Revisions, Enhancements and Bug Fixes
to the FLO-2D Pro Model and Processor Programs
Since October 1, 2012

Updated 8/1/17 (Most recent revisions are displayed in blue below.)
Current Build: 17-08-17

Model revisions are tagged with a build number in the format:

YR.MM.BB

where:

YR is a two digit number of the year that major revisions were implemented (e.g. 12 for 2012);

MM is a two digit number of the month that major revisions were implemented (e.g. 10 for October);

BB is a two digit number that identifies the executable build. A change in the build number represents a significant bug fix or model revision. Build numbers are not changed for typos, minor revisions or enhancements.

For example, 12.10.02 indicates that the 2nd build (revised and recompiled) executable in October, 2012.

FLO-2D Pro Model

Revisions and bug fixes in the FLO.EXE program include (most recent at the bottom):

1. The channel cross section flow depth computation for bankfull discharge was edited from a "less than" to a "less than or equal to" to avoid a potential error when the flow depth exactly matched the bankfull condition (10/26/12). Build No. 12-10-02.

2. The outflow node array allocations code was relocated to accommodate multiple outflow hydrograph conversion to inflow hydrographs. A deallocation statement was mislocated as a result. This is a fatal error that would terminate the model if no outflow nodes were assigned (10/29/12). Build No. 12.10.02.

3. A Green-Ampt infiltration bug was fixed for the volumetric soil moisture deficiency DTHETA. The volumetric soil moisture deficient was reverse with the general soil moisture deficient by multiplying by the porosity (11/12/12). Build No. 12.11.02.

4. A more robust assignment of the infiltration limiting soil depth was implemented to allow for grid elements with no limiting soil depth. Also the hydraulic conductivity adjustment parameter assignment was revised to allow for globally decreasing the spatially variable hydraulic conductivity (11/12/12). Build No. 12.11.02.

5. An error message to check for data in the SED.DAT file for mudflow bypass the read statement and no mudflow data was read by the model resulting in a water flood event even with high concentrations (11/26/12). Build No. 12.11.02.

6. Prescribed levee failure expansion to contiguous flow directions and grid elements was corrected. Originally this expansion as the breach grows was limited to breach scour and when it was revised for prescribed levee failure with horizontal and vertical failure rates, not all of the necessary switches were triggered to identify the expansion directions. The levee failure reporting file (LEVEE.OUT) format was edited (11/29/12). Build No. 12.11.02.

7. Fixed a bug was associated with infiltration when the surface area was zero, there was an immediate volume conservation error (infinity) at the start of the simulation (12/6/12). Build No. 12.11.02.

8. SWMMQIN.OUT file was created to report the storm drain inlet discharge to the storm drain system and model (12/6/12). Build No. 12.11.02.

9. Following the implementation of the SWMMQIN.OUT file in the revision 8 above, it was noted that the wrong timestep was used to compute the discharge volume reported in SWMMQIN.OUT (12/20/12). Build No. 12.12.02.

10. The SWMMQIN.OUT file format was incorrect and not all the inlet discharge was being reported to file (1/21/13). Build No. 13.01.03.

11. The prescribed levee failure routine was edited to include submergence, variable weir coefficients and expansion of the levee breach opening to addition flow directions and grid elements (1/21/13). Build No. 13.01.03.

12. The levee overtopping component was expanded to included DOT submergence criteria that eliminate numerical surging as the headwater to tailwater equilibrium was approached (1/21/13). Build No. 13.01.03.

13. There was an error in the code for channel confluence connections from the right bank of the main channel. This resulted in a severe volume conservation error (1/21/13). Build No. 13.01.03.

14. The hydraulic structure component was expanded to include a better transition from downstream to upstream flow for rating tables that was based on the headwater to tailwater difference (1/21/13). Build No. 13.01.03.

15. An enhancement was made to assign outflow nodes that will generate an inflow hydrograph in the INFLOW.DAT file format to a downstream different grid system. The downstream grid system can be a different size than the upstream grid system but must have an overlapping row of grid elements (1/21/13). Build No. 13.01.03.

16. The generalized culvert equation routine was modified to account for flow equilibration and upstream flow through the levee. The culvert equations designed for inlet and outlet control assumes that the flow is only from upstream to downstream. The range of conditions involving when tailwater equals or exceeds the headwater are not adequately address by the equations. Based on the DOT criteria for using one of the five headwater to tailwater conditions and selecting a minimum discharge did not allow for a smooth transition of the discharge in an unsteady flow routing scenario. A submergence criteria was adopted to enable a smooth transition as the tailwater approached the headwater water surface elevation (1/21/13). Build No. 13.01.03.

17. The Pro Model did not write the CHAN.RGH and FPLAIN.RGH files because these file were replaced by TOPO.RGH and MANNINGSN.RGH. The Pro Model now writes these files, but it all four files should be replaced when using the limiting Froude numbers to adjust the n-values (1/25/13). Build No. 13.01.03.

18. The volume of the discharge hydrograph in HYCROSS.OUT was not being reported for metric units (1/30/13). Build No. 13.01.03.

19. A levee breach element variable was missing from the breach subroutine call. This was a fatal error and would stop the model from running a breach simulation (2/5/13). Build No. 13.02.04.

20. The Horton infiltration model was added. Now the infiltration model options are Green-Ampt, SCS curve number and Horton (2-25-13). Build No. 13.02.04.

21. Channel infiltration was significantly enhanced by the following changes Build No. 13.02.04.:
    - Channel infiltration can be limited by soil depth assignment.
    - Channel hydraulic conductivity can decay exponentially from an initial to a final value triggered by the wetting front reaching the limiting soil depth.
    - Channel hydraulic conductivity (initial and final), and limiting soil depth can be assigned by segment (or reach).

22. BATCH code was included to the PRO code (3/7/13). Build No. 13.02.04:
    - If BATCHCYCLE.DAT file is on the project folder and it contains the switch 'ON', summary dialog window will be skipped and the model will terminates without any User action. Multiple projects can be run by using the batch executable.
    - If BATCHCYCLE.DAT file is on the project folder and it contains the switch 'OFF'. Summary dialog window will be shown. Multiple projects cannot be runby using the batch executable.
    - If there is not a BATCHCYCLE.DAT file on the project folder then the Summary dialog window will be shown and the model termination requires a User action. Multiple projects cannot be run by using the batch executable.

23. The BASE.OUT file format was fixed for grid systems with more than 1 million elements (3/7/13). Build No. 13.02.04.

24. Hydraulic structure arrays INFLONOD and OUTFLONOD were initialized and set equal to zero (3/7/13). Build No. 13.02.04.

25. Levee breach discharge routine was revised to allow the prescribed breach element to discharge into another levee element (3/7/13). Build No. 13.02.04.

26. For the case where the channel can fit inside one grid element, a revision was made to allow floodplain flow exchange across the diagonal when a levee is assigned to the channel element in the center of three channel elements forming a 'L' (3/16/13). Build No. 13-02-04.

27. For a project with hydraulic structures with tailwater control and multiple channels (rill and gully flow), a typo was corrected to recognize the structure inlet flow depth (3/16/13). Build No. 13-02-04.

28. A reporting error in HYCHAN.OUT of the channel discharge and velocity was corrected (3/20/13). Build No. Build No. 13-02-04.

29. Revisions were made to the hydraulic structure routine to further eliminate potential surging when the structure rating curve or table does not match the upstream discharge. Numerical surging can occur when the rating table discharge exceeds the upstream discharge. In the physical system this is possible for a concrete box culvert or bridge with an apron if the flow accelerates through the structure, but numerically it occurs when the rating curve or table is based on underestimated structure roughness or entrance conditions. The model will now automatically revise the rating table discharge as the headwater and tailwater surfaces equilibrate if the INOUTCONT parameter is set to 1. This is a revision as to how this parameter is used. Previously it was used for rating

tables that were based on the difference between the headwater and tailwater (5/2/13). Build No. 13-07-05.

30. Modification to the hydraulic structure headwater flow depth computation was made for adverse bed slope, for velocity head to the structure, and for floodplain structure headwater to tailwater relationships. These revisions were made to reduce or eliminate the potential for numerical surging through the model when the discharge through the structure based on the rating table exceeds the upstream inflow to the structure. These revisions may result in a difference in the maximum flow depths, velocities and discharges when compared to previous models when numerical surging may have occurred (5/2/13). Build No. 13-07-05.

31. The HYDROSTUCT.OUT file was revised to report the average discharge over the output interval instead of the instantaneous discharge at the output interval. This was done to be consistent with the rest of the model reporting (5/2/13). Build No. 13-07-05.

32. Modified the reporting of the hydraulic structure velocities based on flow area for the current time step. These velocities are not used by the model because the discharge is computed directly from the rating curve or table (5/2/13). Build No. 13-07-05.

33. The TIMETOPEAK, TIMETOONEFT and TIMETWOFT output files are now reported when using the multiple channel (rill and gullies) component (5/2/13). Build No. 13-07-05.

34. A warning message for adverse bed slope through the hydraulic structure is now written to the ERROR.CHK file (5/2/13). Build No. 13-07-05.

35. Adjustments were made to the HSUBFACTOR coefficient increment for hydraulic structures that adjusts the rating table or curve discharge when the headwater and tailwater surface approach equilibrium. This was based on a sensitivity analysis (6/25/13). Build No. 13-07-05.

36. If adjustments are made to the hydraulic structure rating table during a simulation, the changes in the rating table pairs are written to the REVISED_ RATING_TABLES.OUT file. This enables the rating table to be adjusted for the next simulation (6/25/13). Build No. 13-07-05.

37. A warning message for an unreasonable rate of change in the discharge versus the rate of change in the stage (depth) for hydraulic structure rating tables is written to the ERROR.CHK file (6/25/13). Build No. 13-07-05.

38. Multiple outflow nodes can be designated to write the outflow hydrograph to the inflow nodes of a separate downstream model with different size grid elements. Inflow hydrographs for up to nine separate downstream grid system can be generated for a single simulation. The ID character O in the OUTFLOW.DAT file must be assigned O1, O2,...O9 (6/25/13). Build No. 13-07-05.

39. An error on the multiple outflow nodes feature was corrected. The error did not introduce any incorrect calculation but it was preventing the code from locating or assigning the upstream outflow hydrograph to the downstream grid element as an inflow for the case of a coarser upstream grid transferring outflow to downstream grid system (6/25/13). Build No. 13-07-05.

40. Modification of the ERROR.CHK file for the multiple outflow nodes feature. The upstream grid cell number is reported to the ERROR.CHK file along with a message when the upstream cell is dry during the total simulation and there is no outflow

hydrograph that can be assigned to the downstream grid system (6/25/13). Build No. 13-07-05.

41. An ERROR.CHK warning message was implemented to check if the hydraulic structure discharge was greater than 1.5 times the inlet discharge. This identifies that the rating curve or table has been inappropriately assigned (6/25/13). Build No. 13-07-05.

42. Storm drain inlet discharge volume must be greater than the existing volume on the grid element (depth-TOL) x surface area to initiate inflow to the storm drain (6/25/13). Build No. 13-07-05.

43. Warning messages are written to ERROR.CHK for hydraulic structures were added to identify component conflicts with ARF values, inflow and outflow nodes, streets, and channels. Hydraulic structure inflow and outflow elements that repeated in HYSTRUC.DAT are identified in the ERROR.CHK file (6/25/13). Build No. 13-07-05.

44. The floodplain to channel hydraulic structure warning messages was fixed to identify adverse slope (6/25/13). Build No. 13-07-05.

45. The limiting discharge capacity from multiple hydraulic structure inlets to an individual outlet (D-line in HYSTRUC.DAT) was revised with an expanded array allocation (6/25/13). Build No. 13-07-05.

46. The reporting format for large grid element numbers in CROSSQ.OUT file was increased (6/25/13). Build No. 13-07-05.

47. A revision was made to assign the instantaneous levee failure width as either the grid element side or the assigned maximum failure width (6/25/13). Build No. 13-07-05.

48. Corrected an error in the reference elevation computation for hydraulic structure flow depth. The bed elevation was used instead of the water surface elevation (6/25/13). Build No. 13-07-05.

49. Corrected an error in the conversion of metric units for the SWMM component (6/25/13). Build No. 13-07-05.

50. A switch was added to activate and deactivate a SWMM node's ponding feature. The ponding variable changes from 0 to 1 depending on the comparison between the FLO-2D water surface elevation and SWMM pressure head. If the switch is activated, the node volume is changed from return flow volume into full volume and overflow is set to 0 (6/25/13). Build No. 13-07-05.

51. A revision was made to allow return flow from the storm drain to the surface water when the storm drain system capacity is exceeded or the pipe pressure exceeds the surface water elevation and the storm drain inlet overflows (6/25/13). Build No. 13-07-05.

52. SWMMQIN.OUT file was modified to report the discharge that flows into and out of a storm drain inlet. This is discharge computed by the FLO-2D to the SWMM model inlets. The SWMM.rpt file includes the pipe inflow and outflow at a junction (6/25/13). Build No. 13-07-05.

53. Mass balance on the SUMMARY.OUT file was modified to report the total volume that flows into and out of the storm drain. The volume remaining in the storm drain system is also reported (6/25/13). Build No. 13-07-05.

54. Added storm drain flapgate option to simulate outfalls with a gate that stops the flow from entering the storm drain system through the outfall. The SWMMFLO.DAT file was modified to include a new variable FLAPGATE (column 8). This variable has the value

of 0 (off - default) or 1 (ON) that activate the flap gate in the outflow nodes (6/25/13). Build No. 13-07-05.

55. Added rating table options (INTYPE=4) to the SWMM storm drain method as a new type of inlet condition. SWMMFLORT.DAT is open/read when inlet type 4 are defined in the storm drain system. The file contains the rating table for all inlets type 4. (6/25/13). Build No. 13-07-05.

56. SWMM error code is now reported to the ERROR.CHK file (FLO-2D file) (6/25/13). Build No. 13-07-05.

57. A dam breach erosion variable assignment error was fixed that precluded the BREACH.OUT file from being populated (7/31/13) Build No. 13-07-05.

58. Levee breach expansion for prescribed breach failures was improved (7/31/13) Build No. 13-07-05.

59. To eliminate the numerical stability issues with grid element evacuation at shallow flows for very small TOL value, the code was revised to redistribute the discharge out of a grid element when evacuation occurs (7/31/13) Build No. 13-07-05.

60. Follow-up with revision 59 for very small TOL values, the TOL value was hardwired to 0.1 ft (0.03 m) for channel flow, bank elements, hydraulic structure and levee overtopping (8/24/13) Build No. 13-07-05.

61. When hydraulic structure inflow and outflow nodes are assigned to contiguous grid elements with a levee on the side joining the inflow and outflow elements, if the levee fails, the hydraulic structure is turned off regardless of the type of prescribed levee failure (instantaneous, with time duration, or horizontal rate of failure (8/24/13) Build No. 13-07-05.

