TECHNICAL MEMORANDUM

Date: July 15, 2022

BKF No.: 20201331

Deliver To: Bruce Dorfman
Mallard Pointe 1915, LLC

From: Christopher Mills
BKF Engineers

Subject: **Mallard Pointe Preliminary Drainage Strategy**

I. BACKGROUND INFORMATION

I.A. Summary

The existing Mallard Pointe Project site is located at 1-22 Mallard Road in City of Belvedere, Marin County. The property is located on three (3) separate parcels which contain 22 existing units. The site is bounded by the Belvedere Lagoon on the north and east sides, Community Road on the west side, and residential units on the south side. The total site area is approximately 2.75 acres, with 2.63 acres being developable (0.12 acres are portions of Belvedere Lagoon). Within this developable area, about 78% is impervious area. The redevelopment improvement of this area includes construction of 42 proposed units, 3 ADUs, parking, and roadways and utilities to support the new developments.

Record information was used as a basis of design and was supplemented with a survey conducted by BKF (March 2022) where gaps in information occurred. The existing stormdrain system is composed of two (2) outfall pipes that cross through the Project site and discharge into Belvedere Lagoon. According to existing record maps depicted in the 2007 Matterson & Associates study[3] and Marin County GIS – (i) Outfall #1 is a 15-inch line located in the center of the site at existing 9 Mallard Road and (ii) Outfall #2 is a 15-inch line located at the southeast corner of the Project site, adjacent to 500 San Rafael Avenue. A drainage area of 19.3-acres is routed to these two (2) outfalls. About 16.6-acres is generated by offsite tributaries that are upstream of the Project site and 2.8-acres is contributed from the Project site itself.

Prior to offsite runoff reaching the Project site and downstream outfalls, runoff is routed to an existing diversion structure located on the Belvedere City Hall property, facing Community Road. This diversion structure routes approximately 6.5 cfs to Outfall #1 and 4.0 cfs to Outfall #2 during a 10-year storm event. Ponding occurs in existing condition at Community Road near Mallard Road, at the curb inlets adjacent the Project site. Based on the 2006 Matterson & Associates study[2], residents have described historical flooding problems that occur about once a year, with ponding depths exceeding six (6) inches.

I.B. Onsite and Offsite
The analysis presented in this technical memorandum focuses on the Mallard Pointe Project onsite and offsite drainage system operation during the 10-year storm event. The onsite analysis applies Bentley StormCAD to design the Project's proposed onsite stormdrain system. The offsite analysis applies Innovyze XPSWMM to evaluate existing deficiencies of the offsite stormdrain system.

An understanding of existing flooding occurring at Community Road near Mallard Road is required prior to assessing proposed onsite Project hydraulics. Thus, the prerequisite to prepare offsite drainage modeling using XPSWMM. The XPSWMM offsite analysis determined ponding depths at Community Road, and the StormCAD onsite analysis verified the proposed storm system does not worsen existing condition flooding occurring at Community Road.

II. DRAINAGE STRATEGY

II.A. Onsite

Onsite Overview
In the proposed condition, all onsite existing stormdrain lines within the Project site will be removed. Additionally, there are no proposed improvements to existing Outfalls #1 and #2. A new series of treated and untreated stormdrain lines will be installed to accommodate onsite and offsite drainage. The new stormdrain network will reconnect to existing Outfall #1, while Outfall #2 will remain unchanged.

The Project's proposed stormdrain system is analyzed with StormCAD modeling for the 10-year storm event. StormCAD performs steady-state calculations to determine maximum hydraulic grade lines for the system. The onsite design focuses on fulfilling freeboard requirements and preventing increased flooding to the existing condition at Community Road.

A layout of the Project's onsite drainage areas and stormdrain system is shown in **Attachment 1**.

Onsite Analysis

Hydrology

The StormCAD model performs runoff computations via the rational method which requires drainage area, runoff coefficient, and rainfall intensity.

- Drainage Area: The onsite drainage watershed is subdivided into 14 subareas – (i) Subareas 1 through 12 represent each lot's roof area. These subareas will be treated within the respective lot's bioretention area(s). (ii) Subarea 13 represents the Project's roadways, walkways and lot driveway/frontage areas that naturally drain towards the proposed roadways. Subarea 13 drainage is captured via curb inlets within Mallard Road and will be routed through an untreated storm drain line and pumped to a series of bioretention areas. (iii) Subarea 14 represents the landscaped areas that surface flow into the Lagoon and will be considered a "self-treating" area.

- Runoff Coefficient: The impervious areas (roadway, roof, walkway) apply a runoff coefficient of 0.80, and the pervious areas (landscape, bioretention) apply a runoff coefficient of 0.30.
- Rainfall Intensity: A time of concentration of 5 minutes is assumed for each subarea, and rainfall intensities are adopted from NOAA Atlas 14.

Hydraulics

The Project's proposed stormdrain pipes are designed with assumptions consistent with available studies[2,3,4] and will adequately convey the 10-year storm event. The StormCAD modeling computes hydraulic grade line by solving Manning's equation and head losses. Factors that affect hydraulic grade line include pipe size, head losses (which include friction, entrance, bend and exit losses), and tailwater elevation.

The hydraulic modeling using StormCAD requires the following for simulation runs:

- Storm Utility Data: The onsite stormdrain system horizontal design follows BKF's Mallard Point Tentative Map, dated May 2022. The vertical design adheres to minimum pipe cover and minimum slope to achieve a minimum velocity of two (2) feet per second when flowing full.
- Boundary Condition: A winter water surface elevation[4] of 2.43 feet (NAVD 88) was used as the tailwater elevation at the outfall discharging into Belvedere Lagoon.

Onsite Results

The proposed storm system conveys the 10-year design flow while meeting a minimum of twelve (12) inches of freeboard and minimum flow velocities. Similarly, the Project's proposed stormdrain design reduces existing flooding at Community Road to a minimum of six (6) inches below the structure rim elevation. The StormCAD onsite analysis results are shown in **Attachment 2**.

Note: The mimimum twelve (12) inches of freeboard is not maintained for the onsite proposed system at two (2) catchbasins along Community Road, however, the proposed storm improvements reduce flooding at Community Road in comparison to existing condition.

II.B. Offsite

Offsite Overview

The offsite drainage system analysis for the Project is conducted with XPSWMM to quantify runoff causing ponding at Community Road near Mallard Road. The XPSWMM modeling is created for the existing storm drain system and aims to determine the following: (i) performance of existing system during a 10-year, 24-hour storm and (ii) total flow tributary to the lowest catch basin at Community Road. An understanding of the existing system operation is crucial to ensure the Project's proposed onsite storm drain system is not creating adverse hydraulic impacts in context of the existing condition.

The XPSWMM offsite modeling is a one-dimensional flow simulation combining hydrology and hydraulic computations. The model determines rainfall losses for watersheds and routes runoff hydrographs through conduits using conservation equations.

