

**PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT'S
TECHNICAL POLICY**

POLICY NO: Technical Policy, TECH-033

EFFECTIVE DATE: August 1, 2013

REVISION DATE: DRAFT 1/27/20

POLICY NAME: Criteria for Two-Dimensional Modeling

PURPOSE: To standardize Two-Dimensional Modeling for hydrologic and /or hydraulic studies in Pima County, Arizona.

BACKGROUND: Two-Dimensional (2-D) flood routing modeling is typically used in those areas where flows are distributary and/or non-uniform and where the terrain is too complex to be modeled accurately by one-dimensional models designed for riverine floodplains. The changes in flow patterns associated with such runoff make it necessary to utilize 2-D models that react both to the terrain and hydraulic fluctuations through the duration of the flood hydrograph. A 2-D model can include rainfall and/or runoff modeling. This policy outlines the Pima County Regional Flood Control District's (District) standards for 2-D model submittals ~~for watersheds less than 10 square miles.~~

POLICY:

Two-Dimensional (2-D) modeling reports submitted to the District for review shall adhere to the following procedures:

- A. The report shall state the name, ~~and the~~ version and build number of the 2-D model used. Be aware some models and versions may not be considered a hydrologic and/or hydraulic numerical model meeting the minimum requirements to be acceptable for remapping a floodplain through the Federal Emergency Management Agency (FEMA). The 2-D model submitted to the District must be in a version the District is able to review.
- B. Unless otherwise approved by the District, the 2-D model and subsequent map products shall contain digitally projected data with the following projection control:
 - Projection: _____ = State Plane, Arizona Central Zone
 - Horizontal Datum : _____ = NAD83-92(HARN)
 - Units: _____ = International Feet
 - Vertical Datum: _____ = NAVD-88
- C. The digital elevation data shall be incorporated into the 2-D model using the following criteria:
 1. The ~~selected~~ grid size must ~~be able to~~ capture the detail required for the project, and digital elevation data must be adequate to support the selected grid resolution. The engineer shall provide justification for the size of the grid elements. It is

recommended the engineer discuss the grid element size with the District before conducting the study.

2. Two dimensional models allow for flow to spread out across the Digital Elevation Model (DEM). Therefore it is often necessary to extend the limits of the DEM upstream and downstream from the project site to allow for the natural expansion and contraction of the flow through the duration of the hydrograph.
3. An electronic copy of the DEM in ASCII format is to be supplied to the District if the data does not come from an accessible public source. If from a public source, the source shall be identified in the report.

D. Hydrology can be modeled with some 2-D modeling software although the software may limit the type of hydrologic methods used. When using 2-D software to perform hydrologic modeling, the following criteria shall be followed:

1. Watershed delineation may be difficult due to the distributary nature of the ~~watershed terrain~~. The watershed delineation shall include all potential contributing drainage areas and locations of interest. In addition to the DEM, the use of aerial photography, including historical aerial photography is recommended to discern watershed boundaries. Preliminary models may be useful to determine the location of breakout flows from the contributing watershed.
2. Modeling criteria shall follow District *Technical Policies TECH-010, TECH-015 and TECH-018*.
3. The rainfall values are not to be aerially-reduced unless approved otherwise by the District.
4. In order to reduce the size of or otherwise limit the upstream modeling extent of the 2-D model, hydrologic modeling of portions of the watershed upstream of the project may be accomplished by methods presented in *Technical Policy TECH-018*, and the resulting flood hydrograph may be input into the 2-D model as inflow hydrographs. Rainfall shall be added to the model downstream of inflow hydrographs, unless the engineer justifies that adding rainfall will not have any significant impact to the total inundation maps or the total flow volume. The rainfall distribution shall be the same as the design storm used to produce the inflow hydrograph.

