

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

1. Document Title/Number: FEMFLOW3D - A Finite-Element Program for the Simulation of Three-Dimensional Groundwater System--Documentation and Source Code Review: A Document by Timothy J. Durbin, Inc.		2. Document Date: June 2006		
3. Revision Number: Draft		4. Originator/Organization: SNWA		
5. Responsible SNWA Project Mgr.: Andrew Burns		6. Date Comments Due: ---		
7. Review Criteria: FULL				
8. Reviewer/Organization/Phone No.: HCI Hydrologic Consultants, Inc. of Colorado - Houmao Liu				
10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
1.	General	Provide sample problems related to specific features such as multi-compartments, faults, node collapsing, specified had, specified flux, and river. These sample problems will provide users with examples for setting up particular models using the special features of FEMFLOW3D	The contrived problem with fault is such a problem. It will be included in Appendix A.	
2.	General	Define the maximum dimension of each of the problems that FEMFLOW3D is designed to solve in the User Manual.	Text added to Section 1 describing the nodal dimensions.	
3.	General	Clarify or recommend the approaches and software used to prepare the input files and to analyze the model results.	Text added to a new Section 1.4 to describe GMS and its utility.	
4. TOC, pg. iii	S	Add "Appendix" to Table of Contents.	Appendix A has been added to the TOC page.	
5. Pg. 2nd line, 3rd para.	S	"Confirm" should be "confined" and "unconfirmed" should be "unconfined."	Confirm and unconfirmed have been changed to confined and unconfined.	
6. Pg. 1-3, 1st para.	S	". . .given the user-defined parameters, the word "given" does not seem appropriate.	Text changed to "based upon"	
7. Pg. 1-5, Line 6	S	Line six below Equation 1-2, $K_i$ should be $K_{ij}$ .	$K_i$ has been changed to $K_{ij}$	
8. Pg 1-6, second to last line	S	There should be a comma between ". . .1-5" and "a wedge. . ."	A comma has been added where indicated.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
9. Pg. 1-9, 3rd sentence	S	"A fault also possesses conductive . . . into or from the fault plane" is not clear to the reader.	This text was changed to remove the word "plane" and instead rely on the word "fault".	
10. Pg. 1-11, 2nd para, last sentence	S	"This feature. . . within a well" needs further explanation.	Added text discussing local radial flow to a well and how FEMFLOW3D can accommodate this feature.	
11. Pg. 2-3, Equ. 2-2	S	The left side of the equation should be $H_{I,t}^{(k+1)}$	Equation has been modified.	
12. Pg. 2-3, Equ. 2-3	S	Give users a recommended range of values for $\alpha, \gamma, \varepsilon$ .	Changed Text	
13. Pg. 2-3, last sentence	S	In $\varepsilon = 0.01$ feet, "feet" should be removed.	The word "feet" has been removed.	
14. Pg. 2-5, 3rd para.	S	Below Equation 2-6, "= n x 1 vector" should be "= an x 1 vector".	"= n x 1 vector" has been changed to "= an x 1 vector".	
15. Pg. 2-6, 1st sentence	S	Add "{" to "L11. . ."	The bracket has been added where indicated.	
16. Pg. 2-7, 1st para. last sentence	S	$C_{Ij}$ should be changed to $C_I$ .	$C_{Ij}$ has been changed to $C_I$ .	
17. Pg. 2-8	S	Equation 2-22 should read as follows $X_I^{k+l} - X_I^k$ .	Equation has been changed as indicated.	
18. Pg. 2-8, 2nd line below Equ. 2-22	S	$X_j^{(k+1)}$ should be changed to $X_I^{(k+1)}$ .	Inline equation has been changed as indicated.	
19. Pg. 2-9, 3rd para. below Equ. 2-25	S	Below Equation 2-25, "= n x 1 vector" should be "= an x 1 vector".	"= n x 1 vector" has been changed to "= an x 1 vector".	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