<u>Offsite Analysis</u>

Hydrology

For Project hydrology, the XPSWMM modeling requires the following watershed parameters: rainfall depth, rainfall distribution, area, imperviousness, and losses. These parameters are described herein:

- <u>Rainfall Depth</u>: Rainfall data is adopted from NOAA Atlas 14 – 10-year, 24-hour depth is 5.04 inches.
- <u>Rainfall Distribution</u>: The rainfall distribution follows the Natural Resources Conservation Service (NRCS) Type IA 24-hour synthetic pattern.
- <u>Area</u>: Watersheds are delineated per County LiDAR and utility maps – offsite boundaries shown on **Exhibit 1** in **Attachment 3**.
- <u>Imperviousness</u>: Impervious fractions are estimated from aerial imagery with engineering judgement.
- <u>Losses</u>: The precipitation loss rates follow the Soil Conservation Service (SCS) runoff curve number (CN) method, where a CN of 80 is applied for pervious area with an assumed soil type "D".

Hydraulics

The offsite system hydraulics are evaluated for the 10-year, 24-hour storm to verify peak discharges and surcharged flows for the existing system. The storm drain network setup is based on the following:

- <u>Storm Utility Data</u>: Storm drain rims, inverts, diameters, and lengths based on field surveying performed in March 2022 – modeled storm drain network displayed on **Exhibit 2** in **Attachment 3**.
- <u>Boundary Condition</u>: The model applies a downstream hydraulic boundary condition at the two (2) outfalls discharging into Belvedere Lagoon – a winter water surface elevation of 2.43 feet (NAVD 88) is applied per the Stetson Engineers Belvedere Lagoon Hydrologic and Hydraulic Report (2014).

<u>Offsite Results</u>

A summary of the 10-year, 24-hour results from the XPSMM offsite analysis is tabulated in **Table 1** through **Table 3** in **Attachment 3**, which includes max watershed runoff and storm system max hydraulic grade lines, flows, and velocities.

III. CONCLUSION

The StormCAD onsite calculations presented herein confirm the proposed onsite stormdrain system safely captures and conveys the 10-year storm event. The StormCAD results show the 10-year hydraulic grade line is contained within catch basins along Community Road; represented as structures MH-31 and MH-32 in the model (refer to **Attachment 2**) – see tabulated results below. This result indicates a reduction in flooding due to the proposed onsite stormdrain infrastructure. For comparison, results of the XPSWMM offsite modeling are shown for the existing catch basins along Community Road.

StormCAD Onsite Structure ID	XPSWMM Offsite Structure ID	Structure Rim Elevation	StormCAD Onsite 10-Year Max HGL	XPSWMM Offsite 10-Year Max HGL
MH-32	N-03	6.61 feet	5.98 feet	6.62 feet
MH-31	N-04	6.26 feet	5.46 feet	6.53 feet

IV. ATTACHMENTS

1. Preliminary Stormwater Concept
2. StormCAD Onsite Analysis
3. XPSWMM Offsite Analysis
   - Exhibit 1. Watershed Map
   - Exhibit 2. Stormdrain Model Map
   - Table 1. Model 10-Year Hydrology Data
   - Table 2. Model 10-Year Hydraulic Data – Nodes
   - Table 3. Model 10-Year Hydraulic Data – Links
   - Reference 1 – NOAA Atlas 14
   - Reference 2 – Technical Release 55: 24-Hour Rainfall
   - Reference 3 – Technical Release 55: Curve Numbers

V. REFERENCES

1. "Section VI. Drainage Facilities, Subsection 24.0.520 – Hydrologic and Hydraulic Design," By Marin County, CA Municode.
2. "Belvedere Community Road Drainage Improvements," By Mattern & Associates. Dated November 14, 2006.
3. "Belvedere Community Road Drainage Improvements," By Mattern & Associates. Dated April 27, 2007.
4. "Overview of Lagoon Water," Stetson Engineer Inc., Dated 2014.

ATTACHMENT 1.
PRELIMINARY STORMWATER CONCEPT

DMA SUMMARY TABLE

BOUNDARY	CONVENTIONAL SURFACE (SF)			DRAINS TO	REQUIRED LID OR BMP (SF)	PROVIDED LID OR BMP (SF)	TOTAL (SF)	TOTAL (ACRE)
WATERSHED	ROOF	HARDSCAPE	LSP					
DMA-1a	1,287	151	662	IMP 1a	64	84	2,184	0.05
DMA-1b	1,285	90	177	IMP 1b	57	128	1,552	0.04
DMA-2a	3,033	72	370	IMP 2a	128	129	3,604	0.08
DMA-2b	443	127	148	IMP 2b	24	26	718	0.02
DMA-3a	909	-	116	IMP 3a	38	55	1,080	0.02
DMA-3b	2,319	-	-	IMP 3b	93	118	2,437	0.06
DMA-4	2,253	154	338	IMP 4	100	251	2,996	0.07
DMA-5a	2,373	-	601	IMP 5a	101	143	3,117	0.07
DMA-5b	1,500	-	-	IMP 5b	60	144	1,644	0.04
DMA-6	2,252	-	99	IMP 6	91	123	2,474	0.06
DMA-7a	2,704	-	282	IMP 7	111	116	3,102	0.07
DMA-7b	523	-	-	IMP 7b	21	24	547	0.01
DMA-8a	2,455	60	173	IMP 8a	102	147	2,835	0.07
DMA-8b	1,019	151	254	IMP 8b	49	62	1,486	0.03
DMA-9	3,220	207	505	IMP 9	142	178	4,110	0.09
DMA-10	2,070	220	693	IMP 10	99	154	3,137	0.07
DMA-11	4,025	2,121	607	IMP 11	252	317	7,070	0.16
DMA-12a	908	-	273	IMP 12a	39	141	1,322	0.03
DMA-12b	1,945	-	30	IMP 12b	78	96	2,071	0.05
DMA-12c	1,967	-	34	IMP 12c	79	96	2,097	0.05
DMA-12d	1,970	-	29	IMP 12d	79	96	2,095	0.05
DMA-12e	2,895	-	-	IMP 12e	116	128	3,023	0.07
DMA-12f	1,412	-	38	IMP 12f	57	63	1,513	0.03
DMA-12g	5,020	-	-	IMP 12g	201	221	5,241	0.12
DMA-12h	897	259	508	IMP 12h	51	92	1,756	0.04
DMA-13	-	22,129	4,096	IMP 13	926	1,028	27,253	0.63
DMA-14a	-	585	2,168	IMP 14a	293	322	3,075	0.07
DMA-14b	-	553	1,814	IMP 14b	277	303	2,670	0.06
DMA-14c	-	711	1,221	IMP 14c	356	388	2,320	0.05
DMA-14d	-	887	1,321	IMP 14d	444	457	2,665	0.06
DMA-14e	-	534	1,684	IMP 14e	267	317	2,535	0.06
DMA-14f	-	362	1,805	IMP 14f	181	243	2,410	0.06
DMA-14g	-	832	3,334	IMP 14g	416	454	4,620	0.11
DMA-14h	-	356	1,877	IMP 14h	178	282	2,515	0.06
DMA-14i	-	504	840	IMP 14i	252	306	1,650	0.04
DMA-14j	-	890	843	IMP 14j	445	447	2,180	0.05
DMA-14k	-	933	1,575	IMP 14k	467	467	2,975	0.07
OVERALL TOTAL	50,684	32,888	28,515	-			120,079	2.76

