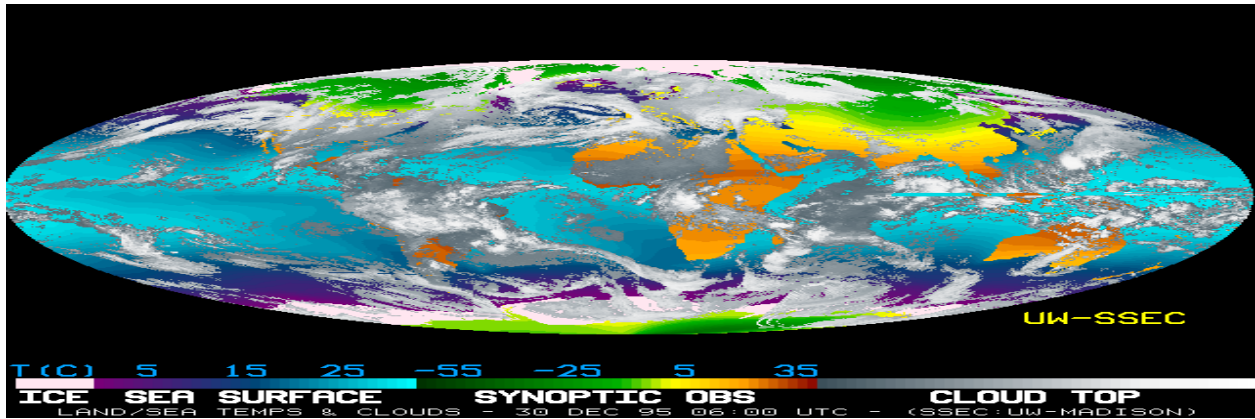


STA ANCHOR

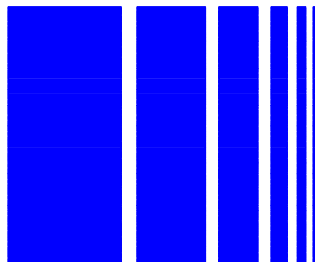
VERSION 3.1

A PROGRAM FOR DRAG ANCHOR PERFORMANCE PREDICTION

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USER MANUAL AND TECHNICAL DOCUMENTATION



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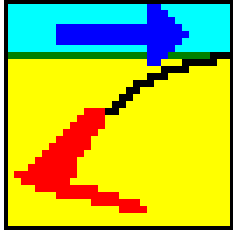
CONTENTS

Section and Subject	Page No.
1.0 INTRODUCTION	1
2.0 HARDWARE AND SYSTEM REQUIREMENTS	2
3.0 INSTALLING THE PROGRAM.....	3
4.0 OVERVIEW OF RUNNING THE PROGRAM.....	5
4.1 Running Ultimate Load Calculations.....	7
4.2 Objectives of the Ultimate Load Calculations	7
4.3 Running Calculations on the Proof Load Sheet.....	8
4.4 Objectives of the Proof Load Sheet Calculations	8
4.5 Running Comparison Sheet.....	9
5.0 MODELING SEA BED SOIL STRENGTH PROFILES	10
6.0 DETAILED DESCRIPTION OF INPUT DATA	12
6.1 Anchor Data.....	12
6.2 Wire (or Chain) Data.....	17
6.3 Soil Data	20
6.4 Depth Range and Proof Load	21
7.0 DESCRIPTION OF SUMMARY RESULTS	23
7.1 Summary Results from the Equilibrium Calculations	23
7.2 Ultimate Load Results After Equilibrium Calculations.....	25
7.3 Displaying Tabular Results	27
8.0 PROGRAM FEATURES AND THE MACRO BUTTONS.....	28
8.1 Macros Used for Program Set-up	28
8.2 Macros Used to Determine Anchor Equilibrium	31
8.3 Macros Used to Observe, Print and Save Results.....	33
8.4 Macros Used to Move Between and Link Sheets	39
9.0 GENERAL METHOD OF SOLUTION	41
10.0 GEOTECHNICAL FORCES AT THE ANCHOR	44
11.0 COMMENTS ON USE OF STA ANCHOR	46
11.1 Soils with Small, or Zero, Strength Increase With Depth	46
11.2 Input Geometry Checking With Graphical Results	46
11.3 Tips on Running the Calculate Equilibrium Macro More Quickly	46
12.0 COMPARISON SHEET	48
13.0 CALIBRATION OF STA ANCHOR	51

APPENDICES

APPENDIX 1	CALIBRATION RUNS FOR NEAR SHORE ANCHOR TESTS, SEPT. 1994
APPENDIX 2	CALIBRATION RUNS FOR LARGE SCALE ANCHOR TESTS, OCT. 1990
APPENDIX 3	HOLDING CAPACITY COMPARISONS BETWEEN STA ANCHOR AND NCEL TABLES
APPENDIX 4	ANCHOR SOLUTION METHODS
APPENDIX 5	STA ANCHOR PROGRAM MACRO CODE
APPENDIX 6	DESCRIPTION OF SOLUTION METHOD FOR PROOF LOAD SHEET

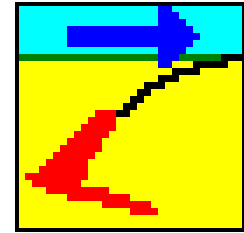
STA ANCHOR



**A PROGRAM FOR DRAG ANCHOR
PERFORMANCE PREDICTION**

VERSION 3.01

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1.0 INTRODUCTION

STA ANCHOR is a program for predicting the performance of drag embedment anchor systems in sea bed soils. Version 3.01 is for cohesive soils only. The anchor system is defined as the anchor and the attached mooring line (wire or chain) which is buried with the anchor up to the level of the sea bed. The program predicts the anchor system performance in terms of applied mooring load, anchor burial depth, buried mooring line geometry, and many other parameters.

There are four sets of information the user must input: anchor data, line data, soil data, and control parameters. Numerous macro buttons are available to help the user input information and to run the program. An Ultimate Load Sheet, a Proof Load Sheet, and a Comparison Sheet are provided, enabling the user to produce a comprehensive report on the anchor system behavior.

The Version 1.0 program was partially developed during a Joint Industry-funded Project organized by Omega Marine International, where 2-ton and 7-ton drag anchors were tested in the Gulf of Mexico in the summer of 1990. Results from these tests were used to calibrate STA ANCHOR Version 1.0. The Version 3.0 program was partially developed during another Joint Industry-funded Project. However, most of the development effort has been funded internally by STA. The program was substantially modified from the earlier version in order to be able to include vertically loaded anchors (VLAs) in an analysis. Version 3.0 of the program deals with cohesive soils and silts, which have strength properties which can be characterized by an undrained shear strength depth profile.

2.0 *HARDWARE AND SYSTEM REQUIREMENTS*

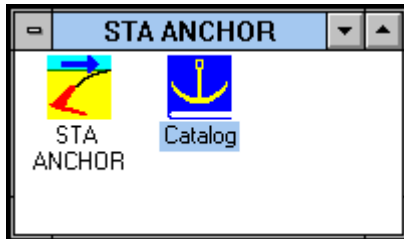
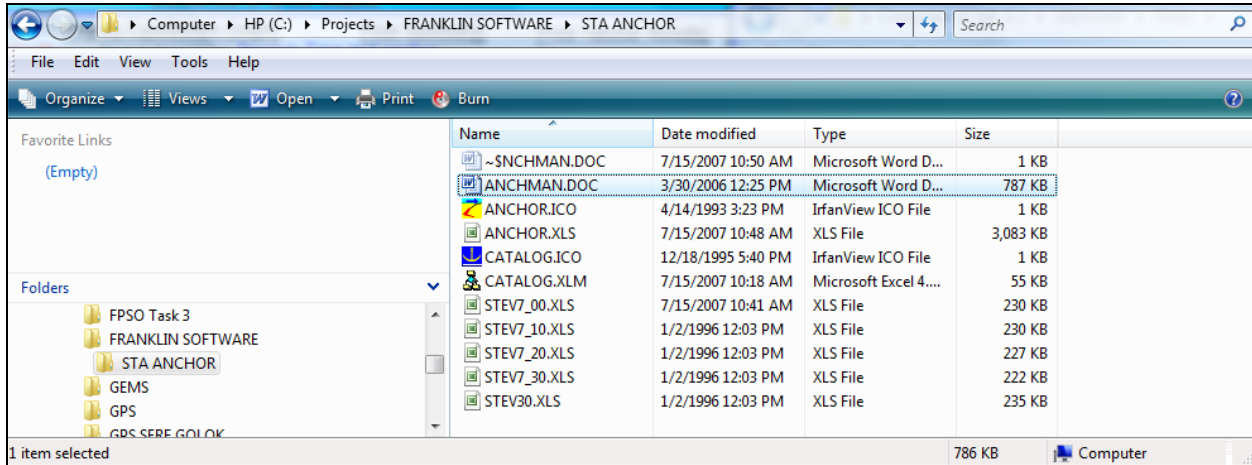
A PC running Excel in versions from Excel 5 to Excel 2007 in Windows or Vista is a requirement. Excel 4 does not support the macro language used in STA ANCHOR and therefore cannot be used.

Results may be printed on any printer compatible with the spreadsheet program. A laser printer will give the best looking tabular results and a color printer or plotter will give the best looking graphical results. A high resolution monitor of at least 17” diagonal width is recommended.

3.0 ***INSTALLING THE PROGRAM - In Windows Only***

Put ALL files into a directory called, for example, STA ANCHOR.

The directory should have the files that appear in the figure below:



Two icon files can be added to your desktop if the program is to be run frequently. You will have to instruct your machine to assign the correct paths to the files.

The program can then be started by double-clicking the anchor program icon or opening Excel and then selecting the STA ANCHOR program (File Name: ANCHOR.XLS).

You are now ready to run the program. When it has loaded you will be presented with **The Ultimate Load Sheet**. Data from a previous run will be shown. For best user interface a high resolution 17" monitor should be used. On smaller monitors the *View, Zoom* option must be set to less than 100% if the full width of the data input area is to be viewed. This makes some data difficult to read.

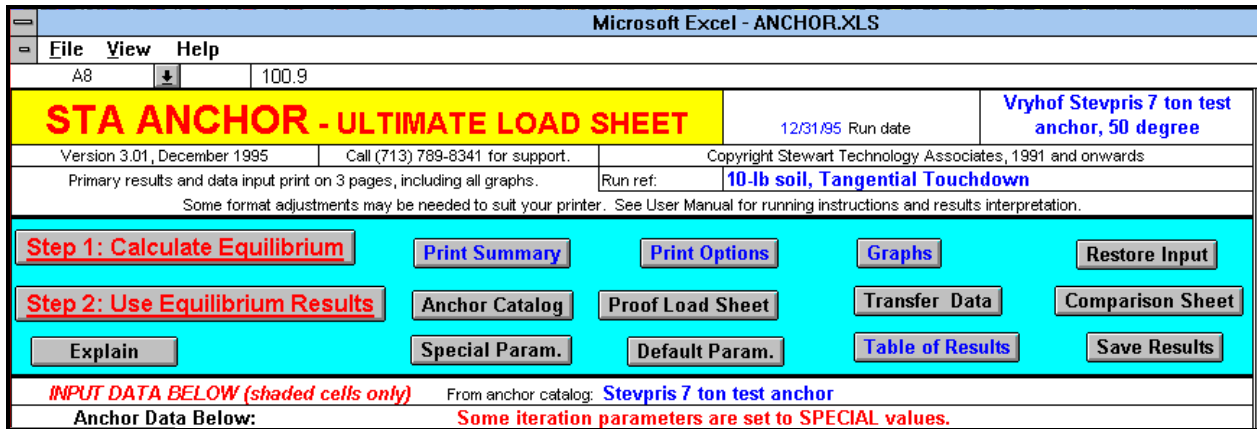
The next section explains how to run the program.

4.0 OVERVIEW OF RUNNING THE PROGRAM

The STA ANCHOR program consists of numerous worksheets, macro sheets (Visual Basic modules) and dialog boxes. The majority of these sheets are hidden. Three sheets are visible:

1. The primary input and results worksheet called **The Ultimate Load Sheet**.
2. A second similar looking worksheet called **The Proof Load Sheet**
3. A third woorksheet called **The Comparison Sheet**.

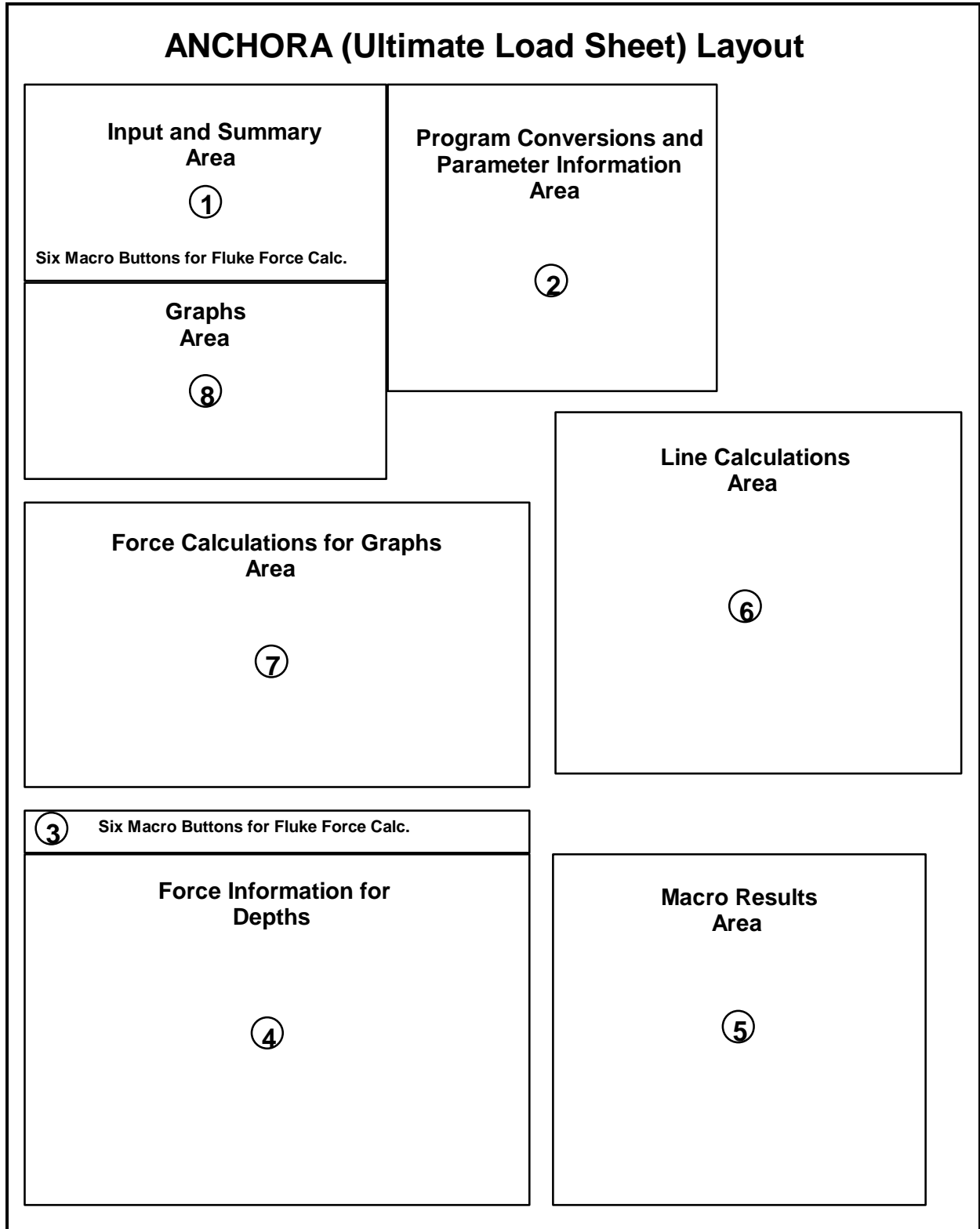
The Ultimate Load Sheet is displayed when the program first loads. The top of this sheet is illustrated below.



If you cannot see the full width of the display illustrated above you may wish to click on the *View* menu, then select *Zoom*, and specify something less than 100%. If you only have VGA resolution and a monitor smaller than the 17" recommended, you may not be able to see the full display illustrated above and still read the data. In this case it is recommended to use the scroll bars to move around, leaving the *zoom* rate set so that the data is legible. STA strongly recommends a better monitor if you have this problem.

The Ultimate Load Sheet is very large and is divided into eight main areas, as shown in the following diagram. You may investigate any of these areas, but to begin with you should remain in area 1, at the top left hand corner of the sheet. This is the Input Data and Summary Results area.

You may wish to experiment with the macro buttons shown above, and jump to the Proof Load Sheet, then on to the Comparison Sheet. On either of these sheets you will find macro buttons to jump you back to the Ultimate Load Sheet. If you do scroll around the large Ultimate Load Sheet you will also come upon macro buttons labeled *Home*. Clicking on any of these buttons will jump you back to cell A1, in the uppermost left hand corner of the Ultimate Load Sheet.



Schematic Layout of Ultimate Load Worksheet

4.1 Running Ultimate Load Calculations

There are three basic steps to running the ultimate load calculations:

1. Input all anchor data, wire (or chain) data, soil data, and control parameters. Use macro buttons to input data or set parameters as desired, and select depth range to be investigated.
2. Run the *Step 1: Calculate Equilibrium* macro. Run until equilibrium has been found.
3. Run the *Step 2: Use Equilibrium Results* macro.

Warning! Running the Calculate Equilibrium macro may take more than one hour on a 486 machine if a large range of equilibrium depths are found.

Once the macros have both run successfully you may print the summary and graphs and save the results as desired by using the macros available.

4.2 Objectives of The Ultimate Load Calculations

The prime objective of the ultimate load calculations is to determine the ultimate holding capacity of the anchor system (the anchor itself, the forerunner, and the soil). The user must specify the following input data:

- anchor geometry and weight
- the chain or wire size and weight plus uplift angle (if any) at sea bed
- the soil undrained shear strength with depth
- a starting depth at which to search for equilibrium
- a maximum depth, beyond which equilibrium is not expected

The program seeks anchor equilibrium at the starting depth. If successful, and if the anchor wants to dive deeper, the program goes to the next depth, which is defined by the starting depth plus one hundredth of the depth range specified by the user. This process is continued until either the maximum depth specified is reached, or until a depth at which the anchor can dive no deeper is found. This is the ultimate load depth.

Warning! Depths reported by STA ANCHOR are depths to the anchor shackle. The program automatically accounts for the soil strength (which is normally stronger) in the area between the shackle and the fluke.

At each depth where equilibrium is found the program stores the line tension at the sea bed and the horizontal and vertical components of line tension applied to the anchor shackle.

A second objective of the ultimate load calculations is to determine the anchor depth at the desired proof load. For this to be successful a range of depths that encompass the proof load depth must be investigated. Although the desired proof load can be specified by the user before the equilibrium calculations are performed, the proof load can be changed to any value of interest after the equilibrium calculations are complete without affecting anything except the proof load results.

Warning! Proof load depths and other proof load results on the Ultimate Load Sheet are found for the same line angle at the sea bed as specified for the ultimate load calculations.

The program performs extensive iterative calculations at each depth. It finds a line tension and geometry in the soil which results in a horizontal load at the anchor equal to the anchor's horizontal resistance at that depth. If the associated vertical component of line tension applied to the anchor is less than the anchor's diving force at that depth, the program continues to the next depth.

4.3 Running Calculations on the Proof Load Sheet

The Proof Load Sheet is similar to Version 1.0 of STA ANCHOR. It is a stand-alone application within STA ANCHOR Version 3, and can be run in isolation or in conjunction with the Ultimate Load Sheet and the Comparison Sheet. There are two basic steps to running the Proof Load Sheet calculations:

1. Input all anchor data, wire (or chain) data, soil data, and control parameters. Select anchor system load to be investigated.
2. Adjust control parameters until all warnings disappear and an optimum (usually upper bound) solution has been found.

The program will report if the anchor holds the load or not, and show where the anchor has gone, line geometry, etc.

4.4 Objectives of The Proof Load Sheet Calculations

The prime objective of the Proof Load Sheet calculations is to determine the anchor system holding capacity and anchor performance, given a specific applied mooring line load and uplift angle (if any) at the sea bed. The user must specify the following input data:

- anchor geometry and weight
- the chain or wire size and weight plus uplift angle (if any) at sea bed
- the soil undrained shear strength with depth
- anchor starting position (depth and angle)
- control parameters of delta drag increment & delta angle change increment

The program determines the line forces applied to the anchor shackle and moves the anchor if the horizontal force exceeds the anchor resistance. If the moment balance about the shackle is such that the anchor is not at equilibrium, the program will also rotate the anchor. The amount of movement and rotation at each step are set by the user-specified delta terms. The solution method is more fully described in Appendix 6.

The Proof Load Sheet can be used to determine what an anchor will do if embedded to a certain depth by a horizontal line pull (found, for example, on the Ultimate Load Sheet, and represented as the proof load) and then the line at the sea bed has uplift and/or the line tension is increased (or decreased) above the proof load. In many cases it will be found that the anchor will embed further if the line load is increased and uplift at the sea bed does not exceed 15°.

4.5 Running Comparison Sheet

The comparison sheet permits the results of runs performed on the Ultimate Load Sheet and the Proof Load Sheet to be compared. The comparison shows anchor (shackle) depths and line geometries resulting from the following load cases:

- Ultimate Capacity (from Ultimate Load Sheet)
- Proof Load (from Ultimate Load Sheet)
- Load Condition Specified on Proof Load Sheet
- One Extra Line Condition (line attached to shackle at proof load depth)

This provides a way of summarizing an anchor design study. For example, it can show what is anticipated when the proof load is applied to the anchor, compared to what would happen if the ultimate load was applied, assuming the line to have zero uplift at the sea bed. Additionally, the effect of applying a load in excess of the proof load, but less than the ultimate load, possibly with uplift at the sea bed, can also be shown.

