APPENDIX 4.8

Hydrology and Water Resources

PRELIMINARY STORM DRAINAGE STUDY
OPTION A – 66 LOTS

FOR

DAVIDON HOMES PROPERTY

PETALUMA, CALIFORNIA

Prepared by BKF Engineers

Job No.: 20020038

December 2016

CLIENT:

Davidon Homes
1600 South Main Street
Suite 150
Walnut Creek, CA 94596

DESIGN ENGINEER:

BKF Engineers
255 Shoreline Drive
Suite 200
Redwood City, CA 94065

TABLE OF CONTENTS

1.0 INTRODUCTION

Davidon Homes proposed development of 66 single-family residential homes on an approximate 58.6-acre site. The project will install storm drain in the streets that will ultimately discharge to Kelly Creek. Development of the site will increase runoff that could adversely impact down stream facilities.

The 58.6-acre project site is part of a 360-acre sub basin of the Kelly Creek drainage basin that crosses “D” street just south of Windsor Drive as shown on the attached Exhibit 1: Drainage Map.

This report has been prepared to analyze the impacts to the storm drain system caused by development of the 58.6-acre Davidon Homes site. This report identifies pre-development and post-development peak discharges from the drainage sub-basin and estimates storm water detention needs required to limit post-development peak discharge to pre-development levels.

2.0 EXISTING CONDITIONS

Most of the 58.6-acre site (portions of Tributart 1D and 2H) is part of the larger 360-acre Kelly Creek drainage basin that crosses under “D” Street through a 7.5 foot by 7.5 foot box culvert near the intersection of “D” Street and Windsor Drive. Similar to the majority of the Kelly Creek drainage basin west of “D” Street, this site is covered with grasses and mature trees and is used for livestock grazing. A small portion of the site (Tributary 4) drains to the storm drain system at the intersection of Windsor Drive and D Street, which connects to Kelly Creek downstream of the box culvert that crosses under D Street. Another small portion of the site (Tributary 3) drains to Windsor Drive and flows west, eventually entering a storm drain system that continues westward. See Exhibit 1.

3.0 DESIGN CRITERIA

This storm drain analysis has been prepared in conformance with the Sonoma County Water Agency Flood Control Design Criteria (SCWA FCDC) using the Rational Method.

Assumptions

- Runoff Coefficients (C) (assuming 20 percent slope)

  From Plate B-1, SCWA FCDC

Parks and vegetated areas	0.45
Residential over 1/2 acre	0.50
Residential 1/4 to 1/2 acre	0.58
Single Family Residential	0.68

- Design Storm Event

  10-year storm for minor waterways of one square mile or less

  100-year storm for major waterways of four square miles or more

- Minimum Time of Concentration (Tc)

  10 minutes for lots smaller than 1/2 acre

  15 minutes for Lots 1/2 acre and larger

- Rainfall Intensity, (I)

  Based on the equation from Plate B-2, SCWA FCDC

  $I_{10} = 7.08/Tc^{(0.526)}$

  $I_{100} = 10.15/Tc^{(0.529)}$

The basic rainfall intensity equations applies to 30 inches of mean seasonal precipitation and are adjusted by the factor K shown in Plate B-4 (SCWA FCDC) for the actual mean seasonal precipitation in the project area as shown on the Isohyetal map, Plate B-3. Based on Plate B-3 the project site receives approximately 25 inches of rainfall a year. The K factor for 25 inches of mean seasonal precipitation is 0.83.

Storm water quality features incorporated in to the site will be designed to treat 0.2 inches/hour of runoff. This will delay the treatment flow (0.2 inches per hour) runoff from the site by approximately 2 hours, effectively reducing the peak discharge from the site by 0.2 inches per hour. Therefore, the calculations presented in this study are conservative. This benefit will be documented in more detail in the project hydrology report prepared during development of the project construction documents.

Table 1: Rainfall Intensity

Tc	I_{10}, 10 Year Rainfall Intensity		I_{100}, 100 Year Rainfall Intensity	
	Base	Corrected	Base	Corrected
10	2.11	1.75	3.00	2.49
15	1.70	1.41	2.42	2.01
20	1.46	1.22	2.08	1.73
30	1.18	0.98	1.68	1.39
45	0.96	0.79	1.35	1.12
60	0.82	0.68	1.16	0.97

Base rainfall intensity for areas with 30 inches annual precipitation
Corrected rainfall intensity is site specific based on 25 inches annual precipitation

- Storm water storage volume will be estimated based on the following equation derived from rational method. This equation assumes the proposed runoff hydrograph distribution is triangular shape and the duration of the hydrograph is three times of Tc in proposed condition. In our experience, this equation provides a good estimate of storm runoff detention volume for preliminary project analysis in the San Francisco Bay area. A more detailed volume calculation will be determined during construction document phase of the project after street sections, site plans and grading are finalized.

$V=3/2 \times Tc \times (Q_{pr} \text{ peak} - Q_{ex} \text{ peak})$

Where:

V = Required Storage Volume
Tc = Time of concentration
Q_{pr} peak = Proposed peak discharge from the watershed after development
Q_{ex} peak = Existing peak discharge from the watershed

4.0 STORM DRAIN SYSTEM EVALUATION

The site is divided into four drainage areas based on discharge points. The calculations for runoff from each drainage basin for the 10 year and 100 year storm are detailed in the attached spreadsheets. Implementation of stormwater quality features will modify the drainage patterns. A portion of drainage basin 2H will now be a part of 1D. Drainage basin 4 previously flowed to the storm drain system at the intersection of D Street and Windsor Drive, which connects to Kelly Creek after crossing D Street but now flows directly to Kelly Creek on the project site. The box culvert conveying flows from Kelly Creek under D Street was analyzed to determine if it has adequate capacity for the proposed condition.

This storm drain analysis uses a runoff coefficient, C factor, of 0.45 for undeveloped areas of the sub-basin that represent parks and vegetated areas. A C factor of 0.68 is used for development of the site. The runoff coefficient used for the developed condition is representative of single family development on lots smaller than 1/4 acre and is conservative when applied to this project where many of the lots will be larger than 1/4 acre. This will result in lower peak storm water discharge from the site than represented by these calculations. This will be documented in the hydrology report prepared as part of the project construction documents.

This analysis uses 15 minutes as the initial time of concentration. The flow time for each sub-basin is then added to the initial time of concentration to develop the time of concentration at the discharge from each sub-basin. The flow time for each sub-basin is approximated using a flow velocity of 10 feet per second. This was then checked using the average slope of the sub-basin flow channel and an idealized channel cross section with 2H:1V side slopes and a roughness factor of 0.025.

The storm water detention volume required to limit post development peak discharge to predevelopment levels for the 10-year and the 100-year storm was then calculated.

5.0 SUMMARY AND CONCLUSIONS

The proposed development of the 58.6-acre site will increase the amount of impervious surface in, and runoff from, the 360-acre Kelly Creek sub basin studied in this report. Table 2 summarizes the peak runoff for the 10-year and the 100-year storm for the existing and proposed conditions.

Table 2: Summary of Peak Kelly Creek Discharge at “D” Street

Basin	Storm Event	Peak Discharge Existing Condition (cfs)	Peak Discharge Proposed Condition (cfs)
1 and 2	10-year	179.80	187.95
1 and 2	100-year	255.33	266.89
3	10-Year	2.90	1.46
3	100-Year	4.13	2.08
4	10-Year	5.33	7.41
4	100-Year	7.58	10.53

Analysis of the existing 7.5 foot square box culvert under “D” Street shows that it has adequate capacity for the 100-year storm under the proposed condition without surcharge. See the box culvert nomograph attached.

Storm water will be detained on site to limit peak post-development discharge to peak pre-development levels. For basins 1, 2, and 4, the project will detain the increase in flow over the existing condition. Runoff for basin 3 will decrease in the proposed condition and no detention is necessary. Below is a sample calculation of the required detention volume for drainage basin 1 and 2 during a 10-year storm. The detention volume is a 1.5 times product of the difference in peak flows (proposed and existing) multiplied by the time of concentration.

Sample Calculation:

Detention volume required for drainage basin 1 and 2 during a 10-year storm

$$V = \frac{3}{2} * Tc * (Q_{pr} - Q_{ex})$$

$$V = \frac{3}{2} * (23.83\ \text{min}) * \frac{60\ sec}{1\ min} * (183.45\ cfs - 179.80\ cfs)$$

$$V = 7{,}282.155\ cf$$

Table 3 summarizes storm water detention requirements.

Table 3: Storm Water Detention Volume

Drainage Basin	Storm Event	Detention Volume (cf)
1 and 2	10-Year	17,473
1 and 2	100-Year	24,812
3	10-Year	0
3	100-Year	0
4	10-Year	2,805
4	100-Year	3,973

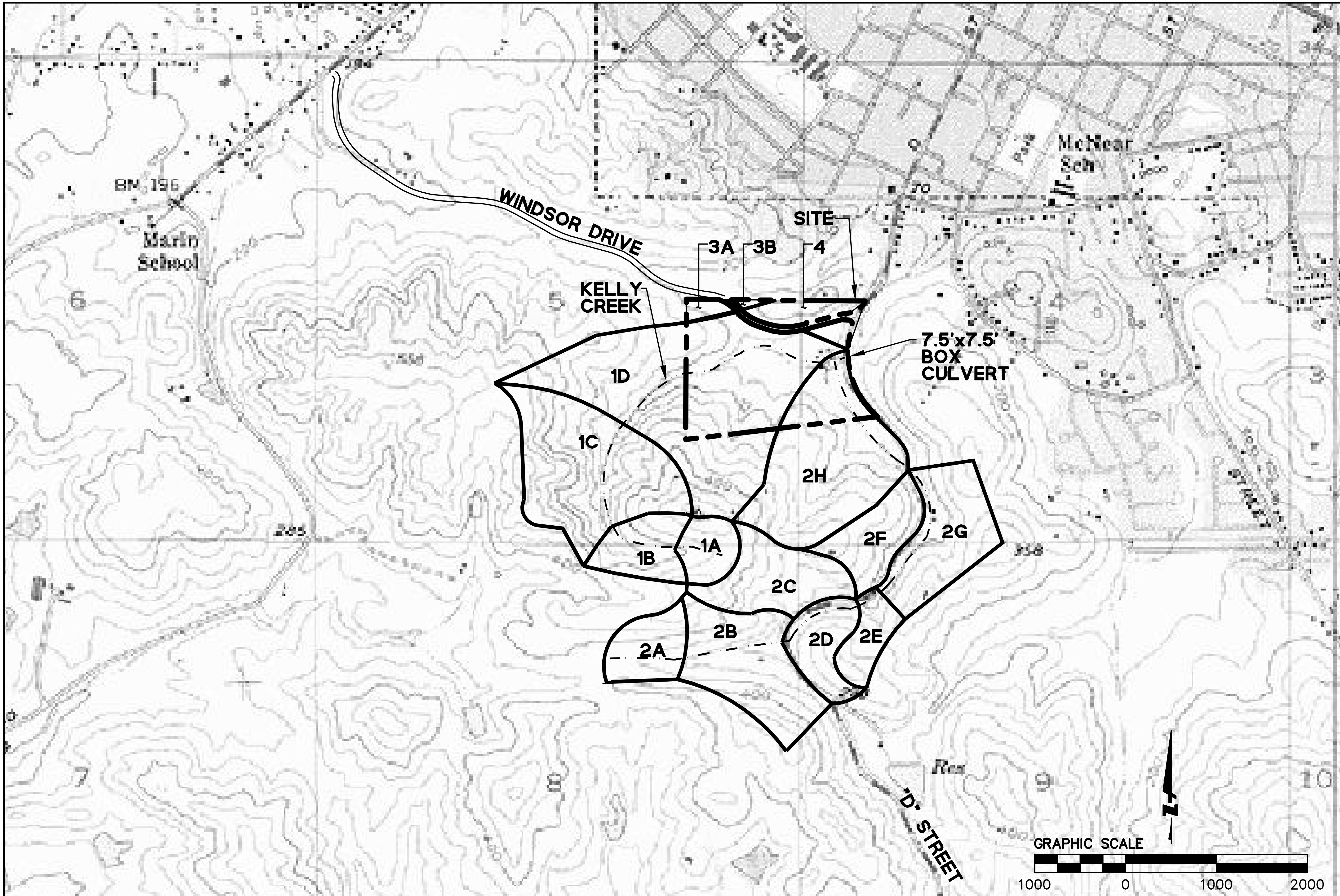
The site provides multiple opportunities to incorporate storm water detention into the project to reduce peak post-development discharge from the site. Opportunities include:

- Providing oversized storm drain pipe and metering flow from the storm drain system using a smaller diameter pipe or an orifice.

- Incorporating areas of detention integral with the storm water quality features. Ponding can be allowed in these areas and storm water can be metered using weirs or constrained orifices to reduce peak storm water runoff.
- Providing a weir in the Kelly Creek tributary adjacent to D Street to allow storm water to pond and reduce peak discharge from Kelly Creek tributary.

See Exhibit 2 for plan showing drainage basins and conceptual detention measures within each basin. A more detailed analysis of the project storm drain system and detention requirement will be prepared to accompany the project improvement plans and final map.

