RIVERSIDE COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
RIVERSIDE, CALIFORNIA

Tucalota Creek

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PREPARED BY: MANIK SETHI

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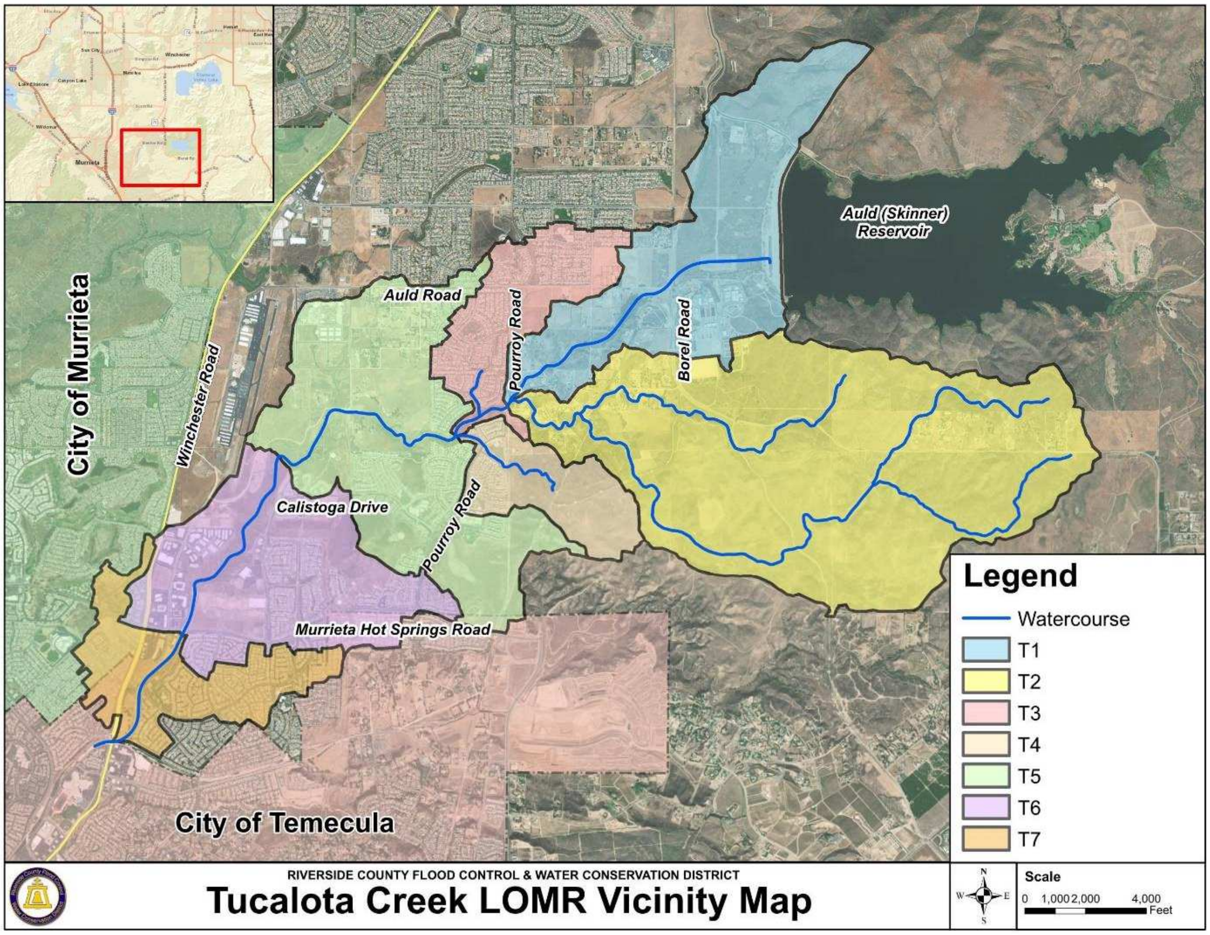
1. Introduction

Tucalota Creek Watershed is a 11.5 sq. mile watershed located in unincorporated Riverside County, city of Temecula, and city of Murrieta in the area between Skinner Reservoir and Winchester Road. Tucalota Creek has eight reaches dubbed Mainline, Tributary T3, Tributary T4, Tributary T2-A, Tributary T2-B, Tributary T2-C, Tributary T2-D, and Tributary T2-E. Tucalota Creek is part of the Murrieta Creek Watershed. Tucalota first confluences with Santa Gertrudis Creek and subsequently discharges into Murrieta Creek and ultimately Santa Margarita Creek within the City of Temecula.

Currently, the Tucalota Creek area is mapped as Zone Unshaded X or Zone D. The Riverside County Flood Control and Water Conservations District's (District) objective in this analysis is to map the floodplain as a Federal Emergency Management Agency (FEMA) Zone AE and remove the current Zone D designation. The goal is to piggyback on the Warm Springs Tributary C PMR (LOMR Case No. 21-09-0027S, 316-PMR ongoing), which will print the Flood Insurance Rate Map (FIRM) Panel Numbers 06065C2710G, 06065C2090G, 06065C2095G, 06065C2730G, and 06065C2735G. The FIRM Panels to be revised by Tucalota Creek are 06065C2710G, 06065C2720G, 06065C2730G, 06065C2735G, 06065C2040G, and 06065C2045G. Figure 1 shows a vicinity map of the area as well as the Tucalota Creek watersheds.

Figure 1: Vicinity Map



2. Hydrology

The FEMA Flood Insurance Study (FIS) does not include any hydrologic information for Tucalota Creek. The area is currently mapped as a Zone D and Zone Unshaded X.

A new hydrology study was performed by the District to obtain the 100-year flowrate for the various reaches of Tucalota Creek. The study only considers existing conditions of the watersheds. The guidelines in the District's Hydrology Manual were used to prepare a synthetic unit hydrograph rainfall-runoff model for the Tucalota Creek Watersheds using HEC-HMS. Excerpts from the hydrology manual as well as the finalized hydrology study are located in Appendix B. The following sections will describe the hydrology study.

2.1 Watershed Characteristics

Tucalota Creek Mainline extends from the valley just downstream of Lake Skinner Dam all the way to Winchester Road, near the city of Temecula boundary limits. Tributary T3 extends from Lilac Sky Lane to the confluence with the Mainline, just downstream of Honey Pine Road. Tributary T4 extends from the Metropolitan Water Line to a confluence point with the Mainline downstream of Pourroy Road. Tributary T2-E starts just south of Ashfield Lane and confluences with Tributary T2-D, which starts just north of Halifax Lane. Tributary T2-C starts at the confluence off T2-E/T2-D and confluences with T2-B 800 feet south of Kaarla Lane. Tributary T2-B starts about 2500 feet upstream of Borel Road. The total watershed area being revised is 11.5 square miles. All watersheds were composed using District 4-foot topography and tract information for developed areas.

Foothills comprise the majority of each watershed, with valley areas only being present in the T3, T6, and T7 portions of the watershed. These areas use an S-graph that is a combination of 50% valley and 50% foothill. The watercourses in the upstream watersheds are comprised mainly of natural channels. The watercourse for Tributary T3 contains storm drain infrastructure throughout the watershed. Tributary T4 contains improvements on the downstream side but is mainly natural flow on the upstream side. The downstream main watercourses are comprised mainly of streets and District storm drains, which lowers the hydrologic n-value.

Lag: A lag was determined for use in the synthetic unit hydrograph method. The lag was calculated based on the physical characteristics of the drainage area and the empirical formulas in Figure 2.