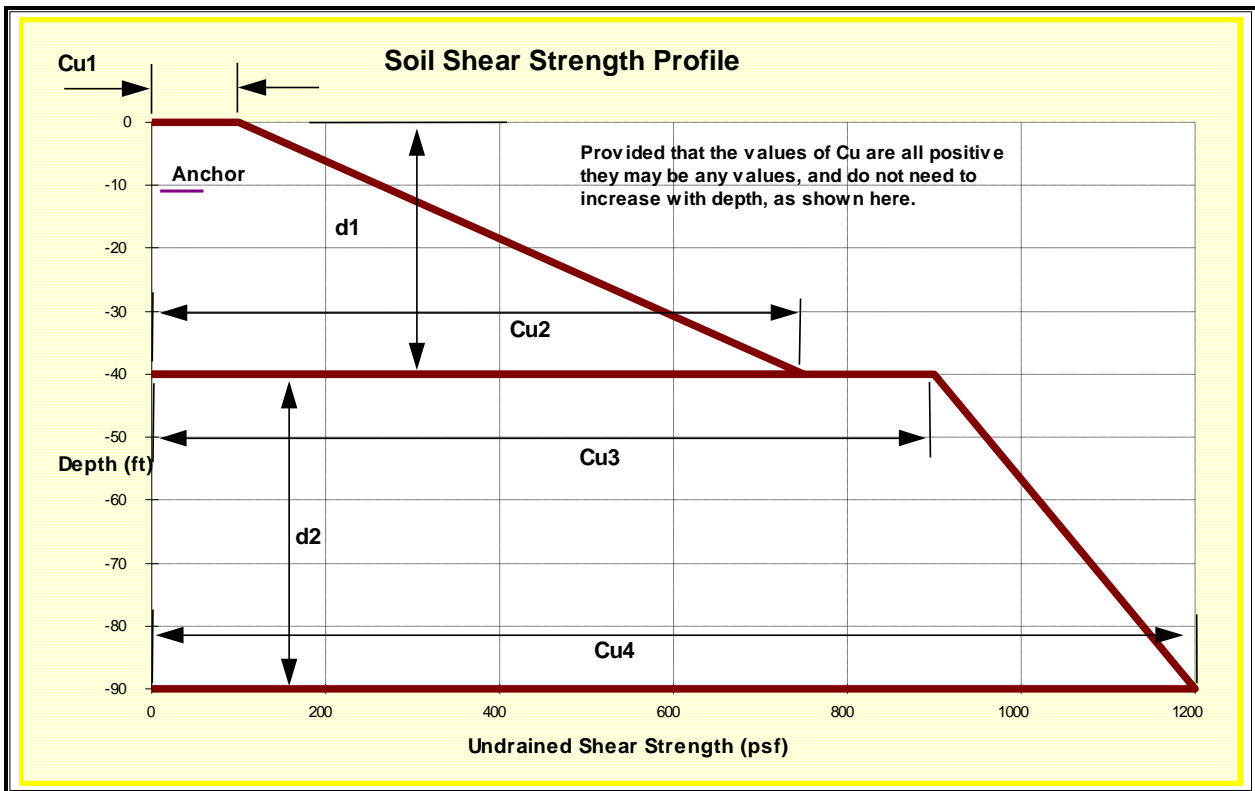
The following sections of the manual provide more detailed descriptions of the data input and results from STA ANCHOR.

5.0 MODELING SEA BED SOIL STRENGTH PROFILES

The program permits the user to input a soil undrained shear strength profile which may start from any value at the sea bed surface and may linearly increase, decrease, or remain constant with depth down to a level beneath the sea bed selected by the user. At this selected depth, a step increase (or decrease) to a new undrained shear strength may occur. Beneath this selected depth, the soil undrained shear strength may be specified to linearly increase, linearly decrease, or remain constant to a second selected depth beneath the sea bed, which must be deeper than the maximum burial depth of the anchor. The input data for the soil is shown below.

90 psf	Cu1, at surface	6.00	Nc1, at surface
1090 psf	Cu2, at bottom of 1st layer	15.00	Nc2, at depth of 5°F
1090 psf	Cu3, at top of 2nd layer	100.00 ft	d1, depth of 1st layer
2000 psf	Cu4, at bottom of 2nd layer	58.00 ft	d2, thickness of 2nd layer

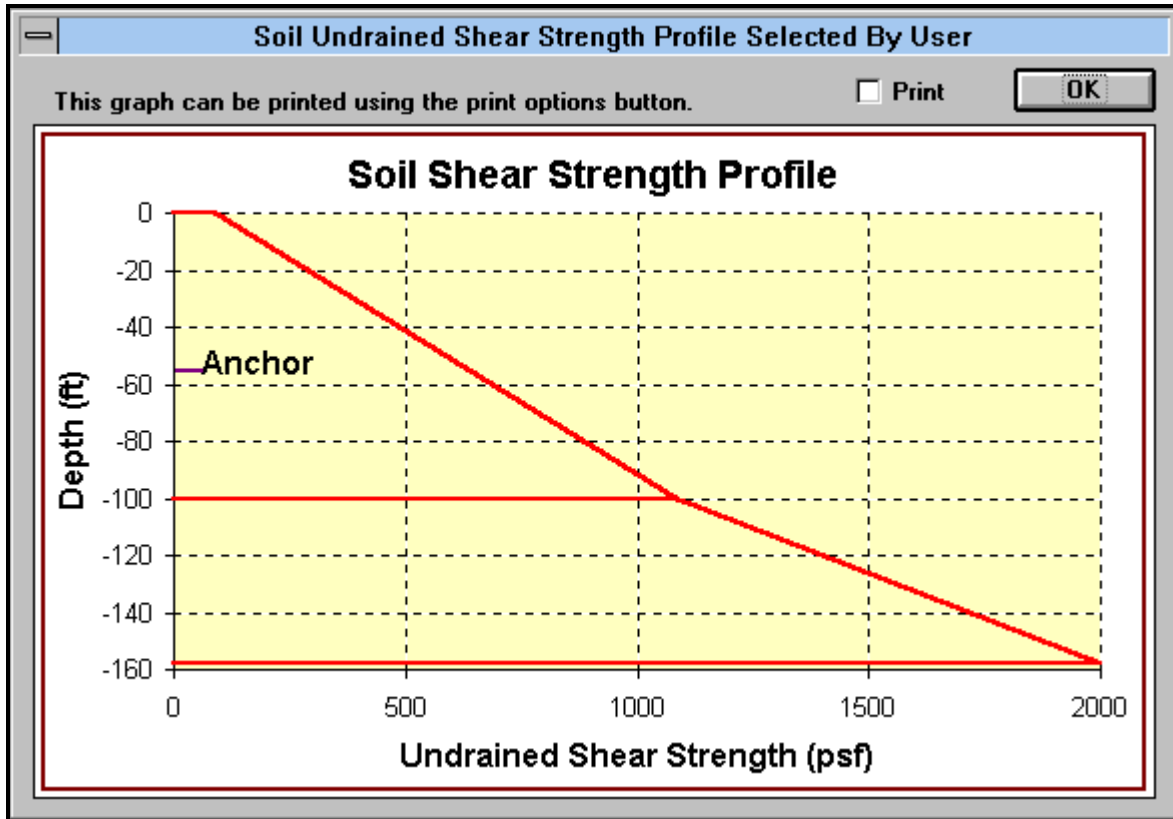
The figure below shows the type of soil profile that may be specified, with the nomenclature adopted by the program.



To view the soil strength profile in STA Anchor simply pick one of the input cells in the soil data block and press the Explain Button. A dialog box, as illustrated in the following figure, will appear showing the user-specified soil strength profile. This dialog box will also indicate the location of the anchor within the soil (ultimate load position from most recent analysis). Note

that a selection box is shown with the word “Print” beside it. If the user clicks on this box the graph will be printed when the “OK” button is clicked. Otherwise the dialog box will simply disappear.

Dialog box for soil shear strength graph



6.0 DETAILED DESCRIPTION OF INPUT DATA

The input data is entered in four data blocks on the spreadsheet. The first data block contains parameters associated with the anchor weight and geometry. The second block is associated with the wire (or chain) data. The third data block relates to the soil, and the last data block specifies the depth range and proof load to be investigated.

6.1 Anchor Data:

6.1.1 Af, fluke area

This is the area of the fluke, sometimes referred to as the "positive" fluke area. The center of this area must also be determined and is labeled f1 in the figures on pages 13 & 14.

Anchor Data Below:	
100.90 sqft	Af, fluke area
10.71 ft	F, fluke length
5.28 sqft	Af2, fluke projected area
70.37 sqft	As1, shank shear area
27.00 sqft	As2, shank projected area
15.53 kip	W, anchor weight
1.00	fluke shear area multiplier
2.50	shank shear area multiplier

6.1.2 F, fluke length

The maximum length of the fluke from back to front.

6.1.3 Af2, fluke projected area

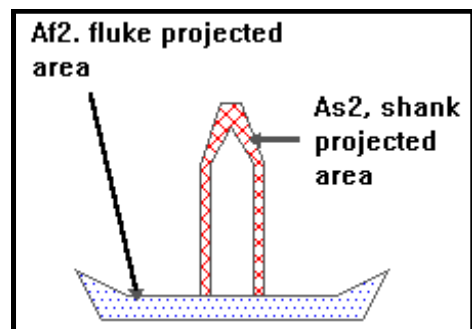
This is the frontal area that the fluke projects against the soil and is subject to normal forces, calculated using the bearing coefficient, Nc.

6.1.4 As1, shank shear area

This is the area of the shank as viewed from the side. The center of this area must be determined also. The center point is labeled s1 in the figures on the following pages.

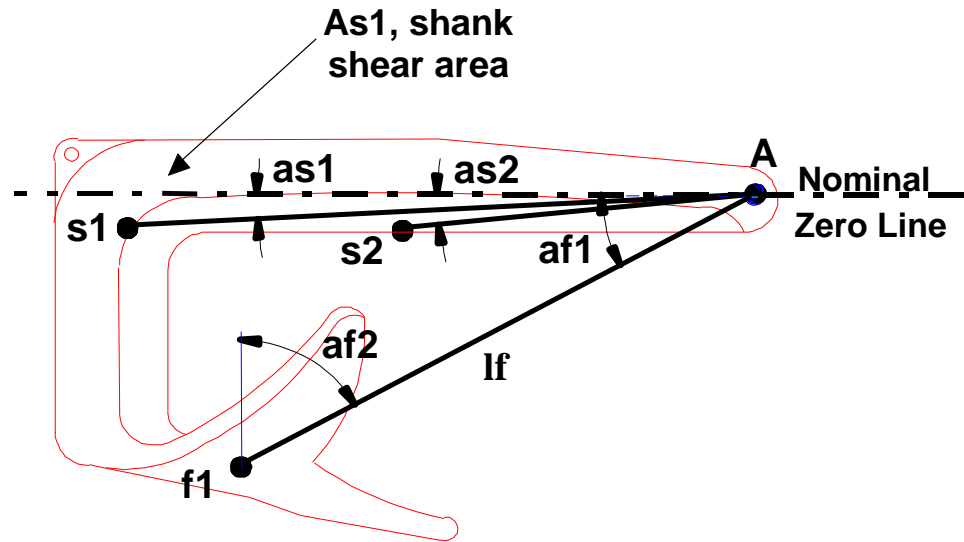
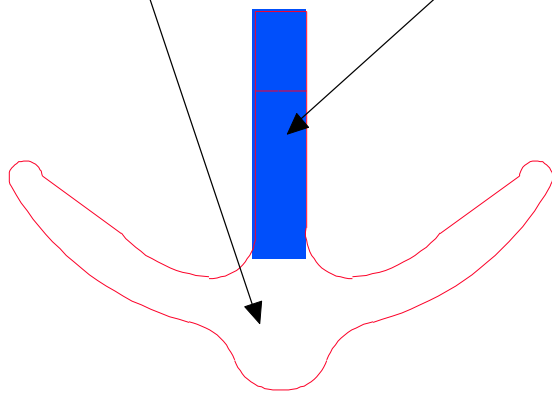
6.1.5 As2, shank projected area

This is the frontal area of the shank. For open shanks, the area of open sections is not included. For shanks with non-parallel sides, an allowance must be made for the projected area of the non-parallel parts. Forces on this area, As2, are calculated using the bearing coefficients, Nc1 and Nc2, as input in the soils data section.



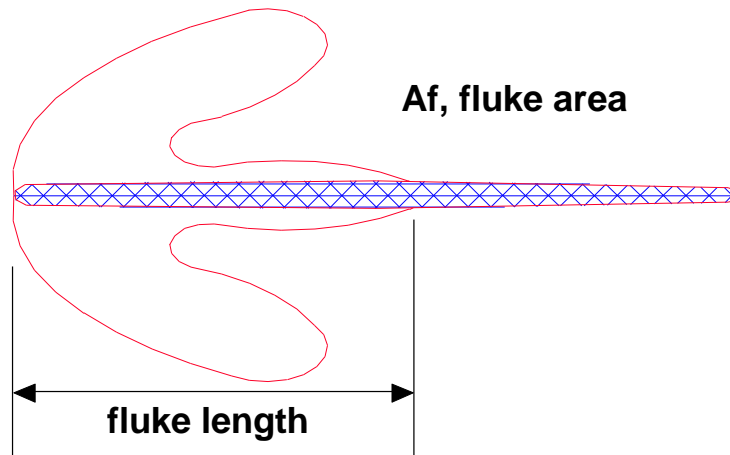
STA ANCHOR Nomenclature & Geometry

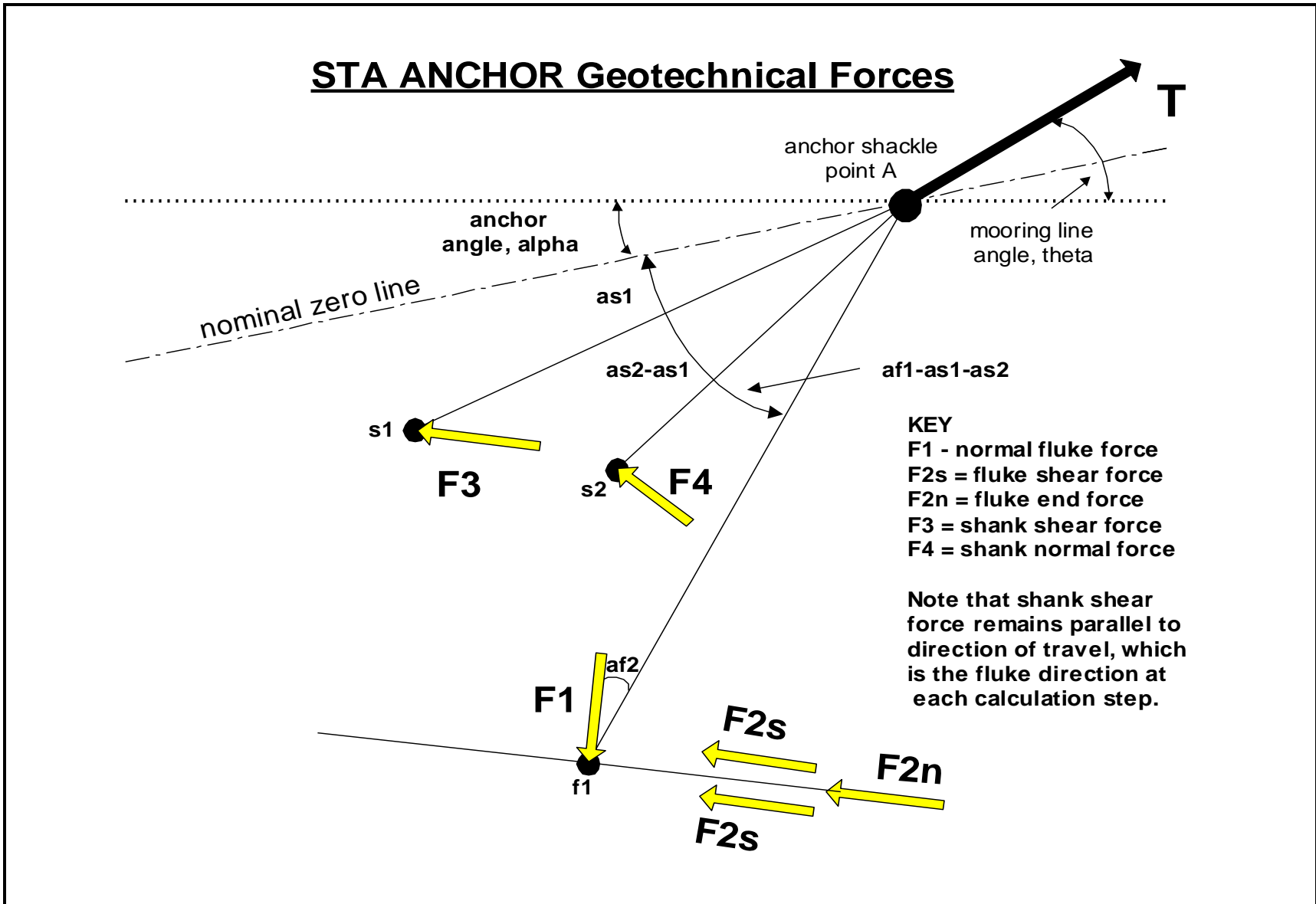
Af2, fluke projected area
As2, shank projected area



KEY

- f1 = fluke center of area
- s1 = shank center of shear area
- s2 = shank center of normal area
- lf = fluke distance from A to f1
- ls1 = 1st shank distance from A to s1
- ls2 = 2nd shank distance from A to s2
- af1 = 1st fluke angle
- af2 = 2nd fluke angle
- as1 = 1st shank angle
- as2 = 2nd shank angle
- nominal zero line does not have to be parallel to fluke.





6.1.6 *W, anchor weight*

This is the anchor weight in kips. It is used in logical equations within the program to determine if mooring line loads can cause upward movement of the anchor. The location of the center of the weight is not considered by the program.

6.1.7 *Fluke shear area multiplier*

This term is used to account for the total shear forces on the upper and lower sides of the anchor fluke. It is not generally appropriate to use a value of 2 unless the anchor is extremely "clean" and has a narrow fluke angle (more generally appropriate to sand rather than soft cohesive soils). For mud anchors, a value of 1.75 is suggested, reflecting 75% of the lower surface of the fluke being subject to shear forces. In stiff clays, this may be reduced further to account for a lower shear stress between the anchor fluke and the soil than the undrained shear strength of the soil.

6.1.8 *Shank shear area multiplier*

This term is used to multiply the side area of the shank, term A_{s1} above, to account for shanks which have either two sides and are solid or have hollow sections as in large fabricated mud anchors. For solid shanks, a multiplier of up to 2 may be used. For hollow shanks with parallel sides, a maximum value of 4 is appropriate. For hollow shanks with non-parallel sides, a value of as low as 2 may be appropriate. Note that within the term A_{s1} an allowance must be made for the shear areas of interconnecting "horizontal" members bearing in mind that there will be this multiplier on A_{s1} . A further reduction in this term may be appropriate in stiff clays, to account for a lower shear stress between the anchor fluke and the soil than the undrained shear strength of the soil.

6.1.9 *Nominal zero line*

The nominal zero line is not an input in the program but is a reference line for three of the angles described below. This line must be drawn through the center of the shackle padeye but may be drawn in any orientation. However, the results are easier to interpret if a consistent method is used. The Bruce and Stevpris anchors calibrated in Appendix 1 were characterized by using a nominal zero line parallel to the upper edge of the shank. This method worked well because a change in fluke/shank angle did not change angles α_1 and α_2 described below. The Bruce Denla calibrated in Appendix 1 was characterized with a nominal zero line connecting the shackle padeye to the rear fluke padeye used for recovery. This method was less desirable because a fluke/shank angle change results in new angles α_1 and α_2 and length l_f below.

As mentioned earlier, this line can be drawn anywhere, although some locations may cause confusion when viewing the equilibrium results. An example of a confusing result is a nominal zero line drawn parallel to the fluke surface. This reference line is accurate to use, but when the equilibrium rotation angle is calculated to be negative, the user must remember how the angles are defined.

Note that all four angles defined below are different than the fluke/shank angles as defined by Bruce and Vryhof anchors.

6.1.10 *af1, 1st fluke angle*

This is the angle made between the "nominal zero line" and the line connecting the shackle padeye to the center of area of the fluke, f1. (See previous figures.) This angle will vary as the fluke/shank angle changes.

21.00°	af1, 1st fluke angle
33.50°	af2, 2nd fluke angle
15.00°	as1, 1st shank angle
25.00°	as2, 2nd shank angle
15.17 ft	lf, fluke distance
9.08 ft	ls1, 1st shank distance
7.00 ft	ls2, 2nd shank distance
0.77	calibration coef. for vertical anchor

6.1.11 *af2, 2nd fluke angle*

This is the angle made between the normal to the fluke at its center of area f1 and the line joining the center of area to the anchor shackle padeye. (previous figures) This angle will also vary as the fluke/shank angle changes.

6.1.13 *as1, 1st shank angle*

This is the angle between the "nominal zero line" and the line connecting the shackle padeye to the center of the side area, s1, of the shank. (previous figures) If the nominal zero line is defined relative to the shank, this angle will not vary as the fluke/shank angle varies.

6.1.14 *as2, 2nd shank angle*

The point s2 is defined as the location of the center of pressure for the shank projected area, As2. Angle as2 is measured between the line connecting s2 to the shackle padeye and the nominal zero line. If the nominal zero line is defined relative to the shank, this angle will not vary as the fluke/shank angle varies.

6.1.15 *lf, fluke distance*

This is the distance between the anchor shackle padeye and the center of area of the fluke. This distance may vary slightly as the fluke/shank angle changes.

6.1.16 *ls1, 1st shank distance*

This is the distance between the anchor shackle padeye and the point estimated to be the center of the side area, s1, of the shank.

6.1.17 *ls2, 2nd shank distance*

This is the distance between the anchor shackle padeye and the point estimated to be the center of pressure for normal forces on the shank, s2.

6.1.18 Calibration coef. for vert. anch. force

This is a combined coefficient to account for reduced soil strength due to disturbance and for calibrating the program results with those from model or full scale tests. This coefficient multiplies the vertical forces calculated to be available at the anchor (resisting uplift). In other words, if the program has calculated that in undisturbed soil, a force of 200 kips is available to maintain anchor trajectory and further embedment when a horizontal or inclined load is applied, a calibration coefficient of 0.7 would result in the program showing a value of only 140 kips at that point in the calculations. In the absence of calibration data, a value of 0.8 is the maximum that should be used for this coefficient. The calibrations in Chapter 12 for the four anchors tested in the Near Shore Tests all have different coefficients.

6.2 Wire (or Chain) Data:

6.2.1 Switch for wire or chain, 1 = wire, 2 = chain

The user may select either chain or wire for the analysis. If this input term is set to 1, the program will assume that a wire is used. The

1	Switch: 1=wire, 2=chain.
3.50 in	D1, wire or chain diameter
3.73 ft	Length of Upper Line elements
671.9 kip	Computed Ultimate Line Load at Sea B

area projected normal to the center line of a wire is unit length multiplied by the wire diameter. The area considered by the program normal to the center line of a chain is unit length multiplied by 2.6 times the bar diameter of the chain. The circumference of a wire is considered by the program simply to be π multiplied by the wire diameter. The circumference of an equivalent section of chain subject to tangential forces is considered by the program to be 10 times the bar diameter.