© Brian Kangas Foulk



BKF
ENGINEERS / SURVEYORS / PLANNERS
540 PRICE AVENUE
REDWOOD CITY, CA 94063
650/482-6300
650/482-6399 (FAX)

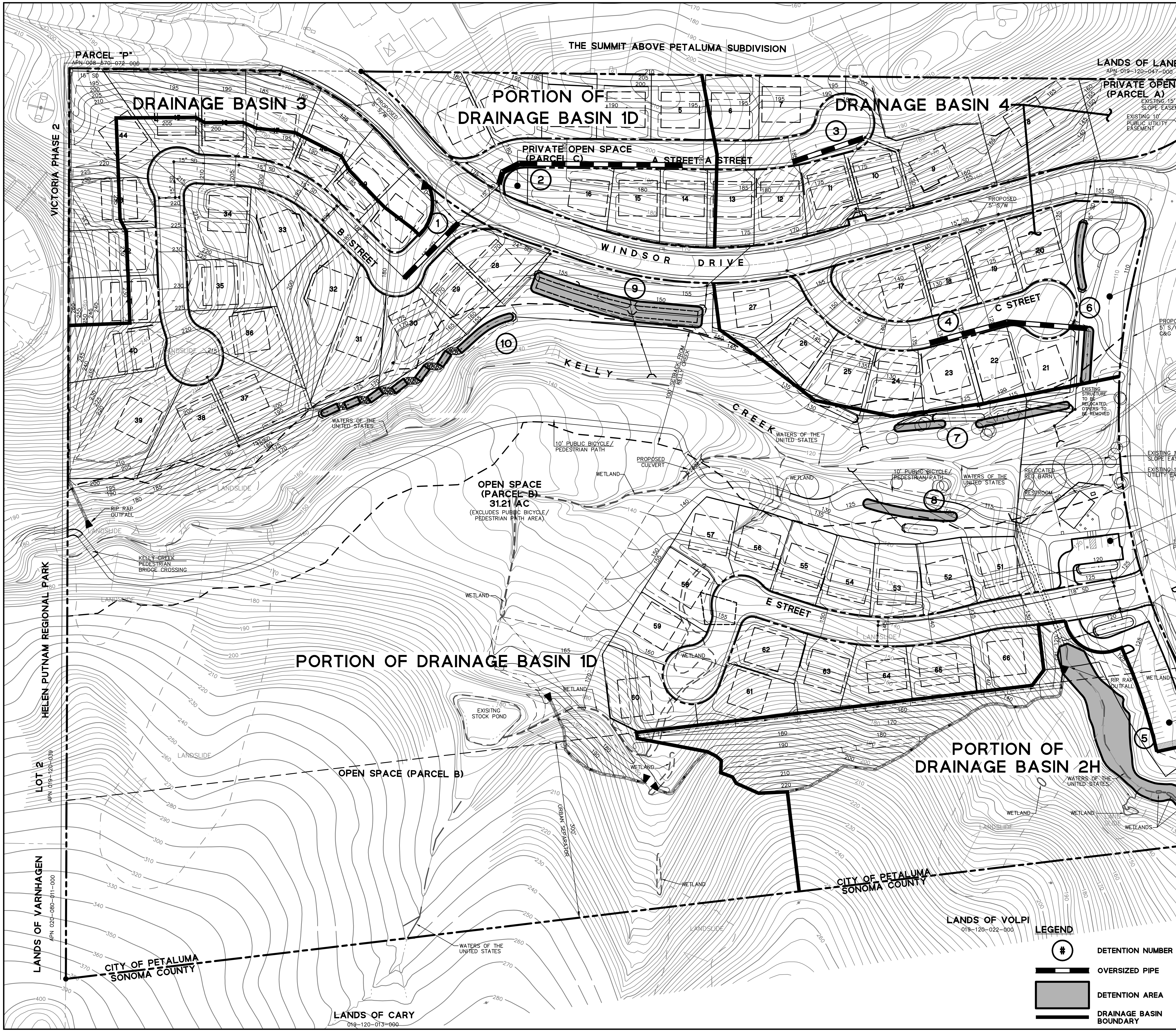
DAVIDON HOMES/UOP
PRELIMINARY STORM DRAINAGE STUDY
EXHIBIT 1: DRAINAGE MAP

PETALUMA SONOMA CALIFORNIA

No.	Revisions

Date 12/10/13
Scale 1"=1000'
Design TRM
Drawn LVO
Approved TA
Job No 20020038

Drawing Number:
1 OF 1



DETENTION SUMMARY:

1	OVERSIZED PIPE	2,500 CF
2	OVERSIZED PIPE	4,100 CF
3	OVERSIZED PIPE	2,300 CF
4	OVERSIZED PIPE	5,300 CF
5	INLINE DETENTION KELLY CREEK TRIBUTARY	15,800 CF
6	BIORETENTION	3,600 CF
7	BIORETENTION	4,500 CF
8	BIORETENTION	3,000 CF
9	BIORETENTION	26,000 CF
10	BIORETENTION	5,600 CF
	TOTAL:	72,700 CF

© BKF ENGINEERS

BKF
ENGINEERS / SURVEYORS / PLANNERS
255 SHORELINE DRIVE, SUITE 200
REDWOOD CITY, CA 94065
650/482-6300
650/482-6399 (FAX)

DAVIDON HOMES / SCOTT RANCH
PRELIMINARY STORM DRAINAGE STUDY
EXHIBIT 2: CONCEPTUAL DETENTION EXHIBIT- OPTION A 66 LOT PLAN

CITY OF PETALUMA — SONOMA COUNTY — CALIFORNIA

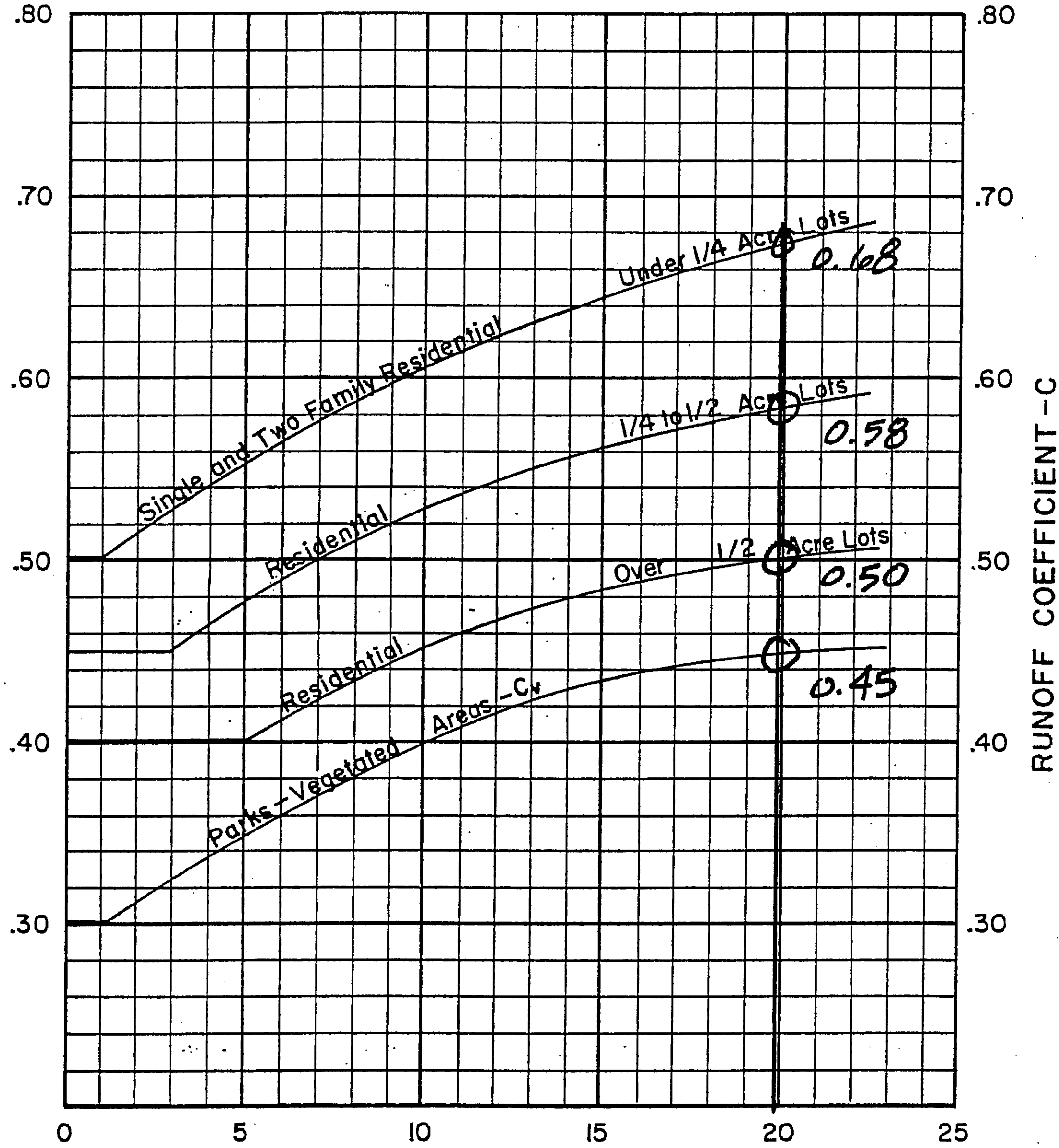
Date	12/09/2013
Scale	1"=60'
Design	RKB
Drawn	MQT
Approved	TRM
Job No	20020038

Revisions / No.

Sheet Number:

DRAWING NAME: J:\Eng02\020038\DWG\Exhibits\12_0825-Stormwater Detention\Detention Exhibit - 66 Lot Plan.dwg
PLOT DATE: 12-06-16 PLOTTED BY: berr

RUNOFF COEFFICIENTS FOR RATIONAL FORMULA



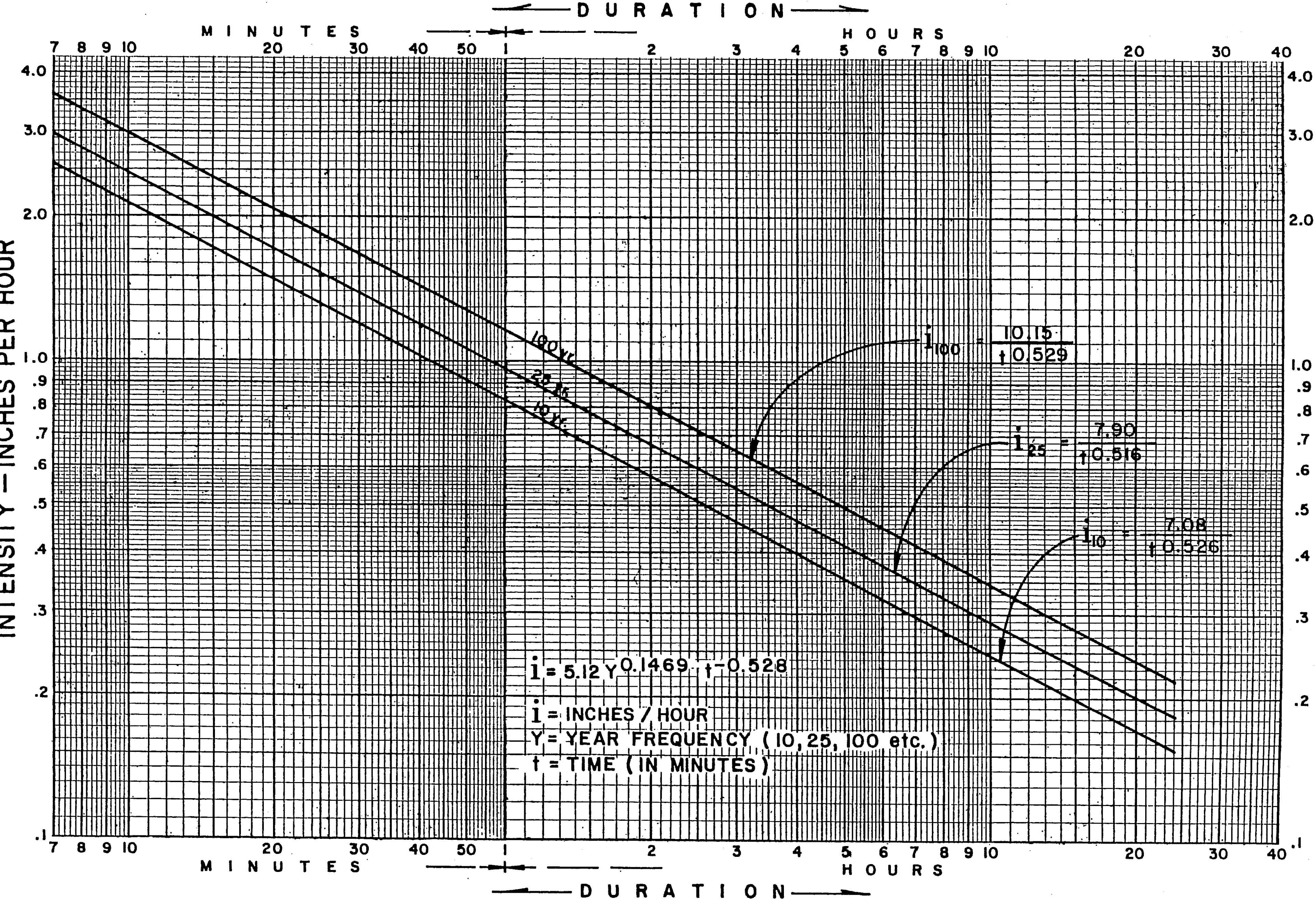
AVERAGE GROUND SLOPE %
(NOT SLOPE OF CHANNEL OR STORM DRAIN)

NOTE: Commercial, Industrial & Multiple Residential Areas

C_P = 0.9 (Based on paving, roofs, etc.)
When vegetated area exceeds 20% of total, C_V from vegetated curve may be used to reduce above C_P as follows:

