INV" &&&&      *
   ELBWSR - ELEVATION OF BACKFILL WATER SURFACE RIGHT SIDE (FT).     *
                                                                     *
C. DRAIN FACTORS AND ATREST MULTIPLIERS                              *
                                                                     *
  C(1) CONTENTS                                                      *
                                                                     *
  *****************************************                          *
  *  PDRNWL PDRNWR PDRNSL PDRNSR ATRESTS  **************************
  *****************************************

  C(2) DEFINITIONS

   &&& INCLUDE WALL DRAIN EFFECTIVENESS DATA ONLY IF
       'WDRNOP' - "YES" &&&
   PDRNWL - PERCENT EFFECTIVENESS OF LEFT WALL DRAIN

   &&& INCLUDE ONLY IF 'MODE' - "INV" &&&
   PDRNWR - PERCENT EFFECTIVENESS OF RIGHT WALL DRAIN

   &&& INCLUDE SLAB DRAIN EFFECTIVENESS DATA ONLY IF
   'SDRNOP' - "YES" &&&
   PDRNSL - PERCENT EFFECTIVENESS OF LEFT SLAB DRAIN

   &&& INCLUDE ONLY IF 'MODE' - "INV" &&&
   PDRNSR - PERCENT EFFECTIVENESS OF RIGHT SLAB DRAIN
   *** INCLUDE ONLY FOR WEDGE ANALYSIS OF BACKFILL -
       ('BTYPE' - "WEDA" OR "WEDPL" OR "WEDPR") &&&
   ATRESTS - FACTOR BY WHICH HORIZONTAL COMPONENT OF ACTIVE
   SOIL FORCES FROM WEDGE ANALYSIS OF BACKFILL ARE MULTIPLIED
   TO OBTAIN ATREST HORIZONTAL FORCES (1.0 FOR ACTIVE CASE)


SECTION 9.  SOIL LOADING BY WEDGE METHOD.
            &&&& INCLUDE ONLY IF 'BTYPE' - "WEDA"
                 OR "WEDPL" OR "WEDPR" &&&&

A. BACKFILL MATERIAL PROPERTIES

  A(1) CONTENTS

  ****************************************
  *  UWSD UWSS SPHI SCOHE DELFW 'SYMTB'  *
  ****************************************

  A(2) DEFINITIONS

  UWSD = UNIT WEIGHT OF SOIL, DRAINED (K/CF).

  UWSS - UNIT WEIGHT OF SOIL, SATURATED (K/CF).
```

```
SPHI - ANGLE OF INTERNAL FRICTION OF BACKFILL(DEG).

SCOHE - COHESION VALUE FOR BACKFILL (KSF).

DELFW - FRICTION ANGLE FOR WALL BACKFILL SURFACE (DEG).

&&&& INCLUDE ONLY IF 'MODE' = "INV" &&&&
'SYMTB' - BACKFILL SYMMETRY OPTION.
'SYMTB' - "SYM" FOR SYMMETRICAL BACKFILL.
'SYMTB' - "NON" FOR NONSYMMETRICAL BACKFILL.
```

B. BACKFILL DESCRIPTION--LEFT SIDE

B(1) CONTENTS

```
*************************************************
*  SOJL SOKL SOLL SOML UWSURL ELGSL ANBSL ELRSL  *
*************************************************
```

B(2) DEFINITIONS

```
SOJL - HORIZONTAL PROJECTION OF SLOPPED BACKFILL (FT).

SOKL - HORIZONTAL LENGTH OF LEVEL BACKFILL ADJACENT
       TO EXTERIOR WALL (FT).

SOLL - DISTANCE TO BEGINNING OF SURCHARGE
       FROM EXTERIOR FACE OF WALL (FT).
SOML - WIDTH OF UNIFORM SURCHARGE ON GROUND SURFACE (FT).

UWSURL - UNIT WEIGHT OF UNIFORM SURCHARGE ON GROUND (KSF).

ELGSL - ELEVATION OF BACKFILL GROUND SURFACE (FT).

ANBSL- ANGLE OF BACKFILL WITH HORIZONTAL (DEG).
       GROUND SLOPES UP FROM WALL FOR POSITIVE ANGLE.

ELRSL - ELEVATION OF ROCK SURFACE ON EXTERIOR
        WALL (FT).
```

C. BACKFILL DESCRIPTION--RIGHT SIDE &&&&
&&&& INCLUDE ONLY IF 'SYMTB' = "NON" AND 'MODE' = "INV" &&&&

C(1) CONTENTS

```
*************************************************
*  SOJR SOKR SOLR SOMR UWSURR ELGSR ANBSR ELRSR  *
*************************************************
```

C(2) DEFINITIONS

SAME AS LEFT SIDE

```
SECTION 10.  LOAD - DEFORMATION METHOD.
             &&&&  INCLUDE ONLY FOR BTYPE = 'LDM' &&&

A. HEADER

  A(1) CONTENTS

  *******************
  *  NPTS NCW NCRL  *
  *******************

  A(2) DEFINITIONS

   NPTS = NUMBER OF POINTS PROVIDED ON NONLINEAR RESISTING
          FORCE-DISPLACEMENT CURVE; MINIMUM OF TWO POINTS
          REQUIRED; MAXIMUM OF EIGHT POINTS PERMITTED.

   NCW = NUMBER OF CURVES TO BE INPUT FOR WALLS;
         CURVES CAN BE USED FOR BACKFILL
         OR ROCK CONTACT (MAXIMUM OF SIX).

   NCRL = NUMBER OF CURVE LOCATIONS (MAXIMUM OF 20).

B. WALL LOADING CURVES  ***** REPEAT NCW TIMES **********************
                                                                    *
  B(1) CONTENTS ODD LINES                                           *
                                                                    *
  ********************************************                      *
  *  DEF(1)  DEF(2) .........DEF(NPTS) (FT)  ***********************
  ********************************************                      *
                                                                    *
  B(2) CONTENTS EVEN LINES, 2 TO 2 TIMES NCW                        *
                                                                    *
  **************************************************                *
  *  FORCE (1) FORCE(2).........FORCE(NPTS) (KSF)  *****************
  **************************************************

  B(3) DEFINITIONS

   DEF(J) = DEFORMATION ON CURVE FOR POINT J (FT).
   FORCE(J) = CORRESPONDING FORCE FOR POINT J (KSF).

C. CURVE LOCATIONS AND MULTIPLIERS **REPEAT NCRL TIMES **************
                                                                    *
  C(1) CONTENTS                                                     *
                                                                    *
  ***********************************                               *
  *  WALLM NREFC DISTC DEFM FORCEM  *********************************
  ***********************************
```

C(2) DEFINITIONS

WALLM - WALL MEMBER NUMBER ; WALLS ARE NUMBERED FROM 11 TO NCHANNELS + 11 FROM LEFT TO RIGHT (INPUT DATA FOR EACH WALL SHOULD BE GROUPED INTO ONE SEQUENCE PER WALL).

NREFC - NUMBER OF REFERENCED CURVE (10.B) A NEGATIVE VALUES CREATES CURVE WITH SAME NUMERICAL VALUES AS CURVE NREFC BUT ALL SIGNS ARE CHANGED AND ORDER OF POINTS ON CURVE IS REVERSED.

DISTC - DISTANCE FROM BOTTOM OF MEMBER TO POINT WHERE CURVE IS APPLIED (INPUT VALUES FOR DISTC SHOULD DECREASE CONSECUTIVELY FOR EACH CURVE. (IE. INPUT FROM TOP TO BOTTOM OF WALL).

DEFM - DEFLECTION MULTIPLIER; NUMBER BY WHICH REFERENCE CURVE DEFLECTIONS ARE MULTIPLIED.

FORCEM - FORCE MULTIPLIER; NUMBER BY WHICH REFERENCE CURVE FORCES ARE MULTIPLIED.

SECTION 11. EMPIRICAL SOIL DESCRIPTION.
&&& INCLUDE ONLY FOR BTYPE - 'EMP'&&&

A. BACKFILL PROPERTIES

A(1) CONTENTS

```
****************************
*  UWSD  UWSS  EKSL  EKSR  *
****************************
```

A(2) DEFINITIONS

UWSD - UNIT WEIGHT OF SOIL, DRAINED (K/CF).

UWSS - UNIT WEIGHT OF SOIL, SATURATED (K/CF).

EKSL - LATERAL SOIL COEFFICIENT (RATIO OF LATERAL PRESSURE TO EFFECTIVE WEIGHT OF SOIL) FOR LEFT EXTERIOR WALL.

&&&& INCLUDE ONLY IF 'MODE' = "INV" &&&&
EKSR - SIM1LAR TO EKSL FOR RIGHT EXTERIOR WALL.

```
B. SOIL AND ROCK ELEVATIONS

  B(1) CONTENTS

  ********************************
  *  ELGSL  ELRSL  ELGSR  ELRSR  *
  ********************************

  B(2) DEFINITIONS

   ELGSL = ELEVATION OF BACKFILL LEFT SIDE (FT).

   ELRSL = ELEVATION OF ROCK SURFACE ON LEFT EXTERIOR
           WALL (FT).

   &&&& INCLUDE NEXT TWO ITEMS ONLY IF 'MODE' = "INV" &&&&
   ELGSR = ELEVATION OF BACKFILL RIGHT SIDE (FT).

   ELRSR = ELEVATION OF ROCK SURFACE ON RIGHT EXTERIOR
           WALL (FT)


SECTION 12.  SPECIAL LOAD CASES.
           &&&&& INCLUDE ONLY IF NSPEC > 0  &&&&&

  ***********REPEAT NSPEC TIMES *************************************
                                                                   *
A. CONTROL                                                         *
                                                                   *
  A(1) CONTENTS.                                                   *
                                                                   *
  *******************************                                  *
  *  NLDMEM  NEMR  SLFS  LOADIDS ***********************************
  *******************************                                  *
                                                                   *
  A(2) DEFINITION                                                  *
                                                                   *
   NLDMEM = NUMBER OF MEMBERS LOADED THIS CASE,(>= 1.)             *
                                                                   *
   NEMR = NUMBER OF REFERENCE EM-LOAD CASE WHOSE LOADS             *
   WILL BE ADDED TO THESE SPECIAL LOADS. IF NEMR = 0,              *
   THE ANALYSIS IS MADE WITH THE SPECIAL LOADS AND                 *
   THE WEIGHT OF THE CHANNEL AS THE ONLY APPLIED LOADS.            *
                                                                   *
   &&&& INCLUDE ONLY IF 'METHOD' = "SD" &&&&                       *
   SLFS = 'SD' LOAD FACTOR FOR ALL LOADS FOR THIS SPECIAL          *
   LOAD CASE, INCLUDING REFERENCED EMLIKE LOADS (>1.).             *
                                                                   *
   LOADIDS = ALPHA NUMERIC IDENTIFICATION OF LOAD                  *
             ( 1 TO 20  CHARACTERS INCLUDING EMBEDDED BLANKS)      *
                                                                   *
```

```
B. MEMBER LOAD LINES   ***** REPEAT NLDMEM TIMES ******************
                                                                  *
  B(1) CONTENTS                                                   *
                                                                  *
  ***********************                                         *
  *  LDMEM NCONC NDIST ********************************************
  ***********************                                         *
                                                                  *
  B(2) DEFINITIONS                                                *
                                                                  *
   LDMEM - MEMBER NUMBER.                                         *
                                                                  *
   SLAB MEMBERS ARE NUMBERED FROM LEFT TO RIGHT.                  *
   (FROM 1 TO NCHANNELS + 2)                                      *
   WALL MEMBERS ARE NUMBERED FROM LEFT TO RIGHT                   *
   (FROM 11 TO NCHANNELS + 11)                                    *
   ALL LOADS BELOW TOP OF SLAB SHOULD BE REFERENCED               *
    TO A SLAB MEMBER.                                             *
   ANY LOAD WITHIN LENGTH OF SLAB MAY BE REFERENCED               *
   TO ANY SLAB MEMBER EXCEPT MISSING HEELS.                       *
   'LEFT' END OF WALLS IS TOP OF SLAB FOR DISTANCES.              *
   X FORCES FOR SLABS AND WALLS ARE HORIZONTAL, POSITIVE TO RIGHT. *
   Y FORCES FOR SLABS AND WALLS ARE VERTICAL, POSITIVE UP.        *
   'C' FORCES (COUPLES) ARE POSITIVE COUNTERCLOCKWISE.            *
   ALL FORCES AND COUPLES ARE APPLIED AT CENTROID OF MEMBER.      *
                                                                  *
   NCONC - NUMBER OF CONCENTRATED LOADS THIS MEMBER (MAX 15).     *
           CONCENTRATED LOADS (KIPS/FT OF WALL) SIMULATE          *
           LINE LOADS PARALLEL TO LONGITUDINAL AXIS.              *
                                                                  *
   NDIST - NUMBER OF DISTRIBUTED LOADS THIS MEMBER (MAX 5).       *
           DISTRIBUTED LOADS (KIPS/FT/FT OF WALL) SIMULATE        *
           PRESSURES ON ONE FOOT STRIP OF WALL.                   *
                                                                  *
C. CONCENTRATED LOADS ***** REPEAT NCONC TIMES ********************
                                                                  *
  C(1)   CONTENTS                                                 *
                                                                  *
  ********************                                            *
  *  DC FXM FYM FCM ***********************************************
  ********************                                            *
                                                                  *
  C(2) DEFINITIONS                                                *
                                                                  *
   DC - DISTANCE FROM LEFT END OF MEMBER TO LOAD (FT).            *
                                                                  *
   FXM, FYM = MAGNITUDES OF X AND Y LOADS (KIPS/FT).              *
                                                                  *
   FCM = MAGNITUDE OF CONCENTRATED COUPLE (KIP-FT/FT).            *
                                                                  *
D. DISTRIBUTED LOADS **** REPEAT NDIST TIMES **********************
                                                                  *
  D(1) CONTENTS                                                   *
```

```
                                                                  *
**********************************                                *
* 'DIRECTION'  D1M Q1M D2M Q2M  **********************************
**********************************
```

D(2) DEFINITIONS

```
 'DIRECTION' - "X" FOR HORIZONTAL LOADS,
             - "Y" FOR VERTICAL LOADS, OR
             - "C" FOR COUPLES
```

D1M - DISTANCE FROM LEFT END OF MEMBER TO START OF LOAD (FT).

```
Q1M - MAGNITUDE OF LOAD AT D1M (KIP/SF) OR
                               (KIP-FT/SF) FOR COUPLE
```

D2M - DISTANCE FROM LEFT END OF MEMBER TO END OF LOAD (FT).

```
Q2M = MAGNITUDE OF LOAD AT D2M (KIP/SF) OR
                                (KIP-FT/SF) FOR COUPLE
```

SECTION 13. BEAM ON ELASTIC FOUNDATION DESCRIPTION.
&&&& INCLUDE ONLY IF 'FTYPE' - "SPR" &&&&

A. FOUNDATION DESCRIPTION

A(1) CONTENTS

```
****************************************************
*  FPF  SCFV  SCFH  FCOHE  DELFF  NANCK  AKP  AKM  *
****************************************************
```

A(2) DEFINITIONS

FPF = AVERAGE CRUSHING STRENGTH OF FOUNDATION MATERIAL (KSF).

SCFV - AVERAGE FOUNDATION "SPRING" MODULUS IN VERTICAL DIRECTION (KCI).

SCFH = AVERAGE FOUNDATION "SPRING" MODULUS IN HORIZONTAL DIRECTION (KCI).

FCOHE - COHESION SURFACE VALUE FOR FOUNDATION SURFACE (KSF).

DELFF - FRICTION ANGLE FOR FOUNDATION SURFACE (DEG).

```
NANCK - NUMBER OF TENSION ONLY ELASTIC ANCHORS(MAX 10)
        FOR 'GEOMOP' = "NON"
*********** OR ************
NANCK = NUMBER OF TENSION ONLY ELASTIC ANCHORS FROM THE
        CENTERLINE TO THE RIGHT EXTERIOR WALL, INCLUDING
        CENTERLINE ANCHOR IF PRESENT (MAX 5)
```

&&&& INCLUDE ANCHOR DATA ONLY IF NANCK > 0 &&&&

AKP = TENSION ONLY ELASTIC SPRING CONSTANT FOR ANCHORS (KSF).
(UNITS ARE KIP/FT FOR ONE FOOT SLICE OF CHANNEL).

AKM = MAXIMUM TENSILE CAPACITY OF ANCHORS FOR ONE FOOT SLICE OF CHANNEL (K/F).

B. DISTANCES TO ELASTIC ANCHORS &&&&
&&&& INCLUDE ONLY IF NANCK > 0 &&&&

B(1) CONTENTS

```
************************************
*  ASP(1)  ASP(2)...... ASP(NANCK)  *
************************************
```

B(2) DEFINITIONS

ASP(I) = DISTANCES TO TENSION ONLY ELASTIC ANCHORS (FT)
FIRST DISTANCE IS MEASURED FROM RIGHT FACE OF LEFT MOST EXTERIOR WALL. SUBSEQUENT DISTANCES ARE MEASURED FROM PRECEDING ANCHOR.
FOR 'GEOMOP' = 'SYM" INPUT ONLY ANCHORS ON LEFT SIDE OF CHANNEL CENTERLINE. EQUIVALENT ANCHORS WILL BE CREATED BY PROGRAM ON RIGHT SIDE OF CENTERLINE

```
** EXCEPT ANCHORS LOCATED WITHIN 0.1 FT OF CENTERLINE **
** WILL NOT BE "DOUBLED" BY PROGRAM                   **
```

SECTION 14. EMPIRICAL FOUNDATION DESCRIPTION.
&&&& INCLUDE ONLY IF 'FTYPE' = "EMP" &&&&

A. FOUNDATION DESCRIPTION

A(1) CONTENTS

```
*****************************************
*  PRAT  XUNIF  XSLOP  FPF  FCOHE  DELFF  *
*****************************************
```

A(2) DEFINITIONS

PRAT = RATIO OF "P/A" PRESSURE IN INNER PORTION OF FOUNDATION TO THAT ON OUTER EDGES.

XUNIF = LENGTH OVER WHICH OUTER PRESSURE EXTENDS ON BOTH ENDS OF FOUNDATION (FT).

XSLOP = SLOPING DISTANCE CONNECTING INNER AND OUTER PRESSURES (FT).

FPF = AVERAGE CRUSHING STRENGTH OF FOUNDATION MATERIAL (KSF).

FCOHE - COHESION VALUE FOR FOUNDATION SURFACE (KSF).

DELFF - FRICTION ANGLE FOR FOUNDATION SURFACE (DEG).

APPENDIX B: CHANNEL EXAMPLE PROBLEMS

1. Several examples with input and selected output have been included in this appendix. If complete printed and graphical output for each example were included, the volume of this text would be excessive. Thus, it was decided to provide complete output for one design example and selected output for the other design and investigation examples. Table B.1 contains a list of the problems with their most important characteristics. Program options were chosen to illustrate program capabilities rather than necessarily the "best" options for any given example.

2. Each of the seven examples has a brief description of the problem followed by the input file. For the first example, the input file (Sheet 5 of Figure B.1) is contained within a complete interactive run in which the input file was created and the example was run. For the remainder of the examples only the final input files are given. However, these later input files were generated using the line number option. Thus, the reader can see to which data section each line belongs from the line number. The fourth and fifth digits from the right are the section number. For instance for design example 2 (Figure B.4), line numbers 09010 and 09020 are for data Section 9.

3. Each input file is followed by the plot of the channel geometry with soil and water elevations. These plots were generated using the plot program described in Appendix A. Complete graphical output is included only for the first example. The other examples have some selected graphical output with the geometry plot file. The graphical outputs are followed by either complete or partial output files. The first five examples use the design mode and the last two are investigation examples.

Example 1

4. Example 1 is the simplest case. It consists of the design of a single channel with level backfill and no groundwater. The wall loading is based on active pressures using the wedge solution, and the pressures under the invert slab are based on the Winkler spring approach. Two EM-like load cases were considered: CASE I - Channel Empty, and CASE II - Channel Full (the active pressure was increased by a factor of 1.8 for Case II).

Table B.1 Channel Example Problems

EXAMPLE NO.	MODE	DESIGN METHOD	NUMBER OF BAYS	WALL DRAINS OPTION	SLAB DRAINS OPTION	NO. EM-LIKE LOAD CASES	BACK-FILL TYPE	NO. SPECIAL LOAD CASES	FOUND-ATION TYPE	NO. OF ANCHORS
1	DES	WSD	1	NO	NO	2	WEDA	0	SPR	0
2	DES	WSD	1	NO	NO	2	WEDA	0	EMP	0
3	DES	SD	1	NO	NO	2	WEDA	0	SPR	0
4	DES	WSD	1	YES	YES	2	WEDA	0	SPR	0
5	DES	WSD	2	NO	NO	2	WEDA	0	SPR	5
6	INV	WSD	2	YES	YES	2	WEDPR	1	SPR	0
7	INV	WSD	1	NO	NO	1	LDM	1	SPR	0

NOTES

DES - Design Mode
WSD - Working Stress Design
WEDA - Active Wedge
LDM - Load-Deformation Method
SPR - Spring Foundation

INV - Investigation Mode
SD - Strength Design
WEDPR - Passive Wedge / Right Wall
EMP - Empirical

5. This example (Figure B.1) illustrates the use of the CURFBC editor to build a simple input data file for the design of a single-bay channel. Responses to editor questions are preceded by a "?" prompt. These responses by the user are also shown in lower case to make them easy to distinguish from the program prompts. After building the input file, the data are displayed and an additional opportunity to edit the file is provided. In this example, the file was found correct and not "edited" a second time. Next the data input was stored as line-numbered data file under the name previously input by the user. It is recommended that it be stored for documentation and in case it needs to be rerun, or it can later be used as the starting point for another design. Design variable iterations are shown and may be used to help the designer understand which elements are critical in the design of the channel.

6. After the design is completed, the user can display the output immediately. If this option is chosen, several levels of displaying output are available. However, in this example the display output option was not chosen. Instead the output file was stored and was then available for later review and printing.

7. The graphical output (Figure B.2) includes a sketch of the channel, showing soil and water elevations and sheets with pressures, internal forces and moments on the members, and required areas of steel. The complete printed output file, shown in Figure B.3, contains complete input echo, final dimensions, safety factors, steel requirements, member pressures, and member forces and stresses.

```
                    CUFRBC
  BASIN AND CHANNEL ANALYSIS & DESIGN PROGRAM
  WRITTEN BY C. O. HAYS, UNIVERSITY OF FLORIDA

  ***************************
  * REVISED    18 JULY  89  *
  ***************************

  DO YOU WANT TO OPERATE IN A SEMI BATCH MODE
  WITH THE PRIMARY TERMINAL INPUT REQUIRED BEING
  THE NAMES OF EXISTING DATA FILES ?
? n
  READ EXISTING INPUT DATA FILE ?
? n
  DO YOU WISH TO USE ON LINE EDITOR TO -
  CREATE A NEW DATA FILE - OR -
  MODIFY EXISTING DATA FILE ?
 "CRE" , "MOD" , OR "NO"
? cre
  DO YOU WISH TO SEE A BRIEF DESCRIPTION ON HOW TO
  USE EDITOR TO CREATE OR MODIFY DATA ?
? n

      I.1  HEADING

  INPUT NLINES OF HEADING (NLINES 1 TO 4)
  INCLUDE NLINES AT START OF FIRST HEADERLINE

? 3 u-wall design example #1 - spring foundation pressures
? h=20  w=30 level backfill
? btype=weda  ftype=spr  atrest=1.8


      I.2 MODE AND PROCEDURE

    MODE  METHOD    TYPE  NUMBER   INPUT  OUTPUT    PLOT
   "DES"   "WSD"   "BAS"    OF      FILE    FILE    FILE
     OR      OR      OR    BAYS   (FILE NAMES START WITH
   "INV"    "SD"   "CHA"             LETTER, < 7 CHARACTERS)

?  des  wsd  cha  1  dsgnai dsgnao dsgnap
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 1 of 8)

```
          DRAIN OPTIONS
       WALL            SLAB
      WDRNOP          SDRNOP
   "YES" OR "NO"  "YES" OR "NO"
 ?      no no

       I.3A  WORKING STRESS DESIGN DATA
               CONCRETE        /  STEEL
   STRENGTH  WEIGHT   ALLOWABLE STRESS
        FPC  WTCONC       FCA      FSA
      (KSI)   (KCF)      (KSI)    (KSI)
 ?     3.0  .15 1.35  20 20

       I.3A  WORKING STRESS DESIGN DATA
               CONCRETE        /  STEEL
   STRENGTH  WEIGHT   ALLOWABLE STRESS
        FPC  WTCONC       FCA      FSA
      (KSI)   (KCF)      (KSI)    (KSI)
 ?      3  .15 1.35 20

   WILL SLAB HAVE HEEL ?
 ?  yes


     I.4  GEOMETRY *** UNITS ARE FEET OR INCHES ***

  LEFT EXTERIOR WALL

              ELEVATION         /     WIDTH
       TOP   BOTTOM     SLAB      TOP   BOTTOM
    ELTOPL   ELBRKL   ELSLAB   WALLTL   WALLBL
      (FT)     (FT)     (FT)     (IN)     (IN)
 ?     20       20        0       20       17

  SLAB AND HEEL DIMENSIONS

            DEPTH      /         WIDTHS(LEFT)
             SLAB         HEEL     HEEL  CHANNEL
      LEFT   CENTER                MAX.
    DEPTHL   DEPTHC   WHEELL  WHEELLM   WIDTHL
      (IN)     (IN)     (FT)     (FT)     (FT)
 ?    18        12       .5       .5       30
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 2 of 8)

```
     I.5 REINFORCEMENT FOR DESIGN OPTION


  NUMBER OF LAYERS
   WALL     SLAB
 NOLAYW  NOLAYSB

?  1        1


 CLEAR COVER (IN)

 COVER(1) COVER(2) COVER(3) COVER(4)

?    2.5    3        3        2.5


 MAXIMUM AREAS PER LAYER AND DIAMETERS

  WALL BELOW BREAK          SLAB
     AREA     DIAM.     AREA    DIAM.
   AWBMAX   DWBMAX   ASBMAX   DSBMAX
  (SI/FT)     (IN)  (SI/FT)     (IN)
?    3        1.25      3      1.25

      I.7 LOAD CONTROL DATA
  NUMBER OF EM-LIKE LOAD CASES
?
  BACKFILL TYPE (WEDA/WEDPL/WEDPR/LDM/EMP/)
? weda
  FOUNDATION TYPE (SPR/EMP)
? spr
  MINIMUM UPLIFT FACTOR OF SAFETY
? 1.1
  MINIMUM BEARING FACTOR OF SAFETY
? 1.1
      I.8  HYDRAULIC STRESS AND STRENGTH DATA
  REPEAT FOR EACH EM-LIKE LOAD CASE

  EM-LIKE LOAD CASE 1
   INPUT ALLOWABLE STRESS MULTIPLIER AND LOAD ID
   ASMUL    'LOADIDH'
?  1       channel empty

 SYMMETRICAL WATER ELEVATIONS (FT)

    BACKFILL     CHANNEL
        LEFT        LEFT
      ELBWSL      ELCWSL
?     -5            0
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 3 of 8)

```
   BACKFILL
    ATRESTS
?      1

  EM-LIKE LOAD CASE 2
   INPUT ALLOWABLE STRESS MULTIPLIER AND LOAD ID
   ASMUL    'LOADIDH'
?   1       channel full

 SYMMETRICAL WATER ELEVATIONS (FT)

    BACKFILL     CHANNEL
        LEFT        LEFT
      ELBWSL      ELCWSL
?       -5         20
   BACKFILL
    ATRESTS
?      1.8


      I.9 SOILS DATA FOR WEDGE METHOD



 BACKFILL SOIL PROPERTIES

      UNIT WEIGHTS        PHI    COHESION  WALL FRICTION
  DRAINED       SAT.     ANGLE                  ANGLE
      UWSD      UWSS      SPHI       SCOHE      DELFW
     (KCF)     (KCF)     (DEG)       (KSF)      (DEG)
?     .13       .14       30          0           15

 BACKFILL DATA LEFT SIDE (SYMMETRICAL)
                 DISTANCES               /
    BACKFILL            SURCHARGE                    BACKFILL        ROCK
 SLOPE    HORZ.     START   LENGTH    WEIGHT    ELEV.    ANGLE      ELEV.
  SOJL     SOKL      SOLL     SOML    UWSURL    ELGSL    ANBSL      ELRSL
  (FT)     (FT)      (FT)     (FT)     (KSF)     (FT)    (DEG)       (FT)
   0        0         0        0        0         20       0          -5


       I.13 ELASTIC SPRING FOUNDATION PROPERTIES

                   SOIL                          / ANCHORS
 STRENGTH     SPRING MODULI  COHESION FRICTION    NUMBER
              VERT.    HORZ.
      FPF      SCFV     SCFH     FCOHE    DELFF    NANCK
    (KSF)     (KCI)    (KCI)     (KSF)    (DEG)
?      8        .5       .25       0        25        0
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 4 of 8)

```
 DISPLAY INPUT DATA FILE ?
? y .