Watershed parameters: MicroStation was used to determine length of longest watercourses, length of watercourse from centroid, drainage areas, and slopes. See Table 1 for these parameters for each watershed.

Manning's n-value: The visually estimated mean of the Manning's n values of all collection of streams and channels in each watershed was analyzed. Table 1 shows the n-values used for each watershed. The analysis used aerial imagery, District facilities, and field visits. The values were chosen based on how developed the areas are, how many improvements exist in the area, and how many of the main watercourses in the watershed use these improvements.

Figure 2: Hydrology Manual Lag Equations

$$\text{Lag (hours)} = 24\bar{n}\left[\frac{L \cdot L_{ca}}{S^{1/2}}\right]^{.38}$$

where:

$\bar{n}$ = The visually estimated mean of the n (Manning's formula) values of all collection streams and channels within the watershed

L = Length of longest watercourse - miles

Lca = Length along longest watercourse, measured upstream to a point opposite the centroid of the area - miles

S = Overall slope of longest watercourse between headwaters and the collection point feet per mile

Table 1: Watershed Parameters

Tucalota Creek				
Watershed	T1	T2	T3	T4
Drainage Area (sq. miles)	1.77	4.01	0.70	0.54
Longest Watercourse (miles)	3.77	5.86	2.13	1.64
Lca (miles)	1.76	3.30	1.03	0.81
Slope (feet/mile)	325.1	67.5	39.5	58.6
N-value	.030	.035	.015	.020
S-graph	Foothill	Foothill	Foothill/Valley	Foothill
Lag (hrs)	.500	1.16	.241	.246
Watershed	T5	T6	T7	T2-A
Drainage Area (sq. miles)	2.07	1.56	0.80	N/A
Longest Watercourse (miles)	2.79	1.88	1.79	N/A
Lca (miles)	1.06	0.67	0.82	N/A
Slope (feet/mile)	61.3	138.3	112.0	N/A
N-value	.015	.015	.015	N/A
S-graph	Foothill	Foothill/Valley	Foothill/Valley	N/A
Lag (hrs)	.249	.160	.170	N/A
Watershed	T2-B	T2-C	T2-D	T2-E
Drainage Area (sq. miles)	1.17	1.49	0.50	0.72
Longest Watercourse (miles)	2.82	3.46	2.01	2.06
Lca (miles)	1.55	1.92	0.91	1.03
Slope (feet/mile)	86.4	63.6	109.6	124.0
N-value	.035	.035	.035	.035
S-graph	Foothill	Foothill	Foothill	Foothill
Lag (hrs)	.631	.784	.432	.447

Based on the empirical formulas in Figure 2, watershed parameters, and the chosen n-values, each watershed had a calculated lag time shown in Table 1. T2-A was not analyzed in detail, as T2 watershed provides the flowrate for that area. Discussion on why this decision was made is detailed in Section 2.5.

2.2 Precipitation

The 100-year 3-hr, 6-hr, and 24-hr storm durations were analyzed. Point rainfall data is taken from the District Hydrology Manual 100-year rainfall isohyets. These represent data from California NOAA Atlas 2, Volume 11. Based on the plates E-5.1 to E-5.6, the 3-hr and 6-hr storms have the same rainfall in all watersheds. For the 24-hr storm, the watershed with the highest rainfall was used for all watersheds. This was 4.6"over 24-hours. Attached in Appendix B is a document showing that FEMA has accepted the use of Civil D for the District, which utilizes NOAA Atlas 2 rainfall values.

The precipitation depths were taken directly from point rainfall isohyetal maps from the District's Hydrology Manual. All precipitation values are based on "NOAA Atlas 2, Precipitation Frequency Atlas of the Western United States, Volume XI California" by the National Weather Service.

Precipitation values are similar to other studies in the area, such as the Warm Springs Tributaries A, B, and C.

A depth area adjustment for the rainfall was not considered for these as each watershed is relatively small and a depth area adjustment would not result in any significant precipitation change. Table 2 notes the precipitation values for each storm.

Table 2: Precipitation Values for all Watersheds

Duration	100-year Point Precipitation (inches)
3-hr	1.80
6-hr	2.50
24-hr	4.60

2.3 Soils and Land Uses

In order to determine the infiltration for the Tucalota Creek watersheds, the hydrologic soil groups were determined. These are based on the United States Department of Agriculture – Natural Resources Conservation Service – SSURGO Database. The database provides a map classifying the soil groups from "A" to "D", with classifications being "A" having the highest infiltration rate due to coarser soils and "D" having the lowest infiltration rate due to clays or other obstructions. A description of the soil groups from the District Hydrology Manual is included in Table 3 below.

Table 3: Soil Group Descriptions

Soil Group	Description
A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

ArcGIS 10.3 was used to intersect the basin and sub-basin boundaries (delineated using MicroStation) with the NRCS soil database map and ultimately calculate the areas of each soil group. Tucalota Creek watershed contains only three of the four soil types. Soil Type A is not present in any of the watersheds. Soil percentages are shown in Table 4 below. The high percentage of soil type C present in many of the watersheds indicates a moderately high runoff potential. Some watersheds, such as T3 and T7, have a high percentage of watershed B, which indicates a moderately lower runoff potential. This indicates that except T3 and T7, the watershed soils are slightly resistant to infiltration. Figure 4 shows a map of the soil groups throughout the watershed and Table 4 shows the percentage of soils in each watershed.

Table 4: Soil Groups by Watershed

Soil Type	A (%)	B (%)	C (%)	D (%)
T1	0	28	45	28
T2	0	07	60	33
T3	0	47	34	20
T4	0	24	7	5
T5	0	28	6	4
T6	0	24	74	1
T7	0	71	29	0
T2-B	0	08	84	8
T2-C	0	01	65	33
T2-D	0	15	54	31
T2-E	0	0	39	60

Land use, another factor in determining the watershed's infiltration rate, was determined based on existing condition. Land use can be used to determine the impervious area of each watershed. Existing land use was determined using the county and city general plans, aerial imagery, google earth street view, and field visits. Where the watersheds went into the city of Temecula or the city of Murrieta, the general plans for those cities, in addition to aerial imagery, were used to create the land use. The areas corresponding to each land use category were drawn out in MicroStation and then exported to an ArcGIS shapefile so they could be intersected with NRCS soil database. A land use map is included in Figure 5. Three of the four watershed variables, watershed, land use, and soils were intersected within ArcMAP to create a shape with all the attributes in it.

Land cover conforms directly to the data given by the District Hydrology Manual Plate E-6.1. The land cover was drawn in MicroStation manually based on aerial imagery and converted to shapefile. The land cover was added to each shape in ArcMAP after the fact to complete the watershed characteristics. Land Cover map is shown in Figure 3 below. A shapefile with all these watershed attributes is located in Appendix B. Table 5 shows the land uses within the Tucalota Creek watershed.