The following criteria shall be applied to create rainfall distribution for cases where PC-Hydro is used to create the inflow hydrographs:

- a. When the watershed is less than one square mile, or results in a PC-Hydro time of concentration of less than one hour, the NOAA Atlas 14 Point Precipitation Values from the Upper 90% confidence limit values for the 5, 10, 15, 30 and 60 minute storms are to be used to create a rainfall distribution. These rainfall Intensity-Duration-Frequency (IDF) values are to be used with the peak intensity rainfall value centered in the Isohyetal graph for a total duration of one hour.

~~b. When the watershed modeled by PC-Hydro has a time of concentration of between one hour and two hours, the NOAA Atlas 14 Point Precipitation Values from the Upper 90% confidence limit values for the 5, 10, 15, 30, 60 and 120 minute storms are to be used to create a rainfall distribution. These rainfall Intensity Duration Frequency (IDF) values are to be used with the peak intensity rainfall value centered in the Isohyetal graph for a total duration of two hours.~~

~~e.b.~~ If other hydrological criteria are to be used other than that described above, the hydrological methodology is to be discussed with and approved by the District prior to report submittal.

5. Hydraulic modeling of 2-D models are to follow the following guidelines:

- a. Multiple runs may be necessary in dynamic distributary areas. Dynamic distributary areas are regions in which there is a greater chance of flow redistribution overtime. Dynamic distribution areas are subject to channel avulsion and sedimentation. Such areas may also be susceptible to debris changing the discharge distribution. Multiple floodplain models may be necessary to account for flow re-distribution. Multiple runs may include but are not necessarily limited to creating channel blockage (or levee) situations to force more flow into other paths, or increasing the discharge values along each flow path. The multiple runs are to be combined to create a map from the maximum depths, water surface elevations and flows. Careful examination of the site conditions, soils, historical aerial photography and hydraulic conditions are warranted prior to developing the flow variables. Consultation with District staff is recommended prior to mapping flows in active distributary areas.
- b. Hydraulic structures such as culverts, detention basins, levees, constructed channels or natural channels be modeled following the guidelines within the user's manual for the software program. The engineer is to provide a narrative description of the hydraulic structures modeled.

6. The output of a 2-D model is to include the following:

a. The output data for the entire modeling domain, in the form of gridded shapefile or raster image is to include:

i. Grid identification (#)

ii. Ground elevation (ft. above mean sea level in the vertical datum currently used by the District)

iii. Maximum Flow Depth (ft.)

iv. Maximum Water Surface Elevation (ft. above mean sea level)

v. Maximum Velocity (ft/s)

Peak Discharge

b. Unique output data may be required depending on type of project. Such output data may include but is not necessarily limited to:

- i. Flow vectors (direction)
- ii. Duration of inundation (hrs.)
- iii. flow depth > 3 feet

iv. Momentum computations such as

- 1. velocity * depth (ft²/s)
- 2. velocity-squared * depth (ft³/s²)

~~velocity times depth of flow or the square of the velocity times depth of flow~~

~~Duration of inundation~~

c. If floodplain flow-recording cross sections are generated, the placement of the cross sections are to ~~include peak discharge values which will be the summation of discharge values from grid cells across the cross section. When practicable, the placement of the cross section is to~~ be perpendicular to the flow path as determined at the moment of maximum inundation. Output generated from the flow recording cross sections shall include:

- i. -Cross Section identification number (#)
- ii. Peak discharge (cfs)
- iii. Total volume (acre-ft)
- iv. Hydrograph

~~e. Shape file data is required by the District with 2-D models. Data is to include:~~

~~d.~~

~~e. Separate grid shape files for:~~

~~f. Grid identification~~

~~g. Ground elevation~~

~~h. Maximum flow depth from data output~~

~~i. Maximum water surface elevation from data output~~

~~j. Maximum velocity from data output~~

~~k.~~

~~l.~~

~~m. Unique shape file data may be required depending on type of project. Such output data may include but is not necessarily limited to:~~

~~n. Flow vectors~~

~~o. Momentum data such as velocity times depth of flow or the square of the velocity times depth of flow~~

~~p. Duration of inundation~~

~~q.~~

~~r.d. When practicable, water surface contours generated from maximum water surface elevation data.~~

e. Floodplain inundation feature classes may be requested by the District. In order to generate a useful floodplain management tool, polygon shapefiles should have:

- i. Vertices reduced to simplify the data management stress on GIS platforms.
- ii. Smooth boundary limits to match the digital terrain and aerial photography.
- iii. Disconnected floodplain polygons reduced or eliminated.
- iv. Isolated non-inundation areas within the greater floodplain area reduced or eliminated.

f. The engineer shall include point or line shapefiles for the hydraulic structures.