3 DESIGN EXAMPLE 1
H=20 W=30 LEVEL BACKFILL
BTYPE=WEDA FTYPE=SPR ATREST=1.8
  DES  WSD  CHA       1     DSNGAI  DSNGAO  DSNGAP
  NO   NO
     3.000      .150     1.350   20.000
    20.000   20.000     0.000   10.000   17.000
    18.000   12.000      .500      .500   30.000
  1  1
     2.500    3.000     3.000    3.500
     3.000    1.250     3.000    1.250
  2  WEDA   SPR      1.10      1.10
    1.000  CHANNEL EMPTY
    -5.000    0.000
     1.000
    1.000  CHANNEL FULL
    -5.000   20.000
     1.800
     .130      .140   30.000    0.000   15.000
     0.00      0.00      0.00      0.00    0.000  20.000  0.000  -5.000
      8.000       .500       .250     0.000    25.000    0



  DO YOU WISH TO USE ON LINE EDITOR TO -
  CREATE A NEW DATA FILE - OR -
  MODIFY EXISTING DATA FILE ?
 "CRE" , "MOD" , OR "NO"
? no

 STORE INPUT DATA FILE ?
? yes

  INPUT DATA WILL BE STORED ON FILENAME DSNGAI
  DO YOU WISH INPUT DATA FILE TO BE LINE NUMBERED ?
? y

  CONTINUE DESIGN ?
? y
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 5 of 8)

```
 DO YOU WISH TO SEE DESIGN VARIABLE ITERATIONS ?
? y
FACTORS OF SAFETY
EM-LIKE LOAD CASE  1      UPLIFT FOS =9999.99       BEAR FOS =   0.00
                          HORIZONTAL EQUILIBRIUM FACTOR = 9999.99
EM-LIKE LOAD CASE  2      UPLIFT FOS =9999.99       BEAR FOS =   0.00
                          HORIZONTAL EQUILIBRIUM FACTOR = 9999.99

 ***************************************************
 START OF DESIGN PROCEDURE *************************
 ***************************************************


WALL/ITERATION/BOTTOM THICKNESS(IN)

                        STRESS AND OTHER RATIOS AT BASE
                LOADCASE   FC/FCA   FS/FSA   VC/VCA     P/PO   DBAL/D
11/1/17.
                       1   1.124      .855     .704     .041    1.143
 WALL 11 IS OVERSTRESSED AT BASE
11/2/34.
                       1    .303      .331     .297     .028     .492
                       2    .070      .034     .059     .028     .111
11/3/25.5
                       1    .510      .493     .423     .033     .697
                       2    .118      .070     .084     .033     .259
11/4/21.25
                       1    .720      .631     .531     .036     .868
                       2    .165      .101     .105     .036     .354
11/5/19.125
                       1    .886      .728     .606     .039     .987
                       2    .202      .122     .120     .039     .417
11/6/17.
                       1   1.124      .855     .704     .041    1.143
11/7/18.
                       1   1.000      .791     .654     .040    1.064
11/8/19.
                       1    .897      .735     .611     .039     .995
                       2    .204      .124     .121     .039     .421
 REANALYZE FOR REVISED WALL PRESSURES DUE TO CHANGED WALL GEOMETRY
 -----------------------------------------------------------------
FACTORS OF SAFETY
EM-LIKE LOAD CASE  1      UPLIFT FOS =9999.99       BEAR FOS =   0.00
                          HORIZONTAL EQUILIBRIUM FACTOR = 9999.99
EM-LIKE LOAD CASE  2      UPLIFT FOS =9999.99       BEAR FOS =   0.00
                          HORIZONTAL EQUILIBRIUM FACTOR = 9999.99
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 6 of 8)

```
WALL/ITERATION/BOTTOM THICKNESS(IN)

                        STRESS AND OTHER RATIOS AT BASE
                LOADCASE   FC/FCA   FS/FSA   VC/VCA     P/PO   DBAL/D
11/1/19.
                        1     .907     .742     .616     .039    1.001
                        1     .995     .980     .616     .039    1.001
                        1    1.001     .999     .616     .039    1.001
 REANALYZE FOR REVISED WALL PRESSURES DUE TO CHANGED WALL GEOMETRY
 ----------------------------------------------------------------
FACTORS OF SAFETY
EM-LIKE LOAD CASE  1      UPLIFT FOS =9999.99      BEAR FOS =   0.00
                          HORIZONTAL EQUILIBRIUM FACTOR = 9999.99
EM-LIKE LOAD CASE  2      UPLIFT FOS =9999.99      BEAR FOS =   0.00
                          HORIZONTAL EQUILIBRIUM FACTOR = 9999.99

WALL/ITERATION/BOTTOM THICKNESS(IN)

                        STRESS AND OTHER RATIOS AT BASE
                LOADCASE   FC/FCA   FS/FSA   VC/VCA     P/PO   DBAL/D
11/1/20.
                        1     .824     .696     .580     .038     .943
                        2     .206     .130     .126     .038     .420
 WALLS SUCCESSFULLY SIZED

 START OF DESIGN FOR UPLIFT

 INPUT SLAB DIMENSIONS INCREASED DURING WALL DESIGN

 SLAB DEPTHS (IN)    HEEL          LOAD   UPLIFT
 LEFT   RIGHT     LENGTH  (FT)     CASE      FOS
 20.00    12.00         .50
                                      1  9999.99
                                      2  9999.99
 DESIGN FOR UPLIFT SUCCESSFULLY COMPLETED

LOAD CASE   BEARING
              FOS
        1      6.05
        2      3.73
 START OF BASE SLAB DESIGN

SLAB DEPTHS(IN)
LEFT/CENTER
                        STRESS AND OTHER RATIOS ALONG MEMBERS
                 LOAD
                 CASE MEMBER POINT FC/FCA FS/FSA VC/VCA    P/PO DBAL/D
20. 12.
                    1     2     1   .944   .706   .731   .061  1.047
                    1     2     1  1.047   .975   .731   .061  1.047
 BASE SLAB OVERSTRESSED
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 7 of 8)

```
LOAD CASE  BEARING
             FOS
        1     6.09
        2     3.71

SLAB DEPTHS(IN)
LEFT/CENTER
                       STRESS AND OTHER RATIOS ALONG MEMBERS
                 LOAD
                 CASE MEMBER POINT FC/FCA FS/FSA VC/VCA   P/PO DBAL/D
21. 12.
                    1      2     1   .862   .664   .693   .059   .989
                    1      2     2   .508   .324   .672   .064   .752
                    1      2     3   .182   .054   .431   .069   .312
                    1      2     4   .032  -.023   .164   .073  0.000
                    1      2     5   .066  -.007   .025   .079  0.000
                    1      2     6   .092  -.001   .000   .089  0.000
                    2      2     1   .158   .096   .298   .028   .363
                    2      2     2   .023  -.003   .157   .029  0.000
                    2      2     3   .021  -.004   .041   .030  0.000
                    2      2     4   .025  -.003   .016   .032  0.000
                    2      2     5   .021  -.007   .024   .035  0.000
                    2      2     6   .024  -.008   .000   .039  0.000
 BASE SLAB SUCCESSFULLY SIZED
 START STEEL SELECTION

 ***************************************************
 DESIGN COMPLETED
 ***************************************************

 DISPLAY OUTPUT ?
? n
 STORE OUTPUT FILE ?
? y
 OUTPUT WILL BE STORED ON FILENAME DSGNAO
 STORE INFORMATION FOR LATER PLOTS ?
? y
 FILENAME FOR FUTURE PLOT IS DSGNAP
 CONTINUE PROGRAM ?
? n
$REVERT.CCL
```

Figure B.1 Interactive Run For Design Example 1 (Sheet 8 of 8)

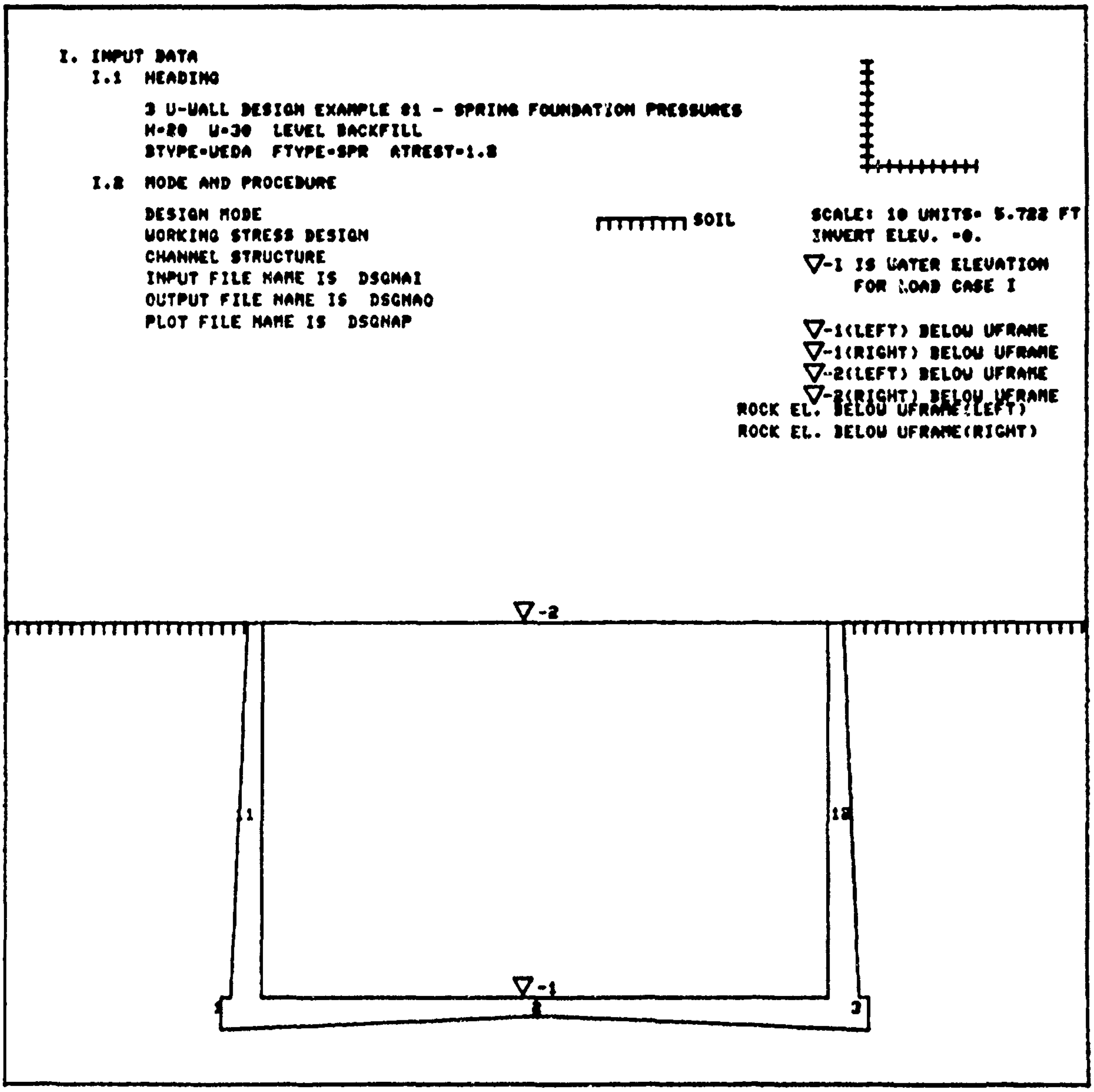


Figure B.2 Complete Graphical Output For Example 1 (Sheet 1 of 13)

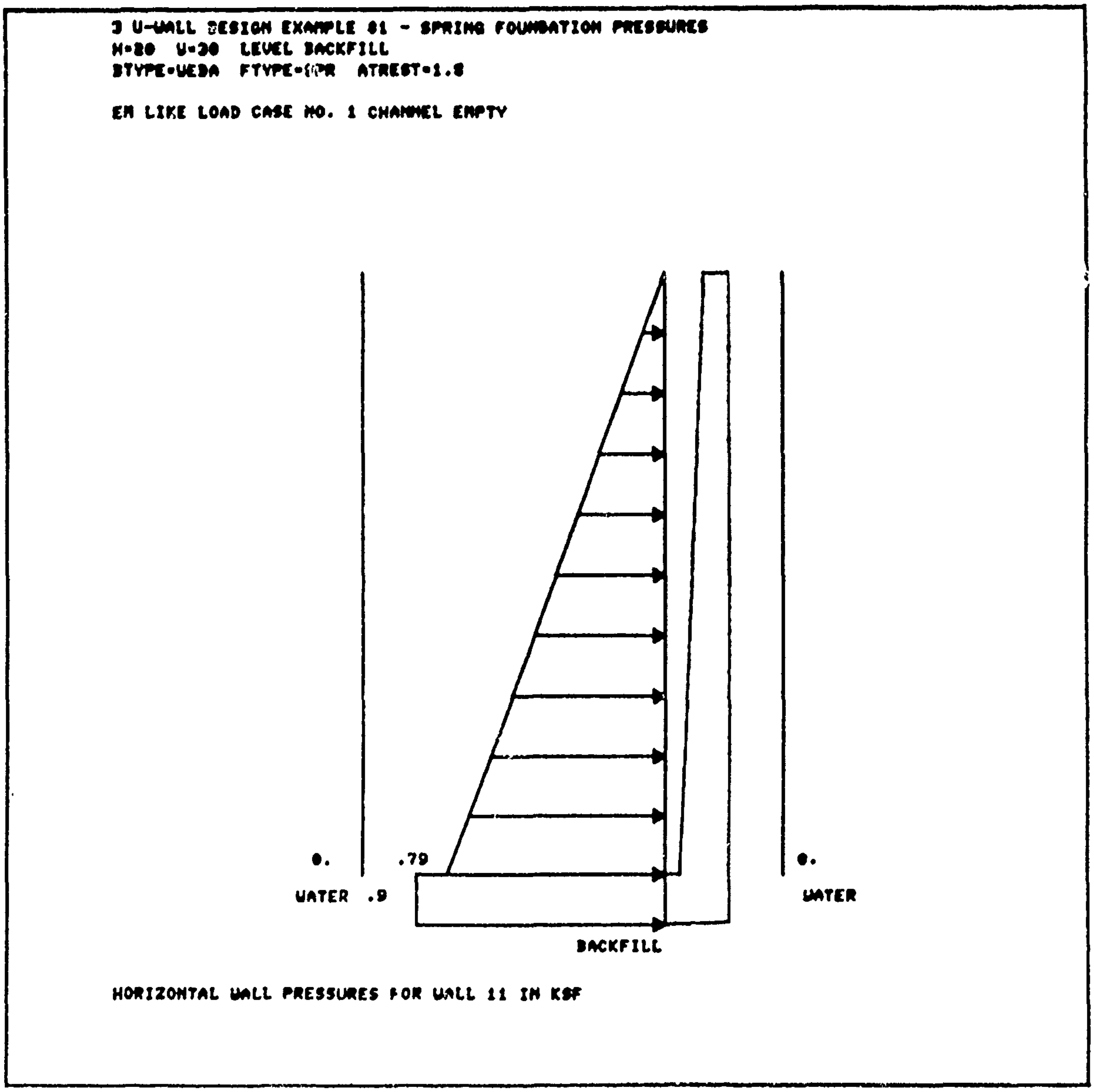


Figure B.2 Complete Graphical Output For Example 1 (Sheet 2 of 13)

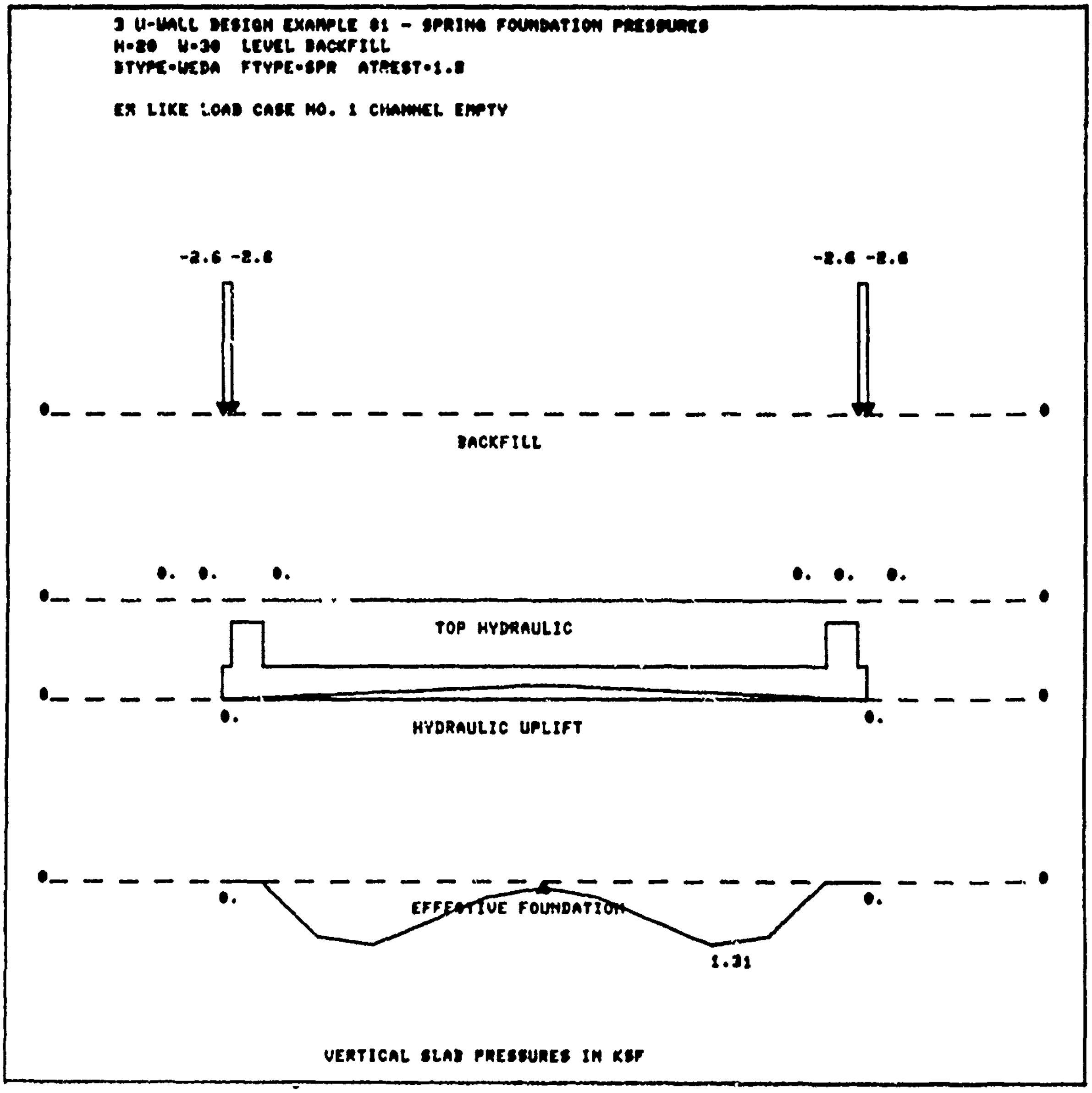


Figure B.2 Complete Graphical Output For Example 1 (Sheet 3 of 13)

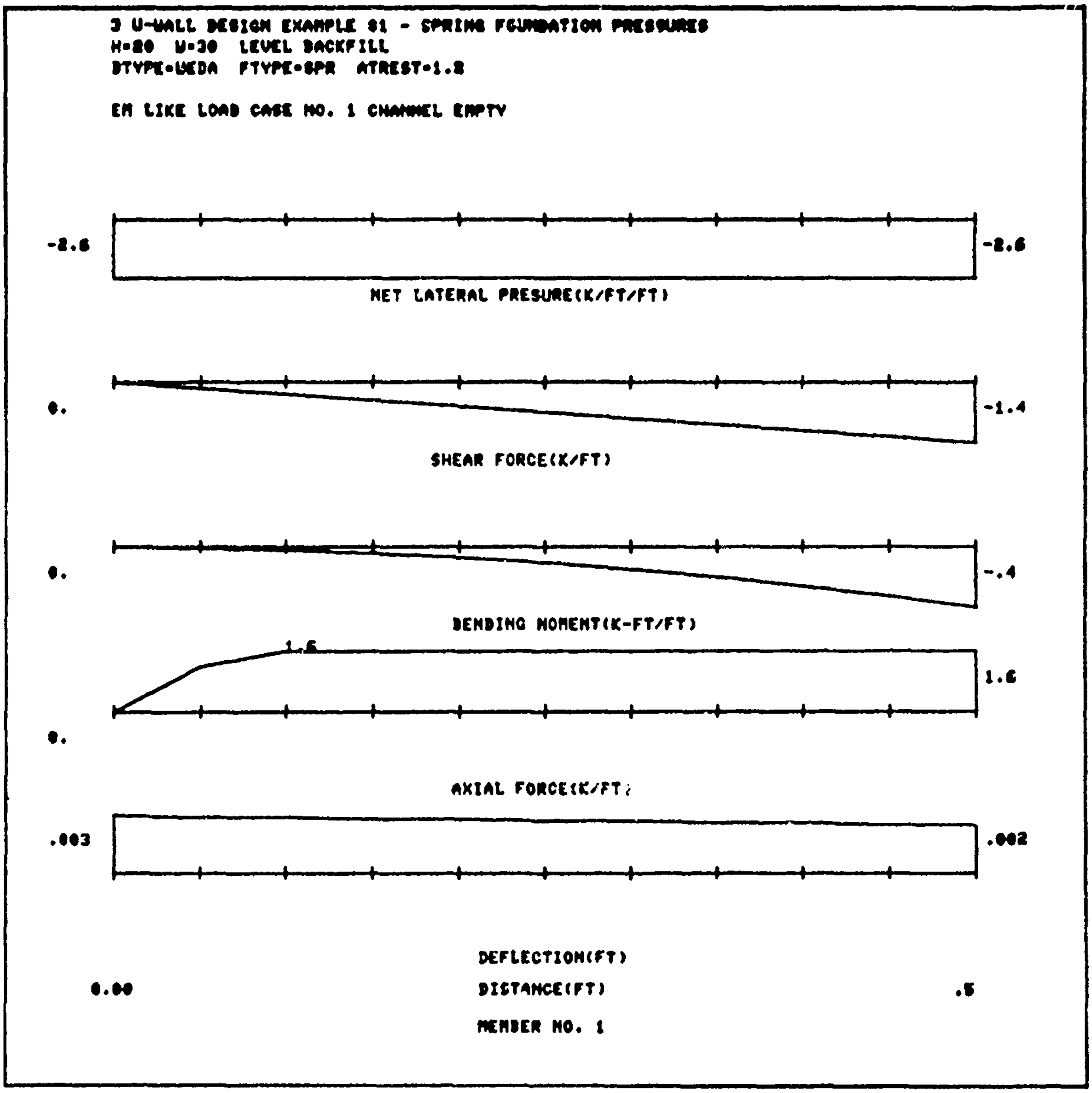


Figure B.2 Complete Graphical Output For Example 1 (Sheet 4 of 13)

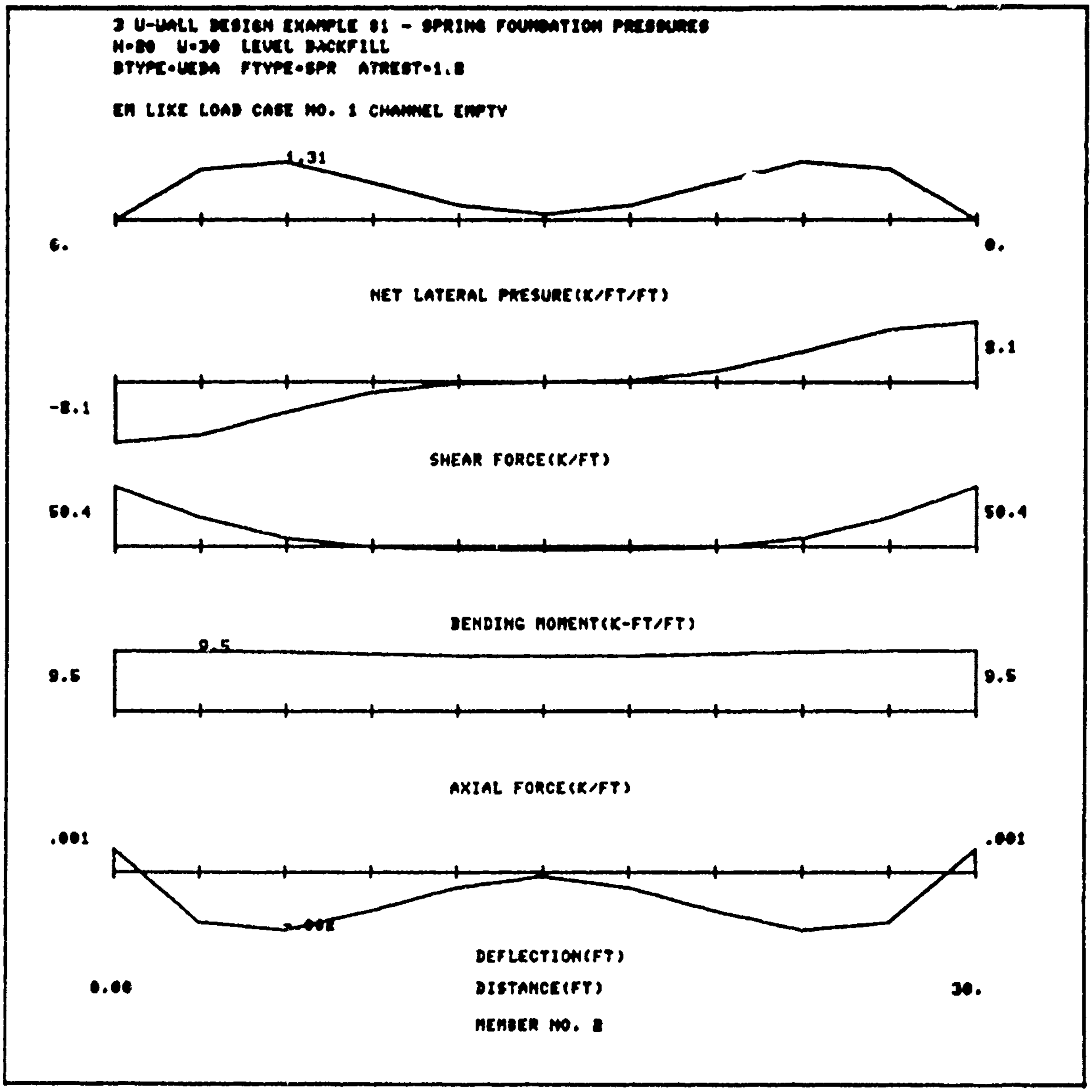


Figure B.2 Complete Graphical Output For Example 1 (Sheet 5 of 13)

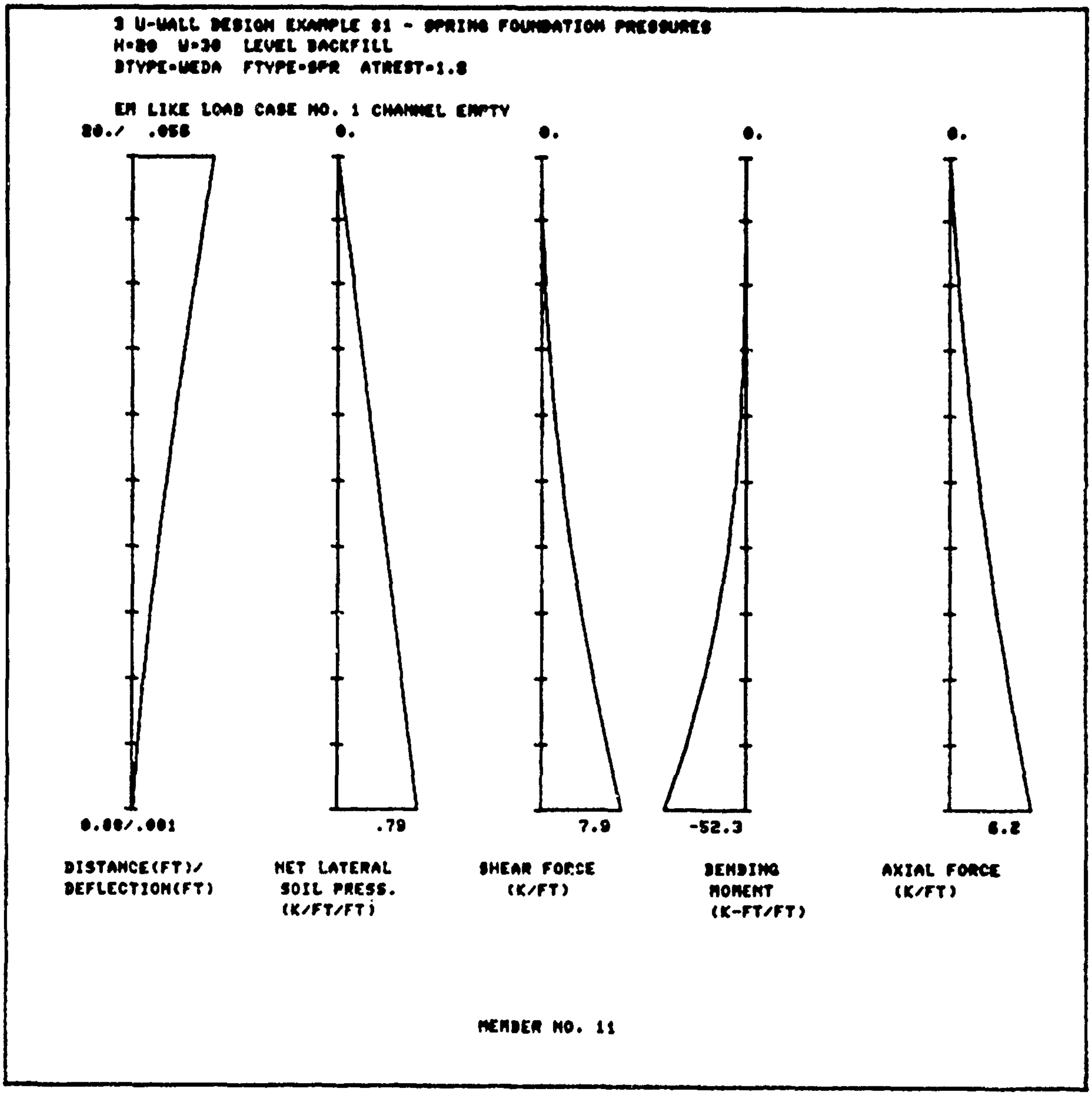


Figure B.2 Complete Graphical Output For Example 1 (Sheet 6 of 13)

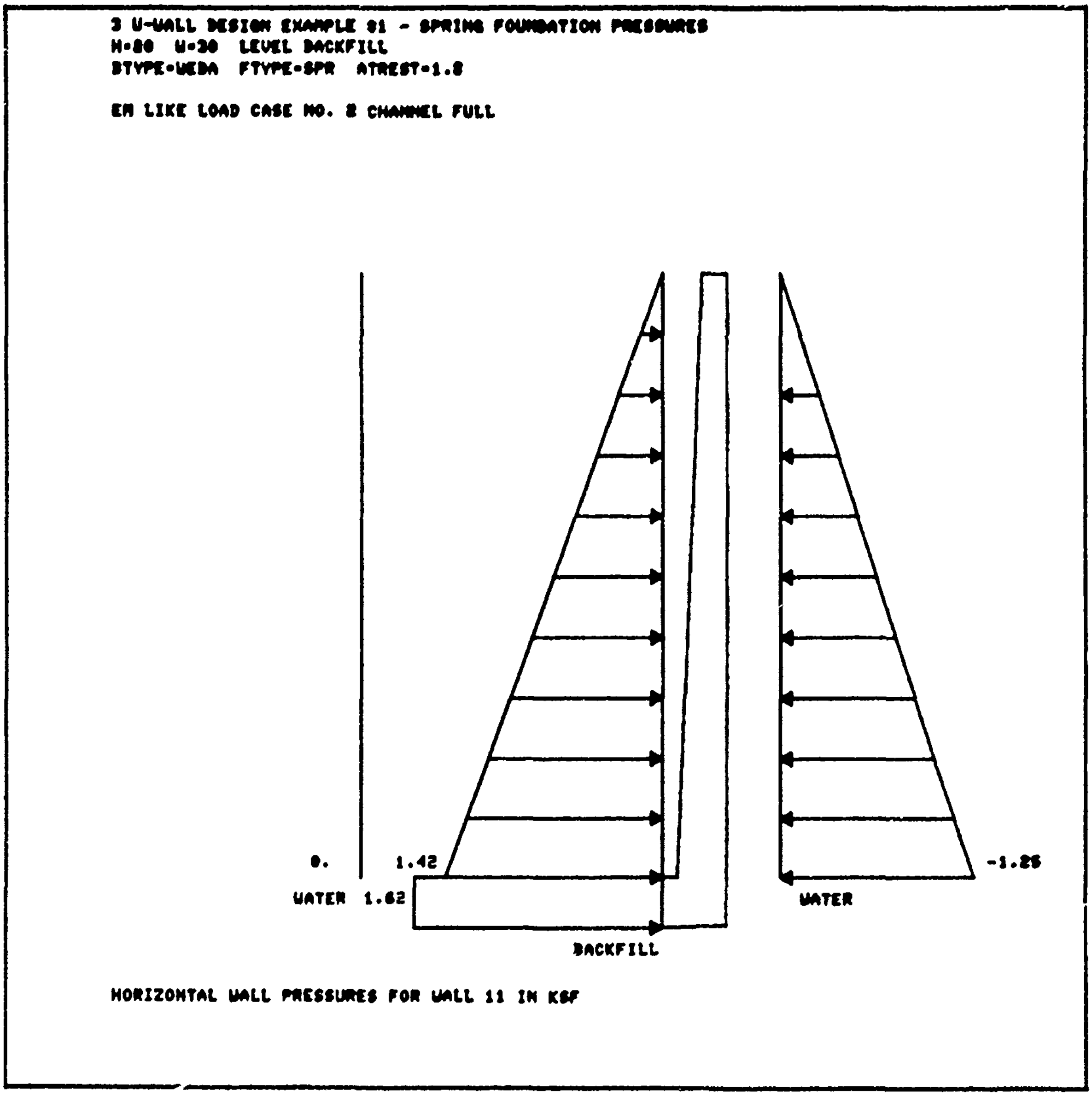


Figure B.2 Complete Graphical Output For Example 1 (Sheet 7 of 13)

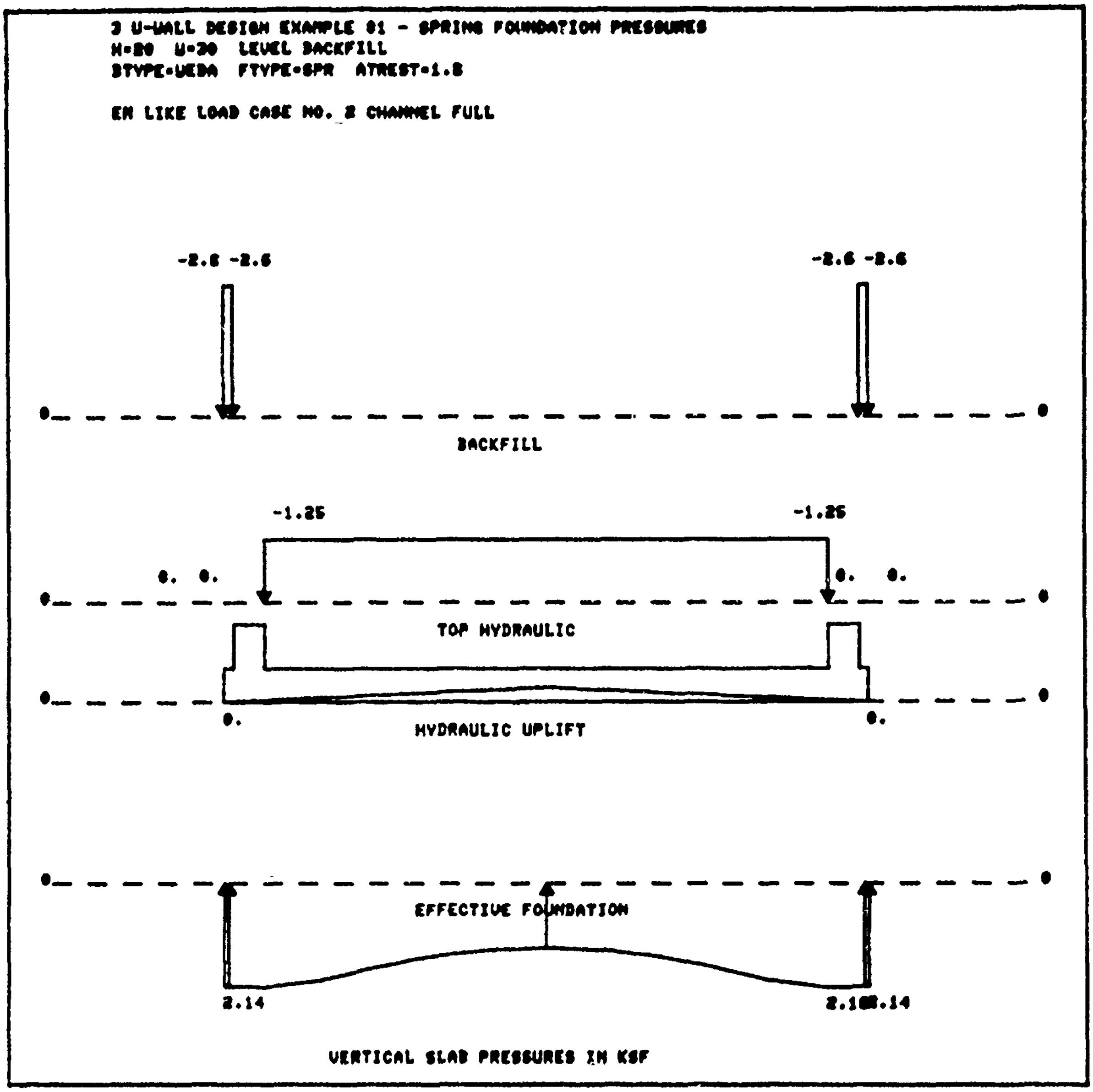


Figure B.2 Complete Graphical Output For Example 1 (Sheet 8 of 13)