LEGEND

- EXISTING PROPERTY LINE
- PROPOSED PROJECT BOUNDARY
- PROPOSED PROPERTY LINE
- BUILDING SETBACK
- BULKHEAD LIMITS
- 100 YEAR BASE FLOOD ELEVATION
- ROAD CENTERLINE
- DRAINAGE MANAGEMENT AREA
- ROOF AREA
- IMPERVIOUS AREA
- LANDSCAPE AREA
- BIORETENTION AREA
- SELF-RETAINING AREA
- OVERLAND FLOW

NOTES

1. PROPOSED BUILDINGS ARE SHOWN FOR REFERENCE ONLY, REFER TO ARCHITECTURAL DRAWINGS FOR ADDITIONAL INFORMATION.

ABBREVIATIONS

DMA	DRAINAGE MANAGEMENT AREA
REQ'D	REQUIRED
SF	SQUARE FEET

STORMWATER CONTROL PLAN

July 15, 2022

Graphic Scale
1"=30'
30' 15' 0 30' 60'

MALLARD POINTE

Belvedere, California

MALLARD POINTE 1951 LLC
Project Sponsor

BKF ENGINEERS
1646 N. CALIFORNIA BLVD.
SUITE 400
WALNUT CREEK, CA 94596
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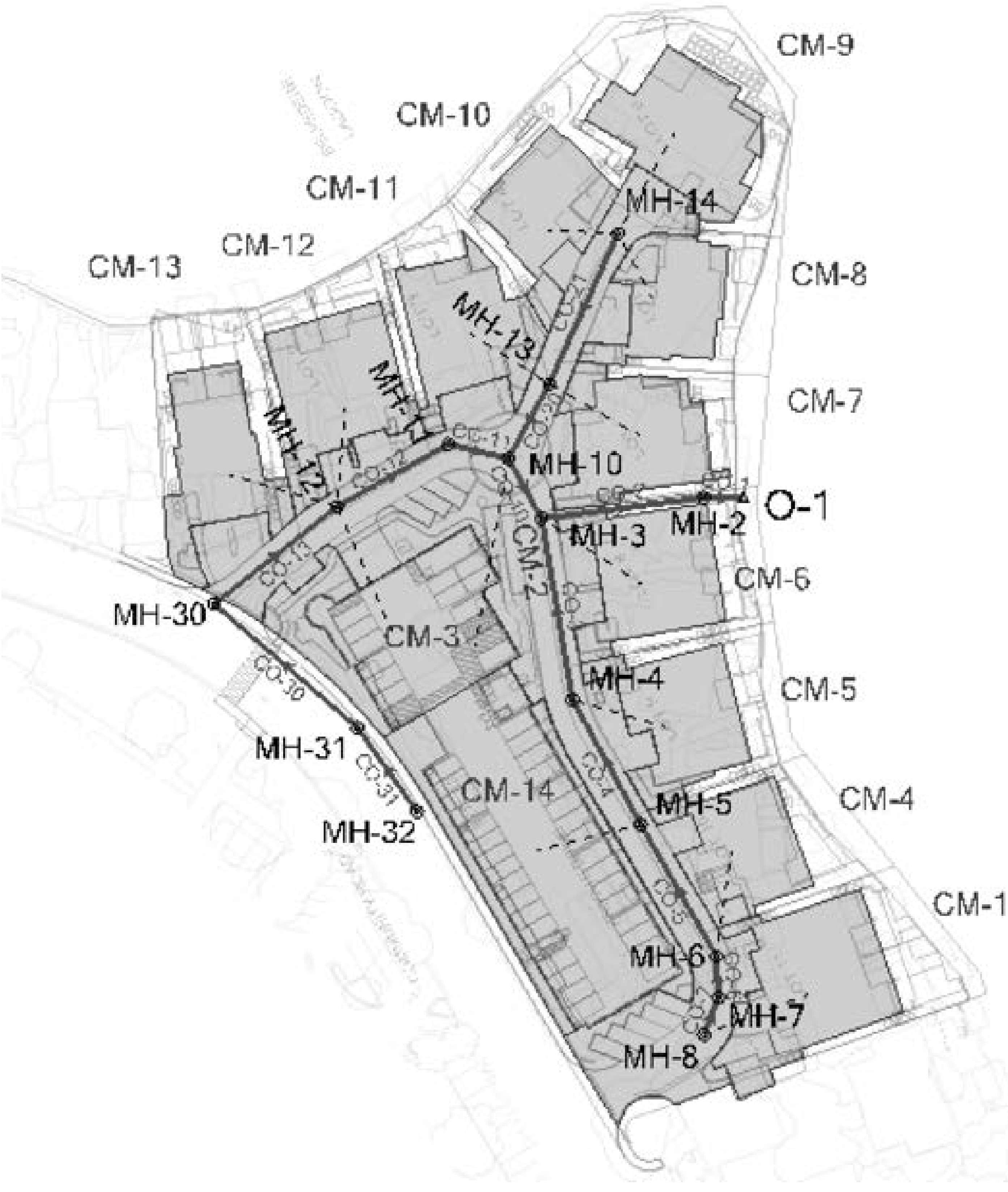
TM-6