20. Pg. 2-11, 1st para. Line 7	S	"efficiently" should be "efficiency".	The word "efficiently" has been changed to "efficiency".	
21. 1st para. Line 9	S	"system of equations" should be the end of the sentence with a period.	Text has been modified as indicated.	
22. Pg. 2-11, 1st para, Line 10	S	"with" should be "With.	Text has been modified as indicated.	
23. Pg. 2-11, 2nd para, Line 3	S	"nodes read" should be changed to "NODES reads"	"nodes read" has been changed to "NODES reads" as indicated.	
24. Pg. 2-11, 4th para. Line 1	S	". . . NODES, adjustment. . ." should be ". . .NODES, mesh adjustment. . ."	". . . NODES, adjustment. . ." has been changed to ". . .NODES, mesh adjustment. . ."	
25. Pg. 2-11, third to last line	S	". . . position the node too close. . ." should be changed to ". . . Position of the node is too close. . ."	". . . position the node too close. . ." has been changed to ". . . Position of the node is too close. . ."	
26. Pg. 2-16, Equ 2-29	S	Add explanation for $\phi_i$ .	added "a linear interpolating (or basis) function [ $L^0$ ]"	
27. Pg. 2-16, last sent.	S	Last sentence is not clear.	Text was removed after reference to (Pinder and Gray, 1977) to help clarify.	
28. Pg. 2-18, Equ. 2-37	S	$\int_{\Omega} q$ should be $\int_{\Gamma} q$ .	Equation has been modified.	
29. Pg. 2-19, line above Equ 2-39.	S	"The interpolating functions for the node I are. . ." should be changed to "the interpolating function for the node I is."	"The interpolating functions for the node I are. . ." has been changed to "the interpolating function for the node I is."	
30. Pg. 2-19, Equ 2-39	S	Equation "d <sub>i</sub> y should be "d <sub>i</sub> z".	Equation "d <sub>i</sub> y has been changed to "d <sub>i</sub> z".	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
31. Pg. 2-19	S	Add explanation of "z".	Added "the coordinate in the z-direction"	
32. Pg. 2-19 3rd and 4th line below Equ. 2-39.	S	"Triangular" should be "tetrahedron".	"Triangular" has been changed to "tetrahedron".	
33. Pg. 2-23, second to last line	S	"Equation 2-62 should be "Equation 2-63."	"Equation 2-62 has been changed "Equation 2-63."	
34. Pg. 2-24, 2nd para. line 1	S	"Equation 2-35 should be "Equation 2-36."	"Equation 2-35 has been changed to "Equation 2-36."	
35. Pg. 2-24, 3rd para. Line 2	S	"Equations 2-63 and 2-64 should be "Equations 2-64 and 2-65."	"Equations 2-63 and 2-64 have been changed to "Equations 2-64 and 2-65."	
36. Pg. 2-24, 3rd para. Line 3	S	"Equation 2-35 should be "Equation 2-36."	"Equation 2-35 has been changed to "Equation 2-36."	
37. Pg. 2-25, Line 10.	S	In the section titled "Background" Equations 2-34 and 2-35 should be Equations 2-35 and 2-36.	The section titled "Background" Equations 2-34 and 2-35 have been changed to Equations 2-35 and 2-36.	
38. Pg. 2-27, Equ. 2-80	S	In the explanation, "the computed heat at node F" should be changed to "the computed head at node I".	In the explanation, "the computed heat at node F" has been changed to "the computed head at node I".	
39. Pg. 2-27, last para.	S	In the section title "Groundwater Storage" Equations, 2-43, 2-61, and 2-85 should be changed to 2-44, 2-62, and 2-80.	In the section title "Groundwater Storage" Equations, 2-43, 2-61, and 2-85 have been changed to 2-44, 2-62, and 2-80.	
40. Pg. 2-28, Equ. 2-81	S	There should be an explanation and guidance for users on how to assign the weight factor to the node.	Added significant text as well as figures and equations to discuss how weights should be assigned.	
41. Pg. 2-29, second to last line	S	Equation 2-68 should be changed to 2-67.	Equation 2-68 has been changed to 2-67.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