62. An improvement was made permit instantaneous levee breach failures to revert to overland flow instead of broad crest weir flow. This revision will predict wall failure discharge more accurately and eliminate potential surging (8/24/13) Build No. 13-07-05.

63. The hydraulic structure rating table revisions are written to file. The number of revisions was reduced by changing the incremental depth variation (8/24/13) Build No. 13-07-05.

64. Error messages were added to identify levees assigned against boundary elements and in outflow nodes (9/7/13) Build No. 13-07-05.

65. Two potential array zero assignments were fixed for checking the channel interior elements (9/7/13) Build No. 13-07-05.

66. A levee instantaneous failure variable was inadvertently added to the levee overtopping routine. This cause was fatal error if no levee failure mode was on (9/7/13) Build No. 13-07-05.

67. The rainfall depth area reduction factors were incorrectly assigned to interior channel elements that were wider than two elements. This may cause a minor volume conservation error (9/7/13) Build No. 13-07-05.

68. A debug file can be generated with all the hydraulic information for a specific grid element for each computational timestep. The output data includes timestep, depth, velocity, water surface elevation, discharge in eight direction, n-value, Froude number, hydraulic structure discharge, and levee overtopping. To create the DEBUG.OUT file, the DEBUG.DAT must be prepared. This file is one-line with four data entries space

delimited containing: grid element, start time and end time (hrs), and floodplain, channel or street switch (1,2 or 3 respectively) (9/7/13) Build No. 13-07-05.

69. A long culvert bug was fixed. The discharge variable was not initialized in the correct location (9/7/13) Build No. 13-07-05.

70. The channel can now terminate on the alluvial fan or floodplain with flow exchange from all the channel end grid elements. If the channel bank elements at the end of the channel are separate by one or more elements, all the elements between the banks and the bank elements will discharge to the floodplain (9/7/13) Build No. 13-07-05.

71. An error message will be generated if a time-stage element has a bed elevation that is higher than the specified stage (9/7/13) Build No. 13-07-05.

72. To further reduce numerical instability for bridge hydraulic structures, an option was incorporated into the hydraulic structure routine to shut off the rating table for flow depths less than 1 ft (0.3 m) or when the SUBFACTOR is less than 0.02 (nearly equal tailwater and headwater surfaces). The hydraulic structure inflow and outflow nodes must be contiguous. To activate this option, set the culvert length parameter CLENGTH = 1.0 while the culvert diameter CDIAMETER = 0. (9/7/13) Build No. 13-07-05.

73. An error was found in the assignment of the flow width for 8-direction WRF values. The Pro model WRF values in ARF.DAT were expanded from 4-directions to 8-directions. The computation of the flow width for one or more of the directions could be in error due to an error in the array index variable. This could affect some of the diagonal flow direction velocities (11/13/13). Build No. 13-11-06.

74. The error messages were expanded in ERROR.CHK for reading the SWMMFLO.DAT file (11/13/13). Build No. 13-11-06.

75. A channel array parameter allocation was expanded to for the side connectivity. This was a fatal error (11/13/13). Build No. 13-11-06.

76. The hydraulic structure routine had two RETURN commands that should have been CYCLE commands. These bugs were introduced in bug fix 72 above. This caused the hydraulic structure routine to generate completely garbage data in some cases (12/17/13). Build No. 13-11-06.

77. The channel terminating on the floodplain using all the elements between the left and right banks had a conflict with the confluences and need to be expanded for channel segments joined by hydraulic structures (12/17/13). Build No. 13-11-06.

78. The SWMM storm drain model interface was enhanced to include: street and channel inlet exchange, outfall node discharge to channel and default grid element elevation to the rim elevation assigned in the SWMM.inp file (01/10/14). Build No. 13-11-06.

79. New output files were created to report results during runtime. FPRIMELEV.OUT reports the floodplain elevation, the rim elevation, the comparison between them and the new floodplain elevation. (01/10/14). Build No. 13-11-06.

80. New output files were created to report results during runtime. SWMMOUTFIN.OUT reports the outfall discharges from SWMM to FLO-2D. (01/10/14). Build No. 13-11-06.

81. New output files were created to report results during runtime. CHVOLUME.OUT reports the OUTFLOW TO SWMM and the INFLOW FROM SWMM for an outfall that discharges to a channel grid. (01/10/14). Build No. 13-11-06.

82. New Errors are written to the error.chk file: Multiple inlets to a grid. (01/10/14).). Build No. 13-11-06.

83. First line of the SWMMFLO.dat (path) was eliminated. The model automatically searches for the swmm data files on the FLO-2D project folder. (01/10/14).). Build No. 13-11-06.

84. Notation of coordinates in TOPO.DAT was expanded to make room for larger coordinates (01/16/14).). Build No. 13-11-06.

85. The code was modified to read the new SWMFLO.DAT that contains the name of the junctions defined in the INP file. (02/19/14). Build No. 13-11-06.

86. The channel terminating on the floodplain using all the elements between the left and right banks were revised (02/19/14). Build No. 13-11-06

87. An incorrectly assigned index was found on the SWMM reporting subroutine output_saveNodeResults (02/19/14). Build No. 13-11-06.

88. The error messages were expanded in ERROR.CHK for reading the SWMMFLO.DAT file with SWMM ID for Inlets (02/19/14). Build No. 13-11-06.

89. The error messages were expanded in ERROR.CHK to report a warning message for those inlets that have different datum for FLO-2D and SWMM (floodplain and invert elevations) (02/19/14). Build No. 13-11-06.

90. The error messages were expanded in ERROR.CHK to report a warning message for the invert elevation of the outfall (02/19/14). Build No. 13-11-06.

91. The error messages were expanded in ERROR.CHK to report multiple storm drain inlets to a single FLO-2D grid cell (02/19/14). Build No. 13-11-06.

92. The channel termination routine was further revised (see revision 70 above) to facilitate the flow distribution out of the internal channel elements to the floodplain at the end of a channel without a channel outflow node. The floodplain elevation in the channel end exchange elevation was reset to the channel bed elevation. A document describing the channel termination methodology is available (3/10/14). Build No. 14-03-07.

93. The prescribed dam and levee breach routine was improved to include submergence by downstream ponding. In the case where the breach discharge fills a bermed, leveed area or confined area, the breach discharge is reduced when the tailwater submerges breach from having free overfall. The breach weir discharge computation reverts to overland floodplain flow through the breach when the ratio of tailwater to headwater is 0.9 (3/10/14). Build No. 14-03-07.

94. The horizontal breach rate for the prescribed levee breach routine was assigned a decay function. When the vertical breach failure reaches the foundation beach elevation, the maximum shear stress is computed. Subsequently, the horizontal breach rate is computed as the original horizontal breach rate multiplied by the ratio of the breach shear stress to the maximum shear stress. The shear ratio is also set to zero (i.e. the horizontal breach rate is zero) if the breach velocity is less than 3 fps (1 mps) (3/10/14). Build No. 14-03-07.

95. A TIME.OUT file sorting bug was fixed and the TIME.OUT file reporting is correct (3/10/14). Build No. 14-03-07.

96. The warning message for levees assigned to the boundary was turned off. If a levee is assigned along a boundary, the model ignores it (3/10/14). Build No. 14-03-07.

97. The numerical stability was improved for street routing component for shallow flow. This will reduce the frequency of timestep decrements for shallow street flow (3/10/14). Build No. 14-03-07.

98. Rainfall runoff from buildings using the IRAINBUILDING switch in RAIN.DAT was enhanced. When IRAINBUILDING = 1, the n-values within the building for all the ARF = 1 elements are set to 0.03. The water surface elevations outside the building are ignored when computing the discharge from the building elements to the nodes outside the building. The TOL value inside the buildings is minimize to a value of 0.03 ft (0.01 m) to enhance building runoff (3/10/14). Build No. 14-03-07.

99. A revision was made to the floodplain outflow nodes elevations. When the outflow node elevation is greater than the contiguous upstream grid element elevations, the slope between the contiguous upstream element and then next upstream element is computed and the outflow node elevation is adjusted using that computed slope. If the criteria for a slope adjustment is not met, then the outflow node is assigned an elevation 0.1 ft (0.03 m) lower than the lowest contiguous upstream element (3/14/14). Build No. 14-03-07.

100. The breach output file TIMEONEFT.OUT was not reporting the channel times when the corresponding floodplain element was not inundated (4/18/14). Build No. 14.03.07.

101. The prescribed levee and dam horizontal breach rate is set to zero for a velocity less than 3 fps that is based on the breach discharge. The local side discharge was incorrectly used instead of the total breach discharge and was corrected (4/27/14). Build No. 14.03.07.

102. A warning message was implemented for the condition where the infiltration initial abstraction exceeds the TOL value for the depression storage (4/27/14). Build No. 14.03.07.

103. The channel confluence variable array assignment was expanded. The array size was limited to the number of channel segments. This was expanded by 50 for a project with numerous confluences and split flows that exceeded the number of segments. (4/27/14). Build No. 14.03.07.

104. A new output file was generated to provide additional dam breach timing data as follows:

Node   X-coord   Y-coord   Floodwave Arrival Time   Flood Time   Peak Time   Deflood Time   Max WS

Where:
Floodwave Arrival Time: Time in hours from when the breach discharge exceeds 0.01 cfs or cms to when the floodplain grid element flow depth exceeds 0.1 ft or 0.3 m.

Flood Time: Time (hrs) from when the breach discharge exceeds 0.01 (cfs or cms) to when a given grid element flow depth exceeds 0.5 ft or 0.15 m on the floodplain.

Peak Time: Time (hrs) from when the breach discharge exceeds 0.01 (cfs or cms) to when a given grid element flow depth reaches a maximum depth.

Deflood Time: Time (hrs) from when the flood arrives at a grid element (flow depth exceeds 0.5 ft or 0.15m) to the time when the flood recedes to a depth lower than 0.5 ft or 0.15 m.

Max WS: The maximum water surface for a given floodplain grid element is reported.

105. A mathematical typo (.EQ.1 instead of .EQ.2) was discovered that caused the hydraulic structure option INOUTCONT = 2 for upstream flow through structure to be by-passed (6/12/14). Build No. 14.03.07.

106. An incorrectly assigned index was found on an array on the SWMM DISCHARGE subroutine that recalculates the total volume accumulated since the last SWMM Timestep. In those cases the flow depth was not getting correctly updated and the volume

that leaves the FLO-2D grid cell and passes to SWMM was not subtracted. This behavior was observed only for large projects (06/12/14). Build No. 14-07-08.

107. Existing error messages are expanded and new messages are created in ERROR.CHK for FLO-2D SWMM Integrated model (06/12/14). Build No. 14-07-08.

108. Model stops and report a message when: (06/12/14). Build No. 14-07-08

- More than one storm drain inlet assign to a single cell
- Simulation times between FLO-2D and SWMM are not compatible

109. SWMM inlet flow depths for the dynamic wave are passed through FLO-2D SWMM interface for comparison with FLO-2D flow depths at inlet grid cells (06/12/14). Build No. 14-07-08

110. Surcharge depth assigned in the SWMMFLO.DAT file are passed through the FLO-2D SWMM interface and assigned to the corresponding inlet node in SWMM. Both models were modified to be able to calculate the time when the manhole cover is popped and then the manhole can receive inflow and outflow (return flow to the surface) (06/12/14). Build No. 14-07-08.

111. The Storm Drain Totals were updated on the SUMMARY.OUT file. The storm drain volumes were being incorrectly reported for some isolated simulations (06/12/14). Build No. 14-07-08.

112. Additional Output files are written when the "Time Lapse Output" switch is activated as follow:

- ITIMTEP:0, No output results are written to the TIMDEP File
- ITIMTEP:1, Only TIMDEP.OUT file is written
- ITIMTEP:2, TIMDEP.OUT and HDF5 files are written
- ITIMTEP:3, TIMDEP.OUT and NETCDF4 files are written
- ITIMTEP:4, All output files are written. (06/12/14). Build No. 14-07-08

113. For levee instantaneous failure, the flow hydraulics after failure were not using the base elevation and n-value of the overland flow. The switch for instantaneous failure was not used in all subroutines (8/2/2014). Build No. 14-07-08.

114. Formatting for the SUPER.OUT file was enhanced. Only the 100 first channel elements are now written (8/2/2014). Build No. 14-07-08.

115. Simulation time is automatically pass from FLO-2D (SIMUL variable in CONT.DAT) to the storm drain engine (11/4/2014). Build No. 14-11-09.

116. Ending time and date of the storm drain simulation (End Analysis On in the *.inp file) is being automatically calculated based on the SIMUL time from the CON.DAT file (11/4/2014). Build No. 14-11-09.

117. Outfall elevation can be set lower than the ground. If the FLO-2D model has ponded flows covering an outfall invert, the WSEL can be assigned as a ground elevation and will represent initial head to the outfall. This head is always present during the simulation. During the simulation water may be added to either the outfall grid element surface water or the upstream storm drain pipe and the pipe flow can go in either direction based on the head comparison (11/4/2014). Build No. 14-11-09.

118. A volume conservation error was generated for the condition when the outfall is higher the floodplain or channel bed. The outfall received water into the storm drain when the

WSEL is greater than the invert. In addition, the evacuation of the grid element water volume above the invert was possible if the inflow discharge to the outfall exceeded the available volume. This error was fixed (11/4/2014). Build No. 14-11-09.

119. A warning message was added for those culverts assigned the generalized culvert equation that had a zero culvert length in the HYSTRUC.DAT file (11/4/2014). Build No. 14-11-09.

120. A warning message was added for those natural channel cross sections with rating tables having less than 10 stations in the cross section. If a rectangular or trapezoidal channel geometry is being simulated, use the appropriate prescribed geometry instead of the natural channel geometry to preserve accuracy (11/4/2014). Build No. 14-11-09.

121. The option for a hydraulic structure to share discharge from a channel element to the floodplain element using a rating table or the generalized culvert equations was created. This finalizes all the possible hydraulic structure combinations of floodplain to floodplain, channel to channel, floodplain to channel and channel to floodplain (11/4/2014). Build No. 14-11-09.

122. For rainfall on buildings, downspout discharge can be computed using a hydraulic structure rating table. The hydraulic structure will connect the roof (floodplain element) to the ground (floodplain element). Water will shared between grid elements when it exceeds the TOL value. Roof parapet walls can be assigned using the levee component on the outside of the building elements. Flow can overtop the parapet walls (11/4/2014). Build No. 14-11-09.

123. The channel can be terminated on the floodplain without a channel outflow node. The channel interior elements and the bank elements will share discharge with the next downstream floodplain element. The interior channel element grid element elevation should be set to the thalweg elevations and the downstream floodplain elevations should be lower than the end of the channel thalweg elevation (11/4/2014). Build No. 14-11-09.

124. The assignment of interior channel elements between the two bank elements in a very large channel with small elements was not correct. Some interior channel elements were being missed. The algorithm for selecting the interior channel elements was revised (11/4/2014). Build No. 14-11-09.

