PIMA COUNTY
FLOOD CONTROL

MEMORANDUM

DATE: January 24, 2018

TO: Eric Shepp, PE
Deputy Director

FROM: Rachael Weissman, CFM
Senior Hydrologist

Andy Seiger
Civil Engineering Manager

SUBJECT: Hydrologic and Hydraulic Analysis of Canoa Hills Golf Course

A hydrologic and hydraulic analysis was completed on the Canoa Hills Golf Course in Green Valley, AZ. The golf course consists of approximately 130 acres of fairway, surrounded by elevated subdivisions. The fairway occupies the bottoms of the natural drainages, which generally run from the NW to the SE. Interstate 19 forms the downstream end of the golf course; culverts convey the surface runoff from the golf course under the Interstate and to the Santa Cruz River. With a few exceptions, the natural channels were eliminated during fairway construction by smoothing the drainage bottoms. Improvements include paved cart paths, ponds, and culverts under the residential streets which cross the fairway. Some of these culverts serve a dual purpose of drainage and cart access. The golf course has not been active for about three years. The grounds have been maintained minimally, including mowing. This analysis was based on existing conditions.

Hydrology

The contributing watershed to the 130 acre golf course is 1,719 acres. The upstream most area of the watershed consists of mine tailings on a very steep slope. Downstream of the mine tailings but upstream of the golf course is undeveloped natural dessert with rolling hills and defined washes. The washes flow into the golf courses, which have typically been graded to distribute flow in a sheet-like manner across the width of the fairway. In one case, a natural channel continues adjacent to the fairway.

The 100-year (1% annual chance) discharge was analyzed for this site using Pima County Regional Flood Control District PC Hydro version 6.1 software. Flow paths, soils, and vegetation types were analyzed using spatial analysis tools in ArcGIS. The site was divided into four drainage areas. A summary of the 100-year discharges is in the table below. A map of the drainage areas and the Hydrologic Data Sheets are provided as an attachment.

Wastershed	Area (acres)	100-Year Discharge (cfs)	USGS Regression Equation (cfs)
1	615	1,725	1,226
2	119	685	362
3	57	215	193
4	928	1,816	1,605
3+4	986	1,921	1,668

Hydraulics

The 100-year floodplain was delineated using HEC-RAS and HEC-GeoRAS software. Routing of the flood wave was not investigated, so the volume of ponded water predicted by this hydraulic analysis at certain locations was not compared to the available volume of runoff in the hydrograph. A flood routing investigation may reduce the magnitude of ponding at these areas. Ground elevation data was collected from 2015 PAG LiDAR data, which was processed into a 2-foot resolution digital elevation model (DEM) that was used for cross section data and floodplain mapping. Ten culverts were modeled within HEC-RAS, culvert sizes were field verified. Culvert invert elevations were collected from the DEM. Manning's "n" values used within this model are based on existing conditions. The limits of the resulting 100-Year Floodplain can be seen on the attached map.

During the 100-year storm event, Drainage Way 1 (Watershed 1) generally inundates the entire fairway, up to the steep slopes coming off the subdivisions. Stormwater will fill the ponds used as water features for the golf course. There is 1-10'x10' concrete box culvert that is under Camino Del Sol which is undersized and model results show the roadway being overtopped. The culvert causes backwater which inundates the club house with up to 1 foot of water. Downstream of Camino Del Sol the channel is reestablished and runs along the north side of the fairway. The channel is a natural sand and rock bottom and has fairly dense vegetated overbanks. During a field visit, significant downcutting was observed and railroad ties used as bank stabilization. In some places banks were more than 6 feet tall. At the downstream end of this drainage way the fairway widens and flows spread. Underneath the I-19 frontage road there are 2-6' corrugated metal pipe culverts, which are also undersized, model results show flow overtopping the frontage road.