$$C_T = C_V \frac{A_V}{A_T} + C_P \frac{A_P}{A_T}$$

SONOMA COUNTY WATER AGENCY



NOTE: THE INFORMATION SHOWN IS SUBJECT TO ANNUAL REVISION AS ADDITIONAL RAINFALL DATA BECOMES AVAILABLE

RAINFALL
INTENSITY vs DURATION

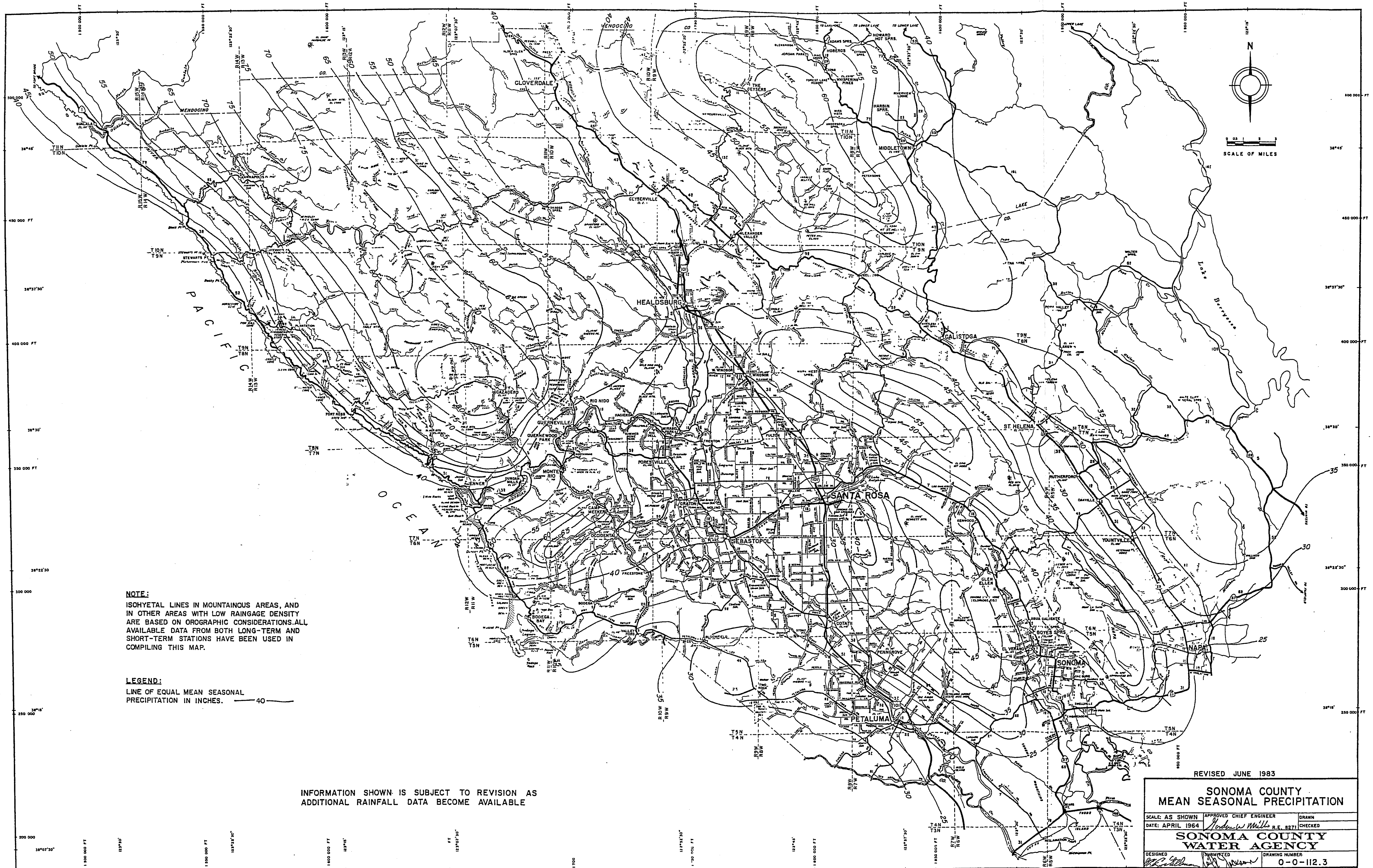
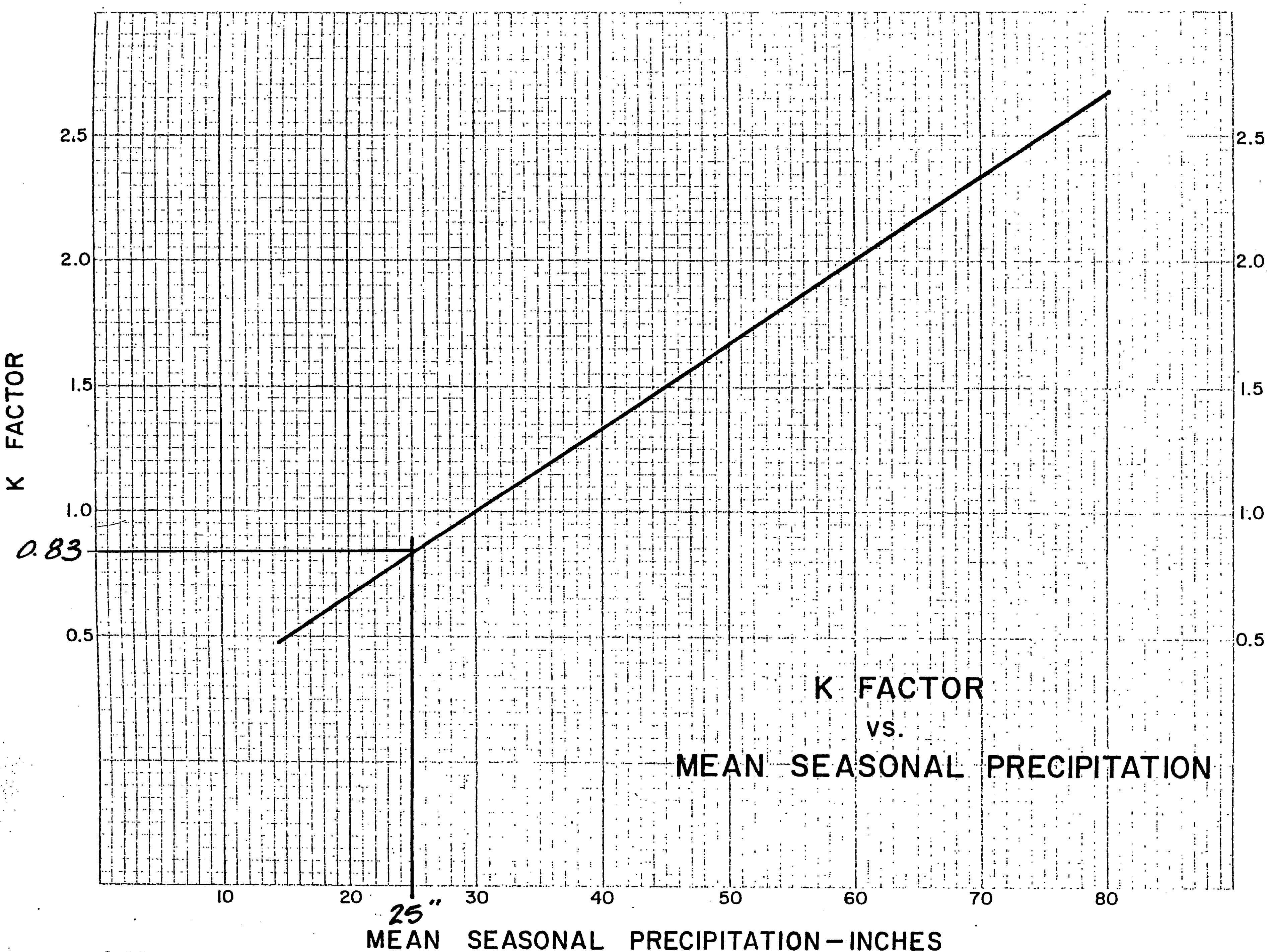

PACIFIC OCEAN
CLOVERDALE
GEYSERVILLE
HEALDSBURG
CALISTOGA
ST. HELENA
MIDDLETOWN
THE GEYSERS
CAZADERO
GUERNEVILLE
RIO NIDO
MONTE RIO
JENNER
FORESTVILLE
SANTA ROSA
SEBASTOPOL
OCCIDENTAL
FREESTONE
BODEGA
BODEGA BAY
COTATI
PENNGROVE
PETALUMA
GLEN ELLEN
KENWOOD
EL VERANO
BOYES SPRS.
AGUA CALIENTE
SONOMA
NAPA
YOUNTVILLE
OAKVILLE
RUTHERFORD
WINDSOR
FULTON
GRATON
SCALE OF MILES
NOTE:
ISOHYETAL LINES IN MOUNTAINOUS AREAS, AND IN OTHER AREAS WITH LOW RAINGAGE DENSITY ARE BASED ON OROGRAPHIC CONSIDERATIONS. ALL AVAILABLE DATA FROM BOTH LONG-TERM AND SHORT-TERM STATIONS HAVE BEEN USED IN COMPILING THIS MAP.
LEGEND:
LINE OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES. —40—
INFORMATION SHOWN IS SUBJECT TO REVISION AS ADDITIONAL RAINFALL DATA BECOME AVAILABLE
REVISED JUNE 1983
SONOMA COUNTY
MEAN SEASONAL PRECIPITATION
SCALE: AS SHOWN
DATE: APRIL 1964
APPROVED CHIEF ENGINEER
R.E. 8271
DRAWN
CHECKED
SONOMA COUNTY WATER AGENCY
DESIGNED
SUBMITTED
DRAWING NUMBER
0-0-112.3

PLATE No. B-3



2-66

PLATE No. B-4

Table 4: Weighted Runoff Coefficients

Basin 1D

Total Area	107.41	ac
Open Space Area	91.62	ac
Developed Area	15.79	ac
C, Open space	0.45	
C, Developed	0.68	
C, Weighted	**0.48**	

Basin 2H

Total Area	45.33	ac
Open Space Area	45.30	ac
Developed Area	0.00	ac
C, Open Space	0.45	
C, Developed	0.68	
C, Weighted	**0.45**	

Basin 3

Total Area	2.07	ac
Open Space Area	1.62	ac
Developed Area	0.45	ac
C, Open Space	0.45	
C, Developed	0.68	
C, Weighted	**0.50**	

Basin 4

Total Area	7.94	ac
Open Space Area	0.56	ac
Developed Area	7.37	ac
C, Open Space	0.45	
C, Developed	0.68	
C, Weighted	**0.66**	

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 5: Peak Runoff, 10 Year Storm, Existing Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	1.70	0.83	0.45	2.66	2.66	4.53	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	1.63	0.83	0.45	5.45	8.11	13.21	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	1.53	0.83	0.45	19.80	27.91	42.59	Creek
1D	95.72	170.45	130	2800	0.05		4.67	23.17	1.36	0.83	0.45	35.75	63.66	86.30	Creek
Subtotal	170.45														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	1.70	0.83	0.45	4.92	4.92	8.38	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	1.61	0.83	0.45	11.69	16.61	26.78	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	1.53	0.83	0.45	11.56	28.18	42.99	Creek
2D	14.59	90.03				15.00		15.00	1.70	0.83	0.45	5.45	33.63	9.28	Overland
2E	5.69	95.72				15.00		15.00	1.70	0.83	0.45	2.13	35.75	3.62	Overland
2F	16.37	112.09				15.00		15.00	1.70	0.83	0.45	6.11	41.87	10.42	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	1.42	0.83	0.45	10.90	52.76	74.69	Creek
2H	48.75	190.02	50	1500	0.03		2.50	23.83	1.34	0.83	0.45	18.21	70.97	94.78	Creek
subtotal	190.02														
Total	360.47							23.83	1.34				134.64	179.80	
Tributary 3	4.56	4.56				15.00		15.00	1.70	0.83	0.45	1.70	1.70	2.90	
Tributary 4	8.38	8.38				15.00		15.00	1.70	0.83	0.45	3.13	3.13	5.33	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 6: Peak Runoff, 100 Year Storm, Existing Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	2.42	0.83	0.45	2.66	2.66	6.44	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	2.32	0.83	0.45	5.45	8.11	18.78	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	2.17	0.83	0.45	19.80	27.91	60.52	Creek
1D	95.72	170.45	130	2800	0.05		4.67	23.17	1.93	0.83	0.45	35.75	63.66	122.56	Creek
Subtotal	170.45														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	2.42	0.83	0.45	4.92	4.92	11.92	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	2.29	0.83	0.45	11.69	16.61	38.07	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	2.17	0.83	0.45	11.56	28.18	61.10	Creek
2D	14.59	90.03				15.00		15.00	2.42	0.83	0.45	5.45	33.63	13.20	Overland
2E	5.69	95.72				15.00		15.00	2.42	0.83	0.45	2.13	35.75	5.15	Overland
2F	16.37	112.09				15.00		15.00	2.42	0.83	0.45	6.11	41.87	14.81	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	2.01	0.83	0.45	10.90	52.76	106.10	Creek
2H	48.75	190.02	50	1500	0.03		2.50	23.83	1.90	0.83	0.45	18.21	70.97	134.59	Creek
subtotal	190.02														
Total	360.47							23.83	1.90				134.64	255.33	
Tributary 3	4.56	4.56				15.00		15	2.42	0.83	0.45	1.70	1.70	4.13	
Tributary 4	8.38	8.38				15.00		15.00	2.42	0.83	0.45	3.13	3.13	7.58	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

BKF Engineers
12/18/2013
J:\MAIN\2002\020038\06 Design\C Storm Drain\Project Description\13_1209-Kelly Creek Option A.xlsex 100 yr storm

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 7 Peak Runoff, 10 Year Storm, Proposed Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	1.70	0.83	0.45	2.66	2.66	4.53	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	1.63	0.83	0.45	5.45	8.11	13.21	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	1.53	0.83	0.45	19.80	27.91	42.59	Creek
1D	107.41	182.14	130	2800	0.05		4.67	23.17	1.36	0.83	0.48	43.13	71.04	96.30	Creek
Subtotal	182.14														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	1.70	0.83	0.45	4.92	4.92	8.38	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	1.61	0.83	0.45	11.70	16.61	26.78	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	1.53	0.83	0.45	11.56	28.18	42.99	Creek
2D	14.59	90.03				15.00		15.00	1.70	0.83	0.45	5.45	33.62	9.28	Overland
2E	5.69	95.72				15.00		15.00	1.70	0.83	0.45	2.13	35.75	3.62	Overland
2F	16.37	112.09				15.00		15.00	1.70	0.83	0.45	6.11	41.86	10.42	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	1.42	0.83	0.45	10.90	52.76	74.69	Creek
2H	45.33	186.60	50	1500	0.03		2.50	23.83	1.34	0.83	0.45	16.93	69.69	93.07	Creek
subtotal	186.60														
Total	368.73							23.83	1.34				140.74	187.95	

Tributary 3	2.07	2.07				15		15	1.70	0.83	0.50	0.86	0.86	1.46	

Tributary 4	7.94	7.94				15.00		15.00	1.70	0.83	0.66	4.35	4.35	7.41	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 8: Peak Runoff, 100 Year Storm, Proposed Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	2.42	0.83	0.45	2.66	2.66	6.44	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	2.32	0.83	0.45	5.45	8.11	18.78	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	2.17	0.83	0.45	19.80	27.91	60.52	Creek
1D	107.41	182.13	130	2800	0.05		4.67	23.17	1.93	0.83	0.48	43.13	71.04	136.76	Creek
Subtotal	182.13														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	2.42	0.83	0.45	4.92	4.92	11.91	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	2.29	0.83	0.45	11.70	16.61	38.07	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	2.17	0.83	0.45	11.56	28.18	61.09	Creek
2D	14.59	90.03				15.00		15.00	2.42	0.83	0.45	5.45	33.62	13.20	Overland
2E	5.69	95.72				15.00		15.00	2.42	0.83	0.45	2.13	35.75	5.15	Overland
2F	16.37	112.09				15.00		15.00	2.42	0.83	0.45	6.11	41.87	14.81	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	2.01	0.83	0.45	10.90	52.76	106.10	Creek
2H	45.33	186.60	50	1500	0.03		2.50	23.83	1.90	0.83	0.45	16.93	69.69	132.17	Creek
subtotal	186.60														
Total	368.73							23.83	1.90				140.74	266.89	

Tributary 3	2.07	2.07				15		15	2.42	0.83	0.50	0.86	0.86	2.08	

Tributary 4	7.94	7.94				15.00		15.00	2.42	0.83	0.66	4.35	4.35	10.53	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Reach 1B

Man Made Channels -- English Units

Civil Tools for Windows
(04-14-2003, 07:18:36)

```
          Flow Depth = 0.525 ft
            Flowrate = 4.500 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.13000 ft/ft
   Channel Roughness = 0.025
         Wetted Area = 0.55 sf
    Wetted Perimeter = 2.35 ft
            Velocity = 8.16 fps
          Froude No. = 2.81
                Flow = Super-Critical
```

Reach 1B

Man Made Channels -- English Units

Civil Tools for Windows
(04-14-2003, 07:22:29)

```
         Flow Depth = 0.932 ft
           Flowrate = 17.000 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.08700 ft/ft
   Channel Roughness = 0.025
        Wetted Area = 1.74 sf
   Wetted Perimeter = 4.17 ft
           Velocity = 9.78 fps
         Froude No. = 2.53
               Flow = Super-Critical
```

UOP Kelly Creek Flow

100 yr flow, natural channel

Man Made Channels -- English Units

Civil Tools for Windows
(04-18-2003, 10:17:32)

```
          Flow Depth = 5.089 ft
            Flowrate = 200.000 cfs
Channel Bottom Width = 2.000 ft
  Channel Side Slope = 0.500 ft/ft
       Channel Slope = 0.02000 ft/ft
   Channel Roughness = 0.035
        Wetted Area = 23.13 sf
    Wetted Perimeter = 13.38 ft
            Velocity = 8.65 fps
         Froude No. = 0.84
                Flow = Sub-Critical
```

Reach 1D

Man Made Channels -- English Units
Civil Tools for Windows
(04-14-2003, 07:25:10)

```
          Flow Depth = 2.365 ft
            Flowrate = 138.000 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.04000 ft/ft
   Channel Roughness = 0.025
        Wetted Area = 11.18 sf
    Wetted Perimeter = 10.58 ft
            Velocity = 12.34 fps
          Froude No. = 2.00
                Flow = Super-Critical
```