6.2.2 D1, wire or chain diameter

In the case of analysis for mooring wires, this is simply the wire diameter; for chains, the chain bar diameter.

6.2.3 Length of upper line elements and Applied mooring load

The Version 1.00 program required these two values as input from the user. These two cells are highlighted in bright green in this version and are not available for user input. These green highlighted cells are intended to be used as a visual cue. When the *Calculate Equilibrium* macro is run, the program computes a line element size and an applied mooring load and writes these values to the first summary section, cells A32 and A33. When the *Use Equilibrium Results* macro is run the results from cells A32 and A33 are written into the green highlighted cells and used for further calculations. Nonmatching values in cells A19 and A32 and cells A20 and A33 means that the equilibrium calculations have not been used yet. See Chaps 9 & 10 for more details on these macros.

6.2.4 Tangential wire force coefs.: normal

These two terms should both be 1.0. They modify the line tangential and normal forces in the soil.

1.00	<-tangential wire force coefs.: normal->	1.00
0.95	calibration coef. for horiz.drag	
23.00 lbf/ft	submerged weight of wire	or chain
0.00°	angle at sea bed (0° for deepest burial)	
2.92 ft	Depth for Nc max for wire/chain	

6.2.5 Calibration coef. for horiz. drag

This coefficient is included to enable the program to report the same horizontal drag distance as is measured in either model or full scale tests. The algorithms in the program are designed to end up with the correct embedment depth but do not correctly account for the drag distance which is needed to achieve that embedment depth. This term, a calibration coefficient for horizontal drag, is included to simply factor the drag distance based upon the drag embedment depth. If it is put to 1, the raw results from the program will be seen and generally the drag distance will be too short. STA ANCHOR can only approximate drag embedment lengths.

6.2.6 Weight

This is the submerged weight of the mooring cable or the mooring chain in pounds per foot. The STA Help dialog box for chain weights is below:

chains size (in)	weight in air (lb/ft)	weight in water (lb/ft)	Break Strength (kip)	chains size (in)	weight in air (lb/ft)	weight in water (lb/ft)	Break Strength (kip)
2	40.7	35.4	489	4 5/8	204.2	177.7	2265
2 1/4	50.2	43.7	611	4 3/4	216.4	188.3	2372
2 3/8	55.5	48.3	676	4 7/8	228.7	199.0	2479
2 1/2	63.4	55.2	744	5	239.6	208.5	2589
2 3/4	75.4	65.6	889	5 1/8	250.8	218.2	2700
2 7/8	83.4	72.6	965	5 1/4	258.3	224.7	2811
3	89.3	77.7	1044	5 3/8	277.9	241.8	2925
3 1/8	98.0	85.3	1125	5 1/2	290.0	252.3	3038
3 1/4	106.9	93.0	1209	5 5/8	298.1	259.3	3154
3 3/8	114.6	99.7	1295	5 3/4	319.0	277.5	3270
3 1/2	121.8	106.0	1383	6	340.6	296.3	3504
3 3/4	139.1	121.0	1566	6 3/16	363.0	315.8	3682
4	156.0	135.7	1756	6 3/8	366.0	335.8	3881
4 1/8	165.0	143.6	1855	6 9/16	409.8	356.5	4042
4 1/4	174.0	151.4	1955	6 3/4	434.2	377.8	4223
4 3/8	184.0	160.1	2057	7	459.3	399.6	4465

The STA Help dialog box for wire weights is shown below: These dialog boxes are shown if you click on the *Explain* macro button when your cursor is in the weight input cell.

STA Help

Properties for 6 x 91 IWRC Extra Improved Plow Steel wire

wire size (in)	weight in air (lb/ft)	weight in water (lb/ft)	Break Strength (kip)	wire size (in)	weight in air (lb/ft)	weight in water (lb/ft)	Break Strength (kip)
2	7.4	6.4	362	4	29.6	25.8	1354
2 1/8	8.4	7.3	406	4 1/4	33.3	29.0	1518
2 1/4	9.4	8.1	454	4 1/2	37.4	32.5	1688
2 3/8	10.4	9.0	302	4 3/4	41.7	36.3	1864
2 1/2	11.6	10.1	554	5	46.2	40.2	2048
2 5/8	12.8	11.1	610	5 1/4	49.8	43.3	2240
2 3/4	14.0	12.2	666	5 1/2	54.5	47.4	2438
3	16.6	14.4	786	5 3/4	59.6	51.9	2640
3 1/4	19.5	17.0	916	6	65.0	56.6	2852
3 1/2	22.7	19.7	1054				
3 3/4	26.0	22.6	1200				

6.2.7 Angle at sea bed

This is the angle which the mooring line makes to the horizontal at the point where it leaves the sea bed. In most cases this is likely to be zero, representing the situation where the mooring line lays along the sea bed for a distance before the anchor forces cause it to dip down into the sea bed. A positive angle may be used where the mooring line comes down to the sea bed in a non-tangential fashion.

6.2.8 Depth for Nc max for wire/chain

This depth (in feet) is the depth of the maximum Nc value. It is recommended to use 10 times the diameter of the wire used in the analysis, or 10 times the bar diameter, if chain is used. There may be reason to increase this depth where surface sediments are very weak and the bearing capacity equations are inappropriate.

6.3 Soil Data:

6.3.1 Cu1, at surface

This is the undrained shear strength of the soil at the surface of the sea bed in pounds per square foot. It should be noted that the program may have difficulty in finding a solution to the geometry for heavy chains and mooring wires in the area near the sea bed unless this term has a positive value. The program will not work if a value of 0 is used and typically a minimum value of 50 pounds per square foot is necessary to avoid numerical instabilities. The physical explanation of the problem is that the program predicts negative curvature of the mooring line in the area close to the sea bed.

6.3.2 Cu2, at bottom of 1st layer

The user can specify two soil layers, and this is the undrained shear strength at the bottom of the first layer. The strength is varied uniformly between Cu1 and Cu2.

6.3.3 Cu3, at top of 2nd layer

This is the undrained shear strength at the top of the second layer. Cu3 may be less than, equal to, or greater than Cu2.

6.3.4 Cu4, at bottom of 2nd layer

This is the undrained shear strength at the bottom of the second layer. Cu4 may be greater or less than Cu3. The undrained shear strength is taken to vary uniformly between Cu3 and Cu4.

6.3.5 Nc1, at surface

This is the bearing capacity coefficient at the surface of the sea bed. Typically a value of 6 is recommended.

6.3.6 Nc2, at depth of 5*F

This is the bearing capacity coefficient at a depth equal to 5 fluke lengths. Typically a value of 15 is suggested for embedment evaluations. This value is the maximum value of the bearing capacity coefficient used at all depths greater than 5 fluke lengths beneath the sea bed. For anchors subject to long-term large loads where drained shear strength conditions may be appropriate, Nc2, should be reduced to a maximum of 9 and the undrained shear strength should not be used. STA ANCHOR cannot presently handle these conditions.

6.3.7 d1, depth of 1st layer

This is the depth in feet of the 1st layer of sea bed soil. It has undrained shear strength Cu1 at its surface and Cu2 at its bottom.

6.3.8 *d2, thickness of 2nd layer*

This is the thickness of the 2nd soil layer which lies beneath the 1st soil layer and has undrained shear strength Cu_3 at its top and Cu_4 at its bottom.

6.4 Depth Range and Proof Load:

The *Calculate Equilibrium* macro searches for an anchor equilibrium position between two values, a starting depth and a maximum depth. The program makes 100 divisions between two depths and begins testing depths from the starting depth until an equilibrium position is found. See Chapter 11 for tips on how to select these values to run the program faster.

6.4.1 *Starting depth in feet*

The minimum depth for which equilibrium is checked.

6.4.2 *Maximum depth in feet*

The maximum depth for which equilibrium is checked.

6.4.3 *Desired Proof Load (In line at sea bed)*

This is the proof load the user anticipates will be applied when the anchor is installed. Typically an anchor factor of safety against failure of 1.5 is used, meaning that the ultimate capacity of the anchor system (anchor and forerunner) should be 1.5 times greater than the maximum load to be resisted by the system. When the system is installed a proof load is applied which is equal to the maximum calculated design load.

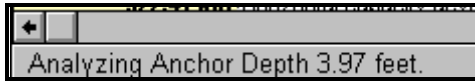
In this cell the user can specify any load of interest. This load may also be changed without affecting the main equilibrium results. The program simply searches for the anchor depth at which the proof load would be achieved. If the depth range investigated does not encompass that at which the proof load is reached, “out of range” warnings will appear in the Summary Results section.

Note that the proof load in this cell is achieved with the same line angle as specified at the sea bed for the ultimate load. This will normally be zero degrees, corresponding to tangential touchdown, resulting in maximum embedment depth. However, the user may use the Proof Load Sheet to investigate other angles, or the line angle for the ultimate load embedment calculations may be varied to any value of interest.

STA ANCHOR - ULTIMATE LOAD SHEET		12/31/95 Run date	Vryhof Stevpris 7 ton test anchor, 50 degree
Version 3.01, December 1995	Call (713) 789-8341 for support.	Copyright Stewart Technology Associates, 1991 and onwards	
Primary results and data input print on 3 pages, including all graphs.		Run ref:	10-lb soil, Tangential Touchdown
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.			
<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Step 1: Calculate Equilibrium</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Print Summary</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Print Options</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Graphs</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Restore Input</div> </div> <div style="display: flex; justify-content: space-between; align-items: center; margin-top: 10px;"> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Step 2: Use Equilibrium Results</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Anchor Catalog</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Proof Load Sheet</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Transfer Data</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Comparison Sheet</div> </div> <div style="display: flex; justify-content: space-between; align-items: center; margin-top: 10px;"> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Explain</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Special Param.</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Default Param.</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Table of Results</div> <div style="border: 1px solid black; border-radius: 10px; padding: 2px 5px; background-color: white;">Save Results</div> </div>			
INPUT DATA BELOW (shaded cells only) From anchor catalog: Stevpris 7 ton test anchor			
Anchor Data Below:		Some iteration parameters are set to SPECIAL values.	
100.90 sqft	Af, fluke area	21.00°	af1, 1st fluke angle
10.71 ft	F, fluke length	33.50°	af2, 2nd fluke angle
5.28 sqft	Af2, fluke projected area	15.00°	as1, 1st shank angle
70.37 sqft	As1, shank shear area	25.00°	as2, 2nd shank angle
27.00 sqft	As2, shank projected area	15.17 ft	lf, fluke distance
15.53 kip	W, anchor weight	9.08 ft	ls1, 1st shank distance
1.00	fluke shear area multiplier	7.00 ft	ls2, 2nd shank distance
2.50	shank shear area multiplier	0.77	calibration coef. for vertical anchor force
Wire (or chain) Data Below:		Ultimate Load Results Reflect Equilibrium	
1	Switch: 1=wire, 2=chain.	1.00	<-tangential wire force coeffs.: normal-> 1.00
3.50 in	D1, wire or chain diameter	0.95	calibration coef. for horiz.drag
3.73 ft	Length of Upper Line elements	23.00 lbf/ft	submerged weight of wire or chain
671.9 kip	Computed Ultimate Line Load at Sea Bed	0.00°	angle at sea bed (0° for deepest burial)
		2.92 ft	Depth for Nc max for wire/chain
Soil Data Below:		NOTE! Wire selected for analysis.	
90 psf	Cu1, at surface	6.00	Nc1, at surface
1090 psf	Cu2, at bottom of 1st layer	15.00	Nc2, at depth of 5°F
1090 psf	Cu3, at top of 2nd layer	100.00 ft	d1, depth of 1st layer
2000 psf	Cu4, at bottom of 2nd layer	58.00 ft	d2, thickness of 2nd layer
Depth Range & Proof Load:		Warning! Calculations interrupted. Click on Calcuate Equilibrium again.	
The starting and maximum depths define the interval for which equilibrium is checked.		100.00 ft	maximum depth of analysis for anchor equilibrium
1.00 ft	starting depth	450.2 kip	Desired Proof Load (in line at sea bed)
		Note! Proof load can be changed at any time.	

The above figure shows how the completed input for a run should appear.

7.0 DESCRIPTION OF SUMMARY RESULTS



While the program is running the Calculate Equilibrium macro a message will appear in the status bar at the bottom of your screen indicating what anchor depth is currently being analyzed.

Summary results are divided into two sections, **Summary Results from Equilibrium Calculations** and **Ultimate Load Results After Equilibrium Calculations Used**. This is because equilibrium results are determined in a two-step process. (See Chapters 9 and 10.) The first summary section contains the results from the *Calculate Equilibrium* macro. The second summary section contains the results from the *Use Equilibrium Calculations* macro.

7.1 Summary Results from the Equilibrium Calculations

7.1.1 Depth of anchor shackle at equilibrium

The calculated equilibrium depth of the shackle padeye from the *Calculate Equilibrium* macro. This cell is highlighted red if no equilibrium is found. (See Chapters 9 and 10.)

7.1.2 Length of upper line elements


The program automatically divides the mooring line from the entry point at the sea bed, down to the end of the line, into 100 elemental lengths. The length of the upper elements is specified by this term and is determined in the *Calculate Equilibrium* macro. The program will shorten the elements in areas where there are large force changes or large deflections occurring. The theoretical mooring line will be taken slightly past the anchor shackle depth. This cell is highlighted red if no equilibrium is found.

7.1.3 Applied Mooring Load

This is the load calculated from the *Calculate Equilibrium* macro to make the anchor achieve equilibrium at the calculated depth. The load is applied at the sea bed. This cell is highlighted red if no equilibrium is found.

7.1.4 Horizontal anchor resistance @ proof load

This value is determined from the resistance value range found in the depth range investigated and the user-specified Desired Proof Load. Once a set of results has been computed, the user may vary the Desired Proof Load and the new value of Horizontal anchor resistance will be almost instantly determined.

Summary Results from the Equilibrium Calculations			Ultimate Load Results Reflect Equilibrium		
55.45 ft	Depth of Anchor Shackle at Equilibrium	1.49	Ult. Load divided by proof load	175.6 kip	TAv_proof
3.73 ft	Length of Upper Line elements used for equilibrium	33.75°	equilibrium rotation angle 1	Use for VLAs	Maximum
671.9 kip	Applied Mooring Load used for equilibrium	1.75°	equilibrium rotation angle 2	1056.5 kip	Vertical
351.4 kip	Horizontal anchor resistance @ proof load	37.7 ft	Shackle depth at Proof Load	ONLY!	Capacity
Ultimate Load Results After Equilibrium Calculations			Explain Summary Results		
522.41 kip	Horizontal capacity developed at anchor	709.86 kip	Vertical capacity developed at anchor		
506.61 kip	Horizontal load applied at anchor shackle	302.41 kip	Vertical load applied at anchor shackle		
165.30 kip	Horizontal load lost in soil/wire interaction	407.45 kip	Excess vertical capacity		
314.31 ft	Drag distance in analysis	55.45 ft	Depth of embedment of anchor shackle		
33.75°	Alpha, maximum anchor rotation	30.83°	Angle of line to horiz. at anchor shackle		
56.56 ft	Maximum depth in analysis for line in soil	394.88 ft	Length of line in soil		
			The Normal Force F1 has been calculated using a linear relationship.		

The above figure illustrates how a set of summary results should appear

7.1.5 Ult. Load divided by proof load

The ratio of the calculated ultimate load divided by the user-specified desired proof load. The loads are calculated for identical conditions (anchor geometry, soil shear strength profile, wire or chain size, line angle at sea bed, etc.). However, for typical soil shear strength profiles, the anchor depth at a lower load will be less and it will be in weaker soil.

7.1.6 Equilibrium rotation angles 1 and 2

The calculated rotation angles for equilibrium from the *Calculate Equilibrium* macro. The first angle may be negative, depending on the orientation chosen for the nominal zero line. (See Chapter 5.) The second angle is the fluke angle relative to horizontal.

This cell offers the user another visual cue to check if equilibrium results have been used yet. Cells E32 and A41 will be equal if the *Use Equilibrium Results* macro has been run.

7.1.7 Shackle depth at proof load

This value is determined from the depth range investigated and the user-specified Desired Proof Load. Once a set of results has been computed, the user may vary the Desired Proof Load and the new value of shackle depth at proof load will be almost instantly determined.

7.1.8 T_{Av} proof

This is the vertical anchor resistance at the proof load specified. It is determined from the resistance value range found in the depth range investigated and the user-specified Desired Proof Load. Once a set of results has been computed, the user may vary the Desired Proof Load and the new value of vertical anchor resistance will be almost instantly determined.

7.1.9 Maximum Vertical Capacity

This value is only relevant for vertically loaded anchors (VLAs) but is reported for all equilibrium calculations. This is the load held by the anchor when a force is applied normal to the fluke area through the center of area of the fluke.

7.2 Ultimate Load Results After Equilibrium Calculations

7.2.1 Horizontal capacity developed at anchor

This is the maximum horizontal force found to exist at the anchor itself and does not include the resistive force coming from soil reactions against the mooring line.

7.2.2 Horizontal load applied at anchor shackle

This is the maximum value of horizontal load applied by the mooring line to the anchor.

7.2.3 Horizontal load lost in soil/wire interaction

This is the value of horizontal force which occurs because of soil and wire (or chain) interaction. The sum of this force and the horizontal capacity developed at the anchor give the total holding capacity of the wire (or chain) and anchor system.

7.2.4 Drag distance in analysis

This is the maximum drag distance considered in the analysis and corresponds to that shown on the graph of anchor embedment trajectory. As noted earlier, STA ANCHOR cannot predict this distance. The distance calculated by the program is a function of the horizontal coefficient described in the input section.

7.2.5 Alpha, maximum anchor rotation

Alpha is the angle in degrees through which the anchor rotates during the analysis. See Figure 3, where alpha is measured from the nominal zero line. For anchors with stable performance, alpha will increase to a maximum value which will normally correspond to the anchor fluke being from between 20 degrees to within 1 degree from horizontal. When this cell (A41) is equal to the value in cell E32, the *Use Equilibrium Results* macro has been run.

7.2.6 Maximum depth in analysis for line in soil

This term represents the maximum depth to which the theoretical mooring line model was extended. It is necessary for this depth to be equal to or greater than the final drag embedment depth of the anchor shackle padeye. However, for best accuracy, this value should be a little in excess of the final anchor padeye depth by varying the input data term "length of upper line elements".

7.2.7 Vertical capacity developed at anchor

This is the final maximum vertical capacity at the anchor shackle. It is not necessarily the same as the force that would be needed to extract the anchor, but is the vertical downwards force which balances the upwards components of force coming from the applied mooring line load.

7.2.8 Vertical load applied at anchor shackle

This term is the maximum vertical load at the end of the analysis being applied by the mooring line to the anchor shackle.

7.2.9 Excess vertical capacity

This term is the difference between the above two values. This value should be insignificant at equilibrium.

7.2.10 Depth of embedment of anchor shackle

This is the maximum embedment found at the end of the analysis. Note that it is depth at the anchor shackle, not at the fluke tip. The distance from the anchor shackle to the fluke tip should be added to this value in order to determine total maximum penetration of the anchor flukes. Note that the analysis, at each calculation step, considers the average soil strength at a level between the shackle and the fluke.

7.2.11 Angle of line to horiz. at anchor shackle

This is the angle that the anchor line makes to the horizontal at the final point in the analysis. The tension in the line is equal to the square root of the sum of the squares of the vertical and horizontal components which are reported above.

7.2.12 Length of line in soil

This is the line length from the anchor shackle to the sea bed, with the anchor at it ultimate dive depth and the ultimate load applied. Line length in the soil at the specified proof load can be found on the Proof Load Sheet or on the Comparison Sheet.

7.3 Displaying Tabular Results

Clicking on the macro button Table of Results will cause the program to display a dialog box permitting the user to scroll through results at all equilibrium depths. This dialog box is shown below.

Dialog box for display of table of results

Table of Results for Selected Depth Range				
load applied to line at sea bed	calculated shackle depth	calculated Thoriz at anchor	calculated Tvertical at anchor	Description of what anchor does
79 kip	1.0 ft	77 kip	5 kip	Anchor Dives
87 kip	2.0 ft	82 kip	9 kip	Anchor Dives
94 kip	3.0 ft	88 kip	12 kip	Anchor Dives
101 kip	4.0 ft	94 kip	16 kip	Anchor Dives
109 kip	5.0 ft	100 kip	20 kip	Anchor Dives
116 kip	6.0 ft	106 kip	23 kip	Anchor Dives
124 kip	7.0 ft	112 kip	27 kip	Anchor Dives
132 kip	8.0 ft	119 kip	30 kip	Anchor Dives
140 kip	9.0 ft	125 kip	34 kip	Anchor Dives
148 kip	9.9 ft	132 kip	37 kip	Anchor Dives
157 kip	10.9 ft	138 kip	41 kip	Anchor Dives
165 kip	11.9 ft	145 kip	45 kip	Anchor Dives
174 kip	12.9 ft	151 kip	49 kip	Anchor Dives
182 kip	13.9 ft	158 kip	53 kip	Anchor Dives
191 kip	14.9 ft	165 kip	57 kip	Anchor Dives
200 kip	15.9 ft	172 kip	61 kip	Anchor Dives
209 kip	16.9 ft	179 kip	65 kip	Anchor Dives
219 kip	17.9 ft	186 kip	69 kip	Anchor Dives
228 kip	18.9 ft	193 kip	74 kip	Anchor Dives
238 kip	19.9 ft	201 kip	78 kip	Anchor Dives
248 kip	20.8 ft	209 kip	83 kip	Anchor Dives
258 kip	21.9 ft	216 kip	88 kip	Anchor Dives
268 kip	22.9 ft	224 kip	92 kip	Anchor Dives

Run Reference
10-lb soil, Tangential Touchd...

Scroll up and down the list to examine the variation of applied line load with anchor shackle depth and forces induced at the shackle by the line in the sea bed.