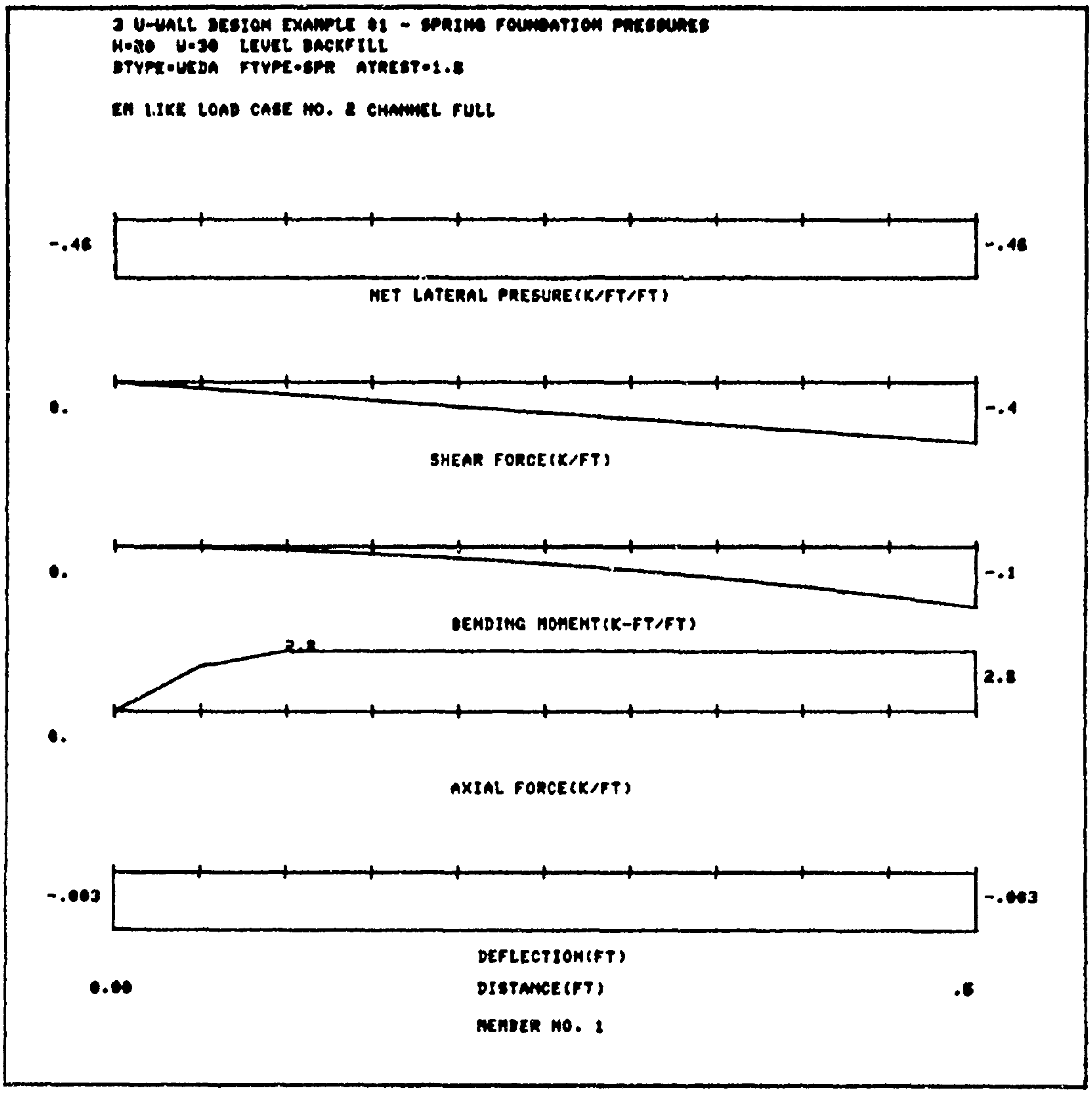


Figure B.2 Complete Graphical Output For Example 1 (Sheet 9 of 13)

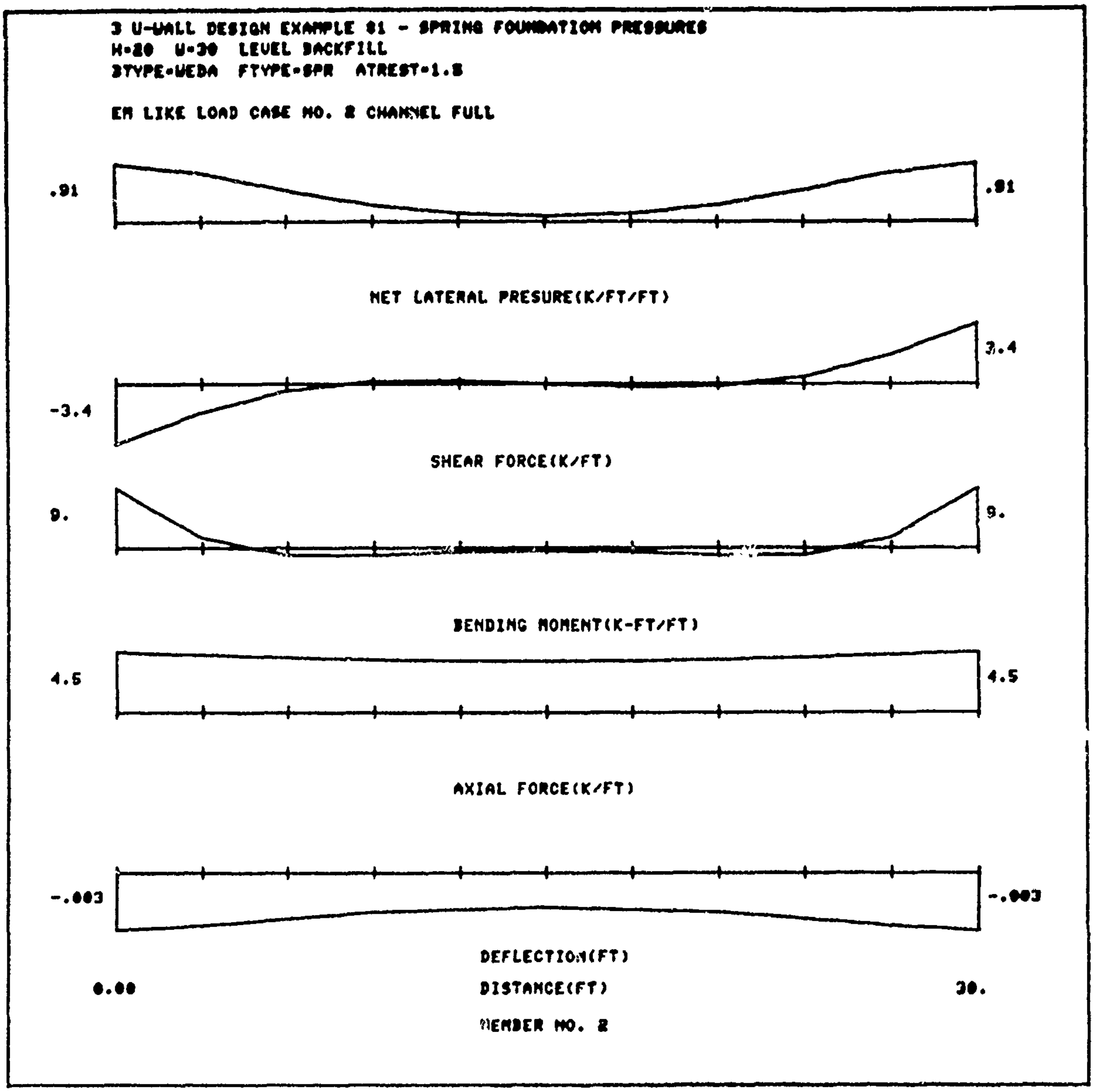


Figure B.2 Complete Graphical Output For Example 1 (Sheet 10 of 13)

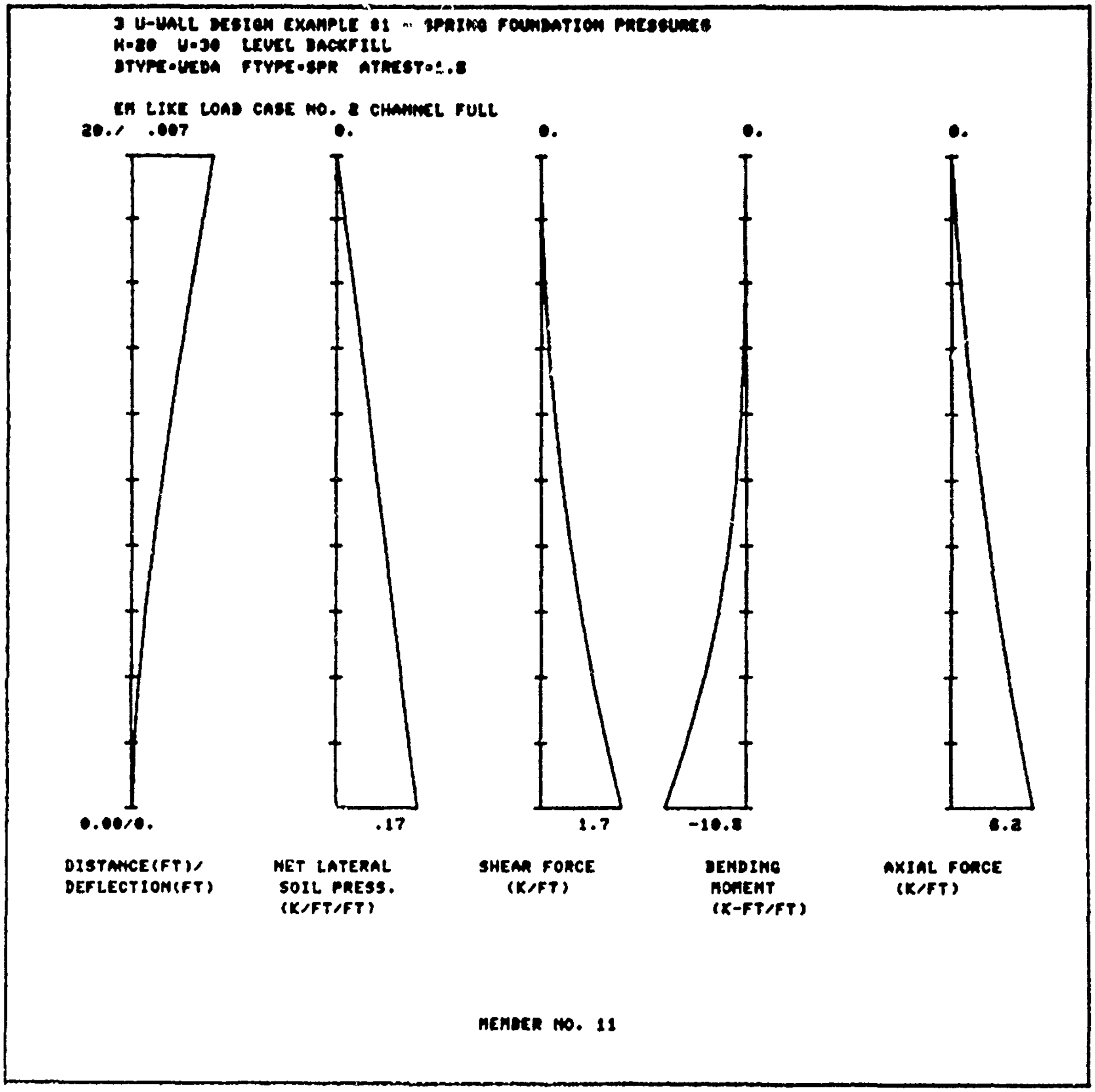


Figure B.2 Complete Graphical Output For Example 1 (Sheet 11 of 13)

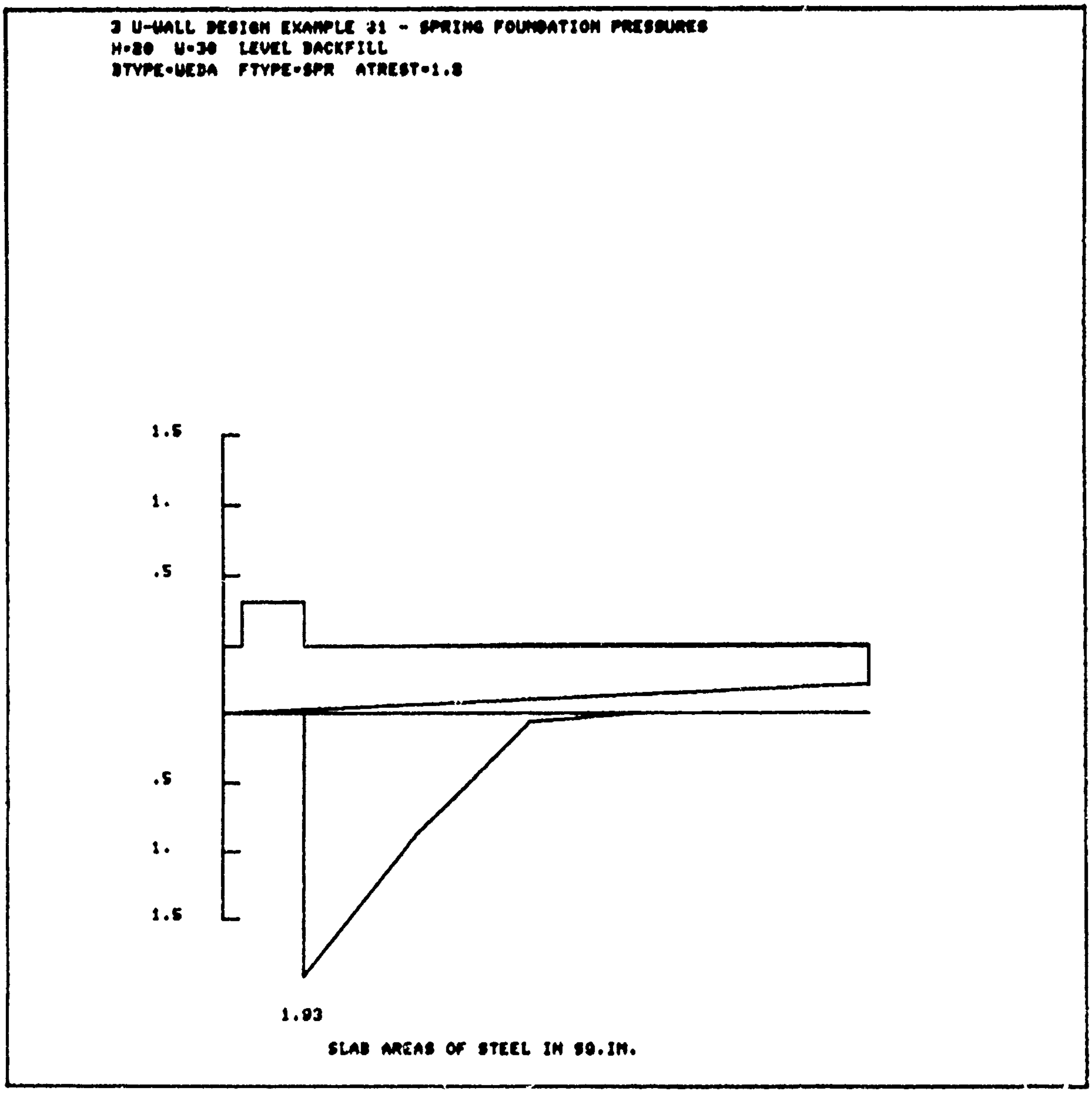


Figure B.2 Complete Graphical Output For Example 1 (Sheet 12 of 13)

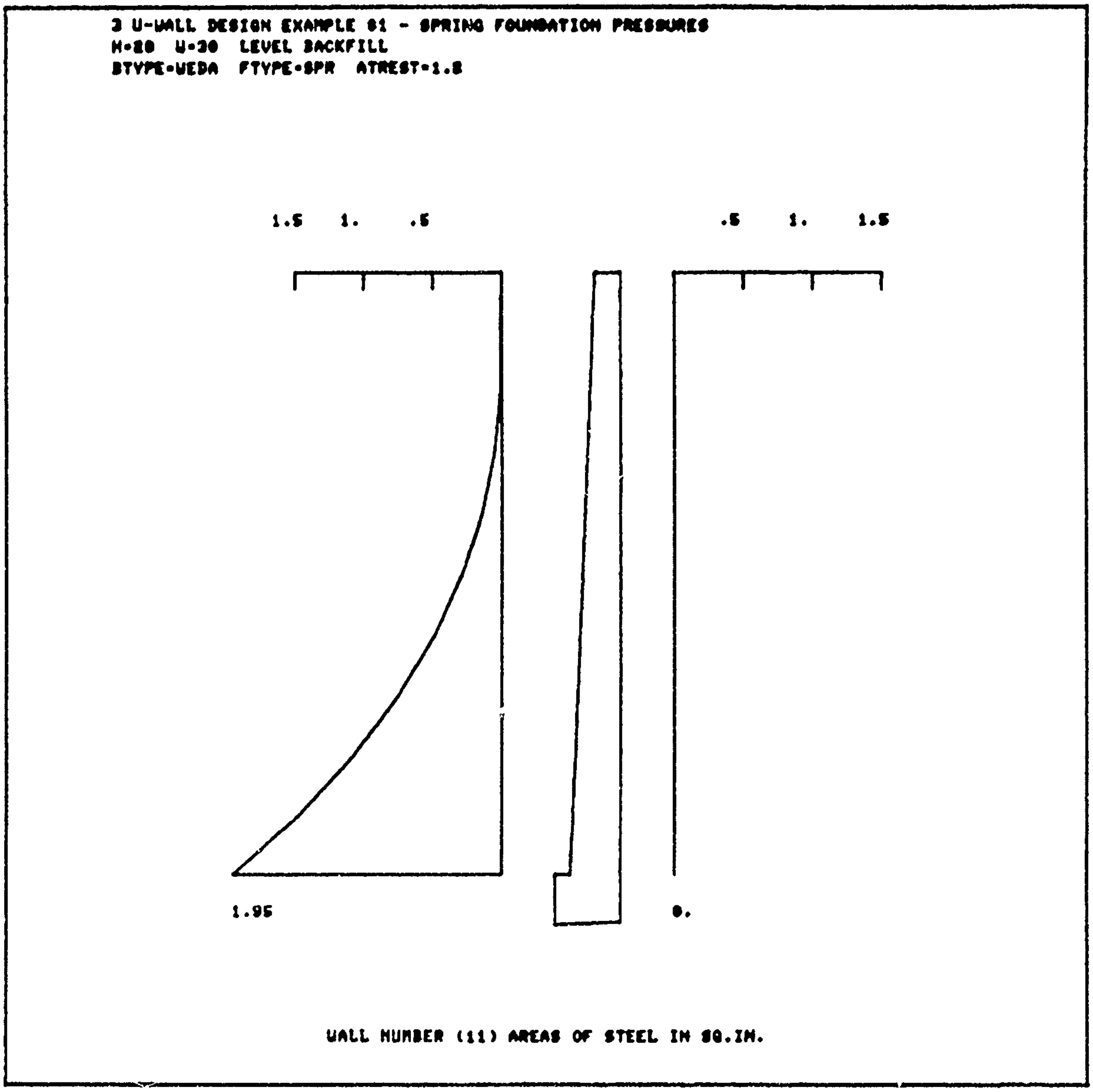


Figure B.2 Complete Graphical Output For Example 1 (Sheet 13 of 13)

```
 ************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF   *
*            BASINS AND CHANNELS                  *
*               BY C. O. HAYS                     *
*           REVISED   18 JULY  1989               *
************************************************


    I.    INPUT DATA *** AND FINAL DESIGN VALUES ***
                     *** FOR DESIGN VARIABLES    ***

    I.1  HEADING

    3 U-WALL DESIGN EXAMPLE #1 - SPRING FOUNDATION PRESSURES
    H=20  W=30  LEVEL BACKFILL
    BTYPE=WEDA  FTYPE=SPR  ATREST=1.8


    I.2   MODE AND PROCEDURE

          DESIGN MODE
          WORKING STRESS DESIGN
          1 CHANNEL STRUCTURE
          INPUT FILE NAME IS "DSGNAI"
          OUTPUT FILE NAME IS "DSGNAO"
          PLOT STORAGE FILE NAME IS "DSGNAP"

          WALL DRAIN DATA OMITTED
          BASE SLAB DRAIN DATA OMITTED


    I.3 MATERIAL PROPERTIES

       CONCRETE:
         ULTIMATE STRENGTH         = 3.000   KSI
         MODULUS OF ELASTICITY     = 3123.   KSI
         UNIT WEIGHT               =  .150   KCF
         ALLOWABLE STRESS          =  1.35   KSI


       REINFORCEMENT:
         ALLOWABLE STRESS          =   20.0   KSI
         MODULUS OF ELASTICITY     = 29000.   KSI
         MODULAR RATIO             =   9.28
```

Figure B.3 Complete Output File For Example 1 (Sheet 1 of 13)

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION			/ WIDTH		
TOP	BOTTOM	SLAB	TOP	BOTTOM	
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL	
(FT)	(FT)	(FT)	(IN)	(IN)	
20.00	20.00	0.00	10.00	17.00	
			10.00	20.00	(FINAL DESIGN VALUES)

SLAB AND HEEL DIMENSIONS

DEPTH	/	WIDTHS(LEFT)		
SLAB		HEEL	HEEL	CHANNEL
LEFT	CENTER		MAX.	
DEPTHL	DEPTHC	WHEELL	WHEELLM	WIDTHL
(IN)	(IN)	(FT)	(FT)	(FT)
18.00	12.00	.50	.50	30.00
21.00	12.00	.50	(FINAL DESIGN VALUES)	

I.5 REINFORCEMENT FOR DESIGN OPTION

NUMBER OF LAYERS	
WALL	SLAB
NOLAYW	NOLAYSB
1	1

CLEAR COVER (IN)

COVER(1)	COVER(2)	COVER(3)	COVER(4)
2.50	3.00	3.00	3.50

MAXIMUM AREAS PER LAYER AND DIAMETERS

WALL BELOW BREAK		SLAB	
AREA	DIAM.	AREA	DIAM.
AWBMAX	DWBMAX	ASBMAX	DSBMAX
(SI/FT)	(IN)	(SI/FT)	(IN)
3.00	1.25	3.00	1.25

Figure B.3 Complete Output File For Example 1 (Sheet 2 of 13)

I.7 LOADING CONTROL

```
2 EM-LIKE LOAD CASES
USING ACTIVE WEDGE METHOD FOR SOIL PRESSURES
ELASTIC SPRING FOUNDATION
MINIMUM UPLIFT FACTOR OF SAFETY  = 1.10
MINIMUM BEARING FACTOR OF SAFETY = 1.10
```

I.8 HYDRAULIC STRESS AND STRENGTH DATA

```
******** EM-LIKE LOAD CASE  1   ********CHANNEL EMPTY        ********
         ALLOWABLE STRESS MULTIPLIER =  1.00
**********************************************************************

SYMMETRICAL WATER ELEVATIONS (FT)

   BACKFILL     CHANNEL
       LEFT        LEFT
     ELBWSL      ELCWSL
      -5.00        0.00

AT REST MULTIPLIERS

  BACKFILL
   ATRESTS
      1.00


******** EM-LIKE LOAD CASE  2   ********CHANNEL FULL         ********
         ALLOWABLE STRESS MULTIPLIER =  1.00
**********************************************************************

SYMMETRICAL WATER ELEVATIONS (FT)

   BACKFILL     CHANNEL
       LEFT        LEFT
     ELBWSL      ELCWSL
      -5.00       20.00
```

Figure B.3 Complete Output File For Example 1 (Sheet 3 of 13)

AT REST MULTIPLIERS

BACKFILL
ATRESTS
1.80

I.9 SOILS DATA FOR WEDGE METHOD

BACKFILL SOIL PROPERTIES

UNIT WEIGHTS		PHI	COHESION	WALL FRICTION
DRAINED	SAT.	ANGLE		ANGLE
UWSD	UWSS	SPHI	SCOHE	DELFW
(KCF)	(KCF)	(DEG)	(KSF)	(DEG)
.130	.140	30.000	0.000	15.000

BACKFILL DATA LEFT SIDE (SYMMETRICAL)

DISTANCES				/			
BACKFILL		SURCHARGE			BACKFILL		ROCK
SLOPE	HORZ.	START	LENGTH	WEIGHT	ELEV.	ANGLE	ELEV.
SOJL	SOKL	SOLL	SOML	UWSURL	ELGSL	ANBSL	ELRSL
(FT)	(FT)	(FT)	(FT)	(KSF)	(FT)	(DEG)	(FT)
0.00	0.00	0.00	0.00	0.00	20.00	0.00	-5.00

I.13 ELASTIC SPRING FOUNDATION PROPERTIES

	SOIL			/	ANCHORS
STRENGTH	SPRING MODULI		COHESION	FRICTION	NUMBER
	VERT.	HORZ.			
FPF	SCFV	SCFH	FCOHE	DELFF	NANCK
(KSF)	(KCI)	(KCI)	(KSF)	(DEG)	
8.00	.500	.250	0.00	25.00	0

Figure B.3 Complete Output File For Example 1 (Sheet 4 of 13)

O. OUTPUT RESULTS

O.1 FACTORS OF SAFETY

FACTOR OF SAFETY AGAINST UPLIFT	FACTOR OF SAFETY AGAINST BEARING	HORIZONTAL EQUILIBRIUM FACTOR	EM-LIKE LOAD CASE	SPECIAL LOAD CASE
9999.99	6.09	9999.99	1	
9999.99	3.71	9999.99	2	

O.2 SUMMARY OF STEEL REQUIREMENTS BY MEMBER

************* MEMBER 2 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00						
3.00						
6.00	1.250	.01			.0001	13.09
9.00	1.250	.01			.0001	11.52
12.00	1.250	.01			.0001	9.95
15.00	1.250	.01			.0001	8.38

********** BOTTOM STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00	1.250	1.93			.0102	15.74
3.00	1.250	.87			.0051	14.17
6.00	1.250	.06			.0004	12.59
9.00						
12.00						
15.00						

Figure B.3 Complete Output File For Example 1 (Sheet 5 of 13)

```
              ************* MEMBER 11 *************

              ********** TOP STEEL **********
DISTANCE   BAR        AREAS (SI/FT)     STEEL RATIO  DEPTH(D)
    (FT)  DIAM.            BY LAYER         AS/12*D      (IN)
          (IN)      1      2      3
  20.00
  18.00  1.250    .01                         .0001      7.88
  16.00  1.250    .01                         .0001      8.88
  14.00  1.250    .06                         .0005      9.88
  12.00  1.250    .15                         .0011     10.88
  10.00  1.250    .29                         .0020     11.88
   8.00  1.250    .49                         .0032     12.88
   6.00  1.250    .75                         .0045     13.88
   4.00  1.250   1.08                         .0060     14.88
   2.00  1.250   1.48                         .0077     15.88
   0.00  1.250   1.95                         .0096     16.88

              ********** BOTTOM STEEL **********
                         NONE REQUIRED FOR STRENGTH



       0.3 OUTPUT OF MEMBER PRESSURES *** BY LOAD CASE ***



******** EM-LIKE LOAD CASE  1    ********CHANNEL EMPTY       ********
*********************************************************************


              ************* MEMBER  1 *************

                         VERTICAL PRESSURES (KSF)
      DISTANCE          HYDRAULIC    BACKFILL  EFFECTIVE
          (FT)        TOP     BOTTOM           FOUNDATION
          0.00       0.00       0.00     -2.60       0.00
           .25       0.00       0.00     -2.60       0.00
           .50       0.00       0.00     -2.60       0.00

       RESULTANT HORIZONTAL FORCES ON HEEL (K/FT)
       AND CORRESPONDING ECCENTRICITIES (FT)
         VERTICAL HEELFACE    BOTTOM SURFACE
        BACKFILL HYDRAULIC HYDRAULIC  EFF. FDN.
          1.58      0.00       0.00       0.00    FORCE
          0.00      0.00       0.00       0.00    ECC.
```

Figure B.3 Complete Output File For Example 1 (Sheet 6 of 13)

****** PRESSURES AND RESULTANT FORCES WITH ECCENTRICITIES ******

ON RIGID BLOCK UNDER WALL **** 11 ****

	VERT. PRESS.(KSF) BOTTOM SURFACE LEFT EDGE	RIGHT EDGE	/	RES. HORZ. FORCES(K/FT) BOT. OF SLAB HYDRAULIC	EFF. FDN.	
EFF. FDN.	0.00	0.00		0.00	0.00	FORCE
HYDRAULIC	0.00	0.00		0.00	0.00	ECC.

************* MEMBER 2 *************

VERTICAL PRESSURES (KSF)

DISTANCE (FT)	HYDRAULIC TOP	HYDRAULIC BOTTOM	EFFECTIVE FOUNDATION
0.00	0.00	0.00	0.00
3.00	0.00	0.00	1.14
6.00	0.00	0.00	1.31
9.00	0.00	0.00	.84
12.00	0.00	0.00	.33
15.00	0.00	0.00	.12
18.00	0.00	0.00	.33
21.00	0.00	0.00	.84
24.00	0.00	0.00	1.31
27.00	0.00	0.00	1.14
30.00	0.00	0.00	0.00

RESULTANT HORIZONTAL FORCES ON BOTTOM OF SLAB (K/FT)
AND CORRESPONDING ECCENTRICITIES (FT)

HYDRAULIC	EFF.FDN.	
0.00	.00	FORCE
0.00	.33	ECC.

************* MEMBER 11 *************

HORIZONTAL PRESSURES (KSF)

DISTANCE (FT)	BACKFILL	HYDRAULIC LEFT	HYDRAULIC RIGHT	EFFECTIVE FORCE-DEF.
20.00	0.00	0.00	0.00	0.00
18.00	.08	0.00	0.00	0.00
16.00	.16	0.00	0.00	0.00
14.00	.24	0.00	0.00	0.00
12.00	.32	0.00	0.00	0.00
10.00	.39	0.00	0.00	0.00
8.00	.47	0.00	0.00	0.00
6.00	.55	0.00	0.00	0.00
4.00	.63	0.00	0.00	0.00
2.00	.71	0.00	0.00	0.00
0.00	.79	0.00	0.00	0.00
-.88	.90	0.00		

Figure B.3 Complete Output File For Example 1 (Sheet 7 of 13)

```
     RESULTANT VERTICAL FORCES (K/FT) ON WALL
      AND CORRESPONDING ECCENTRICITIES (FT)
       BACKFILL HYDRAULIC
          -2.47       0.00    FORCE
           -.55       0.00     ECC.


 ******** EM-LIKE LOAD CASE  2   ********CHANNEL FULL        ********
*********************************************************************


             ************* MEMBER  1 *************

                         VERTICAL PRESSURES (KSF)
       DISTANCE         HYDRAULIC   BACKFILL  EFFECTIVE
           (FT)       TOP     BOTTOM            FOUNDATION
           0.00      0.00       0.00     -2.60        2.14
            .25      0.00       0.00     -2.60        2.14
            .50      0.00       0.00     -2.60        2.14

      RESULTANT HORIZONTAL FORCES ON HEEL (K/FT)
      AND CORRESPONDING ECCENTRICITIES (FT)
        VERTICAL HEELFACE    BOTTOM SURFACE
       BACKFILL HYDRAULIC HYDRAULIC  EFF. FDN.
           2.84       0.00       0.00       -.03    FORCE
           0.00       0.00       0.00       -.86     ECC.


    ******  PRESSURES AND RESULTANT FORCES WITH ECCENTRICITIES ******

              ON RIGID BLOCK UNDER WALL ****    11 ****
          VERT. PRESS.(KSF)     /     RES. HORZ. FORCES(K/FT)
            BOTTOM SURFACE      /           BOT. OF SLAB
          LEFT EDGE RIGHT EDGE /         HYDRAULIC EFF. FDN.
EFF. FDN.       2.14       2.16                 0.00       -.08     FORCE
HYDRAULIC       0.00       0.00                 0.00       -.85      ECC.


             ************* MEMBER  2 *************

                   VERTICAL PRESSURES (KSF)
       DISTANCE         HYDRAULIC    EFFECTIVE
           (FT)       TOP     BOTTOM FOUNDATION
           0.00     -1.25       0.00       2.16
           3.00     -1.25       0.00       2.02
           6.00     -1.25       0.00       1.74
           9.00     -1.25       0.00       1.51
          12.00     -1.25       0.00       1.38
          15.00     -1.25       0.00       1.34
```

Figure B.3 Complete Output File For Example 1 (Sheet 8 of 13)

18.00	-1.25	0.00	1.38
21.00	-1.25	0.00	1.51
24.00	-1.25	0.00	1.74
27.00	-1.25	0.00	2.02
30.00	-1.25	0.00	2.16

RESULTANT HORIZONTAL FORCES ON BOTTOM OF SLAB (K/FT)
AND CORRESPONDING ECCENTRICITIES (FT)

HYDRAULIC	EFF.FDN.	
0.00	-.00	FORCE
0.00	.33	ECC.