125. For a project with many roadway, levee or other embankments, the LEVOVERTOP.OUT was getting too large and was taking hours to reformat. The levee overtopping discharge output was limited to selected levee elements in LEVEE.DAT. The selection is based on assigning a negative value to a levee element. Only those negative levee elements in LEVEE.DAT will have output data written to the LEVOVERTOP.OUT file (11/4/2014). Build No. 14-11-09.

126. An error in the multiple channel infiltration routine was discovered. Several lines of code were duplicated thereby double accounting the multiple channel infiltration (11/4/2014). Build No. 14-11-09.

127. Fix a channel infiltration error for limiting flow depth. The infiltration was ceased for global limiting soil depth if no individual spatially variable channel limiting soils depth were not assigned (11/2/14). Build No. 14-11-09.

128. An improvement was made to the IMPACT.OUT and SPECENERGY.OUT files. The maximum impact pressure and specific energy were based on the maximum velocity and the corresponding flow depth when the maximum velocity occurred. While this is fine

almost all of the time, it was noted that there are some instances during a frontal wave progression that the maximum velocity may occur with a shallow depth. The correct was to compare the maximum impact pressure and specific energy for each timestep regardless of when the maximum velocity occurred (12/09/14). Build No. 14-11-09.

129. Spatially variable tolerance was created. TOLSPATIAL.DAT file can be created from the updated GDS. (12/09/14). Build No. 14-11-09.

130. A line was fixed for the initialization of the variable that carry the discharge of hydraulic structures when the Hydraulic structure is not equal to IFPORCHAN(I) = 3. (01/08/15). Build No. 14-11-09.

131. A portion of the SCS infiltration code was left out of the most recent compilation of the model because some routines were moved around to improve the organization of the code. This resulted in a major volume conservation error at the start of the SCS model. (01/12/15). Build No. 14-11-09.

132. Several code revisions were necessary to enable the general culvert equations to correctly predict upstream flow through the culvert when the tailwater surface elevation exceeded the headwater elevation. These revisions include a check for negative numbers in the routine, revision to the variable names for upstream flow and sign direction for upstream flow through the culvert. (01/21/15). Build No. 14-11-09.

133. The *'channel extension through the levee'* error messaging statement was bypassed with a recent update. This revision re-instates the levee and channel conflict testing. (01/23/15). Build No. 14-11-09.

134. Items were updated in the Summary.out report file (2/17/15). Build No. 15.02.10.

135. New alluvial channel avulsion routine. This new component for alluvial fans predicts potential multiple channel avulsion and new path based on channel overtopping flows, steepest flow path, width and depth channel geometry relationships (02/20/15). Build No. 15.02.10.

136. Fixed spikes for the storm drain inlets where oscillations in the hydrograph were observed (2/20/15). Build No. 15.02.10.

137. Adjustments were made to the general culvert equations for outlet control criteria. The flow depth criteria was adjusted to eliminate overlap between partial submergences and full pipe flow outlet control (2/23/15). Build No. 15-02-10.

138. The error messages for the right bank extension were revised and updated (2/23/15). Build No. 15.02.10.

139. The spatially variable TOL code was (Revision 129 above) modified to make sure that the assigned TOL value matched the appropriate grid element (and its neighbor) (2/23/15). Build No. 15.02.10.

140. The overland shallow flow n-value was hardwired to 0.1 for flow depths less than 0.1 ft (0.03 m) and an n-value of 0.05 or less (2/23/15). Build No. 15.02.10.

141. A modification was made for shallow flow volume conservation. If the volume out of the grid element exceeds the storage plus inflow volumes, the grid element volume is set to zero and the outflow is redistributed to the neighbor grid elements. This computation was modified to limit the adjustment to only the outflow directions (2/23/15). Build No. 15.02.10.

142. Error.chk file was edited and errors were reviewed and simplified. (3/20/15). Build No. 15.05.11.

143. Multiple assignments of 'channel to floodplain' hydraulic structures in the same data file (HYSTRUC.DAT) caused a volume conservation error related to summation of structure volume diverted from the channel. This was corrected with an appropriate identification of the hydraulic structure in the channel. (3/27/15). Build No. 15.05.11.

144. ITIMDEP criteria was changed to (3/27/15 - Build No. 15.05.11):
    0 = no TIMDEP file is written.
    1 = timdep.out
    2 = hdf5 binary output
    3 = NetCDF binary output
    4 = ALL

145. The wetted perimeter for the channel natural cross section geometry overbank flow was adjusted. This was not increasing with increased flow depth over the top of banks (4/20/2015). Build No. 15.07.12.

146. A new file (EVACUATEDCHAN.OUT) to report the complete evacuation of channel volume for shallow flow during channel stability assessments was added (4/20/2015). Build No. 15.07.12.

147. The sediment distribution in the trapezoidal channel and the resultant modified channel geometry for scour/deposition was revised in the sediment transport routine (4/20/2015). Build No. 15.07.12.

148. Code was added to limit bank channel bank scour (4/20/2015). Build No. 15.07.12.

149. The reporting of the sediment transport volume conservation in SUMMARY.OUT was expanded to include final channel sediment storage (4/20/2015). Build No. 15.07.12.

150. Calculation of convective/local terms was adjusted for the main channel in confluence elements (4/27/2015).   Build No. 15.07.12.

151. The project folder and path is written to the FLO-2D runtime window status bar at the bottom of the screen (4/27/2015). Build No. 15.07.12.

152. The CHVOLUME.OUT column header labels and format for metric was edited (4/27/2015). Build No. 15.07.12.

153. The SUMMARY.OUT file was modified to enable a detailed comparison of the exchange volumes between the surface water flooding and the storm drain (5/4/2015) Build No. 15.07.12. The revisions to the SUMMARY.OUT file include exchange volumes with the Storm Drain component were divided into four categories:

    ✓ Storm Drain Inflow - inflow through inlets and outfalls.

    ✓ Storm Drain Outflow - discharge outflow back to the surface water through outfalls and the discharge outflow off the storm drain system.

    ✓ Return Flow - Storm Drain discharge to the surface water through inlets plus the inlet ponded flow that re-enters the storm drain system when storage capacity is available.

    ✓ The following volumes are extracted directly from the SWMM.rpt file and written to SUMMARY.OUT for comparison:

- **WET WEATHER INFLOW** - The inflow to the storm drain system through inlets and outfalls.
- **EXTERNAL INFLOW** – The direct inflow to the storm drain system from external sources.
- **EXTERNAL OUTFLOW** - The total outflow that leaves the storm drain system.
- **Total Storm Drain Storage** – Includes all the storm drain volume storage in nodes and links.
- **Continuity error** – Volume conservation error internal to the storm drain engine.

154. The channel floodplain exchange routine was revised to have a minimum n-value of 0.065 for the channel bank element overland flow. This was required to avoid automated assignment of very low street n-values to the channel bank elements where the overbank velocities are typically low (5/5/2015). Build No. 15.07.12.

155. Additional criteria was added for the assignment of the floodplain elevation in comparison to the channel top of bank element elevation. Originally, if the channel top of bank elevation is different from the floodplain elevation for the bank element by more than 1.0 ft, the floodplain elevation is reset to the channel top of bank elevation. For small grid elements this can be a significant slope for overbank discharge. A slope calculation has been implemented. If the slope between the top of bank and the floodplain exceeds one percent (0.01), the model reassigns the floodplain elevation to the top of bank. This represents a 0.2 ft difference for a 20 ft grid element (5/5/2015). Build No. 15.07.12.

156. A building collapse routine was added to the model. By assigning negative ARF-values for either totally or partially blocked elements in ARF.DAT, the removal of buildings during the flood event can be simulated when velocity and depth criteria for the collapse of the buildings is exceeded (5/5/2015). Build No. 15.07.12.

157. Uniform flow in the storm drain inlet hydrograph were observed when the orifice equation was used. The discharge was reset to zero for some orifice conditions and generated spikes in the inlets. Changes were also requires in the VC2005-CON to fix this issue (5/5/2015). Build No. 15.07.12.

158. Additional Output files are written when the "Time Lapse Output" switch is activated as follow:
- ITIMTEP: 0, no output results are written to the TIMDEP File
- ITIMTEP: 1, only TIMDEP.OUT file is written
- ITIMTEP: 2, only the TIMDEP in HDF5 binary format is written
- ITIMTEP: 3, only the TIMDEP file for the creation of the NETCDF4 file is written
- ITIMTEP: 4, All output files are written.
- ITIMTEP: 5, TIMDEPCELL.OUT (ASCII FILE) is created for only those cells list in TIMDEPCELL.DAT file (05/20/15). Build No. 15.07.12

159. New error messages have been added or enhanced for the FLO-2D Storm Drain component (05/25/15). Build No. 15.07.12:

- THERE IS AN OUTFLOW NODE AND A STORM DRAIN INLET ASSIGNED TO GRID CELL.
- THERE IS AN OUTFLOW NODE AND A STORM DRAIN OUTFALL ASSIGNED TO GRID CELL.
- THERE IS AN INFLOW NODE AND A STORM DRAIN INLET ASSIGNED TO GRID CELL.
- THERE IS AN INFLOW NODE AND A STORM DRAIN OUTFALL ASSIGNED TO GRID CELL.
- THERE IS A LEVEE AND A STORM DRAIN INLET ASSIGNED TO GRID CELL.
- THERE IS A LEVEE AND A STORM DRAIN OUTFALL ASSIGNED TO GRID CELL.
- THERE IS A STORM DRAIN INLET OR OUTFALL ASSIGNED TO COMPLETELY BLOCKED GRID CELL.
- THERE IS A HYDRAULIC STRUCTURE AND A STORM DRAIN INLET ASSIGNED TO GRID CELL.
- THERE IS A HYDRAULIC STRUCTURE AND A STORM DRAIN OUTFALL ASSIGNED TO GRID CELL.
- MULTIPLE INLETS ASSIGNED TO ONE GRID CELL.
- CELLS ASSIGNED TO ONE INLET.
- THE GRID ELEMENT FLOODPLAIN OR STREET ELEVATIONS WERE REVISED DURING THE SIMULATION TO THE STORM DRAIN INLET RIM ELEVATIONS FOR THE FOLLOWING GRID ELEMENTS (PLEASE REVIEW AND REVISE FPRIMELEV.OUT FILE IF NECESSARY).
- THE TYPE 4 STORM DRAIN INLET ELEVATIONS ARE DIFFERENT THAN THE GRID ELEMENT FLOODPLAIN ELEVATIONS.   NO ACTION WAS TAKEN DURING THE SIMULATION.   PLEASE REVIEW AND REVISE IF NECESSARY.
- NOTE: THE STORM DRAIN OUTFALL INVERT ELEVATION SHOULD BE EQUAL TO OR GREATER THAN THE FLOODPLAIN/CHANNEL/STREET ELEVATION. NO ACTION IS TAKEN. PLEASE REVIEW AND REVISE IF NECESSARY. THE MODEL WILL NOT TERMINATE DUE TO THIS WARNING.
- THERE ARE A MISSING OR INAPPROPIATE STORM DRAIN INLET GEOMETRY IN FILE.
- REVIEW STORM DRAIN INLET: ',A25,' DRAIN TYPE: ',i5,' ON GRID CELL: ',I10,' ERROR.
- THERE ARE STORM DRAIN INLETS ON CHANNEL GRID ELEMENTS, THE CHANNEL BED ELEVATION IS DIFFERENT THAN THE INVERT ELEVATION. NO ACTION WAS TAKEN DURING THE SIMULATION. PLEASE REVIEW AND REVISE IF NECESSARY.
- GRID ELEMENT (FLOODPLAIN SWALES) WERE REVISED DURING THE SIMULATION TO THE STORM DRAIN INLET INVERT ELEVATIONS FOR THE FOLLOWING GRIDS (PLEASE REVIEW AND REVISE FPRIMELEV.OUT FILE IF NECESSARY).
- THE TYPE 5 (MANHOLE) STORM DRAIN INLET ELEVATIONS ARE DIFFERENT THAN THE GRID ELEMENT FLOODPLAIN ELEVATIONS. NO ACTION WAS TAKEN DURING THE SIMULATION. PLEASE REVIEW AND REVISE IF NECESSARY.
- VERTICAL INLET OPENING ON A 1D CHANNEL WITH STORM DRAIN INLET INVERT ELEVATION DIFFERENT THAN THE GRID ELEMENT FLOODPLAIN ELEVATIONS. NO ACTION WAS TAKEN DURING THE SIMULATION. PLEASE REVIEW AND REVISE IF NECESSARY.
- NOTE: Inlet on a 1-D channel end of segment where the channel flow is discharging to the storm drain pipe, the invert elevation should be channel bed elevation.
- NOTE: Floodplain swale where the flow is discharging to a storm drain pipe or culvert, the invert elevation should be equal to the grid element floodplain elevation.
- THE FOLLOWING STORM DRAIN OUTFALL NODES ARE IN CHANNEL INTERIOR ELEMENTS, RE-ASSIGN TO THE CHANNEL ELEMENTS IN CHAN.DAT.

160. Build versions are now being compared between FLO-2D engine and VC2005-CON engine for version discrepancies. (06/05/15). Build No. 15-07-12.

161. Channel (CHAN.DAT) data input subroutine has been updated to fix an issue when bank elevation was less than 1 ft. (06/12/15). Build No. 15.07.12.

162. Storm Drain data (SWMMFLO.DAT) data input subroutine was updated to use a less demanding algorithm and includes all previous versions of the files. (06/12/15). Build No. 15.07.12.

163. An inconsistency in the transfer of parameters between the FLO-2D surface layer and the storm drain component was identified. This produces zero flow been routed in the storm drain system for some conditions in metrics. (06/05/15). Build No. 15-07-12.

164. Free outfalls and underground free outfalls in the storm drain system were reviewed to hold the FLO-2D boundary condition (WSE) for all cases. (06/05/15). Build No. 15-07-12.

165. Channel flow area reporting to the HYCHAN.OUT was corrected for trapezoidal and rectangular channels when various channel geometries were mixed together in the same channel segment (06/07/15). Build No. 15-07-12.

166. Channel routing solution algorithm was revised to improve the following:
    ✓ Confluence momentum terms.
    ✓ Velocity prediction if the solution algorithm does converge.
    ✓ Seed velocity estimate (smoothed out difference between the predictor and diffusive wave estimate.
    ✓ A new output file (CHANNEL_CONVERGENCE.OUT) was created to list the channel element, simulation, and various computed velocities used when the solution did not convergence. This is an indicator of potential channel surging elements that can be reviewed.

These changes resulting in the ability to increase the Courant number and maintain numerical stability (06/07/15). Build No. 15-07-12.

167. In SUMMARY.OUT an extra line of output was added to report the area of inundation for depths greater than 0.5 ft (0.15 m) (06/07/15). Build No. 15-07-12.