OK

8.0 PROGRAM FEATURES AND THE MACRO BUTTONS

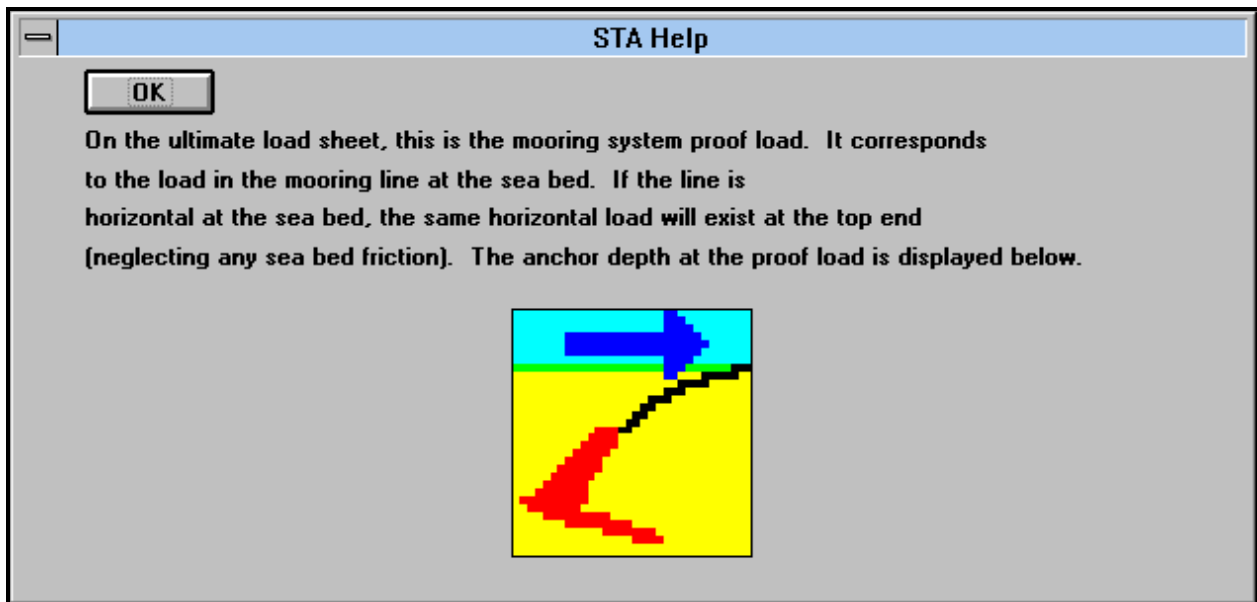
There are many macro buttons available for the user. The macros are in four categories: those used to set up the spreadsheet and calculation parameters, those used to determine equilibrium and results, those used to record and print the information from an equilibrium run, and those used to move between and link sheets.

8.1 Macros Used for Program Set-up

8.1.1 Explain (Context Sensitive HELP Feature)

This is a macro used as on-line help for the user input values. Running this macro defines the information needed for input in the cell that is selected when this macro is clicked. The help works only for the cells highlighted in yellow.

Example of Explain dialog box



8.1.2 Anchor Catalog

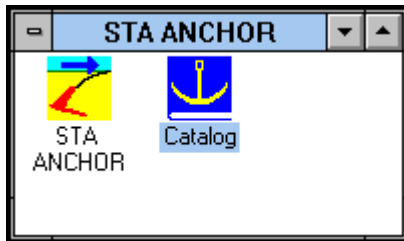
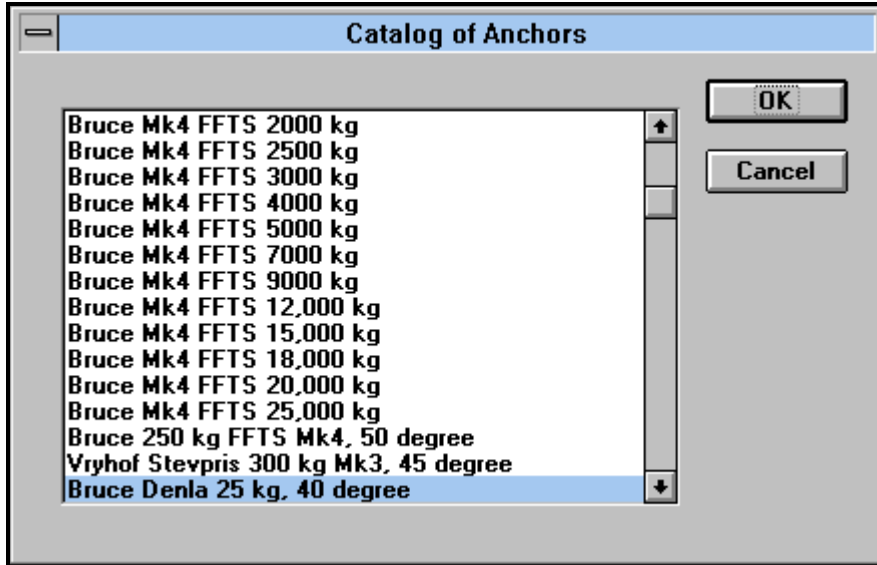
The *Anchor Catalog* is a macro that opens a file called CATALOG.XLM containing the anchor information required in the Anchor Data section for some Bruce and Vryhof anchors. The catalog contains the anchor areas, angles, lengths, and coefficients of each anchor in the catalog by name and weight.

The purpose of the catalog is two-fold: to help the user input data more easily and to help prevent calculation errors in determining anchor data input.

Clicking the *Anchor Catalog* macro button brings up a list box from which an anchor may be selected by name and weight. Upon selecting an anchor and clicking *OK*, the macro inserts all the Anchor Data input values. After using the macro, the input values may be edited if desired. For example, this will be necessary if the anchor is checked for a nonstandard fluke/shank angle, which affects af_1 , af_2 , lf , and as_1 and as_2 .

The *Anchor Catalog* macro file CATALOG.XLM has been created separately so that future updates of the catalog do not require updates of the entire program. Future versions of the anchor catalog will enable the user to enter their own anchors into the list box.

Anchor Catalog dialog box



Note also that without starting STA ANCHOR, the Anchor Catalog can be opened and edited by simply clicking on the Catalog icon setup in the STA ANCHOR program group during installation.

8.1.3 Default Parameters

Clicking the *Default Parameters* button configures some internal parameters used in the equilibrium calculations. The default parameters are set to have fairly tight convergence criteria making the program runs fairly lengthy.

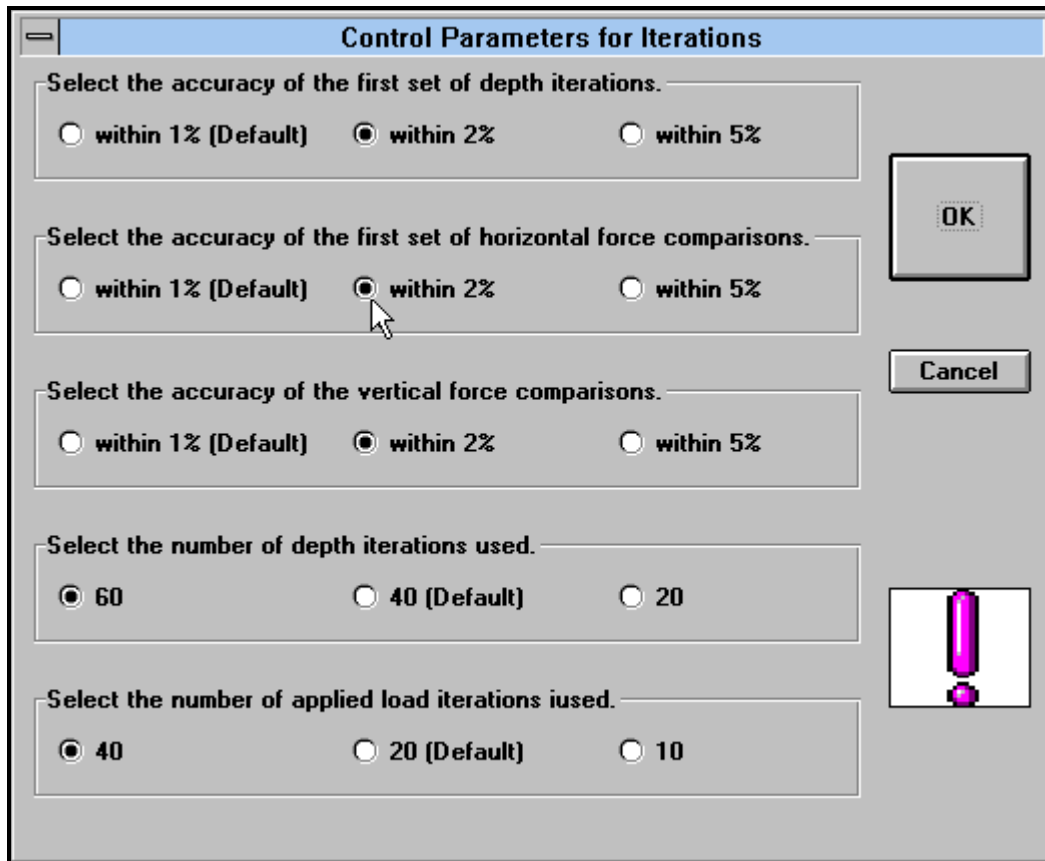
8.1.4 Special Parameters

The *Special Parameters* macro opens up a dialog box that allows the user to change some of the configuration parameters in the equilibrium calculations. These include the convergence percentage criteria for force and depth comparisons and the number of iterations allowed for convergence calculations. (See Chapters 9 and 10.)

An increase in the convergence percentage criteria can help the program to run more quickly, although not dramatically. This is because loosening the convergence criteria results in more depths being analyzed for equilibrium.

Some anchors, particularly VLAs, are more sensitive to the equilibrium calculations. If an anchor is very sensitive, it may not reach convergence at some depths. If this happens frequently, a larger number of iterations can be selected from the *Special Parameters* macro. This will increase the calculation time considerably.

Special Parameters Dialog Box



Control Parameters for Iterations

Select the accuracy of the first set of depth iterations.

within 1% (Default) within 2% within 5%

Select the accuracy of the first set of horizontal force comparisons.

within 1% (Default) within 2% within 5%

Select the accuracy of the vertical force comparisons.

within 1% (Default) within 2% within 5%

Select the number of depth iterations used.

60 40 (Default) 20

Select the number of applied load iterations used.

40 20 (Default) 10

OK

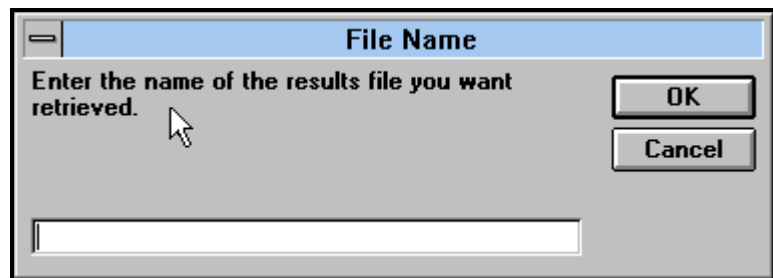
Cancel

Warning icon

8.1.5 Restore Input

This macro will enable the user to input information used in an earlier run more quickly. If the earlier run was saved by using the *Save Results* macro, that information may be retrieved using the *Restore Input* macro. Click the macro button and then enter the name of

the file whose input is to be retrieved. Note that both the input information and the table of results are retrieved. Note that if a wide range of depths was investigated and the results saved,



File Name

Enter the name of the results file you want retrieved.

OK

Cancel

Input field

all depth information will be restored. The program currently allows restoring file inputs from the current directory only.

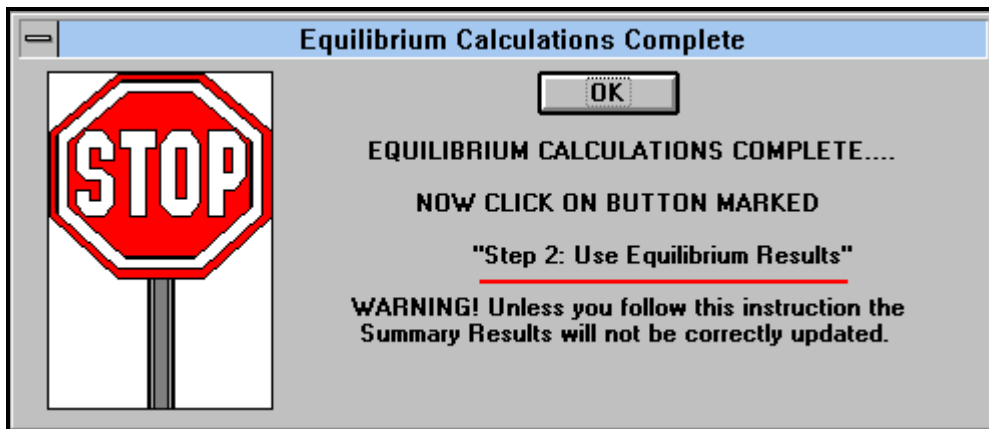
8.2 Macros Used to Determine Anchor Equilibrium

8.2.1 Step 1: Calculate Equilibrium

The *Calculate Equilibrium* macro is used after all input data is finalized. This macro is an extensive Visual Basic program and takes some minutes to run. Run times of up to one hour may be experienced on 486 machines, depending on the number of equilibrium depths (See Chapters 9 and 10.) The results of the equilibrium calculations are reported in the **Summary Results from the Equilibrium Calculations** section. If no equilibrium is found, the summary section has red highlighted cells saying so. A message will also appear in cell A34 telling the user what to do if this is the case. The three warnings that may appear if no equilibrium is found are:

- Decrease the starting depth in cell A28--it is deeper than equilibrium: this means the starting depth chosen in cell A28 is too great. Reduce this value and try again.
- Increase the max depth in cell F27--it isn't deep enough for equilibrium: this means equilibrium lies deeper than the maximum depth specified. Increase the value in cell F27. Increasing the starting depth will also speed the next program calculations.
- Decrease the maximum depth in cell F27--increments too large to find equilibrium: this means that the 100 depth increments analyzed for equilibrium between the starting and maximum depths are too large for one to be an equilibrium position. Decreasing the maximum depth (or increasing the starting depth) will reduce the size of the increments and allow for equilibrium to be determined.

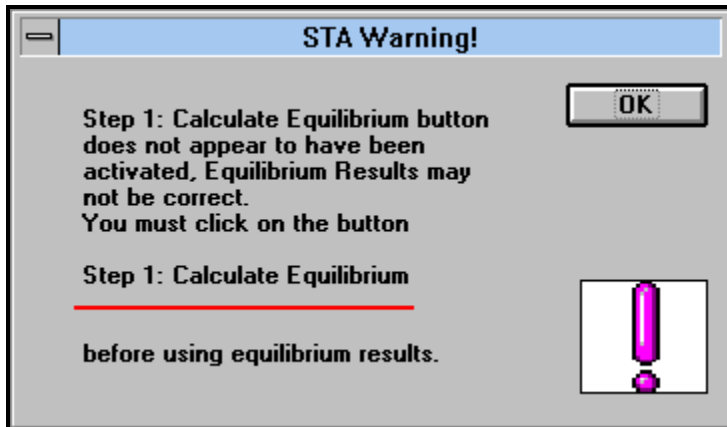
These cases are further described in Chapters 9 and 10, which explains the details of the program.



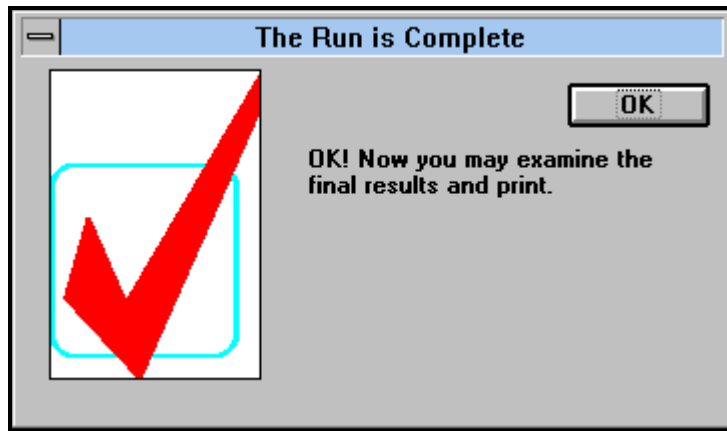
After a run is complete the program will present this dialog box.

8.2.2 Step 2:

Use Equilibrium Results



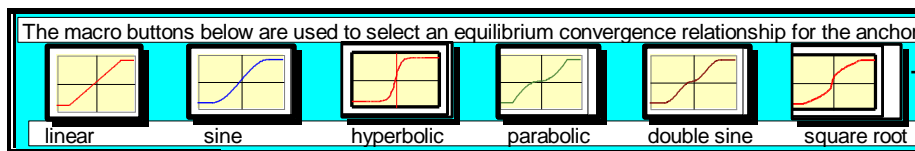
This macro is to be used after the equilibrium conditions are found. Running this macro re-plots the graphs to use the current equilibrium information and updates the results in the second summary section. This macro runs fairly quickly. If the macro button is pressed before the Calculate Equilibrium macro has run, a warning dialog box shows.



Once the macro has been run successfully, the following dialog box will be presented. This same dialog box will also be presented when a set of saved results is restored, as this same macro is run during the restore process.

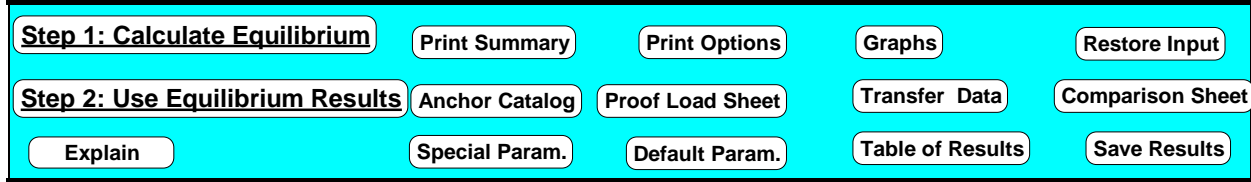
8.2.3 Special Macros to Control Anchor Equilibrium Convergence

At the bottom of the results area on the Ultimate load sheet there are six small graphs. Each graph is a macro button which is used to select the type of anchor behavior to be modeled when the fluke is within 5° from horizontal. In this angle range the equilibrium angle is generally found. The fluke normal force is reduced to zero if the fluke becomes horizontal. If the fluke rotates past horizontal, the fluke normal force reverses and acts upwards. The normal force is reduced from a maximum (plate bearing force) to zero in this angle range using one of the six available relationships described underneath the macro buttons illustrated below. Appendix 4 shows a comparison between each relationship. In general, the solution is relatively insensitive to this relationship.



8.3 Macros Used to Observe, Print and Save Results

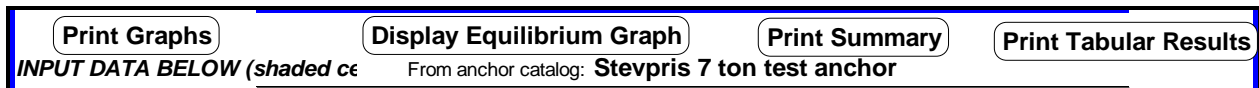
The main macro buttons available on the Ultimate Load Sheet are shown below.



The main macro buttons available on the Proof Load Sheet are shown below.



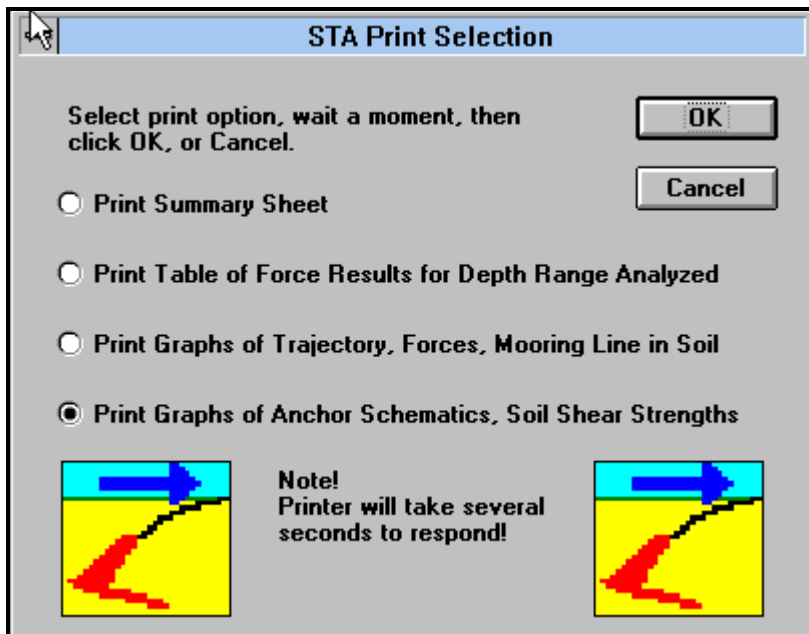
The main macro buttons available on Saved Load Case Sheet are shown below.



8.3.1 Print Summary

This macro button is used to print the input and summary sections of the spreadsheet (See figure on page 34). This print out was generated simply by clicking the *Print Summary* button. This button works the same way on the Ultimate, the Proof, and the Saved Case Load Sheets.