************* MEMBER 11 *************

DISTANCE (FT)	BACKFILL	HORIZONTAL PRESSURES (KSF) HYDRAULIC LEFT	RIGHT	EFFECTIVE FORCE-DEF.
20.00	0.00	0.00	0.00	0.00
18.00	.14	0.00	-.13	0.00
16.00	.28	0.00	-.25	0.00
14.00	.43	0.00	-.38	0.00
12.00	.57	0.00	-.50	0.00
10.00	.71	0.00	-.63	0.00
8.00	.85	0.00	-.75	0.00
6.00	1.00	0.00	-.88	0.00
4.00	1.14	0.00	-1.00	0.00
2.00	1.28	0.00	-1.13	0.00
0.00	1.42	0.00	-1.25	0.00
-.88	1.62	0.00		

RESULTANT VERTICAL FORCES (K/FT) ON WALL
AND CORRESPONDING ECCENTRICITIES (FT)

BACKFILL	HYDRAULIC	
-2.47	0.00	FORCE
-.55	0.00	ECC.

O.4 OUTPUT OF MEMBER FORCES / STRESSES *** BY LOAD CASE ***

Figure B.3 Complete Output File For Example 1 (Sheet 9 of 13)

******** EM-LIKE LOAD CASE 1 ********CHANNEL EMPTY ********
****

************* MEMBER 1 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
0.00	.0	-.00	.00	.003	-2.60	21.00
.25	-.1	-.72	1.58	.003	-2.60	20.87
.50	-.4	-1.43	1.58	.002	-2.60	20.74

************* MEMBER 2 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
0.00	50.4	-8.08	9.48	.001	0.00	19.86
3.00	24.5	-7.06	9.48	-.001	1.14	18.29
6.00	6.9	-4.03	9.32	-.002	1.31	16.72
9.00	-.6	-1.40	8.98	-.001	.84	15.15
12.00	-2.3	-.19	8.71	-.000	.33	13.57
15.00	-2.6	.00	8.61	-.000	.12	12.00
18.00	-2.3	.19	8.71	-.000	.33	13.57
21.00	-.6	1.40	8.98	-.001	.84	15.15
24.00	6.9	4.03	9.32	-.002	1.31	16.72
27.00	24.5	7.06	9.48	-.001	1.14	18.29
30.00	50.4	8.08	9.48	.001	0.00	19.86

REVIEW OF ELASTIC STRESSES

DISTANCE	TENSION AREA	FACE	DEPTH (D)	STEEL STRESS	CONCRETE STRESS COMPRESS.	SHEAR
(FT)	(SI/FT)		(IN)	(KSI)	(KSI)	(KSI)
0.00	1.93	BOT	15.74	19.98	1.33	.043
3.00	.87	BOT	14.17	19.99	1.00	.042
6.00	.06	BOT	12.59	19.93	.62	.027
9.00	.01	TOP	11.52	-.77	.06	.010
12.00	.01	TOP	9.95	-.35	.13	.002
15.00	.01	TOP	8.38	-.31	.17	.000

Figure B.3 Complete Output File For Example 1 (Sheet 10 of 13)

************* MEMBER 11 *************

DISTANCE (FT)	BENDING MOMENT (K-FT/FT)	FORCES SHEAR (K/FT)	FORCES AXIAL (K/FT)	LATERAL DEFLECT. (FT)	NET LATR. PRESSURE (KSF)	THICKNESS (IN)
20.00	-.0	-.00	.00	.056	0.00	10.00
18.00	-.1	.12	.31	.049	.08	11.00
16.00	-.4	.36	.67	.043	.16	12.00
14.00	-1.4	.75	1.10	.036	.24	13.00
12.00	-3.4	1.30	1.61	.030	.32	14.00
10.00	-6.6	2.02	2.20	.023	.39	15.00
8.00	-11.3	2.88	2.86	.018	.47	16.00
6.00	-17.9	3.91	3.59	.012	.55	17.00
4.00	-26.7	5.10	4.40	.008	.63	18.00
2.00	-38.1	6.44	5.29	.004	.71	19.00
0.00	-52.3	7.90	6.22	.001	.79	20.00

REVIEW OF ELASTIC STRESSES

DISTANCE (FT)	TENSION AREA (SI/FT)	FACE	DEPTH (D) (IN)	STEEL STRESS (KSI)	CONCRETE STRESS COMPRESS. (KSI)	SHEAR (KSI)
20.00	0.00	TOP	7.50	0.00	.00	.000
18.00	.01	TOP	7.88	-.02	.01	.001
16.00	.01	TOP	8.88	17.07	.18	.003
14.00	.06	TOP	9.88	19.98	.30	.006
12.00	.15	TOP	10.88	19.98	.42	.010
10.00	.29	TOP	11.88	19.98	.55	.014
8.00	.49	TOP	12.88	19.99	.68	.019
6.00	.75	TOP	13.88	19.99	.81	.023
4.00	1.08	TOP	14.88	19.99	.95	.029
2.00	1.48	TOP	15.88	19.99	1.09	.034
0.00	1.95	TOP	16.88	19.98	1.23	.039

******** EM-LIKE LOAD CASE 2 ********CHANNEL FULL ********
****

************* MEMBER 1 *************

DISTANCE (FT)	BENDING MOMENT (K-FT/FT)	FORCES SHEAR (K/FT)	FORCES AXIAL (K/FT)	LATERAL DEFLECT. (FT)	NET LATR. PRESSURE (KSF)	THICKNESS (IN)
0.00	-.0	.00	.00	-.002	-.46	21.00
.25	-.0	-.18	2.83	-.002	-.46	20.87
.50	-.1	-.36	2.82	-.002	-.46	20.74

Figure B.3 Complete Output File For Example 1 (Sheet 11 of 13)

************* MEMBER 2 *************

DISTANCE (FT)	BENDING MOMENT (K-FT/FT)	FORCES SHEAR (K/FT)	FORCES AXIAL (K/FT)	LATERAL DEFLECT. (FT)	NET LATR. PRESSURE (KSF)	THICKNESS (IN)
0.00	9.0	-3.43	4.45	-.002	.91	19.86
3.00	1.6	-1.62	4.26	-.002	.77	18.29
6.00	-1.0	-.39	4.05	-.002	.49	16.72
9.00	-1.1	.13	3.89	-.002	.26	15.15
12.00	-.6	.17	3.80	-.002	.13	13.57
15.00	-.5	-.00	3.77	-.002	.09	12.00
18.00	-.6	-.17	3.80	-.002	.13	13.57
21.00	-1.1	-.13	3.89	-.002	.26	15.15
24.00	-1.0	.39	4.05	-.002	.49	16.72
27.00	1.6	1.62	4.26	-.002	.77	18.29
30.00	9.0	3.43	4.45	-.002	.91	19.86

REVIEW OF ELASTIC STRESSES

DISTANCE (FT)	TENSION AREA (SI/FT)	FACE	DEPTH (D) (IN)	STEEL STRESS (KSI)	CONCRETE STRESS COMPRESS. (KSI)	CONCRETE STRESS SHEAR (KSI)
0.00	1.93	BOT	15.74	2.84	.24	.018
3.00	.87	BOT	14.17	-.07	.05	.010
6.00	.01	TOP	13.09	-.15	.04	.003
9.00	.01	TOP	11.52	-.12	.05	.001
12.00	.01	TOP	9.95	-.27	.04	.001
15.00	.01	TOP	8.38	-.34	.05	.000

************* MEMBER 11 *************

DISTANCE (FT)	BENDING MOMENT (K-FT/FT)	FORCES SHEAR (K/FT)	FORCES AXIAL (K/FT)	LATERAL DEFLECT. (FT)	NET LATR. PRESSURE (KSF)	THICKNESS (IN)
20.00	-.0	-.00	-.00	.007	0.00	10.00
18.00	-.0	.03	.31	.006	.02	11.00
16.00	-.1	.08	.67	.005	.03	12.00
14.00	-.3	.16	1.10	.004	.05	13.00
12.00	-.7	.28	1.61	.004	.07	14.00
10.00	-1.3	.44	2.20	.003	.09	14.00
8.00	-2.3	.63	2.86	.002	.10	16.00
6.00	-3.6	.85	3.59	.001	.12	17.00
4.00	-5.5	1.11	4.40	.001	.14	18.00
2.00	-7.9	1.40	5.29	.000	.15	19.00
0.00	-10.8	1.72	6.22	.000	.17	20.00

Figure B.3 Complete Output File For Example 1 (Sheet 12 of 13)

REVIEW OF ELASTIC STRESSES

DISTANCE	TENSION AREA	FACE	DEPTH (D)	STEEL STRESS	CONCRETE STRESS COMPRESS.	SHEAR
(FT)	(SI/FT)		(IN)	(KSI)	(KSI)	(KSI)
20.00	0.00	TOP	7.50	0.00	.00	.000
18.00	.01	TOP	7.88	-.04	.00	.000
16.00	.01	TOP	8.88	-.06	.01	.001
14.00	.06	TOP	9.88	-.04	.02	.001
12.00	.15	TOP	10.88	.20	.04	.002
10.00	.29	TOP	11.88	.97	.08	.003
8.00	.49	TOP	12.88	1.70	.12	.004
6.00	.75	TOP	13.88	2.20	.16	.005
4.00	1.08	TOP	14.88	2.55	.19	.006
2.00	1.48	TOP	15.88	2.80	.23	.007
0.00	1.95	TOP	16.88	2.99	.26	.008

Figure B.3 Complete Output File For Example 1 (Sheet 13 of 13)

Example 2

8. The second example is identical to the first, except the empirical base slab option is used. The resulting base slab pressure distributions are shown in the computer graphic output (Figure B.5). The partial printed output file contains the echo of data, safety factors, final design dimensions, and steel requirements. The final designs for examples one and two are similar except for significant differences in the steel at the center of the base slabs of the two designs.

```
01010 3 U-WALL DESIGN EXAMPLE #2 - EMPIRICAL FOUNDATION PRESSURES
01020 H=20  W=20  LEVEL BACKFILL
01030 BTYPE=WEDA  FTYPE=EMP  ATREST=1.8
02010   DES  WSD  CHA      1    DSGNBI  DSGNBO  DSGNBP
02020   NO   NO
03010     3.000     .150    1.350   20.000
04010    20.000   20.000    0.000   10.000   17.000
04020    18.000   12.000     .500     .500   30.000
05010   1  1
05020     2.500    3.000    3.000    3.500
05030     3.000    1.250    3.000    1.250
07010  2  WEDA    EMP     1.10     1.10
08010    1.000  CHANNEL EMPTY
08020    -5.000    0.000
08030     1.000
08040    1.000  CHANNEL FULL
08050    -5.000   20.000
08060     1.800
09010      .130     .140   30.000    0.000   15.000
09020      0.00     0.00     0.00     0.00    0.000   20.000  0.0 -5.0
14010        .500      2.000      10.000       8.000       0.000  25.000
```

Figure B.4 Input File For Example 2

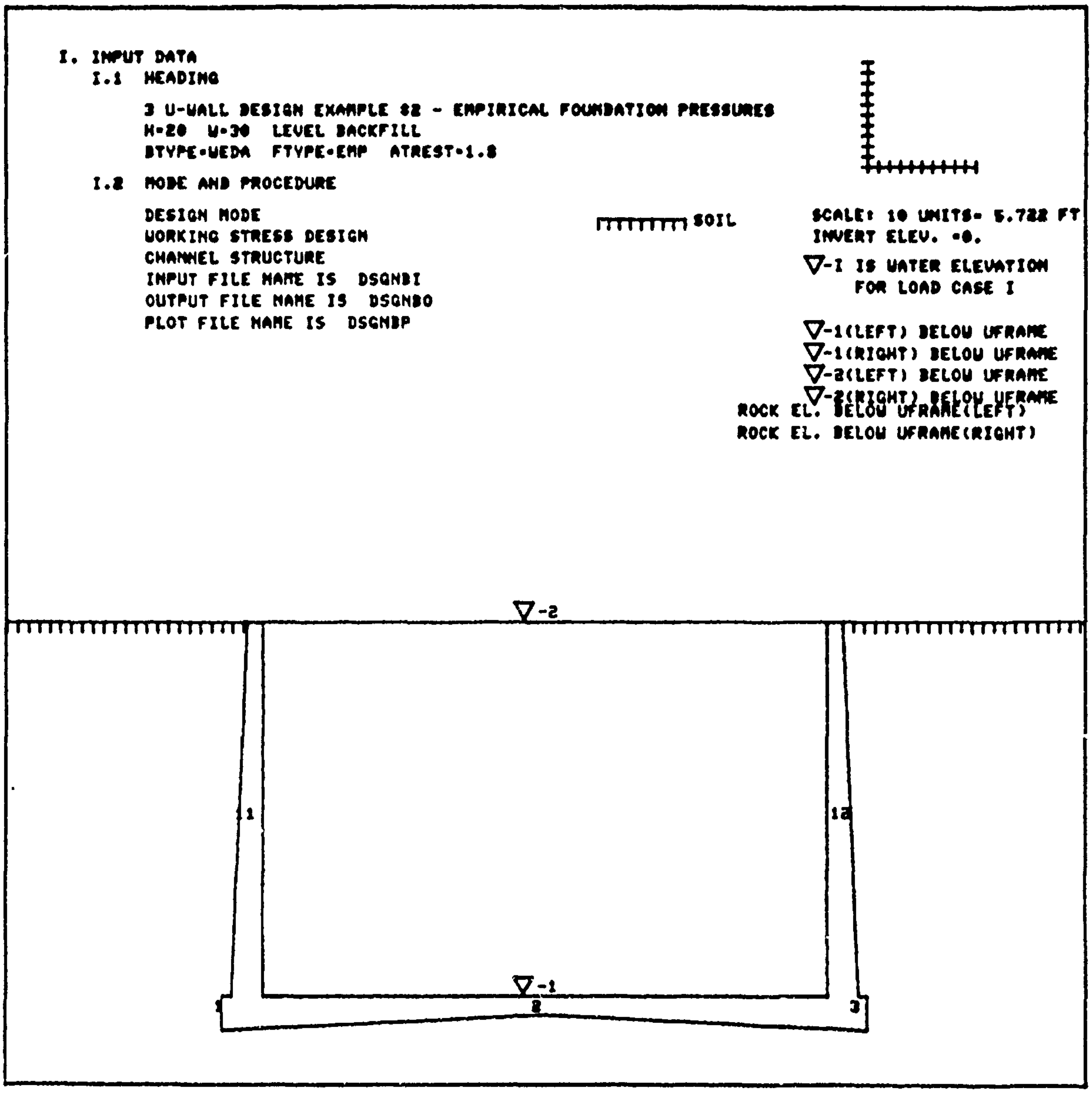


Figure B.5 Partial Graphic Output For Example 2 (Sheet 1 of 3)

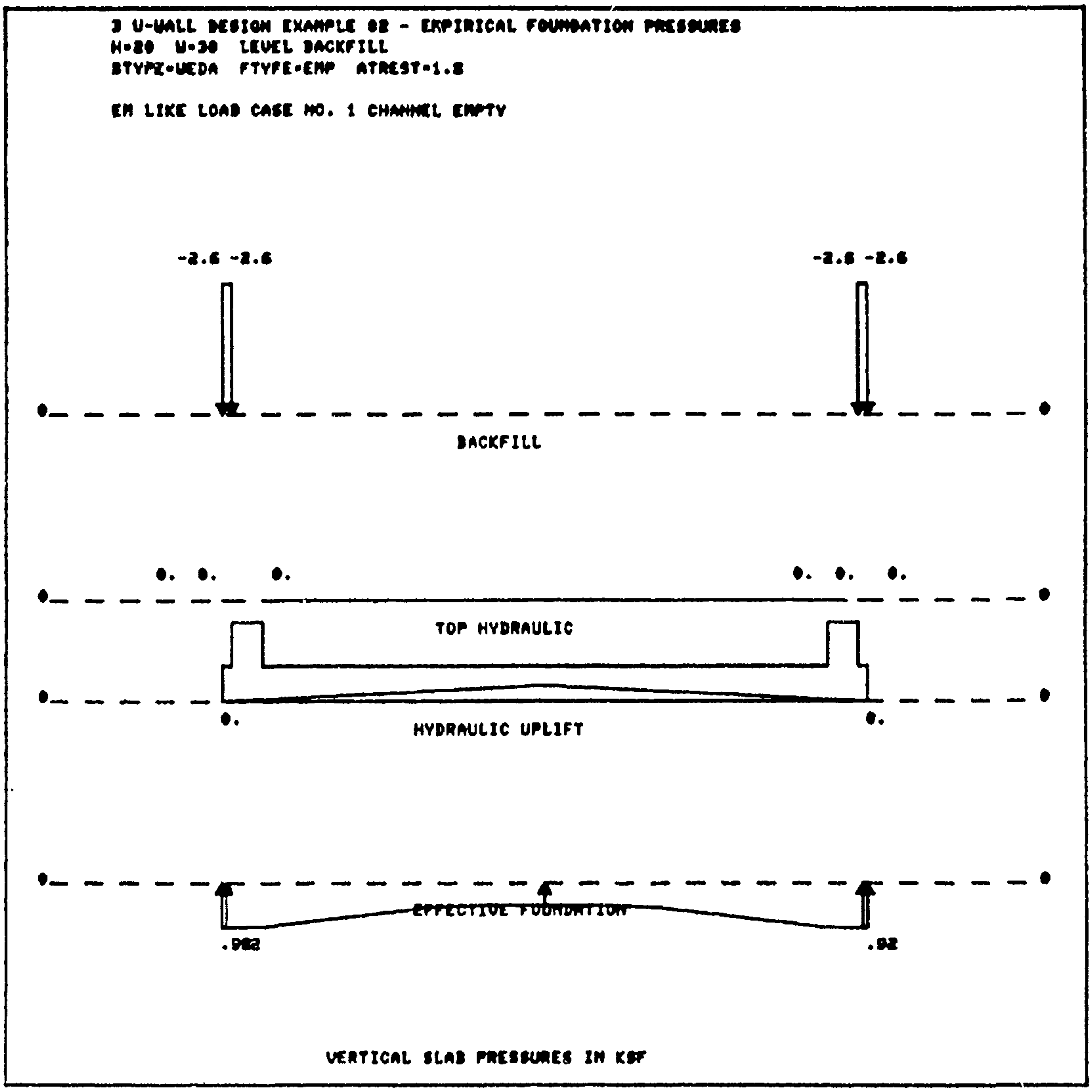


Figure B.5 Partial Graphic Output For Example 2 (Sheet 2 of 3)

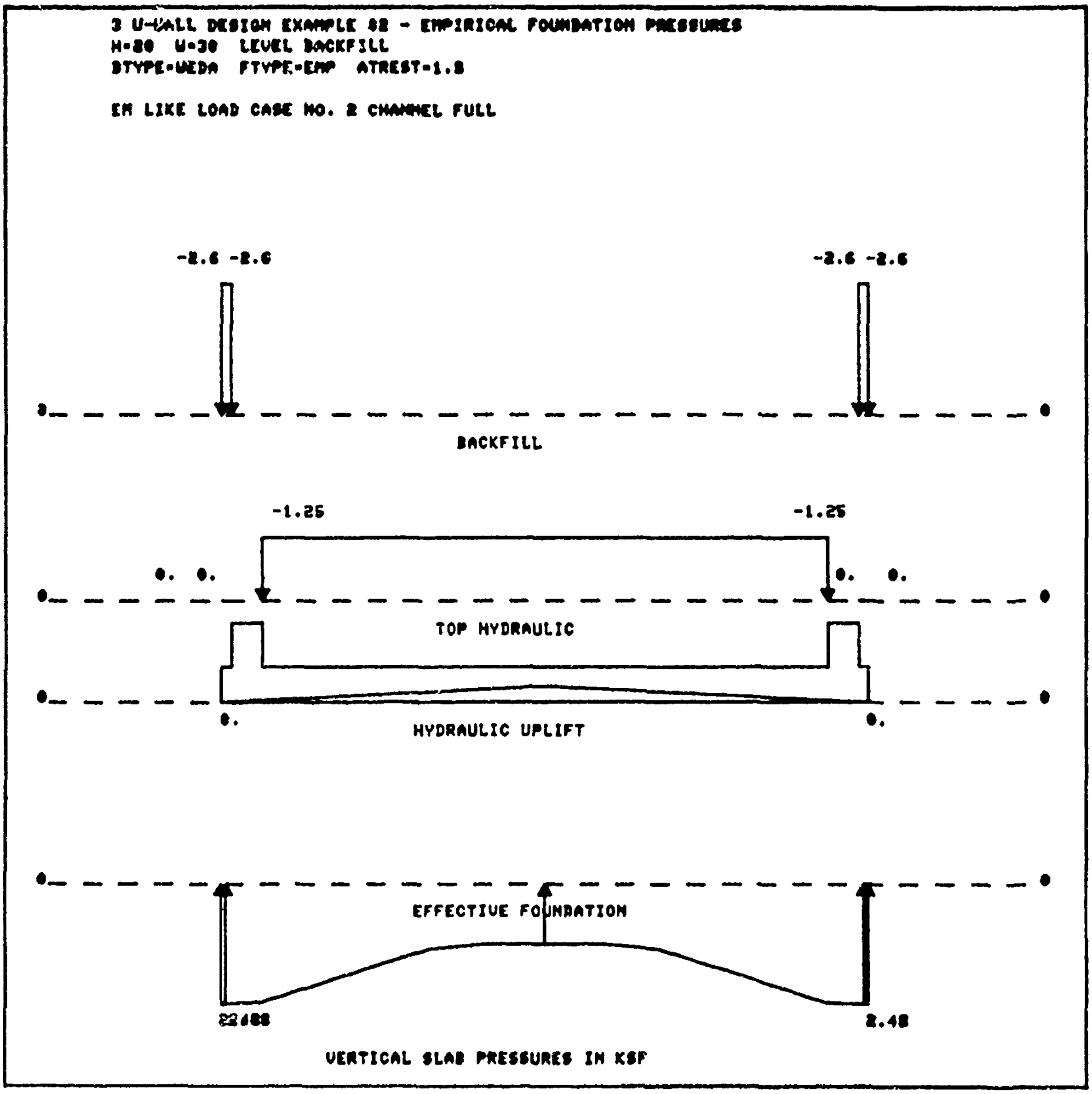


Figure B.5 Partial Graphic Output For Example 2 (Sheet 3 of 3)

```
*************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF   *
*            BASINS AND CHANNELS                 *
*               BY C. O. HAYS                    *
*           REVISED   18 JULY  1989              *
*************************************************


    I.    INPUT DATA *** AND FINAL DESIGN VALUES ***
                     *** FOR DESIGN VARIABLES    ***

    I.1  HEADING

    3 U-WALL DESIGN EXAMPLE #2 - EMPIRICAL FOUNDATION PRESSURES
    H=20  W=30  LEVEL BACKFILL
    BTYPE=WEDA  FTYPE=EMP  ATREST=1.8


    I.2   MODE AND PROCEDURE

          DESIGN MODE
          WORKING STRESS DESIGN
          1 CHANNEL STRUCTURE
          INPUT FILE NAME IS "DSGNBI"
          OUTPUT FILE NAME IS "DSGNBO"
          PLOT STORAGE FILE NAME IS "DSGNBP"

          WALL DRAIN DATA OMITTED
          BASE SLAB DRAIN DATA OMITTED


    I.3 MATERIAL PROPERTIES

       CONCRETE:
         ULTIMATE STRENGTH         = 3.000   KSI
         MODULUS OF ELASTICITY     = 3123.   KSI
         UNIT WEIGHT               =  .150   KCF
         ALLOWABLE STRESS          =  1.35   KSI


       REINFORCEMENT:
         ALLOWABLE STRESS          =   20.C    KSI
         MODULUS OF ELASTICITY     = 29000.    KSI
         MO^ULAR RATIO             =   9.28
```

Figure B.6 Partial Output File For Example 2 (Sheet 1 of 5)

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION			/ WIDTH		
TOP	BOTTOM	SLAB	TOP	BOTTOM	
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL	
(FT)	(FT)	(FT)	(IN)	(IN)	
20.00	20.00	0.00	10.00	17.00	
			10.00	20.00	(FINAL DESIGN VALUES)

SLAB AND HEEL DIMENSIONS

DEPTH		/	WIDTHS(LEFT)	
	SLAB	HEEL	HEEL	CHANNEL
LEFT	CENTER		MAX.	
DEPTHL	DEPTHC	WHEELL	WHEELLM	WIDTHL
(IN)	(IN)	(FT)	(FT)	(FT)
18.00	12.00	.50	.50	30.00
22.00	12.00	.50	(FINAL DESIGN VALUES)	

I.5 REINFORCEMENT FOR DESIGN OPTION

NUMBER OF LAYERS	
WALL	SLAB
NOLAYW	NOLAYSB
1	1

CLEAR COVER (IN)

COVER(1)	COVER(2)	COVER(3)	COVER(4)
2.50	3.00	3.00	3.50

MAXIMUM AREAS PER LAYER AND DIAMETERS

WALL BELOW BREAK		SLAB	
AREA	DIAM.	AREA	DIAM.
AWBMAX	DWBMAX	ASBMAX	DSBMAX
(SI/FT)	(IN)	(SI/FT)	(IN)
3.00	1.25	3.00	1.25

Figure B.6 Partial Output File For Example 2 (Sheet 2 of 5)

I.7 LOADING CONTROL

2 EM-LIKE LOAD CASES
USING ACTIVE WEDGE METHOD FOR SOIL PRESSURES
EMPIRICAL FOUNDATION DESCRIPTION
MINIMUM UPLIFT FACTOR OF SAFETY - 1.10
MINIMUM BEARING FACTOR OF SAFETY - 1.10

I.8 HYDRAULIC STRESS AND STRENGTH DATA

```
******** EM-LIKE LOAD CASE  1    ********CHANNEL EMPTY        ********
         ALLOWABLE STRESS MULTIPLIER -  1.00
**********************************************************************
```

SYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL LEFT ELBWSL	CHANNEL LEFT ELCWSL
-5.00	0.00

AT REST MULTIPLIERS

BACKFILL ATRESTS
1.00

```
******** EM-LIKE LOAD CASE  2    ********CHANNEL FULL         ********
         ALLOWABLE STRESS MULTIPLIER -  1.00
**********************************************************************
```

SYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL LEFT ELBWSL	CHANNEL LEFT ELCWSL
-5.00	20.00

AT REST MULTIPLIERS

BACKFILL ATRESTS
1.80

Figure B.6 Partial Output File For Example 2 (Sheet 3 of 5)

I.9 SOILS DATA FOR WEDGE METHOD

BACKFILL SOIL PROPERTIES

UNIT WEIGHTS DRAINED UWSD (KCF)	SAT. UWSS (KCF)	PHI ANGLE SPHI (DEG)	COHESION SCOHE (KSF)	WALL FRICTION ANGLE DELFW (DEG)
.130	.140	30.000	0.000	15.000

BACKFILL DATA LEFT SIDE (SYMMETRICAL)

BACKFILL SLOPE SOJL (FT)	DISTANCES HORZ. SOKL (FT)	SURCHARGE START SOLL (FT)	LENGTH SOML (FT)	/ WEIGHT UWSURL (KSF)	BACKFILL ELEV. ELGSL (FT)	ANGLE ANBSL (DEG)	ROCK ELEV. ELRSL (FT)
0.00	0.00	0.00	0.00	0.00	20.00	0.00	-5.00

I.14 EMPIRICAL FOUNDATION DESCRIPTION

PRESSURE RATIO PRAT	DISTANCE UNIFORM XUNIF (FT)	SLOPING XSLOP (FT)	BEARING FPF (KSF)	STRENGTH COHESION FCOHE (KCI)	FRICTION DELFF (DEG)
.50	2.00	10.00	8.00	0.00	25.00

O. OUTPUT RESULTS

O.1 FACTORS OF SAFETY

FACTOR OF SAFETY AGAINST UPLIFT	BEARING	HORIZONTAL EQUILIBRIUM FACTOR	EM-LIKE LOAD CASE	SPECIAL LOAD CASE
9999.99	8.65	9999.99	1	
9999.99	3.23	9999.99	2	

Figure B.6 Partial Output File For Example 2 (Sheet 4 of 5)

O.2 SUMMARY OF STEEL REQUIREMENTS BY MEMBER

************* MEMBER 2 *************

********** TOP STEEL **********
NONE REQUIRED FOR STRENGTH

********** BOTTOM STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00	1.250	1.91			.0096	16.61
3.00	1.250	1.40			.0078	14.87
6.00	1.250	1.01			.0064	13.12
9.00	1.250	.75			.0055	11.37
12.00	1.250	.60			.0052	9.62
15.00	1.250	.76			.0080	7.88

************* MEMBER 11 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
20.00						
18.00	1.250	.01			.0001	7.88
16.00	1.250	.01			.0001	8.88
14.00	1.250	.06			.0005	9.88
12.00	1.250	.15			.0011	10.88
10.00	1.250	.29			.0020	11.88
8.00	1.250	.49			.0032	12.88
6.00	1.250	.75			.0045	13.88
4.00	1.250	1.08			.0060	14.88
2.00	1.250	1.48			.0077	15.88
0.00	1.250	1.95			.0096	16.88

********** BOTTOM STEEL **********
NONE REQUIRED FOR STRENGTH

Figure B.6 Partial Output File For Example 2 (Sheet 5 of 5)

Example 3

9. The third example is identical to the first, except the strength design procedure is used. The partial printed output file contains the echo of data, final design dimensions, safety factors, and steel requirements. The design based on the strength procedures using a 40-ksi yield stress resulted in larger concrete thicknesses and smaller quantities of steel than the first example based on an allowable steel stress of 20 ksi. The ease with which an example can be revised to switch between allowable stress and strength design options should make the program a valuable tool to the designer.

```
01010 3 U-WALL DESIGN EXAMPLE #3 - SPRG FND PRESSURES W/ STR DESIGN
01020 H=20  W=30  LEVEL BACKFILL
01030 BTYPE=WEDA  FTYPE=SPR  ATREST=1.8
02010   DES   SD    CHA       1     DSGNCI   DSGNCO   DSGNCP
02020   NO    NO
03010     3.000      .150   40.000      .250  HYD
04010    20.000    20.000    0.000    10.000   17.000
04020    18.000    12.000     .500      .500   30.000
05010    1  1
05020     2.500     3.000    3.000     3.500
05030     3.000     1.250    3.000     1.250
07010  2  WEDA    SPR      1.10      1.10
08010    1.900   CHANNEL EMPTY
08020    -5.000     0.000
08030     1.000
08040    1.900   CHANNEL FULL
08050    -5.000    20.000
08060     1.800
09010      .130      .140   30.000     0.000   15.000
09020      0.00      0.00     0.00      0.00    0.000    20.0  0.0  -5.0
13010     8.000       .500      .250      0.000    25.000    0
```

Figure B.7 Input File For Example 3

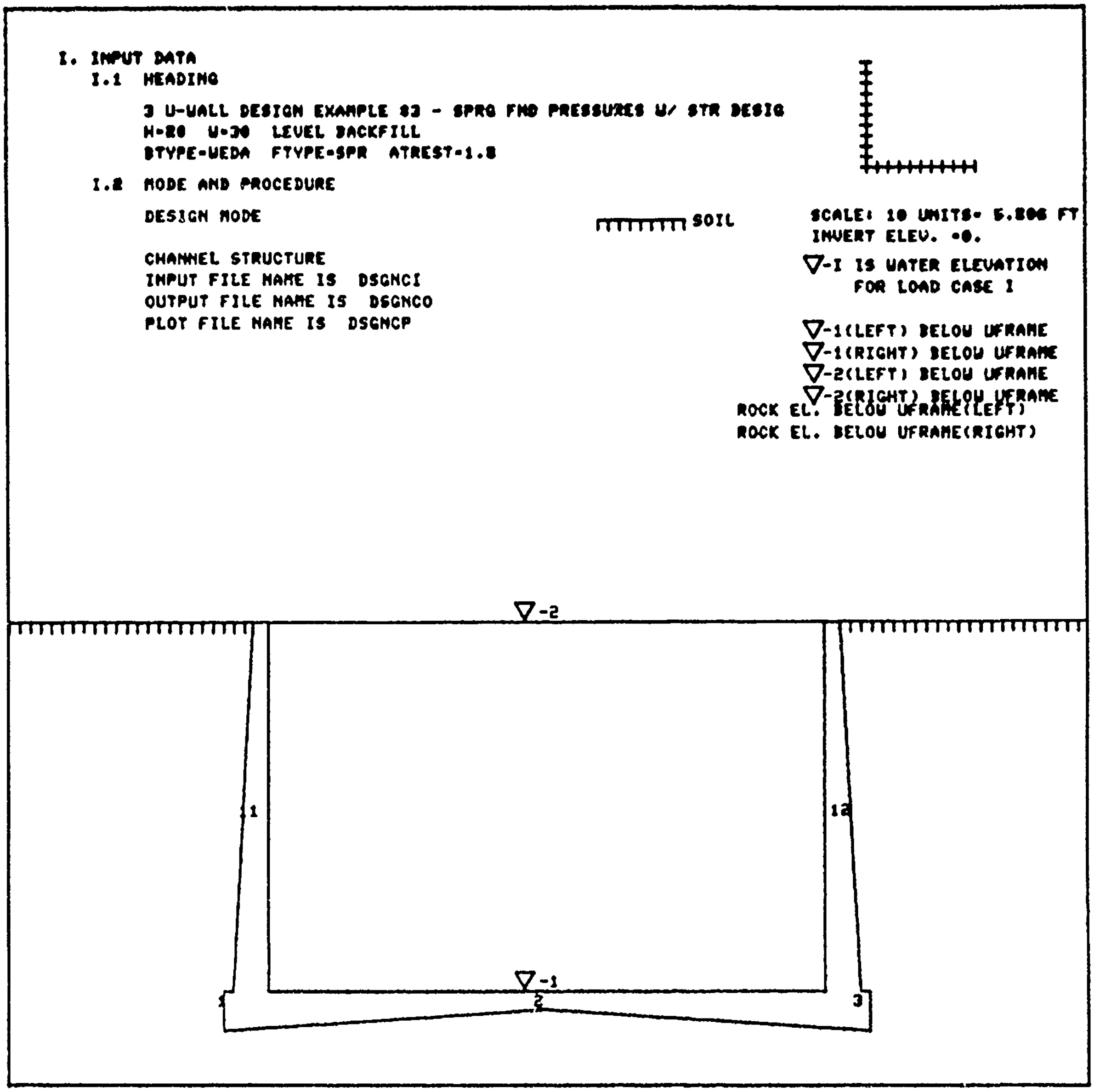


Figure B.8 Partial Graphic Ouput For Example 3

```
**************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF   *
*            BASINS AND CHANNELS                 *
*               BY C. O. HAYS                    *
*           REVISED   18 JULY  1989              *
**************************************************


    I.    INPUT DATA *** AND FINAL DESIGN VALUES ***
                     *** FOR DESIGN VARIABLES    ***

    I.1  HEADING

    3 U-WALL DESIGN EXAMPLE #3 - SPRG FND PRESSURES W/ STR DESIGN
    H=20  W=30  LEVEL BACKFILL
    BTYPE=WEDA  FTYPE=SPR  ATREST=1.8


    I.2   MODE AND PROCEDURE

          DESIGN MODE
          STRENGTH DESIGN
          1 CHANNEL STRUCTURE
          INPUT FILE NAME IS "DSGNCI"
          OUTPUT FILE NAME IS "DSGNCO"
          PLOT STORAGE FILE NAME IS "DSGNCP"

          WALL DRAIN DATA OMITTED
          BASE SLAB DRAIN DATA OMITTED


    I.3 MATERIAL PROPERTIES

       CONCRETE:
         ULTIMATE STRENGTH         = 3.000   KSI
         MODULUS OF ELASTICITY     = 3123.   KSI
         UNIT WEIGHT               =  .150   KCF


       REINFORCEMENT:
         YIELD STRENGTH            =   40.0   KSI
         MODULUS OF ELASTICITY     = 29000.   KSI
         MAX. TENSION STEEL RATIO  =   .250
```