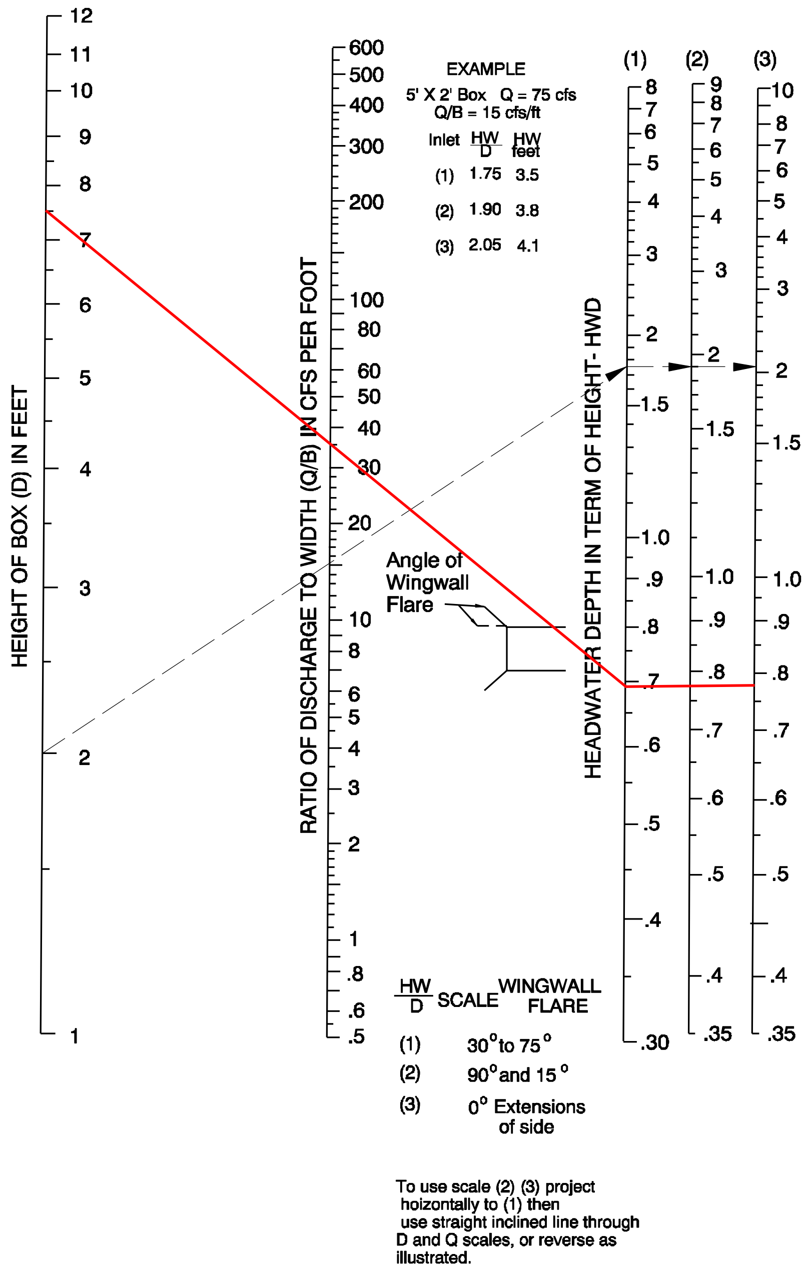
Reach 2H

Man Made Channels -- English Units

Civil Tools for Windows
(04-14-2003, 07:55:34)

```
          Flow Depth = 2.128 ft
            Flowrate = 95.000 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.03330 ft/ft
   Channel Roughness = 0.025
        Wetted Area = 9.05 sf
    Wetted Perimeter = 9.52 ft
            Velocity = 10.49 fps
          Froude No. = 1.79
                Flow = Super-Critical
```

HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL



7.5' X 7.5' Box
Q = 263 cfs
Q/B = 35 cfs/ft
HW/D = .77
HW = 5.8'

BUREAU OF PUBLIC ROADS JAN. 1963

PRELIMINARY STORM DRAINAGE STUDY
OPTION B – 63 LOTS

FOR

DAVIDON HOMES PROPERTY

PETALUMA, CALIFORNIA

Prepared by BKF Engineers

Job No.: 20020038

December 2016

CLIENT:

Davidon Homes
1600 South Main Street
Suite 150
Walnut Creek, CA 94596

DESIGN ENGINEER:

BKF Engineers
255 Shoreline Drive
Suite 200
Redwood City, CA 94065

TABLE OF CONTENTS

1.0 INTRODUCTION

Davidon Homes proposed development of 63 single family residential homes on an approximate 58.6-acre site. The project will install storm drain in the streets that will ultimately discharge to Kelly Creek. Development of the site will increase runoff that could adversely impact down stream facilities.

The 58.6-acre project site is part of a 360-acre sub basin of the Kelly Creek drainage basin that crosses "D" street just south of Windsor Drive as shown on the attached Exhibit 1: Drainage Map.

This report has been prepared to analyze the impacts to the storm drain system caused by development of the 58.6-acre Davidon Homes site. This report identifies pre-development and post-development peak discharges from the drainage sub-basin and estimates storm water detention needs required to limit post-development peak discharge to pre-development levels.

2.0 EXISTING CONDITIONS

Most of the 58.6-acre site (portions of Tributary 1D and 2H) is part of the larger 360-acre Kelly Creek drainage basin that crosses under "D" Street through a 7.5 foot by 7.5 foot box culvert near the intersection of "D" Street and Windsor Drive. Similar to the majority of the Kelly Creek drainage basin west of "D" Street, this site is covered with grasses and mature trees and is used for livestock grazing. A small portion of the site (Tributary 4) drains to the storm drain system at the intersection of Windsor Drive and D Street, which connects to Kelly Creek downstream of the box culvert that crosses under D Street. Another small portion of the site (Tributary 3) drains to Windsor Drive and flows west, eventually entering a storm drain system that continues westward. See Exhibit 1.

3.0 DESIGN CRITERIA

This storm drain analysis has been prepared in conformance with the Sonoma County Water Agency Flood Control Design Criteria (SCWA FCDC) using the Rational Method.

Assumptions

- Runoff Coefficients (C) (assuming 20 percent slope)

  From Plate B-1, SCWA FCDC

Parks and vegetated areas	0.45
Residential over 1/2 acre	0.50
Residential 1/4 to 1/2 acre	0.58
Single Family Residential	0.68

- Design Storm Event

  10-year storm for minor waterways of one square mile or less

  100-year storm for major waterways of four square miles or more

- Minimum Time of Concentration (Tc)

  10 minutes for lots smaller than 1/2 acre

  15 minutes for Lots 1/2 acre and larger

- Rainfall Intensity, (I)

  Based on the equation from Plate B-2, SCWA FCDC

  $I_{10} = 7.08/Tc^{(0.526)}$

  $I_{100} = 10.15/Tc^{(0.529)}$

The basic rainfall intensity equations applies to 30 inches of mean seasonal precipitation and are adjusted by the factor K shown in Plate B-4 (SCWA FCDC) for the actual mean seasonal precipitation in the project area as shown on the Isohyetal map, Plate B-3. Based on Plate B-3 the project site receives approximately 25 inches of rainfall a year. The K factor for 25 inches of mean seasonal precipitation is 0.83.

Storm water quality features incorporated in to the site will be designed to treat 0.2 inches/hour of runoff. This will delay the treatment flow (0.2 inches per hour) runoff from the site by approximately 2 hours, effectively reducing the peak discharge from the site by 0.2 inches per hour. Therefore, the calculations presented in this study are conservative. This benefit will be documented in more detail in the project hydrology report prepared during development of the project construction documents.

Table 1: Rainfall Intensity

Tc	I_{10}, 10 Year Rainfall Intensity		I_{100}, 100 Year Rainfall Intensity	
	Base	Corrected	Base	Corrected
10	2.11	1.75	3.00	2.49
15	1.70	1.41	2.42	2.01
20	1.46	1.22	2.08	1.73
30	1.18	0.98	1.68	1.39
45	0.96	0.79	1.35	1.12
60	0.82	0.68	1.16	0.97

Base rainfall intensity for areas with 30 inches annual precipitation
Corrected rainfall intensity is site specific based on 25 inches annual precipitation

- Storm water storage volume will be estimated based on the following equation derived from rational method. This equation assumes the proposed runoff hydrograph distribution is triangular shape and the duration of the hydrograph is three times of Tc in proposed condition. In our experience, this equation provides a good estimate of storm runoff detention volume for preliminary project analysis in the San Francisco Bay area. A more detailed volume calculation will be determined during construction document phase of the project after street sections, site plans and grading are finalized.

$V=3/2 \times Tc \times (Q_{pr} \text{ peak} - Q_{ex} \text{ peak})$

Where:

V = Required Storage Volume
Tc = Time of concentration
Q_{pr} peak = Proposed peak discharge from the watershed after development
Q_{ex} peak = Existing peak discharge from the watershed

4.0 STORM DRAIN SYSTEM EVALUATION

The site is divided into four drainage areas based on discharge points. The calculations for runoff from each drainage basin for the 10 year and 100 year storm are detailed in the attached spreadsheets. Implementation of stormwater quality features will modify the drainage patterns. A portion of drainage basin 2H will now be a part of 1D. Drainage basin 4 previously flowed to the storm drain system at the intersection of D Street and Windsor Drive, which connects to Kelly Creek after crossing D Street but now flows directly to Kelly Creek on the project site. The box culvert conveying flows from Kelly Creek under D Street was analyzed to determine if it has adequate capacity for the proposed condition.

This storm drain analysis uses a runoff coefficient, C factor, of 0.45 for undeveloped areas of the sub-basin that represent parks and vegetated areas. A C factor of 0.68 is used for development of the site. The runoff coefficient used for the developed condition is representative of single family development on lots smaller than 1/4 acre and is conservative when applied to this project where many of the lots will be larger than 1/4 acre. This will result in lower peak storm water discharge from the site than represented by these calculations. This will be documented in the hydrology report prepared as part of the project construction documents.

This analysis uses 15 minutes as the initial time of concentration. The flow time for each sub-basin is then added to the initial time of concentration to develop the time of concentration at the discharge from each sub-basin. The flow time for each sub-basin is approximated using a flow velocity of 10 feet per second. This was then checked using the average slope of the sub-basin flow channel and an idealized channel cross section with 2H:1V side slopes and a roughness factor of 0.025.

The storm water detention volume required to limit post development peak discharge to predevelopment levels for the 10-year and the 100-year storm was then calculated.

5.0 SUMMARY AND CONCLUSIONS

The proposed development of the 58.6-acre site will increase the amount of impervious surface in, and runoff from, the 360-acre Kelly Creek sub basin studied in this report. Table 2 summarizes the peak runoff for the 10-year and the 100-year storm for the existing and proposed conditions.

Table 2: Summary of Peak Kelly Creek Discharge at “D” Street

Basin	Storm Event	Peak Discharge Existing Condition (cfs)	Peak Discharge Proposed Condition (cfs)
1 and 2	10-year	179.80	187.95
1 and 2	100-year	255.33	266.89
3	10-Year	2.90	1.46
3	100-Year	4.13	2.08
4	10-Year	5.33	7.20
4	100-Year	7.58	10.23

Analysis of the existing 7.5 foot square box culvert under “D” Street shows that it has adequate capacity for the 100-year storm under the proposed condition without surcharge. See the box culvert nomograph attached.

Storm water will be detained on site to limit peak post-development discharge to peak pre-development levels. For basins 1, 2, and 4, the project will detain the increase in flow over the existing condition. Runoff for basin 3 will decrease in the proposed condition and no detention is necessary. Below is a sample calculation of the required detention volume for drainage basin 1 and 2 during a 10-year storm. The detention volume is a 1.5 times product of the difference in peak flows (proposed and existing) multiplied by the time of concentration.

Sample Calculation:

Detention volume required for drainage basin 1 and 2 during a 10-year storm

$$V = \frac{3}{2} * Tc * \left(Q_{pr} - Q_{ex}\right)$$

$$V = \frac{3}{2} * (23.83\ \mathrm{min}) * \frac{60\ sec}{1\ min} * (183.45\ cfs - 179.80\ cfs)$$

$$V = 7{,}282.155\ cf$$

Table 3 summarizes storm water detention requirements.

Table 3: Storm Water Detention Volume

Drainage Basin	Storm Event	Detention Volume (cf)
1 and 2	10-Year	17,473
1 and 2	100-Year	24,812
3	10-Year	0
3	100-Year	0
4	10-Year	2,520
4	100-Year	3,568

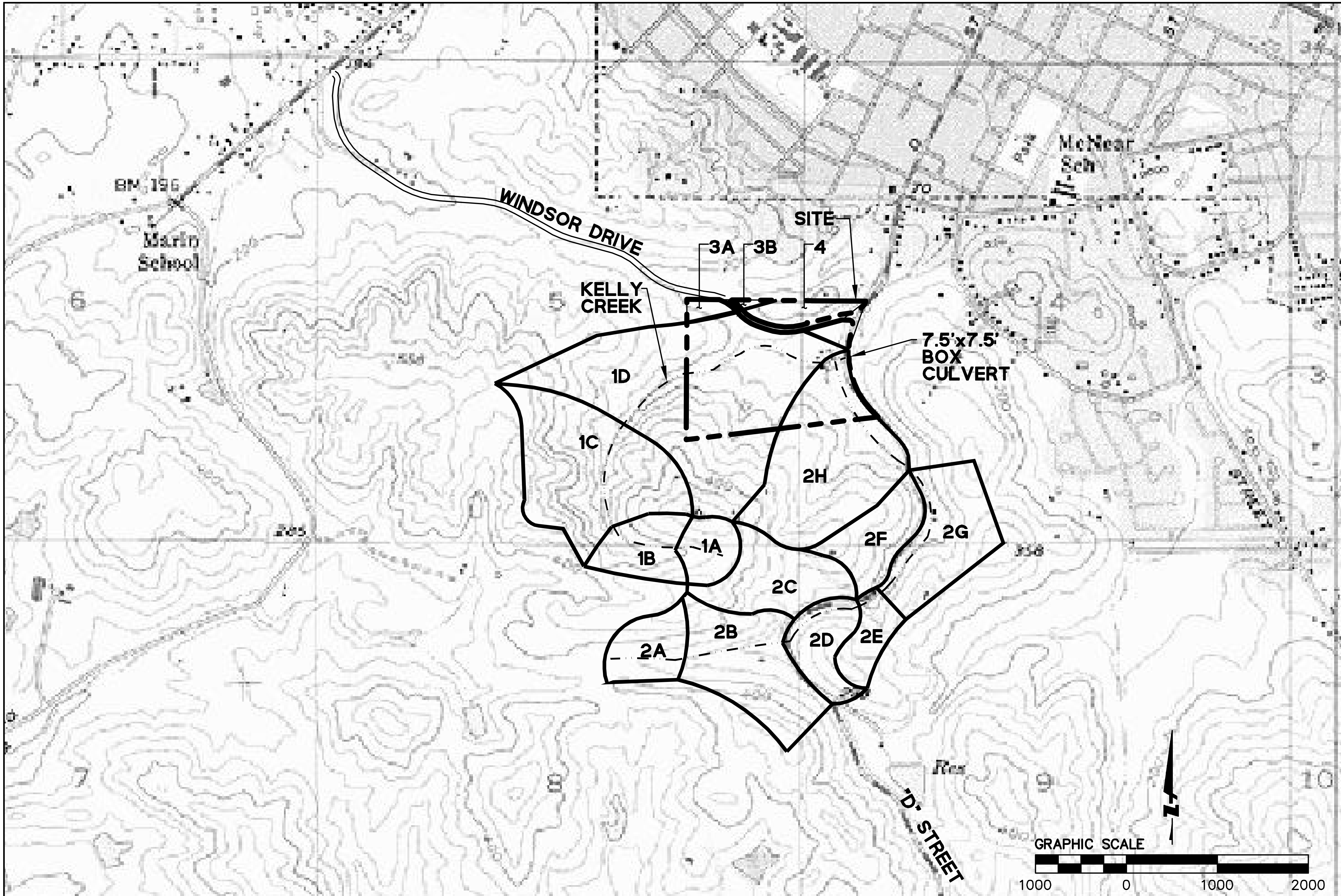
The site provides multiple opportunities to incorporate storm water detention into the project to reduce peak post-development discharge from the site. Opportunities include:

- Providing oversized storm drain pipe and metering flow from the storm drain system using a smaller diameter pipe or an orifice.