~~B. The engineer is also to include point or line shape files for the hydraulic structures.~~

~~7. In addition to traditional hydrologic and hydraulic map products, reports submitted with 2-D models shall include paper and/or PDF map(s) with the grid elements shown with grid identification numbers. When hydrologic and hydraulic work maps are provided they shall be prepared in conformance with *District Standard DS-305*.~~

8. The report is to include the digital 2-D model input and output data on disk, or portable hard drive, or an FTP shared access website.

9. Technical guidance for hydrologic and hydraulic modeling utilizing the FLO-2D (V. 2009, Pro) software is provided as Attachment A.

APPROVED BY:

Suzanne Shields, P.E.
Director and Chief Engineer

Date

Attachment A

***FLO-2D (V. 2009, Pro) Technical Guidance for Hydrologic and Hydraulic modeling
in Unincorporated Pima County, Arizona***

Effective Date: January 28, 2020

This version of the guidance document has not been adopted by the Pima County Board of Supervisors. Effective this date, it is to be implemented in its draft form and utilized on a case-by-case basis.

Purpose: To provide guidance for and standards regarding floodplain modeling using the FLO-2D (versions 2009, Pro) software package, with the intent of improving the consistency of modeling results generated by Pima County Regional Flood Control District (District) staff and modeling submitted to the County by qualified applicants.

The following guidance document is provided as **Attachment A** to the District's Technical Policy, TECH-033: Criteria for Two Dimensional Modeling.

Background: FLO-2D is a proprietary computer software program that conducts two-dimensional rainfall-runoff models. Two-dimensional models like FLO-2D provide an analytical environment suitable for mapping distributary flow conditions common to the southern Arizona terrain. FLO-2D (versions 2009, Pro) is FEMA approved to support hydrologic and hydraulic analyses in Pima County, Arizona.

Suzanne Shields, P.E.
Director

Date

Outline

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2. Verification (-)
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5. TOLER.DAT
 - a. TOL (Surface Detention, ft.)
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6. INFIL.DAT
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7. ARF.DAT
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 - a. Application (-)
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 - c. RAINABS (Rainfall Interception and Abstraction, inches)
 - d. R_TIME(I) (Rainfall Time, hours)
 - e. R_DISTR(I) (Rainfall Depth, Cumulative Percentage)
 - f. RAINARF(I) (Rainfall Depth Area Reduction)
9. MANNINGS_N.DAT
 - a. FP(I,J) (Manning's n roughness coefficient)
10. INFLOW.DAT
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11. OUTFLOW.DAT
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12. FPXSEC.DAT
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 - b. IFLO(N) (Direction of Expected Flow)
13. CHAN.DAT
14. STREET.DAT
15. LEVEE.DAT

Technical Guidance

1. Application

- a. Written justification for the use of a FLO-2D model to support a hydrologic and/or hydraulic analysis submittal to the District shall be provided.
- b. It is recommended to discuss the use of FLO-2D with the District prior to conducting any significant modeling efforts.
- c. The latest version/build number of FLO-2D should be used for analyses submitted to the District.