ATTACHMENT 2.
STORMCAD ONSITE ANALYSIS

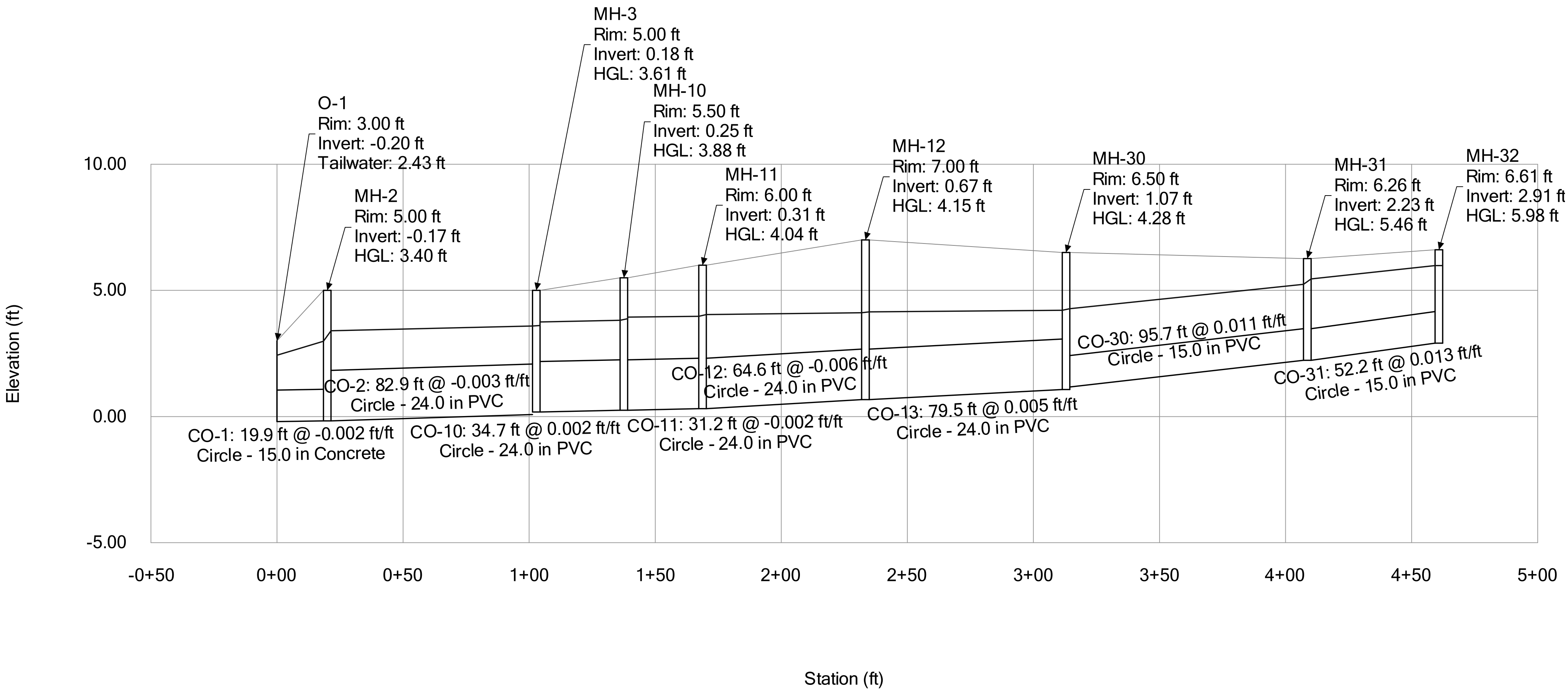
OVERALL STORMCAD MODEL



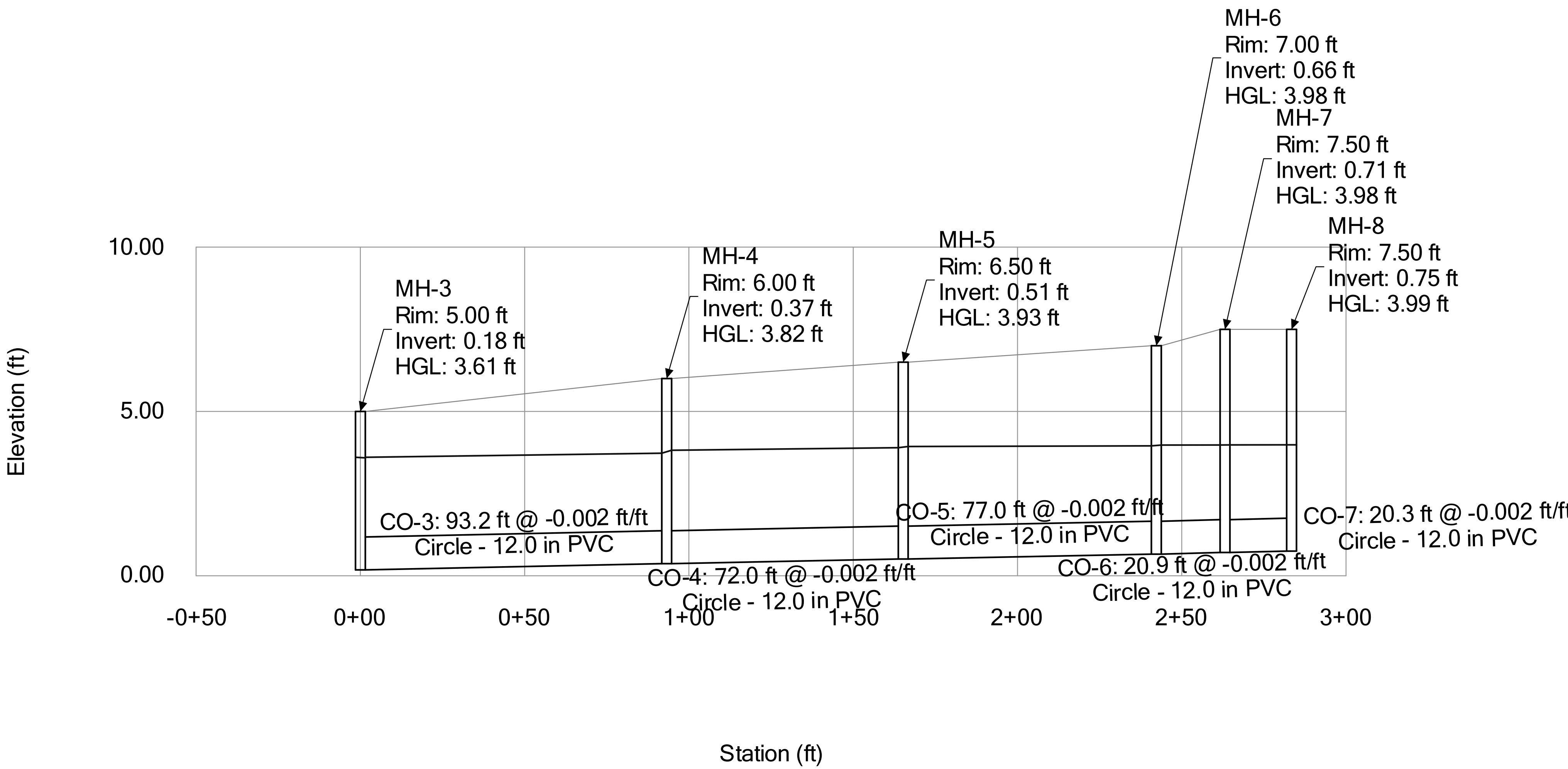
FlexTable: Conduit Table

Label	Start Node	Stop Node	Flow (cfs)	Capacity (Design) (cfs)	Diameter (in)	Length (Unified) (ft)	Slope (Calculated) (ft/ft)	Manning's n	Invert (Start) (ft)	Invert (Stop) (ft)	Velocity (ft/s)
CO-1	O-1	MH-2	10.74	2.51	15.0	19.9	-0.002	0.013	-0.20	-0.17	8.76
CO-2	MH-2	MH-3	10.81	12.42	24.0	82.9	-0.003	0.013	-0.17	0.08	3.44
CO-3	MH-3	MH-4	1.30	1.61	12.0	93.2	-0.002	0.013	0.18	0.37	1.66
CO-4	MH-4	MH-5	1.18	1.57	12.0	72.0	-0.002	0.013	0.37	0.51	1.50
CO-5	MH-5	MH-6	0.54	1.57	12.0	77.0	-0.002	0.013	0.51	0.66	0.68
CO-6	MH-6	MH-7	0.35	1.74	12.0	20.9	-0.002	0.013	0.66	0.71	0.44
CO-7	MH-7	MH-8	0.36	1.58	12.0	20.3	-0.002	0.013	0.71	0.75	0.46
CO-11	MH-10	MH-11	7.51	9.92	24.0	31.2	-0.002	0.013	0.25	0.31	2.39
CO-20	MH-10	MH-13	1.15	1.63	12.0	43.2	-0.002	0.013	0.35	0.44	1.46
CO-10	MH-10	MH-3	10.10	10.15	24.0	34.7	0.002	0.013	0.25	0.18	3.21
CO-12	MH-11	MH-12	7.54	16.89	24.0	64.6	-0.006	0.013	0.31	0.67	2.40