- Incorporating areas of detention integral with the storm water quality features. Ponding can be allowed in these areas and storm water can be metered using weirs or constrained orifices to reduce peak storm water runoff.
- Providing a weir in the Kelly Creek tributary adjacent to D Street to allow storm water to pond and reduce peak discharge from Kelly Creek tributary.

See Exhibit 2 for plan showing drainage basins and conceptual detention measures within each basin. A more detailed analysis of the project storm drain system and detention requirement will be prepared to accompany the project improvement plans and final map.

© Brian Kangas Foulk



540 PRICE AVENUE
REDWOOD CITY, CA 94063
650/482-6300
650/482-6369 (FAX)

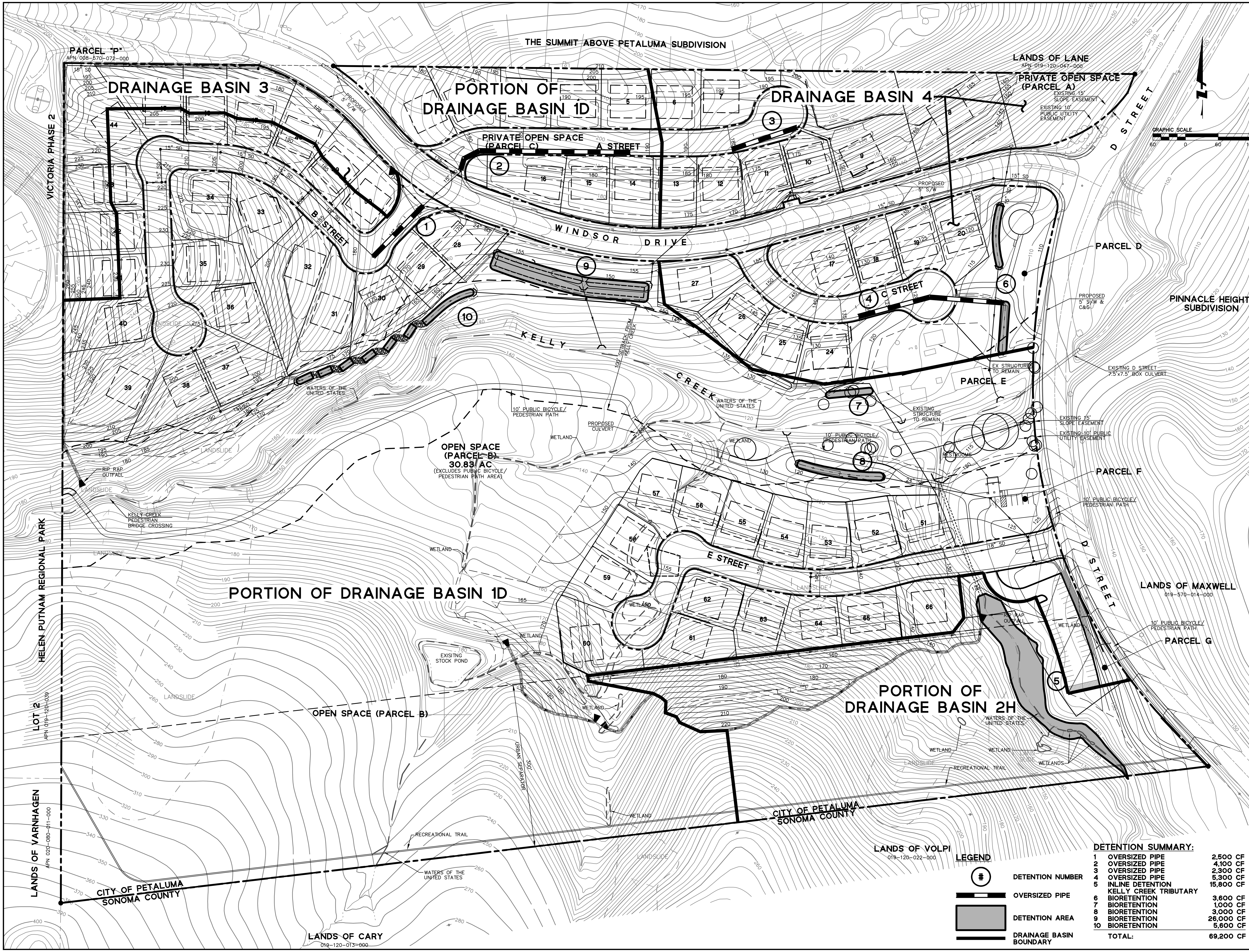
BKF
ENGINEERS / SURVEYORS / PLANNERS

DAVIDON HOMES/UOP
PRELIMINARY STORM DRAINAGE STUDY
EXHIBIT 1: DRAINAGE MAP

PETALUMA SONOMA CALIFORNIA

Date 12/10/13
Scale 1"=1000'
Design TRM
Drawn LVO
Approved TA

Drawing Number:
1 OF 1



DETENTION SUMMARY:

1	OVERSIZED PIPE	2,500 CF
2	OVERSIZED PIPE	4,100 CF
3	OVERSIZED PIPE	2,300 CF
4	OVERSIZED PIPE	5,300 CF
5	INLINE DETENTION KELLY CREEK TRIBUTARY	15,800 CF
6	BIORETENTION	3,600 CF
7	BIORETENTION	1,000 CF
8	BIORETENTION	3,000 CF
9	BIORETENTION	26,000 CF
10	BIORETENTION	5,600 CF
	TOTAL:	69,200 CF

© BKF ENGINEERS

BKF ENGINEERS / SURVEYORS / PLANNERS
255 SHORELINE DRIVE, SUITE 200
REDWOOD CITY, CA 94065
650/482-6300
650/482-6399 (FAX)

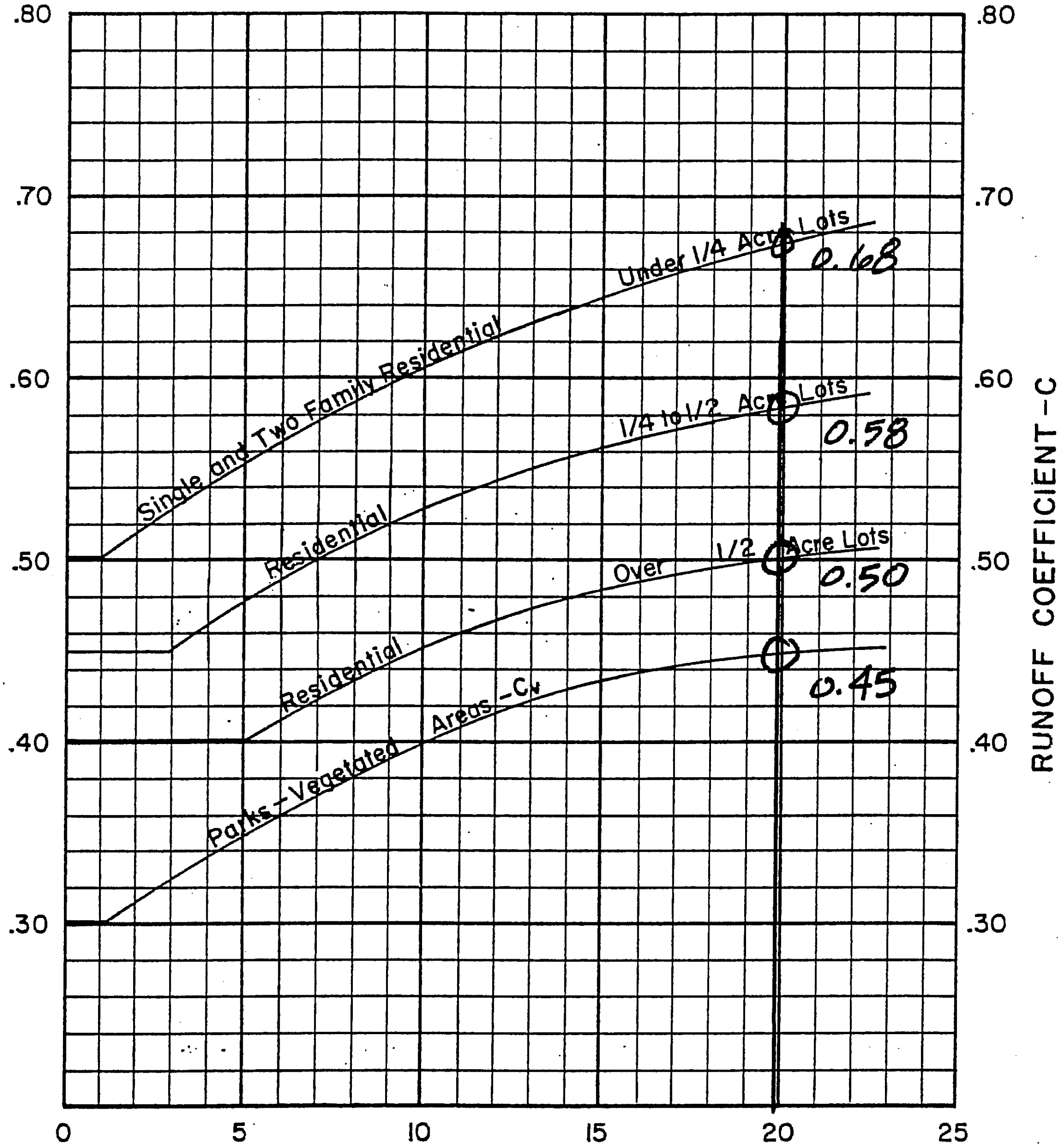
DAVIDON HOMES / SCOTT RANCH
PRELIMINARY STORM DRAINAGE STUDY
EXHIBIT 2: CONCEPTUAL DETENTION EXHIBIT- OPTION B 63 LOT PLAN

CITY OF PETALUMA — SONOMA COUNTY — CALIFORNIA

Date 12/09/2013
Scale 1"=60'
Design RKB
Drawn MQT
Approved TRM
Job No. 20020038
Sheet Number:

DRAWING NAME: J:\Eng02\020038\DWG\Exhibits\12_0825-Stormwater Detention\Detention Exhibit - 63 Lot Plan.dwg
PLOT DATE: 12-06-16 PLOTTED BY: berr

RUNOFF COEFFICIENTS
FOR
RATIONAL FORMULA



AVERAGE GROUND SLOPE %
(NOT SLOPE OF CHANNEL OR STORM DRAIN)

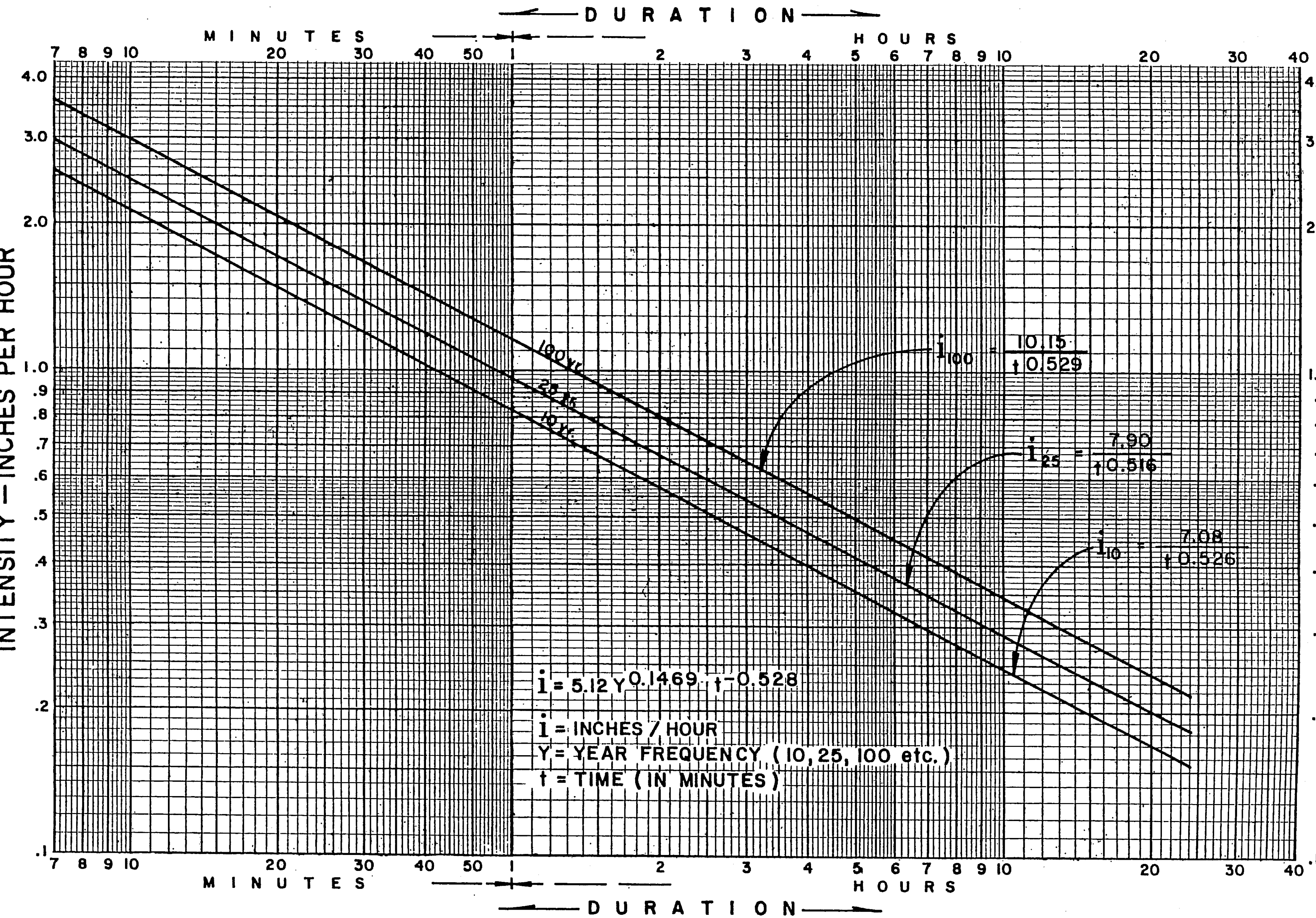
NOTE: Commercial, Industrial & Multiple Residential Areas

C_P = 0.9 (Based on paving, roofs, etc.)