8.3.2 Print Options



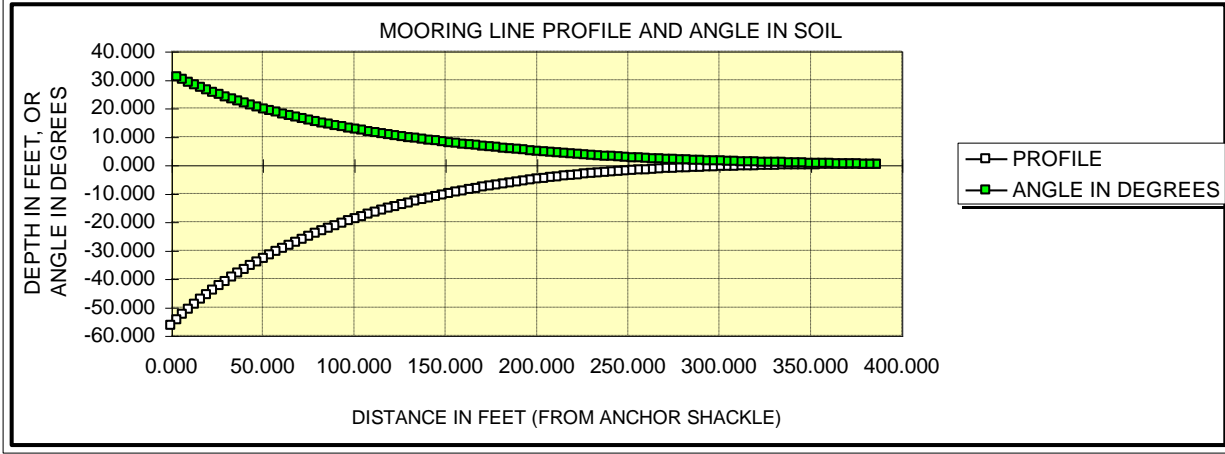
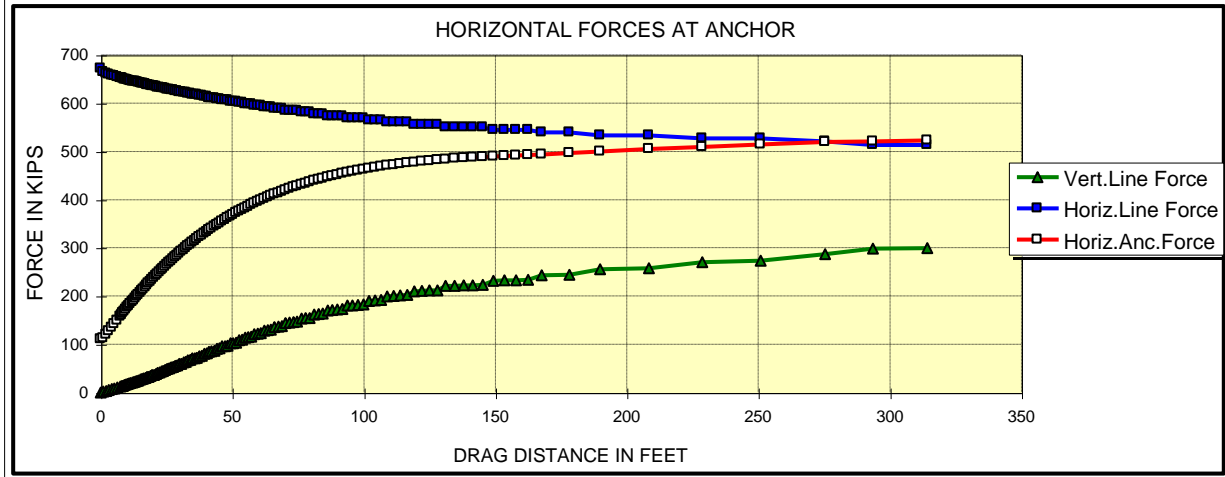
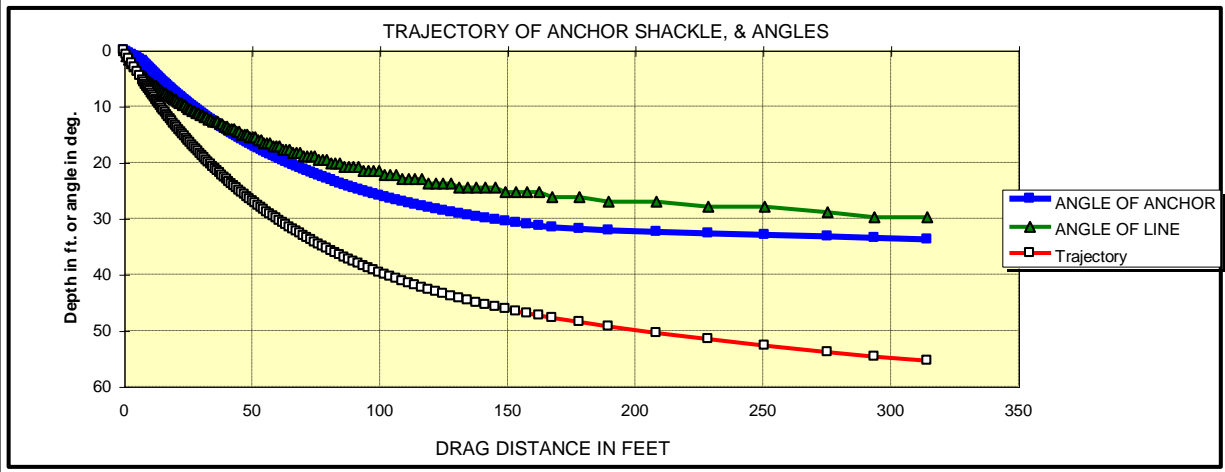
This macro brings up the dialog box shown to the left. The two sets of graphs that can be printed are shown in the figures on pages 35 and 36.

Note that the Summary sheet can also be printed from this dialog box, as can the Table of Results.

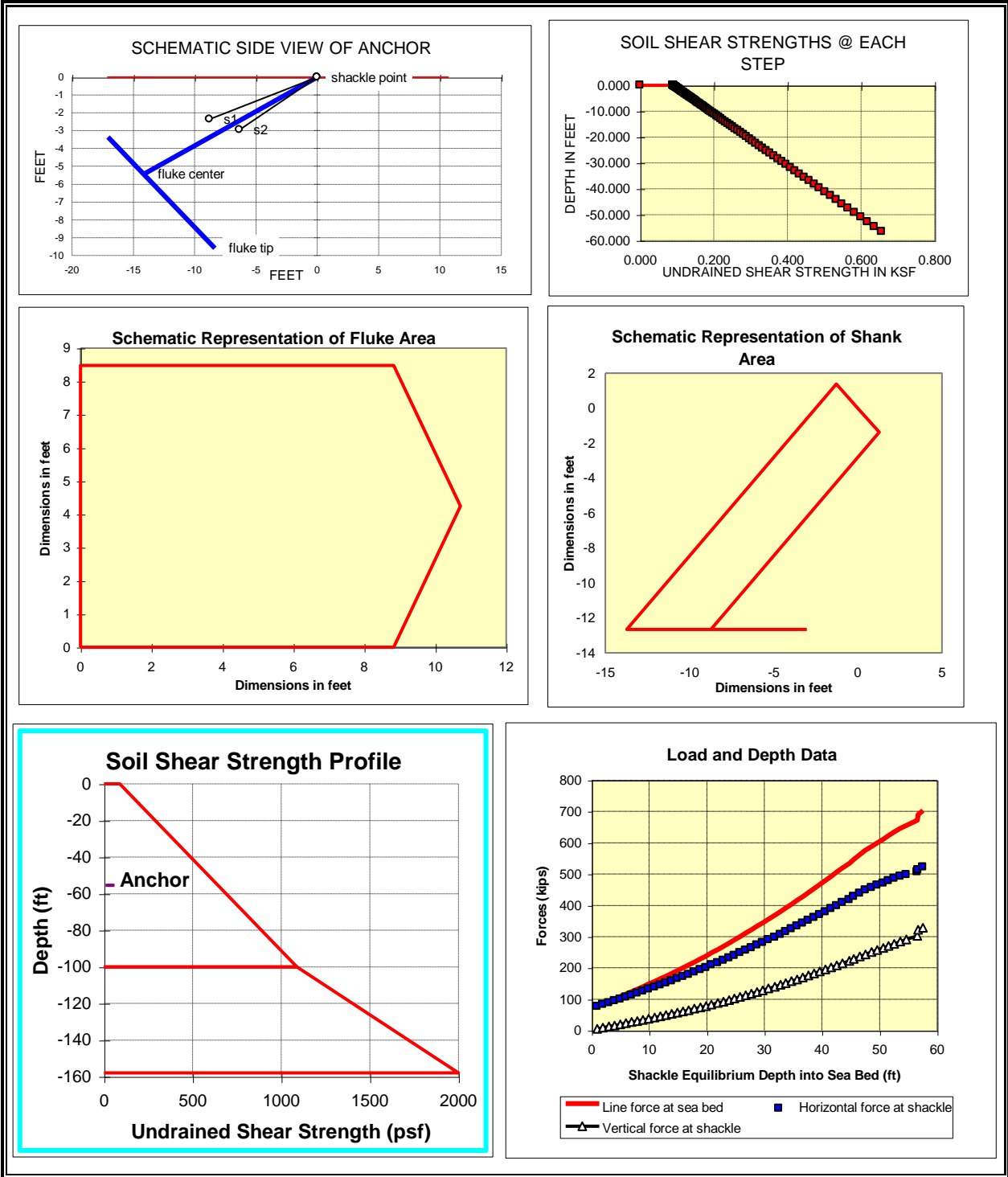
STA ANCHOR - ULTIMATE LOAD SHEET		1/1/96 Run date	Vryhof Stevpris 7 ton test anchor, 50 degree		
Version 3.01, December 1995		Call (713) 789-8341 for support.		Copyright Stewart Technology Associates, 1991 and onwards	
Primary results and data input print on 3 pages, including all graphs.			Run ref:	10-lb soil, Tangential Touchdown	
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.					
Step 1: Calculate Equilibrium		Print Summary	Print Options	Graphs	Restore Input
Step 2: Use Equilibrium Results		Anchor Catalog	Proof Load Sheet	Transfer Data	Comparison Sheet
Explain		Special Param.	Default Param.	Table of Results	Save Results
INPUT DATA BELOW (shaded cells only) From anchor catalog: Stevpris 7 ton test anchor					
Anchor Data Below:		Some iteration parameters are set to SPECIAL values.			
100.90 sqft	Af, fluke area	21.00°	af1, 1st fluke angle		
10.71 ft	F, fluke length	33.50°	af2, 2nd fluke angle		
5.28 sqft	Af2, fluke projected area	15.00°	as1, 1st shank angle		
70.37 sqft	As1, shank shear area	25.00°	as2, 2nd shank angle		
27.00 sqft	As2, shank projected area	15.17 ft	lf, fluke distance		
15.53 kip	W, anchor weight	9.08 ft	ls1, 1st shank distance		
1.00	fluke shear area multiplier	7.00 ft	ls2, 2nd shank distance		
2.50	shank shear area multiplier	0.77	calibration coef. for vertical anchor force		
Wire (or chain) Data Below: Ultimate Load Results Reflect Equilibrium		1.00	<-tangential wire force coeffs.: normal->	1.00	
1	Switch: 1=wire, 2=chain.	0.95	calibration coef. for horiz.drag		
3.50 in	D1, wire or chain diameter	23.00 lbf/ft	submerged weight of wire or chain		
3.73 ft	Length of Upper Line elements	0.00°	angle at sea bed (0° for deepest burial)		
671.9 kip	Computed Ultimate Line Load at Sea Bed	2.92 ft	Depth for Nc max for wire/chain		
Soil Data Below:		NOTE! Wire selected for analysis.			
90 psf	Cu1, at surface	6.00	Nc1, at surface		
1090 psf	Cu2, at bottom of 1st layer	15.00	Nc2, at depth of 5°F		
1090 psf	Cu3, at top of 2nd layer	100.00 ft	d1, depth of 1st layer		
2000 psf	Cu4, at bottom of 2nd layer	58.00 ft	d2, thickness of 2nd layer		
Depth Range & Proof Load:		Warning! Calculations interrupted. Click on Calculate Equilibrium again.			
The starting and maximum depths define the interval for which equilibrium is checked.					
1.00 ft	starting depth	Note! Proof load can be changed at any time.	100.00 ft	maximum depth of analysis for anchor equilibrium	
			450.2 kip	Desired Proof Load (in line at sea bed)	
Summary Results from the Equilibrium Calculations		Ultimate Load Results Reflect Equilibrium			
55.45 ft	Depth of Anchor Shackle at Equilibrium	1.49	Ult. Load divided by proof load	175.6 kip	TAV_proof
3.73 ft	Length of Upper Line elements used for equilibrium	33.75°	equilibrium rotation angle 1	Use for VLAs	Maximum Vertical Capacity
671.9 kip	Applied Mooring Load used for equilibrium	1.75°	equilibrium rotation angle 2	1056.5 kip	
351.4 kip	Horizontal anchor resistance @ proof load	37.7 ft	Shackle depth at Proof Load	ONLY!	
Ultimate Load Results After Equilibrium Calculations		Explain Summary Results			
506.27 kip	Horizontal capacity developed at anchor	303.92 kip	Vertical capacity developed at anchor		
506.61 kip	Horizontal load applied at anchor shackle	302.41 kip	Vertical load applied at anchor shackle		
165.30 kip	Horizontal load lost in soil/wire interaction	1.51 kip	Excess vertical capacity		
314.31 ft	Drag distance in analysis	55.45 ft	Depth of embedment of anchor shackle		
33.75°	Alpha, maximum anchor rotation	30.83°	Angle of line to horiz. at anchor shackle		
56.56 ft	Maximum depth in analysis for line in soil	394.88 ft	Length of line in soil		
The macro buttons below are used to select an equilibrium convergence relationship for the anchor					
linear	sine	hyperbolic	parabolic	double sine	square root
The Normal Force F1 has been calculated using a linear relationship.					
Different Force Function Used: Recalculate Equilibrium					

Result of clicking on the Print Summary macro button

Run ref: 10-lb soil, Tangential Touchdown Vryhof Stevpris 7 ton test anchor, 50 degree
STA ANCHOR - ULTIMATE LOAD SHEET: Page 1 of 2 graphic pages. 12/31/95 run date



First set of standard graphs in typical printout.



Second set of standard graphs in typical printout.

10-lb soil, Tangential Touchdown				
Table of Results for Selected Depth Range				
load applied to line at seabed	calculated shackles depth	calculated Thoriz at anchor	calculated Tvertical at anchor	Description of what anchor does
79 kip	1.0 ft	77 kip	5 kip	Anchor Dives
87 kip	2.0 ft	82 kip	9 kip	Anchor Dives
94 kip	3.0 ft	88 kip	12 kip	Anchor Dives
101 kip	4.0 ft	94 kip	16 kip	Anchor Dives
109 kip	5.0 ft	100 kip	20 kip	Anchor Dives
116 kip	6.0 ft	106 kip	23 kip	Anchor Dives
124 kip	7.0 ft	112 kip	27 kip	Anchor Dives
132 kip	8.0 ft	119 kip	30 kip	Anchor Dives
140 kip	9.0 ft	125 kip	34 kip	Anchor Dives
148 kip	9.9 ft	132 kip	37 kip	Anchor Dives
157 kip	10.9 ft	138 kip	41 kip	Anchor Dives
165 kip	11.9 ft	145 kip	45 kip	Anchor Dives
174 kip	12.9 ft	151 kip	49 kip	Anchor Dives
182 kip	13.9 ft	158 kip	53 kip	Anchor Dives
191 kip	14.9 ft	165 kip	57 kip	Anchor Dives
200 kip	15.9 ft	172 kip	61 kip	Anchor Dives
209 kip	16.9 ft	179 kip	65 kip	Anchor Dives
219 kip	17.9 ft	186 kip	69 kip	Anchor Dives
228 kip	18.9 ft	193 kip	74 kip	Anchor Dives
238 kip	19.9 ft	201 kip	78 kip	Anchor Dives
248 kip	20.8 ft	209 kip	83 kip	Anchor Dives
258 kip	21.9 ft	216 kip	88 kip	Anchor Dives
268 kip	22.9 ft	224 kip	92 kip	Anchor Dives
279 kip	23.9 ft	232 kip	97 kip	Anchor Dives
289 kip	24.8 ft	240 kip	102 kip	Anchor Dives
300 kip	25.8 ft	248 kip	107 kip	Anchor Dives
311 kip	26.8 ft	256 kip	112 kip	Anchor Dives
322 kip	27.8 ft	264 kip	118 kip	Anchor Dives
333 kip	28.8 ft	272 kip	123 kip	Anchor Dives
344 kip	29.7 ft	281 kip	128 kip	Anchor Dives
356 kip	30.7 ft	289 kip	134 kip	Anchor Dives
368 kip	31.8 ft	298 kip	140 kip	Anchor Dives
379 kip	32.8 ft	306 kip	146 kip	Anchor Dives
391 kip	33.7 ft	315 kip	151 kip	Anchor Dives
403 kip	34.7 ft	324 kip	157 kip	Anchor Dives
416 kip	35.7 ft	333 kip	163 kip	Anchor Dives
428 kip	36.7 ft	342 kip	169 kip	Anchor Dives
441 kip	37.7 ft	351 kip	176 kip	Anchor Dives
453 kip	38.6 ft	360 kip	182 kip	Anchor Dives
466 kip	39.6 ft	370 kip	188 kip	Anchor Dives
479 kip	40.6 ft	379 kip	195 kip	Anchor Dives
493 kip	41.6 ft	389 kip	201 kip	Anchor Dives
506 kip	42.6 ft	398 kip	208 kip	Anchor Dives
520 kip	43.6 ft	408 kip	215 kip	Anchor Dives
534 kip	44.8 ft	417 kip	222 kip	Anchor Dives
547 kip	45.6 ft	428 kip	229 kip	Anchor Dives
562 kip	46.6 ft	438 kip	236 kip	Anchor Dives
576 kip	47.6 ft	448 kip	243 kip	Anchor Dives
589 kip	48.6 ft	457 kip	250 kip	Anchor Dives
600 kip	49.6 ft	464 kip	257 kip	Anchor Dives
611 kip	50.6 ft	471 kip	264 kip	Anchor Dives
623 kip	51.6 ft	478 kip	270 kip	Anchor Dives
634 kip	52.6 ft	486 kip	277 kip	Anchor Dives
646 kip	53.6 ft	493 kip	284 kip	Within 0.5% of Equilibrium
655 kip	54.6 ft	498 kip	290 kip	Within 0.5% of Equilibrium
672 kip	56.6 ft	507 kip	302 kip	Within 0.5% of Equilibrium
691 kip	56.7 ft	513 kip	322 kip	Within 0.5% of Equilibrium
703.21	57.535	521.61	328.434	Too Deep

8.3.2 Print Options (Continued)

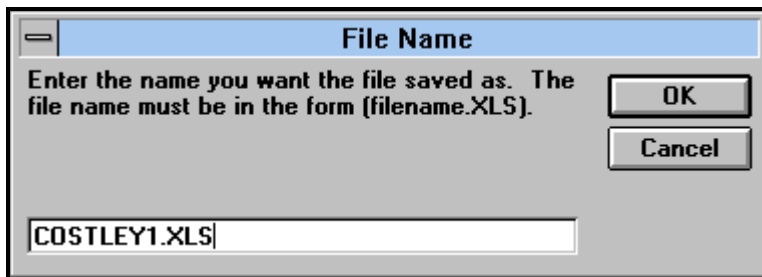
The table of results for each of the depth ranges investigated (where equilibrium has been found) can be printed from the *Print Options* macro (see dialog box on page 32). An example is shown to the left. This same table can be reviewed in a dialog box, as illustrated on page 27, by clicking on the *Table of Results* macro button.

The user may move around the Ultimate Load Sheet using the scroll bars or the arrow keys, and find this table located as illustrated on page 6, near the middle of the sheet. The table can also be easily located in sheets of saved results, if the saved results file is opened.

8.3.3 Save Results

This macro is set up to allow the user to save the input, summary results, main graphs, and table of results. To do so, click the *Save Results* button. An input box will come up; type the name of the file the results should be saved as, and then click *OK*. The program is currently set up to save files only to the directory in use, and requires standard DOS file names to be used, ending with suffix “.XLS”. Maximum file name length is eight characters plus the .XLS suffix. The macro then opens a template file called ANCHOR.XLT but saves the file with the name entered in the input box. The file is closed and the user is returned to the main program. The saved file is about 250k compared to the 3.5 meg size of the program file. A file saved in this way can be used to input data using the *Restore Input* macro button.

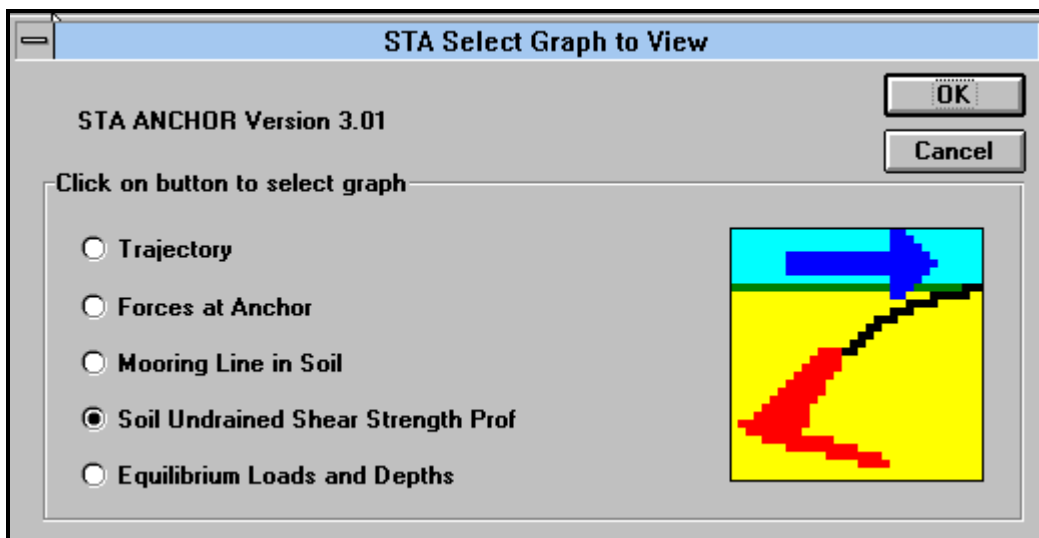
Save Results Dialog Box



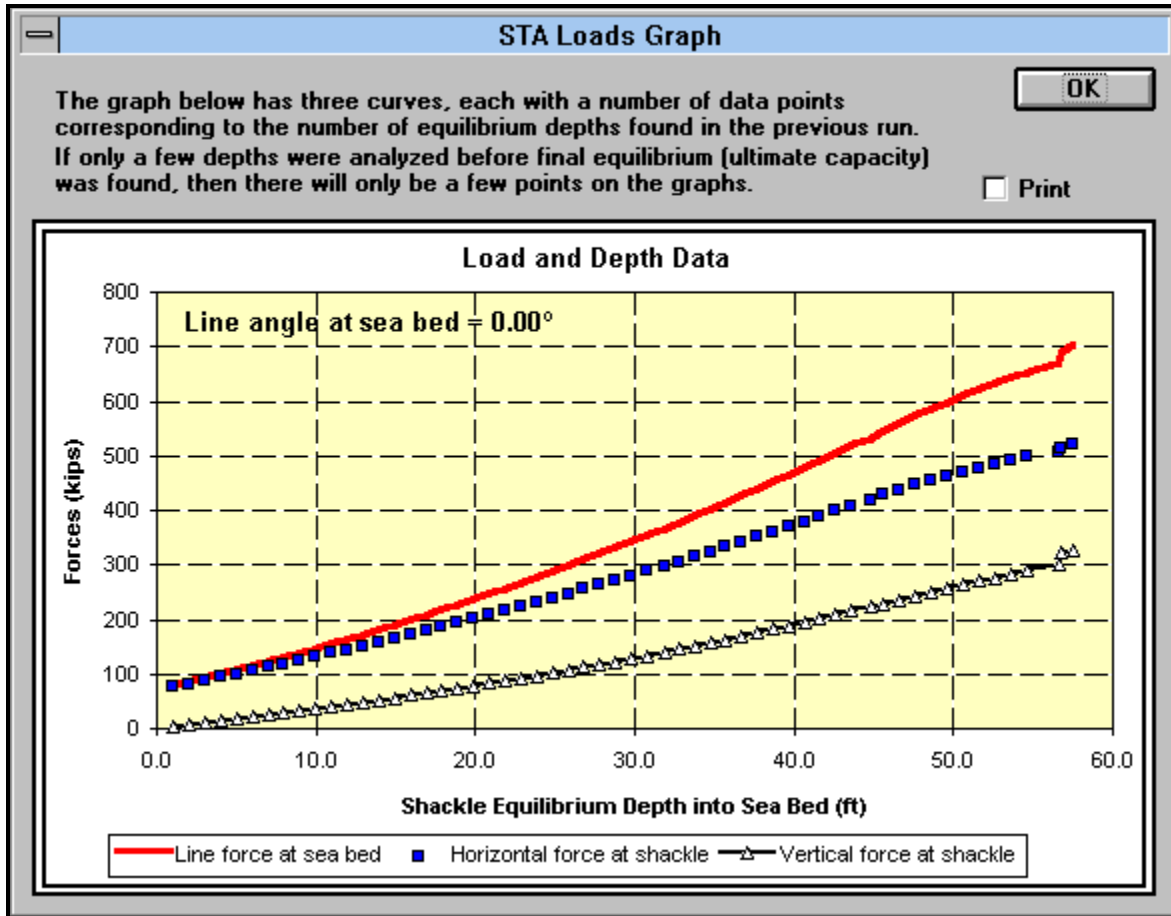
8.3.4 Graphs

Clicking the button *Graphs* brings up the following dialog box:

Dialog box for graph selection



An example of a graph that may be displayed is shown in the following figure.