CO-21	MH-13	MH-14	0.71	1.60	12.0	83.8	-0.002	0.013	0.44	0.61	0.91
CO-31	MH-32	MH-31	6.48	7.37	15.0	52.2	0.013	0.013	2.91	2.23	5.28
CO-30	MH-31	MH-30	6.48	6.80	15.0	95.7	0.011	0.013	2.23	1.17	5.28
CO-13	MH-30	MH-12	6.48	16.04	24.0	79.5	0.005	0.013	1.07	0.67	2.06

Profile Report
Engineering Profile - O1-MH32 (MPPR_SDMODEL.stsw)

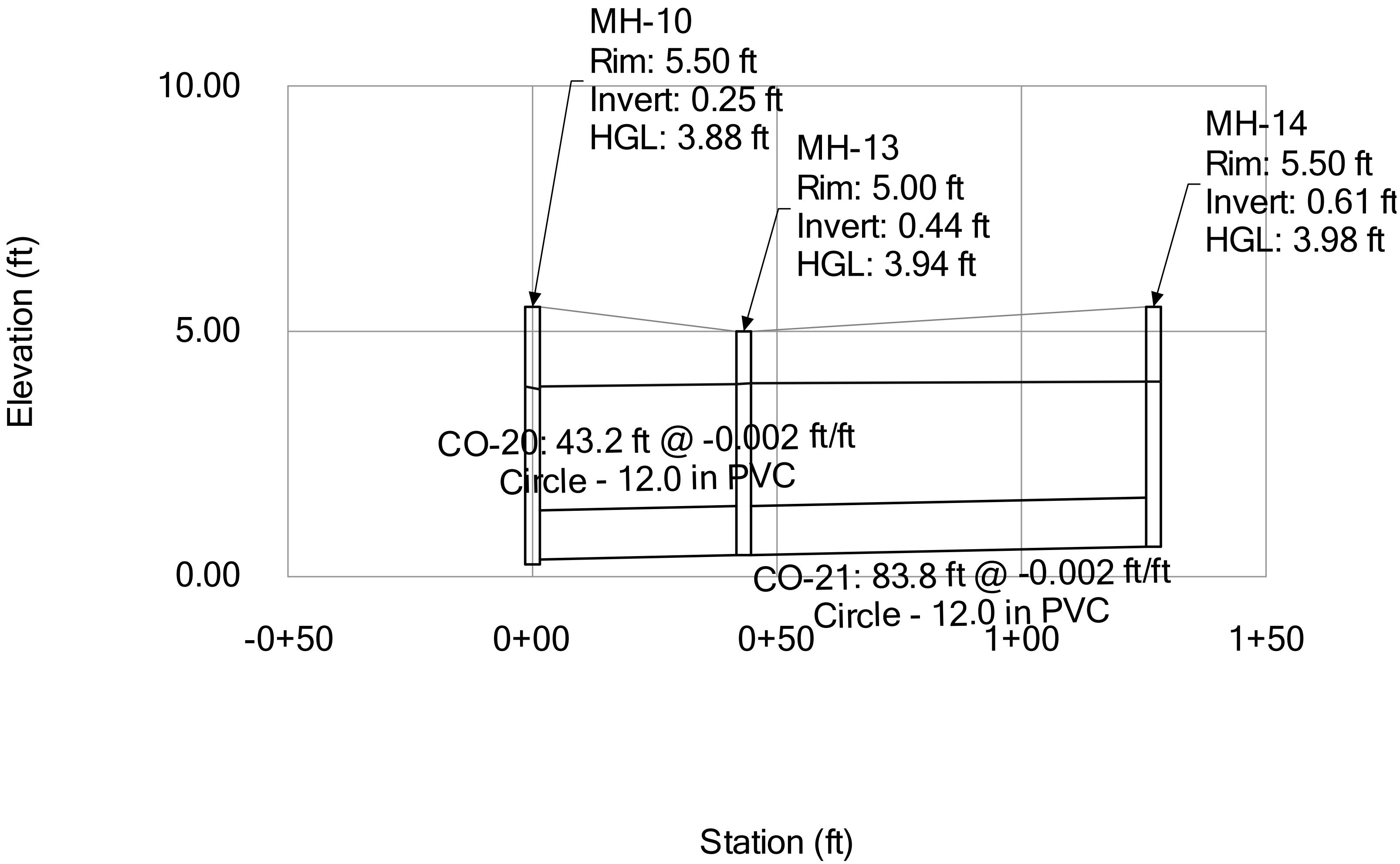


Profile Report
Engineering Profile - MH3-MH8 (MPPR_SDMODEL.stsw)



Profile Report

Engineering Profile - MH10-MH14 (MPPR_SDMODEL.stsw)



ATTACHMENT 3.
XPSWMM OFFSITE ANALYSIS

XPSWMM OFFSITE ANALYSIS

EXHIBITS

Attachment 3.

ATTACHMENT 3 - EXHIBIT 1. WATERSHED MAP

MALLARD POINTE XPSWMM OFFSITE ANALYSIS

SCALE: 1" = 40'

MALLARD POINTE
BELVEDERE, CA
JULY 21, 2022
PREPARED BY

BKF ENGINEERS
255 SHORELINE DRIVE
SUITE 200
REDWOOD CITY, CA 94065
(650) 482-6300
www.bkf.com

ATTACHMENT 3 - EXHIBIT 2. STORM DRAIN MODEL MAP

MALLARD POINTE XPSWMM OFFSITE ANALYSIS

SCALE: 1" = 20'

MALLARD POINTE
BELVEDERE, CA
JULY 21, 2022
PREPARED BY

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(650) 482-6300
www.bkf.com

XPSWMM OFFSITE ANALYSIS

TABLES

Attachment 3.