168. The levee breach expansion into other grid elements was corrected for the case of multiple prescribed breaches. The reporting in LEVEE.OUT had to be corrected also (06/07/15). Build No. 15-07-12.

169. The simplified storm drain routine for the hydraulic structures where multiple inflow nodes can outlet to the same outflow node was modified to allow the outflow collector node to discharge to a channel. This is unrelated to the FLO-2D storm drain component (10/22/15). Build No. 15-10-13.

170. A new output file, CHAN_INTERIOR_NODES.OUT (file number 263) was created to identify those floodplain elements that are internal to the channel to be identified for mapping purposes (10/22/15). Build No. 15-10-13.

171. Reading the channel data for the variable geometry power regression relationships was fixed. The read code with channel bank elevations was distorted with the INTEL compiler (10/22/15). Build No. 15-10-13.

172. The calculation that accumulates the inflow volume, than then is passed through the Storm Drain inlets, was review to make sure volumes match exactly between surface and storm drain layers. (10/22/15). Build No. 15-10-13.

173. Storm Drain Inflow was dampened and three different dampen calculations were imposed to reduce inflow oscillations at inlets. (10/22/15). Build No. 15-10-13.

174. The California Office of Emergency Service Dam Breach reporting times was revised for the Flood Time definition. The criteria was increased from 0.5 ft (0.15 m) to 2.0 (0.61 m). The Flood Time definition actually only applied to channel flow and some criteria

was selected for floodplain flooding. This corresponds to time to two ft criteria that is typical for dam breach mapping. (11/19/15). Build No. 15-10-13.

175. Reporting to OVERBANK.OUT file was altered to reflect only the overbank volume and surface area in the grid element (11/19/15). Build No. 15-10-13.

176. The channel bank elevations were initialized to zero for CHAN.DAT files without bank elevations. This eliminates the potential for assigning random numbers to the bank elevation arrays if the data is not read but assigned automatically (11/19/15). Build No. 15-10-13.

177. The channel termination on floodplain (without outflow nodes) routine was revised to eliminate errors introduced when setting the internal channel elements at the end of the channels for more than one channel segment. The routine was simplified to better identify the channel elements sharing with the floodplain at the end of a channel segment (1/11/16). Build No. 15-10-13.

178. Reporting the multiple channel maximum water surface elevations was corrected. The maximum water surface elevation in MAXWSELEV.OUT and TIMDEP.OUT was in error because the multiple channel depth was subtracted twice from the water surface elevation for these two files (1/11/16). Build No. 15-10-13.

179. Channel termination on floodplain routine (see 177 above) still had problems. One problem was that the channel segments that terminated with a hydraulic structure or a confluence were not correctly addressed when the improvements were added in early January (1/27/16). Build No. 15-10-13.

180. The floodplain overland flow in 8-directions timestep incrementing/decrementing routine was improved. When the Courant number is exceeded, the model now resets the timestep to the computed Courant number timestep. In addition, the rate of change in the timestep increment was adjusted (2/22/16). Build No. 16-02-14.

181. Supercritical flow reporting in SUPER.OUT was revised. The file now reports a summary of all the channel and floodplain supercritical flow in the model at the end of the simulation and resorts the data based on the Froude number in descending order. This file can be used in conjunction with VELTIMEFP.OUT and TIME.OUT to adjust unreasonable velocities and n-values in the model (2/22/16). Build No. 16-02-14.

182. The dam breach erosion expansion routine was adjusted to report the expansion discharge based on the ratio of breach width within a given grid element to the total breach width. This is now similar to the prescribed breach width expansion routine (2/22/16). Build No. 16-02-14.

183. The floodplain cross section reporting was improved. The reported average cross section velocity was based on the discharge divided by the average flow depth and grid element width. The width was the grid element size. This method of reporting enables the user to evaluate the discharge by multiplying the average velocity, flow depth and width in the HYCROSS.OUT file. For one grid element and potential flow direction, however, the flow width should be the flow direction width not the grid element width. For the case of a single grid element in the cross section, the average cross section velocity was being under-reported (2/22/16). Build No. 16-02-14.

184. The natural cross section routine was revised to vertically extend the lowest bank elevation to the higher bank elevation at runtime. This eliminated the potential for having an exceedingly low bank with a very small flow area. This will be similar to the

HEC-RAS assessment of channel cross sections. It will not significantly change the potential for overbank discharge exchange with the floodplain. It will only increase the flow area for channel hydraulic computations (3/28/16). Build No. 16-02-14.

185. Two new output files are generated (3/28/16):

DEPRESSED_ELEMENTS.OUT - This file is generated at the end of the data input at runtime. Every grid element elevation is checked with its neighbors' elevations to see if it is depressed based on a minimum difference of the DEPRESSDEPTH variable which replaces the ISUPER switch in CONT.DAT. A value of DEPRESSDEPTH = 3.0 ft is suggested. This depth will ignore minor small depression elements which can fill and overview.

LOW_LEVEE_CREST_ELEVATIONS.OUT - . Having a levee represent a wall that is only 0.1 ft above the ground is pointless. This condition could occur because of shape file elevation assignments or the grid element interpolation. The same variable DEPRESSDEPTH in the ISUPER variable position in CONT.DAT is used to evaluate the minimum difference in the levee crest elevations compared to the ground elevation on both sides of the levee. If used with DEPRESSED_ELEMENTS.OUT, the DEPRESSDEPTH variable either has to be the same value or two separate independent simulations are required for different values (use SIMUL = 0.1 or 0.01 hrs for each). If you used the DEPRESSDEPTH = 3.0 ft (or higher) to generate the depressed elements, the DEPRESSED_ELEMENTS.OUT file could be renamed and DEPRESSDEPTH reassigned to 1.0 ft (or lower) to generate LOW_LEVEE_CREST_ELEVATIONS.OUT file. Build No. 16-02-14.

186. An error in the box culvert switch for the generalized culvert equations was fixed. A full culvert flow inlet condition was being ignored with this error (3/28/16). Build No. 16-02-14.

187. The generalized culvert equation routine was not reporting upstream flow if the hydraulic structure connecting two channel segments was separated by more than one channel element. The code was modified to identify the correct upstream flow condition when the tailwater exceeded the headwater for separated channel elements. The same modification also enable the tributary confluence upstream flow to be reported in the HYCHAN.OUT file (3/28/16). Build No. 16-02-14.

188. The hydraulic structure floodplain to channel criteria to have the flow moving upstream in the channel to reverse flow with higher tailwater than headwater was considered unnecessary and removed. The flow through the hydraulic structure from downstream to upstream will depend solely on water surface elevation not momentum for the floodplain to channel option (3/30/16). Build No. 16-02-14.

189. StormDrain_ERROR.CHK file was created to report storm drain errors and warning messages. The storm drain error and warning messages were removed from the ERROR.CHK file (3/30/16). Build No. 16-02-14.

190. Existing errors and warnings for the storm drain system were reviewed and some warnings/errors were expanded. Modifications were implemented in those error/warnings related to conflicts between storm drain features and surface components as well as the outfall elevations checks (3/30/16). Build No. 16-02-14.

191. AVVELRES array for the subroutine that calculates the cross sectional analysis was initialized and set equal to zero (3/30/16). Build No. 16-02-14.

192. A new data file was implemented to enable the building collapse routine to be initiated. Building collapse is now based on three structure vulnerability curves (4/6/16). Build No. 16-02-14.

193. Calculation of mudflow velocities were ignored when recent improvements were made to the overland routing model. It was necessary to revise the mudflow velocity computation to include recent advancements to speed up the model (4/22/16). Build No. 16-02-14.

194. An error reading trapezoidal channel data at the end of a segment when the initial depth for next channel segment was non-zero was fixed (5/21/16). Build No. 16-02-14.

195. The TIMDEP.OUT file was revised to include a zero time output interval with all zeros for all reported values, so that the various plots made this file have an initial zero starting point. Previously, the first set of reported data was the first nonzero output interval (5/21/16). Build No. 16-02-14.

196. The FLO-2D surface water engine runtime speed has been enhanced with OpenMP code for sharing the computation workload between multiple processors. This is an on-going effort to reduce the model runtimes. The first expansion has focused on the overland flow loops since it is the most computation expensive loop in the model. The model runtime has been reduced by about 50% over the previous build (6/27/16). Build No. 16-06-15.

197. Prior to the implementation of the OpenMP code, the computation algorithm and timestep incrementing/decrementing scheme was improved. Computational algorithm enhancements involved adjustments to initial solution velocity estimate and changes to the default solution when the full momentum equation solution did not converge. The solution to the floodplain and channel routing algorithms was revised to improve the following:

   ✓ The timestep decrement was reduced to the Courant criteria timestep when the stability criteria was not met. This reduced the number of timestep decrements and sped up the model.
   ✓ The timestep accelerator function and default value was modified (see below).
   ✓ Seed velocity estimate was adjusted and the difference between the predictor and diffusive wave estimate was smoothed out.
   ✓ The predicted velocity was modified if the solution algorithm did not converge.
   ✓ Two new output files were created (CHANNEL_CONVERGENCE.OUT and FLOODPLAIN_CONVERGENCE.OUT) that list the channel or floodplain element, simulation time, and the various computed intermediate velocities used when the solution did not convergence. This is an indicator of potential surging elements that can be reviewed.

The incremental rate of change in the timestep parameter (TIME_ACCEL) was adjusted and the default value was changed from 0.1 to 1.0. A higher TIME_ACCEL parameter will result in larger timestep increments. When the computational timestep is less than 1.0 second and a simulation timestep loop was successfully completed without exceeding the stability criteria, the timestep is incremented by the TIME_ACCEL (default 1.0) x 0.001. So if the timestep was 0.5, then next timestep would be increased to 0.501 seconds. If the timestep is greater than 1 second, then the timestep increment is:

$$DSEC = DSEC + TIME\_ACCEL*0.0085/XFAST$$

where:

DSEC = computational timestep in seconds

TIME_ACCEL = user defined accelerator parameter ranging from 0.1 to 10.0 with a default of 1.0

XFAST = XFAST + 0.001 for each successfully completed timestep loop when DSEC > 1.0 second. XFAST resets to 1.0 each time the DSEC timestep is decremented.

198. This algorithm increases the timestep uniformly until the timestep DSEC is greater than 1 second. When DSEC > 1.0, successive increases in DSEC result in a larger values of XFAST which begins to slow down the timestep rate of change. The maximum timestep is limited to 30 seconds (6/27/16). Build No. 16-06-15.

    NOTE: It is necessary to reset TIME_ACCEL = 1. in the TOLER.DAT file for most existing models. This is accomplished automatically at runtime if TIME_ACCEL = 0.1 when a new simulation is initiated.

199. Following a recent change in the channel bank surface area computation, the floodplain surface area in the channel bank elements was being over estimated for trapezoidal channel on diagonal flow directions when the channel extension was 2 grid elements or more (6/29/16). Build No. 16-06-15.

200. A recent bug was fixed. The conversion to Open MP code included a number of revisions from a REAL number to a DOUBLE PRECISION number for the routing parameters. In a few code locations, other variables that computed with the new double precision numbers must also be converted from real to double precisions. Data transfer across subroutines will be in error when mixing the two formats causing the model to blow up (6/29/16). Build No. 16-06-15.

201. The channel wetted perimeter computation for overbank flow was incorrect for the revised natural cross section vertical extension of the lowest bank elevation to the higher bank elevation at runtime (7/13/16). Build No. 16-06-15.

202. The dam breach reporting criteria was revised to better conform with the California Office of Emergency Services requirements that the deflood time is the time elapsed from the initial failure of the dam until the measured location returns to its preflood water elevation prior to failure (7/13/16). Build No. 16-06-15.

203. New volumes are reported in the SUMMARY.OUT file (7/15/16). Build No. 16-06-15.

    STORM DRAIN SYSTEM STORAGE: Storage volume in the pipe system at the end of the simulation.

    STORM DRAIN MASS BALANCE: Mass balance volume conservation calculated as:
    Total Inflow - Total Outflow + System Storage

204. Depth area reduction factors RAINARF can now be applied to the spatially and temporally variable rainfall component for NEXRAD data. To accomplish this, simply add the RAINARF data to the RAIN.DAT file with the IRAINREAL switch on as follows (8/8/16) Build No. 16-06-15:

> In RAIN.DAT line 1, set IRAINREAL = 1, and IRAINBUILDING = 0 or 1
> Line 2: RTT = 0, RAINABS = 0, IRAINARF =1, MOVINGSTORM = 0
> Line 3 to the end: IRGRID(IJ), RAINARF(IRGRID(IJ))

205. Several dam breach erosion bugs were corrected. The most important error was some of the subroutine transfer parameters were out of order. This error was imposed with the new OpenMP code. It resulted in no breach discharge being computed. A couple of minor bugs included the sediment gradation for fines in a small breach was over-estimated and the pipe roughness term was being reset to zero (7/13/16). Build No. 16-06-15.

206. The floodplain element between separated right bank elements when the channel consisted of two elements (just left and right bank elements) was not properly identified with the channel interior elements and sharing discharge across the channel from the left bank element to this floodplain element occurred. This problem was resolved by designating this floodplain element as an interior channel element (8/14/16). Build No. 16-06-15.

207. Several output files text format was revised including EVACUATEDCHAN.OUT, CHANNEL _CONVERGENCE.OUT, and DEPRESSED_ELEMENTS.OUT (8/23/16). Build No. 16-06-15.

208. Two new output files were created. The EVACUATEDFP.OUT reports floodplain elements that have the volume completed removed for one timestep because the outflow to the element exceeds the inflow resulting in a redistribution of the 8-direction discharge to eliminate the potential for any negative volumes being reported. The second file DAMBREACH_VOLUME.OUT reports the volume associated with dam breach discharge as function of output interval (8/23/16). Build No. 16-06-15.

209. HYDRAULIC STRUCTURE_RUNTIME WARNINGS.OUT file was expanded to include messages that were originally in the ERROR.CHK file (8/23/16). Build No. 16-06-15.

210. An error message was implemented to identify that the user is not in a folder with a CONT.DAT file (8/23/16). Build No. 16-06-15.

211. For channels that terminate on the floodplain without a channel outflow node, a code revision was made to avoid completely evacuating the channel volume in the last channel element when only rainfall is the inflow to the channel resulting in very shallow depths. This will eliminate potential minor volume conservation errors that result from more water being shared to the floodplain than is in the channel (8/28/16). Build No. 16-06-15.

212. The hydraulic structure routing option for upstream flow was revised for when water becomes ponded around the outlet node and there is no inflow velocity to the outflow

node. Without inflow velocity, there was no upstream flow through the hydraulic structure even though the outflow node water surface elevation exceeded the upstream water surface elevation. The code was revised to allow upstream flow for the tailwater control condition (INOUTCONT=2) when the water surface is higher in outflow nodes neighbor elements with a lower bed elevation (8/28/16). Build No. 16-06-16.