Downcutting in Drainage Way 1

Drainage Way 2 (Watershed 2) originates within the former driving range. The 2-10'x10' concrete box culverts under Camino Del Sol contain the flow 100-year discharge. These culverts are also used as a golf cart path under the roadway. The 100-year floodplain within this drainage way is generally along the low flow area on the north side of the fairway. The floodplain widens and flow depths become deeper downstream as undersized culverts cause backwater. There are 2-4' corrugated metal pipe culverts under Camino Del Pato and 1-5' corrugated metal pipe culvert under the I-19 frontage road. Model results show that both of these roadways are overtopped during the 100-year event.

Driving Range, Headwaters of Drainage Way 2, looking upstream (to the NE)

Drainage Way 3 (Watershed 3) is a tributary to Drainage Way 4. Drainage Way 3 begins just upstream of Camino Urbano, where there is 1-30" corrugated metal pipe culvert, which cannot contain the 100-year discharge and does overtop this residential road. However, downstream of Camino Urbano, the fairway provides adequate capacity, leaving much of the fairway outside of the 100-year floodplain. At Camino Del Sol there are 2-48" corrugated metal pipe culverts, which contain the 100-year discharge. Downstream of Camino Del Sol there is a small grouted rock channel that flows downstream about 500 feet then discharges into the golf course green. The confluence of Drainage Way 3 with Drainage Way 4 occurs about 600 feet south of where Via De La Gloria dead-ends.

Grouted Rock Channel, Drainage Way 3

Drainage Way 4, like Drainage Way 1, is generally inundated the entire width of the fairway during the 100-year event. There are 2-10'x5' concrete box culverts at Camino Del Huarache which are undersized and model results show flow going over the road. At Camino Del Sol, flow is constricted through 1-8'x8' concrete box culvert which is also undersized and overtopped during the 100-year event. Downstream of Camino Del Sol and the confluence with Drainage Way 3, flows spread out to fill the fairway, with the exception of small hills along the golf course. At the downstream end of the drainage way, there are 2-10'x6' concrete box culverts under I-19 which contain the 100-year discharge.

Typical Low Flow Path

Subdivision Drainage

There are nine subdivisions which discharge storm runoff into the general vicinity of the golf course. Subdivision drainage flows down streets with curb and gutter, then discharges into drainage easements, which outlet into the golf course through constructed down-chutes. The designs of these down-chutes vary, but some examples seen were steep grouted rock channels, smooth paved chutes, or dumped rock, which may have railroad ties or grouted rip-rap as energy dissipaters at the downstream end to slow the water and redistribute it across the golf course. Locations of these drainage outlets can be seen on the attached map.

This subdivision drainage infrastructure seems to be functioning properly and constructed well. It is assumed that allowing the subdivision drainage to disperse over the golf course supplemented the irrigation needs of the golf course. Maintenance will be needed downstream of these drainage outlets, as erosion could occur easily with high velocity flows coming off the steep slopes.

Grouted Rock Outlet from Subdivision with Railroad Tie Dissipater at Downstream End

Concrete Paved Outlet from Subdivision with Grouted Rock at Downstream End

Conclusions

Without maintenance of the fairways for the last few years, the low areas of the fairways have begun to erode and develop small channels. In many places, this erosion has exposed corrugated plastic drain piping (approximately 6 inches in diameter). This piping was installed about 6 inches below ground in the low areas of the fairway, presumably to prevent the fairways from becoming water-logged during Monsoons. In addition, at a few locations channels are beginning to reestablish adjacent to the golf cart paths and eroding underneath the path. A byproduct of the erosion is sedimentation, which was also witnessed along the path.

In general, Drainage Ways 1 and 4 are more floodprone, they have the largest discharges and widest floodplains. It is expected that more erosion will occur within these drainage ways due to higher velocities. Restoration will be needed in these areas to control erosion of the forming channel. Drainage Ways 2 and 3 provide the most non floodprone space.