Table 5: Land Use

Land Use Type	Impervious (%)
Agriculture	0%
Business Park/Light Industrial	90%
Commercial Office/Retail	90%
Estate Density Residential	25%
Low Density Residential	40%
Medium Density Residential	50%
Mid-High/High Density Residential	60%
Very High Density Residential	70%
Apartments/Condos	80%
Rural Residential	20%
Rural Mountains	5%
Public Facilities	20%
Mixed Use Planning	90%
Open Space	0%

Figure 3: Land Cover Map

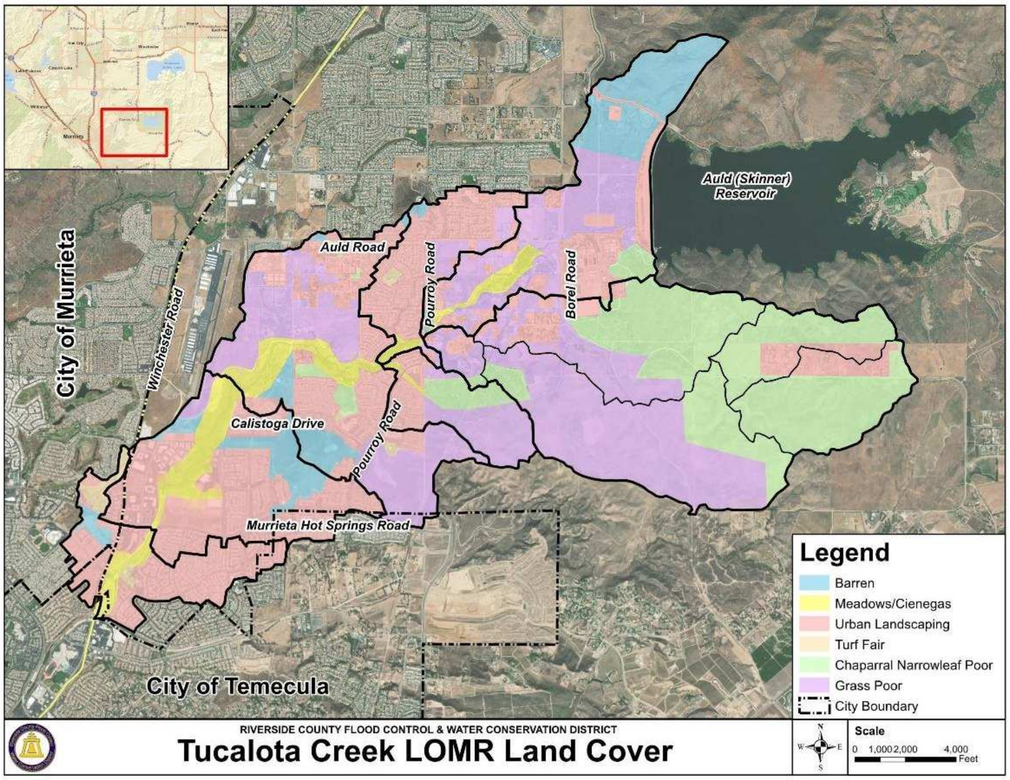


Figure 4: Soils Map

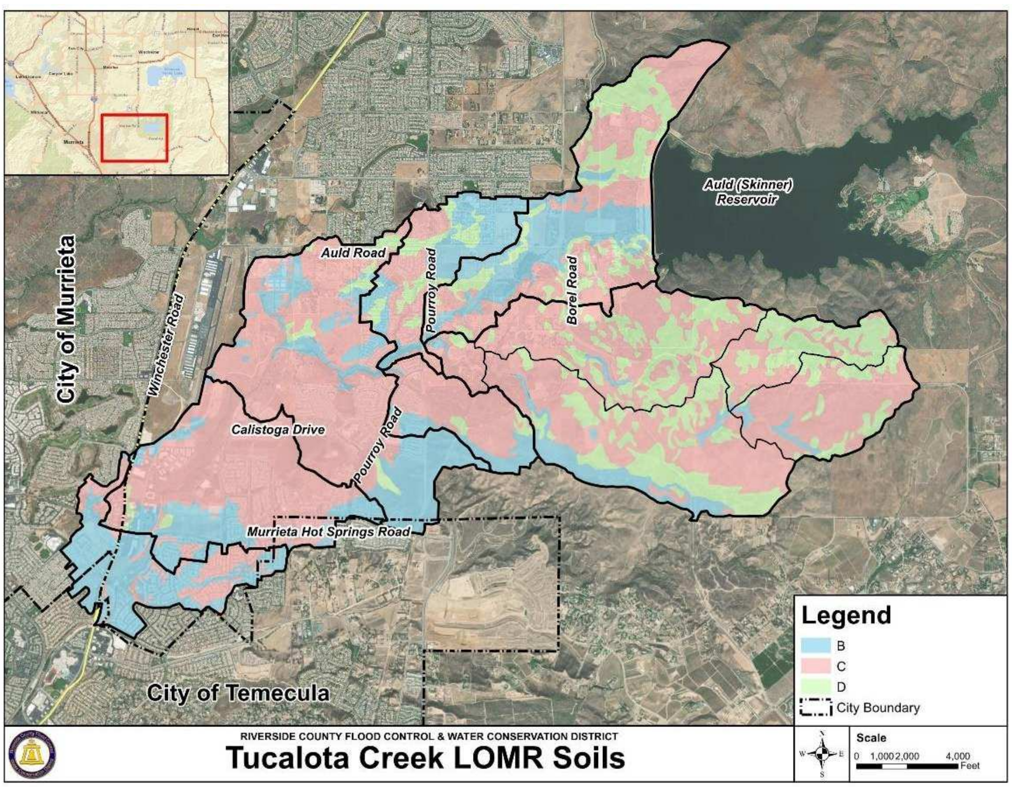
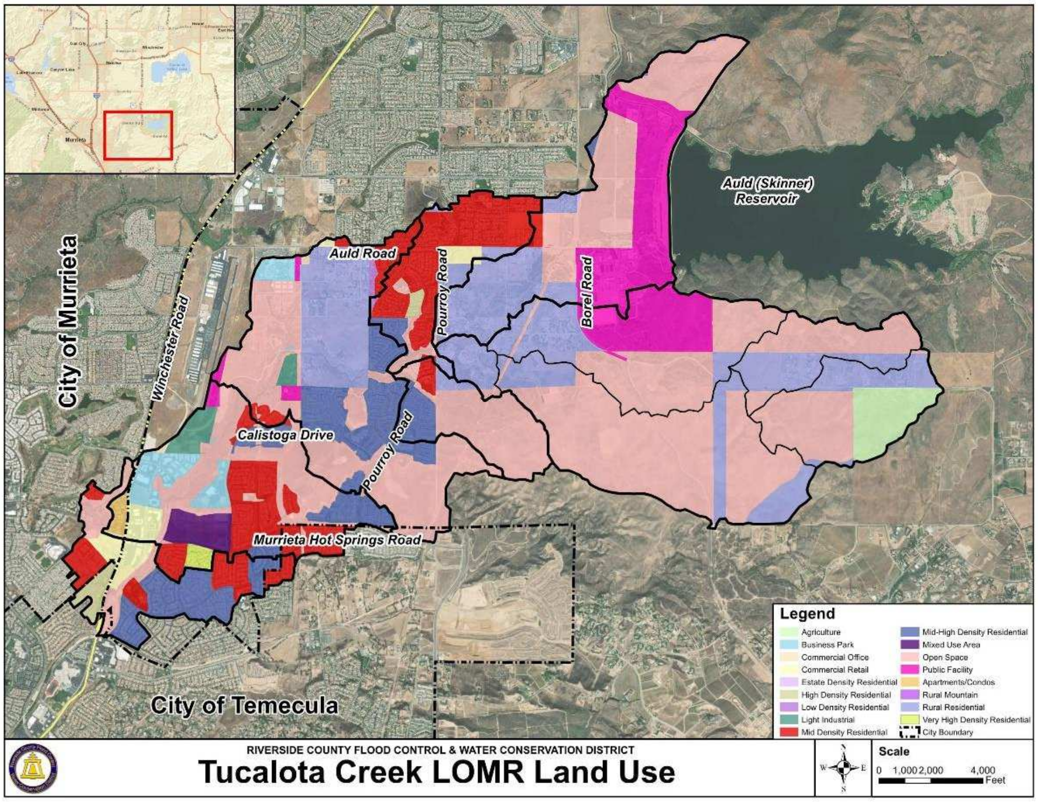


Figure 5: Land Use Map



2.4 Infiltration Losses and Runoff Index

Infiltration losses are also dependent on the Antecedent Moisture Condition (AMC), the degree of soil saturation prior to a flood producing storm event. The AMC ranges from I to III with AMC III having the highest runoff potential. Per the criteria in the District's Manual, AMC II was used for the 100-year frequency storm analyzed in this report. This AMC II condition was used to determine the infiltration rate once the runoff index (RI) was determined.