2. Verification

- a. To verify the accuracy of the FLO-2D modeling results, the District may request the submittal of additional information. Data requests may include, but are not limited to comparisons to other modeling processes and/or observed data sets, including:
 - i. Gauge data
 - ii. NextRAD data
 - iii. Regression equations
 - iv. Volumetric comparisons
 - v. HEC-HMS , HEC-RAS
 - vi. Aerial photography
 - vii. TR-55 travel time

3. Grid Element Size (ft.)

- a. Grid size should be a function of the purpose of the model. The following provides guidelines for selecting the appropriate grid size.
 - i. If possible, grid element size should be equal to or greater than twice the average DTM point spacing.
 - ii. For hydraulic modeling, the grid size shall be no greater than 30 ft.
 - iii. For hydrologic modeling, the grid size area (square-feet) should be no greater than one-tenth of the peak discharge (cfs) being modeled.
 - iv. In order to properly simulate travel times through well-defined or visible (sand bed) channels and linear features (street) for accurate hydrologic modeling, the modeling effort should maximize the faithful reproduction of the channel/street geometry. Where two or more grids fit within the bottom of the channel or street, no 1-D channel/street segments are required. However, where geometry of street/visible channels cannot be faithfully simulated with the grid, then inclusion of 1-D channel/street segments is recommended, or application of other methods to correct the overland flow times for the slower velocity due to the poor reproduction of channel geometry.
- b. Written documentation stating the origin and specifics of the DTM data used for modeling shall be provided. In particular, provide at a minimum the date the elevation data was collected, the vertical and horizontal datum that was used to collect the data, the method of collection, and a statement of both horizontal and vertical accuracy and average sampling size.
- c. The District recommends that the applicant pursue and receive approval of grid size selection prior to initiating substantial modeling efforts.

4. CONT.DAT

- a. SIMULT (Simulation Time, hours)
 - i. Simulation time shall be set to capture the maximum depth condition for all grid cells.
 - ii. Simulation time should, at minimum, extend into the receding limb of the hydrograph being modeled, capturing the peak discharge conditions throughout the areas of interest.
 - iii. Should flood volume be of interest to the analysis, the simulation time should extend until minimal flooding occurs through the areas of interest.
- b. TOUT (Output Time Interval, hours)
 - i. The output time interval shall be set small enough for the model to construct accurate output hydrographs.
- c. AMANN (Manning's n Coefficient Increment)
 - i. The AMANN parameter should be turned off (set to -99). Written justification is required for AMANN values not set to -99 (see SHALLOWN guidance).
- d. FROUDL (Limiting Froude Number)
 - i. A global Limiting Froude Number should be used, typically within the range of 0.90-0.95.
 - ii. For grid cells with steep slopes or smooth, armored surfaces where supercritical flow may occur, FROUDL may be set at 1.2 or higher.
 - iii. FROUDL may be spatially variable.
 - iv. For Limiting Froude Number for Channels (FROUDC) and for Streets (STRFNO), see CHAN.DAT and STREET.DAT, respectively.
 - v. Review of the ROUGH.OUT and TIME.OUT output files is recommended to aid verification of proper roughness selections against resulting Froude numbers.
- e. SHALLOWN (Shallow Manning's n Coefficient)
 - i. SHALLOWN should be not be used unless written justification is provided that demonstrates roughness varies by depth.
 - ii. The SHALLOWN parameter is not used when AMANN is turned off (set to -99).
 - iii. The SHALLOWN parameter may be set to a value between 0 and 0.2 for watersheds that are predominately natural when it is determined that roughness varies by depth.
 - iv. Unless otherwise justified, the SHALLOWN parameter should not be used for highly urbanized watersheds when unreasonably low velocities occur over smooth impervious surfaces compared to normal depth calculations.

5. TOLER.DAT

- a. TOLGLOBAL (Surface Detention, ft)
 - i. The TOLGLOBAL parameter should be set to 0.01 ft (0.12 in) for rainfall-runoff modeling.
 - ii. The TOLGLOBAL parameter may be spatially variable, implementing the TOLSPATIAL.DAT file.