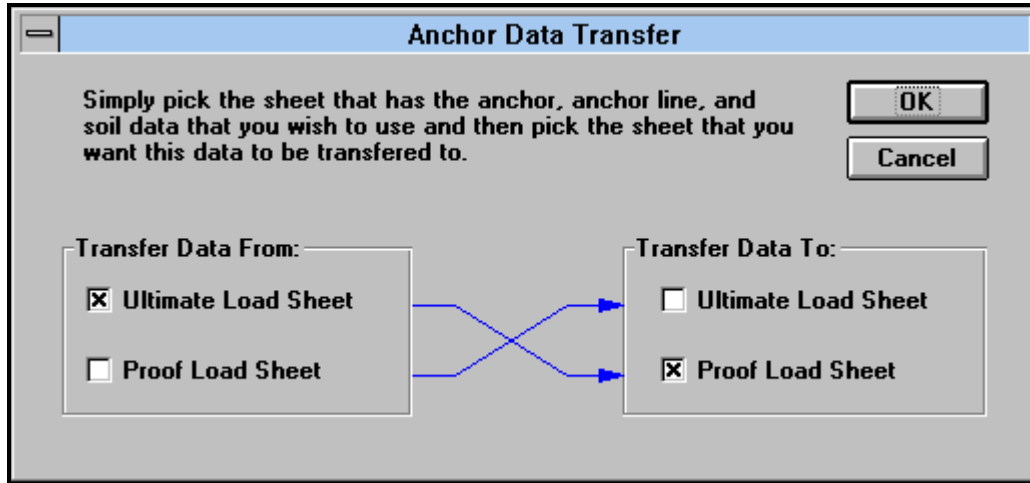
If the user checks the *Print* selection box, before clicking on *OK*, the graph will be printed.

8.4 Macros Used to Move Between and Link Sheets

8.4.1 Transfer Anchor Data

This macro allows the user to transfer the anchor, anchor line, and soils data between the Ultimate Load Sheet and the Proof Load Sheet and vice versa. When this button is pressed a dialog box will appear which asks the user what sheet contains the data that is to be transferred. It also ask the user which sheet will receive the data. Once these options are chosen the user simply clicks *OK* and the data is transferred. If the anchor data being transferred is from the Proof Load Sheet to Ultimate Load Sheet the user will see CALC. EQUILIB. in the “Length of Upper Line Elements” and “applied mooring load” cells on the Ultimate Load Sheet. These messages will disappear once the user runs the Calculate Equilibrium” button and then the “Use Equilibrium Results” button.

Dialog Box for *Transfer Data*



8.4.2 Go To Proof Load Sheet

This macro allows the user to switch over to the Proof Load Sheet by pressing the *Proof Load Sheet* button.

8.4.3 Go To Comparison Sheet

This macro allows the user to switch over to the Comparison Sheet by pressing the *Comparison Sheet* button.

Use of the Proof Load Sheet is more fully described in Appendix 6.

Use of the Comparison Sheet is described in Chapter 12.

9.0 GENERAL METHOD OF SOLUTION

STA ANCHOR is a very large spreadsheet program with many different calculations involved. This chapter contains some detailed descriptions of spreadsheet sections and calculations in order to give the user the best background possible to run the program. Excel 5 has two different ways of performing calculations and STA ANCHOR uses both. An understanding of how these differ will help in understanding the program structure.

The first way of calculation is through formula commands. An example of the formula command is cell F42, length of line in soil. Selecting this cell shows the following line in the formula bar:

=SUM(AE70:\$AE\$170),

which means the summation of the values in cells AE70 through AE170. Changing any cell value used in a formula command results in the entire spreadsheet being recalculated.

Very many cells contain formula commands dependent upon the user input data. If more than a few input data cells need to be changed, it is time-saving to turn this calculation feature off. This is done by selecting the **Tools** menu and then choosing **Option....** Select the Calculation tab when the dialog box appears and then check the box under Manual Calculations. Click *OK* to return to the main program. Returning to automatic recalculations is done by selecting that check box in the dialog box described above.

The second way the program performs calculations is through a macro. The Excel 5 macro language is Visual Basic, a way to write programming code directly into a spreadsheet. The Visual Basic code in STA ANCHOR is written on separate sheets hidden from view. The macros in STA ANCHOR run only when the user specifies so by clicking the appropriate macro button.

The *Anchor Catalog* macro offers a good example of both types of calculations. Upon clicking the *Anchor Catalog* button, the macro begins to run and a list box appears with a selection of anchors. The user selects one and click *OK*. The macro then turn the calculation feature to Manual, writes the 16 anchor data values into the appropriate input locations, turns the calculation feature back to automatic, which makes the spreadsheet recalculate, and then the macro ends and returns the user to the main program.

The program spreadsheet titled "ANCHORA", the Ultimate Load Sheet, is quite large and contains many different calculation areas. The input, summary, and graph areas have already been described earlier in this manual. The schematic on page 6 shows the layout of the sheet. Each area is numbered in the order used by the program and will be described in that order below.

Area 1. Input and Summary area. This has been described at length in earlier sections of the manual.

Area 2. Program Conversions and Parameter Information. This area contains numerous cells that perform some simple calculations used elsewhere. For example,

angles entered in degrees are converted to radians in this area. Parameters changed using the *Default Parameters* or the *Special Parameters* macros are recorded in this area also.

Area 3. This area contains six macros that change the way the normal fluke force is calculated. See Chapter 10 for this description.

Area 4. Force information for depths. This area contains the preparation calculations used for the equilibrium macros. These cells are all calculated using formula commands. Cell O324 is the starting depth and cell O424 is the maximum depth from the input control parameters. Cells O325-O423 are the increments in between.

Area 5. Macro Results. This area is filled in when the user runs the Calculate Equilibrium macro. All cells in this area are outputs from the macro calculations. The flow of the equilibrium calculations is as follows:

1. The equilibrium macro reads the depth value in cell O324 and the horizontal and vertical components of anchor forces at that depth.
2. The macro then guesses a line element size and applied load and begins a number of iterative calculations to test for equilibrium at that depth.
3. The macro tests each iteration, checking to see if the line element size and applied load chosen result in line calculations (performed on a hidden sheet) whose depth and horizontal tension component are within some percentage of the values in cells O324 and N324, the horizontal anchor force. The default parameters use 10% and 40 iterations to get there.
4. The iterations just described are an initial rough guess. Once the forces and depths have converged to the given percentage, another set of iterations begins to match the results 10 times better. The default parameters here are 1% and 20 iterations.
5. When the forces and depths have converged within the specified percent, the program compares the computed vertical tension component of the line to the vertical anchor force. Three things can happen:
 - a) the vertical tension component is less than the vertical anchor force, so the anchor is not at equilibrium and will dive,
 - b) the vertical forces are within 1% of each other, so the anchor is at an equilibrium depth,
 - c) the vertical tension is greater than the vertical anchor force, so the anchor is too deep for equilibrium.
6. The iteration results for the depth O324 are reported in cells P324-X324. If the anchor is not too deep, the macro steps to the next depth in O325 and repeats.
7. The macro continues until a depth too deep for equilibrium is reached. The macro then reports to the **Summary Results from Equilibrium Calculations** the depth with the closest iteration results and ends.

The user is strongly encouraged to view the iteration results recorded here from the macro. Reviewing this area after equilibrium calculations can help the user see what is happening.

Area 6. Line Calculations. This area contains all calculations related to the line (wire or chain). The line calculations referred to in step 3) above are the same as those in area 6 but occur on another sheet hidden from view. This is because the cells in area 7 and graphs in area 8 are linked to those cells in area 6 by formula commands. The equilibrium macro uses a separate sheet to speed the calculations up.

Area 7. Force Calculations for graphs. These forces are computed in part by formula commands and in part from calculations performed on yet another hidden sheet when the user runs the *Use Equilibrium Results* macro.

Area 8. Graphs. The graphs in this area are updated from area 7 information after running the *Use Equilibrium Results* macro.

10.0 GEOTECHNICAL FORCES AT THE ANCHOR

STA ANCHOR computes geotechnical forces on the principal structural parts of the anchor as shown in the table below.

Anchor Part	Normal force	Shear force
Fluke main area	yes	yes*
Fluke "projected" area	yes	no
Shank "shear" area	no	yes*
Shank "projected" area	yes	no

* indicates that the magnitude of the shear force can be adjusted to be on a reduced area

The figure on page 13 shows these areas schematically idealized for mud anchors. The forces are applied generally at the centers of each area. The fluke normal force is the principal anchor depressing, or embedding, force. This force is applied at the center of the fluke area and is normal to the fluke. The maximum value of the force is calculated to be equal to the undrained shear strength of the soil (at a particular depth) multiplied by the fluke area, multiplied by the bearing capacity factor (for that particular depth) multiplied by a combined calibration and correction factor for soil disturbance. Initially, during embedment, the anchor fluke is generally at a rather steep angle to horizontal. As stable embedment proceeds the fluke angle generally becomes close to horizontal. Hence the fluke normal force is initially directed at an angle close to horizontal, and gradually becomes more nearly vertical downwards. The normal force is discussed in greater detail at the end of this chapter.

The fluke shear force is calculated parallel to the fluke, and is equal to the undrained shear strength of the soil, multiplied by the fluke area, multiplied by a coefficient, the fluke shear area multiplier. This coefficient is used to account for the lack of adhesion in most soils on the back face of the fluke as the anchor embeds. A multiplier of 2.0 would simulate a fluke with full contact with the soil on both faces, with the full soil shear strength developed on both faces (this would generally be the situation for an anchor in a cohesive soil after a day or less, after embedment). For very smooth anchor flukes in very stiff clays, it is unlikely that the full soil shear strength will be mobilized on the fluke surface. The shear area multiplier can be further reduced to account for this effect together with the lack of contact on the back face. Hence in some cases a multiplier of less than 1.0 may be appropriate.

The shear force on the shank is calculated parallel to the direction of travel of the anchor and is equal to the shear area of the shank, multiplied by the undrained shear strength of the soil, multiplied by the fluke shear area multiplier. As in the case of the fluke shear force, the shear area multiplier is used to account for the soil contact on both sides of the shank, as well as on internal faces in the case of hollow fabricated

shanks. A multiplier of 4.0 would simulate a hollow shank with full contact with the soil on the inside and outside of both sides.

As mentioned earlier, the normal fluke force maximum is

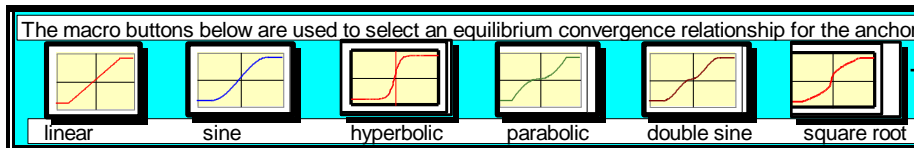
$$\text{force} = (A_f) (S_u) (N_c) (\text{vertical calibration coefficient}).$$

The program uses this as the normal fluke force when the fluke is greater than 5 degrees from horizontal.

As an anchor is embedded, if the anchor fluke area passes through the horizontal the direction of the fluke normal fluke force reverses. (This is why an anchor may be unable to embed under certain conditions.) STA ANCHOR seeks to account for this force reversal by assuming a force versus angle function within 5 degrees of horizontal.

The program is initially set to use the linear function, but any of the other forcing functions may be chosen. Each graph is actually a macro button. For example, by clicking the graph labeled "sinusoidal", all normal fluke force calculations in STA ANCHOR use the sinusoidal function.

The macro buttons that control the selection of which equilibrium convergence function is used are shown below. They are found on the Ultimate Load Sheet beneath the Summary Results Section.



The user may experiment with these different force functions as desired. STA ANCHOR Version 1.0 used the square root function.

It should be noted that no technical papers have been found that supports these force functions.

11.0 COMMENTS ON USE OF STA ANCHOR

11.1 Soils With Small, or Zero, Strength Increase With Depth

If the anchor enters a soil layer which has a small, or even a zero, strength increase with depth, the horizontal resisting force at the anchor may hold constant, or may decrease as further anchor rotation occurs. However, if the anchor continues to penetrate, the system (anchor plus mooring line) capacity will continue to increase as the system is pulled deeper into the soil. A limiting value will be reached when the vertical component of line tension applied to the anchor exceeds its vertical resistance.

11.2 Input Geometry Checking With Graphical Results

Use the graph named "SCHEMATIC SIDE VIEW OF ANCHOR" to check that the input data represents the anchor geometry required. While a detailed diagram of the anchor cannot be produced by the program, a schematic diagram is always generated. This schematic diagram may be compared with the figure on page 13, in this manual, in order to check that centers of area are in approximately the correct position and that angles have been input with the correct sign convention, etc. An example of this diagram is shown on the next page, together with the two other schematic views produced to help with anchor geometry data checking.

11.3 Tips on Running the Calculate Equilibrium Macro More Quickly

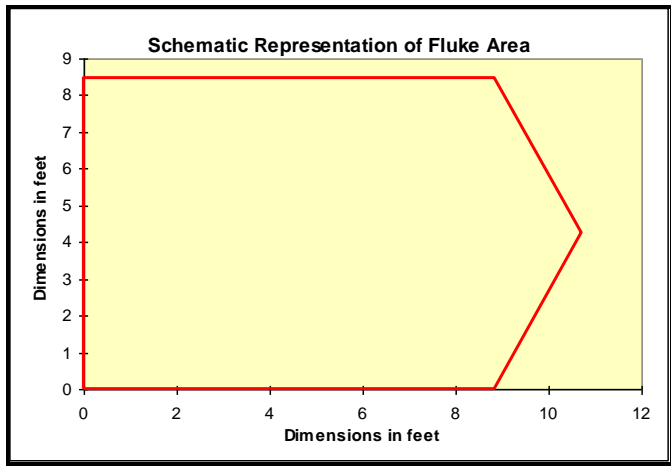
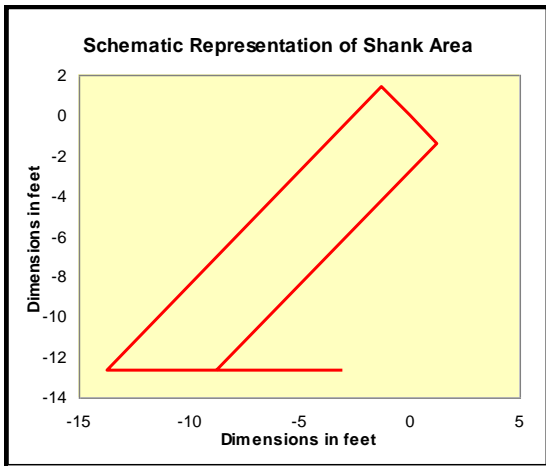
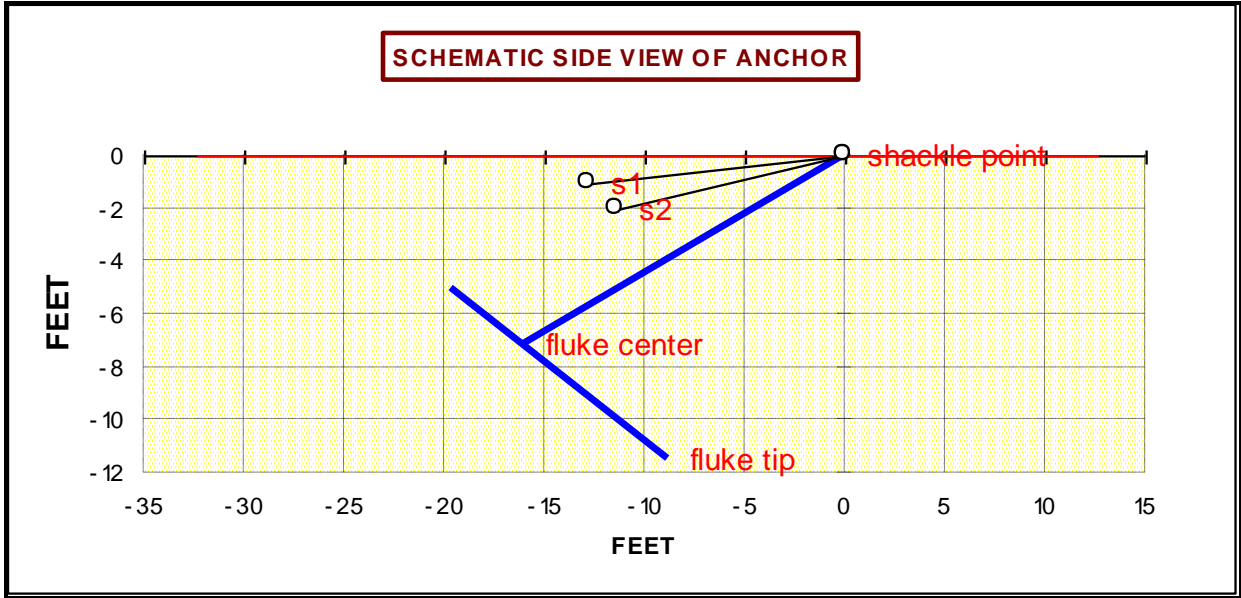
The starting depth chosen should be less than the expected equilibrium depth, while the maximum depth chosen should be greater than the expected equilibrium. Three examples are described below, assuming an anchor with an equilibrium depth of 50 feet.

Example 1. A starting depth of 5 feet and a maximum depth of 105 feet are chosen. The equilibrium macro checks for equilibrium at depths 5 feet, 6, 7, 8, etc. If 50 feet is an equilibrium depth, the macro will have checked 45 depths before finding equilibrium at 50 feet.

Example 2. A starting depth of 45 feet and a maximum depth of 145 feet are chosen. The macro checks for equilibrium at 45 feet, 46, 47, 48, 49, and finds equilibrium at 50 feet. Clearly this run is much faster than example 1 run.

Example 3. A starting depth of 45 feet and a maximum depth of 55 feet are chosen. The macro checks for equilibrium at depths 45.1 feet, 45.2, 45.3, 45.4, etc. It finally finds equilibrium at 50 feet after checking 50 depths. This run would be the longest of the three examples.

Clearly the selection of starting and maximum values has a great effect on the duration of the macro run. A novice user can expect to spend awhile adjusting to the way the program runs. As the user gains a feel for anchor equilibrium depths and becomes familiar with the program, the run times should decrease dramatically as appropriate starting and maximum depths are chosen.



12.0 COMPARISON SHEET

This Comparison Sheet permits the user to compare the line geometries and anchor positions analyzed on the Ultimate Load Sheet and the Proof Load Sheet on one graph. Additionally, one further line geometry can be analyzed on this sheet, with the line connected to the shackle and the anchor at the proof load depth, determined from the Ultimate Load Sheet. This facility allows the user to determine forces at the anchor shackle once the anchor has been proof loaded with the mooring line having any amount of uplift at the sea bed. The user may edit the run reference, add comments, define a line load at the sea bed, and an uplift angle, as shown in the figure below.