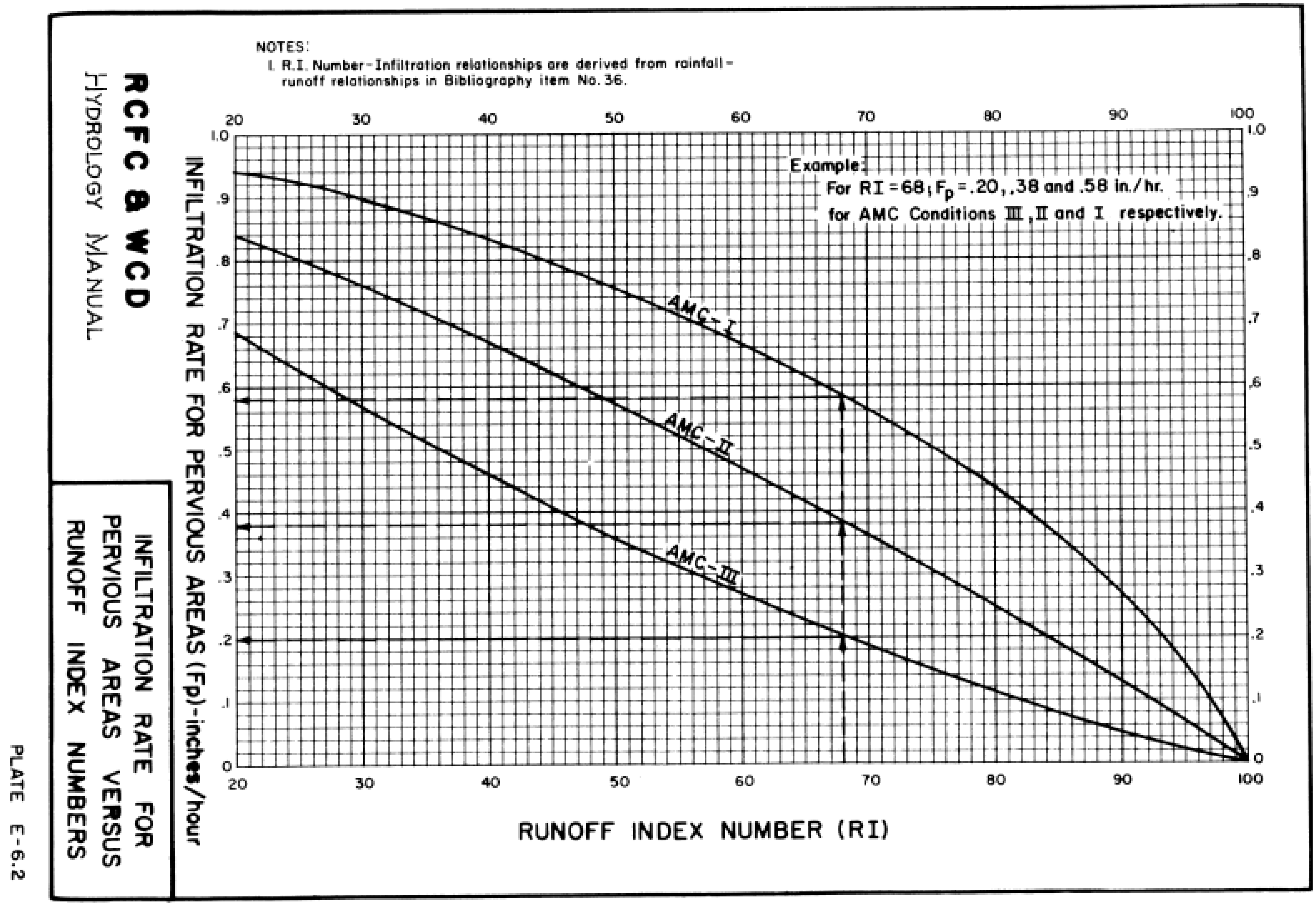
The Soil Conservation Service (now the National Resources Conservation Service) method outlined in the Hydrology Manual uses runoff index numbers in calculating infiltration rates. The runoff index numbers represent runoff potential and range from 0 to 100 with 100 having the highest runoff potential (i.e., lowest infiltration/abstraction). Plate E.6-1 (Figure 6 below) of the District Hydrology Manual tabulates runoff index numbers for AMC II condition for each cover type/quality of cover and each soil group. These values are then calculated as an area weighted average and used to get a runoff index number for each watershed. These averaged runoff index numbers are used to calculate an infiltration rate. Calculations for the assigned RI value is included in Appendix B excel spreadsheet.

Figure 6: RI Table from Hydrology Manual Plate E-6.1

RUNOFF INDEX NUMBERS OF HYDROLOGIC SOIL-COVER COMPLEXES FOR PERVIOUS AREAS-AMC II

Cover Type (3)	Quality of Cover (2)	Soil Group A	B	C	D
NATURAL COVERS -					
Barren (Rockland, eroded and graded land)		78	86	91	93
Chaparrel, Broadleaf (Manzonita, ceanothus and scrub oak)	Poor	53	70	80	85
	Fair	40	63	75	81
	Good	31	57	71	78
Chaparrel, Narrowleaf (Chamise and redshank)	Poor	71	82	88	91
	Fair	55	72	81	86
Grass, Annual or Perennial	Poor	67	78	86	89
	Fair	50	69	79	84
	Good	38	61	74	80
Meadows or Cienegas (Areas with seasonally high water table, principal vegetation is sod forming grass)	Poor	63	77	85	88
	Fair	51	70	80	84
	Good	30	58	72	78
Open Brush (Soft wood shrubs - buckwheat, sage, etc.)	Poor	62	76	84	88
	Fair	46	66	77	83
	Good	41	63	75	81
Woodland (Coniferous or broadleaf trees predominate. Canopy density is at least 50 percent)	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	28	55	70	77
Woodland, Grass (Coniferous or broadleaf trees with canopy density from 20 to 50 percent)	Poor	57	73	82	86
	Fair	44	65	77	82
	Good	33	58	72	79
URBAN COVERS -					
Residential or Commercial Landscaping (Lawn, shrubs, etc.)	Good	32	56	69	75
Turf (Irrigated and mowed grass)	Poor	58	74	83	87
	Fair	44	65	77	82
	Good	33	58	72	79

Figure 7: Infiltration Rate Table Plate E-6.2



Since the SCS method only considers infiltration rates in pervious areas, the infiltration rate (Fp) found was adjusted to account for the percentage of impervious area using the equation on Page E-8 of the Manual, shown below.