When vegetated area exceeds 20% of total, C_V from vegetated curve may be used to reduce above C_P as follows:

$$C_T = C_V \frac{A_V}{A_T} + C_P \frac{A_P}{A_T}$$

SONOMA COUNTY WATER AGENCY



NOTE: THE INFORMATION SHOWN IS SUBJECT TO ANNUAL REVISION AS ADDITIONAL RAINFALL DATA BECOMES AVAILABLE

RAINFALL
INTENSITY vs DURATION

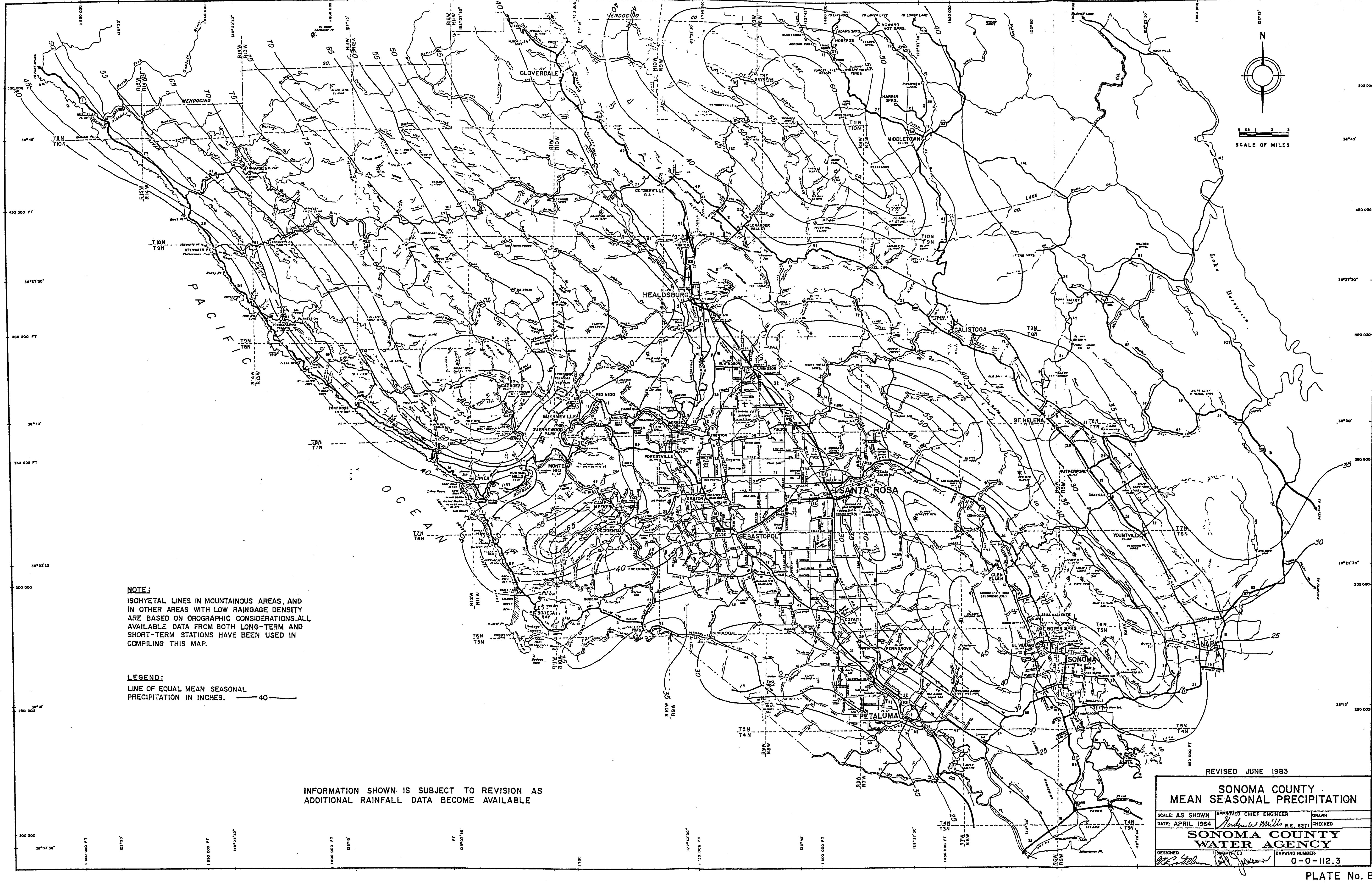
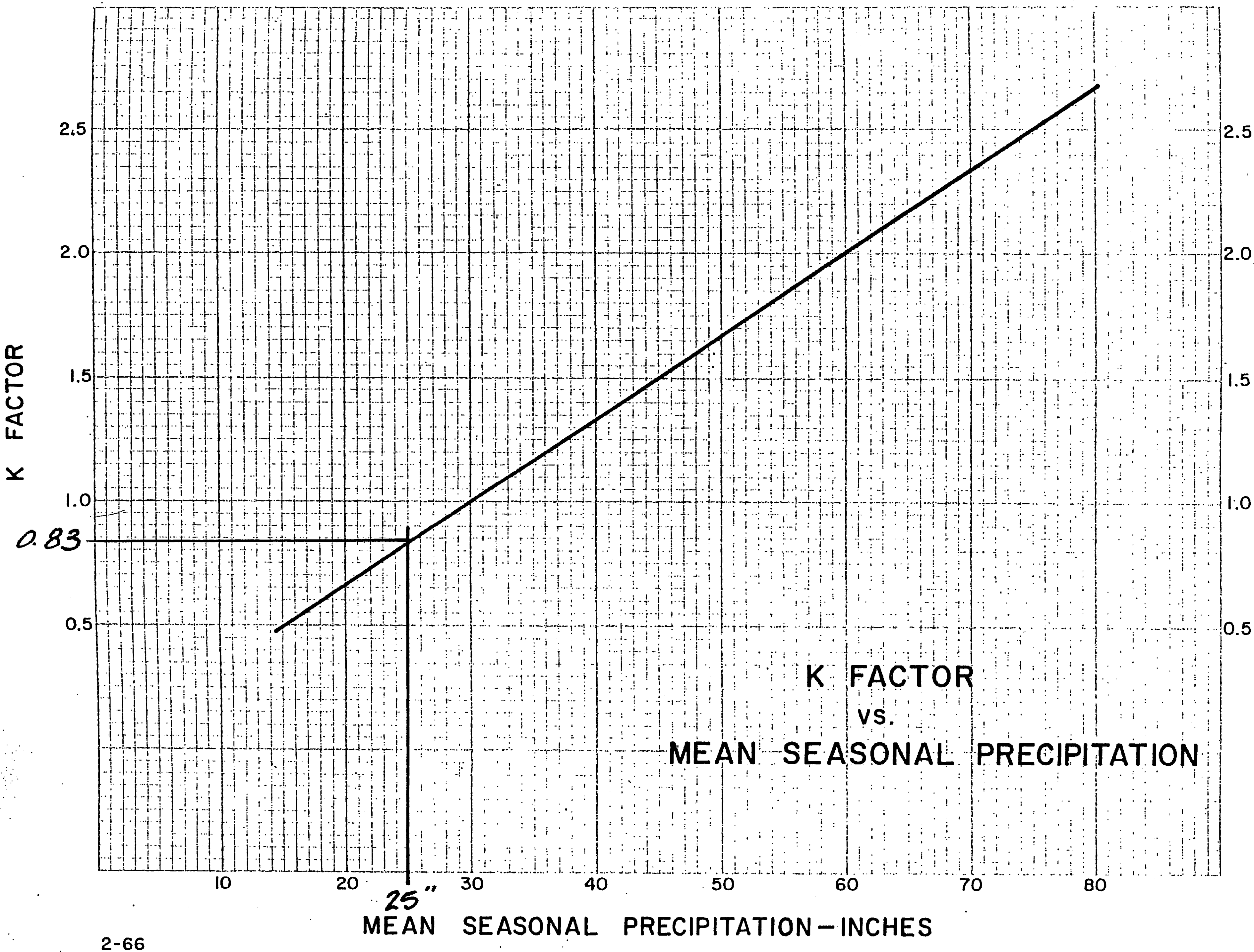

SONOMA COUNTY
MEAN SEASONAL PRECIPITATION
SCALE: AS SHOWN
DATE: APRIL 1964
APPROVED CHIEF ENGINEER
R.E. 8271
DRAWN
CHECKED
SONOMA COUNTY
WATER AGENCY
DESIGNED
SUBMITTED
DRAWING NUMBER
0-0-112.3
REVISED JUNE 1983
NOTE:
ISOHYETAL LINES IN MOUNTAINOUS AREAS, AND IN OTHER AREAS WITH LOW RAINGAGE DENSITY ARE BASED ON OROGRAPHIC CONSIDERATIONS. ALL AVAILABLE DATA FROM BOTH LONG-TERM AND SHORT-TERM STATIONS HAVE BEEN USED IN COMPILING THIS MAP.
LEGEND:
LINE OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES. —40—
INFORMATION SHOWN IS SUBJECT TO REVISION AS ADDITIONAL RAINFALL DATA BECOME AVAILABLE
N
SCALE OF MILES
PACIFIC
OCEAN
CLOVERDALE
GEYSERVILLE
HEALDSBURG
SANTA ROSA
SEBASTOPOL
PETALUMA
SONOMA
NAPA
CALISTOGA
ST. HELENA
RUTHERFORD
OAKVILLE
YOUNTVILLE
MIDDLETOWN
GUERNEVILLE
RIO NIDO
FORESTVILLE
MONTE RIO
JENNER
CAZADERO
OCCIDENTAL
FREESTONE
BODEGA
BODEGA BAY
VALLEY FORD
BLOOMFIELD
COTATI
PENNGROVE
GLEN ELLEN
KENWOOD
EL VERANO
BOYES SPRS.
AGUA CALIENTE
FULTON
WINDSOR
GRATON
HACIENDA
ALEXANDER VALLEY
THE GEYSERS
HARBIN SPRS.
MENDOCINO
LAKE
CO.
Lake Berryessa
GUALALA
STEWARTS PT.
ANNAPOLIS
FORT ROSS

PLATE No. B-3


K FACTOR
vs.
MEAN SEASONAL PRECIPITATION
K FACTOR
MEAN SEASONAL PRECIPITATION—INCHES
2.5
2.0
1.5
1.0
0.83
0.5
10
20
25"
30
40
50
60
70
80

2-66

Table 4: Weighted Runoff Coefficients

Basin 1D			
	Total Area	107.41	ac
	Open Space Area	91.62	ac
	Developed Area	15.79	ac
	C, Open space	0.45	
	C, Developed	0.68	
	C, Weighted	**0.48**	
Basin 2H			
	Total Area	45.33	ac
	Open Space Area	45.30	ac
	Developed Area	0.00	ac
	C, Open Space	0.45	
	C, Developed	0.68	
	C, Weighted	**0.45**	
Basin 3			
	Total Area	2.07	ac
	Open Space Area	1.62	ac
	Developed Area	0.45	ac
	C, Open Space	0.45	
	C, Developed	0.68	
	C, Weighted	**0.50**	
Basin 4			
	Total Area	7.94	ac
	Open Space Area	1.31	ac
	Developed Area	6.62	ac
	C, Open Space	0.45	
	C, Developed	0.68	
	C, Weighted	**0.64**	

Table 5: Peak Runoff, 10 Year Storm, Existing Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	1.70	0.83	0.45	2.66	2.66	4.53	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	1.63	0.83	0.45	5.45	8.11	13.21	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	1.53	0.83	0.45	19.80	27.91	42.59	Creek
1D	95.72	170.45	130	2800	0.05		4.67	23.17	1.36	0.83	0.45	35.75	63.66	86.30	Creek
Subtotal	170.45														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	1.70	0.83	0.45	4.92	4.92	8.38	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	1.61	0.83	0.45	11.69	16.61	26.78	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	1.53	0.83	0.45	11.56	28.18	42.99	Creek
2D	14.59	90.03				15.00		15.00	1.70	0.83	0.45	5.45	33.63	9.28	Overland
2E	5.69	95.72				15.00		15.00	1.70	0.83	0.45	2.13	35.75	3.62	Overland
2F	16.37	112.09				15.00		15.00	1.70	0.83	0.45	6.11	41.87	10.42	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	1.42	0.83	0.45	10.90	52.76	74.69	Creek
2H	48.75	190.02	50	1500	0.03		2.50	23.83	1.34	0.83	0.45	18.21	70.97	94.78	Creek
subtotal	190.02														
Total	360.47							23.83	1.34				134.64	179.80	
Tributary 3	4.56	4.56				15.00		15.00	1.70	0.83	0.45	1.70	1.70	2.90	
Tributary 4	8.38	8.38				15.00		15.00	1.70	0.83	0.45	3.13	3.13	5.33	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 6: Peak Runoff, 100 Year Storm, Existing Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	2.42	0.83	0.45	2.66	2.66	6.44	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	2.32	0.83	0.45	5.45	8.11	18.78	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	2.17	0.83	0.45	19.80	27.91	60.52	Creek
1D	95.72	170.45	130	2800	0.05		4.67	23.17	1.93	0.83	0.45	35.75	63.66	122.56	Creek
Subtotal	170.45														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	2.42	0.83	0.45	4.92	4.92	11.92	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	2.29	0.83	0.45	11.69	16.61	38.07	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	2.17	0.83	0.45	11.56	28.18	61.10	Creek
2D	14.59	90.03				15.00		15.00	2.42	0.83	0.45	5.45	33.63	13.20	Overland
2E	5.69	95.72				15.00		15.00	2.42	0.83	0.45	2.13	35.75	5.15	Overland
2F	16.37	112.09				15.00		15.00	2.42	0.83	0.45	6.11	41.87	14.81	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	2.01	0.83	0.45	10.90	52.76	106.10	Creek
2H	48.75	190.02	50	1500	0.03		2.50	23.83	1.90	0.83	0.45	18.21	70.97	134.59	Creek
subtotal	190.02														
Total	360.47							23.83	1.90				134.64	255.33	
Tributary 3	4.56	4.56				15.00		15	2.42	0.83	0.45	1.70	1.70	4.13	
Tributary 4	8.38	8.38				15.00		15.00	2.42	0.83	0.45	3.13	3.13	7.58	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 7 Peak Runoff, 10 Year Storm, Proposed Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	1.70	0.83	0.45	2.66	2.66	4.53	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	1.63	0.83	0.45	5.45	8.11	13.21	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	1.53	0.83	0.45	19.80	27.91	42.59	Creek
1D	107.41	182.14	130	2800	0.05		4.67	23.17	1.36	0.83	0.48	43.13	71.04	96.30	Creek
Subtotal	182.14														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	1.70	0.83	0.45	4.92	4.92	8.38	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	1.61	0.83	0.45	11.70	16.61	26.78	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	1.53	0.83	0.45	11.56	28.18	42.99	Creek
2D	14.59	90.03				15.00		15.00	1.70	0.83	0.45	5.45	33.62	9.28	Overland
2E	5.69	95.72				15.00		15.00	1.70	0.83	0.45	2.13	35.75	3.62	Overland
2F	16.37	112.09				15.00		15.00	1.70	0.83	0.45	6.11	41.86	10.42	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	1.42	0.83	0.45	10.90	52.76	74.69	Creek
2H	45.33	186.60	50	1500	0.03		2.50	23.83	1.34	0.83	0.45	16.93	69.69	93.07	Creek
subtotal	186.60														
Total	368.73							23.83	1.34				140.74	187.95	
Tributary 3	2.07	2.07				15		15	1.70	0.83	0.50	0.86	0.86	1.46	
Tributary 4	7.94	7.94				15.00		15.00	1.70	0.83	0.64	4.23	4.23	7.20	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 8: Peak Runoff, 100 Year Storm, Proposed Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin	Sum	Difference			Sub-Basin	Travel*	Total	(base)+						Type
	(ac)	(ac)	(ft)	(ft)	(ft/ft)	(min)	(min)	(min)	(in/hr)					(cfs)	
Tributary 1															
1A	7.12	7.12	70	550	0.13	15.00		15.00	2.42	0.83	0.45	2.66	2.66	6.44	Overland
1B	14.59	21.71	70	800	0.09		1.33	16.33	2.32	0.83	0.45	5.45	8.11	18.78	Creek
1C	53.02	74.73	90	1300	0.07		2.17	18.50	2.17	0.83	0.45	19.80	27.91	60.52	Creek
1D	107.41	182.13	130	2800	0.05		4.67	23.17	1.93	0.83	0.48	43.13	71.04	136.76	Creek
Subtotal	182.13														
Tributary 2															
2A	13.17	13.17	80	850	0.09	15.00		15.00	2.42	0.83	0.45	4.92	4.92	11.91	Overland
2B	31.31	44.48	60	1000	0.06		1.67	16.67	2.29	0.83	0.45	11.70	16.61	38.07	Creek
2C	30.96	75.44	50	1100	0.05		1.83	18.50	2.17	0.83	0.45	11.56	28.18	61.09	Creek
2D	14.59	90.03				15.00		15.00	2.42	0.83	0.45	5.45	33.62	13.20	Overland
2E	5.69	95.72				15.00		15.00	2.42	0.83	0.45	2.13	35.75	5.15	Overland
2F	16.37	112.09				15.00		15.00	2.42	0.83	0.45	6.11	41.87	14.81	Creek
2G	29.18	141.27	60	1700	0.04		2.83	21.33	2.01	0.83	0.45	10.90	52.76	106.10	Creek
2H	45.33	186.60	50	1500	0.03		2.50	23.83	1.90	0.83	0.45	16.93	69.69	132.17	Creek
subtotal	186.60														
Total	368.73							23.83	1.90				140.74	266.89	