213. For the various flood reporting files such as time to peak, time to one foot, time to two foot, time to flooding and deflood time, there are two cases that have been separated: no level or dam breach, and breaching. If there is a levee or dam breach, the start time for the flooding parameters will be based on time of breach. If there is only typical flooding with no dam or levee breach, then the start will be the start of the model at hour 0.0. If there are flood inflows to the model with a dam breach, the areas flooded outside of the dam breach area of inundation will be reported in the time to flooding files if they exceed the maximum depth after the breach. There is no way to separate normal flooding from the breach flooding. For reservoirs with a starting water surface the initial depth elements are excluded from the time to flooding files (9/15/16). Build No. 16-06-16.

214. Two automated Manning's n-value adjustments are now turned off if AMANN = -99 (CONT.DAT) that is the switch for turning off the floodplain depth variable n-values. These included flood routing algorithm non-convergence n-values increases and n-value adjustments for overbank flow exchange Froude numbers that exceed 0.5 (9/15/16). Build No. 16-06-16.

215. The Horton infiltration method when combined with multiple channels generated a Fortran error for a non-initialized array associated with Green-Ampt impervious areas. This was corrected by identifying the infiltration method with the multiple channel option activated (9/19/16). Build No. 16-06-16.

216. A distinction has been made for the start times of the Time to 1 ft and Time to 2 ft for levee and dam breach models. Some parties wanted the start time to be the model time start time of 0.0 hrs, others wanted the levee or dam breach initiation time to be the start time. This is complicated if there is multiple levee or dam breaches or if there are inflow hydrographs or rainfall not associated with a dam breach. There can only be one start time for a time to one ft or two ft of depth and the distinction between flows mixing from multiple breaches or from an inflow flood hydrograph with a breach hydrograph as to which flow contributes to the one ft or two ft is impossible. If you want the time to one ft or two to be based on the model start time, there are no data file changes. If you want the start time to one ft or two ft to be based on the levee or dam breach time, then it necessary to revise one variable depending on prescribed breach or breach erosion as follows:

For prescribed breach if FAILTIM < 0.0 (e.g -1.0 or -25.4) , the start time will be based on the dam breach. If FAILTIM = 0. (fails immediately) and the start time is to be based on the dam or levee breach time, assign FAILTIM = -99.0 and FAILTIM is reset to 0. Otherwise, the FAILTIM is greater than or equal to 0.0 hr, the start time to 1 ft or 2 ft is the start time of the model (0.0 hr).

For breach erosion: The same approach...if GBREACHTIME = 0 or a positive time, the start time is the model start time (0.0 hr). If GBREACHTIME is less than 0.0, then the start time is the first dam or levee breach time. If GBREACHTIME = -99.0, the start time is the dam or levee breach time but GBREACHTIME reverts to 0.0. (9/19/16). Build No. 16-06-16.

217. Several 1-D street routing/floodplain flow exchange errors were introduced with the channel termination code that were fatal and caused volume conservation. These were fixed by further separating the channel and street code. (10/2/16). Build No. 16-06-16.

218. A sort routine bug was introduced in the output reporting code. This was a fatal error that failed to exit a do loop and stopped the model from completing writing the output data to file (10/7/16). Build No. 16-06-16.

219. A flag error in the building rainfall runoff routine was identified that stopped the roof rainfall from routing. This error was the result of array indexing and resulting in no roof runoff when the IRAINBUILDING switch was activated (10/7/16). Build No. 16-06-16.

220. The building collapse routine was modified by using a different collapse equation for higher velocities and depths as suggested by the research team (10/15/16). Build No. 16-06-16.

221. The breach erosion routine had an error for the breach topwidth calculation. When the breach bottom width exceeded the maximum bottom width, the equation computed only the incremental value not the total topwidth plus the incremental increase (10/15/16). Build No. 16-06-16.

222. The Time for One Foot Depth and the Time for Two Feet Depth had a writing issue when the breach routine is activated in the code. The calculated time was reported on a range between 0 and 0.10 hrs independently of the time of simulation (10/16/16). Build No. 16-06-16.

223. A revision to the temporal output was made. The TIMDEP.OUT ASCII file is created for all ITIMTEP options from 1 to 4. See Data Input Manual page 34 for more details. The option ITIMTEP= 3 now writes two files: TIMEDEP.OUT and NETCDF4 files (10/26/16). Build No. 16-06-16.

224. The outflow nodes list in OUTFLOW.DAT are no longer written in the DEPRESSED_ELEMENTS.OUT file (10/26/16). Build No. 16-06-16.

225. An reporting error in ROUGH.OUT was corrected involving the initialization of the maximum Manning's n-value array (10/26/16). Build No. 16-06-16.

226. An error in the DAMBREACH_VOLUME.OUT file was fixed. The FLO-2D code was writing the total breached volume to this file for every successful timestep and every breach element direction. The code was changed to write the volume only once for all breached elements and only for the output interval not the timesteps (10/26/16). Build No. 16-06-16.

227. A comment was added to the SD ManholePopUp.OUT file to clarify the Pop Off Pressure Head (PH) reported in the file and how it compares to the PH reported in the SWMM.RPT. The new comment is: Pop Off Pressure Head is an instantaneous head that removes the manhole cover. This pressure head can be different to the reported pressure head in the SWMM.RPT file (10/26/16). Build No. 16-06-16.

228. An Open MP code 'CRITICAL' statement was removed from the rainfall subroutine call in the overland flow routing algorithm. This 'CRITICAL' statement appreciably slowed down the model (3 times slower) and was implemented one month ago because of an array index conflict. The conflict was removed by renaming the INDEX parameter (10/27/16). Build No. 16-06-16.

229. The building collapse routine was revised to use the maximum velocity on the grid element contiguous to the building element instead of the directional velocity (11/13/16). Build No. 16-06-16.

230. The discharge and velocity for hydraulic structure connecting channel elements was being erroneously reported in HYCHAN.OUT as negative instead of positive (11/13/16). Build No. 16-06-16.

231. The mudflow algorithm channel variables were re-assigned to double precision numbers to match other code revisions for OpenMP (11/13/16). Build No. 16-06-16.

232. The sort routines for reporting the output in VELTIMEFP.OUT, ROUGH.OUT and SUPER.OUT in descending order was limited to only the top 100 elements to reduce the time required prepare the output files (11/21/16). Build No. 16-06-16.

233. Similar to the channel termination on the floodplain, inflow to the channel can now be exchanged from the floodplain to the channel interior elements. Overland flow will enter the upstream end of the channel. The floodplain elements connected to the channel should have an elevation that reflects the channel thalweg (11/27/16). Build No. 16-06-16.

234. For levee failure the time to peak was not being written to the output file (11/28/16). Build No. 16-06-16.

235. The BASE.OUT file is no longer generated unless the summary output parameter NOPRTFP is not equal to 2 in the CONT.DAT file. The BASE.OUT file can be huge and most of the information is extraneous and is not used graphically. Similarly levee overtopping flow reporting to the LEVOVERTOP.OUT now requires that the levee grid element number in line L of the LEVEE.DAT file be assigned as negative number. Each levee element to be reported in the LEVOVERTOP.OUT must be assigned as a negative number. The breach levee elements in LEVEE.OUT are now reported individually as a hydrograph in XXXX_LEVEE.OUT where XXXX is the failed levee element (12/27/16). Build No. 16-06-16.

236. Three reporting errors were fixed. 1. There was no data output in HYCROSS.OUT due to recent change to optional output to BASE.OUT. 2. HYCHAN.OUT was reporting a -1000.0 maximum stage when the levee failure component was assigned due to the recent

change in dam failure start time. 3. The recently added DAMBREACH_VOLUME.OUT was reporting cubic feet instead of acre-ft (12/2/16). Build No. 16-06-16.

237. Rainfall depth area reduction values (RAINARF values) can now be applied to the spatially varied rainfall component for NEXRAD rainfall data (IRAINREAL option). Line 2 in RAIN.DAT is required for this to assign the IRAINARF = 1. If no rainfall depth area reduction is being simulated then line 2 is optional (12/8/16). Build No. 16-06-16.

238. There were multiple errors in the coding of the Toffaleti sediment transport equation that were fixed. This was primarily due to the errors in the reference. Multiple references were consulted to re-derive and check the coding (12/16/16). Build No. 16-06-16.

239. The TIMETOPEAK was not being reported with levee prescribed breach failure for any grid elements because a trigger was being reset to initiate the start time for tracking the time to peak (12/16/16). Build No. 16-06-16.

240. A compilation error was resolved that created severe volume conservation errors at the outset of a realtime (NEXRAD) rainfall simulation (12/27/16). Build No. 16-06-16.

241. The sediment transport code was re-organized for the Open MP code and several errors in the Toffaleti equations were corrected (12/27/16). Build No. 16-06-16.

242. The levee failure code was reviewed and a minor bug in the index of IXLABEL array was fixed in the numerical routine. This bug can produce a crash in the FORTRAN routine for some specific levee failure cases (1/15/16). Build No. 16-06-16.

243. The initialization of the RAINARF arrays was fixed (1/9/17). Build No. 16.06.16.

244. An error message was added for turning of the channel ICHANNEL = 0 and leaving channel inflow hydrographs (C-lines) in the INFLOW.DAT file (1/10/17). Build No. 16.06.16.

245. The start time for dam and levee breaches reporting for time to 1 ft was adjusted (1/13/17). Build No. 16.06.16.

246. Individual levee or dam breach discharge hydrographs are reported to output files with the name GRID ELEMENT NO_LEVEE.OUT (e.g. 2345_LEVEE.OUT) to facilitate review of the breach discharge originally reported in LEVEE.OUT for all grid elements (1/13/17). Build No. 16.06.16.

247. A new binary LEVEE.HDF5 output file is written for levee failure. The following variables are written for each grid direction (1 to 8) and for the output failure time (01/15/17, Build No. 16.06.16):

   - Grid Element
   - Breach Elevation
   - Water Surface Elevation
   - Discharge
   - Failure Width
   - Total Q

248. A revision to the temporal output was made, the TIMDEP NETCDF4 file and TIMDEPCELL.OUT were reviewed, the variables were reorganized. The Output files that are written when the "Time Lapse Output" switch is activated are:

   • ITIMTEP: 0, no output results are written to the TIMDEP File
   • ITIMTEP: 1, only TIMDEP.OUT file is written
   • ITIMTEP: 2, only the TIMDEP in HDF5 binary format is written
   • ITIMTEP: 3, only the TIMDEP file for the creation of the NETCDF4 file is written
   • ITIMTEP: 4, All output files are written.
   • ITIMTEP: 5, TIMDEPCELL.OUT (ASCII FILE) is created for only those cells listed in TIMDEPCELL.DAT file (01/20/17). Build No. 16.06.16

249. The sort routine for the ROUGH.OUT, SUPER.OUT and VELTIME.OUT files was revised to speed up the reporting (1/23/17). Build No. 16.06.16.

250. Sediment routing by size fractions was improved with several bug fixes, automated scour depth limitation around inflow and outflow nodes (1/23/17). Build No. 16.06.16.

251. Fixed a bug in the levee discharge file name for item 245 above (2/3/17). Build No. 16.06.16.

252. Revisions were made to the levee overtopping weir flow including weir coefficient adjustments, bugs in the OpenMP code parameter assignment, and a modification to headwater to tailwater assessment for submergence (2/24/17). Build No. 16.06.16.

253. A new starting computational timestep of 5 seconds instead of 1 second was assigned except for a model with a starting reservoir water surface elevation (2/24/17). Build No. 16.06.16.

254. Reporting for dam or levee breach overtopping output file initialization was modified. A missing parameter in the call statement for the pipe breach subroutine was added (2/24/17). Build No. 16.06.16.

255. A significant redesign of read code for the channel geometry power regression relationship was implemented. Bank elevations cannot be assigned in the range of -0.5 ft to 0.5 ft above sea level. (2/24/17). Build No. 16.06.16.

256. Some OpenMP code was implement for parameter initialization, array assignment and file plotting (2/24/17). Build No. 16.06.16.

257. Channel flow assessment depth for the Courant number stability parameter was revised and a modification was added to channel limiting Froude number Manning's n-value increment (2/24/17). Build No. 16.06.16.

258. FLO-2D compares the rim elevation with the grid element elevation and reports the differences in the FPRIMELEV.OUT. If the rim elevation and floodplain elevations are different, the model reassigns the floodplain elevation to the rim elevation based on the assumption that the rim elevation was surveyed and the grid element elevation was interpolated. The model uses the rim elevation as the reference to determine the water surface elevation and inlet flow depth. The revised bed or floodplain elevations are not reported in the FPLAIN.DAT file. These are only modified at runtime and reported to

FPRIMELEV.OUT file. For the floodplain revisions, the user must review the FPRIMELEV.OUT and adjust the elevations in FPLAIN.DAT to match the modifications in the FPRIMELEV.OUT. Two new files are written FPLAIN_SDElev.RGH and TOPO_SDElev.RGH, these files contains the elevation changes from the FPRIMELEV.OUT file. They should replace the FPLAIN.DAT and TOPO.DAT files when using a Storm Drain system to adjust the surface elevation. RIM elevations for the inlets located in channel or street cells are not checked and must be verified by the user (1/25/16). Build No. 16-06-16.

259. The total inflow volume summation was edited for the rainfall on buildings (4/27/17). Build No. 16-06-16.

260. A new output file PRESCRIBED_BREACH Q.OUT reports the prescribed levee and dam breach failure discharge by output interval (5/2/17). Build No. 16-06-16.

261. The sediment transport incipient motion criteria using the Shield's diagram was updated to include the revisions made by Gessler in the Simons and Senturk (1976) book Sediment Transport Technology. The minimum Shields parameter was set to 0.03. The critical shear stress parameter in MPM Smart sediment transport equation and in the dam breach piping erosion was also adjusted. (5/9/17). Build No. 16-06-16.

262. SUMMARY.OUT: additional storm drain totals are reported to add more detail to the water volume exchange between the surface and storm drain layers. Example: direct inflows in the storm drain features (5/13/17). Build No. 17-08-17.

263. Channel interior nodes (grid elements inside the 1-D channel bank elements that do not exchange flow with the floodplain elements) can be read and edited from the CHAN_INTERIOR_NODES.DAT file. If this file exists the model will read it first before identifying any additional interior nodes that may be missed. This file can be created by renaming the CHAN_INTERIOR_NODES.OUT file that is created with the initial simulation. The purpose of this file is to add any missing interior elements that the model may miss at runtime because the channel is very wide and the size of the grid elements is small resulting in numerous interior elements. In this situation, sharp bends and numerous extensions into a single right bank element may result in some interior elements being missed along the right bank. The missing elements can be added to the CHAN_INTERIOR_NODES.DAT file (6/8/17). Build No. 16-06-16.

264. The hydraulic structure submergence criteria was adjusted for tailwater to headwater ratio greater than 0.8 to limit the submergence factor to 1 percent (6/21/17). Build No. 16-06-16.