Equation for adjusted infiltration rate, from Page E-8 of the Manual:

$$F = F_p(1.00 - 0.9A_i)$$

where,

Fp = Loss rate for pervious areas in inch/hr. (Plate E-6.2)
F = Adjusted loss rate in inch/hr.
Ai = Impervious area in decimal percent

The adjusted infiltration rate is combined with the precipitation discussed in Section 2.2 to create a rainfall hyetograph to be used in HEC-HMS hydrologic modeling.

2.5. Hydrologic Modeling

Finally, the resulting information for each of the above variables was used to generate runoff hydrographs and peak flow rates for each watershed to be used in the modeling. Three different storm scenarios were analyzed to determine which gave the highest runoff potential: 3-hour, 6-hour, and 24-hour storm. The 1-hour storm was not analyzed as it is mainly used in rational hydrology.

2.5.1. HEC-HMS Hydrology

HEC-HMS V4.3 was utilized to calculate runoff and account for routing between the watersheds within Tucalota Creek. It was initially intended to create a single HEC-HMS hydrologic model to account for every single watershed, however, watershed T2 had multiple streams within it that the District desires to map as a floodplain. When watershed T2 was split up to account for this, it was discovered that T2-A was far too small to accurately use synthetic unit hydrograph methodology. Watershed T2-A is only 82 acres big, which is far underneath the minimum boundary of 300 acres for the synthetic unit hydrograph method. Watersheds T1 through T7 are dubbed as Main Watersheds and watersheds T2-A through T2-E are dubbed as T2 Sub Watersheds. Figure 8 below shows the Main Watersheds and Figure 9 shows the T2 Sub Watersheds with the Main Watersheds. Note the relative size of T2-A compared to all other watersheds. Also note that Sub Watersheds T2-A through T2-E are completely covering Main Watershed T2 in Figure 9.

Once this was discovered, it was decided to create two different HEC-HMS models, one to account for just the Main Watersheds and another to account for just the T2 Sub Watersheds. The T2 Sub Watersheds HEC-HMS model will only account for watersheds T2-B, T2-C, T2-D, and T2-E. Watershed T2-A is not represented in any model. Instead, the HEC-HMS results for T2 in the Main Watershed model will be the flow rate used for watershed T2-A since T2-A and T2 share the same concentration point and the routing within the watershed is not needed.

Figure 8: Main Watersheds

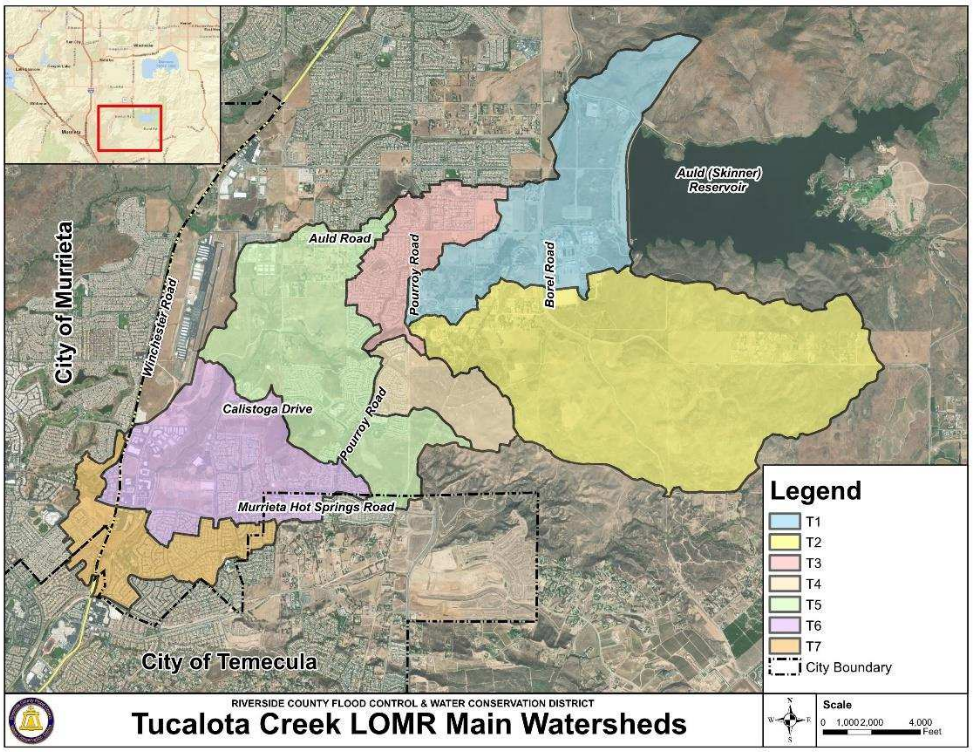
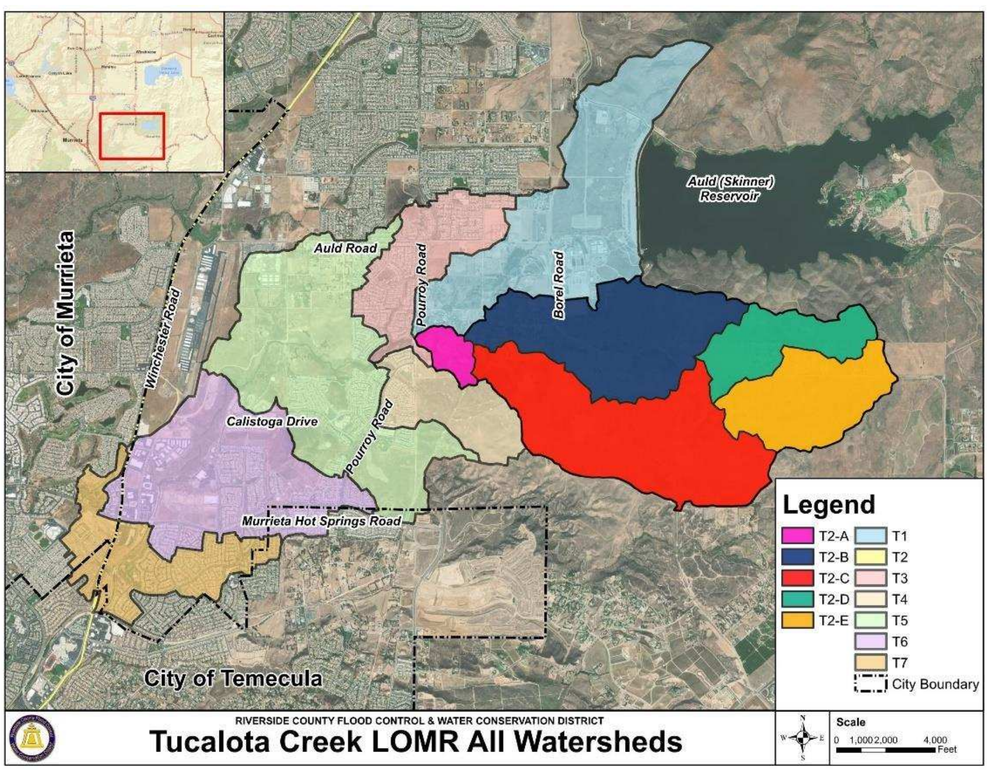


Figure 9: Watershed Comparison



The information presented in sections 2.1, 2.2, 2.3, and 2.4 are first input into District HEC-HMS preprocessor to generate effective rainfall hyetograph and s-graph data. All watersheds are put through the processor except for T2-A. Outputs from the preprocessor are then input into HEC-HMS as user defined losses since HEC-HMS does not have an option for the loss method the District uses. Preprocessor outputs can be found in Appendix B.