- iii. A written description of the TOLGLOBAL parameter used in the model shall be provided. Justification shall be provided when the TOL parameter is not set to the default value of 0.01 ft (0.12 in), and/or when spatially variable.
 - b. DEPTOL (Tolerance Value for Percent Change in Flow Depth)
 - i. The DEPTOL parameter shall be set to zero (turned off).
 - ii. Written justification shall be provided when the DEPTOL parameter is not set to zero.
 - c. COURANT (Numerical Stability Coefficient)
 - i. COURANT should be set to the default value of 0.6.
 - ii. If the model is stable, increase COURANT by increments of 0.1, to a maximum of 0.8, to decrease model runtime. If the model is unstable, reduce COURANT by increments of 0.1, to a minimum of 0.3, until model stability is reached.
 - d. TIME_ACCEL (Coefficient to increase the rate if incremental timestep)
 - i. TIME_ACCEL should be set to the default value of 0.1, creating a more stable simulation.
 - ii. TIME_ACCEL set to a value of 0.2 or greater may result in faster simulations and should be accompanied by a statement ensuring model run stability and output accuracy.

6. INFIL.DAT

- a. INFMETHOD (Infiltration Method)
 - i. Hydrologic modeling shall employ the SCS Curve Number Method, consistent with Technical Policy TECH-018: Acceptable Model Parameterization for Determining Peak Discharges.
- b. SCSN(N) (Spatially Variable SCS Curve Number)
 - i. The Curve Number shall be spatially variable to match soil, vegetation, and land use conditions specific to the individual grid cells. Impervious surfaces providing flood storage (i.e. roads, parking lots) should be simulated with a modified curve number.
- c. ABSTSCS (Initial Abstraction, inches)
 - i. ABSTSCS shall be set to zero, which will trigger F2D to automatically calculate the initial abstraction per the SCS method.

7. ARF.DAT

- a. ARF (Area Reduction Factors)
 - i. For hydrologic models, ARF values should be used to simulate impervious surfaces that do not provide flood storage (i.e. buildings with roofs). ARF values for individual grid cells shall be consistent with *Table D-3: Summary of Approximate Impervious Cover Percentages for Various Land Development Types*, from Pima County's current PC-Hydro User Guide.
- b. WRF (Width Reduction Factor)
 - i. Any use of the WRF parameter shall include a written justification.

8. RAIN.DAT

- a. Application (-)

- i. For a hydrologic-only model, the RAIN.DAT file shall be used.
 - ii. For a hydraulic-only model, the RAIN.DAT file shall not be used.
 - iii. For a hydrologic-hydraulic mixed model, the RAIN.DAT file shall be used.
- b. IRAINBUILDING
 - i. When using ARF.DAT to simulate the impervious cover of buildings' roofs,
 - 1. IRAINBUILDING shall be set to zero (0) if the roofs convey stormwater directly to the storm drain system, through which it is eliminated as runoff.
 - 2. IRAINBUILDING shall be set to one (1) if the roofs convey stormwater to the ground and contributes to runoff.
 - 3. A written statement shall be provided regarding the setting of IRAINBUILDING.
- c. RTT (Rainfall Depth, Total, inches)
 - i. The total rainfall depth shall be consistent with Technical Policy TECH-010: Rainfall Input for Hydrologic Modeling.
- d. RAINABS (Rainfall interception and abstraction, inches)
 - i. RAINABS shall be set to zero. Infiltration of rainfall shall be modeled with INFIL.DAT.
 - ii. A written justification shall be provided when the interception and abstraction of rainfall is being modeled.
- e. R_TIME(I) (Rainfall Time, hours)
 - i. The rainfall distribution shall be consistent with Technical Policy TECH-018: Acceptable Model Parameterization for Determining Peak Discharge, and equivalent to any inflow hydrographs (see INFLOW.DAT) within the model.
- f. R_DISTR(I) (Rainfall Depth, cumulative percentage)
 - i. See "R_TIME(I)" above.
- g. RAINARF(I) (Rainfall Depth Area Reduction)
 - i. Rainfall depth may be spatially variable, while maintaining consistency with Technical Policies TECH-010: Rainfall Input for Hydrologic Modeling and TECH-033: Criteria for Two-Dimensional Modeling.
 - ii. RAINARF, a value between 0 and 1, is multiplied against the total rainfall depth, RTT, to calculate and assign the reduced rainfall depth to the coordinating grid cells, IRGRID(I).