Tributary 3	2.07	2.07				15		15	2.42	0.83	0.50	0.86	0.86	2.08	

Tributary 4	7.94	7.94				15.00		15.00	2.42	0.83	0.64	4.23	4.23	10.23	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Reach 1B

Man Made Channels -- English Units
Civil Tools for Windows
(04-14-2003, 07:18:36)

```
         Flow Depth = 0.525 ft
           Flowrate = 4.500 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.13000 ft/ft
   Channel Roughness = 0.025
        Wetted Area = 0.55 sf
    Wetted Perimeter = 2.35 ft
           Velocity = 8.16 fps
         Froude No. = 2.81
               Flow = Super-Critical
```

Reach 1B

Man Made Channels -- English Units

Civil Tools for Windows
(04-14-2003, 07:22:29)

```
          Flow Depth = 0.932 ft
            Flowrate = 17.000 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.08700 ft/ft
   Channel Roughness = 0.025
         Wetted Area = 1.74 sf
    Wetted Perimeter = 4.17 ft
            Velocity = 9.78 fps
          Froude No. = 2.53
                Flow = Super-Critical
```

UOP Kelly Creek Flow

100 yr flow, natural channel

Man Made Channels -- English Units

Civil Tools for Windows
(04-18-2003, 10:17:32)

```
          Flow Depth = 5.089 ft
            Flowrate = 200.000 cfs
Channel Bottom Width = 2.000 ft
  Channel Side Slope = 0.500 ft/ft
       Channel Slope = 0.02000 ft/ft
   Channel Roughness = 0.035
        Wetted Area = 23.13 sf
    Wetted Perimeter = 13.38 ft
            Velocity = 8.65 fps
          Froude No. = 0.84
                Flow = Sub-Critical
```

Reach 1D

Man Made Channels -- English Units

Civil Tools for Windows
(04-14-2003, 07:25:10)

```
          Flow Depth = 2.365 ft
            Flowrate = 138.000 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.04000 ft/ft
   Channel Roughness = 0.025
        Wetted Area = 11.18 sf
    Wetted Perimeter = 10.58 ft
            Velocity = 12.34 fps
          Froude No. = 2.00
                Flow = Super-Critical
```

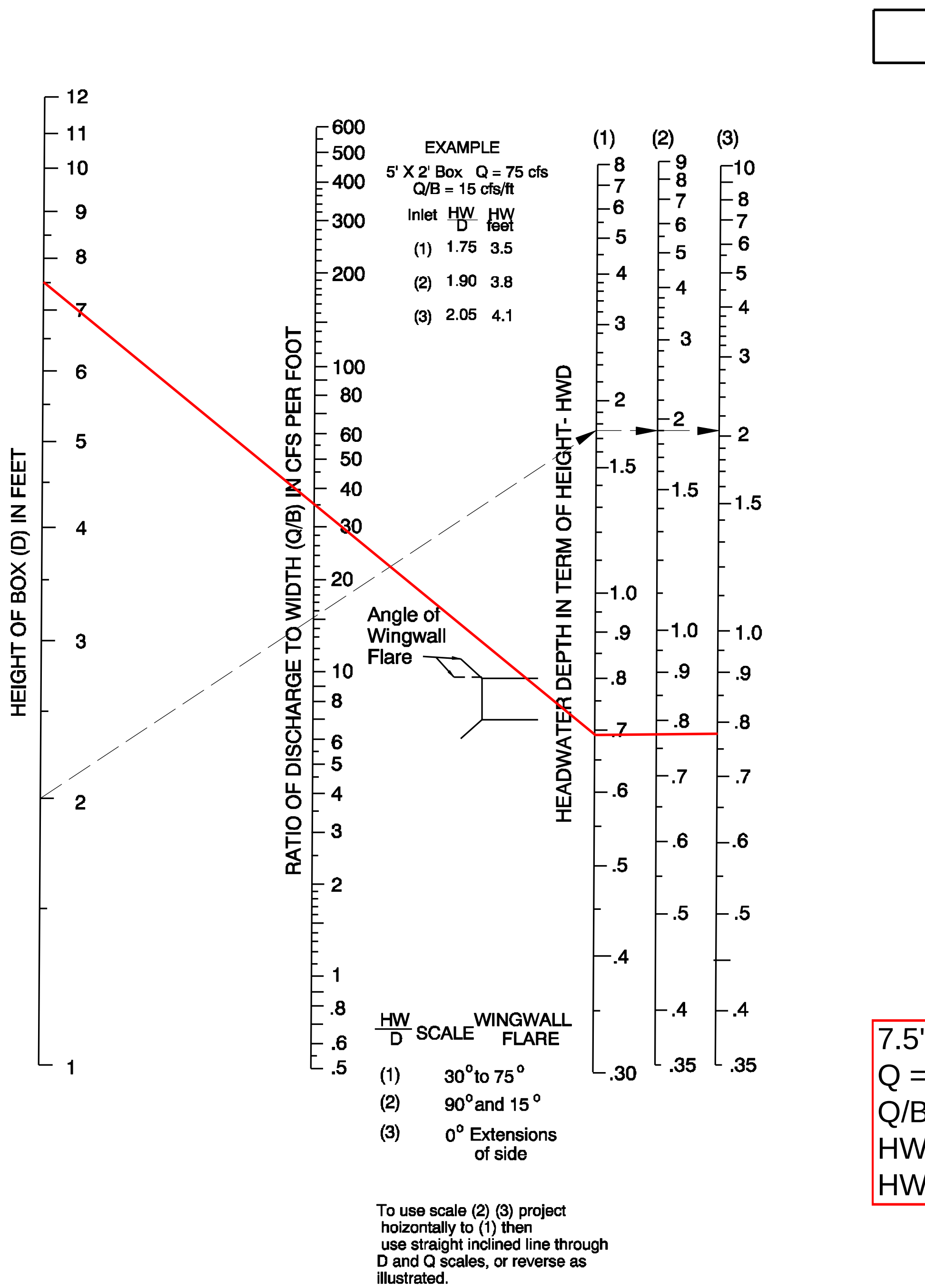
Reach 2H

Man Made Channels -- English Units

Civil Tools for Windows
(04-14-2003, 07:55:34)

```
          Flow Depth = 2.128 ft
            Flowrate = 95.000 cfs
Channel Bottom Width = 0.000 ft
  Channel Side Slope = 2.000 ft/ft
       Channel Slope = 0.03330 ft/ft
   Channel Roughness = 0.025
        Wetted Area = 9.05 sf
    Wetted Perimeter = 9.52 ft
            Velocity = 10.49 fps
          Froude No. = 1.79
                Flow = Super-Critical
```

HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL



7.5' X 7.5' Box
Q = 263 cfs
Q/B = 35 cfs/ft
HW/D = .77
HW = 5.8'

BUREAU OF PUBLIC ROADS JAN. 1963

PRELIMINARY STORM DRAINAGE STUDY
28 LOT REVISED PROJECT

FOR

DAVIDON HOMES PROPERTY

PETALUMA, CALIFORNIA

Prepared by BKF Engineers

Job No.: 20020038

July 2018

CLIENT:

Davidon Homes
1600 South Main Street
Suite 150
Walnut Creek, CA 94596

DESIGN ENGINEER:

BKF Engineers
255 Shoreline Drive
Suite 200
Redwood City, CA 94065

TABLE OF CONTENTS

1.0 INTRODUCTION

Davidon Homes proposes a revised project of 28 single family residential homes on a larger 14.48-acre portion of an approximate 58.6-acre site. The project will install storm drain in the streets that will ultimately discharge to Kelly Creek.

The 58.6-acre site is part of a 360-acre sub basin of the Kelly Creek drainage basin that crosses "D" street just south of Windsor Drive as shown on the attached Exhibit 1: Drainage Map.

This report has been prepared to analyze the impacts to the storm drain system caused by development of the 14.48-acre Davidon Homes site. This report identifies pre-development and post-development peak discharges from the drainage sub-basin and estimates storm water detention needs required to limit post-development peak discharge to pre-development levels.

2.0 EXISTING CONDITIONS

Most of the larger 58.6-acre site (portions of Tributary 1D) is part of the larger 360-acre Kelly Creek drainage basin that crosses under "D" Street through a 7.5 foot by 7.5 foot box culvert near the intersection of "D" Street and Windsor Drive. Similar to the majority of the Kelly Creek drainage basin west of "D" Street, this site is covered with grasses and mature trees and is used for livestock grazing. A small portion of the site (Tributary 4) drains to the storm drain system at the intersection of Windsor Drive and D Street, which connects to Kelly Creek downstream of the box culvert that crosses under D Street. Another small portion of the site (Tributaries 3A and 3B) drains to Windsor Drive and flows west, eventually entering a storm drain system that continues westward. See Exhibit 1.

3.0 DESIGN CRITERIA

This storm drain analysis has been prepared in conformance with the Sonoma County Water Agency Flood Control Design Criteria (SCWA FCDC) using the Rational Method.

Assumptions

- Runoff Coefficients (C) (assuming 20 percent slope)
  From Plate B-1, SCWA FCDC

Parks and vegetated areas	0.45
Residential over 1/2 acre	0.50
Residential 1/4 to 1/2 acre	0.58
Single Family Residential	0.68

- Design Storm Event
  10-year storm for minor waterways of one square mile or less
  100-year storm for major waterways of four square miles or more

- Minimum Time of Concentration (Tc)
  10 minutes for lots smaller than 1/2 acre
  15 minutes for Lots 1/2 acre and larger

- Rainfall Intensity, (I)
  Based on the equation from Plate B-2, SCWA FCDC
  $I_{10} = 7.08/Tc^{(0.526)}$
  $I_{100} = 10.15/Tc^{(0.529)}$

The basic rainfall intensity equations applies to 30 inches of mean seasonal precipitation and are adjusted by the factor K shown in Plate B-4 (SCWA FCDC) for the actual mean seasonal precipitation in the project area as shown on the Isohyetal map, Plate B-3. Based on Plate B-3 the project site receives approximately 25 inches of rainfall a year. The K factor for 25 inches of mean seasonal precipitation is 0.83.

Storm water quality features incorporated in to the site will be designed to treat 0.2 inches/hour of runoff. This will delay the treatment flow (0.2 inches per hour) runoff from the site by approximately 2 hours, effectively reducing the peak discharge from the site by 0.2 inches per hour. Therefore, the calculations presented in this study are conservative. This benefit will be documented in more detail in the project hydrology report prepared during development of the project construction documents.

Table 1: Rainfall Intensity

Tc	I_{10}, 10 Year Rainfall Intensity		I_{100}, 100 Year Rainfall Intensity	
	Base	Corrected	Base	Corrected
10	2.11	1.75	3.00	2.49
15	1.70	1.41	2.42	2.01
20	1.46	1.22	2.08	1.73
30	1.18	0.98	1.68	1.39
45	0.96	0.79	1.35	1.12
60	0.82	0.68	1.16	0.97

Base rainfall intensity for areas with 30 inches annual precipitation
Corrected rainfall intensity is site specific based on 25 inches annual precipitation

- Storm water storage volume will be estimated based on the following equation derived from rational method. This equation assumes the proposed runoff hydrograph distribution is triangular shape and the duration of the hydrograph is three times of Tc in proposed condition. In our experience, this equation provides a good estimate of storm runoff detention volume for preliminary project analysis in the San Francisco Bay area. A more detailed volume calculation will be determined during construction document phase of the project after street sections, site plans and grading are finalized.

$V=3/2 \times Tc \times (Q_{pr}\text{ peak} - Q_{ex}\text{ peak})$

Where:

V = Required Storage Volume

Tc = Time of concentration

Q_{pr} peak = Proposed peak discharge from the watershed after development

Q_{ex} peak = Existing peak discharge from the watershed

4.0 STORM DRAIN SYSTEM EVALUATION

The site is divided into four drainage areas based on discharge points. The calculations for runoff from each drainage basin for the 10 year and 100 year storm are detailed in the attached spreadsheets. Implementation of stormwater quality features will modify the drainage patterns. Drainage basin 2 has remained the same. Drainage basin 3 within the project limits has increased in impervious area. However, the overall tributary area for drainage basin 3 has reduced in size and continues to drain to Windsor Drive and flow west, eventually entering a storm drain system that continues westward. Drainage basin 4 also has a smaller tributary area and continues to flow into the storm drain system at the intersection of D Street and Windsor Drive, which connects to Kelly Creek after crossing D Street. The box culvert conveying flows from Kelly Creek under D Street was analyzed to determine if it has adequate capacity for the proposed condition.

This storm drain analysis uses a runoff coefficient, C factor, of 0.45 for undeveloped areas of the sub-basin that represent parks and vegetated areas. A C factor of 0.68 is used for development of the site. The runoff coefficient used for the developed condition is representative of single family development on lots smaller than 1/4 acre and is conservative when applied to this project where many of the lots will be larger than 1/4 acre. This will result in lower peak storm water discharge from the site than represented by these calculations. This will be documented in the hydrology report prepared as part of the project construction documents.

This analysis uses 15 minutes as the initial time of concentration. The flow time for each sub-basin is then added to the initial time of concentration to develop the time of concentration at the discharge from each sub-basin. The flow time for each sub-basin is approximated using a flow velocity of 10 feet per second. This was then checked using the average slope of the sub-basin flow channel and an idealized channel cross section with 2H:1V side slopes and a roughness factor of 0.025.

The storm water detention volume required to limit post development peak discharge to predevelopment levels for the 10-year and the 100-year storm was then calculated.

5.0 SUMMARY AND CONCLUSIONS

The proposed development of the 14.48-acre site will increase the amount of impervious surface in, and runoff from, the 360-acre Kelly Creek sub basin studied in this report. The proposed storm water detention basin will reduce discharge into Kelly Creek to match or be below predevelopment levels. Table 2 summarizes the peak runoff for the 10-year and the 100-year storm for the existing and proposed conditions without any storm water detention basin.