Figure B.9 Partial Output File For Example 3 (Sheet 1 of 5)

HYDRAULIC STRENGTH PARAMETERS

MAXIMUM CONCRETE STRAIN	=	.0015
STRESS BLOCK DEPTH RATIO	=	.5500
STRESS BLOCK STRESS RATIO	=	.8500
USABLE COMPRESSION RATIO	=	.7000
PHI FACTOR (PURE AXIAL)	=	.70
PHI FACTOR (PURE FLEXURE)	=	.90
PHI FACTOR (SHEAR)	=	.85

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION		/	WIDTH		
TOP	BOTTOM	SLAB	TOP	BOTTOM	
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL	
(FT)	(FT)	(FT)	(IN)	(IN)	
20.00	20.00	0.00	10.00	17.00	
			10.00	23.00	(FINAL DESIGN VALUES)

SLAB AND HEEL DIMENSIONS

DEPTH		/	WIDTHS(LEFT)	
	SLAB	HEEL	HEEL	CHANNEL
LEFT	CENTER		MAX.	
DEPTHL	DEPTHC	WHEELL	WHEELLM	WIDTHL
(IN)	(IN)	(FT)	(FT)	(FT)
18.00	12.00	.50	.50	30.00
26.00	12.00	.50	(FINAL DESIGN VALUES)	

I.5 REINFORCEMENT FOR DESIGN OPTION

NUMBER OF LAYERS	
WALL	SLAB
NOLAYW	NOLAYSB
1	1

CLEAR COVER (IN)

COVER(1)	COVER(2)	COVER(3)	COVER(4)
2.50	3.00	3.00	3.50

Figure B.9 Partial Output File For Example 3 (Sheet 2 of 5)

MAXIMUM AREAS PER LAYER AND DIAMETERS

WALL BELOW BREAK		SLAB	
AREA	DIAM.	AREA	DIAM.
AWBMAX	DWBMAX	ASBMAX	DSBMAX
(SI/FT)	(IN)	(SI/FT)	(IN)
3.00	1.25	3.00	1.25

I.7 LOADING CONTROL

2 EM-LIKE LOAD CASES
USING ACTIVE WEDGE METHOD FOR SOIL PRESSURES
ELASTIC SPRING FOUNDATION
MINIMUM UPLIFT FACTOR OF SAFETY = 1.10
MINIMUM BEARING FACTOR OF SAFETY = 1.10

I.8 HYDRAULIC STRESS AND STRENGTH DATA

******** EM-LIKE LOAD CASE 1 ********CHANNEL EMPTY ********
STRENGTH DESIGN LOAD FACTOR = 1.90
****

SYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL	CHANNEL
LEFT	LEFT
ELBWSL	ELCWSL
-5.00	0.00

AT REST MULTIPLIERS

BACKFILL
ATRESTS
1.00

******** EM-LIKE LOAD CASE 2 ********CHANNEL FULL ********
STRENGTH DESIGN LOAD FACTOR = 1.90
****

SYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL	CHANNEL
LEFT	LEFT
ELBWSL	ELCWSL
-5.00	20.00

Figure B.9 Partial Output File For Example 3 (Sheet 3 of 5)

AT REST MULTIPLIERS

BACKFILL
ATRESTS
1.80

I.9 SOILS DATA FOR WEDGE METHOD

BACKFILL SOIL PROPERTIES

UNIT WEIGHTS		PHI	COHESION	WALL FRICTION
DRAINED	SAT.	ANGLE		ANGLE
UWSD	UWSS	SPHI	SCOHE	DELFW
(KCF)	(KCF)	(DEG)	(KSF)	(DEG)
.130	.140	30.000	0.000	15.000

BACKFILL DATA LEFT SIDE (SYMMETRICAL)

	DISTANCES			/			
BACKFILL		SURCHARGE			BACKFILL		ROCK
SLOPE	HORZ.	START	LENGTH	WEIGHT	ELEV.	ANGLE	ELEV.
SOJL	SOKL	SOLL	SOML	UWSURL	ELGSL	ANBSL	ELRSL
(FT)	(FT)	(FT)	(FT)	(KSF)	(FT)	(DEG)	(FT)
0.00	0.00	0.00	0.00	0.00	20.00	0.00	-5.00

I.13 ELASTIC SPRING FOUNDATION PROPERTIES

	SOIL			/	ANCHORS
STRENGTH	SPRING MODULI		COHESION	FRICTION	NUMBER
	VERT.	HORZ.			
FPF	SCFV	SCFH	FCOHE	DELFF	NANCK
(KSF)	(KCI)	(KCI)	(KSF)	(DEG)	
8.00	.500	.250	0.00	25.00	0

O. OUTPUT RESULTS

O.1 FACTORS OF SAFETY

FACTOR OF SAFETY		HORIZONTAL	EM-LIKE	SPECIAL
AGAINST		EQUILIBRIUM	LOAD	LOAD
UPLIFT	BEARING	FACTOR	CASE	CASE
9999.99	6.21	9999.99	1	
9999.99	3.61	9999.99	2	

Figure B.9 Partial Output File For Example 3 (Sheet 4 of 5)

0.2 SUMMARY OF STEEL REQUIREMENTS BY MEMBER

************* MEMBER 2 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00						
3.00						
6.00	1.250	.01			.0000	15.61
9.00	1.250	.01			.0000	13.20
12.00	1.250	.01			.0000	10.79
15.00	1.250	.01			.0001	8.38

********** BOTTOM STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00	1.250	1.50			.0063	19.93
3.00	1.250	.63			.0030	17.52
6.00	1.250	.01			.0000	15.11
9.00						
12.00						
15.00						

************* MEMBER 11 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
20.00						
18.00	1.250	.01			.0001	8.18
16.00	1.250	.01			.0001	9.48
14.00	1.250	.05			.0004	10.78
12.00	1.250	.13			.0009	12.08
10.00	1.250	.25			.0016	13.38
8.00	1.250	.42			.0024	14.68
6.00	1.250	.64			.0034	15.98
4.00	1.250	.93			.0045	17.28
2.00	1.250	1.27			.0057	18.58
0.00	1.250	1.68			.0071	19.88

********** BOTTOM STEEL **********

NONE REQUIRED FOR STRENGTH

Figure B.9 Partial Output File For Example 3 (Sheet 5 of 5)

Example 4

10. Example 4 is a somewhat more complex version of example 1. Ground water, wall and slab drains, a sloping backfill, and a surcharge loading have been added to the simpler channel of example 1. The resulting base slab pressure distributions are shown in the computer graphic output (Figure B.11). The partial printed output file contains the echo of data, safety factors, final design dimensions, and steel requirements.

```
01010 4 U-WALL DESIGN EXAMPLE #4 - SPRING FOUNDATION PRESSURES
01020 H=20  W=30  SLOPING/SURCHG BACKFILL
01030 BTYPE=WEDA  FTYPE=SPR  ATREST=1.8
01040 GRNDWATER @ 14' - DRAINS 50% EFFECTIVE
02010   DES  WSD  CHA      1    DSGNDI  DSGNDO  DSGNDP
02020   YES  YES
03010     3.000     .150    1.350   20.000
04010    20.000   20.000    0.000   10.000   22.000    5.000
04020    24.000   12.000     .500     .500   30.000    7.000
05010   1  1
05020     2.500    3.000    3.000    3.500
05030     3.000    1.250    3.000    1.250
07010  2  WEDA   SPR     1.10     1.10
08010    1.000  CHANNEL EMPTY
08020    14.000    0.000
08030    50.000   50.000    1.000
08040    1.000  CHANNEL FULL
08050    14.000   20.000
08060    50.000   50.000    1.800
09010      .130     .140   30.000    0.000   15.000
09020     20.00     5.00    25.00     8.00    1.000   20.0  27.0  -5.0
13010     8.000      .500      .250    0.000    25.000    0
```

Figure B.10 Input File For Example 4

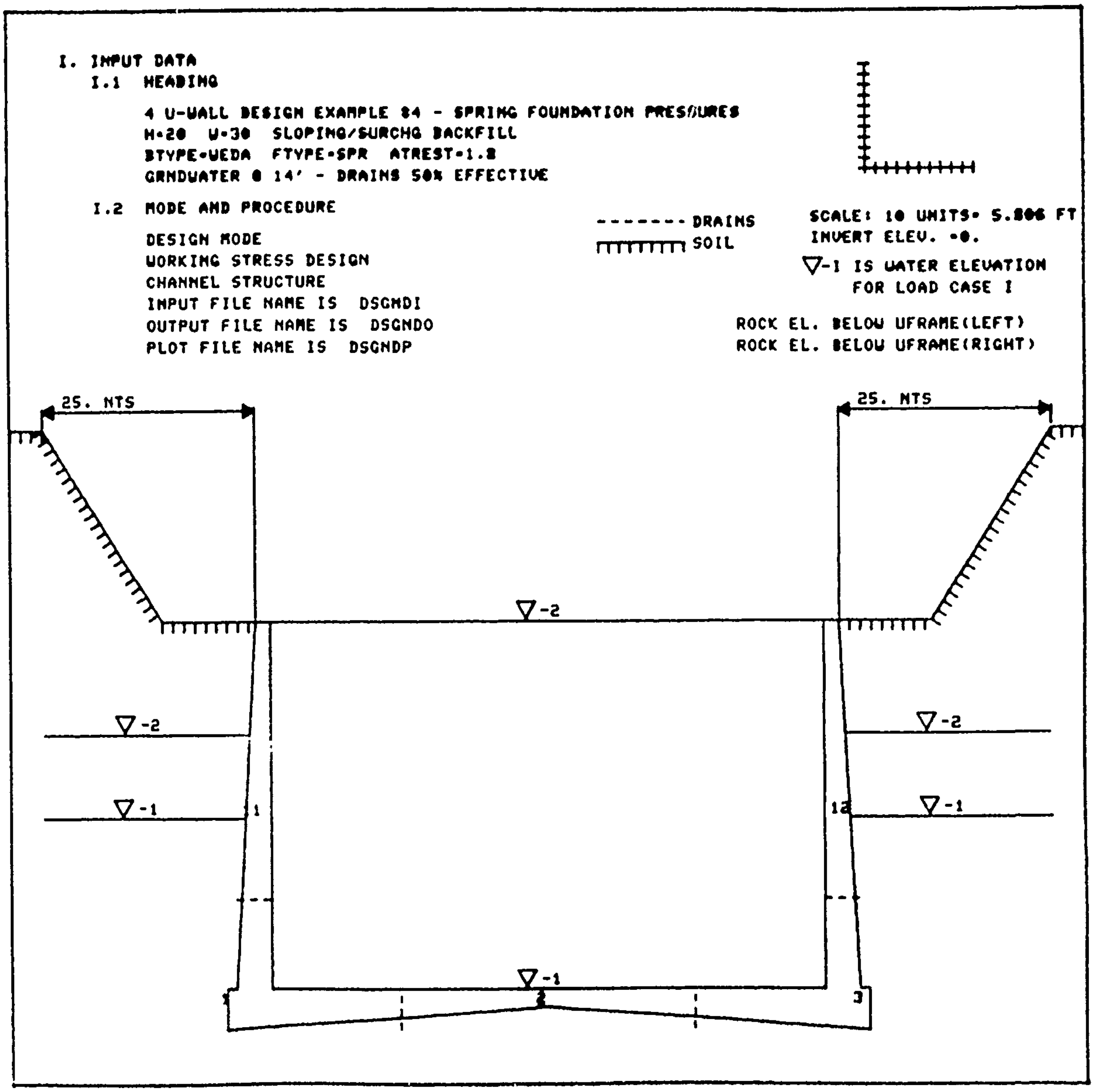


Figure B.11 Partial Graphic Output For Example 4 (Sheet 1 of 3)

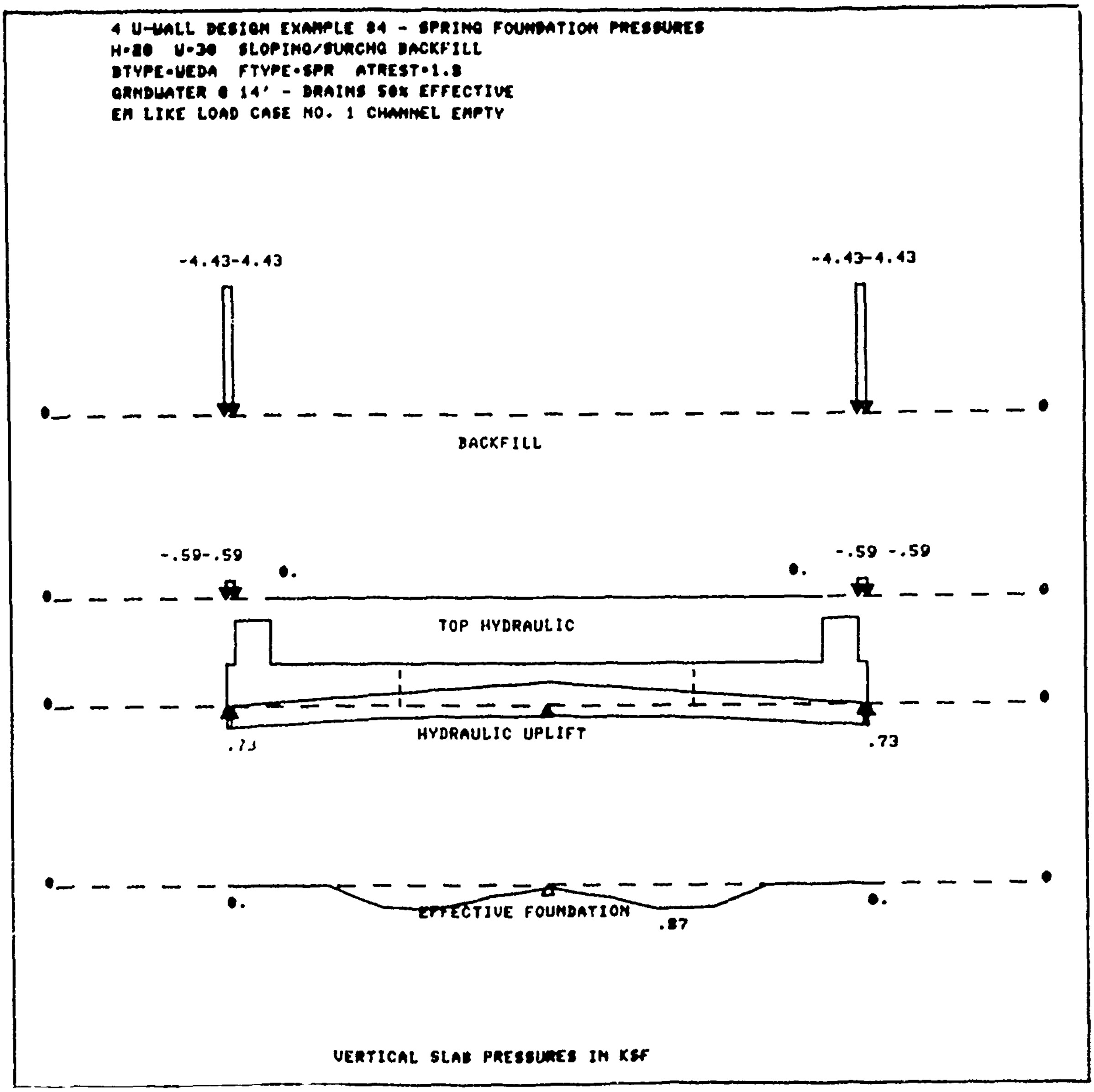


Figure B.11 Partial Graphic Output For Example 4 (Sheet 2 of 3)

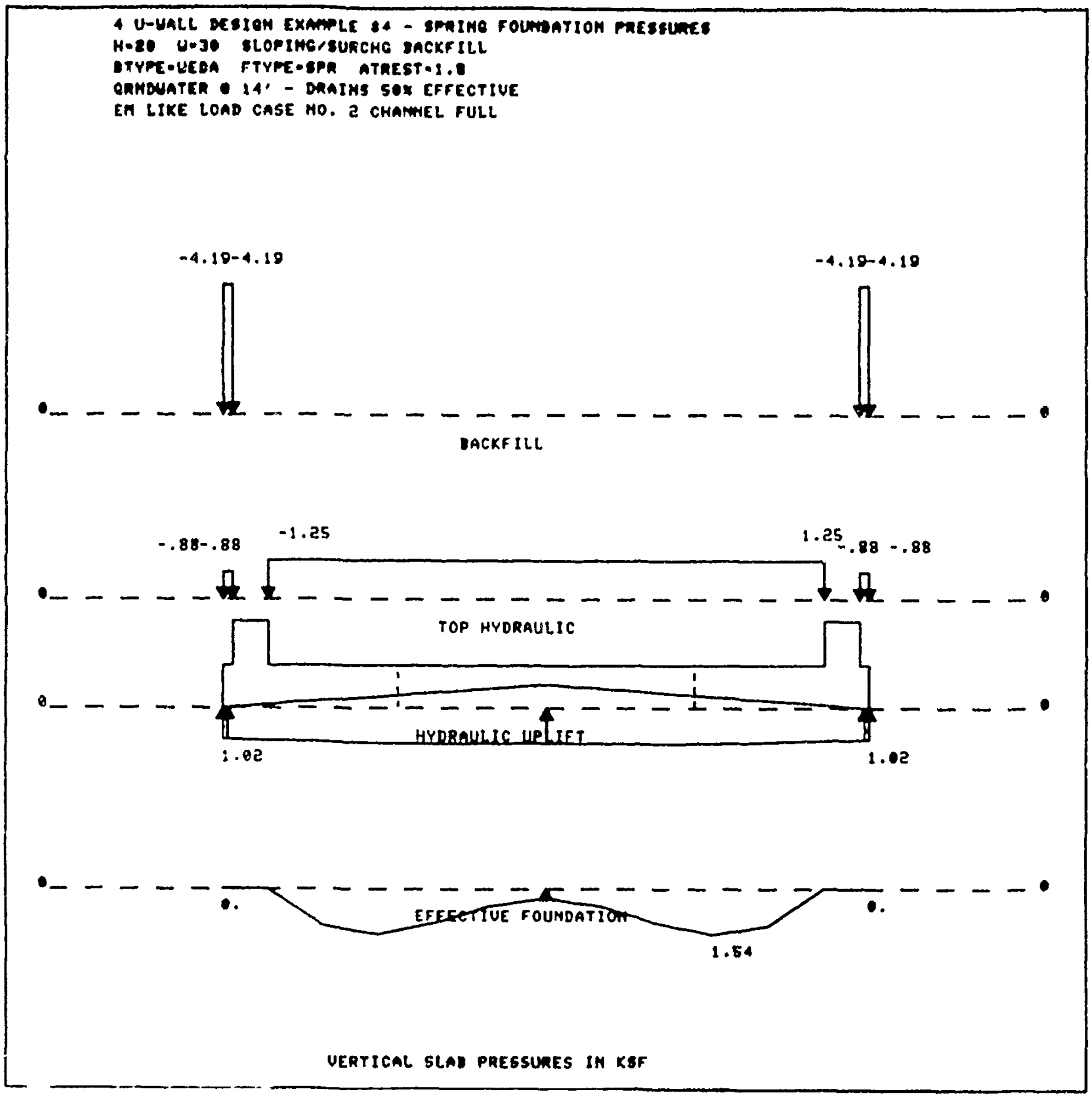


Figure B.11 Partial Graphic Output For Example 4 (Sheet 3 of 3)

```
************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF   *
*            BASINS AND CHANNELS                 *
*               BY C. O. HAYS                    *
*          REVISED   18 JULY  1989               *
************************************************
```

```
    I.    INPUT DATA *** AND FINAL DESIGN VALUES ***
                     *** FOR DESIGN VARIABLES    ***

    I.1  HEADING

    4 U-WALL DESIGN EXAMPLE #4 - SPRING FOUNDATION PRESSURES
    H=20  W=30  SLOPING/SURCHG BACKFILL
    BTYPE=WEDA  FTYPE=SPR  ATREST=1.8
    GRNDWATER @ 14' - DRAINS 50% EFFECTIVE


    I.2   MODE AND PROCEDURE

          DESIGN MODE
          WORKING STRESS DESIGN
          1 CHANNEL STRUCTURE
          INPUT FILE NAME IS "DSGNDI"
          OUTPUT FILE NAME IS "DSGNDO"
          PLOT STORAGE FILE NAME IS "DSGNDP"

          WALL DRAIN DATA INCLUDED
          BASE SLAB DRAIN DATA INCLUDED


    I.3 MATERIAL PROPERTIES

       CONCRETE:
         ULTIMATE STRENGTH          = 3.000   KSI
         MODULUS OF ELASTICITY      = 3123.   KSI
         UNIT WEIGHT                =  .150   KCF
         ALLOWABLE STRESS           =  1.35   KSI


       REINFORCEMENT:
         ALLOWABLE STRESS           =   20.0   KSI
         MODULUS OF ELASTICITY      = 29000.   KSI
         MODULAR RATIO              =   9.28
```

Figure B.12 Partial Output File For Example 4 (Sheet 1 of 5)

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION			/ WIDTH		ELEV.
TOP	BREAK	SLAB	TOP	BOTTOM	DRAIN
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL	ELDRL
(FT)	(FT)	(FT)	(IN)	(IN)	(FT)
20.00	20.00	0.00	10.00	22.00	5.00
			10.00	23.00	(FINAL DESIGN VALUES)

SLAB AND HEEL DIMENSIONS

DEPTH	/		WIDTHS(LEFT)		
			HEEL	CHANNEL	WALL TO
			'AX.		DRAIN
			.M	WIDTHL	DRSPL
			.T)	(FT)	(FT)
			.50	30.00	7.00
.0		.50	(FINAL DESIGN VALUES)		

I.5 REINFORCEMENT FOR DESIGN OPTION

NUMBER OF LAYERS	
WALL	SLAB
NOLAYW	NOLAYSB
1	1

CLEAR COVER (IN)

COVER(1)	COVER(2)	COVER(3)	COVER(4)
2.50	3.00	3.00	3.50

MAXIMUM AREAS PER LAYER AND DIAMETERS

WALL BELOW BREAK		SLAB	
AREA	DIAM.	AREA	DIAM.
AWBMAX	DWBMAX	ASBMAX	DSBMAX
(SI/FT)	(IN)	(SI/FT)	(IN)
3.00	1.25	3.00	1.25

I.7 LOADING CONTROL

2 EM-LIKE LOAD CASES
USING ACTIVE WEDGE METHOD FOR SOIL PRESSURES
ELASTIC SPRING FOUNDATION
MINIMUM UPLIFT FACTOR OF SAFETY - 1.10
MINIMUM BEARING FACTOR OF SAFETY = 1.10

Figure B.12 Partial Output File For Example 4 (Sheet 2 of 5)

I.8 HYDRAULIC STRESS AND STRENGTH DATA

```
******** EM-LIKE LOAD CASE  1   ********CHANNEL EMPTY        ********
         ALLOWABLE STRESS MULTIPLIER =  1.00
**********************************************************************


SYMMETRICAL WATER ELEVATIONS (FT)

   BACKFILL      CHANNEL
       LEFT         LEFT
     ELBWSL       ELCWSL
      14.00         0.00


DRAIN FACTORS AND AT REST MULTIPLIERS

  PERCENT EFFECTIVE / MULTIPLIER
  LEFTWALL    SLABLEFT   BACKFILL
    PDRNWL      PDRNSL    ATRESTS
     50.00       50.00       1.00


******** EM-LIKE LOAD CASE  2   ********CHANNEL FULL         ********
         ALLOWABLE STRESS MULTIPLIER =  1.00
**********************************************************************


SYMMETRICAL WATER ELEVATIONS (FT)

   BACKFILL      CHANNEL
       LEFT         LEFT
     ELBWSL       ELCWSL
      14.00        20.00


DRAIN FACTORS AND AT REST MULTIPLIERS

  PERCENT EFFECTIVE / MULTIPLIER
  LEFTWALL    SLABLEFT   BACKFILL
    PDRNWL      PDRNSL    ATRESTS
     50.00       50.00       1.80
```

Figure B.12 Partial Output File For Example 4 (Sheet 3 of 5)

I.9 SOILS DATA FOR WEDGE METHOD

BACKFILL SOIL PROPERTIES

UNIT WEIGHTS DRAINED	SAT.	PHI ANGLE	COHESION	WALL FRICTION ANGLE
UWSD	UWSS	SPHI	SCOHE	DELFW
(KCF)	(KCF)	(DEG)	(KSF)	(DEG)
.130	.140	30.000	0.000	15.000

BACKFILL DATA LEFT SIDE (SYMMETRICAL)

DISTANCES				/			
BACKFILL		SURCHARGE			BACKFILL		ROCK
SLOPE	HORZ.	START	LENGTH	WEIGHT	ELEV.	ANGLE	ELEV.
SOJL	SOKL	SOLL	SOML	UWSURL	ELGSL	ANBSL	ELRSL
(FT)	(FT)	(FT)	(FT)	(KSF)	(FT)	(DEG)	(FT)
20.00	5.00	25.00	8.00	1.00	20.00	27.00	-5.00

I.13 ELASTIC SPRING FOUNDATION PROPERTIES

	SOIL			/	ANCHORS
STRENGTH	SPRING MODULI VERT.	HORZ.	COHESION	FRICTION	NUMBER
FPF	SCFV	SCFH	FCOHE	DELFF	NANCK
(KSF)	(KCI)	(KCI)	(KSF)	(DEG)	
8.00	.500	.250	0.00	25.00	0

O. OUTPUT RESULTS

O.1 FACTORS OF SAFETY

FACTOR OF SAFETY AGAINST UPLIFT	BEARING	HORIZONTAL EQUILIBRIUM FACTOR	EM-LIKE LOAD CASE	SPECIAL LOAD CASE
1.82	9.22	9999.99	1	
1.75	5.20	9999.99	2	

Figure B.12 Partial Output File For Example 4 (Sheet 4 of 5)

0.2 SUMMARY OF STEEL REQUIREMENTS BY MEMBER

************* MEMBER 2 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00						
3.00						
6.00						
9.00						
12.00	1.250	.01			.0001	10.96
15.00	1.250	.01			.0001	8.38

********** BOTTOM STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00	1.250	2.16			.0087	20.79
3.00	1.250	1.40			.0064	18.21
6.00	1.250	.51			.0027	15.63
9.00	1.250	.01			.0001	13.04
12.00						
15.00						

************* MEMBER 11 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
20.00						
18.00	1.250	.01			.0001	8.18
16.00	1.250	.01			.0001	9.48
14.00	1.250	.05			.0004	10.78
12.00	1.250	.13			.0009	12.08
10.00	1.250	.26			.0016	13.38
8.00	1.250	.45			.0026	14.68
6.00	1.250	.75			.0039	15.98
4.00	1.250	1.19			.0057	17.28
2.00	1.250	1.76			.0079	18.58
0.00	1.250	2.48			.0104	19.88

********** BOTTOM STEEL **********
NONE REQUIRED FOR STRENGTH

Figure B.12 Partial Output File For Example 4 (Sheet 5 of 5)

Example 5

11. Example 5 is the final design example for a two-bay channel with elastic anchors to help resist uplift. The internal water elevations were set different to allow for the design of the central wall. The only unsymmetrical loading allowed by the program in the design mode is for the case of unequal internal water elevations for a two-bay U-frame. As for all designs, the designer is responsible to ensure that sufficient load cases are specified to define the critical conditions for all portions of the channel.