Routing is required through T3, T5, T6, and T7 for the Main Watershed model and only T2-C for the T2 Sub Watershed model. Flow from tributaries and upstream watersheds must make their way through these watersheds. Muskingum Cunge routing is used in HEC-HMS. The routing is based on the ground characteristics of each watershed. MicroStation V8 was used to generate the slope (ft/ft), length (ft), and average approximate cross section of each watershed. These were then input directly into HEC-HMS. The resulting Main Watershed and T2 Sub Watershed HEC-HMS models can be viewed in Appendix B. Tables 6 and 7 below show the results for each watershed directly from the model. Tables 8 and 9 show the routing results directly from the two models. Green cells highlight which flow rate governs for this study.

Table 6: HEC-HMS Main Watershed Model Results

Storm Event	T1	T2	T3	T4	T5	T6	T7
3 HR	978	1588	472	379	1452	1238	597
6 HR	887	1501	436	341	1298	1095	534
24 HR	426	914	184	144	540	439	205

Table 7: HEC-HMS T2 Sub Watershed Model Results

Storm Event	T2-B	T2-C	T2-D	T2-E
3 HR	620	710	306	438
6 HR	572	662	280	396
24 HR	189	132	321	315

For each watershed individually, the 3-hour storm governed the flow rate used in the modeling. Note that not all flow rates highlighted in green are used in the modeling but are the governing flow rate for that individual watershed.

Table 8: HEC-HMS Main Watershed Routing Results

Storm Event	102	103	104	105	106
3 HR	2109	2444	3102	3442	3457
6 HR	2123	2578	3317	3554	3580
24 HR	1245	1480	1878	2184	2315

Table 9: HEC-HMS T2 Sub Watersheds Routing Results

Storm Event	203	205	205 T2-C Side
3 HR	741	1583	1028
6 HR	676	1554	N/A
24 HR	280	819	N/A

When routing is considered, the six-hour storm governs, which is expected of watersheds with larger area. This is why the Main Watersheds model routing results show the 6-hour storm governing in all concentration points. For each individual watershed, the 3-hour storm governs. And for the T2 Sub Watersheds routing results, the 3-hour storm governs, which is consistent with the results of the T2 watershed, since that is also governed by the 3-hour storm.

The only flow rate that the HEC-HMS models do not give us is the flow rate created just upstream of the 205 concentration point within the T2-C watershed. This flow rate should be a culmination of the flows from T2-C, T2-D, and T2-E. To account for this flow rate, the 3-hour hydrograph for T2-C was added to the hydrograph created by the routing of T2-D and T2-E above it. The highest flow rate after adding the hydrographs together is used as the governing flow rate of the HEC-RAS reach within T2-C.

2.5.2 Skinner Reservoir

Lake Skinner is a reservoir created in 1973 at the upstream limits of Tucalota Creek, near Bachelor Mountain. The reservoir is operated and maintained by Metropolitan Water District and has a storage capacity of over 40,000 acre-feet. Although Skinner Reservoir effectively cuts off the upper Tucalota Creek watershed from the lower portion under typical storm conditions, under the 100-year storm, runoff from the reservoirs to lower Tucalota is possible.

To account for the reservoir, a 24-hour storm needs to be considered since that is the storm that produces the highest volume and, therefore, the highest runoff downstream. The District has decided to use the flow rate calculated by the US Army Corps of Engineers (USACE) in the 2000 Murrieta Creek Feasibility Study. The Feasibility Study calculates hydrology from 2001, as well as a future condition at 2051. Since the outlet structure for Skinner Reservoir has a set capacity, the flow rate out of the reservoir is the same in both 2001 and 2051 conditions, at 2080 CFS. In order to stay conservative, the District has decided to add the 2080 CFS flow rate from the outlet structure directly to each concentration point along the mainline. This is conservative because it is very unlikely to have a 24-hour storm on the upstream side of Tucalota Creek and a 6-hour storm on the downstream side of Tucalota Creek happen in a way where both storms cause a runoff peak at the same time and confluence with each other. However, for this study the District is choosing to utilize this flow addition.

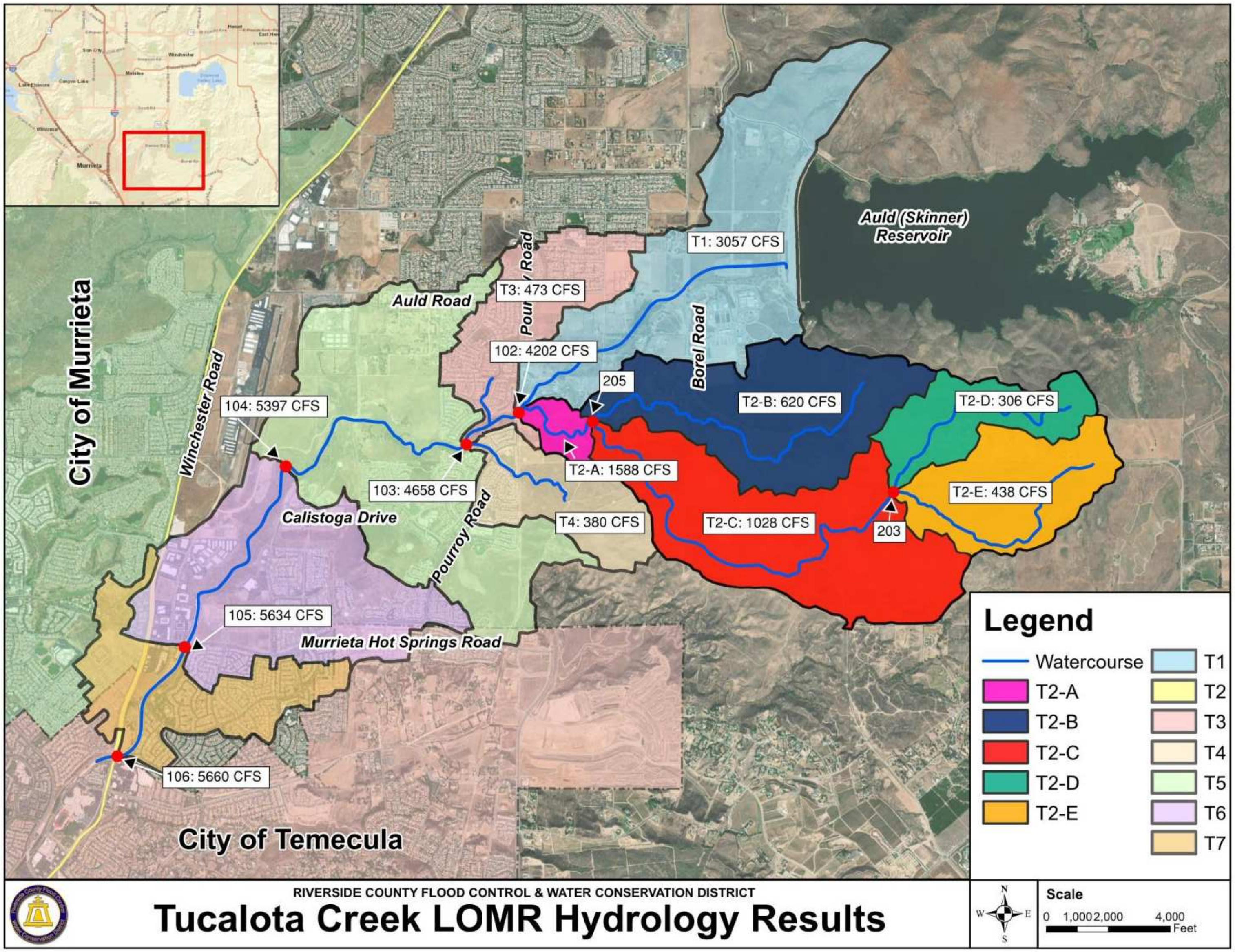
2.5.3 Final Flowrates

Tables 8 and 9 show the final flowrates calculated with the HEC-HMS models. Table 10 shows the final flow rates including impacts from Skinner Reservoir, which is used in the accompanied HEC-RAS model. Figure 10 shows an exhibit displaying the watersheds and flow rates used in the hydraulic modeling.