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42. Pg. 2-30, Line 3 below Equ. 2-83.	S	“. . .the context head-independent. . .” should be “. . .the context of head-independent. . .”	“. . .the context head-independent. . .” has been changed to “. . .the context of head-independent. . .”	
43. Pg. 2-31, last para. 1st line	S	“Equation 2-89” should be “Equation 2-88”.	“Equation 2-89” has been changed to “Equation 2-88”.	
44. Pg. 2-35, Equ 2-107	S	$H_j^{(t-1)}$ should be $H_j^{(t-\Delta t)}$ .	Equation has been modified as indicated.	
45. Pg. 2-36, line above Equ 2-110	S	The word “in to” should be one word.	“into” has been changed to one word.	
46. Pg. 2-36, 2 lines above Equ. 2-111	S	“can are” should be “can be”.	“can are” has been changed to “can be”.	
47. Pg. 2-37, Equ 2-114	S	Explanation of $Q_w$ for Equation 2-114 “. . .injection for. . .” should be “. . .injection rate for. . .”	Explanation of $Q_w$ for Equation 2-114 “. . .injection for. . .” has been changed to “. . .injection rate for. . .”	
48. Pg. 2-41. Equ 2-129	S	Equation 2-129 $q_{EI} = C_{EI}(C_{EI} - H_I)$ should read as $q_{EI} = C_{EI}(H_{EI} - H_I)$ .	Equation has been changed as indicated.	
49. Pg. 2-41, 2nd to last line	S	Equation 2-68 should be “2-67”.	Equation 2-68 has been changed to “2-67”.	
50. Pg. 2-43, third to last line	S	Equation 2-131 should be “Equation 2-138”.	Equation 2-131 has been changed to “Equation 2-138”.	
51. Pg. 2-44	S	Last sentence above Equation 2-143, is not very clear; if $C_{ri}$ equals zero, why do we still need the second term of the equation?	This is OK.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