12. The base slab pressure distributions are shown in the computer graphic output (Figure B.14). The partial printed output file contains the echo of data, anchor forces, safety factors, final design dimensions, and steel requirements. The anchor forces are all well below the input maximums. Thus the anchors could probably be reduced in size or number and the program rerun.

```
01010 4 U-WALL DESIGN EXAMPLE #5 - 2-BAY CHANNEL
01020 EXT WALL HT = 20  CTR WALL = 18  W=20,20  FTG = 15
01030 BTYPE=WEDA  FTYPE=SPR  ATREST=1.8
01040 INCL 5 TENSION ANCHORS EA SIDE WITH 16' OF WATER
02010   DES  WSD  CHA      2    DSGNEI  DSGNEO  DSGNEP
02020   NO   NO
03010     3.000     .150    1.350   20.000
04010    20.000   20.000    0.000   10.000   17.000
04020    22.000   18.000    0.500    0.500   20.000  15.000
04030    18.000   12.000   24.000
05010   1  1
05020     2.500    3.000    3.000    3.500
05030     3.000    1.250    3.000    1.250
07010  2  WEDA   SPR     1.10     1.10
08010 SYM     1.000  CHANNEL EMPTY
08020    16.000    0.000
08030     1.000
08040 NON     1.000  ONE CHANNEL FULL
08050     8.000   18.000    0.000
08060     1.800
09010      .130     .140   30.000    0.000   15.000
09020      0.00     0.00     0.00     0.00    0.000   20.000  0.0 -5.0
13010     8.000      .500   0.250     0.000  25.000  5  30.000  15.000
13020      -1.400      5.100      5.100      5.100      5.100
```

Figure B.13 Input File For Example 5

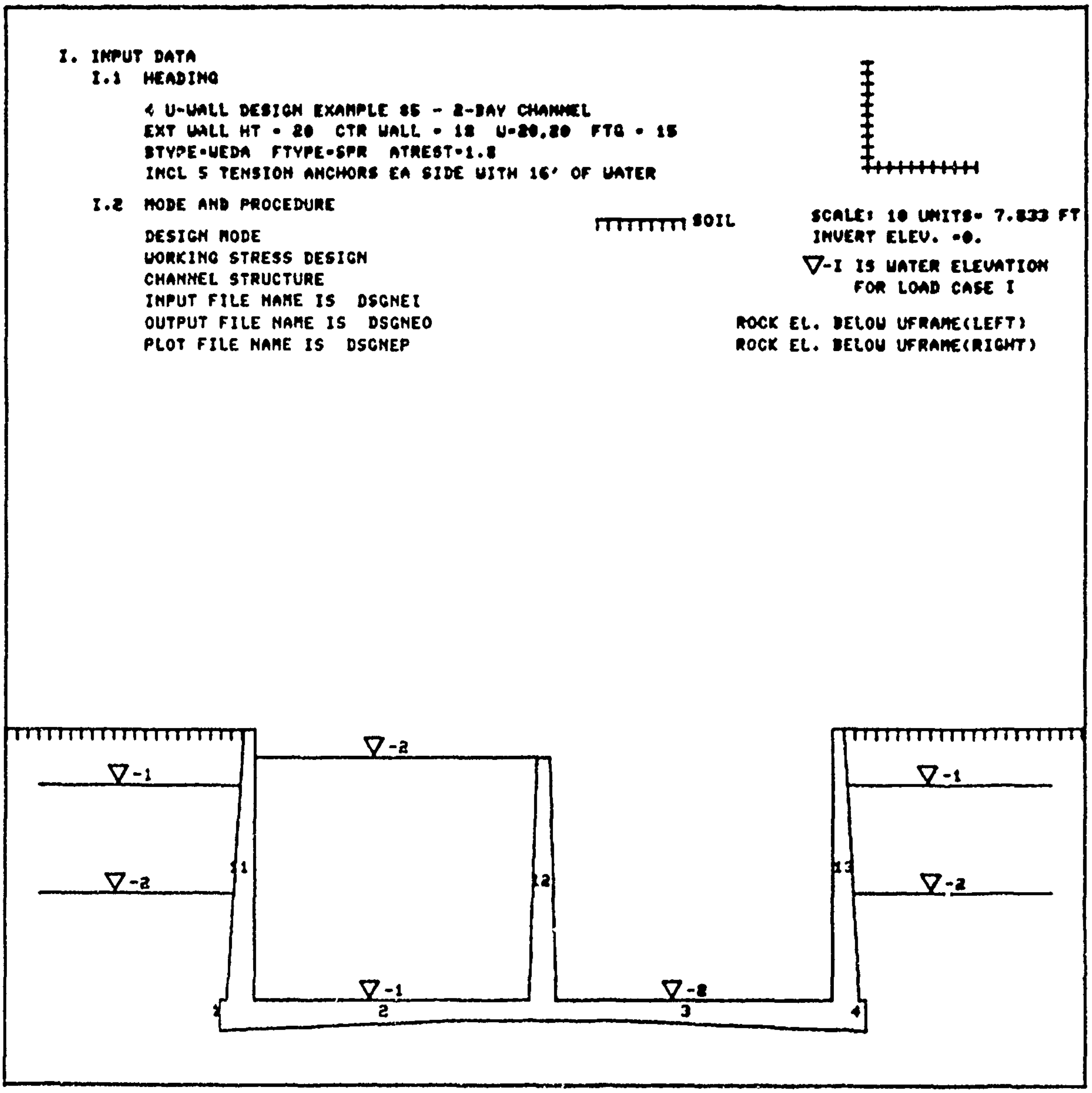


Figure B.14 Partial Graphic Output For Example 5 (Sheet 1 of 3)

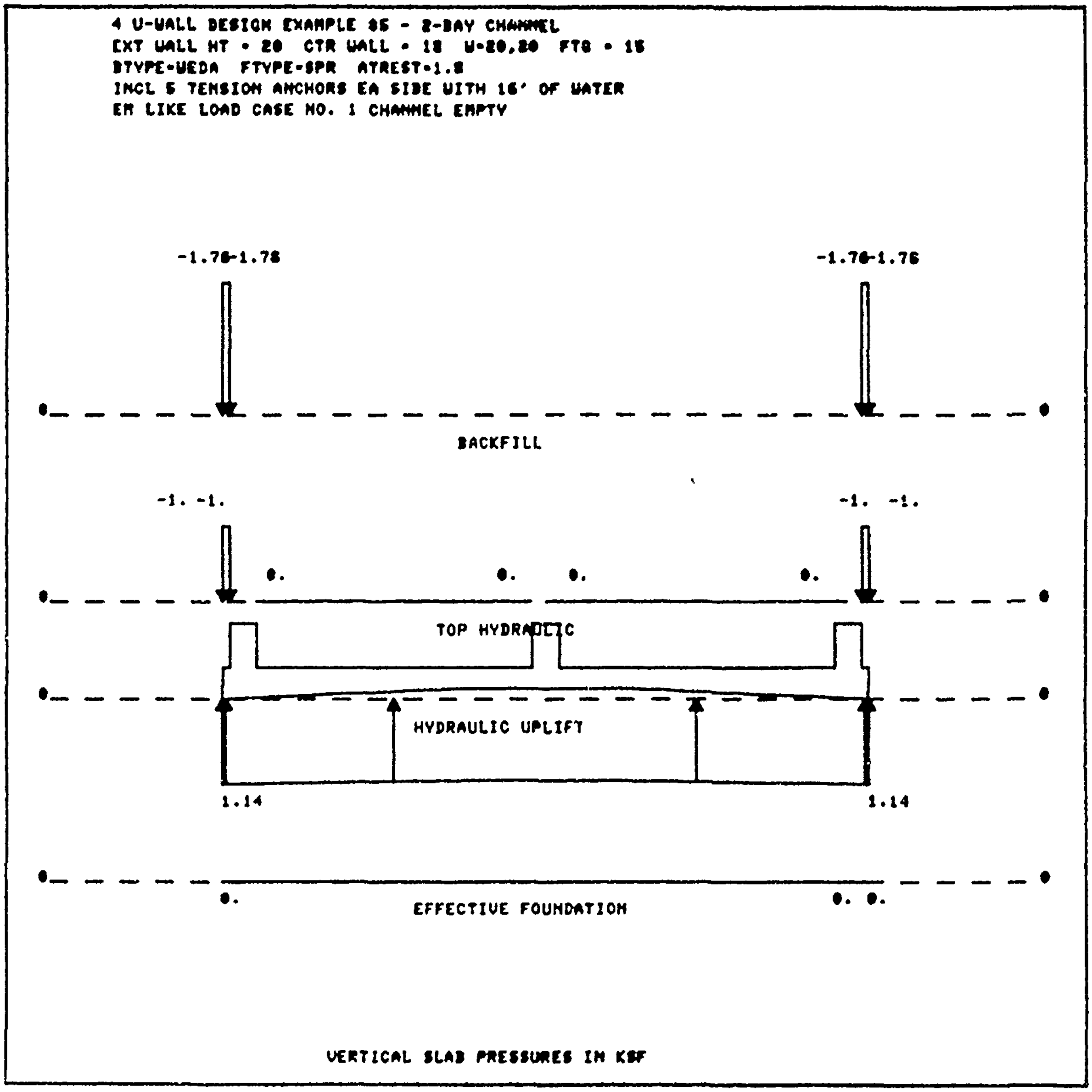


Figure B.14 Partial Graphic Output For Example 5 (Sheet 2 of 3)

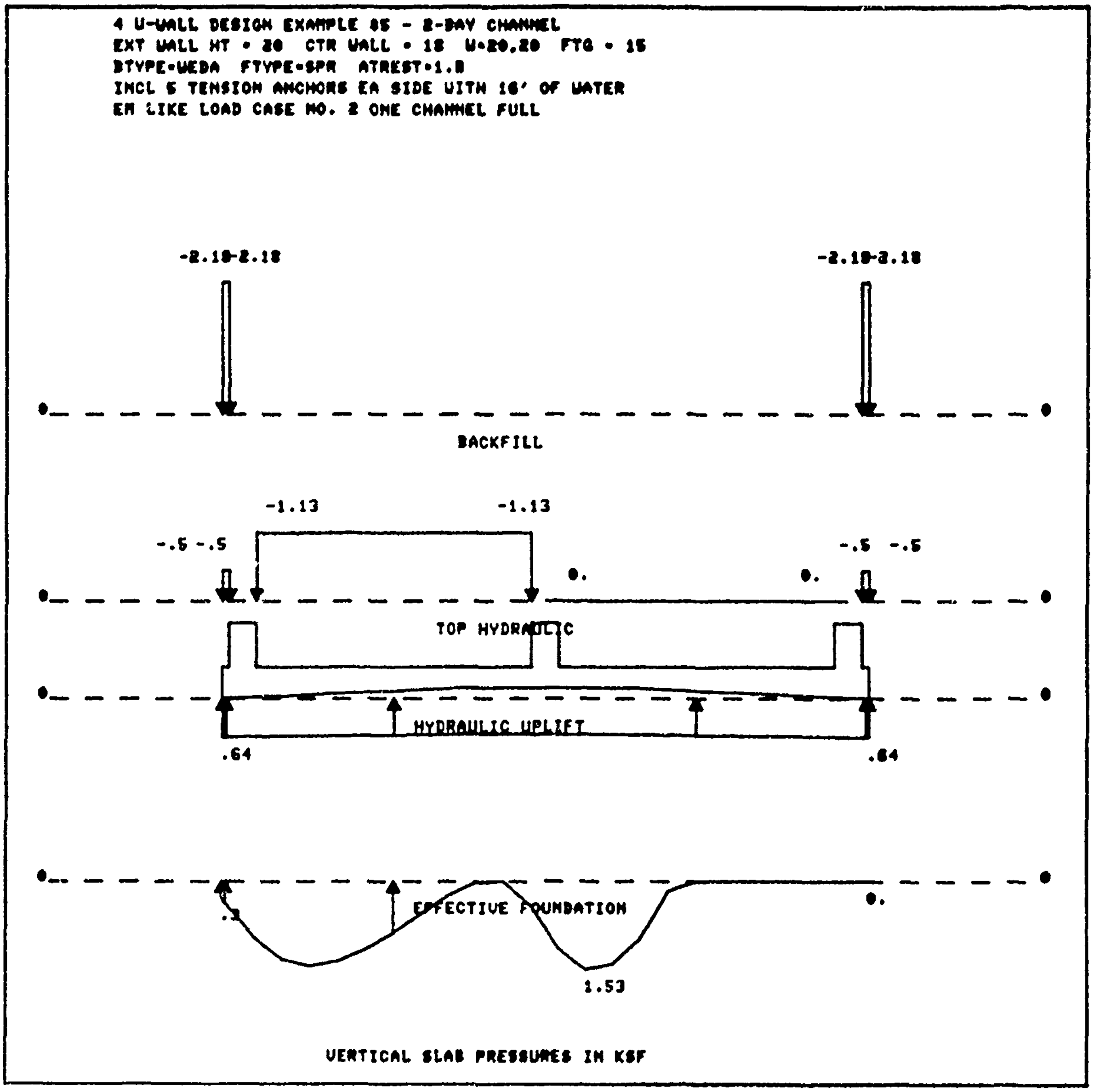


Figure B.14 Partial Graphic Output For Example 5 (Sheet 3 of 3)

```
**************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF   *
*              BASINS AND CHANNELS               *
*                 BY C. O. HAYS                  *
*             REVISED   18 JULY  1989            *
**************************************************


    I.    INPUT DATA *** AND FINAL DESIGN VALUES ***
                     *** FOR DESIGN VARIABLES    ***

    I.1  HEADING

    4 U-WALL DESIGN EXAMPLE #5 - 2-BAY CHANNEL
    EXT WALL HT = 20  CTR WALL = 18  W=20,20  FTG = 15
    BTYPE=WEDA  FTYPE=SPR  ATREST=1.8
    INCL 5 TENSION ANCHORS EA SIDE WITH 16' OF WATER


    I.2   MODE AND PROCEDURE

          DESIGN MODE
          WORKING STRESS DESIGN
          2 CHANNEL STRUCTURE
          INPUT FILE NAME IS "DSGNEI"
          OUTPUT FILE NAME IS "DSGNEO"
          PLOT STORAGE FILE NAME IS "DSGNEP"

          WALL DRAIN DATA OMITTED
          BASE SLAB DRAIN DATA OMITTED


    I.3 MATERIAL PROPERTIES


       CONCRETE:
         ULTIMATE STRENGTH          = 3.000    KSI
         MODULUS OF ELASTICITY      = 3123.    KSI
         UNIT WEIGHT                =  .150    KCF
         ALLOWABLE STRESS           =  1.35    KSI


       REINFORCEMENT:
         ALLOWABLE STRESS           =   20.0    KSI
         MODULUS OF ELASTICITY      = 29000.    KSI
         MODULAR RATIO              =   9.28
```

Figure B.15 Partial Output File For Example 5 (Sheet 1 of 7)

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION			WIDTH		
TOP	BOTTOM	SLAB	TOP	BOTTOM	
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL	
(FT)	(FT)	(FT)	(IN)	(IN)	
20.00	20.00	0.00	10.00	17.00	
			10.00	24.00	(FINAL DESIGN VALUES)

SLAB AND HEEL DIMENSIONS

DEPTH			WIDTHS(LEFT)		
	SLAB	HEEL	HEEL	CHANNEL	WALL TO
LEFT	CENTER		MAX.		SLAB BREAK
DEPTHL	DEPTHC	WHEELL	WHEELLM	WIDTHL	DISCL
(IN)	(IN)	(FT)	(FT)	(FT)	(FT)
22.00	18.00	.50	.50	20.00	15.00
27.00	18.00	.50	(FINAL DESIGN VALUES)		

INTERIOR WALL DIMENSIONS

ELEV.	WALL THICKNESS		
TOP	TOP	BOTTOM	
ELTOPC	WALLTC	WALLBC	
(FT)	(IN)	(IN)	
18.00	12.00	24.00	
	12.00	24.00	(FINAL DESIGN VALUES)

I.5 REINFORCEMENT FOR DESIGN OPTION

NUMBER OF LAYERS	
WALL	SLAB
NOLAYW	NOLAYSB
1	1

CLEAR COVER (IN)

COVER(1)	COVER(2)	COVER(3)	COVER(4)
2.50	3.00	3.00	3.50

Figure B.15 Partial Output File For Example 5 (Sheet 2 of 7)

```
MAXIMUM AREAS PER LAYER AND DIAMETERS

 WALL BELOW BREAK           SLAB
    AREA    DIAM.     AREA    DIAM.
  AWBMAX   DWBMAX   ASBMAX   DSBMAX
 (SI/FT)     (IN)  (SI/FT)     (IN)
    3.00     1.25     3.00     1.25

    I.7 LOADING CONTROL

        2 EM-LIKE LOAD CASES
        USING ACTIVE WEDGE METHOD FOR SOIL PRESSURES
        ELASTIC SPRING FOUNDATION
        MINIMUM UPLIFT FACTOR OF SAFETY  = 1.10
        MINIMUM BEARING FACTOR OF SAFETY = 1.10


    I.8 HYDRAULIC STRESS AND STRENGTH DATA


******** EM-LIKE LOAD CASE  1   ********CHANNEL EMPTY        ********
         ALLOWABLE STRESS MULTIPLIER =  1.00
**********************************************************************


SYMMETRICAL WATER ELEVATIONS (FT)

   BACKFILL     CHANNEL
       LEFT        LEFT
     ELBWSL      ELCWSL
      16.00        0.00


AT REST MULTIPLIERS

  BACKFILL
   ATRESTS
      1.00


******** EM-LIKE LOAD CASE  2   ********ONE CHANNEL FULL     ********
         ALLOWABLE STRESS MULTIPLIER =  1.00
**********************************************************************


NONSYMMETRICAL WATER ELEVATIONS (FT)

   BACKFILL     CHANNEL     CHANNEL
       LEFT        LEFT       RIGHT
     ELBWSL      ELCWSL      ELCWSR
       8.00       18.00        0.00
```

Figure B.15 Partial Output File For Example 5 (Sheet 3 of 7)

AT REST MULTIPLIERS

BACKFILL
ATRESTS
1.80

I.9 SOILS DATA FOR WEDGE METHOD

BACKFILL SOIL PROPERTIES

UNIT WEIGHTS DRAINED	SAT.	PHI ANGLE	COHESION	WALL FRICTION ANGLE
UWSD	UWSS	SPHI	SCOHE	DELFW
(KCF)	(KCF)	(DEG)	(KSF)	(DEG)
.130	.140	30.000	0.000	15.000

BACKFILL DATA LEFT SIDE (SYMMETRICAL)

DISTANCES				/			
BACKFILL		SURCHARGE			BACKFILL		ROCK
SLOPE	HORZ.	START	LENGTH	WEIGHT	ELEV.	ANGLE	ELEV.
SOJL	SOKL	SOLL	SOML	UWSURL	ELGSL	ANBSL	ELRSL
(FT)	(FT)	(FT)	(FT)	(KSF)	(FT)	(DEG)	(FT)
0.00	0.00	0.00	0.00	0.00	20.00	0.00	-5.00

I.13 ELASTIC SPRING FOUNDATION PROPERTIES

	SOIL				/	ANCHORS	
STRENGTH	SPRING MODULI VERT.	HORZ.	COHESION	FRICTION	NUMBER	SPRING MODULUS	MAXIMUM FORCE
FPF	SCFV	SCFH	FCOHE	DELFF	NANCK	AKP	AKM
(KSF)	(KCI)	(KCI)	(KSF)	(DEG)		(KSF)	(K/F)
8.00	.500	.250	0.00	25.00	5	30.00	15.00

DISTANCES TO ELASTIC ANCHORS (FT)

ASP(1)	ASP(2)..........			
-1.400	5.100	5.100	5.100	5.100

Figure B.15 Partial Output File For Example 5 (Sheet 4 of 7)

O. OUTPUT RESULTS

O.1 FACTOR OF SAFETY AND ANCHOR FORCES

FACTOR OF SAFETY AGAINST UPLIFT	FACTOR OF SAFETY AGAINST BEARING	HORIZONTAL EQUILIBRIUM FACTOR	EM-LIKE LOAD CASE	SPECIAL LOAD CASE
3.60	9999.99	9999.99	1	
7.31	5.24	9999.99	2	

******** EM-LIKE LOAD CASE 1 ********CHANNEL EMP˜ ********
^ .**************

ANCHOR FORCES AND FACTORS OF SAFETY

DISTANCE FROM LEFT END OF SLAB (FT)	ANCHOR FORCE (KIP/FT)	ANCHOR SAFETY FACTOR
1.10	2.51	5.98
6.20	2.09	7.17
11.30	1.83	8.20
16.40	1.69	8.90
21.50	1.63	9.20
25.50	1.63	9.19
30.60	1.69	8.89
35.70	1.83	8.19
40.80	2.09	7.17
45.90	2.51	5.98

******** EM-LIKE LOAD CASE 2 ********ONE CHANNEL FULL ********
****

ANCHOR FORCES AND FACTORS OF SAFETY

DISTANCE FROM LEFT END OF SLAB (FT)	ANCHOR FORCE (KIP/FT)	ANCHOR SAFETY FACTOR
1.10	0.00	9999.99
6.20	0.00	9999.99
11.30	0.00	9999.99
16.40	0.00	9999.99
21.50	0.00	9999.99

Figure B.15 Partial Output File For Example 5 (Sheet 5 of 7)

25.50	0.00	9999.99
30.60	0.00	9999.99
35.70	.08	189.25
40.80	.34	44.13
45.90	.79	18.94

O.2 SUMMARY OF STEEL REQUIREMENTS BY MEMBER

************* MEMBER 2 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00						
2.00						
4.00						
6.00						
8.00						
10.00						
12.00						
14.00	1.250	.01			.0001	14.89
16.00	1.250	.11			.0006	14.38
18.00	1.250	.47			.0027	14.38
20.00	1.250	.98			.0057	14.38

********** BOTTOM STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
0.00	1.250	2.39			.0092	21.59
2.00	1.250	1.97			.0080	20.56
4.00	1.250	1.62			.0069	19.53
6.00	1.250	1.21			.0055	18.50
8.00	1.250	.90			.0043	17.48
10.00	1.250	.59			.0030	16.45
12.00	1.250	.34			.0018	15.42
14.00	1.250	.20			.0012	14.39
16.00	1.250	.06			.0003	13.88
18.00	1.250	.07			.0005	13.88
20.00	1.250	.18			.0011	13.88

Figure B.15 Partial Output File For Example 5 (Sheet 6 of 7)

************* MEMBER 11 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
20.00						
18.00	1.250	.01			.0001	8.28
16.00	1.250	.02			.0002	9.68
14.00	1.250	.07			.0006	11.08
12.00	1.250	.15			.0010	12.48
10.00	1.250	.32			.0019	13.88
8.00	1.250	.58			.0032	15.28
6.00	1.250	.93			.0047	16.68
4.00	1.250	1.39			.0064	18.08
2.00	1.250	1.95			.0083	19.48
0.00	1.250	2.63			.0105	20.88

********** BOTTOM STEEL **********
NONE REQUIRED FOR STRENGTH

************* MEMBER 12 *************

********** TOP STEEL **********

DISTANCE (FT)	BAR DIAM. (IN)	AREAS (SI/FT) BY LAYER 1	2	3	STEEL RATIO AS/12*D	DEPTH(D) (IN)
18.00						
16.20	1.250	.01			.0001	9.58
14.40	1.250	.01			.0001	10.78
12.60	1.250	.06			.0004	11.98
10.80	1.250	.15			.0009	13.18
9.00	1.250	.29			.0017	14.38
7.20	1.250	.48			.0026	15.58
5.40	1.250	.74			.0037	16.78
3.60	1.250	1.06			.0049	17.98
1.80	1.250	1.44			.0063	19.18
0.00	1.250	1.90			.0078	20.38

********** BOTTOM STEEL **********
NONE REQUIRED FOR STRENGTH

Figure B.15 Partial Output File For Example 5 (Sheet 7 of 7)

Example 6

13. Example 6 is an investigation of a two-bay channel. Two options not allowed in the design mode are used for this example, the passive wedge solution, and special loads. The passive wedge solution is selected for the right wall based on the ground profile and surcharge conditions. As discussed in the text, the passive wedge pressures are not used directly for the right wall. The stress conditions are reviewed at a number of points in the channel which requires that the steel areas and positions be input at the review sections.

14. The partial printed output file contains the echo of data and safety factors, in addition to information about the stress conditions at the review points. Output Section 0.2 contains a summary of the critical stress conditions for all load cases (two Em-like load cases plus the special loads combine with the second Em-like load case). The complete output Section 0.3 would contain detailed stress conditions for each individual load case. However, only the results for Em-like load case one are included herein for brevity.

```
01010 4 INVESTIGATION EXAMPLE 1
01020  2-BAY CHANNEL W/ SPECIAL LOADS
01030 HL=20  HC=16  HR=12;   WL=16  WR=14
01040 BTYPE = WEDPR  FTYPE = SPR  SLOPE/SRCHG ON LEFT
02010   INV  WSD  CHA       2     INEX1I  INEX1O  INEX1P
02020   YES  YES  NON
03010     3.000     .150    1.350   20.000
04010    20.000   18.000    0.000   12.000   32.000    5.000
04020    12.000   12.000   10.000   21.000    5.000
04030    35.000   30.000     .500   16.000    8.000   14.000
04040    25.000     .500    8.000   14.000   12.000
04050    16.000   12.000   20.000
06010  5  ARE
06020     2.500    3.000    3.000    3.500
06030    11    2
06040     0.000    1    1
06050     1.400    2.830
06060      .750     .440
06070    10.000    1    1
06080      .870     .600
06090      .750     .440
06100    12    1
06110     0.000    1    1
06120     1.300    2.270
06130     1.300    2.200
06140    13    2
06150     0.000    1    1
06160      .890     .600
06170     1.300    2.270
06180     6.000    1    1
06190      .870     .600
06200     1.000    1.000
06210     2    3
06220     0.000    1    1
06230      .440     .600
06240     1.400    2.830
06250     9.000    1    1
06260     1.000    1.440
06270     1.000    1.440
06280    16.000    1    1
06290      .870     .600
06300     1.000    1.790
```

Figure B.16 Input File For Example 6 (Sheet 1 of 2)

```
06310      3    3
06320      0.000    1    1
06330       .750     .440
06340      1.000    1.790
06350      7.000    1    1
06360       .750     .440
06370      1.000    1.790
06380     14.000    1    1
06390       .750     .440
06400      1.000    2.270
07010  2  WEDPR   1  SPR
08010 NON  CASE 1 - CHAN EMPTY
08020     12.000    0.000    0.000   12.000
08030     50.000   50.000   50.000   50.000    1.000
08040 NON  CASE 2-ONE CHAN FULL
08050      0.000   16.000    0.000    0.000
08060     50.000   50.000   50.000   50.000    1.800
09010       .130     .140   30.000    0.000   10.000  NON
09020      20.00     5.00    25.00     8.00    1.000   20.0   17.0   -5.0
09030       0.00     0.00     0.00     0.00    0.000   12.0    0.0   -5.0
12010      1    2  CASE 3 - CONC LDS
12020      11     1     0
12030      20.000     0.000    -5.000     0.000
13010      8.000      .500      .250     0.000    25.000     0
```

Figure B.16 Input File For Example 6 (Sheet 2 of 2)

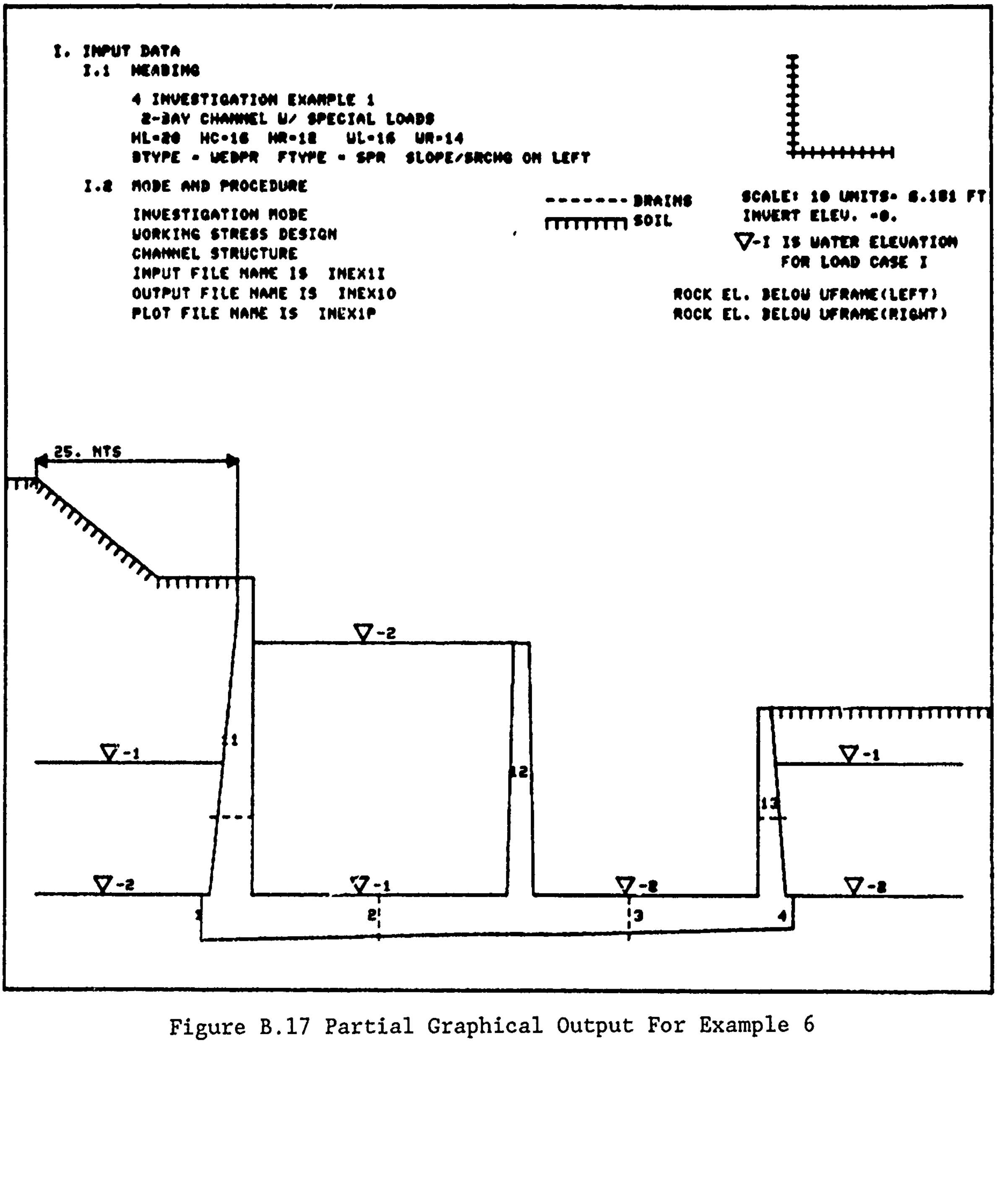


Figure B.17 Partial Graphical Output For Example 6

```
***************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF    *
*           BASINS AND CHANNELS                    *
*              BY C. O. HAYS                       *
*          REVISED  18 JULY  1989                  *
***************************************************
```

I. INPUT DATA

I.1 HEADING

4 INVESTIGATION EXAMPLE 1
2-BAY CHANNEL W/ SPECIAL LOADS
HL=20 HC=16 HR=12; WL=16 WR=14
BTYPE - WEDPR FTYPE - SPR SLOPE/SRCHG ON LEFT

I.2 MODE AND PROCEDURE

INVESTIGATION MODE
WORKING STRESS DESIGN
2 CHANNEL STRUCTURE
INPUT FILE NAME IS "INEX1I"
OUTPUT FILE NAME IS "INEX1O"
PLOT STORAGE FILE NAME IS "INEX1P"

WALL DRAIN DATA INCLUDED
BASE SLAB DRAIN DATA INCLUDED
CHANNEL IS GEOMETRICALLY NONSYMMETRICAL

I.3 MATERIAL PROPERTIES

CONCRETE:

ULTIMATE STRENGTH	= 3.000	KSI
MODULUS OF ELASTICITY	= 3123.	KSI
UNIT WEIGHT	= .150	KCF
ALLOWABLE STRESS	= 1.35	KSI

REINFORCEMENT:

ALLOWABLE STRESS	= 20.0	KSI
MODULUS OF ELASTICITY	= 29000.	KSI
MODULAR RATIO	= 9.28	

Figure B.18 Partial Output File For Example 6 (Sheet 1 of 14)

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION			/ WIDTH		ELEV.
TOP	BREAK	SLAB	TOP	BOTTOM	DRAIN
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL	ELDRL
(FT)	(FT)	(FT)	(IN)	(IN)	(FT)
20.00	18.00	0.00	12.00	32.00	5.00

RIGHT EXTERIOR WALL

ELEVATION	/	WIDTH	/	ELEV.
TOP	BREAK	TOP	BOTTOM	DRAIN
ELTOPR	ELBRKR	WALLTR	WALLBR	ELDRR
(FT)	(FT)	(IN)	(IN)	(FT)
12.00	12.00	10.00	21.00	5.00

SLAB AND HEEL DIMENSIONS

DEPTH	/	WIDTHS(LEFT)			
SLAB		HEEL	CHANNEL	WALL TO	WALL TO
LEFT	CENTER			DRAIN	SLAB BREAK
DEPTHL	DEPTHC	WHEELL	WIDTHL	DRSPL	DISCL
(IN)	(IN)	(FT)	(FT)	(FT)	(FT)
35.00	30.00	.50	16.00	8.00	14.00

RIGHT SIDE SLAB AND HEEL DIMENSIONS

DEPTH /	WIDTH			
SLAB	HEEL	WALL TO DRAIN	CHANNEL	WALL TO SLAB BREAK
DEPTHR	WHEELR	DRSPR	WIDTHR	DISCR
(IN)	(FT)	(FT)	(FT)	(FT)
25.00	.50	8.00	14.00	12.00

INTERIOR WALL DIMENSIONS

ELEV. /	WALL THICKNESS	
TOP	TOP	BOTTOM
ELTOPC	WALLTC	WALLBC
(FT)	(IN)	(IN)
16.00	12.00	20.00

I.6 REINFORCEMENT FOR INVESTIGATION OPTION

5 MEMBERS INVESTIGATED * AREA OPTION FOR REINFORCEMENT

Figure B.18 Partial Output File For Example 6 (Sheet 2 of 14)

```
CLEAR COVER (IN)

COVER(1) COVER(2) COVER(3) COVER(4)
    2.50     3.00     3.00     3.50

MEMBER # 11 *****  2 SECTIONS INVESTIGATED

REINFORCEMENT DESCRIPTION

LOCATION DISTANCE  NUMBER OF LAYERS
                      TOP  BOTTOM
     LOC   DR(FT)   NTOPL   NBOTL

       1     0.00       1       1
                                  ***** TOP STEEL *****
                                  BAR DIAMETER      AREA PER LAYER
                                  OUTER   LAYER - 1
                                  DIAMB    AREAB(1)
                                   1.40         2.83
                                  ***** BOTTOM STEEL *****
                                  BAR DIAMETER      AREA PER LAYER
                                  OUTER   LAYER - 1
                                  DIAMB    AREAB(1)
                                    .75          .44
       2    10.00       1       1
                                  ***** TOP STEEL *****
                                  BAR DIAMETER      AREA PER LAYER
                                  OUTER   LAYER - 1
                                  DIAMB    AREAB(1)
                                    .87          .60
                                  ***** BOTTOM STEEL *****
                                  BAR DIAMETER      AREA PER LAYER
                                  OUTER   LAYER - 1
                                  DIAMB    AREAB(1)
                                    .75          .44

MEMBER # 12 *****  1 SECTIONS INVESTIGATED

REINFORCEMENT DESCRIPTION

LOCATION DISTANCE  NUMBER OF LAYERS
                      TOP  BOTTOM
     LOC   DR(FT)   NTOPL   NBOTL

       1     0.00       1       1
                                  ***** TOP STEEL *****
                                  BAR DIAMETER      AREA PER LAYER
                                  OUTER   LAYER - 1
                                  DIAMB    AREAB(1)
                                   1.30         2.27
```

Figure B.18 Partial Output File For Example 6 (Sheet 3 of 14)

```
                                         ***** BOTTOM STEEL *****
                                         BAR DIAMETER      AREA PER LAYER
                                         OUTER    LAYER - 1
                                         DIAMB    AREAB(1)
                                          1.30        2.20

MEMBER # 13 *****  2 SECTIONS INVESTIGATED

REINFORCEMENT DESCRIPTION

LOCATION DISTANCE  NUMBER OF LAYERS
                      TOP  BOTTOM
     LOC   DR(FT)   NTOPL   NBOTL

       1     0.00       1       1
                                         ***** TOP STEEL *****
                                         BAR DIAMETER      AREA PER LAYER
                                         OUTER    LAYER - 1
                                         DIAMB    AREAB(1)
                                           .89         .60
                                         ***** BOTTOM STEEL *****
                                         BAR DIAMETER      AREA PER LAYER
                                         OUTER    LAYER - 1
                                         DIAMB    AREAB(1)
                                          1.30        2.27
       2     6.00       1       1
                                         ***** TOP STEEL *****
                                         BAR DIAMETER      AREA PER LAYER
                                         OUTER    LAYER - 1
                                         DIAMB    AREAB(1)
                                           .87         .60
                                         ***** BOTTOM STEEL *****
                                         BAR DIAMETER      AREA PER LAYER
                                         OUTER    LAYER - 1
                                         DIAMB    AREAB(1)
                                          1.00        1.00

MEMBER #  2 *****  3 SECTIONS INVESTIGATED

REINFORCEMENT DESCRIPTION

LOCATION DISTANCE  NUMBER OF LAYERS
                      TOP  BOTTOM
     LOC   DR(FT)   NTOPL   NBOTL

       1     0.00       1       1
                                         ***** TOP STEEL *****
                                         BAR DIAMETER      AREA PER LAYER
                                         OUTER    LAYER - 1
                                         DIAMB    AREAB(1)
                                           .44         .60
```