265. For dam breach erosion, one foot (0.3 m) had been added to the dam foundation as the lower limit of the vertical scour. This was an arbitrary observation that most dams do not scour uniformly to bedrock but leave an irregular surface with some core material. The 1 ft increment was removed to provide the use with ultimate control over the bed erosion limit (7/7/17). Build No. 17-08-17.

266. An error was corrected for the building collapse component the width was initially reset to the WRF value after building collapse and this was revised to the side width of the grid element (7/11/17). Build No. 17-08-17.

267. Several changes were made to the reservoir routing for dam breach. The first revision was to assign an n-value of 0.25 to all reservoir elements assigned by using a reservoir water surface elevation in INFLOW.DAT. If the starting reservoir surface elevation is assigned as a negative value, a deadpool is identified that includes all the reservoir grid elements with bed elevations below the dam breach foundation (limiting scour elevation) assigned by the base elevation in the dam breach element. The deadpool is then eliminated from the reservoir routing. The reservoir flow depths are based on the deadpool elevation and the reservoir will not drain lower than the breach foundation elevation. This reduces the reservoir flow depths for the routing algorithm.

   Two additional files are created: TOPO_RES.BAC and MANNING_N_RES.BAC. These files have the new reservoir n-values and deadpool topography and the revisions can be made permanent by renaming these files to TOPO.DAT and MANNINGS_N.DAT and by deleting the FPLAIN.DAT file which will be recreated with the next simulation automatically.

   Finally, the reservoir routing algorithm was revised. Instead of using Manning's equation in its original form, the equation was revised so that the depth or hydraulic radius exponent is computed as a function of the flow depth and slope:

   $$V = 1.486/n \; depth^{exp} \; S^{1/2}$$

   where: $exp = 0.5 - 0.0004 * depth - 30.0 *$ water surface slope

   This results in a depth average velocity on the order of 0.1 to 1.0 fps (0.03 to 0.3 mps) for depths over 20 ft (6.7 m). This equation is based on observations of reservoir surveys and from personal experience (7/13/17). Build No. 17-08-17.

268. The shallow n-value roughness can be spatially variable by simply creating a SHALLOWN_SPATIAL.DAT file with grid element number a shallow n for those grid elements with a shallow n-value that is different from the global SHALLOWN value assigned in the CONT.DAT file. Spatially variable SHALLOWN values will be useful when assigning flow over streets and parking lots.

   For the 1-D channel component, the shallow n-values are assigned by channel segment using the ROUGHADJ variable. The channel segment SHALLOWN value is the global SHALLOWN assigned in CONT.DAT unless the ROUGHADJ is assigned as the fourth variable in line 1 of the CHAN.DAT file for each segment. If ROUGHADJ is assigned then SHALLOWN = ROUGHADJ/2.0. (7/13/17). Build No. 17-08-17.

269. A file DAMBREACH_VOLUME.OUT was created to report the total volume of the breach discharge for the dam breach erosion component (7/13/17). Build No. 17-08-17.

270. Adjustments were made to the dam breach channel slope computation through the dam to account for the size of the core. The dam breach submergence criteria was also modified to limit the submergence factor to 0.01. Finally, the distribution of the sediment scour in

the breach was edited to allow the user to control the removal of the sediment to the breach channel bed or sides of the trapezoidal channel by adjusting the BRATIO parameter. The higher the BRATIO variable, the faster the breach width expands and the slower the vertical rate of erosion. A typical value of BRATIO is 1.5 and general range for this parameter is 0.5 to 4.0 (7/13/17). Build No. 17-08-17.

271. Stormdrain_ERROR.CHK and ERROR.CHK files, warnings and errors for conflicts between components and missing geometry were created or modified in the most current version of the model. Additional error codes with a description are now reported when simulation ends prematurely (7/13/17). Build No. 17-08-17.

Revisions and bug fixes in the Processor Programs include (most recent at the bottom):

1. GDS – Froude.TMP deleted from project folder when project is saved (5/7/12).

2. GDS – Supplement.DAT variables limited to real number with 2 decimals (5/7/12).

3. GDS – General culvert equation dialog box activates when selected (5/7/12).

4. GDS - Right bank check error message changed to "Check Error.chk file for potential bank errors." (5/7/12).

5. GDS – Change WRF values to write the values as ARF WRF(1,2,3,4,5,6,7,8) in the correct order (5/7/12).

6. GDS – Changes made to the writing, reading and porting of the hystruc.dat file (5/7/12).

7. GDS – SWMM display of outflow nodes fixed (5/10/12).

8. GDS – Allow ibackup = 2 to be written to the control variable dialog box (5/11/12).

9. GDS – Shallow n-value range validation changed to 0.01 to 1.0 (5/17/12).

10. GDS - Add D line for storm drain in HYSTRUCT.DAT to limit outlet discharge with multiple inlets (5/17/12).

11. GDS - Hydrograph import error for HEC-1 output files. The 1 hour discharge import error fixed. (7/10/12)

12. GDS – Channel tools moved to channel drop down on tools menu (7/19/12).

13. GDS – Add File Create Grid – Shape file of the computational domain (7/19/2012).

14. GDS - Zoom function with images was refined to avoid zooming out to full view when importing images in a zoom configuration. Infiltration display was turned off when initializing the GDS to eliminate the infiltration the color coverage (10/25/12).

15. GDS - The rain data editor was updated to include the IRAINBUILDING switch on Line 1 of the RAIN.DAT file (10/25/12).

16. GDS - Activated view of any component when created (10/25/12).

17. GDS - Outflow for multiple grid system (10/25/12).

18. GDS - Deleted C F line at LEVEE.DAT when there are no fragility curves (10/27/12).

19. GDS - Pit tool: watershed directions for selected watersheds (10/29/12).

20. GDS - Floating variables editor (Reduction Factors): add "Completely Blocked Grid Element" for and Optional ARF value (10/30/12).

21. GDS - Channels from HEC-RAS: filter stations outside left and right banks (11/28/12).

22. GDS - XSEC.DAT from HEC-RAS is now written with river mile name (12/07/12).

23. GDS - TOLER 2nd line (1,2 or 3 Courant values for floodplain, channel, and street (12/18/12).

24. MAXPLOT - Simplified the do loops for reading the TOPO.DAT file to create the array of contiguous grid elements. This enables the program to load significantly faster (12/18/12).

25. PROFILES - When the water surface profile is plotted, a new file is written WSURF_DIFF.OUT that contains the channel grid element number, cross section name from XSEC.DAT, measured (surveyed) or reported water surface elevation from WSURF.DAT (e.g. HEC-RAS predicted water surface elevation), the FLO-2D predicted water surface, and the difference between them (measured - FLO-2D predicted) (12/18/12).

26. PROFILES - Reading and writing NOFLOCs were added back to PROFILES so that the program can be used for either Version 2009 or the PRO model (1/8/13).

27. GDS - Green-Ampt: new dialog with infiltration calculations for range of cells (01/16/13).

28. GDS - Created cross sections from HEC-RAS file excluding the stations that are outside the left and right banks (01/18/13).

29. GDS - Can now accept Manning value of -99 (01/20/13).

30. GDS - Prints PIT.DAT after applying pit tool: write new elevation, old elevation, and difference (02/16/13).

31. GDS - Pit tool: color rendering of elevation differences (02/17/13).

32. GDS - Pit tool colors for selected watersheds (02/20/13).

33. PROFILES - A new tool was added to the PROFILES to interpolate n-values to flow area. A new icon command on the tool bar activates a dialog box that will display minimum, maximum and average flow areas to the lowest top of bank. The user enters flow area range for interpolation and minimum, maximum and average n-values and the program will assign an n-value to every channel element based on the flow area interpolation. Automated adjustments for adverse slope can also be made (2/25/13).

34. GDS - New infiltration dialog with Horton infiltration. New dialog for channel infiltration with initial and final hydraulic conductivity, and max. soil depth (02/28/13).

35. GDS - Changes in SWMM module to read all lines in [CONDUIT] group in .INP file (03/12/13).

36. GDS - Express editor now includes Horton infiltration (03/20/13).

37. GDS - SWMM module reads connections and draws them with text id (05/21/13).

38. GDS - SWMM module: energy grade lines (06/21/13).

39. GDS - SWMM dialog was revised to add the flapgate option (6/25/13).

40. GDS - Changes were introduced to the SWMM dialog to add the inlet type 4 (rating table condition) (6/25/13).

41. GDS - SWMMFLORT.DAT is created to contain the rating table for all inlets type 4 (6/25/13).

42. GDS - FLO-2D Graphical User Interface has been expanded to plot the inflow and return flow hydrographs as well as the hydraulic and energy grade lines of the drain system (6/25/13).

43. GDS PRO: SWMM dialog with inlet type dropdown list with values 1 to 5. (7/20/2013).

44. GDS PRO writes "Professional Model - Build No. 13-07-05" instead of the previous "Professional Model - Build No. 12.01.01" at the end of the first line of CONT.DAT. (7/31/2013).

45. EPA SWMM GUI - Recompiled to activate the option to review the FLO-2D – EPA SWMM storm drain results in the EPA SWMM GUI once a run has been successfully completed (6/25/13).

46. GDS PRO: stage-time channel and floodplain. Reads/write OUTFLOW.DAT with these changes: the first lines are "K" or/and "O" with stage-time (only the cell number). The corresponding "N" (followed by ""S") lines are written later. At the end of the file, "O" lines without hydrograph are written. (8/14/2013).

47. GDS PRO: drop down list in the dialog to set tail water effect with values 0, 1, or 2. It also reads/writes that variable in HYSTRUCT.DAT file. (9/23/2013).

48. GDS PRO: improved levee interpolation for polyline with few points. (9/26/2013).

49. GDS PRO: SWMM omit BR U and BR D lines in .g01 and .g0? files. (10/2/2013).

50. GDS PRO: reads XSEC.DAT with tabs between values. (10/8/2013).

51. GDS PRO: Channel segment identified with a number in Channel Segment dialog, according with order in CHAN.DAT. (10/13/2013).

52. GDS PRO: Infiltration is off when project loaded. If component is off, it is turned on when created. (10/13/2013).

53. GDS PRO: optional adjustment to the levee interpolation when reading a file of points. After applying the first algorithm GDS shows a dialog with the points and intersected cells, and asking if user want to apply the second adjustment. (10/30/2013).

54. GDS PRO: improvements to levee interpolation. (10/30/2013)

55. GDS – Channel connection feature - Add a Pair button removed (10/30/213)

56. GDS – XSEC.DAT file is written completely when Save As is used (10/30/13).

57. GDS – Help Menu linked to GDS PDF file (10/30/13).

58. GDS – EPA SWMM Inlet Dialogs : flat gate text changed to "flapgate" (10/30/13).

59. GDS - Increased size of coordinates in TOPO.DAT to make room for larger coordinates (10/30/13).

60. GDS – Turn infiltration view of when project loaded (10/30/13).

61. GDS – Outflow conditions were fixed in the IN/OUT dialog (10/30/13).

62. GDS PRO: assigns sediment size fractions to cells in 2 ways: from the Mud and Sediment Transport dialog and with a new command "Grid. Assign Parameters to Selection. Variable Sediment Size Fraction". The cells assigned a sediment group are written as "G" lines in SED.DAT. (11/9/2013).

63. PROFILES - The program will now read any order of cross section number in CHAN.DAT and XSEC.DAT. The only requirement s are for XSEC.DAT to have an equal number or more cross sections than CHAN.DAT and the CHAN.DAT must have a corresponding cross section number in XSEC.DAT. The cross sections in CHAN.DAT and XSEC.DAT can initially be in any order (11/15/13).

64. GDS PR: highlights channel cells when user clicks a row in the table inside the Channel Dialog. (12/17/2013).

65. GDS PRO: SWMM doesn't need to read/write project path in first line of SWMMFLO.DAT. (12/17/2013).

66. PROFILES – A revision was made to renumber the natural cross section numbers in CHAN.DAT correctly when a channel element is deleted (12/18/13).

67. GDS –Outfall Nodes Dialog was created to read the outfall nodes from SWMM.inp file and write the data on the SWMMOUTF.dat file. This file contains the switch that turn ON or OFF the discharge of an outfall from SWMM to FLO-2D. (01/10/14)

68. GDS PRO: SWMM message when more than one inlet is in same cell. (1/22/2014).

69. GDS PRO: clear Green-Ampt dialog tables when loading new project. (2/5/2014).

70. Mapper++: reads elevations below sea level. (2/11/2014).

71. GDS PRO: fix problem when reading FPLAIN.DAT with name in lower cases. (2/11/2014).

72. Mapper++: fix problem with long project long path and name. (2/12/2014).

73. GDS Basic: interpolation from multiple elevation files changed from .DLL in Fortran to VB6. (2/12/2014).

74. GDS PRO: Manning interpolation from shapefile improved. (2/17/2014)

75. GDS – Recognize the channel confluences for those channel segments with DEPINITIAL equal to -1. (03/17/14)

76. Mapper++: fix displacement of values in cells. (3/19/2014).

77. GDS PRO: Solves the problem when creating a levee with polyline that disappeared after reading it. (4/15/2014).

78. GDS PRO: Interpolation issue between 2 values when creating levees with polyline was solved. (4/16/2014).

79. Mapper VB6: reads TIMDEP.OUT with 6 columns. Reads DEPTH.OUT to produce the Max Combined Channel and Floodplain Flow Depths. (4/17/2014).

80. GDS PRO: changes to confluences dialog. Add confluence pair. (4/18/2014).

81. Mapper++: Reads TIMDEP.OUT with 6 columns. (4/30/2014).

82. GDS PRO: Reads .INP files and gives a message indicating that there are conduits with length less than 20 feet. Writes a file SMALL_CONDUITS.CHK and opens Notepad with the contents of the file. (5/2/2014).

83. GDS PRO: compares [OUTFALLS] in .INP files with SWMMOUTF.DAT to see if they are in the same order. If not, gives a message. (5/3/2014).

84. GDS PRO: SMALL_CONDUITS.DAT file name changed to SHORT_CONDUITS.DAT with header: "Name   Inlet Node   Outlet Node   Length". (5/4/2014).

85. GDS PRO: SWMM new curb height column. (5/6/2014).

86. GDS PRO: enhancements for SWMM interface can be summarize as follow:

• Message for inlets in the same cell now only shows the ones that are not junctions.

• Sixth column in SWMM inlets dialog has the title "Height(1) Area(2) Surcharge(5)".

• In "Notes" a line was added: "v. For Drain Type 5: Range 0 to 5 (see guidelines)".In "Notes" line "ii. For Drain Type 3 and 5" changed to "ii. For Drain Type 3:". (5/18/2014).

87. GDS PRO: problem solved in Infiltration dialog. Grid Element Infiltration are now saved. (5/20/2014).

88. GDS – Storm Drain Inlet New Data was added to the SWMMFLO.DAT. A feature option and a Curb Height were added to last columns in the dialog (06/12/14). Build No. 14-07-08.