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52. Pg. 2-14, 2nd para., second to last line	S	"Equation 2-68" should be "Equation 2-67".	Equation 2-68 has been changed to "2-67".	
53. Pg 2-47, Line 8	S	"... assigning recharge of ... should be "... assigning recharge or..."	"... assigning recharge of ... has been changed to "... assigning recharge or..."	
54. Pg. 2-47	S	Second line above Equation 2-150: "introduced by Equation. . ." should be "introduced by fault, Equation. . ."	Second line above Equation 2-150: "introduced by Equation. . ." has been changed to "introduced by fault, Equation. . ."	
55. Pg. 2-48, 1st para. Line 1 and 2	S	". . . Q <sub>ij</sub> . . ." should be ". . . q <sub>j</sub> . . ."	". . . Q <sub>ij</sub> . . ." has been changed to ". . . q <sub>j</sub> . . ."	
56. Pg. 2-49, Line 6, below Equ. 2-157	S	"[L <sup>-2</sup> ]" should be "[L <sup>2</sup> ]"	"[L <sup>-2</sup> ]" has been changed to "[L <sup>2</sup> ]"	
57. Pg. 2-49, Line 7 and 8, below Equ. 2-157	S	"[L <sup>-1</sup> ]" should be "[L <sup>1</sup> ]"	"[L <sup>-1</sup> ]" has been changed to "[L <sup>1</sup> ]"	
58. Pg. 2-49, last line	S	"Equation 2-58" should be "Equation 2-157".	"Equation 2-58" has been changed to "Equation 2-157".	
59. Pg. 3-1	S	Note 3: Need to emphasize the file type should be in Upper Case.	Added sentence stating Upper Case.	
60. Pg. 3-3	S	Note 4, line 3: "if ISLOVE = 1, records 7, 9. . ." should be "if ISLOVE = 1, records 8, 9. . ."	Note 4, line 3: "if ISLOVE = 1, records 7, 9. . ." has been changed to "if ISLOVE = 1, records 8, 9. . ."	
61. Pg. 3-3	S	Note 4, line 4: "if ISLOVE = 2, records 8, 9. . ." should be "if ISLOVE = 1, records 7, 9. . ."	Note 4, line 4: "if ISLOVE = 2, records 8, 9. . ." has been changed to "if ISLOVE = 1, records 7, 9. . ."	
62. Pg 3-5	S	Note 7: should add "if NC() <sub>j</sub> =0, then record 8 is omitted".	"if NC() <sub>j</sub> =0, then record 8 is omitted" has been added at the end of the note.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
63. Pg. 3-6	S	Record 4: Explain "MAT()" in more detail.	Added information to Section 3.4 Note 6. "The material identifier MAT() in Record 4 is used in GMS to display individual hydrogeologic units." Also added a new Note 7, to help clarify.	
64. Pg. 3-9	S	For WSTART: Why do we need both records 2 and 6?	One is for compartments and the other is global.	
65. Pg. 3-9	S	What is the format for Record 2, is it F10.0 or 5F15.0?	The format is 5F15.0.	
66. Pg. 3-9	S	The format for Record 6 should be 5F15.0 not 5F10.0.	The format for Record 6 has been changed to 5F15.0.	
67. Pg. 3-10	S	Subroutine WOUTPUT: there should be more of an explanation of "hydrograph site" and on how to determine "nodal weight"	A reference to the weighting scheme has been added. "The weighting scheme is discussed in Section 2.12." Also new Note 4.	
68. Pg. 3-12	S	Note 10: "CBASE()" should be "CHBASE()".	Note 10: "CBASE()" has been changed to "CHBASE()".	
69. Pg. 3-12	S	Note 10: "CHTASB()" should be "CHTAB()".	Note 10: "CHTASB()" has been changed to "CHTAB()".	
70. Pg. 3-12	S	Note 10: Not clear, why is the specific-head at a particular time the sum of CHBASE() and the transient head? For example, if CHBASE() = 300 and the transient head is 295, then the specified head is 595?	Text added to clarify "The head change is the transient-state change from the steady-state component CHBASE()".	
71. Pg. 3-13	S	Record 3, explain the actual meaning of "Number of well links".	Text changed to "Number of wells"	
72. Pg. 3-13	S	Records 4 and 7: specify the sign (+ or -) for the input rate for injection and pumping.	Added text "A positive flux represents a groundwater recharge, and a negative flux represents a discharge." also added "The scaling factor is positive, unless the user wants to reverse the sign assigned in Record 4."	
73. Pg. 3-14	S	Note 11: "Specified head" should be replaced with "specified flux".	"Specified head" has been replaced with "specified flux" in all 3 places in Note 11.	
74. Pg. 3-16	S	Note 3: "Records 5 and 6 for" should be "records 5 and 6 are repeated for".	"Records 5 and 6 for" has been changed to "records 5 and 6 are repeated for".	
75. Pg. 3-17	S	Record 4: IBREAK() is not included in the source code.	This reference has been removed from the report.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
76. Pg. 3-17	S	Record 5: RNODE() is not an array.	Text changed to RNODEC()	
77. Pg. 3-17	S	Records 7 and 9: Clarify the sign (+ or -) for the input of discharge QXTB and QTB().	Added text "Assigned discharge is always positive" also added "Inflow to channel is positive, and diversion from channel is negative."	
78. Pg. 3-19	S	Record 1: Need to explain that when "IMESH ≠ 0, then output. . .	Added text "If IMESH = 1 in Record 1, then a file is created for input into GMS to display the fault mesh as a three-dimensional object."	
79. Pg. 3-19	S	Record 6: COL is an array.	Text changed to "COL()" to signify array.	
80. Pg. 3-20	S	Record 12: XLEAK() is not an array.	Removed "()" to signify not an array	
81. Pg. 4-7	S	The rotation direction in the input description is not consistent with the input data.	This is OK.	
82. Pg. 1-4 Figure 1-1	S	FAULT should be WFAULT	Figure 1-1 changed to reflect WFAULT	
83. Pg. 1-4 Figure 1-1	S	WSHAPE is not included in the figure	WSHAPE is included in Figure 1-1 (see upper right corner)	
84. Pg. 2-26 Eqn. 2-72 - 2-79	S	"," should be "*", commas should be multiplication symbol	Removed Commas	
85. Pg. 2-26 Eqn. 2-73	S	should be $H_{12} = \sin \alpha_1 * \cos \alpha_3 - \cos \alpha_1 * \sin \alpha_2 * \sin \alpha_3$	Removed Commas	
86. Pg. 2-26 Eqn. 2-74	S	should be $H_{13} = \sin \alpha_1 * \sin \alpha_3 - \cos \alpha_1 * \sin \alpha_2 * \cos \alpha_3$	Removed Commas	
87. Pg. 2-26 Eqn. 2-79	S	should be $H_{32} = \cos \alpha_2 * \sin \alpha_3$	Removed Commas	
88. Pg. 2-26	S	should be added to the manual as Eqn. 2-80 : $H_{33} = \cos \alpha_2 * \cos \alpha_3$	Eqn. Added	



## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

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89. Pg. 2-36, Eqn 2-111	S	$\sum C_w$ should be $\{C_w\}$	The equation seems correct	
90. Pg. 3-2, Record 4	S	CNAME should be CNAME()	Text changed to CNAME()	
91. Pg. 3-4, Record 5	S	NC() should be NC	Text changed to NC	
92. Pg. 3-5, line 3	S	COL should be COL()	COL()	
93. Pg. 3-7 and Pg. 3-8, Record 3	S	KX(), KY(), KZ(), SS(), SY(), ITOP should be changed to XKX(), XKY(), XKZ(), XSS(), XSY(), XITOP	These were changed	
94. Pg. 3-8, Record 5	S	ALPHA1(), ALPHA2(), ALPHA3() should be changed to XALPHA1, XALPHA2, XALPHA3	These were changed	
95. Pg. 3-9, Record 6	S	Does not exist in the code	Deleted	
96.	General	In general, the source code is very well designed and organized with good "readability". The author assigned variable names based on the intended application of that variable. The source code implements all the features described in the User Manual.	Thank You. No Response Required.	
97.	General	Although the description of each subroutine, along with variables, is provided in the User Manual, the readability of the code itself would be improved if the following were added -- as Comments -- to the Source Code: 1) A brief description of the purpose of each subroutine; and 2) A description of each key variable used in the subroutine.	This will be addressed when time permits. Thank You.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