STA ANCHOR - COMPARISON SHEET		Vryhof Stevpris 7 ton test anchor, 50 degree	
Run ref:	300 kips load at 20 degree uplift angle	1/1/96 10:58	
<p>This sheet allows the user to compare various forerunner geometries in the soil. The geometry that would exist if the anchor had been pulled to its ultimate capacity is shown, together with the geometry developed by application of the proof load.</p> <p>Note! The depth range investigated must be sufficient to encompass the anchor's proof load equilibrium depth.</p> <p>The forerunner geometry from the proof load sheet is added to the comparison chart, below. Additionally the user may specify another set of sea bed line load conditions for a comparison. For example significant line uplift may be examined.</p>			
User	The Anchor is shown to dive from 37.7' to 52' when a load 36% larger than the proof load is applied to the		
Comments:	line at the sea bed with a 10° uplift angle. Forces at the shackle for a 300 kip line load with 20° uplift also shown.		
<input type="button" value="Optimize Line Elements"/> <input type="button" value="Ultimate Load Sheet"/> <input type="button" value="Proof Load Sheet"/> <input type="button" value="Optimize Proof Load Element Lengths"/>			
If line elements solver fails, manually adjust length term below, right.		If proof load solver fails, manually adjust terms over to right.	
300.0 kips	user defined line load at sea bed for this sheet	20.00°	user defined line angle at sea bed for this sheet
37.65 ft	Shackle depth at proof load from ult. load sheet	0.79 ft	Length of Upper Line elements for this sheet
37.69 ft	max soil depth in soil analysis	0.10% diff. between shackle depth and numerical wire depth	
671.9 kips	maximum line load at sea bed from ultimate load sheet	Line element lengths OK	
611.0 kips	applied mooring line load at sea bed from proof load sheet	Comparison Line Geometry (this sheet) Satisfactory	

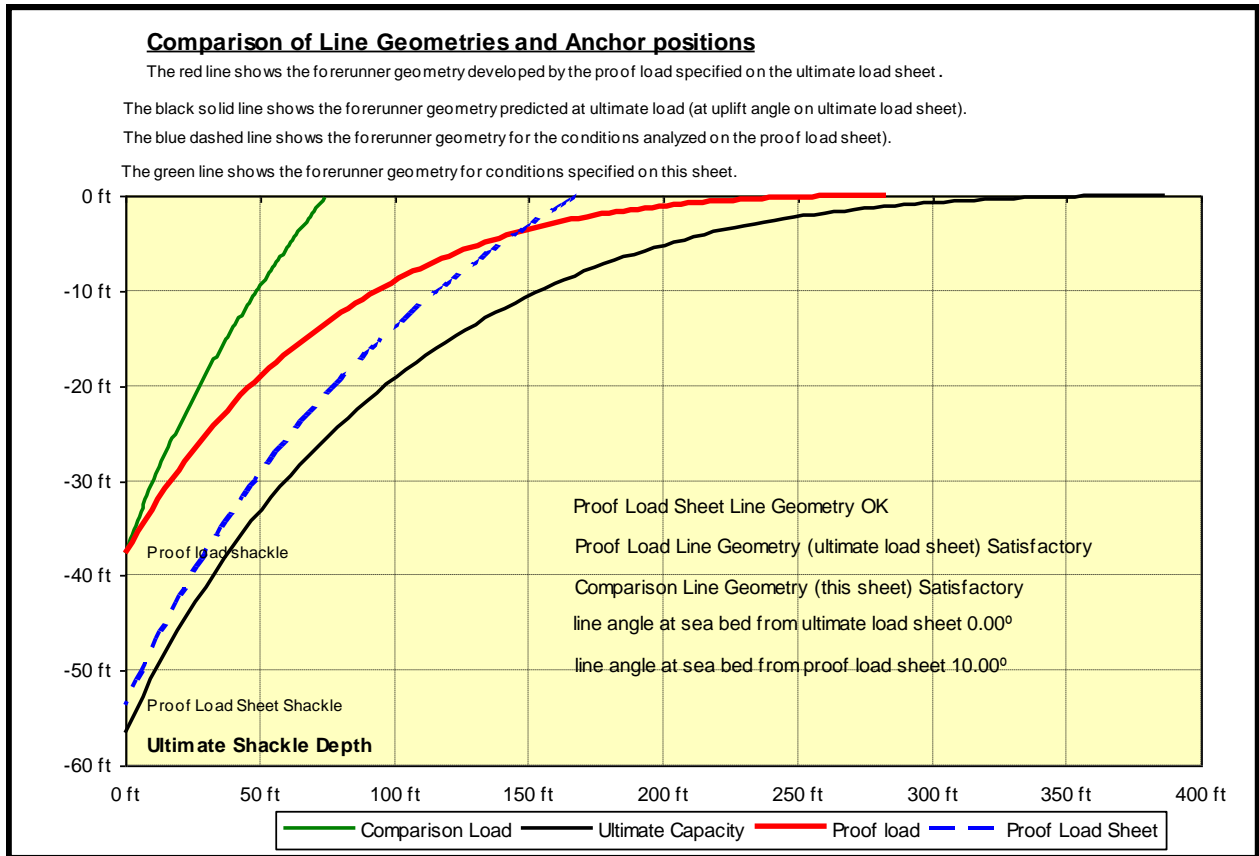
The macro button *Optimize Line Elements* is provided to automatically find an optimum line element size which results in an accurate line geometry for the line specified on this sheet. The macro button *Optimize Proof Load Element Lengths* is provided to automatically find an optimum line element size which results in an accurate line geometry for the proof load specified on the Ultimate Load Sheet.

The line size in this sheet is the same as that specified on the Ultimate Load Sheet. The soil shear strength profile is the same as that specified on the Ultimate Load Sheet. The line specified on this sheet is attached to the shackle at the depth found for the shackle when the system has the proof load applied, as specified on the Ultimate Load Sheet.

No anchor movement is investigated on this sheet, but forces applied to the shackle are determined.

The comparison shows anchor (shackle) depths and line geometries resulting from the following load cases:

- Ultimate Capacity (from Ultimate Load Sheet)
- Proof Load (from Ultimate Load Sheet)
- Load Condition Specified on Proof Load Sheet
- One Extra Line Condition (line attached to shackle at proof load depth)

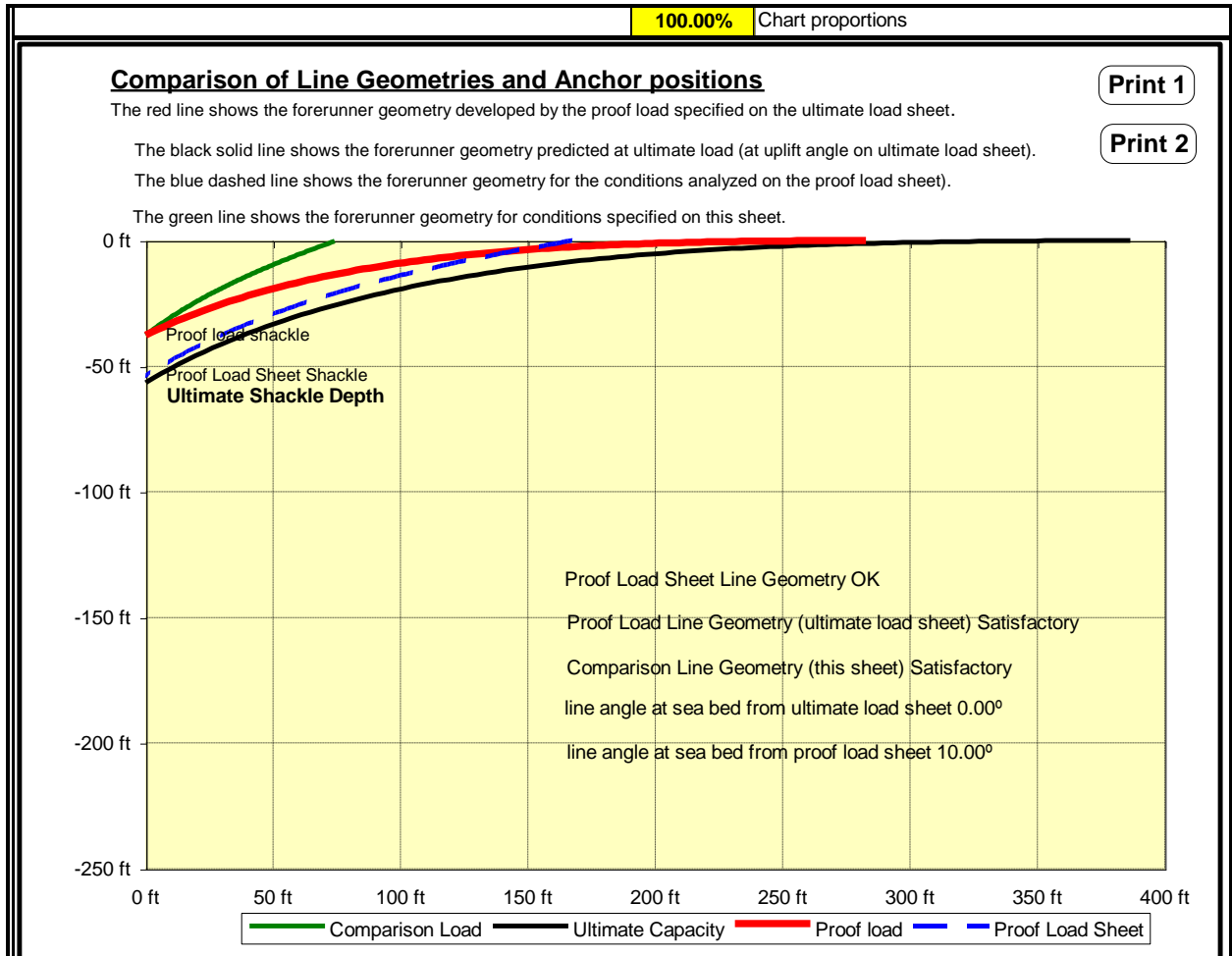


The above figure shows a typical set of results produced with the Comparison Sheet. In this example, a Stevpris 7 tonne test anchor, coupled with a 3.5” diameter wire, is found to provide an ultimate load capacity of 671.9 kips at the sea bed, with the wire having zero uplift. The shackle penetrates to a depth of 55.45 feet at ultimate load in the soil (with strength characteristics specified on the Ultimate Load Sheet). Under the proof load of 450 kips, also specified on the Ultimate Load Sheet, the shackle depth is found to be 37.7 feet (with the mooring line having zero uplift at the sea bed. The line geometry with this proof load is the thickest line shown in the above graph. The lowest mooring line profile shown corresponds to that which would be achieved if the ultimate load was applied to the anchor line. The dashed line illustrates the geometry of the mooring line in the soil corresponding to the conditions analyzed on the Proof Load Sheet. Here the user has specified a 10° uplift at the sea bed and a 611 kip load in the

line. The anchor has penetrated to a depth of 52 feet (at the shackle) and is found to hold the applied load. The uppermost line in the graph shows the line geometry in the sea bed that would exist with a 300 kip line load at the sea bed and a 20° uplift angle. The bottom of this line is at the 37.7 foot proof load shackle depth. A comparison of summary results is given in tabular form in the figure below.

Comparison Sheet Summary of Results		300 kips load at 20 degree uplift angle	
221.2 kips	Horizontal line force applied at shackle	170.8 kips	Vertical line force applied at shackle
<i>Horizontal load at shackle less than that generated at proof load</i>		<i>Vertical load at shackle less than that generated by proof load</i>	
37.06%	horizontal proof load margin	2.70%	vertical proof load margin
<i>Horizontal load at shackle less than ultimate load capacity</i>		<i>Vertical load at shackle less than ultimate load capacity</i>	
56.31%	horizontal ultimate capacity margin	43.80%	vertical ultimate capacity margin
279.5 kips	line tension found at shackle (this sheet)	82.5 ft	line length fm. shackle to sea bed
37.7°	line angle to horizontal at shackle	52.3°	line angle to vertical at shackle
450.2 kips	Proof line load at sea bed from ult. load sheet	611.0 kips	Proof line load at sea bed from proof load sheet
351.4 kips	Proof load horiz. anchor capacity (ult. load sheet)	175.6 kips	Proof load vert. anchor capacity (ult. load sheet)
506.3 kips	Ultimate horiz. anchor capacity (ult. load sheet)	303.9 kips	Ultimate vert.anchor capacity (ult. load sheet)
481.0 kips	Horiz. capacity developed at anchor (proof load sheet)	289.6 kips	Vert. capacity developed at anchor (proof load sheet)

The proportions of the chart on the Comparison sheet can be adjusted by editing the cell just above the chart. The example below shows vertical & horizontal scales equal.



13.0 CALIBRATION OF STA ANCHOR

STA ANCHOR Version 3.01 has undergone various calibrations. These include Large Scale Anchor Tests in the Gulf of Mexico (1990, see Appendix 2), Near Shore Anchor Tests in the Gulf of Mexico (1994, see Appendix 1), and comparisons with the US Navy curves (see Appendix 3). The three specific anchors tested by Aker Omega Inc. in the Gulf of Mexico in September, 1994 in the Near Shore Anchor Tests used to calibrate STA ANCHOR were a Bruce FFTS Mk4 250 kg, a Vryhof Stevpris Mk3 300 kg, and a 25 kg Bruce Denla, a experimental vertically loaded anchor (VLA). The soil at the test site was characterized as having an undrained shear strength with a 100 psf surface value and increasing in strength with depth at a rate of 8 psf/ft.

The fluke/shank angles were:

Bruce FFTS: 50 degrees

Vryhof Stevpris: 45 degrees

Bruce Denla: 40 degrees

Appendix 1 contains print outs from the Print Summary and Print Graphs macros for each anchor calibration run. The last page of the Appendix contains a summary of the results of the Near Shore Anchor Tests relating to program calculations.

Appendix 2 contains print outs from the Print Summary and Print Graphs macros for three of the anchors used in the Large Scale Anchor Tests Joint Industry Project conducted in the Gulf of Mexico in September 1990. The three anchors are a Bruce FFTS Mk4 7 ton, a Vryhof Stevpris 7 ton test anchor, and a Vryhof Stevpris 2 ton test anchor. The last page of the Appendix contains a summary of the results for the Large Scale Anchor Tests relating to program calculations.

Runs using STA ANCHOR have also been compared to the Navy Civil Engineering Laboratory (NCEL) Anchor Holding Capacity Tables for Soft Clays. For these comparisons two anchor types were used, the Bruce FFTS anchor and the Vryhof Stevpris anchor. The anchor catalog, present in the program, has information on these two anchor types for a variety of different sizes. The results of these comparisons are displayed in Appendix 3.

Appendix 1

Calibrations Runs for Near Shore Anchor Tests, Sept. 1994

This Appendix contains print outs from STA ANCHOR for a Bruce FFTS Mk4 250 kg, a Vryhof Stevpris Mk3 300 kg, and a 25 kg Bruce Denla ,an experimental vertically loaded anchor.

A table comparing the Near Shore Anchor Test Results with the results obtained by STA ANCHOR follows the anchor print outs.

STA ANCHOR PROGRAM		10/31/1994 Run date Bruce 250 kg											
Beta Version 3.0, October 1994		Call (713) 789-8341 for support.											
Copyright Stewart Technology Associates, 1991 and onwards		Run ref: Bruce 250 kg for Aker Omega test											
Primary results and data input print on 2 pages, including all graphs.													
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.													
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%;">Explain</td> <td style="width: 20%;">Anchor Catalog</td> <td style="width: 20%;">Default Parameters</td> <td style="width: 20%;">Special Parameters</td> <td style="width: 20%;">Restore Input</td> </tr> <tr> <td>Calculate Equilibrium</td> <td>Use Equilibrium Results</td> <td>Print Summary</td> <td>Print Graphs</td> <td>Save Results</td> </tr> </table>				Explain	Anchor Catalog	Default Parameters	Special Parameters	Restore Input	Calculate Equilibrium	Use Equilibrium Results	Print Summary	Print Graphs	Save Results
Explain	Anchor Catalog	Default Parameters	Special Parameters	Restore Input									
Calculate Equilibrium	Use Equilibrium Results	Print Summary	Print Graphs	Save Results									
INPUT DATA BELOW (shaded cells only)													
Anchor Data Below:		All iteration parameters set to DEFAULT values.											
10.58 Af, fluke area (sq ft)	23.00 af1, 1st fluke angle (deg)	3.45 F, fluke length (feet)	32.00 af2, 2nd fluke angle (deg)										
1.80 Af2, fluke projected area (sqft)	10.00 as1, 1st shank angle (deg)	5.14 As1, shank shear area (sq ft)	31.00 as2, 2nd shank angle (deg)										
1.61 As2, shank projected area (sq ft)	4.45 lf, fluke distance (ft)	0.55 W, anchor weight, (kips)	2.78 ls1, 1st shank distance (ft)										
1.00 fluke shear area multiplier	1.31 ls2, 2nd shank distance (ft)	3.30 shank shear area multiplier	0.61 calibration coef. for vert. anc.force										
Wire (or chain) Data Below:		1.00 <-tangential wire force coefs.: normal->	1.00										
1 Switch for wire or chain, 1=wire, 2=chain.	1.3 calibration coef. for horiz drag	0.75 D1, wire or chain diameter (in)	1.4 submerged weight (lb/ft) of wire or chain										
0.89 Length of Upper Line elements (ft)	10.00 angle at sea bed (deg)	30.33513461 applied mooring load in kips	0.63 Depth for Nc max for wire/chain										
Soil Data Below:		NOTE! Wire selected for analysis.											
100 Cu1, at surface (psf)	6.00 Nc1, at surface	900 Cu2, at bottom of 1st layer (psf)	15.00 Nc2, at depth of 5°F										
900 Cu3, at top of 2nd layer (psf)	100 d1, depth of 1st layer (feet)	1700 Cu4, at bottom of 2nd layer (psf)	100 d2, thickness of 2nd layer (feet)										
Control Parameters Below:		The starting and maximum depths define the interval for which equilibrium is checked.											
12.00 starting depth in feet	32.00 maximum depth of analysis for anchor equilibrium												
Summary Results from the Equilibrium Calculations													
19.800	Depth of Anchor Shackle (ft) at Equilibrium												
0.594	32.24	equilibrium rotation angle, degrees	Maximum										
27.40	2.7630	rotation angle, radians	43.20										
			Vertical										
			Capacity (kips)										
Summary Results After Equilibrium Calculations Used		Explain Summary Results											
23.33	Horizontal capacity developed at anchor (kips)		14.08										
23.92	Horizontal load applied at anchor shackle (kips)		14.49										
5.95	Horizontal load lost in soil/wire interaction (kips)		-0.41										
170.45	Drag distance in analysis (ft)		22.000										
32.16	Alpha, maximum anchor rotation (deg)		31.20										
22.021	Maximum depth in analysis for line in soil (ft)		69.22										
			Length of line in soil										

STA ANCHOR PROGRAM		10/30/1994 Run date	Stevpris 300 kg	
Beta Version 3.0, October 1994		Call (713) 789-8341 for support.		Copyright Stewart Technology Associates, 1991 and onwards
Primary results and data input print on 2 pages, including all graphs.		Run ref:	Stevpris 300 kg for Aker Omega test	
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.				
<div style="display: flex; justify-content: space-around; margin-bottom: 5px;"> Explain Anchor Catalog Default Parameters Spectral Parameters Restore Input </div> <div style="display: flex; justify-content: space-around;"> Calculate Equilibrium Use Equilibrium Results Print Summary Print Graphs Save Results </div>				
INPUT DATA BELOW (shaded cells only)				
Anchor Data Below:		All iteration parameters set to DEFAULT values.		
11.46	Af, fluke area (sq ft)	17.00	af1, 1st fluke angle (deg)	
3.51	F, fluke length (feet)	36.00	af2, 2nd fluke angle (deg)	
0.55	Af2, fluke projected area (sqft)	13.50	as1, 1st shank angle (deg)	
6.69	As1, shank shear area (sq ft)	29.00	as2, 2nd shank angle (deg)	
3.31	As2, shank projected area (sq ft)	5.17	lf, fluke distance (ft)	
0.66	W, anchor weight, (kips)	3.13	ls1, 1st shank distance (ft)	
1.30	fluke shear area multiplier	2.45	ls2, 2nd shank distance (ft)	
2.80	shank shear area multiplier	0.68	calibration coef. for vert. anc.force	
Wire (or chain) Data Below:		1.00	<-tangential wire force coeffs.: normal->	
1	Switch for wire or chain, 1=wire, 2=chain.	1.3	calibration coef. for horiz drag	
0.75	D1, wire or chain diameter (in)	1.4	submerged weight (lb/ft) of wire or chain	
1.04	Length of Upper Line elements (ft)	0.00	angle at sea bed (deg)	
29.57382163	applied mooring load in kips	0.63	Depth for Nc max for wire/chain	
Soil Data Below:		NOTE! Wire selected for analysis.		
100	Cu1, at surface (psf)	6.00	Nc1, at surface	
900	Cu2, at bottom of 1st layer (psf)	15.00	Nc2, at depth of 5°F	
900	Cu3, at top of 2nd layer (psf)	100	d1, depth of 1st layer (feet)	
1700	Cu4, at bottom of 2nd layer (psf)	100	d2, thickness of 2nd layer (feet)	
Control Parameters Below:		The starting and maximum depths define the interval for which equilibrium is checked.		
12.00	starting depth in feet	32.00	maximum depth of analysis for anchor equilibrium	
Summary Results from the Equilibrium Calculations				
18.600	Depth of Anchor Shackle (ft) at Equilibrium			
1.038	Length of Upper Line elements (ft) used for equilibrium	34.48	equilibrium rotation angle, degrees	
29.57	Applied Mooring Load (kips) used for equilibrium	2.5241	rotation angle, radians	45.18
				Maximum Vertical Capacity (kips)
Summary Results After Equilibrium Calculations Used		Explain Summary Results		
23.68	Horizontal capacity developed at anchor (kips)	11.86	Vertical capacity developed at anchor (kips)	
23.69	Horizontal load applied at anchor shackle (kips)	11.88	Vertical load applied at anchor shackle (kips)	
5.88	Horizontal load lost in soil/wire interaction (kips)	-0.02	Excess vertical capacity (kips)	
134.13	Drag distance in analysis (ft)	18.600	Depth of embedment of anchor shackle (ft)	
34.48	Alpha, maximum anchor rotation (deg)	26.63	Angle of line to horiz. at anchor shackle (deg)	
18.601	Maximum depth in analysis for line in soil (ft)	110.03	Length of line in soil	

STA ANCHOR PROGRAM		7/26/1995 Run date		Bruce Denla 25 kg, 40 degree	
Beta Version 3.0, October 1994		Call (713) 789-8341 for support.		Copyright Stewart Technology Associates, 1991 and onwards	
Primary results and data input print on 2 pages, including all graphs.		Run ref:		Comparison with Navy Anchor Holding Cap. Chart	
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.					
[Explain]		[Anchor Catalog]		[Default Parameters]	
[Calculate Equilibrium]		[Use Equilibrium Results]		[Print Summary]	
		[Special Parameters]		[Restore Input]	
		[Print Graphs]		[Save Results]	
INPUT DATA BELOW (shaded cells only)					
Anchor Data Below: All iteration parameters set to SPECIAL values.					
3.60	Af, fluke area (sq ft)	19.00	af1, 1st fluke angle (deg)		
2.51	F, fluke length (feet)	31.00	af2, 2nd fluke angle (deg)		
0.40	Af2, fluke projected area (sqft)	16.00	as1, 1st shank angle (deg)		
0.60	As1, shank shear area (sq ft)	20.00	as2, 2nd shank angle (deg)		
0.22	As2, shank projected area (sq ft)	2.49	lf, fluke distance (ft)		
0.06	W, anchor weight, (kips)	1.25	ls1, 1st shank distance (ft)		
1.50	fluke shear area multiplier	1.20	ls2, 2nd shank distance (ft)		
2.00	shank shear area multiplier	0.63	calibration coef. for vert. anc.force		
Wire (or chain) Data Below:		1.00	<-tangential wire force coeffs.: normal->	1.00	
1	Switch for wire or chain, 1=wire, 2=chain.	0.33	calibration coef. for horiz drag		
0.50	D1, wire or chain diameter (in)	0.6	submerged weight (lb/ft) of wire or chain		
0.41	Length of Upper Line elements (ft)	0.00	angle at sea bed (deg)		
4.834125739	applied mooring load in kips	0.42	Depth for Nc max for wire/chain		
Soil Data Below: NOTE! Wire selected for analysis.					
100	Cu1, at surface (psf)	6.00	Nc1, at surface		
900	Cu2, at bottom of 1st layer (psf)	15.00	Nc2, at depth of 5°F		
900	Cu3, at top of 2nd layer (psf)	100	d1, depth of 1st layer (feet)		
1700	Cu4, at bottom of 2nd layer (psf)	100	d2, thickness of 2nd layer (feet)		
Control Parameters Below:					
The starting and maximum depths define the interval for which equilibrium is checked.		22.00	maximum depth of analysis for anchor equilibrium		
2.00	starting depth in feet				
Summary Results from the Equilibrium Calculations					
10.800	Depth of Anchor Shackle (ft) at Equilibrium				
0.407	Length of Upper Line elements (ft) used for equilibrium	36.72	equilibrium rotation angle, degrees		Maximum Vertical Capacity (kips)
4.83	Applied Mooring Load (kips) used for equilibrium	3.2824	rotation angle, radians	10.36	
Summary Results After Equilibrium Calculations Used		[Explain Summary Results]			
3.23	Horizontal capacity developed at anchor (kips)	2.56	Vertical capacity developed at anchor (kips)		
3.24	Horizontal load applied at anchor shackle (kips)	2.56	Vertical load applied at anchor shackle (kips)		
1.60	Horizontal load lost in soil/wire interaction (kips)	0.00	Excess vertical capacity (kips)		
23.88	Drag distance in analysis (ft)	10.800	Depth of embedment of anchor shackle (ft)		
36.72	Alpha, maximum anchor rotation (deg)	38.28	Angle of line to horiz. at anchor shackle (deg)		
10.846	Maximum depth in anlysis for line in soil (ft)	43.18	Length of line in soil		

Anchor	Near Shore Test Results		STA ANCHOR Results	
	Ultimate Holding Capacity (kip)	Anchor Shackle Penetration (ft)	Ultimate Holding Capacity (kip)	Anchor Shackle Penetration (ft)
*Bruce Denla 25 kg, 40 deg	10.4	10.9	10.4	10.8
Bruce 250 kg FFTS Mk4, 50 deg	26.5	20.4	29.2	19.9
Vryhof Stevpris 300 kg Mk3, 45 deg	28.9	18.1	28.6	17.4
* Ultimate Holding Capacity for the Bruce Denla is for a 90 deg pull out angle. In STA ANCHOR this is the calculated Maximum Vertical Capacity.				