Table 10: Final Flow Rates

Concentration Point Location	Watersheds	HEC-HMS Flow Rate (CFS)	Impact from Skinner Reservoir (CFS)	Final Flow Rate (CFS)
102	T1	978	2080	3,058
102	T1, T2	2,122	2080	4,202
102	T2	1,588	N/A	1,588
103	T3	473	N/A	473
103	T1 - T4	2,578	2080	4,658
103	T4	380	N/A	380
104	T1 - T5	3,317	2080	5,397
105	T1 - T6	3,554	2080	5,634
106	T1 - T7	3,580	2080	5,660
203	T2-D	306	N/A	306
203	T2-E	438	N/A	438
205	T2-C, T2-D, T2-E	1,028	N/A	1,028
205	T2-B	620	N/A	620

Figure 10: Final Flow Rate Exhibit



3. Hydraulic Analysis

The main channels around the majority of Tucalota Creek are deep and ground adjacent to the channels often slope back into the channel. Therefore, the use of a one-dimensional backwater step calculation is appropriate for this mapping analysis. HEC-RAS V5.0.6 is chosen for this 1-D model. HEC-RAS 1-D is capable of utilizing surveyed ground points to generate cross sections to be used in backwater step calculation. The following sections will describe the hydraulic analysis efforts and associated results.

3.1 Effective Model/Duplicate Effective Model

The area is currently mapped as a FEMA Zone D and FEMA Zone Unshaded X. There is no effective model or duplicate effective model. This study will delineate the first FEMA floodplain in the area and piggyback off Warm Springs Tributary C PMR (LOMR Case No. and 21-09-0027S, 316-PMR ongoing).

3.2 Existing Conditions model

There is no effective floodplain to mimic with an existing conditions model. This model is the first one to study the area. Therefore, no existing conditions model exists.

3.3 Proposed Conditions Model

The proposed Mainline floodplain was modeled from upstream of Murrieta Hot Springs up until the dam of Skinner Reservoir. Tributary T3 goes from just east of Lilac Sky Lane to a confluence with the Mainline downstream of Honey Pine Road. Tributary T4 starts near the Metropolitan Water District (MWD) underground aqueduct line and confluences with the Mainline just downstream of Pourroy Road. Tributary T2-A starts upstream of Green Knolls Road and goes down to a confluence with the Mainline, just upstream of Pourroy Road. T2-B goes from northeast of Borel Road and connects to the upstream side of T2-A where it confluences with T2-C. T2-C starts just downstream of Borel Road and connects to T2-A and T2-B. T2-D starts north of Halifax Lane and T2-E starts just south of Ashfield Lane. Both confluence at the upstream side of T2-C.

Most areas within the floodplain limits have little to no improvements. The only areas with improvement are the downstream areas of T4, the entirety of T3, and about 3000' downstream of Pourroy Road in the Mainline. These areas have tract developments near them, however, there is ample open space left for Tucalota Creek.

3.3.1 Topography

Digital Terrain Models (DTMs) were created for this region using LiDAR data. The data was collected on January 9, 2012 for the majority of the area. The downstream most area was collected on August 30, 2010. For the majority of the study area, the LiDAR collected in 2012 and 2010 accurately reflect the existing condition. The only area where the LiDAR does not reflect the existing condition well is Tributary T3, the downstream area of Tributary T4, and the Mainline near the confluences of T3 and T4. After analysis, it was determined that the floodplain was contained within the natural open space channels designated by the tracts and therefore, still reflects the existing condition. No additional mapping was collected for this study. All DTMs were merged and processed in MicroStation and InRoads. All mapping is 4' and meets National Map Accuracy Standards. Vertical datum for all DTM points is NAVD 88.

3.3.2 Section Geometry

Cross sections were cut from the DTMs noted in Section 3.3.1 along the reaches of Tributary A. Most of the flow is natural conveyance, so no as-builts are needed for those areas. As-builts are used in the vicinity of Murrieta Hot Springs Road as the constructed soft bottom channel is owned and maintained by the District. As-builts are also used to model hydraulic structures, such as culverts and bridges and the cross sections at their upstream and downstream faces.

Table 11 indicates the various drawing plans that were considered when building the hydraulic model. All drawings, as-builts, and pertinent survey information is included in Appendix E. Some plans are highlighted to show the important information used in the modeling process. Benchmarks and datums for each plan set were checked prior to modeling. Model cross section descriptions will also note if plans were used in any part of it.

In 2016 a survey as-built was completed of Winchester Road (SR-79 Highway) and Willows Road. An additional survey was completed in 2021 for Honey Pines Road and Pourroy Road culvert crossings.

Table 11: Plans Used in Hydraulic Model

DWG No.	As-built	Title	Reach	Sections Affected
7-0135	4-3-1997	Tucalota Creek – Phase 1 Channel Improvements	Mainline	STA 5000 to STA 7200 and Murrieta Hot Springs Crossing
958t_BR	9-16-2015	Tucalota Creek Bridge Plans Pourroy Road	Mainline	STA 22484 to STA 22620 and Pourroy Road Crossing (Butterfield Stage Road)
7-0149	9-29-1998	Santa Gertrudis Creek Channel Stage 3	Mainline	Downstream boundary condition and confluence as-built flow rate
Bridge Crossings	7-2016	Santa Gertrudis – Tucalota Creek Crossings	Mainline	STA 1002 to STA 1136, SR-79 Highway Crossing, and Willows Street Crossing
Culvert Crossings	12-7-2021	Tucalota Creek Tributary Crossings	Tributaries T3 and T4	T3 STA 1282 to STA 1379 and Honey Pines Road T4 STA 1541 to STA 1675 and Pourroy Road

Junction structures are placed at all locations where a tributary stream confluences with the mainline stream. There are four junction structures: one at the confluence of the Mainline and Tributary T2, one at the confluence of the Mainline and Tributary T4, one at the confluence of T2-B and T2-C, and the last one at the confluence of T2-E and T2-D. All junctions have their reaches measured in MicroStation. The reaches are measured from the centerline point of a cross section to the centerline point of the next cross section downstream. All junctions also use the default energy equation to calculate water surfaces of both the upstream cross sections.

Conveyance obstructions are used in areas where water would not naturally flow downstream due to a physical obstruction, such as a basin or residential structure. Ineffective flow areas are used where water will pond or have zero velocity, such as minor tributary stream lows or at culvert/bridge openings.