Erosion Reestablishing Channel, Exposed Piping

Erosion along Golf Cart Path, Exposed Piping

Sedimentation along Golf Cart Path

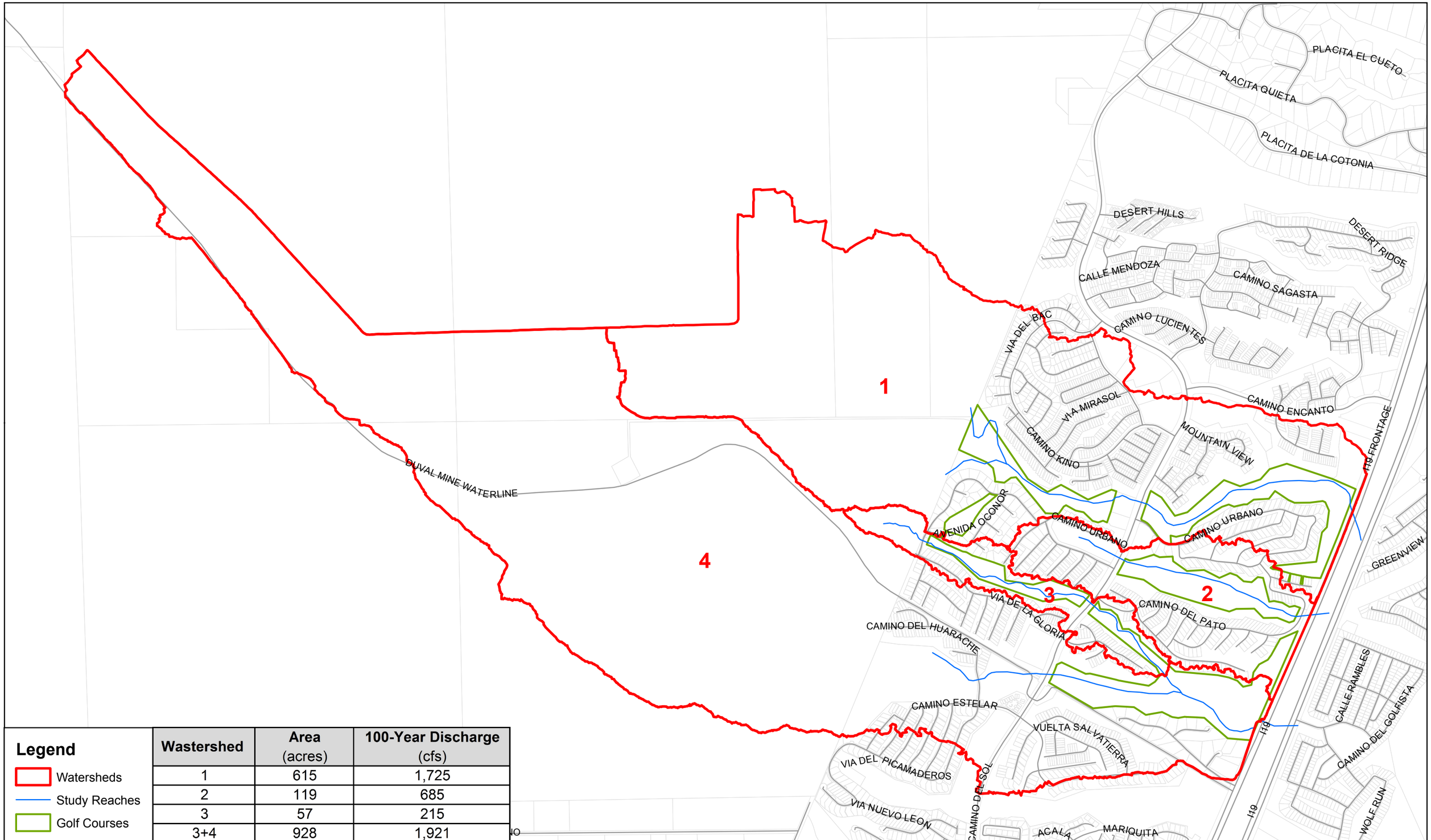
Erosion Upstream of Culvert at I-19 Frontage Road