89. GDS – Type 5 Inlet was added to the SWMMFLO Dialog for manholes with surcharge condition (06/12/14). Build No. 14-07-08.

90. GDS - Error messages are reported now by GDS and new reported files are created (06/12/14). Build No. 14-07-08.

91. Mapper PRO and Mapper++: fix to max. flow plot when value is zero. (6/12/2014).

92. GDS PRO: Writes LEVEE.DAT lines with negative cell number like F   -56732, when the Global checkbox is checked in the levee dialog for prescribed failure. (6/19/2014).

93. GDS PRO: caption "Global – Apply this failure data to all model levee directions" in the levees dialog. (6/26/2014).

94. GDS gives a message when SWMM.INP has a [RAINGAGES] group with TIMESERIES (it should be FILE). (6/22/2014).

95. GDS PRO: ITIMTEP in the FLO-2D variables dialog is a dropdown list with 0,1,2,3, and 4. A value of TIMTEP is needed for 1 to 4 but not for 0. (6/22/2014).

96. GDS PRO: has a checkbox in the inflow/outflow dialog to assign the hydrograph interval (IHOURDAILY). (7/4/2014).

97. GDS PRO and Basic: reads Courant coefficient correctly from TOLER.DAT. (7/21/2014).

98. GDS PRO: Street Elevation Adjustment. Dialog with these capabilities: (from March 2014):

- See selected street element elevations and its neighbor's elevations, elevation differences, distance between its centers, slope between them, and Manning coefficients.

- Elevations and Manning values can be changed to all or selected street elements.

- Adjust Curb Height by assigning a minimum value to particular street elements or raising its value by an amount, or lowering the adjacent gutter elements.

- Adjust Cross Slope from crown street elements to its left and right elements giving a slope percentage.

- From the selected street elements, the cells with the maximum and minimum elevations can be modified.

99. Any two cells can be selected to observe a plot of the slope between them, and the elements that intersect the line that joins them. In the plot, the elevations of the cells between the two selected cells can be smoothed to make continuous leveled elevations

100. GDS PRO: a bug was solved for the confluences assignment. The confluences grid cells were incorrectly assigned for non-adjacent cells (8/01/2014)

101. GDS PRO: Hydraulic structure dialog was revisited to correctly read and write the F lines for Culvert Equations (8/01/2014)

102. GDS PRO: Project with only one confluence is correctly loaded. (8/02/2014).

103. GDS PRO: When a cell of a confluence pair is clicked, the pair is highlighted. (8/02/2014).

104. GDS PRO: CONT.DAT has the text "Professional Model - Build No. 14-08-09" at the end of first line. (8/04/2014).

105. GDS PRO: infiltration dialog checks that Global Soil Porosity is either 0.0 or within range 0.28 to 0.50. (8/10/2014).

106. GDS PRO: infiltration dialog gives a correct warning message associated with the Hydraulic Conductivity value, and gives a new range warning message for the Adjustment field. (8/10/2104).

107. GDS PRO: changes to texts in the Street Elevations Adjustment Tool: now it is called "Cell Elevation Adjustment" to make it more general and not only for street cells. All "Street" texts in the dialog and messages changed to "Cell". (8/11/2014).

108. GDS PRO: imports street elevations polylines and intersects them to cells. 3 street elevation types are imported: street proper, curb, and crown. (9/20/2014).

109. GDS PRO: improvements to the street polyline import and interpolation to cells according to type of polyline (street proper, curb or crown). (10/13/2013).

110. GDS PRO: All texts in SWMM dialogs and messages change from "EPA SWMM" to "Storm Drain" (10/21/2014).

111. GDS PRO: street polyline import and interpolation: After assigning cell elevations from the polylines, GDS draws the interpolated cells in color: curbs-blue, crown-yellow, and street-green. (11/12/2014).

112. GDS PRO: Hydraulic structures dialog: new checkbox in Flood Structure frame: "Channel to Floodplain". (11/13/2014).

113. GDS PRO: new TOLSPATIAL.DAT file for individual cell tolerances. New dialog for the assignment of cell tolerances (individual or selection of cells). (01/10/2015).

114. GDS PRO: TOLSPATIAL.DAT written with cells in ascending order (01/10/2015).

115. GDS PRO: Tolerance value in Properties Dialog can be made zero (0) to exclude it (them) from individual tolerance assignment (01/12/2015).

116. GDS PRO: Multiple channels file, MULT.DAT, reads last possible empty lines (01/14/2015).

117. GDS PRO: FLO-2D control variables dialog: "EPA SWMM" text changed to "Storm Drain" (01/20/2015).

118. GDS PRO: Import Horton shapefile and assign Horton value to cells according to polygon intersections (02/05/2015).

119. GDS PRO: Multiple channel's new parameter Surface Sediment Size AVULD50 (02/28/2015).

120. GDS PRO: Import Manning shapefile: division by zero bug fix (03/03/2015).

121. GDS PRO: Turn components view on/off (03/26/2015).

122. GDS PRO: The Storm Drain FLO-2D Inlets dialog was changed for inlets type 2 and 3. The height of the inlet has to be entered for inlet type 2 instead of the area. Sag Height can be now entered for inlet type 3. (03/26/2015)

123. GDS PRO: Inflow/outflow .HYD files saved/read from .../InOutFlow subdirectory of project (03/26/2015).

124. GDS PRO: Import shapefile to define domain with polygon (04/03/2015).

125. GDS PRO: Initial Coordinates dialog: new adjust coordinates sub-dialog (04/15/2015).

126. GDS PRO: virtual memory increase message (04/17/2015).

127. GDS PRO and Mapper Classic: pgup, pgdn, home, end arrows movement (04/23/2015).

128. GDS PRO: The Reductions Factors dialog window has a new check box to assign building collapse elements as Potential Collapsed Cells. It saves/reads ARF.DAT, writing/reading T lines with negative cell values for totally collapsed cells or for individually selected cells (05/18/2015).

129. Mapper PRO: Fix combined floodplain and channel max flow depth plot due to change in FLO-2D version (05/23/2015).

130. GDS PRO: Enhanced Storm Drain error and warning messages (05/25/2015).

131. Mapper PRO: Plots the range values for all depth and velocity variables between selected minimum and maximum values. A new dialog box was implemented for this option (06/08/205).

132. GDS PRO: Now reads the SWMMOUTF.DAT with potential empty lines at the end fo the file without causing errors (06/09/2015).

133. GDS PRO: Calls Activator.EXE from Help command to activate the update license to simplify the activation process and avoid having to download the activator program. The command is: "Help. Activate..." (06/21/2015).

134. GDS PRO: Fixes an error in the street width assignment. It is now possible to assigns 0 (zero) value for street width directions in Street Realignment Tool (06/22/2015).

135. GDS PRO: Alignment of streets: assign 0 (zero) value to new width directions (06/22/2015).

136. GDS PRO: better response to "Cancel" button in several dialogs (06/29/2015).

137. GDS PRO: new dialog to select components before saving project (07/02/2015).

138. GDS PRO: improvements of error messages when reading data with errors (07/02/2015).

139. GDS PRO and Mapper PRO: improvements to calls to external programs and modules (07/04/2015).

140. GDS PRO: Inflow/Outflow conditions: error capturing when opening command with data errors (07/13/2015).

141. GDS PRO: new command: "View. Components. Storm Drain", turns on/off plot of inlets, outlets, and connections (07/18/2015).

142. GDS PRO: new checkbox "Storm Drain" in Save Dialog (07/20/2015).

143. Mapper PRO: right click on variable plot to select range of values to plot (min to max) (08/27/2015).

144. Mapper PRO: creation of shapefile of selected range of variables to plot (08/27/2015).

145. Mapper PRO: better response and messages to data input errors (09/03/2015).

146. GDS PRO: SWMM: improved readings of .INP files where there are comment lines (09/26//2015).

147. GDS PRO: activate "View. Components. Levees" when importing levees (09/30/2015).

148. GDS PRO: activate "View. Components. Hydraulic Structures" when creating them (09/30/2015).

149. GDS PRO: activate "View. Components. Channel Confluences" when creating them (09/30/2015).

150. GDS PRO: select cells by intersecting a polygon shapefile (10/26/2015).

151. GDS PRO: SWMM. Recalculation of Max. Depths in [JUNTIONS] group and saving of .INP file (11/30/2015).

152. GDS PRO: SWMM. New dialog for the recalculation of Max. Depth in [JUNTIONS] group (11/30/2015).

153. GDS PRO: selection of elements and interpolation of elevations from DTM points (12/30/2015).

154. GDS PRO: improvements to redrawing of DTM points (12/30/2015).

155. GDS PRO: improvements to several file dialogs (12/30/2015).

156. GDS PRO: SWMM: skip comments in [OUTFALLS] group in .INP files (01/04/2016).

157. GDS PRO: new grid element outflow condition with depth discharge. Dialog changes, save and load of OUTFLOW.DAT file (01/27/2016).

158. GDS PRO: LIDAR elevations interpolation: error messages given in one final dialog and not when individual errors are found (01/30/2016).

159. GDS PRO: elevations profile plot along a polyline (03/28/2016).

160. PROFILES: Fixed a read error for natural cross section data bases that was introduced with the previous update (11/04/15). Also added left and right elevations to bed profile and water surface profile plots (11/19/15). Revised the array allocation for rectangular channels with the same bank elevations (1/21/16).

161. PROFILES: Revised to include corresponding low bank vertical extension modification the PRO model. The water surface elevation is now displayed on both sides of an island (3/28/16).

162. HYDROG: The HYCROSS.OUT file format for floodplain cross sections was revised with an addition column of resolved velocities. The HYDROG program was updated to correctly read and plot the discharge data (4/13/16).

163. PROFILES: Fixed the cross section water surface display when the cross section is raised or lower by eliminating the water surface line which no longer is appropriate (4/22/16).

164. GDS PRO: FLO-2D Control variables, Global Data: Shallow Flow n-value valid range was change to [0.0, 1.0] or -99 (04/12/2016).

165. GDS PRO: Command "Highlight Grid Element Number…" Zooms-In to cell with 20 or so surrounding boundary cells. New dialog allows zoom-in or out to 10% to 80%. (04/25/2016).

166. PROFILES: Added a new output file FLOW_AREA_VARIATION.OUT to report dramatic changes in flow area between contiguous channel elements and suggested new n-values to accommodate the flow area variation. Also corrected the bank elevations profiles plots when toggling upstream and downstream and fixed the plotting of the cross section water surface elevation lines which were intersecting the origin (5/19/16).

167. MAXPLOT, HYDROG, PROFILES: These programs were compiled for 64-bit computers (5/19/16).

168. GDS PRO: looks in "C:\Program Files (x86) \EPA SWMM5" for EPASWMM5.EXE" when using command "Tools | Storm Drain | Run Storm Drain GUI...". (06/02/2016).

169. PROFILES: Rectangular and trapezoidal cross sections can now be plotted and viewed in the PROFILES program. They cannot be edited according to the station-elevation displayed, however, because the input data representing these cross sections is depth,

bottom width and side slopes (trapezoidal cross sections) which can be edited graphically in the GDS. The purpose of this revision is to be able to display the cross section shape for all channel segments and review flow area, wetted perimeter and top width (5/24/16).

170. GDS PRO: The cell elevation can be now interpolated along a polyline using the elevations profile tool. (6/27/16).

171. GDS PRO: The inflow and returning hydrograph plots can be now drawn and save to a folder, this can be done for a single inlet or for all of the inlets in the storm drain simulation. Go to Tools | Storm Drain | Storm Drain Discharge Display. (6/27/16).

172. GDS PRO: The clogging factor data file can be created in the SWMMFLO.DAT data dialog for all types of inlets. (6/27/16).

173. PROFILES: Two water surface plotting errors were fixed for islands. (7/13/16).

174. PROFILES: Revisions were made to enable the program to renumber the channel cross sections upon saving when some channel elements and corresponding cross sections were cut out (8/9/16).

175. GDS PRO: InOutFlow subdirectory to store .HYD files, created when project loaded (08/27/2016).

176. GDS PRO: import levees from polyline when many points are in same cell: assign only one cell number (08/31/2016).

177. GDS PRO: reading polylines to create levees (XYZ files). Those polylines that extend to only a single cell can be excluded, the GDS displays a message asking about which option to take. (09/03/2016).

178. GDS PRO: when reading polylines to create levees, polylines outside the domain are excluded. (09/05/2016).

179. GDS PRO: messages and error detection when reading polylines for levees have been enhanced. (09/11/2016).

180. GDS PRO: The sediment specific gravity range have been changed in the Mud and Sediment Transport dialog [0.0, 3.0]. (09/29/2016)

181. GDS PRO: the writing function of the Storm Drain component was enhanced. The SDCLOGGING.DAT is not written if there is no Clogging Factor for any inlet. (10/05/2016)

182. GDS PRO: FLO-2D compares the rim elevation with the grid element elevation and reports the differences in the FPRIMELEV.OUT. The GDS was enhanced to show a table containing the current inlet depth as well as the new max depth based in the PRIMELEV.OUT changes. The user can reset the elevations in the inp by using the "View .INP Max. Depths…" button in the Storm Drain FLO-2D Inlets dialog, go to Tools|Storm Drain|View Storm Drain Inlets Dialog. (10/20/16). Build No. 16-06-16.

183. GDS PRO: TOLSPATIAL.DAT: values with zero tolerance are skipped (11/10/2016).

184. GDS PRO: Storm Drain: .INP file invert elevations and Max. Depth recalculated and written (11/11/2017).

185. GDS PRO: Storm Drain: new dialog for the recalculation of Max.Depth in .INP file (11/18/2016).

186. GDS PRO: Storm Drain: reading [CONDUITS] block with comments (12/13/2016).

187. GDS PRO: calls to FLO-2D models, FLOPRO.EXE or FLOPRO BASIC.EXE depending on user license (01/18/2017)

188. GDS PRO: call to execute SWMM 5.0 GUI from C:\Program Files (x86)\FLO-2D PRO\EPASWMM5.EXE (01/21/2017).

189. GDS PRO: license date checks from especial file (22/02/2017).

190. GDS PRO: creation of FPLAIN.DAT and CADPTS.DAT from TOPO.DAT and MANNINGS_N.DAT (03/09/2017).

191. GDS PRO: changes to value ranges of FLO-2D variables: laminar flow resistance and time lapse output (03/14/2017).

192. GDS PRO: INFIL.DAT read: message when INFMETHOD=1 (Green-Ampt) and 4th. Line missing (03/17/2017).

193. GDS PRO: new splash window with license checks and messages (03/31/2017).

194. GDS PRO: Cell's Manning's n-value calculation from shapefile: polygon algorithm improvement. (04/17/2017).

195. GDS PRO: CONT.DAT reading 4th. and 5th. lines when IFLOODWAY is zero. (04/17/2017).

196. GDS PRO: infiltration from shapefile: checks that selected shapefile variable has a valid range of values. (04/29/2017).