Figure B.18 Partial Output File For Example 6 (Sheet 4 of 14)

```
                                      ***** BOTTOM STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                       1.40        2.83
       2     9.00        1       1
                                      ***** TOP STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                       1.00        1.44
                                      ***** BOTTOM STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                       1.00        1.44
       3    16.00        1       1
                                      ***** TOP STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                        .87         .60
                                      ***** BOTTOM STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                       1.00        1.79


MEMBER #  3 *****  3 SECTIONS INVESTIGATED

REINFORCEMENT DESCRIPTION

LOCATION DISTANCE  NUMBER OF LAYERS
                     TOP  BOTTOM
     LOC   DR(FT)  NTOPL   NBOTL

       1     0.00        1       1
                                      ***** TOP STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                        .75         .44
                                      ***** BOTTOM STEEL *****
                                      BAR DIAMETER      AREA PER LAYER
                                      OUTER   LAYER - 1
                                      DIAMB    AREAB(1)
                                       1.00        1.79
```

Figure B.18 Partial Output File For Example 6 (Sheet 5 of 14)

```
    2     7.00         1        1
                                   ***** TOP STEEL *****
                                   BAR DIAMETER      AREA PER LAYER
                                   OUTER   LAYER - 1
                                   DIAMB    AREAB(1)
                                     .75          .44
                                   ***** BOTTOM STEEL *****
                                   BAR DIAMETER      AREA PER LAYER
                                   OUTER   LAYER - 1
                                   DIAMB    AREAB(1)
                                    1.00         1.79
    3    14.00         1        1
                                   ***** TOP STEEL *****
                                   BAR DIAMETER      AREA PER LAYER
                                   OUTER   LAYER - 1
                                   DIAMB    AREAB(1)
                                     .75          .44
                                   ***** BOTTOM STEEL *****
                                   BAR DIAMETER      AREA PER LAYER
                                   OUTER   LAYER - 1
                                   DIAMB    AREAB(1)
                                    1.00         2.27
```

I.7 LOADING CONTROL

```
   2 EM-LIKE LOAD CASES
   USING ACTIVE AND PASSIVE WEDGES FOR SOIL PRESSURES
   PASSIVE SOLUTION FOR RIGHT WALL
*** WHICH MAY RESULT IN WALL PRESSURES LESS THAN ATREST ***
   1 SPECIAL LOAD CASES WITH DIRECT LOAD INPUT
   ELASTIC SPRING FOUNDATION
```

I.8 HYDRAULIC STRESS AND STRENGTH DATA

```
******** EM-LIKE LOAD CASE  1   ********CASE 1 - CHAN EMPTY ********
**********************************************************************
```

NONSYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL LEFT	CHANNEL LEFT	CHANNEL RIGHT	BACKFILL RIGHT
ELBWSL	ELCWSL	ELCWSR	ELBWSR
12.00	0.00	0.00	12.00

Figure B.18 Partial Output File For Example 6 (Sheet 6 of 14)

DRAIN FACTORS AND AT REST MULTIPLIERS

PERCENT EFFECTIVE				/ MULTIPLIER
LEFTWALL	RIGHTWALL	LEFTSLAB	RIGHTSLAB	BACKFILL
PDRNWL	PDRNWR	PDRNSL	PDRNSR	ATRESTS
50.00	50.00	50.00	50.00	1.00

******** EM-LIKE LOAD CASE 2 ********CASE 2-ONE CHAN FULL ****
****

NONSYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL	CHANNEL	CHANNEL	BACKFILL
LEFT	LEFT	RIGHT	RIGHT
ELBWSL	ELCWSL	ELCWSR	ELBWSR
0.00	16.00	0.00	0.00

DRAIN FACTORS AND AT REST MULTIPLIERS

PERCENT EFFECTIVE				/ MULTIPLIER
LEFTWALL	RIGHTWALL	LEFTSLAB	RIGHTSLAB	BACKFILL
PDRNWL	PDRNWR	PDRNSL	PDRNSR	ATRESTS
50.00	50.00	50.00	50.00	1.80

I.9 SOILS DATA FOR WEDGE METHOD

BACKFILL SOIL PROPERTIES

UNIT WEIGHTS		PHI	COHESION	WALL FRICTION
DRAINED	SAT.	ANGLE		ANGLE
UWSD	UWSS	SPHI	SCOHE	DELFW
(KCF)	(KCF)	(DEG)	(KSF)	(DEG)
.130	.140	30.000	0.000	10.000

BACKFILL DATA LEFT SIDE

DISTANCES				/			
BACKFILL		SURCHARGE			BACKFILL		ROCK
SLOPE	HORZ.	START	LENGTH	WEIGHT	ELEV.	ANGLE	ELEV.
SOJL	SOKL	SOLL	SOML	UWSURL	ELGSL	ANBSL	ELRSL
:)	(FT)	(FT)	(FT)	(KSF)	(FT)	(DEG)	(FT)
20.00	5.00	25.00	8.00	1.00	20.00	17.00	-5.00

Figure B.18 Partial Output File For Example 6 (Sheet 7 of 14)

BACKFILL DATA RIGHT SIDE

BACKFILL		DISTANCES		/			
			SURCHARGE		BACKFILL		ROCK
SLOPE	HORZ.	START	LENGTH	WEIGHT	ELEV.	ANGLE	ELEV.
SOJR	SOKR	SOLR	SOMR	UWSURR	ELGSR	ANBSR	ELRSR
(FT)	(FT)	(FT)	(FT)	(KSF)	(FT)	(DEG)	(FT)
0.00	0.00	0.00	0.00	0.00	12.00	0.00	-5.00

I.12 SPECIAL LOAD CASES

******** SPECIAL LOAD CASE 1 ********CASE 3 - CONC LDS ********
****

NUMBER OF LOADED MEMEBRS = 1
REFERENCE EM-LIKE LOAD CASE = 2

LOAD DATA FOR EACH LOADED MEMBER

MEMBER NUMBER = 11
NUMBER OF CONCENTRATED LOADS = 1
NUMBER OF DISTRIBUTED LOADS = 0

CONCENTRATED LOADS

DISTANCE		LOAD	
	FORCE-X	FORCE-Y	COUPLE
DC	FXM	FYM	FCM
(FT)	(K/FT)	(K/FT)	(KF/FT)
20.00	0.00	-5.00	0.00

I.13 ELASTIC SPRING FOUNDATION PROPERTIES

	SOIL			/	ANCHORS
STRENGTH	SPRING MODULI		COHESION	FRICTION	NUMBER
	VERT.	HORZ.			
FPF	SCFV	SCFH	FCOHE	DELFF	NANCK
(KSF)	(KCI)	(KCI)	(KSF)	(DEG)	
8.00	.500	.250	0.00	25.00	0

Figure B.18 Partial Output File For Example 6 (Sheet 8 of 14)

O. OUTPUT RESULTS

O.1 FACTORS OF SAFETY

FACTOR OF SAFETY AGAINST UPLIFT	FACTOR OF SAFETY AGAINST BEARING	HORIZONTAL EQUILIBRIUM FACTOR	EM-LIKE LOAD CASE	SPECIAL LOAD CASE
1.50	6.28	3.07	1	
3.37	4.71	2.43	2	
3.77	4.13	2.52		1

O.2 SUMMARY OF MEMBER MAXIMUM STRESS OUTPUT

/ IE INDICATES EM-LIKE LOADCASE I IS CRITICAL
/ JS INDICATES SPECIAL LOADCASE J IS CRITICAL

MEMBER 2
REVIEW POINTS

DISTANCE(FT)	0.00	9.00	16.00
SHEAR(KSI)/LOADCASE	.032/ 1S	.009/ 2E	.004/ 1E
THICKNESS(FT)	34.08	31.46	30.00
"TOP" OF SECTION"			
STRESS(KSI)/LOADCASE			
COMP. STEEL	7.58/ 1E	7.07/ 1E	9.36/ 1E
COMP. CONC.	.58/ 1E	.73/ 1E	.88/ 1E
STEEL AREA(SI/FT)	.60	1.44	.60
"BOTTOM" OF SECTION"			
STRESS(KSI)/LOADCASE			
TENS. STEEL	9.18/ 1E	18.38/ 1E	18.22/ 1E
STEEL AREA(SI/FT)	2.83	1.44	1.79
DEPTH(D) (IN)	29.83	27.46	26.00

MEMBER 3
REVIEW POINTS

DISTANCE(FT)	0.00	7.00	14.00
SHEAR(KSI)/LOADCASE	.006/ 1E	.005/ 2E	.000/ 2E
THICKNESS(FT)	30.00	28.25	25.79
"TOP" OF SECTION"			
STRESS(KSI)/LOADCASE			
COMP. STEEL	9.69/ 1E	9.8[illegible]E	11.31/ 2E
COMP. CONC.	.89/ 1E	.9[illegible]E	1.04/ 2E
STEEL AREA(SI/FT)	.44	.44	.44
"BOTTOM" OF SECTION"			
STRESS(KSI)/LOADCASE			
TENS. STEEL	18.12/ 1E	16.41/ 2E	16.16/ 2E
STEEL AREA(SI/FT)	1.79	1.79	2.27
DEPTH(D) (IN)	26.00	24.25	21.79

Figure B.18 Partial Output File For Example 6 (Sheet 9 of 14)

MEMBER 11
REVIEW POINTS

DISTANCE(FT)	0.00	10.00
SHEAR(KSI)/LOADCASE	.033/ 1E	.013/ 2E
THICKNESS(FT)	32.00	20.89
"TOP" OF SECTION"		
STRESS(KSI)/LOADCASE		
TENS. STEEL	9.96/ 2E	10.87/ 2E
STEEL AREA(SI/FT)	2.83	.60
DEPTH(D) (IN)	28.80	17.95
"BOTTOM" OF SECTION"		
STRESS(KSI)/LOADCASE		
COMP. STEEL	7.56/ 1S	2.47/ 1S
COMP. CONC.	.60/ 1S	.39/ 1S
STEEL AREA(SI/FT)	.44	.44

MEMBER 12
REVIEW POINTS

DISTANCE(FT)	0.00
SHEAR(KSI)/LOADCASE	.041/ 2E
THICKNESS(FT)	20.00
"TOP" OF SECTION"	
STRESS(KSI)/LOADCASE	
TENS. STEEL	15.33/ 1S
STEEL AREA(SI/FT)	2.27
DEPTH(D) (IN)	16.35
"BOTTOM" OF SECTION"	
STRESS(KSI)/LOADCASE	
COMP. STEEL	5.17/ 1S
COMP. CONC.	.83/ 1S
STEEL AREA(SI/FT)	2.20

MEMBER 13
REVIEW POINTS

DISTANCE(FT)	0.00	6.00
SHEAR(KSI)/LOADCASE	.066/ 2E	.024/ 2E
THICKNESS(FT)	21.00	15.50
"TOP" OF SECTION"		
STRESS(KSI)/LOADCASE		
COMP. STEEL	8.82/ 2E	.40/ 2E
COMP. CONC.	1.11/ 2E	.37/ 2E
STEEL AREA(SI/FT)	.60	.60

Figure B.18 Partial Output File For Example 6 (Sheet 10 of 14)

"BOTTOM" OF SECTION"

STRESS(KSI)/LOADCASE		
TENS. STEEL	20.36/ 2E	8.34/ 2E
STEEL AREA(SI/FT)	2.27	1.00
DEPTH(D) (IN)	17.85	12.50

0.4 OUTPUT OF MEMBER FORCES / STRESSES *** BY LOAD CASE ***

******** EM-LIKE LOAD CASE 1 ********CASE 1 - CHAN EMPTY ********
****

************* MEMBER 1 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
0.00	-.0	.00	-.00	-.001	-1.34	35.00
.25	-.0	-.44	5.33	-.001	-1.32	34.93
.50	-.2	-.88	5.31	-.001	-1.31	34.85

************* MEMBER 2 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
0.00	75.2	-4.79	16.42	-.001	1.90	34.08
1.60	69.4	-2.56	16.22	-.001	1.75	33.61
3.20	67.1	-.70	15.90	-.001	1.41	33.15
4.80	67.6	.48	15.47	-.000	.88	32.68
6.40	69.0	.91	15.23	.000	.47	32.21
8.00	70.3	1.00	15.21	.001	.44	31.75
9.60	71.6	1.07	15.19	.003	.43	31.28
11.20	73.1	1.13	15.17	.004	.43	30.82
12.80	74.7	1.20	15.16	.006	.42	30.35
14.40	76.5	1.27	15.15	.008	.42	30.00
16.00	78.6	1.35	15.14	.011	.42	30.00

REVIEW OF ELASTIC STRESSES

DISTANCE	STEEL AREAS TENSION	COMPRESS.	STEEL STRESSES TENSION	COMPRESS.	CONCRETE STRESSES COMPRESS.	SHEAR
(FT)	(SI/FT)	(SI/FT)	(KSI)	(KSI)	(KSI)	(KSI)
0.00	2.83	.60	9.18	7.58	.58	.013
9.00	1.44	1.44	18.38	7.07	.73	.003
16.00	1.79	.60	18.22	9.36	.88	.004

Figure B.18 Partial Output File For Example 6 (Sheet 11 of 14)

************* MEMBER 3 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
0.00	78.2	-1.78	15.14	[illegible]	.42	30.00
1.40	75.8	-1.71	15.14	.016	.42	30.00
2.80	73.3	-1.64	15.12	.019	.42	29.72
4.20	70.7	-1.57	15.11	.022	.42	29.23
5.60	68.3	-1.49	15.09	.025	.42	28.74
7.00	66.0	-1.39	15.07	.029	.44	28.25
8.40	63.8	-1.25	15.05	.033	.47	27.75
9.80	61.9	-1.04	15.03	.037	.51	27.26
11.20	60.3	-.78	15.01	.041	.54	26.77
12.60	59.2	-.47	14.99	.046	.57	26.28
14.00	58.5	-.11	14.97	.051	.61	25.79

REVIEW OF ELASTIC STRESSES

DISTANCE	STEEL AREAS TENSION	COMPRESS.	STEEL STRESSES TENSION	COMPRESS.	CONCRETE STRESSES COMPRESS.	SHEAR
(FT)	(SI/FT)	(SI/FT)	(KSI)	(KSI)	(KSI)	(KSI)
0.00	1.79	.44	18.12	9.69	.89	.006
7.00	1.79	.44	16.07	8.99	.84	.005
14.00	2.27	.44	12.74	8.94	.82	.000

************* MEMBER 4 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
0.00	-.1	.65	3.72	.057	-1.00	25.18
.25	-.0	.32	3.71	.058	-.99	25.09
.50	.0	.00	-.00	.059	-.98	25.00

************* MEMBER 11 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
20.00	.0	.00	.00	.012	0.00	12.00
18.00	-.1	.12	.34	.010	.08	12.00
16.00	-.5	.38	.74	.009	.17	14.22
14.00	-1.6	.82	1.24	.007	.26	16.44
12.00	-3.8	1.44	1.85	.006	.36	18.67

Figure B.18 Partial Output File For Example 6 (Sheet 12 of 14)

10.00	-7.4	2.26	2.57	.004	.47	20.89
8.00	-12.8	3.35	3.41	.003	.62	23.11
6.00	-20.8	4.77	4.37	.002	.81	25.33
4.00	-31.9	6.53	5.43	.001	.94	27.56
2.00	-46.8	8.68	6.61	.000	1.22	29.78
0.00	-66.6	11.36	7.94	.000	1.70	32.00

REVIEW OF ELASTIC STRESSES

DISTANCE	STEEL AREAS		STEEL STRESSES		CONCRETE STRESSES	
	TENSION	COMPRESS.	TENSION	COMPRESS.	COMPRESS.	SHEAR
(FT)	(SI/FT)	(SI/FT)	(KSI)	(KSI)	(KSI)	(KSI)
0.00	2.83	.44	9.69	6.70	.55	.033
10.00	.60	.44	6.68	1.01	.23	.010

************* MEMBER 12 *************

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
16.00	.0	-.00	.00	-.029	0.00	12.00
14.40	.0	.00	.25	-.027	0.00	12.80
12.80	-.0	.00	.52	-.024	0.00	13.60
11.20	-.0	.00	.80	-.021	0.00	14.40
9.60	-.0	.00	1.09	-.019	0.00	15.20
8.00	-.0	.00	1.40	-.016	0.00	16.00
6.40	-.0	.00	1.73	-.013	0.00	16.80
4.80	-.0	.00	2.08	-.010	0.00	17.60
3.20	-.0	.00	2.44	-.008	0.00	18.40
1.60	-.0	.00	2.81	-.005	0.00	19.20
0.00	-.0	.00	3.20	-.002	0.00	20.00

REVIEW OF ELASTIC STRESSES

DISTANCE	STEEL AREAS		STEEL STRESSES		CONCRETE STRESSES	
	TENSION	COMPRESS.	TENSION	COMPRESS.	COMPRESS.	SHEAR
(FT)	(SI/FT)	(SI/FT)	(KSI)	(KSI)	(KSI)	(KSI)
0.00	2.27	2.20	-.19	.19	.01	.000

Figure B.18 Partial Output File For Example 6 (Sheet 13 of 14)

************* MEMBER 13 *************

*** USE OF PASSIVE SOLUTION MAY RESULT IN WALL PRESSURES
LESS THAN AT REST CONDITION ***

DISTANCE	BENDING MOMENT	FORCES SHEAR	AXIAL	LATERAL DEFLECT.	NET LATR. PRESSURE	THICKNESS
(FT)	(K-FT/FT)	(K/FT)	(K/FT)	(FT)	(KSF)	(IN)
12.00	-.0	-.00	.00	-.059	0.00	10.00
10.80	.1	-.17	.11	-.053	-.19	11.10
9.60	.5	-.51	.18	-.047	-.37	12.20
8.40	1.5	-1.07	.21	-.042	-.56	13.30
7.20	3.3	-1.85	.20	-.036	-.75	14.40
6.00	6.2	-2.86	.17	-.030	-.94	15.50
4.80	10.5	-4.10	.13	-.025	-1.12	16.60
3.60	16.5	-5.56	.07	-.019	-1.31	17.70
2.40	24.4	-7.24	-.01	-.014	-1.50	18.80
1.20	34.4	-9.14	-.11	-.009	-1.68	19.90
0.00	47.0	-11.22	-.22	-.005	-1.87	21.00

REVIEW OF ELASTIC STRESSES

DISTANCE	STEEL AREAS TENSION	COMPRESS.	STEEL STRESSES TENSION	COMPRESS.	CONCRETE STRESSES COMPRESS.	SHEAR
(FT)	(SI/FT)	(SI/FT)	(KSI)	(KSI)	(KSI)	(KSI)
0.00	2.27	.60	15.84	7.05	.88	.052
6.00	1.00	.60	6.65	.32	.30	.019

Figure B.18 Partial Output File For Example 6 (Sheet 14 of 14)

Example 7

15. Example 7 illustrates the use of the load-deformation method (LDM) for backfill pressures which can only be used in the investigation mode. The LDM option should only be applied by users familiar with soil structure interaction analyses based on what are commonly called p-y curves. Haliburton (1972) gives some elementary rules for developing the required force-deformation curves. The curves used for this example were primarily chosen to illustrate the input procedures in the program.

16. All active soil loading on the base slab, such as the soil weight on the heel, must be input as special loads. Since the force-deformation curves are lateral, any vertical soil loading on the walls must be input as special loads. One and only one special load case must be combined with the LDM loading.

```
01010  3 UFRAME STRUCT - UNSYMMETRICAL ANALYSIS EXAMPLE
01020     TASK GROUP MTG GAINESVILLE 11/ 84
01030  THIRD RUN CUFRBC - LOAD-DEF SOLUTIONS
02010   INV  WSD  CHA      1    INEX2I  INEX2O  INEX2P
02020   NO   NO   NON
03010     3.000     .150    1.350   20.000
04010    25.000   25.000    0.000   18.000   36.000
04020    16.000   16.000   18.000   30.000
04030    36.000   36.000    3.500   33.000
04040    36.000    2.000
06010  0
07010  1  LDM     1  SPR
08010 SYM  NO WATER
08020    -3.000    0.000
10010     5    2    4
10020     -.490    -.049    0.000     .810    8.100
10030    -1.570   -1.570   -2.060  -10.200  -10.200
10040     -.320    -.032    0.000     .190    1.900
10050     -.720    -.720   -1.040   -2.960   -2.960
10060    11   -1    25.00     0.00     0.00
10070    11   -1     0.00     1.00     1.00
10080    12    2    16.00     0.00     0.00
10090    12    2     0.00     1.00     1.00
12010     4    1  SLAB LOADS
12020      1     1      1
12030      0.000     6.480     0.000     0.000
12040 Y    0.000    -4.020    3.500   -3.790
12050      3              1
12060      2.000    -4.170     0.000     0.000
12070 Y    0.000    -1.040    2.000    -.910
12080     11      0      2
12090 Y    0.000     -.090   25.000    0.000
12100 C    0.000      .145   25.000    0.000
12110     12      0      2
12120 Y    0.000     -.180   16.000    0.000
12130 C    0.000     -.145   16.000    0.000
13010    12.000      .150      .060     0.000     0.000     0
```

Figure B.19 Input File For Example 7

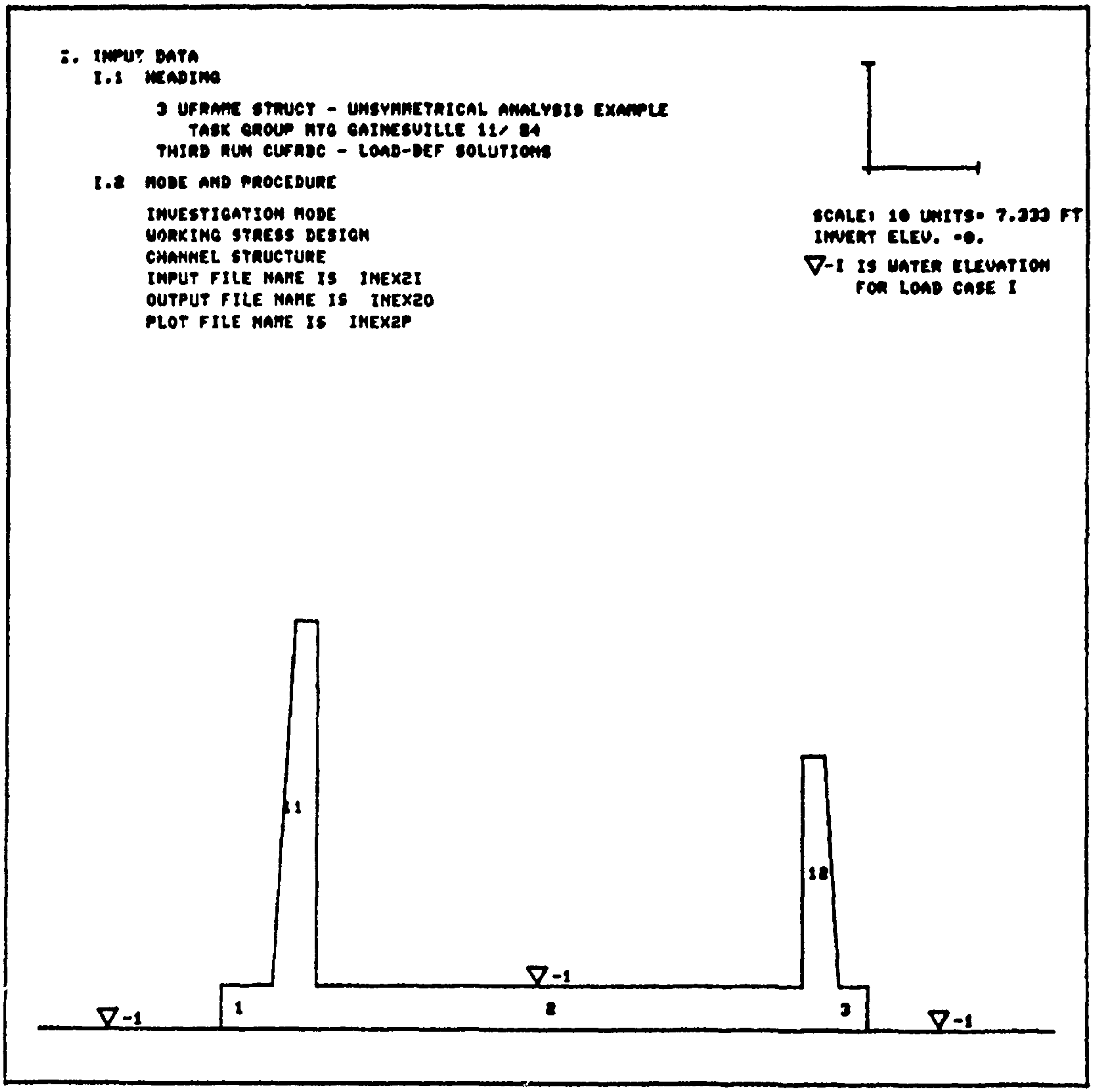


Figure B.20 Partial Graphical Output For Example 7 (Sheet 1 of 9)

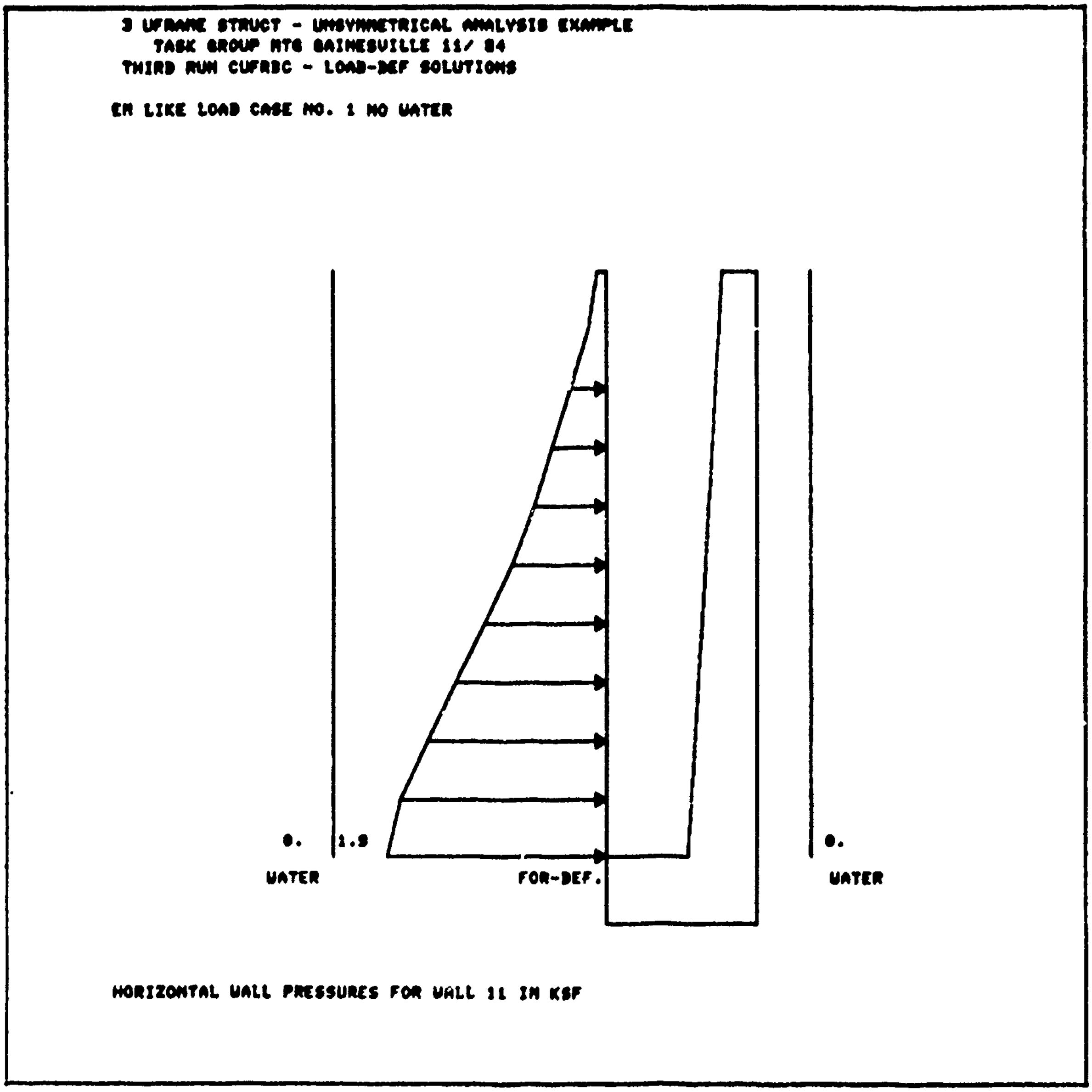


Figure B.20 Partial Graphical Output For Example 7 (Sheet 2 of 9)

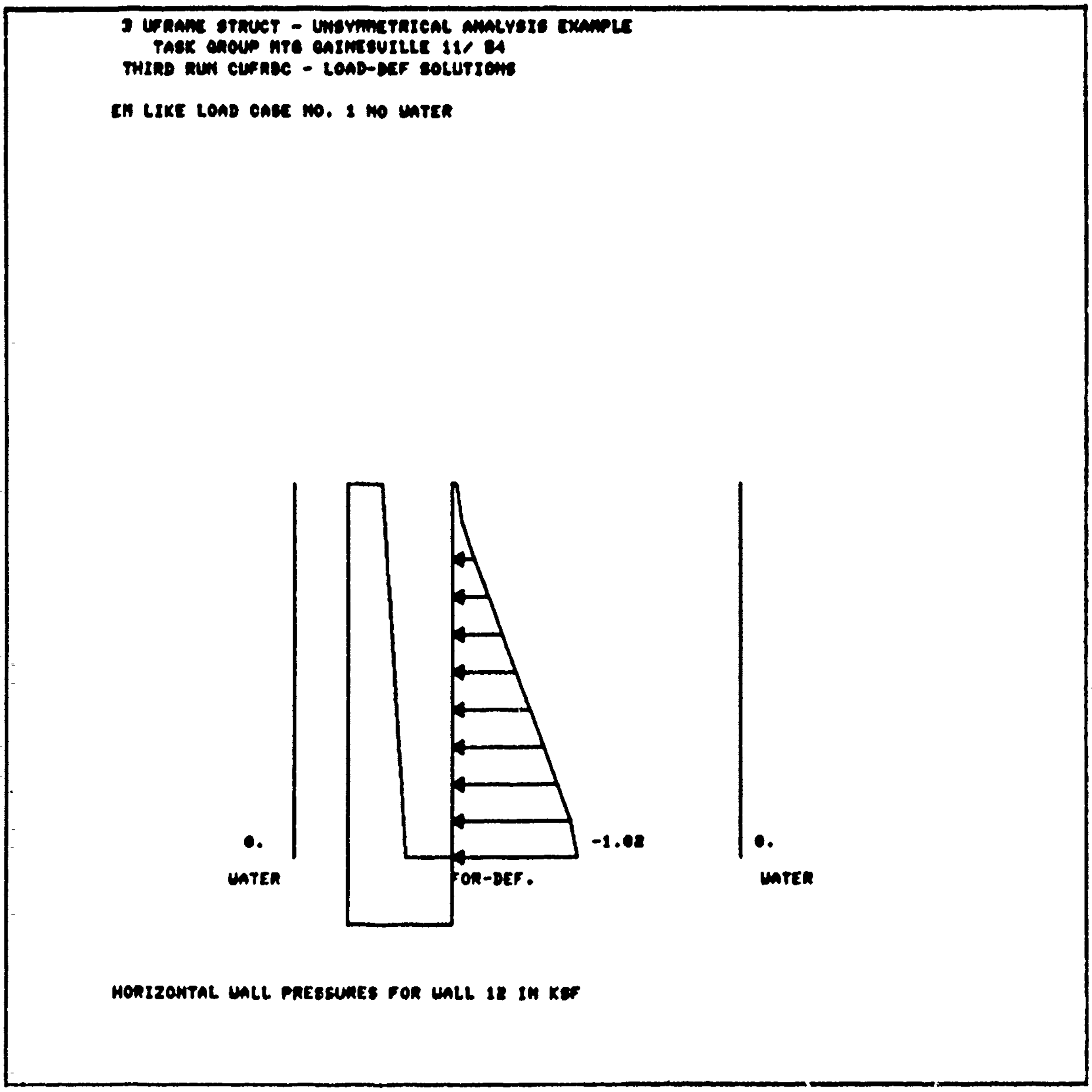


Figure B.20 Partial Graphical Output For Example 7 (Sheet 3 of 9)