Reclamation

The following observations may be valid if the golf course is to be allowed to return to a native state. Due to the manner in which the fairway was constructed by smoothing the drainage bottoms, reestablishment of the washes will be necessary. This process may proceed naturally, or alternatively by excavation guided perhaps by historic channel characteristics obtained from aerial photography. It is anticipated that wash reestablishment will produce sediment which may deposit in and near the ponding areas predicted by the hydraulic analysis. To maintain capacity of culverts, this deposition may need to be managed. Channel re-establishment may also damage the existing cart paths at locations where the cart path intersects the channel. This damage may be minimized by placement of bank protection and bridge construction on the cart path. When the main washes become established, the tributary flow paths back to the down-chutes carrying subdivision drainage onto the golf course will reestablish by head-cutting. Maintenance will be required to prevent this head cutting from damaging the outlet of the down-chutes. Ponds constructed within the fairway may need to be filled or breached.

Attachments:

- Drainage Area Map
- 100-Year Floodplain Map
- Subdivision Drainage Map
- PC Hydro Hydrologic Data Sheets



Legend

- Watersheds
- Study Reaches
- Golf Courses

Wastershed	Area (acres)	100-Year Discharge (cfs)
1	615	1,725
2	119	685
3	57	215
3+4	928	1,921

Canoa Hills Watershed Map

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Canoa Hills 100-Year Floodplain Map

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Canoa Hills 100-Year Floodplain Map

PIMA COUNTY
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HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Pima County	Prepared by:	R. Weissman
Project Name:	Conola Hills Golf Course	Date:	12/28/2017
Concentration Point:	1	Job #	001
Watershed Area:	615.09 Acres	Watershed Type	Suburban Foothills

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	369	1143	0.3228	0.08
2	111	4875	0.0228	0.045
3	88	5934	0.0148	0.035

Length of Watercourse (Lc):	11952	feet	Mean Slope:	0.0207
Length to Cen. of Gravity (Lca):	7045	feet	Weighted Basin Fac:	0.043
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	20

RETURN PERIOD: 100-years NOAA Data Obtained: 2017-12-28 04:22:18 PM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 31.8269 Longitude: -111.0216

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.91	1.38	1.71	2.31	2.86	3.17	3.27	3.71	4.04	4.43

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	26.6	82.3	86.81	0.56
C	53.5	87.6	90.38	0.66
D	19.9	91	93.46	0.757
Imp.	25	99	99	0.959

Weighted Runoff Coef. (Cw):	0.73	
Time of Concentration:	38.9	min
Rainfall Intensity (i) @ Tc:	3.82	in/hr
Runoff Supply Rate (q) @ Tc:	2.78	in/hr
PEAK DISCHARGE:	1725.3	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Pima County	Prepared by:	R. Weissman
Project Name:	Conola Hills Golf Course	Date:	12/29/2017
Concentration Point:	2	Job #	001
Watershed Area:	119.42 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	23	763	0.0301	0.022
2	41	1022	0.0401	0.035
3	20	552	0.0362	0.035
4	44	2441	0.018	0.035

Length of Watercourse (Lc):	4778	feet	Mean Slope:	0.0244
Length to Cen. of Gravity (Lca):	1856	feet	Weighted Basin Fac:	0.033
Veg. Cover Type(s):	Urban Lawns		Veg. Cover Density:	20

RETURN PERIOD: 100-years NOAA Data Obtained: 2017-12-29 11:27:32 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 31.8198 Longitude: -111.0127

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.9	1.37	1.7	2.29	2.83	3.15	3.25	3.69	4.01	4.41

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	46.7	83	87.4	0.573
C	53.3	88	91.15	0.681
D	-	-	-	-
Imp.	25	99	99	0.958