Mallard Pointe XPSWMM Offsite Analysis: Attachment 3 - Table 1. Model 10-Year Hydrology Data

Node ID	Watershed ID	Area (ac)	Impervious (%)	10-Year Max Runoff (cfs)
N-15	A1	14.93	40%	13.98
N-14	A2	0.017	90%	0.02
N-13	A3	0.052	90%	0.06
N-12	A4	0.025	90%	0.03
N-06	A5	0.454	80%	0.52
N-05	A6	0.631	85%	0.73
N-09	A7	0.077	90%	0.09
N-03	A8	0.101	90%	0.12
N-04	A9	0.092	90%	0.11

Mallard Pointe XPSWMM Offsite Analysis: Attachment 3 - Table 2. Model 10-Year Hydraulic Data - Nodes

Node ID	Rim Elev (ft)	Invert Elev (ft)	10-Year Max HGL (ft)	10-Year Max Depth (ft)
OFFSITE	70.00	50.00	----	----
N-15	69.59	65.29	68.90	3.61
N-14	60.70	56.40	58.21	1.81
N-13	51.13	45.58	49.42	3.84
N-12	39.06	36.48	37.16	0.68
N-11	15.95	11.25	14.51	3.26
N-10	11.94	4.94	11.00	6.06
N-07	8.59	1.14	7.22	6.08
N-07-W	8.59	1.14	7.18	6.04
N-09	8.64	4.24	6.81	2.57
Outfall_2	8.00	2.60	3.51	0.91
N-06	7.22	5.42	6.78	1.36
N-05	7.19	4.89	6.66	1.77
N-03	7.11	1.71	6.62	4.91
N-04	6.76	4.21	6.53	2.32
OVERLAND-RELEASE	8.00	0.00	----	----
N-02	4.73	3.68	4.72	1.04
N-01	5.06	-0.44	4.72	5.16
Outfall_1	8.00	-0.20	2.43	2.63

Mallard Pointe XPSWMM Offsite Analysis: Attachment 3 - Table 3. Model 10-Year Hydraulic Data - Links

Link ID	U/S Node ID	D/S Node ID	Type	Diameter (in)	U/S Invert Elev (ft)	D/S Invert Elev (ft)	Length (ft)	Slope (%)	10-Year Flow (cfs)	10-Year Velocity (ft/s)
OFFSITE-AREA	N-15	OFFSITE	Weir	----	----	----	----	----	5.17	----
P-15	N-15	N-14	Conduit	10	66.64	57.25	82	11.43%	8.83	19.31
P-14	N-14	N-13	Conduit	10	56.40	45.58	67	16.17%	8.83	21.76
P-13	N-13	N-12	Conduit	10	45.58	36.48	95	9.53%	8.89	18.20
P-12	N-12	N-11	Conduit	10	36.48	13.95	179	12.57%	8.92	20.24
P-11	N-11	N-10	Conduit	12	13.95	5.00	20	45.20%	8.92	18.72
P-10 (pipe)	N-10	N-07	Conduit	15	4.94	3.19	128	1.37%	7.18	5.72
P-10 (road)	N-10	N-07	Street	12	10.94	7.59	128	2.61%	2.23	1.93
N-07-WEIR	N-07	N-07-W	Weir	----	----	----	----	----	3.94	----
P-07-S	N-07-W	N-09	Conduit	15	4.59	4.24	193	0.18%	3.95	3.20
P-09	N-09	Outfall_2	Conduit	15	5.54	2.60	190	1.55%	5.04	4.32
P-07	N-07	N-03	Conduit	15	3.19	1.71	33	4.48%	5.24	4.21
P-06	N-06	N-05	Conduit	8	5.47	5.19	58	0.48%	0.52	1.74
P-05	N-05	N-03	Conduit	12	4.89	2.91	32	6.14%	1.24	8.52
P-04 (pipe)	N-04	N-03	Conduit	12	4.26	1.71	53	4.81%	-1.36	-1.69
P-04 (road)	N-04	N-03	Street	6	6.26	6.61	53	-0.66%	-0.02	-0.05
OVERLAND RELEASE	N-04	OVERLAND-RELEASE	Weir	----	----	----	----	----	1.48	----
P-03	N-03	N-01	Conduit	15	1.71	-0.19	105	1.81%	5.22	4.18
P-02	N-02	N-01	Conduit	8	3.68	3.11	17	3.39%	-0.10	-0.29
P-01	N-01	Outfall_1	Conduit	15	-0.19	-0.20	126	0.01%	5.22	4.18

XPSWMM OFFSITE ANALYSIS

REFERENCES

Attachment 3.