10. Comment Number/ Location	11. Type <sup>a</sup>	12. Comment	13. Comment Response	14. Accept
98. BASIC	S	FEMFLOW3D has three alternative solvers for solving the system of equations. However, there are no recommendations or criteria included for selecting the most appropriate solver for a specific problem. HCI recommends providing users with some guidance on selection of the most appropriate solver for a particular problem.	Text has been added to Section 1.1. "FEMFLOW3D includes three alternative solvers for solving the system of linear equations generated by the finite-element method at each time-step iteration. The solver SRELAX uses the point overrelaxation method. The solver SITPACK uses a conjugate-gradient method. The solver SAMG uses the algebraic multigrid method. SRELAX is the slowest but most robust of the solvers. SIPACK usually is the fastest for mid-sized problems (10,000 or fewer nodes). SAMG usually is the fastest for large problems (50,000 or more nodes)."	
99. NODES Subroutine	S	This subroutine includes the element pinch-out feature, but the feature is not described in the documentation. Based on HCI's own experience, preparation of pinch-out data is difficult. Thus, HCI recommends providing a detailed description of data requirements and showing a good example for a user to follow.	Text added Section 2.8 "While FEMFLOW3D accommodates hydrogeologic units that pinch out within the model domain, the creation of a finite-element mesh with pinchouts can be difficult because GMS does not include that ability. However, meshes with pinchouts can be approximated in GMS by continuing the pinched out unit beyond the geographic extent of the unit as a thin layer."	
100. SITPACK Subroutine	S	This subroutine can produce different levels of outputs from solver iterations with the variable Level. The User Manual, however, does not explain the meaning of Level and the range of values that should be used.	Text has been added to the notes describing what the various levels cause.	
101. SAMG Subroutine	S	The default parameters are hard-coded in the source code. Are these parameters the optimal parameters? The User Manual should explain the meanings of LEVELX, NCYC1, NCYC2, NCYC3, and NCYC4 and provide the recommended values of these variables.	These values are now explained.	
102. PACK Subroutine	S	In the subroutine PACK1, input data are required, if IMATRIX is 2. This input data, however, are not explained and included in the User Manual. The User Manual should provide instructions on how to create the input data for the input and output of the matrix structure.	Text added "If IMATRIX = 2, the file is read to retrieve the previously saved vectors JA() and IA(). However, the file must be listed in the SUP or FLS file with the file type identifier PAK (see Section 3.1)."	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

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103. WCHAED Subroutine	S	This subroutine uses CHTAB() to identify the table of specified heads for a given node. The User Manual, however, does not explain that CHTAB() should be a global table ID or a local table ID in a given compartment.	Text added to Section 3.8 "If CHTAB() = 0, no table is assigned to the node, and the specified-head equals CHBASE() for all times. The table numbers are local to the compartment, which means that for the first table in any compartment i = 1. Correspondingly, a table in another compartment cannot be assigned to CHTAB()."	
104. WFLUX Subroutine	S	This subroutine uses FXTAB() to identify the table of specified flux for a given node. The User Manual, however, does not explain whether FXTAB() should be a global table ID or a local table ID in a given compartment.	Text added to Section 3.9 "If FXTAB() = 0, no table is assigned to the node, and the specified flux equals FXRATE () for all times. The table numbers are local to the compartment, which means that for the first table in any compartment i = 1. Correspondingly, reference cannot be made to a table in another compartment."	
105. WEVAP Subroutine	S	This subroutine uses ETTAB() to identify the table of specified evaporation rate for a given node. The User Manual, however, does not explain whether ETTAB() should be a global table ID or a local table ID in a given compartment.	Text added to Section 3.10 "If ETTAB() = 0, no table is assigned to the node, and the maximum evapotranspiration rate equals ETMAX () for all times. The table numbers are local to the compartment, which means that for the first table in any compartment i = 1. Correspondingly, reference cannot be made to a table in another compartment."	
106. WRIVER Subroutine	S	Parameters used in the WRIVER code are not clearly described in the documentation. The code is set up to simulate tributary reaches, lateral inflow, and channel geometry. The description of these features, however, is not included in the documentation. This module also has complicated input data that need more explaining and clarification. HCI recommends preparing a simple schematic diagram showing the meaning of the variables to help the user understand the following features: - cross-section link, - QXTB(), the joint of the reach, - width and depth of the river; and - lateral inflow.	Figure 3-2 as well as clarifying text have been added to the document to explain the layout for a stream-channel network.	

## SOUTHERN NEVADA WATER AUTHORITY - WATER RESOURCES DIVISION DOCUMENT REVIEW SHEET

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107.WFAULT Subroutine	S	This module contains complicated input data that need more explanation and clarification. HCI recommends preparing a simple schematic diagram showing the meaning of the input data, such as NFL (number of fault link), In2(,1), and In2(,2), for the WFAULT subroutine.	Figure 3-3 as well as clarifying text have been added to the document to explain the layout for fault links.	

<sup>a</sup> Comment Types: M = Mandatory, S = Suggested.