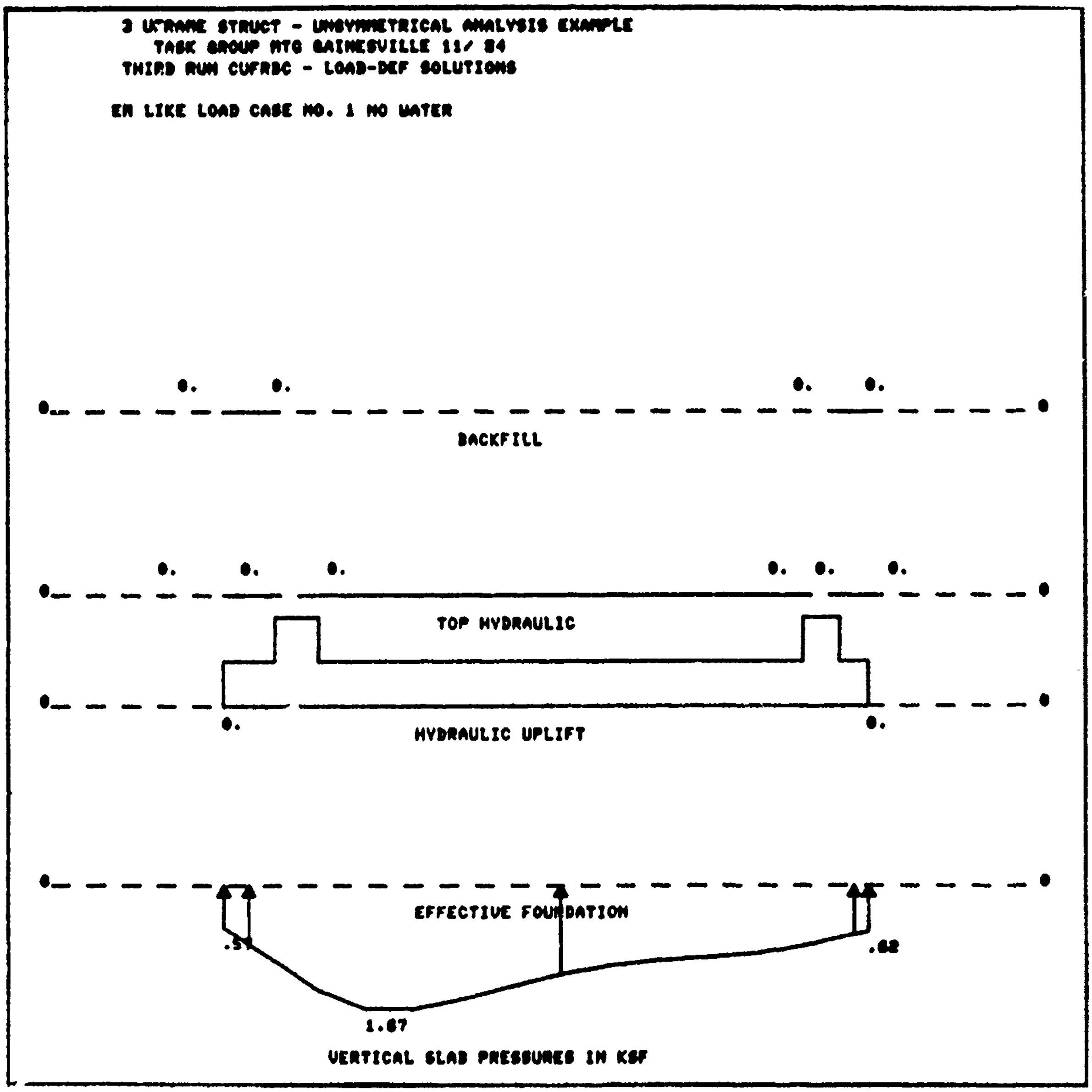


Figure B.20 Partial Graphical Output For Example 7 (Sheet 4 of 9)

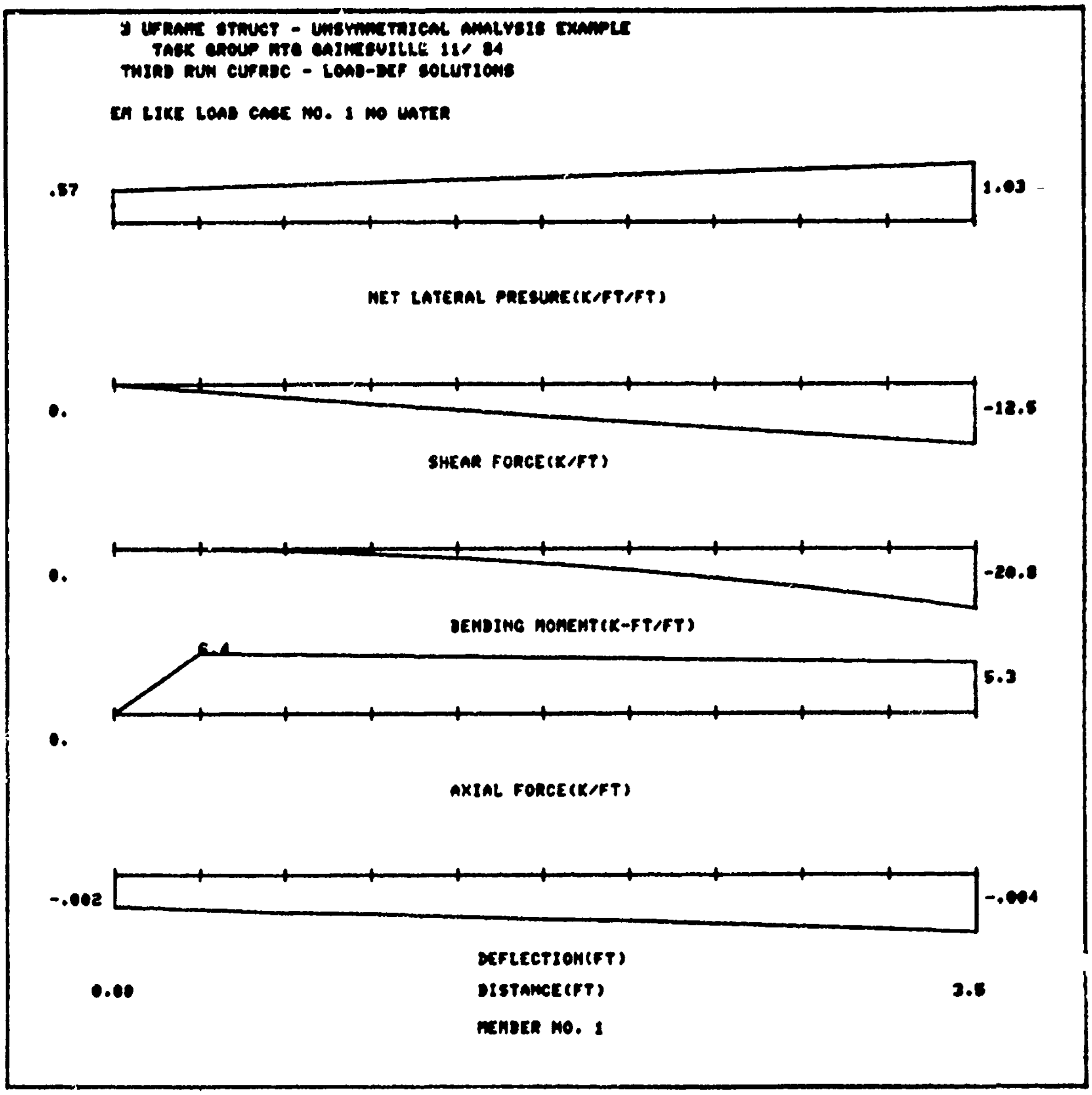


Figure B.20 Partial Graphical Output For Example 7 (Sheet 5 of 9)

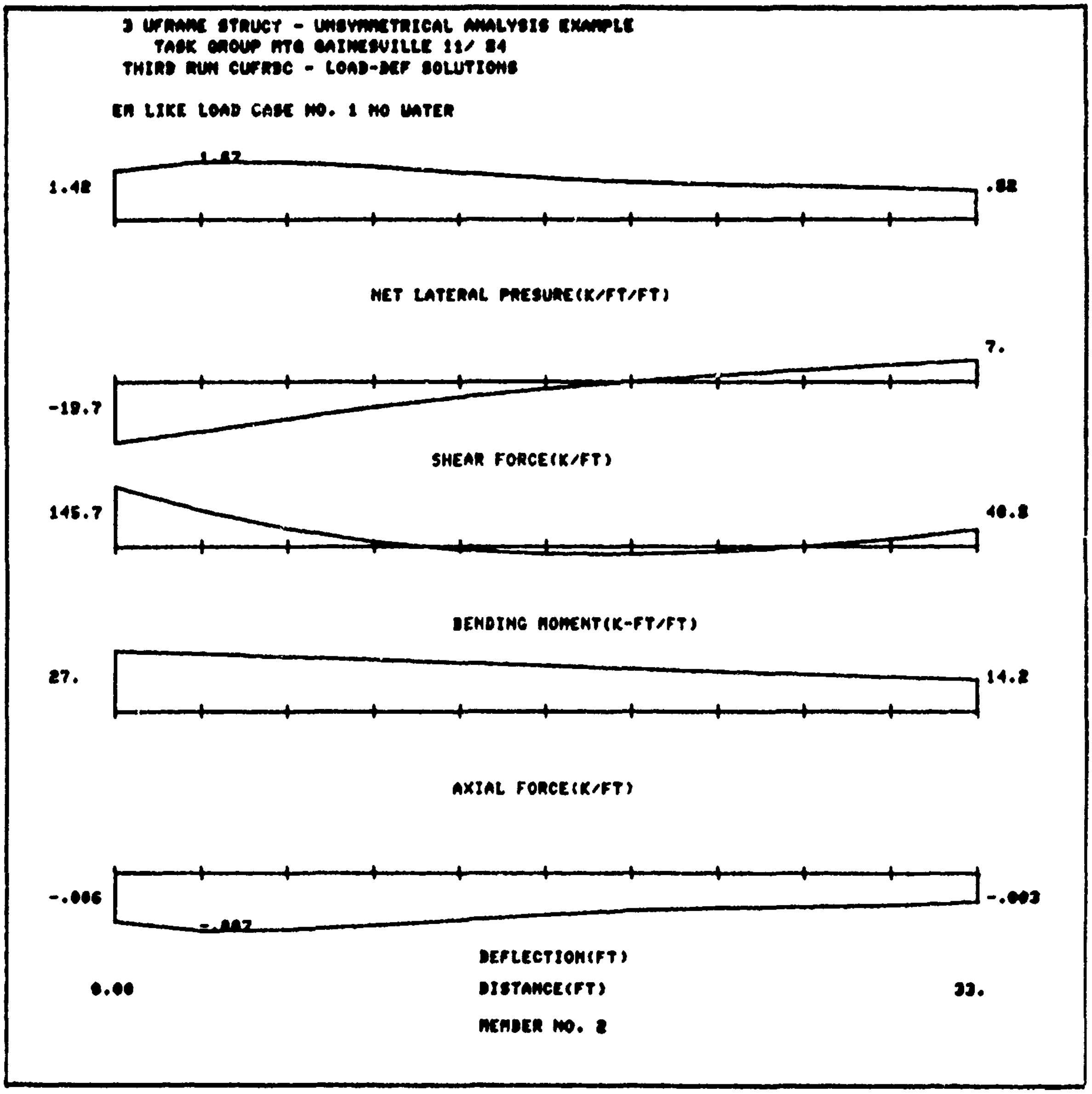


Figure B.20 Partial Graphical Output For Example 7 (Sheet 6 of 9)

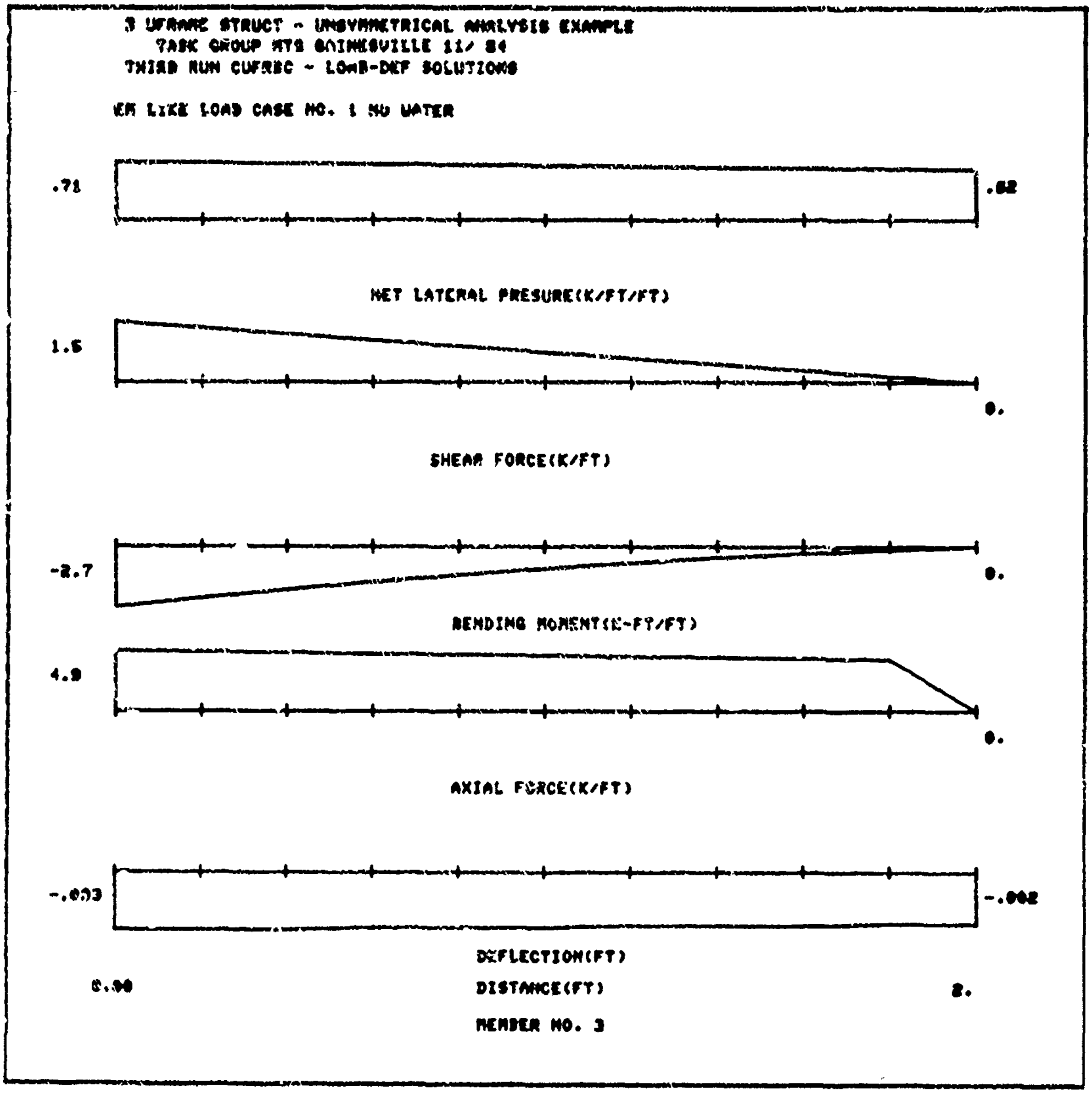


Figure B.20 Partial Graphical Output For Example 7 (Sheet 7 of 9)

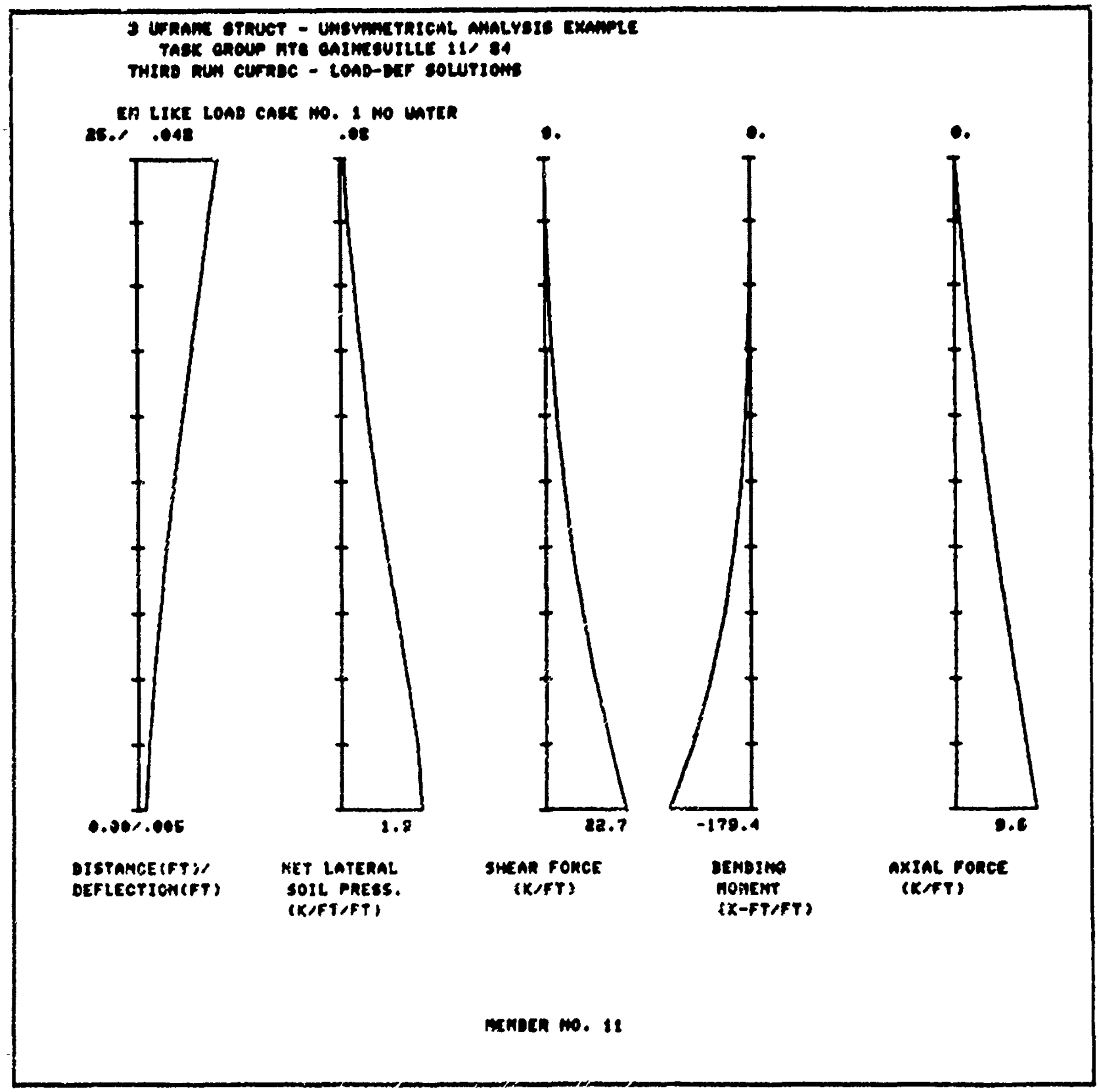


Figure B.20 Partial Graphical Output For Example 7 (Sheet 8 of 9)

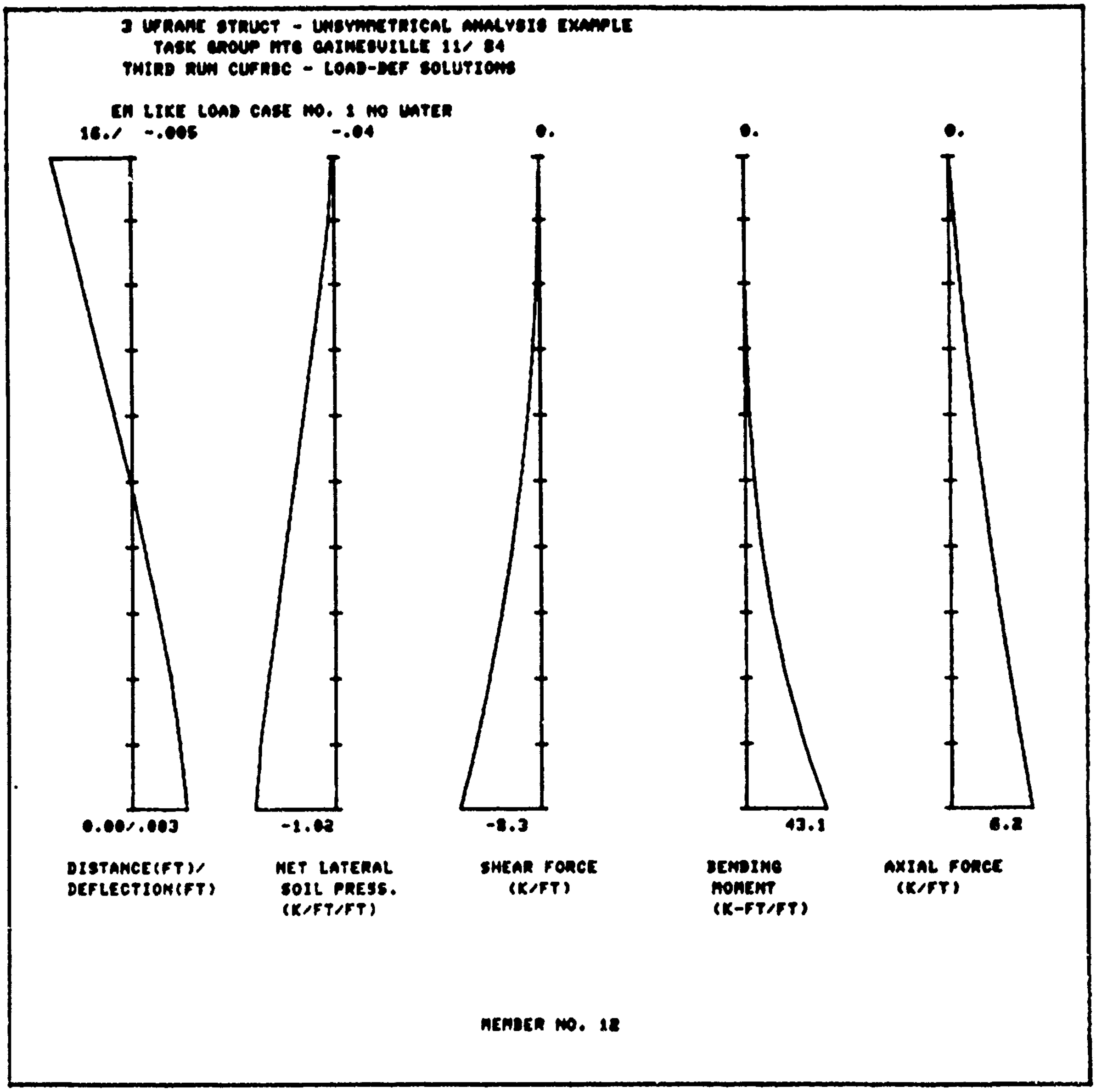


Figure B.20 Partial Graphical Output For Example 7 (Sheet 9 of 9)

```
**************************************************
*  CUFRBC - PROGRAM FOR DESIGN AND ANALYSIS OF   *
*            BASINS AND CHANNELS                 *
*               BY C. O. HAYS                    *
*           REVISED   18 JULY  1989              *
**************************************************
```

I.   INPUT DATA

I.1 HEADING

```
 3 UFRAME STRUCT - UNSYMMETRICAL ANALYSIS EXAMPLE
    TASK GROUP MTG GAINESVILLE 11/ 84
 THIRD RUN CUFRBC - LOAD-DEF SOLUTIONS
```

I.2   MODE AND PROCEDURE

```
INVESTIGATION MODE
WORKING STRESS DESIGN
1 CHANNEL STRUCTURE
INPUT FILE NAME IS "INEX2I"
OUTPUT FILE NAME IS "INEX2O"
PLOT STORAGE FILE NAME IS "INEX2P"

WALL DRAIN DATA OMITTED
BASE SLAB DRAIN DATA OMITTED
CHANNEL IS GEOMETRICALLY NONSYMMETRICAL
```

I.3 MATERIAL PROPERTIES

```
CONCRETE:
  ULTIMATE STRENGTH         = 3.000   KSI
  MODULUS OF ELASTICITY     = 3123.   KSI
  UNIT WEIGHT               =  .150   KCF
  ALLOWABLE STRESS          =  1.35   KSI


REINFORCEMENT:
  ALLOWABLE STRESS          =   20.0   KSI
  MODULUS OF ELASTICITY     = 29000.   KSI
  MODULAR RATIO             =   9.28
```

Figure B.21 Partial Output File For Example 7 (Sheet 1 of 6)

I.4 GEOMETRY *** UNITS ARE FEET OR INCHES ***

LEFT EXTERIOR WALL

ELEVATION			/ WIDTH	
TOP	BOTTOM	SLAB	TOP	BOTTOM
ELTOPL	ELBRKL	ELSLAB	WALLTL	WALLBL
(FT)	(FT)	(FT)	(IN)	(IN)
25.00	25.00	0.00	18.00	36.00

RIGHT EXTERIOR WALL

ELEVATION		/ WIDTH	
TOP	BREAK	TOP	BOTTOM
ELTOPR	ELBRKR	WALLTR	WALLBR
(FT)	(FT)	(IN)	(IN)
16.00	16.00	18.00	30.00

SLAB AND HEEL DIMENSIONS

DEPTH		/ WIDTHS(LEFT)	
	SLAB	HEEL	CHANNEL
LEFT	CENTER		
DEPTHL	DEPTHC	WHEELL	WIDTHL
(IN)	(IN)	(FT)	(FT)
36.00	36.00	3.50	33.00

RIGHT SIDE SLAB AND HEEL DIMENSIONS

DEPTH	WIDTH
SLAB	HEEL
DEPTHR	WHEELR
(IN)	(FT)
36.00	2.00

I.6 REINFORCEMENT FOR INVESTIGATION OPTION

NO MEMBERS INVESTIGATED

I.7 LOADING CONTROL

1 EM-LIKE LOAD CASES
USING LOAD-DEFORMATION METHOD FOR SOIL PRESSURES
1 SPECIAL LOAD CASES WITH DIRECT LOAD INPUT
ELASTIC SPRING FOUNDATION

Figure B.21 Partial Output File For Example 7 (Sheet 2 of 6)

I.8 HYDRAULIC STRESS AND STRENGTH DATA

******** EM-LIKE LOAD CASE 1 ********NO WATER ********
****

SYMMETRICAL WATER ELEVATIONS (FT)

BACKFILL LEFT ELBWSL	CHANNEL LEFT ELCWSL
-3.00	0.00

I.10 LOAD DEFORMATION CURVE DATA

5 POINTS ON CURVES
2 BASIC CURVES
4 LOCATIONS REFERENCING CURVES

CURVE # 1 DEF(FT)/FORCE(KSF)

-.490	-.049	0.000	.810	8.100
-1.570	-1.570	-2.060	-10.200	-10.200

CURVE # 2 DEF(FT)/FORCE(KSF)

-.320	-.032	0.000	.190	1.900
-.720	-.720	-1.040	-2.960	-2.960

WALL	REFERENCE CURVE	DIST. (FT)	MULTIPLIER DEF.	FORCE
WALLM	NREFC	DISTC	DEFM	FORCEM
11	-1	25.00	0.00	0.00
11	-1	0.00	1.00	1.00
12	2	16.00	0.00	0.00
12	2	0.00	1.00	1.00

Figure B.21 Partial Output File For Example 7 (Sheet 3 of 6)

I.12 SPECIAL LOAD CASES

```
******** SPECIAL LOAD CASE 1   ********SLAB LOADS          ********
*********************************************************************


    NUMBER OF LOADED MEMEBRS     = 4
    REFERENCE EM-LIKE LOAD CASE = 1

    LOAD DATA FOR EACH LOADED MEMBER


    MEMBER NUMBER =  1
    NUMBER OF CONCENTRATED LOADS =  1
    NUMBER OF DISTRIBUTED LOADS  =  1


         CONCENTRATED LOADS

DISTANCE                LOAD
          FORCE-X  FORCE-Y   COUPLE
     DC       FXM      FYM      FCM
   (FT)    (K/FT)   (K/FT)  (KF/FT)
   0.00      6.48     0.00     0.00


         DISTRIBUTED LOADS

     TYPE  DISTANCE MAGNITUDE  DISTANCE MAGNITUDE
            TO LOAD   @ START   TO LOAD     @ END
     IDIR       D1M       Q1M       D2M       Q2M
               (FT)    (KSF)*      (FT)    (KSF)*  (* UNITS FOR
        Y      0.00     -4.02      3.50     -3.79     COUPLES KF/SF)


    MEMBER NUMBER =  3
    NUMBER OF CONCENTRATED LOADS =  1
    NUMBER OF DISTRIBUTED LOADS  =  1


         CONCENTRATED LOADS

DISTANCE                LOAD
          FORCE-X  FORCE-Y   COUPLE
     DC       FXM      FYM      FCM
   (FT)    (K/FT)   (K/FT)  (KF/FT)
   2.00     -4.17     0.00     0.00
```

Figure B.21 Partial Output File For Example 7 (Sheet 4 of 6)

DISTRIBUTED LOADS

TYPE	DISTANCE TO LOAD	MAGNITUDE @ START	DISTANCE TO LOAD	MAGNITUDE @ END	
IDIR	D1M	Q1M	D2M	Q2M	
	(FT)	(KSF)*	(FT)	(KSF)*	(* UNITS FOR
Y	0.00	-1.04	2.00	-.91	COUPLES KF/SF)

MEMBER NUMBER = 11
NUMBER OF CONCENTRATED LOADS = 0
NUMBER OF DISTRIBUTED LOADS = 2

DISTRIBUTED LOADS

TYPE	DISTANCE TO LOAD	MAGNITUDE @ START	DISTANCE TO LOAD	MAGNITUDE @ END	
IDIR	D1M	Q1M	D2M	Q2M	
	(FT)	(KSF)*	(FT)	(KSF)*	(* UNITS FOR
Y	0.00	-.09	25.00	0.00	COUPLES KF/SF)
C	0.00	.15	25.00	0.00	

MEMBER NUMBER = 12
NUMBER OF CONCENTRATED LOADS = 0
NUMBER OF DISTRIBUTED LOADS = 2

DISTRIBUTED LOADS

TYPE	DISTANCE TO LOAD	MAGNITUDE @ START	DISTANCE TO LOAD	MAGNITUDE @ END	
IDIR	D1M	Q1M	D2M	Q2M	
	(FT)	(KSF)*	(FT)	(KSF)*	(* UNITS FOR
Y	0.00	-.18	16.00	0.00	COUPLES KF/SF)
C	0.00	-.15	16.00	0.00	

I.13 ELASTIC SPRING FOUNDATION PROPERTIES

STRENGTH	SOIL SPRING MODULI VERT.	HORZ.	COHESION	FRICTION	/ ANCHORS NUMBER
FPF	SCFV	SCFH	FCOHE	DELFF	NANCK
(KSF)	(KCI)	(KCI)	(KSF)	(DEG)	
12.00	.150	.060	0.00	0.00	0

Figure B.21 Partial Output File For Example 7 (Sheet 5 of 6)

O. OUTPUT RESULTS

O.1 FACTORS OF SAFETY

FACTOR OF SAFETY AGAINST UPLIFT	FACTOR OF SAFETY AGAINST BEARING	HORIZONTAL EQUILIBRIUM FACTOR	EM-LIKE LOAD CASE	SPECIAL LOAD CASE
9999.99	7.18	0.00	1	1

Figure B.21 Partial Output File For Example 7 (Sheet 6 of 6)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide. Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide. Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide. Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide. Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide. Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide. Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide. Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80. A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide. Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide. Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report K-83-1	User's Guide. Computer Program With Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide. Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide. Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual. Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide. Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide. Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318 77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide. Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide. For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87-6	Finite-Element Method Package for Solving Steady-State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide. A Three Dimensional Stability Analysis/Design Program (3DSAD) Module	Jun 1987
	Report 1: Revision 1: General Geometry	Jun 1987
	Report 2: General Loads Module	Sep 1989
	Report 6: Free-Body Module	Sep 1989
Instruction Report ITL-87-4	User's Guide. 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II	Aug 1987

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies—Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies—Closed Sections Report 5: Alternate Configuration Miter Gate Finite Element Studies—Additional Closed Sections Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates Report 7: Application and Summary	Aug 1987
Instruction Report GL-87-1	User's Guide. UTEXAS2 Slope-Stability Package, Volume I, User's Manual	Aug 1987
Instruction Report ITL-87-5	Sliding Stability of Concrete Structures (CSLIDE)	Oct 1987
Instruction Report ITL-87-6	Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER)	Dec 1987
Technical Report ITL-87-8	Procedure for Static Analysis of Gravity Dams Using the Finite Element Method — Phase Ia	Jan 1988
Instruction Report ITL-88-1	User's Guide. Computer Program for Analysis of Planar Grid Structures (CGRID)	Feb 1988
Technical Report ITL-88-1	Development of Design Formulas for Ribbed Mat Foundations on Expansive Soils	Apr 1988
Technical Report ITL-88-2	User's Guide. Pile Group Graphics Display (CPGG) Post-processor to CPGA Program	Apr 1988
Instruction Report ITL-88-2	User's Guide for Design and Investigation of Horizontally Framed Miter Gates (CMITER)	Jun 1988
Instruction Report ITL-88-4	User's Guide for Revised Computer Program to Calculate Shear, Moment, and Thrust (CSMT)	Sep 1988
Instruction Report GL-87-1	User's Guide. UTEXAS2 Slope-Stability Package, Volume II, Theory	Feb 1989
Technical Report ITL-89-3	User's Guide. Pile Group Analysis (CPGA) Computer Group	Jul 1989
Technical Report ITL-89-4	CBASIN--Structural Design of Saint Anthony Falls Stilling Basins According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0098	Aug 1989
Technical Report ITL-89-5	CCHAN--Structural Design of Rectangular Channels According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0097	Aug 1989
Technical Report ITL-89-6	The Response-Spectrum Dynamic Analysis of Gravity Dams Using the Finite Element Method; Phase II	Aug 1989
Contract Report ITL-89-1	State of the Art on Expert Systems Applications in Design, Construction, and Maintenance of Structures	Sep 1989

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report ITL-90-1	User's Guide. Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT)	Feb 1990
Technical Report ITL-90-3	Investigation and Design of U-Frame Structures Using Program CUFRBC Volume A: Program Criteria and Documentation Volume B: User's Guide for Basins Volume C: User's Guide for Channels	May 1990