NOAA Atlas 14, Volume 6, Version 2
Location name: Belvedere Tiburon, California, USA*
Latitude: 37.8751°, Longitude: -122.4653°
Elevation: 5.22 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.157 (0.140-0.178)	0.195 (0.174-0.222)	0.249 (0.221-0.284)	0.295 (0.259-0.340)	0.362 (0.305-0.433)	0.416 (0.342-0.511)	0.473 (0.378-0.599)	0.536 (0.413-0.701)	0.625 (0.459-0.859)	0.698 (0.493-1.00)
10-min	0.225 (0.200-0.255)	0.280 (0.249-0.318)	0.357 (0.317-0.407)	0.423 (0.372-0.487)	0.519 (0.437-0.621)	0.596 (0.490-0.732)	0.679 (0.542-0.859)	0.768 (0.593-1.00)	0.896 (0.658-1.23)	1.00 (0.706-1.43)
15-min	0.272 (0.242-0.308)	0.339 (0.302-0.385)	0.432 (0.383-0.492)	0.512 (0.450-0.589)	0.627 (0.529-0.751)	0.721 (0.592-0.886)	0.821 (0.655-1.04)	0.929 (0.717-1.22)	1.08 (0.796-1.49)	1.21 (0.854-1.73)
30-min	0.381 (0.340-0.432)	0.475 (0.423-0.540)	0.606 (0.538-0.690)	0.718 (0.631-0.826)	0.880 (0.742-1.05)	1.01 (0.831-1.24)	1.15 (0.919-1.46)	1.30 (1.00-1.71)	1.52 (1.12-2.09)	1.70 (1.20-2.43)
60-min	0.539 (0.480-0.611)	0.672 (0.598-0.763)	0.857 (0.760-0.976)	1.02 (0.892-1.17)	1.24 (1.05-1.49)	1.43 (1.18-1.76)	1.63 (1.30-2.06)	1.84 (1.42-2.41)	2.15 (1.58-2.96)	2.40 (1.69-3.44)
2-hr	0.788 (0.702-0.893)	0.978 (0.871-1.11)	1.24 (1.10-1.42)	1.47 (1.29-1.70)	1.81 (1.52-2.16)	2.08 (1.71-2.55)	2.37 (1.89-3.00)	2.69 (2.07-3.52)	3.14 (2.31-4.32)	3.52 (2.48-5.04)
3-hr	0.999 (0.890-1.13)	1.24 (1.10-1.40)	1.57 (1.39-1.79)	1.86 (1.63-2.14)	2.28 (1.92-2.73)	2.62 (2.15-3.22)	2.99 (2.39-3.78)	3.39 (2.62-4.44)	3.97 (2.92-5.46)	4.45 (3.14-6.38)
6-hr	1.43 (1.28-1.62)	1.78 (1.58-2.02)	2.25 (2.00-2.57)	2.67 (2.34-3.07)	3.26 (2.75-3.91)	3.75 (3.08-4.61)	4.27 (3.41-5.40)	4.84 (3.73-6.33)	5.65 (4.15-7.77)	6.32 (4.46-9.05)
12-hr	1.93 (1.72-2.19)	2.43 (2.16-2.76)	3.11 (2.76-3.54)	3.69 (3.24-4.25)	4.52 (3.82-5.42)	5.19 (4.27-6.38)	5.90 (4.71-7.47)	6.66 (5.14-8.71)	7.73 (5.68-10.6)	8.61 (6.07-12.3)
24-hr	2.57 (2.31-2.91)	3.27 (2.94-3.71)	4.23 (3.80-4.81)	5.04 (4.49-5.77)	6.18 (5.34-7.29)	7.09 (6.01-8.53)	8.04 (6.67-9.89)	9.06 (7.33-11.4)	10.5 (8.17-13.8)	11.7 (8.79-15.8)
2-day	3.26 (2.94-3.69)	4.13 (3.72-4.69)	5.32 (4.78-6.05)	6.33 (5.64-7.24)	7.74 (6.69-9.13)	8.86 (7.52-10.7)	10.0 (8.33-12.4)	11.3 (9.14-14.3)	13.1 (10.2-17.1)	14.5 (10.9-19.6)
3-day	3.85 (3.47-4.36)	4.86 (4.37-5.51)	6.23 (5.60-7.09)	7.39 (6.59-8.46)	9.02 (7.80-10.6)	10.3 (8.75-12.4)	11.7 (9.69-14.4)	13.1 (10.6-16.6)	15.2 (11.8-19.9)	16.8 (12.7-22.8)
4-day	4.29 (3.87-4.86)	5.42 (4.87-6.14)	6.94 (6.23-7.89)	8.22 (7.33-9.41)	10.0 (8.66-11.8)	11.4 (9.71-13.8)	12.9 (10.7-15.9)	14.5 (11.8-18.3)	16.8 (13.1-22.0)	18.6 (14.0-25.1)
7-day	5.28 (4.76-5.98)	6.68 (6.01-7.58)	8.56 (7.69-9.74)	10.1 (9.02-11.6)	12.3 (10.6-14.5)	14.0 (11.9-16.9)	15.8 (13.1-19.4)	17.7 (14.3-22.3)	20.3 (15.8-26.6)	22.4 (16.9-30.2)
10-day	6.24 (5.62-7.07)	7.92 (7.13-8.98)	10.1 (9.11-11.5)	12.0 (10.7-13.7)	14.5 (12.5-17.1)	16.5 (14.0-19.8)	18.5 (15.3-22.7)	20.6 (16.7-26.0)	23.5 (18.3-30.8)	25.8 (19.5-34.9)
20-day	7.90 (7.11-8.95)	10.1 (9.11-11.5)	13.0 (11.7-14.8)	15.3 (13.6-17.5)	18.3 (15.9-21.6)	20.6 (17.5-24.8)	23.0 (19.0-28.2)	25.3 (20.5-31.9)	28.4 (22.1-37.2)	30.8 (23.2-41.7)
30-day	9.56 (8.61-10.8)	12.3 (11.1-13.9)	15.7 (14.1-17.9)	18.4 (16.4-21.1)	22.0 (19.0-25.9)	24.6 (20.9-29.6)	27.2 (22.5-33.4)	29.7 (24.1-37.5)	33.1 (25.8-43.4)	35.6 (26.8-48.1)
45-day	11.9 (10.8-13.5)	15.3 (13.8-17.4)	19.5 (17.5-22.2)	22.7 (20.3-26.0)	26.9 (23.2-31.7)	29.9 (25.3-35.9)	32.8 (27.2-40.3)	35.6 (28.8-44.9)	39.2 (30.5-51.4)	41.8 (31.6-56.6)
60-day	14.4 (13.0-16.3)	18.4 (16.6-20.9)	23.3 (20.9-26.5)	27.0 (24.1-30.9)	31.7 (27.4-37.4)	35.0 (29.7-42.1)	38.2 (31.7-47.0)	41.3 (33.4-52.1)	45.1 (35.1-59.1)	47.9 (36.1-64.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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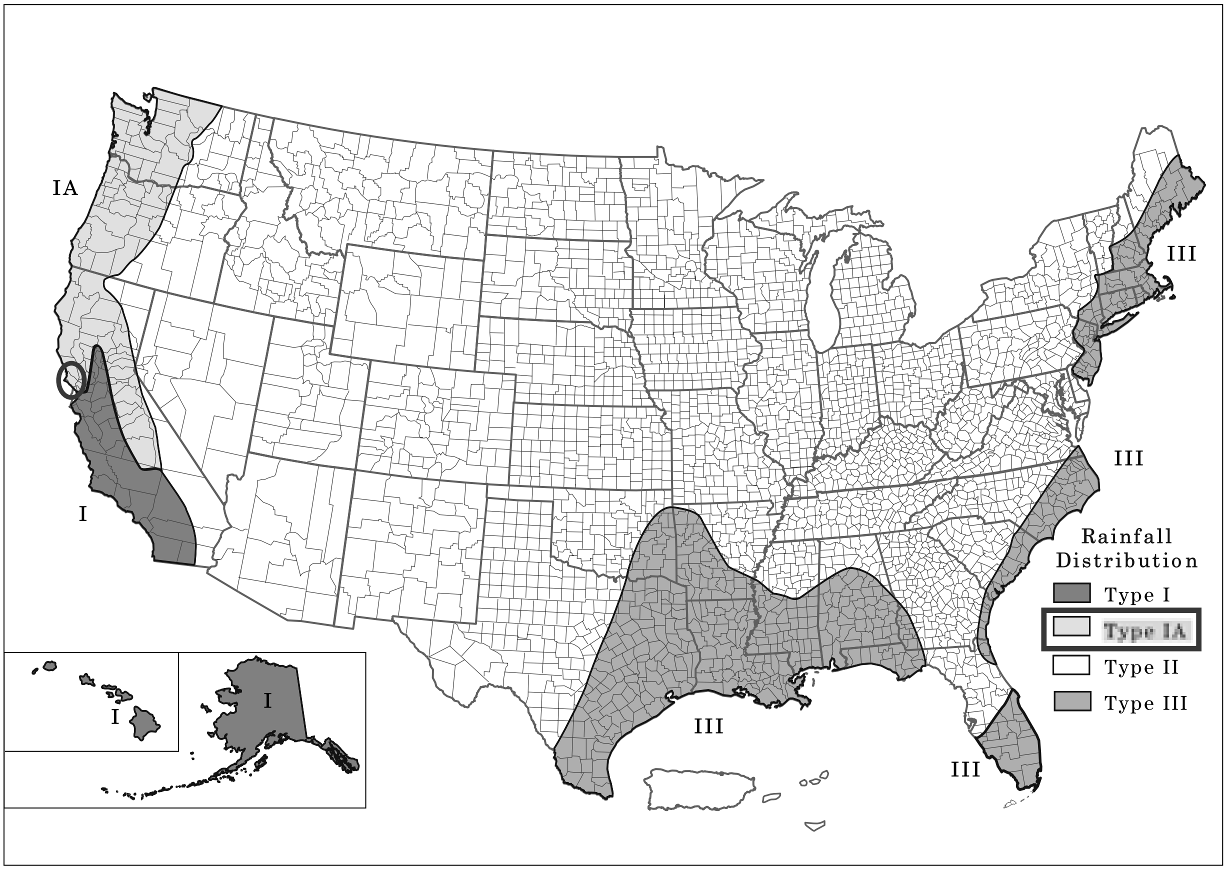
PF graphical