197. GDS PRO: new error capture during loading a faulty project. (04/29/2017).

198. GDS PRO: error in the splash window, an issue was solved loading the GDS in some computers. (05/01/2017).

199. GDS PRO: A new Depth Editor tool have been created to facilitate the implementation of corrections when the RIM elevation need to be defaulted to the Grid Elev, the user can select one or all inlets having differences and automatically recalculate the Max Depths in the inlets as the difference between the Grid elevation minus the Invert Elevation. The corrected Max Depth is saved in the INP file for those inlets selected in the dialog box. (05/10/2017).

200. GDS PRO: reading elevation points from PTS file, it recovers when there are format errors in the input file. (05/19/2017).

201. GDS PRO: splash window was changed. GDS PRO will always run model FLO2D.EXE, but with the limitations indicated in the splash window. (06/22/2017).

202. GDS PRO: will not create BREACH.DAT if there are no G-lines (global data). (07/10/2017).

203. GDS PRO: doesn't write or read the first line with column titles in SDCLOGGINGS.DAT. Column titles are omitted. (07/17/2017).

204. GDS PRO: new file SHALLOW_SPATIAL.DAT with cells with shallow n-value different to global shallow n-value. (08/09/2017).

205. GDS PRO: cell attributes dialog includes field for Spatial Shallow n-value. (08/09/2017).

206. GDS PRO: new command "Grid. Assign Parameters to Selection. Cell Shallow n-value. (08/10/2017).

207. GDS PRO: A dialog to select the inlets and plot the discharge will be displayed; the user can select one by one or select all inlets (**Error! Reference source not found.**), the discharge plots will be saved in a new folder named as StormDrainDischarge in the project folder. The automatic creation of all plots (**Error! Reference source not found.**) in one click facilitates the post processing of results in large projects

Storm Drain Engine (VC2005-CON.dll)

Revisions and bug fixes in the FLO-2D storm drain engine include (most recent at the bottom):

1. Outfall Discharge is transferred from SWMM to FLO-2D (11/10/13)
2. FLO-2D WSE modify the water elevation of Outfall nodes for those cases that apply (11/10/13)
3. A variable that was initialized twice in SWMM Model was corrected (12/01/13)
4. An incorrectly assigned index was found on the SWMM reporting subroutine output_saveNodeResults (01/31/14)

5. The routing method was hardcoded to Dynamic Wave to account for backwater effects, entrance/exit losses, flow reversal and pressurized flow. The integrated model is directly comparing the FLO-2D WSE versus the SWMM Pressure Head that get from the dynamic wave subroutine in SWMM 5. On the previous versions of the FLO-2D SWMM code the integrated model ran using: Steady State, Kinematic Wave or Dynamic Wave. For that reason, the SWMM head was calculated using the FLO-2D area and the volume coming out from SWMM. In SWMM 5 and only for the dynamic wave, the routing is influenced by the water depths maintained at nodes, the excess volume is assumed to pond over the node with a constant water surface. (06/12/14). Build No. 14-07-08.
6. The inertial terms are hardcoded to Dampen option. The inertial terms are reduced when the flow comes closer to being critical and ignore for supercritical flows (06/12/14). Build No. 14-07-08.
7. The subcatchment area was hardcoded equal to the FLO-2D grid element area (06/12/14). Build No. 14-07-08.
8. The subcatchment width was hardcoded equal to the FLO-2D grid element side (06/12/14). Build No. 14-07-08.
9. The wet timestep was hardcoded equal to 1 min (06/12/14). Build No. 14-07-08.
10. The dry timestep was hardcoded equal to 1 min (06/12/14). Build No. 14-07-08.
11. The lengthening timestep is hardcoded as Routing Timestep divided by six (06/12/14). Build No. 14-07-08.

12. Control an input reported flags are hardcoded. The control data and input data are always reported to the *.rpt file (06/12/14). Build No. 14-07-08.

13. The Ponded Area array and Allow Ponding switch were hardcoded. The Allow Ponding switch is on and the Ponded Area is equal to the FLO-2D grid cell size. The pressure head at a node can be above the invert elevation + maximum depth and it is calculated by SWMM 5. In this case either flooding or ponding will only occur when the water depth computed at the node in question exceeds some maximum level. This level equals the sum of the Maximum Depth plus any Surcharge Depth when the node can't pond but just the Maximum Depth when the node can pond. The node cannot pond when it has zero Ponded Area or the Allow Ponding option was turned off (06/12/14). Build No. 14-07-08.

14. An -1#IO expression was found at the *.rpt output file on one inlet on a large project. This expression means undetermined division and it is a division by zero. The problem was identified on the expression that calculates the change in the node depth (dy) in the dynamic wave routing. The surface area on the node was being reset to 0 and a division by zero was triggering the issue. The problem was solved by setting to zero the change in the nodal depth when the surface area is equal to zero (06/12/14). Build No. 14-07-08.

15. FLO-2D WSE at outfall nodes were revised following the criteria discuss in the FLO-2D SWMM Guidelines (06/12/14). Build No. 14-07-08.

16. Simulation options: Start Analysis (time and date) and End Analysis (time and date) are automatically set based on the simulation time SIMUL in CONT.DAT file (11/4/2014). Build No. 14-11-08.

17. FLO-2D storm drain model crashed when the kinematic wave option was specified. This was fixed (11/4/2014). Build No. 14-11-08.

18. FLO-2D storm drain model was not holding the tailwater BC (outfall) on a specific case where the head in the upstream node of the conduit was higher than the head at the outfall node (12/1/14). Build No. 14-11-09.

19. A volume conservation issue was fixed on the channel component. The flow flowing backwards on the pipeline system through an outfall was incorrectly added to the CHVOLUME.OUT files (12/1/14). Build No. 14-11-09.

20. An -1.#QO expression was found at the *.rpt output file on one inlet on a large project. The problem was identified on the expression that initializes the nodal surface area in the dynamic wave routing. (01/23/15). Build No. 14-11-09.

21. An -1.#QO expression was found at the *.rpt output file on one inlet on a large project. The problem was identified on the expression that initializes the nodal surface area in the dynamic wave routing. (01/23/15). Build No. 14-11-09.

22. The SWMM.RPT file was modified to report all Highest Continuity Errors and Highest Flow Instability Indexes instead of just the first 10 errors (5/4/2015) Build No. 15.07.12.

23. The transfer of the outfall hydrographs from the storm drain system to the surface water system was inconsistent. The problem arose from multiple reporting conditions for outfalls nodes versus inlet nodes (5/5/2015). Build No. 15.07.12.

24. Oscillation flow in the storm drain inlet hydrograph was observed when the orifice equation was used. The discharge was reset to zero for some orifice conditions and generated spikes in the inlets (5/5/2015). Build No. 15.07.12.

25. Uniform flow in the storm drain inlet hydrograph was observed when the orifice equation was used. The discharge was hold after the peak for some orifice conditions and generated uniform flow in the inlets (5/10/2015). Build No. 15.07.12.

26. New storm drain returning approach has been implemented (06/10/15). Build No. 15-07-12.

27. Manhole subroutine was revised and modifies to correctly work with the new storm drain returning approach (06/10/15). Build No. 15-07-12.

28. An inconsistency in the transfer of parameters between the FLO-2D surface layer and the storm drain component was identified. This produces zero flow been routed in the storm drain system for some conditions in metrics (06/05/15). Build No. 15-07-12.

29. FLO-2D WSE at inflow and outfall nodes were revised following the criteria discuss in the FLO-2D SWMM Guidelines (06/05/15). Build No. 15-07-12.

30. Surcharge depth is assigned equal to 500 ft for junctions in the storm drain system. They are connections between pipes that should not flood. Inlet surcharge is equal to zero unless users set up something different in the SWMMFLO.DAT or in the SWMM.INP (06/05/15). Build No. 15-07-12.

31. Dampen Conditions for the Storm Drain Inflow was imposed to reduce inflow oscillations at inlets (10/22/15). Build No. 15-10-13.

32. Flooding results were averaged over the report timestep (10/22/15). Build No. 15-10-13.

33. Revisions for the inlet discharge and the flooding were made for those inlets under pressure conditions (10/22/15). Build No. 15-10-13.

34. The Storm Drain model was modified to write results to the SWMM.rpt and to the SWMM.out file when the user terminates the FLO-2D simulation early and before the total simulation time is reached (6/27/16). Build No. 16-06-15.

35. The timesteps between the surface water and storm drain engines were synchronized. The two systems now communicate on FLO-2D computational timestep basis. The storm drain system uses the smaller FLO-2D computational timestep for the water volume exchange as well as for the flow routing through the pipe system. With the more frequent water volume exchange at each FLO-2D computational timestep, the inconsistencies with the exchange volumes between the surface water and storm drain systems were eliminated. The storm drain routing timestep is defined using the following criteria:

    - If the user set up a fixed storm drain timestep instead of a variable timestep in the *.inp file for the storm drain system, then the FLO-2D timestep is used as the routing storm drain timestep.

    - If the user set up the switch for a variable timestep with an adjustment factor in the *.inp file, an internal variable time step is calculated using the selected adjustment factor that functions as a courant number. In the model enhancement, a variable timestep is calculated using the adjustment criteria. FLO-2D surface timestep is compared with the storm drain variable timestep, and the minimum timestep between them is imposed. If the storm drain minimum timestep is not

multiple of the FLO-2D timestep, then a new minimum storm drain timestep is calculated with the condition that it has to be less than the variable timestep calculated by the Courant criteria in the dynamic wave routine, but it must be a multiple of the FLO-2D timestep.

In most of the simulations, the FLO-2D timesteps are small enough for the storm drain solution to converge. If the user observes numerical instabilities in the storm drain results, it is recommended to use the variable timestep with an adjustment factor. The variable time step is calculated using the Courant condition for each conduit (6/27/16). Build No. 16-06-15.

36. When the storm drain flow reaches the soffit of a drop box, the pressure head dampening method is applied for a distance above the invert of 1.25 times the conduit pipe diameter. The surface area is exponentially reduced to the drop box diameter as the flow fills the drop box over this prescribed distance. To more effectively represent the physical system, the pressure head dampening algorithm was to allow the pressure head variation up to be exponentially reduced over to entire drop box to the RIM elevation (6/27/16). Build No. 16-06-15.

37. A new file SDManholePopUp.OUT was created when at least one manhole pops under pressure in the storm drain system (6/27/16). Build No. 16-06-15. This file contains the following information:
   - Manhole ID.
   - Time of occurrence
   - Pressure head
   - Rim elevation + Surcharge Elevation
   - FLO-2D WSE.

38. A storm drain blockage method was implemented using a clogging factor to simulate the reduction of the inlet capacity (6/27/16). Build No. 16-06-15. A new data input file (SDCLOGGING.DAT) was created with the following format:

ID	Grid Cell	Inlet ID	Clogging Factor - C_f (%)	Time for clogging -T_c (hr)
D	2694	I1	25	0.50
D	2409	I2	50	3.25

The inlet discharge calculated using the orifice or weir equations is subject to a reduction at the time for clogging specified by the user. The inlet discharge is calculated and then reduced using the clogging factor using the following equation:

$$Q_R = (1 - C_f)\, Q_c$$

where:

Q_R = reduced inflow discharge

C_f = clogging factor

Q_c = calculated discharge using the orifice/weir equations.

39. The StormDrain_ERROR.CHK file contains all the Storm Drain errors and warnings. They were remove from the ERROR.chk (6/27/16). Build No. 16-06-15.

40. Revision of error and warning messages: Existing errors and warnings for the storm drain system were reviewed and some warnings/errors were expanded. Those error/warnings related to conflicts between storm drain features and surface components as well as the outfall elevations checks were revised. (6/27/16). Build No. 16-06-15.

41. Additional error/warning messages: Additional error checking includes pipe and junction connection elevations. Potential errors are reported to the StormDrain_ERROR.CHK file. Conduit elevations are also checked to avoid errors in the inlet and outlet offset data. (6/27/16). Build No. 16-06-15. The following message is written for a pipe and junction connection elevations error:

THERE ARE CONDUIT ELEVATIONS WITH POTENTIAL ERRORS THAT CAN GENERATE CONNECTION ELEVATIONS ISSUES WITH NODES. PLEASE CHECK OFFSET ELEVATIONS FOR CONDUITS AND INVERT ELEVATIONS AND MAX DEPTHS FOR NODES."

42. Revisions were implemented to surface water and storm drain codes to improve the storm drain volume conservation reporting. The storm drain engine volume conservation typically ranges from 0.01 percent to 10 percent, although the goal is to achieve a volume conservation error of 0.1 percent or less. An improvement in the volume conservation reporting was achieved since the system capacity and inflow discharge are known exactly. Some volume conservation losses in the storage assessment were identified and fixed with verification test cases (6/27/16). Build No. 16-06-15. Some of the revisions that were implemented to the FLO-2D surface and storm drain codes are highlighted:

- For real number arrays, the data accuracy was increased from single precision (8 digits) to double precision (16 digits) to calculate the inflow discharge, returning flow, elevations, pressure head, and others.

- The return flow from the storm drain to the surface water was improved. The excess volume, remaining piping volume, pressure head and depth calculations were enhanced for the following two conditions:

    RIM < PH > FLO-2D WSE

    RIM < PH < FLO-2D WSE

- Some reported volumes were removed from the SUMMARY.OUT file because the recent code modifications.

43. New volumes are reported in the SUMMARY.OUT file (6/27/16). Build No. 16-06-15.

    a. STORM DRAIN SYSTEM STORAGE: storage volume in the pipe system at the end of the simulation.

    b. STORM DRAIN MASS BALANCE: mass balance volume conservation calculated as:

Total Inflow - Total Outflow - Total Storm Drain Return Flow - Storm Drain System Storage

44. Pathname of the FLO-2D Storm Drain Projects was increased up to 254 characters. There is an intrinsic limitation (256 characters) in one of the functions that is used in C++ to open the inp/rpt files(3/20/16). Build No. 16-06-16.

45. An enhancement was implemented for the calculation of the timestep in the storm drain model. The surface and the storm drain systems communicate with each FLO-2D computational timestep throughout the simulation for all conditions, including if the user sets up a variable timestep (3/20/17). Build No. 17-08-17.

46. An enhancement was made to the algorithm that control the spikes in the PH. (5/10/17). Build No. 17-08-17.

47. Rain gages are no longer needed in the Storm Drain data file (INP). (5/10/17). Build No. 17-08-17

48. The FLO-2D Storm Drain model was reviewed, for the current version of the model no sub catchments are needed to virtually represent the FLO-2D grid element, an automatic connection is internally hardwired in the FLO-2D model between the storm drain inlet and the FLO-2D grid (6/15/17). Build No. 17-08-17

49. An inlet has to start with an 'I' to be recognized as an inlet. Manholes are covered inlets that also capture flow from the surface when the cap is removed by a high pressure of the system. The manholes ID have to also start with an 'I'. (6/15/17). Build No. 17-08-17