Weighted Runoff Coef. (Cw):	0.71	
Time of Concentration:	10.6	min
Rainfall Intensity (i) @ Tc:	7.99	in/hr
Runoff Supply Rate (q) @ Tc:	5.69	in/hr
PEAK DISCHARGE:	685.2	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Pima County	Prepared by:	R. Weissman
Project Name:	Conola Hills Golf Course	Date:	01/03/2018
Concentration Point:	3	Job #	001
Watershed Area:	57.28 Acres	Watershed Type	Suburban Foothills

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	46	1330	0.0346	0.045
2	105	4142	0.0254	0.035

Length of Watercourse (Lc):	5472	feet	Mean Slope:	0.0272
Length to Cen. of Gravity (Lca):	2626	feet	Weighted Basin Fac:	0.037
Veg. Cover Type(s):	Urban Lawns		Veg. Cover Density:	75

RETURN PERIOD: 100-years NOAA Data Obtained: 2018-01-03 12:13:48 PM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 31.8201 Longitude: -111.0198

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.9	1.37	1.7	2.29	2.83	3.15	3.25	3.69	4.01	4.41

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	47.3	74	80.69	0.412
C	52.7	83	87.4	0.573
D	-	-	-	-
Imp.	15	99	99	0.958

Weighted Runoff Coef. (Cw):	0.57	
Time of Concentration:	15.7	min
Rainfall Intensity (i) @ Tc:	6.59	in/hr
Runoff Supply Rate (q) @ Tc:	3.73	in/hr
PEAK DISCHARGE:	215.4	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Pima County	Prepared by:	R. Weissman
Project Name:	Conola Hills Golf Course	Date:	01/03/2018
Concentration Point:	4	Job #	001
Watershed Area:	928.49 Acres	Watershed Type	Suburban Foothills

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	297	1778	0.167	0.08
2	164.5	8669	0.019	0.045
3	51.5	3732	0.0138	0.035
4	46	3140	0.0146	0.035

Length of Watercourse (Lc):	17319	feet	Mean Slope:	0.0192
Length to Cen. of Gravity (Lca):	10671	feet	Weighted Basin Fac:	0.045
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	40

RETURN PERIOD: 100-years NOAA Data Obtained: 2018-01-03 03:19:33 PM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 31.8222 Longitude: -111.0344

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.92	1.39	1.73	2.33	2.88	3.2	3.29	3.74	4.08	4.47

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	22.94	81.2	86.04	0.543
C	67.28	86.4	89.76	0.644
D	9.78	89.4	91.88	0.707
Imp.	15	99	99	0.959

Weighted Runoff Coef. (Cw):	0.68	
Time of Concentration:	60.3	min
Rainfall Intensity (i) @ Tc:	2.87	in/hr
Runoff Supply Rate (q) @ Tc:	1.94	in/hr
PEAK DISCHARGE:	1815.8	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Pima County	Prepared by:	R. Weissman
Project Name:	Conola Hills Golf Course	Date:	01/12/2018
Concentration Point:	5	Job #	001
Watershed Area:	985.77 Acres	Watershed Type	Suburban Foothills

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	297	1778	0.167	0.08
2	164.5	8669	0.019	0.045
3	51.5	3732	0.0138	0.035
4	46	3140	0.0146	0.035

Length of Watercourse (Lc):	17319	feet	Mean Slope:	0.0192
Length to Cen. of Gravity (Lca):	10671	feet	Weighted Basin Fac:	0.045
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	40

RETURN PERIOD: 100-years NOAA Data Obtained: 2018-01-12 07:51:18 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 31.8221 Longitude: -111.0336

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.92	1.39	1.73	2.33	2.88	3.2	3.29	3.74	4.08	4.47

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	24.355	81.2	86.04	0.543
C	66.435	86.4	89.76	0.644
D	9.21	89.4	91.88	0.707
Imp.	15	99	99	0.959

Weighted Runoff Coef. (Cw):	0.68	
Time of Concentration:	60.4	min
Rainfall Intensity (i) @ Tc:	2.86	in/hr
Runoff Supply Rate (q) @ Tc:	1.93	in/hr
PEAK DISCHARGE:	1921.1	cfs

Notes:

Watersheds 3 and 4