Appendix 2

Calibrations Runs for Large Scale Anchor Tests, Oct. 1990

This Appendix contains print outs from STA ANCHOR for a Bruce 7 ton FFTS Mk4 anchor, a Vryhof Stevpris 7 ton test anchor, and Vryhof Stevpris 2 ton test anchor. The STA ANCHOR print outs contain two pages for each anchor. The first page contains a summary of the input and output, and second page contains graphs of the mooring line profile, horizontal forces and anchor trajectory. A table comparing the Large Scale Anchor Test Results with the results obtained by STA ANCHOR follows the anchor print outs.

STA ANCHOR - Saved Results		12/16/1995 Run Date	Vryhof Stevpris 7 ton test anchor, 50 degree	
Version 3.01, December 1995 Call (713) 789-8341 for support.		Copyright Stewart Technology Associates, 1991 and onwards		
Primary results and data input print on 2 pages, including all graphs.		Run Ref:	10-lb soil, Tangential Touchdown	
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.				
This file contains results produced by STA ANCHOR Version 3.1. These results can be examined in this file or transferred back to STA ANCHOR for further analysis.				
<u>Print Graphs</u>		<u>Display Equilibrium Graph</u>		<u>Print Summary</u>
<u>Print Tabular Results</u>				
INPUT DATA BELOW (shaded cells) From anchor catalog: Stevpris 7 ton test anchor				
Anchor Data Below: Some iteration parameters are set to SPECIAL values.				
100.90 sqft	Af, fluke area	21.00°	af1, 1st fluke angle	
10.71 ft	F, fluke length	33.50°	af2, 2nd fluke angle	
5.28 sqft	Af2, fluke projected area	15.00°	as1, 1st shank angle	
70.37 sqft	As1, shank shear area	25.00°	as2, 2nd shank angle	
27.00 sqft	As2, shank projected area	15.17 ft	lf, fluke distance	
15.53 kip	W, anchor weight	9.08 ft	ls1, 1st shank distance	
1.00	fluke shear area multiplier	7.00 ft	ls2, 2nd shank distance	
2.50	shank shear area multiplier	0.77	calibration coef. for vertical anchor	
Wire (or chain) Data Below:				
1	Switch: 1=wire, 2=chain.	1.00	-<tangential wire force coeffs.: normal- 1.00	
3.50 in	D1, wire or chain diameter	0.95	calibration coef. for horiz.drag	
3.73 ft	Length of Upper Line elements	23.00 lb/ft	submerged weight of wire	
671.9 kip	Last Ultimate Line Load (before data were edited)	0.00°	angle at sea bed	
		2.92 ft	Depth for Nc max for wire/chain	
Soil Data Below: NOTE! Wire selected for analysis.				
90 psf	Cu1, at surface	6.00	Nc1, at surface	
1090 psf	Cu2, at bottom of 1st layer	15.00	Nc2, at depth of 5°F	
1090 psf	Cu3, at top of 2nd layer	100.00 ft	d1, depth of 1st layer	
2000 psf	Cu4, at bottom of 2nd layer	58.00 ft	d2, thickness of 2nd layer	
Control Parameters Below:				
Starting & maximum depths define the interval for which equilibrium is checked.		100.00 ft	maximum depth of analysis for anchor equilibrium	
1.00 ft	starting depth	450.2 kip	Desired Proof Load (in line at sea bed)	
Summary Results from the Equilibrium Calculations				
55.45 ft	Depth of Anchor Shackle at Equilibrium	1.49	Ult. Load divided by proof load	175.6 kip
3.73 ft	Length of Upper Line elements used for equilibrium	33.75°	equilibrium rotation angle 1	Use for VLAs
671.9 kip	Applied Mooring Load used for equilibrium	1.75°	equilibrium rotation angle 2	1056.5 kip
351.4 kip	Horizontal anchor resistance @ proof load	37.7 ft	Shackle depth at Proof Load	ONLY!
				TAv_proof
				Maximum
				Vertical
				Capacity
Summary Results After Equilibrium Calculations Used				
506.27 kip	Horizontal capacity developed at anchor	303.92 kip	Vertical capacity developed at anchor	
506.61 kip	Horizontal load applied at anchor shackle	302.41 kip	Vertical load applied at anchor shackle	
165.30 kip	Horizontal load lost in soil/wire interaction	1.51 kip	Excess vertical capacity	
314.31 ft	Drag distance in analysis	55.45 ft	Depth of embedment of anchor shackle	
33.75°	Alpha, maximum anchor rotation	30.83°	Angle of line to horiz. at anchor shackle	
56.56 ft	Maximum depth in anlysis for line in soil	394.88 ft	Length of line in soil	
	Large Scale Test Results		STA ANCHOR Results	
Anchor	Ultimate Holding Capacity (kip)	Anchor Shackle Penetration (ft)	Ultimate Holding Capacity (kip)	Anchor Shackle Penetration (ft)
Bruce 7 ton Mk4 FFS	600.0	63.0	626.0	63.0
Vryhof Stevpris 2 ton Test Anchor	206.0	35.5	210.2	35.4
Vryhof Stevpris 7 ton Test Anchor	600.0	61.0	639.0	56.9

Appendix 3

Holding Capacity Comparisons Between STA ANCHOR and the Navy Civil Engineering Laboratory (NCEL) Chart

This Appendix contains results from STA ANCHOR for Bruce FFTS anchors and Vryhof Stevpris anchors for weights varying from 1,500 kg to 20,000 kg. The holding capacities from these STA ANCHOR runs are compared with NCEL Anchor Holding Capacity Charts for Soft Clays. A graph comparing the STA ANCHOR results to the NCEL Table is displayed on the final page of this Appendix.

For this comparison, the following assumptions were made for the STA ANCHOR runs.

- The soil was a 10 lb soil with a 50 psf bearing pressure at the surface.
- The chain size used for the analysis was derived by the following method:
 - Estimating the holding capacity of the anchor from the NCEL chart given the weight of the anchor
 - Divide this holding capacity by 1.5. This is the maximum load the anchor should ever encounter.
 - Multiply the maximum load on the anchor by 3. This is the minimum break strength of the chain.
 - From the minimum break strength a chain size is chosen. The chain is assumed to be oil rig grade.
- The Bruce FFTS anchor has a vertical anchor force coefficient of 0.76 and the Vryhof Stevpris has a vertical anchor force coefficient of 0.78.
- The anchor data (lengths, widths, angles, area multipliers, etc.) are taken from the STA ANCHOR anchor catalog.

Appendix 4

Anchor Solution Methods

This Appendix displays the effects of different anchor solution methods on applied mooring loads and anchor dive depths. The anchor used in the comparison was a Bruce 7 ton Mk4 FFTS which had 3.5" diameter mooring line. The six different anchor solution methods available to the user are the linear method, sine method, hyperbolic method, parabolic method, double sine method, and the square root method.

Appendix 5

STA ANCHOR Macro Code

This Appendix contains print outs of the Visual Basic Macro Code used in STA ANCHOR. The print outs are broken up into Modules. A module is simply a sheet of macro code.

Appendix 6

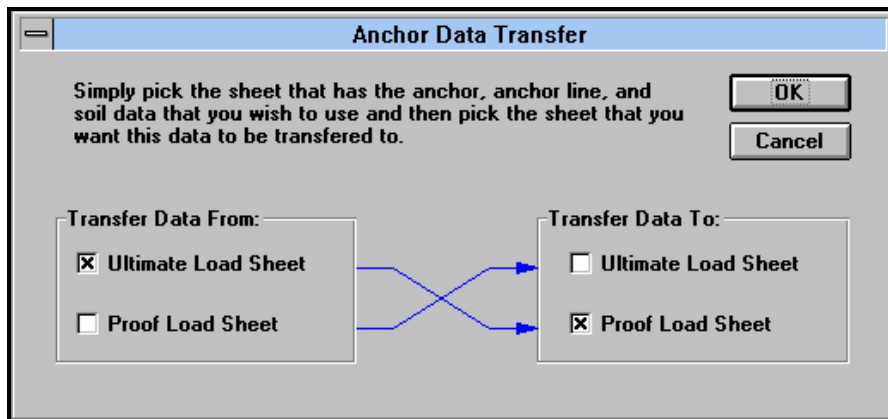
Description of Proof Load Sheet and its Use

This Appendix describes the solution method and input and output variables for the STA ANCHOR Proof Load Sheet. The Proof Load Sheet in Version 3.0 allows the user to determine drag embedment performance of an anchor for a given applied mooring load. This portion of STA ANCHOR, Ver. 3.0 obtains a embedment solution in the same manner as Versions 1.0 and 2.0 of STA ANCHOR. To describe the solution method of the Proof Load Sheet segments from the STA ANCHOR, Ver. 1.0 users manual used in this Appendix. The portions of the Version 1.0 user manual contained in this Appendix include,

- Chapter 6 General Method of Solution
- Chapter 7 Geotechnical Forces at the Anchor

An example Proof Load Sheet is shown on the next page. This sheet permits the user to perform a single analysis of the anchor and mooring line performance. Unlike the Ultimate Load Sheet, this sheet requires the user to specify the load that must be resisted by the anchor system rather than specifying a depth range to be analyzed. Having specified the load, the user must adjust various terms before a satisfactory and accurate result is obtained. Although this is an iterative process, it can be performed in just a few minutes after the user has gained experience.

Typically, the ultimate load calculations will have been performed before the user goes to the Proof Load Sheet. The dat input on the Ultimate Load Sheet may be transferred to the Proof Load Sheet using the Transfer Data macro button, resulting in the dialog



box shown here appearing. However, this is not mandatory and the Proof Load Sheet may be used in isolation at any time. Note the Ultimate Load Sheet data may be transferred to the Proof Load Sheet, or vice versa.

STA ANCHOR - PROOF LOAD SHEET		1/1/96	Run date	Vryhof Stevpris 7 ton test anchor, 50 degree	
Version 3.01, December 1995 Call (713) 789-8341 for support.		Copyright Stewart Technology Associates, 1991 and onwards			
The summary of the results and data input print on 1 page.		Run ref:		Further embedment from 37.7 feet with 10° uplift	
Some format adjustments may be needed to suit your printer. See User Manual for running instructions and results interpretation.					
Print Summary Print Graphs Explain Transfer Data Comparison Sheet Ult. Load Sheet					
INPUT DATA BELOW (shaded cells only) From anchor catalog: Stevpris 7 ton test anchor					
Anchor Data Below:					
100.90 sqft	Af, fluke area	21.00°	af1, 1st fluke angle		
10.71 ft	F, fluke length	33.50°	af2, 2nd fluke angle		
5.28 sqft	Af2, fluke projected area	15.00°	as1, 1st shank angle		
70.37 sqft	As1, shank shear area	25.00°	as2, 2nd shank angle		
27.00 sqft	As2, shank projected area	15.17 ft	lf, fluke distance		
15.53 kip	W, anchor weight	9.08 ft	ls1, 1st shank distance		
1.00	fluke shear area multiplier	7.00 ft	ls2, 2nd shank distance		
2.50	shank shear area multiplier	0.77	calibration coef. for vert. anc.force		
Wire (or chain) Data Below:		1.00	<-tangential wire force coefs.: normal->		1.00
1	Switch for wire or chain, 1=wire, 2=cha	0.95	<- calibration coefs. for horiz.drag ->		4.00
3.50 in	D1, wire or chain diameter	23.00 lb/ft	submerged weight of cable or chain		
1.67 ft	Length of Upper Line elements	10.00°	angle at sea bed		
611.0 kip	applied mooring load in kips	2.92 ft	Depth for Nc max for wire/chain		
Soil Data Below: NOTE! Wire selected for analysis.					
90 psf	Cu1, at surface	6.00	Nc1, at surface		
1090 psf	Cu2, at bottom of 1st layer	15.00	Nc2, at depth of 5°F		
1090 psf	Cu3, at top of 2nd layer	100.00 ft	d1, depth of 1st layer		
2000 psf	Cu4, at bottom of 2nd layer	58.00 ft	d2, thickness of 2nd layer		
Control Parameters Below: Delta angle selected probably OK					
2.68 ft	delta, drag increment (fluke length/4 recommended)	1.00°	delta angle change increment		
37.70 ft	starting depth	30.00°	starting angle		
SUMMARY RESULTS GIVEN BELOW					
		Explain		(See graphs for full results)	
481.0 kips	Horizontal capacity developed at anchor	289.6 kips	Vertical capacity developed at anchor		
480.1 kips	Horizontal load applied at anchor shackle	291.9 kips	Vertical load applied at anchor shackle		
121.6 kips	Horizontal load lost in soil/wire interaction	-2.3 kips	Excess vertical capacity		
175.7 ft	Drag distance in analysis	52.0 ft	Depth of embedment of anchor shackle		
33.8°	Alpha, maximum anchor rotation	31.3°	Angle of line to horiz. at anchor shackle		
53.7 ft	Maximum depth in analysis for line in soil	172.0 ft	Length of line in soil		
Anchor Holds Specified Load					
Line element lengths are OK			Experiment with the control parameters in order to find upper bound solution.		

Note that the user must specify the applied system load on the proof load sheet.

In this example, the anchor has been analyzed beginning at a depth of 37.7 feet (at the shackle). This was the depth (calculated on the Ultimate Load Sheet) to which the anchor was found to penetrate under application of the proof load. The starting angle was 30° (see manual for full explanation) and the mooring line was specified to have a 10° uplift angle at the sea bed. The results show that the anchor embeds further and reaches equilibrium at a shackle depth of 52 feet.

The next page shows a comprehensive explanation of how the user has edited this sheet.

EXPLANATORY NOTES

This copy of the Proof Load Sheet has been annotated in order to explain the analysis being undertaken. Note that every editable cell is provided with a "Help" dialog which can be seen at any time simply by selecting the cell and then clicking on the "Explain" button. The main input data on this sheet has been transferred from the Ultimate Load Sheet using the "Transfer Data" button. The explanation notes added to this sheet describe the input data variables modified for this single specific analysis.

STA ANCHOR - PROOF LOAD SHEET	12/29/95 Run date	Vryhof Stevpris 7 ton test anchor, 50 degree
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Call (713) 789-8341 for support. Copyright Stewart Technology Associates, 1991 and onwards
 Print on 1 page. Run ref: Further embedment from 37.7 feet with 10° uplift
 Print Graphs Explain
 The above title has been changed to indicate the analysis performed on this sheet (Proof Load Sheet) compared to that performed on the main sheet (Ultimate Load Sheet).

In the two cells below, the applied load to be used in the single analysis on this sheet has been specified, together with the length of the upper line elements. Note that the line element length cell must be adjusted carefully by the user until the warnings on this sheet disappear. The objective is to get the maximum depth in the analysis for the line to be just slightly greater than the final depth of imbedment of the anchor shackle.

1.67 ft	Length of Upper Line elements
611.0 kip	applied mooring load in kips

In the two cells below, the anchor starting depth and the drag increment have been specified for this single analysis. The drag increment has been left at 1/4 fluke length. The starting depth for the anchor shackle has been set to the depth predicted from the Ultimate Load Sheet at the proof load specified.

2.68 ft	delta, drag increment (fluke length/4 recommended)
37.70 ft	starting depth

21.00° of 1, 1st fluke angle
 In the two cells below, the calibration coefficients for horizontal drag are shown. The coefficient to the left is the same as that used on the Ultimate Load Sheet. The coefficient on the right has been adjusted such that the same drag distance as on the Ultimate Load Sheet is found on this sheet (when the same conditions are analyzed).
 0.95 <- calibration coefs. for horiz. drag -> 4.00

In the two cells below, the anchor starting angle and the delta angle change increment have been specified for this single analysis. The angle change increment has been adjusted to the smallest value that results in the message "Delta angle selected probably OK." The starting angle has been set to a value estimated to be appropriate for the proof load, from the Ultimate Load Sheet.

1.00°	delta angle change increment
30.00°	starting angle

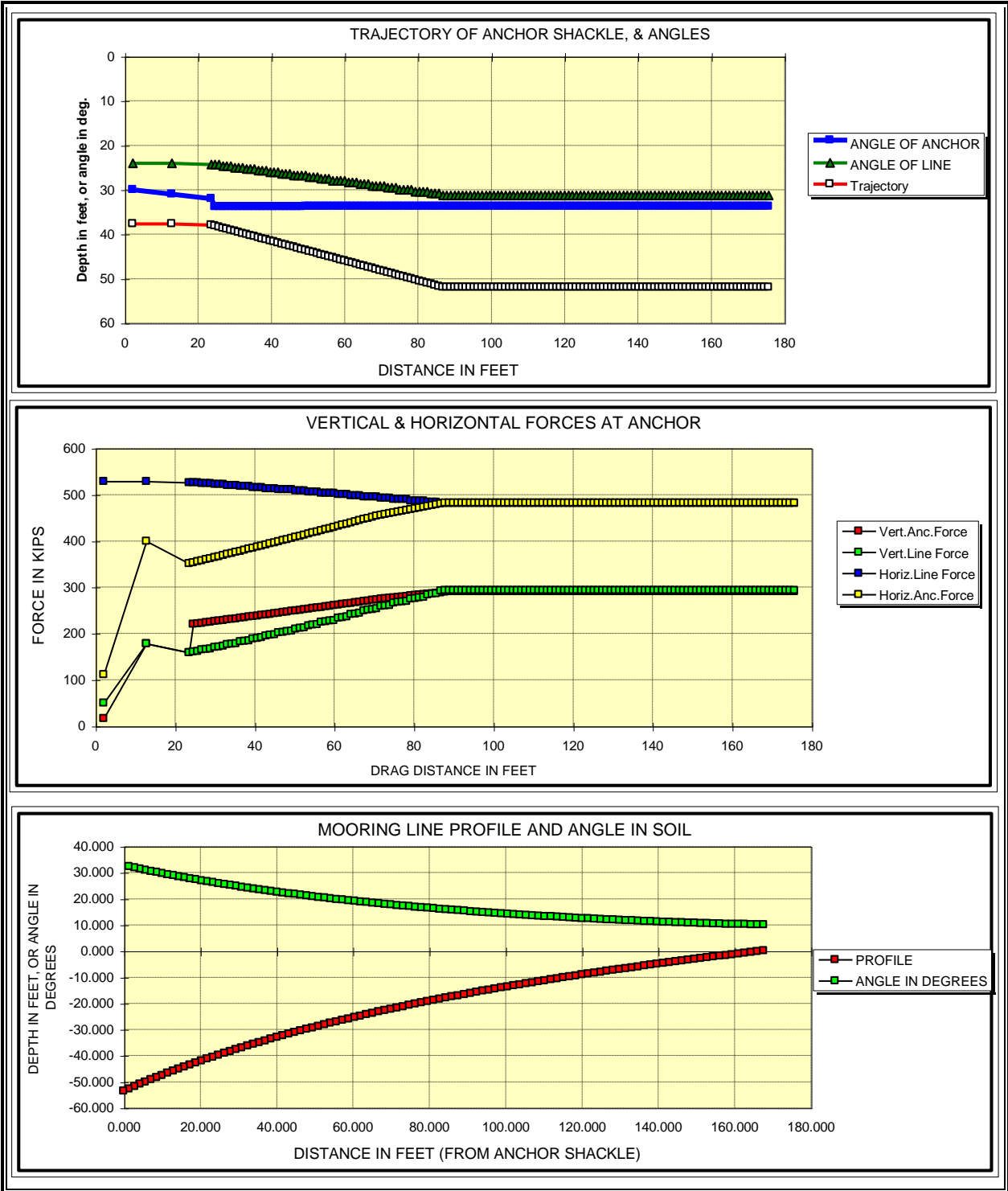
Delta angle selected probably OK

SUMMARY RESULTS GIVEN BELOW		Explain	(See graphs for full results)
481.0 kips	Horizontal capacity developed at anchor	289.6 kips	Vertical capacity developed at anchor
480.1 kips	Horizontal load applied at anchor shackle	291.9 kips	Vertical load applied at anchor shackle
121.6 kips	Horizontal load lost in soil/wire interaction	-2.3 kips	Excess vertical capacity
175.7 ft	Drag distance in analysis	52.0 ft	Depth of embedment of anchor shackle
33.8°	Alpha, maximum anchor rotation	31.3°	Angle of line to horiz. at anchor shackle
53.7 ft	Maximum depth in analysis for line in soil	172.0 ft	Length of line in soil

Anchor Holds Specified Load
 Line element lengths are OK

The two warning messages above indicate, in this example, that the analysis results are satisfactory. The lower message warns the user to either increase or decrease the line element lengths until a satisfactory solution has been obtained. The upper message simply indicates that the anchor holds the load specified for this analysis.

Note that the negative value for "Excess vertical capacity" of -2.3 kips shown above indicates that the anchor is on the verge of pulling out. If this value is more than 2% of the "Vertical capacity developed at anchor" the anchor should be regarded as likely to fail under the conditions specified. Because the solution is numerical, small negative values are acceptable. When the "excess vertical capacity" is positive, the anchor has no tendency to pull out.



These graphs are produced by the Proof Load Sheet.