3.3.3 Structures

There are multiple structures that were modeled in throughout the reaches. The Mainline has four major crossings. The first is Pourroy Road (or Butterfield Stage Road), which is just downstream of the confluence between Mainline and T2-A. Butterfield Stage Road is modeled after the as-built plans and is a 96' wide, single pier row bridge. Murrieta Hot Springs Road which is shown on the Tucalota Creek Stage 1 Plans (7-135) and is a free-span bridge over a constructed trapezoidal channel. Willows Road crossing is shown on surveyed as-builts and is also a free-span bridge. SR-79 is shown on the survey as-builts and is a single pier bridge.

Additionally, in Tributary T3 there is a 4-cell 48" RCP culvert under Honey Pines Road, which is given by the culvert as-builts. In Tributary T4, there is a 5.5-foot RCP underneath Pourroy Road, which is also given by the culvert as-builts. Also, in Tributary T4 is Sorrento Valley Storm Drain. This storm drain conveys flows from the developed tract area of T4 and discharges at the downstream end of Pourroy Road next to the 5.5-foot RCP described above. The flows in this storm drain were deemed significant. Due to this, the flows in the natural channel upstream of the Pourroy Road should not include area from the tracts as they are already contained by Sorrento Storm Drain. Therefore, the flow from Sorrento Valley Storm Drain is subtracted from the calculated flowrate to generate a flow rate upstream. The new flowrate upstream of Pourroy Road is 288 CFS, while the flowrate downstream of Pourroy Road remains as is calculated within the hydrology. As-builts of this facility are included to show the hydrologic data associated with the storm drain. All information for structures can also be found on Table 11.

There are multiple minor crossings that exist throughout the Mainline stream that were not modeled due to extremely low capacities or the majority of flow circumventing the crossing. These included Mazoe Road and Borel Road, both of which have culverts that only contain the low flow.

3.3.4 Manning's N-values

The n-value was chosen to account for the irregularity of the channel bottom and to model the effects of vegetation. Most main channel areas in the Mainline stream have n-values between 0.06 and 0.10 based on field visits and aerial imagery of the streams at various times of the year. A 0.1 is used periodically throughout the Mainline as many areas have high vegetation based on field visit. Main channel n-values for all tributaries except for T4 are 0.06 as there is considerable vegetation or obstruction. T4 was given an n-value of 0.05 on the upstream side and higher near

Pourroy Road due to increased vegetation. Overbanks in all reaches are 0.04 since the vegetation is generally lower and there are little to no obstructions.

Table 12 shows the typical n-values for all reaches.

Table 12: Typical N-values

Cover	N-Value
Mainline Main Channel	0.06-0.10
Mainline Overbank	0.04
Tributary T4 Main Channel	0.05-0.10
Tributaries Overbank	0.04
Tributaries Main Channel	0.06

3.3.5 Flow Regime and Boundary Conditions

The flow regime for all reaches is defaulted to subcritical using the 1-D HEC-RAS computational window. The downstream boundary condition of the Mainline stream is normal depth with a slope of 0.0040 based on as-built plans noted in Table 11. The model was carried down into Santa Gertrudis Creek to ensure that both the confluence flow rate and the backwater from SR-79 bridge is adequately characterized. Downstream boundary conditions for the tributaries are based on the centerline reach length and water surface elevations (WSE) calculated by each junction point. These junction points use the energy equation to determine a starting water surface for the upstream tributaries.

Along Tucalota Creek and its tributaries, flow changes are implemented to ensure that the discharge the channel experiences is accurate. Table 13 below summarizes all the flow rates and the reach and station they start. All flow rates reference Appendix B Hydrology.

Table 13: Summary of Flow Rate Changes

Station (ft)	Reach	Flowrate (CFS)
33109	Mainline	3057
22620	Mainline	4202
21476	Mainline	4658
20342	Mainline	5397
12667	Mainline	5634
5500	Mainline	5660
1306	Mainline	11300 (as-built)
4230	T2-A	1588
16488	T2-B	620
15884	T2-C	1028
24496	T2-D	306

9599	T2-E	438
2400	T3	473
4694/1541	T4 (US Pourroy/DS Pourroy)	288/380

Table 14 below summarizes the model parameters associated with Tucalota Creek LOMR.

Table 14: Model Parameters for Each Reach

Tucalota Creek	**Mainline**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	Normal Depth via As-Builts
Flow Regime	Subcritical
D/S Limits	STA 475
U/S Limits	STA 33109
Tucalota Creek	**T3**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	T3 Junction Point
Flow Regime	Subcritical
D/S Limits	STA 1000
U/S Limits	STA 2400
Tucalota Creek	**T4**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	T4 Junction
Flow Regime	Subcritical
D/S Limits	STA 1000
U/S Limits	STA 4818
Tucalota Creek	**T2-A**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL

D/S Boundary Cond.	T1/T2 Junction Point
Flow Regime	Subcritical
D/S Limits	1000
U/S Limits	4230
Tucalota Creek	**T2-B**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	T2 Downstream Junction Point
Flow Regime	Subcritical
D/S Limits	4476
U/S Limits	16488
Tucalota Creek	**T2-C**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	T2 Downstream Junction Point
Flow Regime	Subcritical
D/S Limits	1000
U/S Limits	15884
Tucalota Creek	**T2-D**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	T2 Upstream Junction Point
Flow Regime	Subcritical
D/S Limits	16219
U/S Limits	24496
Tucalota Creek	**T2-E**
Geometry Name	Final Tucalota Creek
Flow Name	HECHMS+USACE
Plan	Tucalota Creek FINAL
D/S Boundary Cond.	T2 Upstream Junction Point
Flow Regime	Subcritical
D/S Limits	1000
U/S Limits	9599

4. Resulting Floodplain and Impacts

The HEC-RAS detailed study water surface elevations are shown on the topographic workmap in Appendix D, in the HEC-RAS model, and in an Excel file called "HEC-RAS Results WSE" located in Appendix C. The mapped floodplain will stay within its natural flow path for all reaches.

The resulting floodplain for the Mainline and all tributaries will be mapped as a FEMA Zone AE. A floodway will not be designated in this study. It should be noted that, due to a District internal decision, the downstream area of the floodplain will not be mapped as a FEMA Zone AE and will be left as Zone Unshaded X. The mapped floodplain stops at STA 7347. The model for the downstream area is still submitted, however it will not be mapped.

The study will also delineate a new FEMA Zone D boundary just outside of the watershed limits of Tucalota Creek. The FEMA Zone AE will be located within the watershed boundaries. The bottom-line impact is an addition of 421 acres of FEMA Zone AE and removal of 4709 acres of FEMA Zone D. It is proposed to change the area within the watersheds that are not revised to a FEMA Zone AE to a FEMA Zone Unshaded X (area of minimal flooding).

Annotated FIRM Panels will only be created for FIRM Panel Number 06065C2720G, 06065C2740G, 06065C2745G since those are the only published and printed panel. The remaining panels will be printed via Warm Springs Tributary C Physical Map Revision (PMR). This revision will operate under the assumption that Warm Springs Tributary C PMR (LOMR Case No. 21-09-0027S, 316-PMR) will become effective sometime in the future. Once the referenced PMR becomes effective, the remaining FIRM panels will be printed with the Tucalota Creek floodplain displayed on them. Therefore, the delineation of the proposed FEMA Zone D and FEMA Zone AE will only be displayed on the topographic workmap and via shapefiles. Figure 11 shows the proposed conditions floodplains. Note the removed downstream area.

Figure 11: Proposed Conditions Exhibit