9. MANNINGS_N.DAT

- a. FP(I,J) (Manning's n Roughness Coefficient)
 - i. The Manning's n roughness coefficient shall be spatially variable to match the surface roughness conditions specific to the individual grid cells.
 - ii. Table 1 (below), Table 1 in the FLO-2D Reference Manual, and Table 8.1 of the Standards Manual for Drainage Design and Floodplain Management provide suggested Manning's n values for various land use conditions:

Table 1: Suggested Manning's n roughness coefficients for specific land use conditions

<i>n</i>	<i>Land Use</i>
0.020	Streets, Concrete Channels
0.025	Open Space, Lawn
0.030	Right of way (clear area beside pavement)
0.035	Commercial
0.035	Earth channels, constructed
0.035	Roadside swale
0.040	Office, Retail
0.045	Open Space, Light to Medium Brush

<i>n</i>	<i>Land Use</i>
0.055	Retail, Warehousing
0.055	Natural Vegetated Channels
0.065	Manufacture, Salvage
0.065	Open Space, dense and Densely Vegetated Natural Channels
0.065	Residential
0.070	Industrial
0.100	Agriculture
0.100	Detention Basin

- iii. Manning's n roughness coefficients obtained from other sources shall be identified and supported with a written justification.

10. INFLOW.DAT

- a. IHOURLY (Inflow Hydrograph Time Unit)
 - i. The time unit for inflow hydrographs shall be hourly (IHOURLY set to 0).
- b. KHIN(I) (Grid Elements with Inflow Hydrograph)
 - i. An inflow hydrograph should be evenly divided among the adjacent grid cells that represent an estimated top-width of the main-channel at the location of the inflow hydrograph. A normal depth calculation of the peak discharge at the location of the inflow hydrograph may be requested.
 - ii. If multiple models occur in series (upstream to downstream), the outflow hydrograph of the upstream model shall equal the inflow hydrograph of the downstream model.
 - iii. All inflow hydrographs shall be generated from the same rainfall distribution. For a hydrologic-hydraulic mixed model, the rainfall distribution used to generate the inflow hydrographs shall equal the rainfall distribution of RAIN.DAT.

11. OUTFLOW.DAT

- a. NODDC(I) (Grid Elements with Outflow)
 - i. To avoid boundary condition influence, outflow elements should be placed a minimum of five (5) grid cells downstream of the area of interest.
 - ii. Grid cells assigned as outflow nodes should not be assigned other cell node functions, including but not limited to ARF/WRF nodes, hydraulic structure nodes, inflow nodes, and levee nodes.

12. FPXSEC.DAT

- a. NODX(N,J) (Grid Elements of Cross Section)
 - i. Discharge recording cross sections should be placed throughout the model at points of interest. Cross sections should be aligned perpendicular to the direction of the expected flow.
- b. IFLO(N) (Direction of Expected Flow)
 - i. The general direction of expected flow should be assigned to the cross section with a positive integer, corresponding to one of the eight cardinal directions, to account for flow occurring in the neighboring directions:
 - 1. North
 - 2. East
 - 3. South
 - 4. West
 - 5. Northeast
 - 6. Southeast
 - 7. Southwest
 - 8. Northwest
 - ii. Written justification shall be provided if discharge in a specific single direction, obtained by using a negative integer, is collected at a discharge recording cross section.

13. CHAN.DAT

- a. A written justification shall be provided for any use of the CHAN.DAT input file.

14. STREET.DAT

- a. A written justification shall be provided for any use of the STREET.DAT input file.

15. LEVEE.DAT

- a. A written justification shall be provided for any use of the LEVEE.DAT input file.