Figure B-2 Approximate geographic boundaries for NRCS (SCS) rainfall distributions



Rainfall data sources

This section lists the most current 24-hour rainfall data published by the National Weather Service (NWS) for various parts of the country. Because NWS Technical Paper 40 (TP-40) is out of print, the 24-hour rainfall maps for areas east of the 105th meridian are included here as figures B-3 through B-8. For the area generally west of the 105th meridian, TP-40 has been superseded by NOAA Atlas 2, the Precipitation-Frequency Atlas of the Western United States, published by the National Ocean and Atmospheric Administration.

East of 105th meridian

Hershfield, D.M. 1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 40. Washington, DC. 155 p.

West of 105th meridian

Miller, J.F., R.H. Frederick, and R.J. Tracey. 1973. Precipitation-frequency atlas of the Western United States. Vol. I Montana; Vol. II, Wyoming; Vol III, Colorado; Vol. IV, New Mexico; Vol V, Idaho; Vol. VI, Utah; Vol. VII, Nevada; Vol. VIII, Arizona; Vol. IX, Washington; Vol. X, Oregon; Vol. XI, California. U.S. Dept. of Commerce, National Weather Service, NOAA Atlas 2. Silver Spring, MD.

Alaska

Miller, John F. 1963. Probable maximum precipitation and rainfall-frequency data for Alaska for areas to 400 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. of Commerce, Weather Bur. Tech. Pap. No. 47. Washington, DC. 69 p.

Hawaii

Weather Bureau. 1962. Rainfall-frequency atlas of the Hawaiian Islands for areas to 200 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 43. Washington, DC. 60 p.

Puerto Rico and Virgin Islands

Weather Bureau. 1961. Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands for areas to 400 square miles, durations to 24 hours, and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 42. Washington, DC. 94 P.

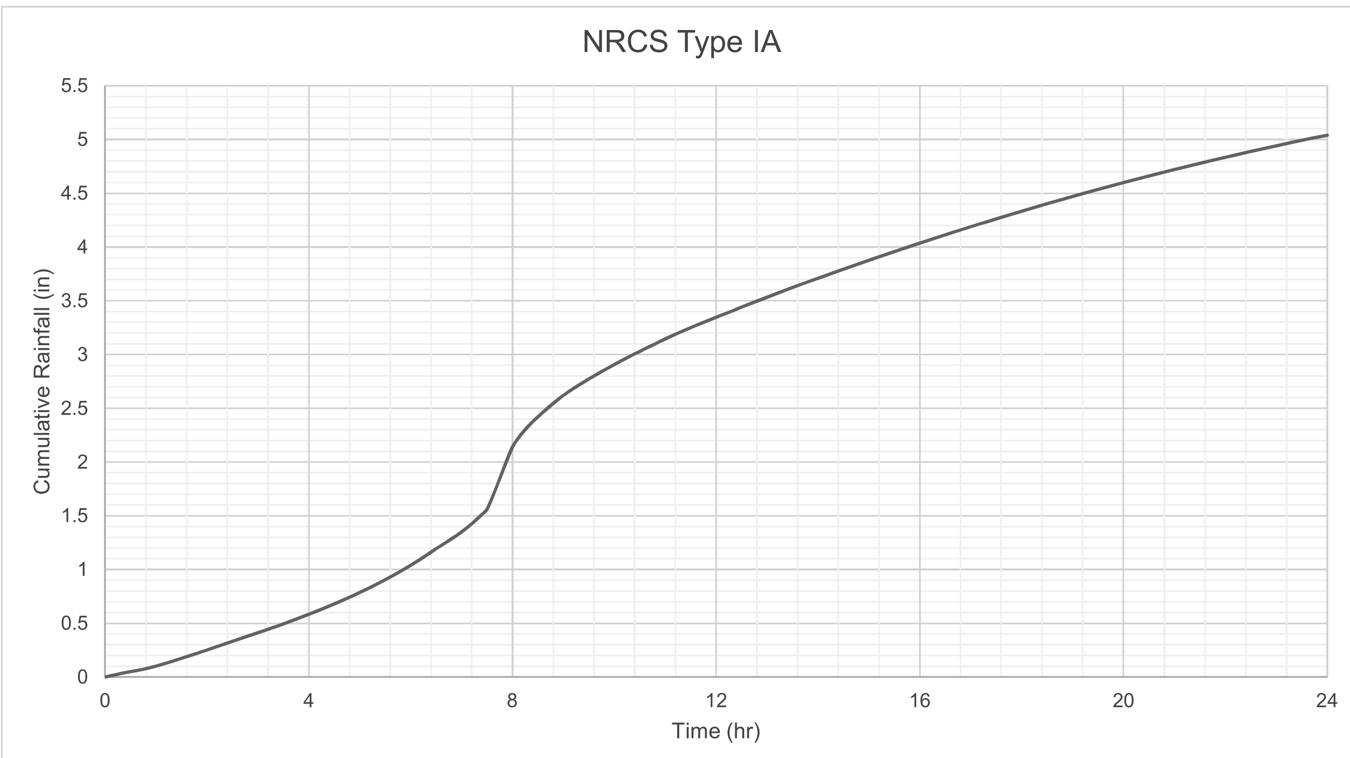

NRCS Type IA
Cumulative Rainfall (in)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
0
4
8
12
16
20
24
Time (hr)

Table 2-2a Runoff curve numbers for urban areas [1/]

Cover description: Cover type and hydrologic condition	Average percent impervious area [2/]	Curve numbers for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3/]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4/]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5/]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.