Table 2: Summary of Peak Kelly Creek Discharge at "D" Street

Basin	Storm Event	Peak Discharge Existing Condition (cfs)	Peak Discharge Proposed Condition (cfs)
1	10-year	87.44	91.14
1	100-year	124.18	129.44
2	10-year	92.28	92.28
2	100-year	131.04	131.04
3	10-Year	2.61	1.52
3	100-Year	3.71	1.75
4	10-Year	5.23	4.74
4	100-Year	7.44	6.73

Analysis of the existing 7.5 foot square box culvert under "D" Street shows that it has adequate capacity for the 100-year storm under the proposed condition without surcharge. See the box culvert nomograph attached.

Storm water will be detained on site to limit peak post-development discharge to peak pre-development levels. For basin 1 the project will detain the increase in flow over the existing condition. Runoff for basins 2, 3, and 4 will remain the same or decrease in the proposed condition and no detention is necessary. Below is a sample calculation of the required detention volume for drainage basin 1 during a 10-year storm. The detention volume is a 1.5 times product of the difference in peak flows (proposed and existing) multiplied by the time of concentration.

Sample Calculation:

Detention volume required for drainage basin 1 during a 10-year storm

$$V = \frac{3}{2} * Tc * \left(Q_{pr} - Q_{ex}\right)$$

$$V = \frac{3}{2} * (23.17\ \text{min}) * \frac{60\ sec}{1\ min} * (\ 91.14\ cfs - \ 87.44\ cfs)$$

$$V = 7{,}730\ \ cf$$

Table 3 summarizes storm water detention requirements.

Table 3: Storm Water Detention Volume

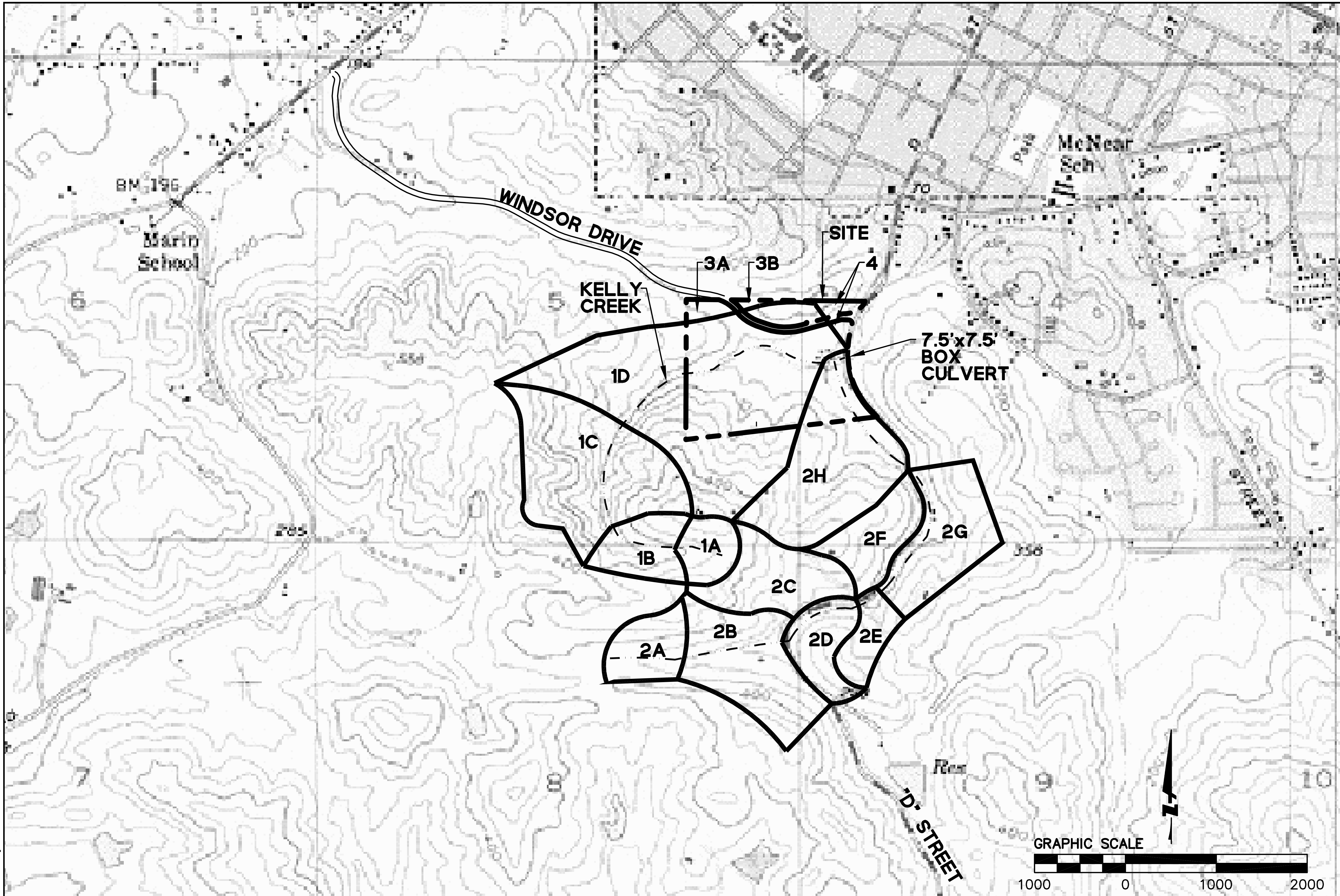
Drainage Basin	Storm Event	Detention Required (cf)
1	10-Year	7,730
1	100-Year	10,977
2	10-Year	N/A
2	100-Year	N/A
3	10-Year	N/A
3	100-Year	N/A
4	10-Year	N/A
4	100-Year	N/A

The site provides multiple opportunities to incorporate storm water detention into the project to further reduce peak post-development discharge from the site. Opportunities include:

- Providing oversized storm drain pipe and metering flow from the storm drain system using a smaller diameter pipe or an orifice.
- Incorporating areas of detention integral with the storm water quality features. Ponding can be allowed in these areas and storm water can be metered using weirs or constrained orifices to reduce peak storm water runoff.

See Exhibit 2 for plan showing drainage basins and conceptual detention measures within each basin. A more detailed analysis of the project storm drain system and detention requirement will be prepared to accompany the project improvement plans and final map.

© Brian Kangas Foulk



255 SHORELINE DRIVE, SUITE 200
REDWOOD CITY, CA 94065
650-482-6300
650-482-6399 (FAX)

BKF
ENGINEERS / SURVEYORS / PLANNERS

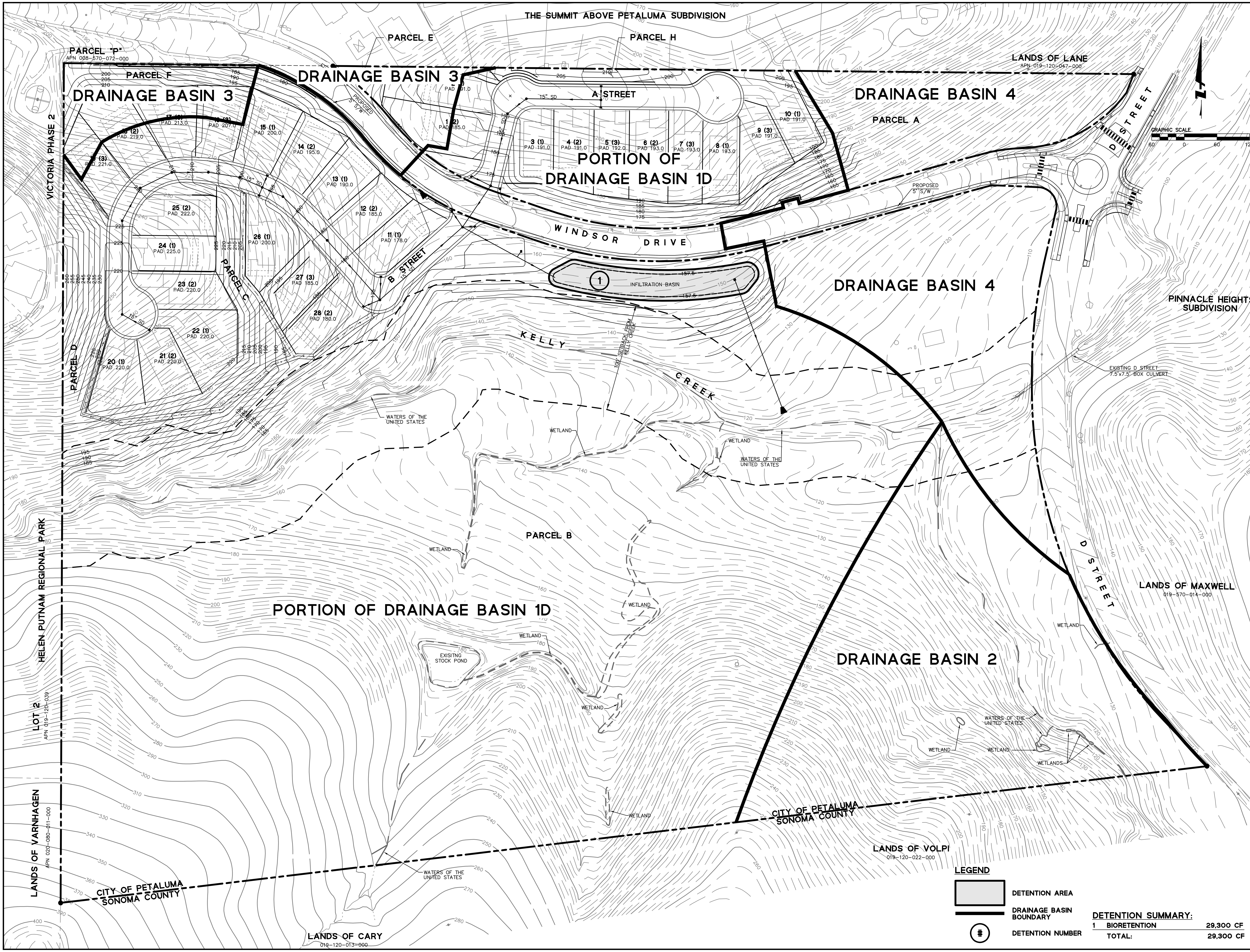
DAVIDON HOMES/UOP
PRELIMINARY STORM DRAINAGE STUDY
EXHIBIT 1: EXISTING DRAINAGE MAP

PETALUMA SONOMA CALIFORNIA

Date 7/6/2018
Scale 1"=1000'
Design TRM
Drawn LVO
Approved TA

Drawing Number:
1 OF 1

© BKF ENGINEERS



255 SHORELINE DRIVE, SUITE 200
REDWOOD CITY, CA 94065
650/482-6300
650/482-6399 (FAX)

BKF ENGINEERS | SURVEYORS | PLANNERS

CALIFORNIA

DAVIDON HOMES / SCOTT RANCH
PRELIMINARY STORM DRAINAGE STUDY
EXHIBIT 2: CONCEPTUAL DETENTION EXHIBIT - 28 LOT PLAN

SONOMA COUNTY

CITY OF PETALUMA

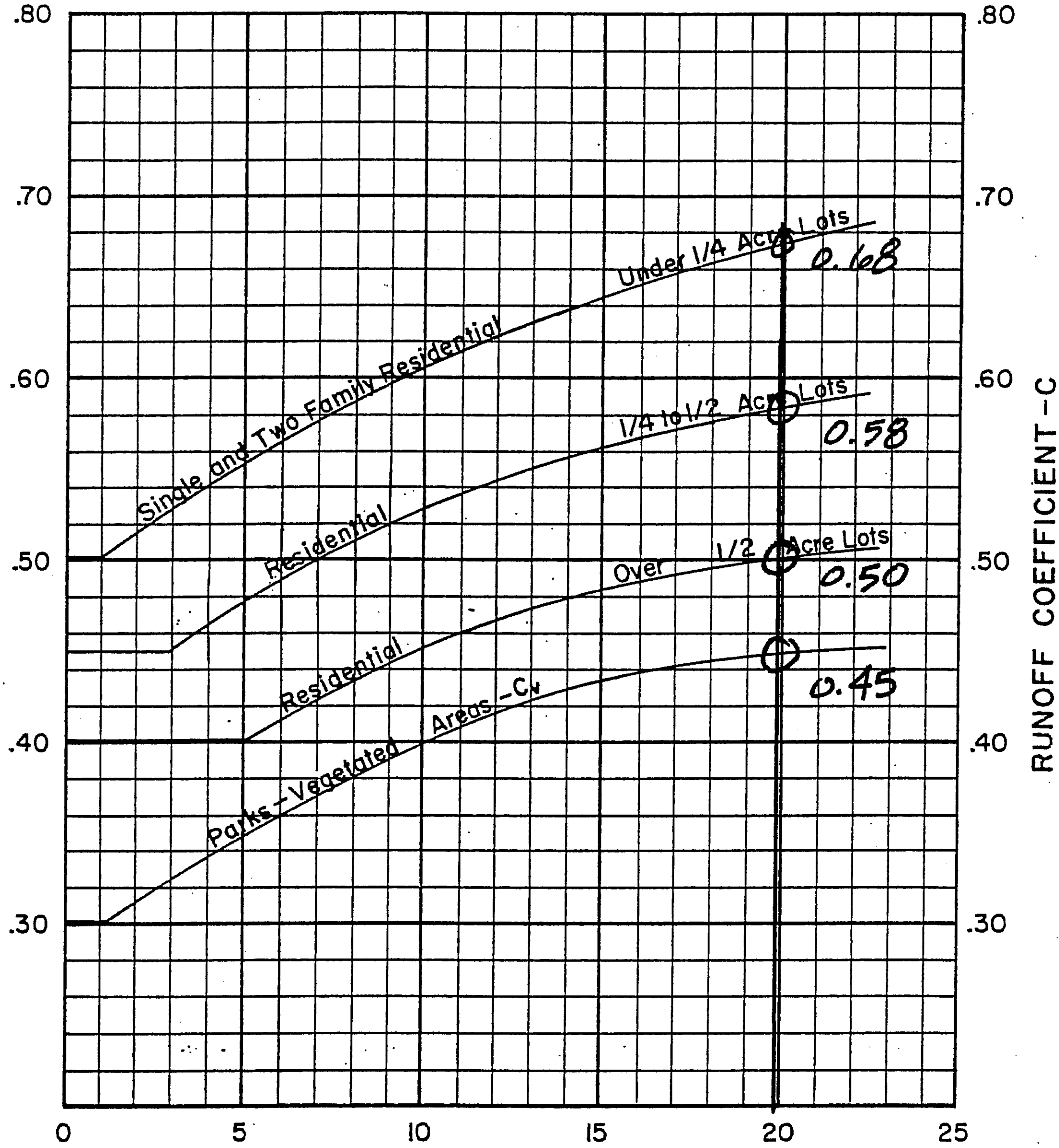
Revisions

Date	06/04/2018
Scale	1"=60'
Design	RKB
Drawn	KCC
Approved	TRM
Job No	20020038

Sheet Number:

DRAWING NAME: K:\MAIN\2002\020038\06 Design\C Storm Drain\Hydrology Report\Exhibits\Detention Exhibit - 28 Lot Plan.dwg
PLOT DATE: 07-17-18 PLOTTED BY: chuk

RUNOFF COEFFICIENTS FOR RATIONAL FORMULA



AVERAGE GROUND SLOPE %
(NOT SLOPE OF CHANNEL OR STORM DRAIN)

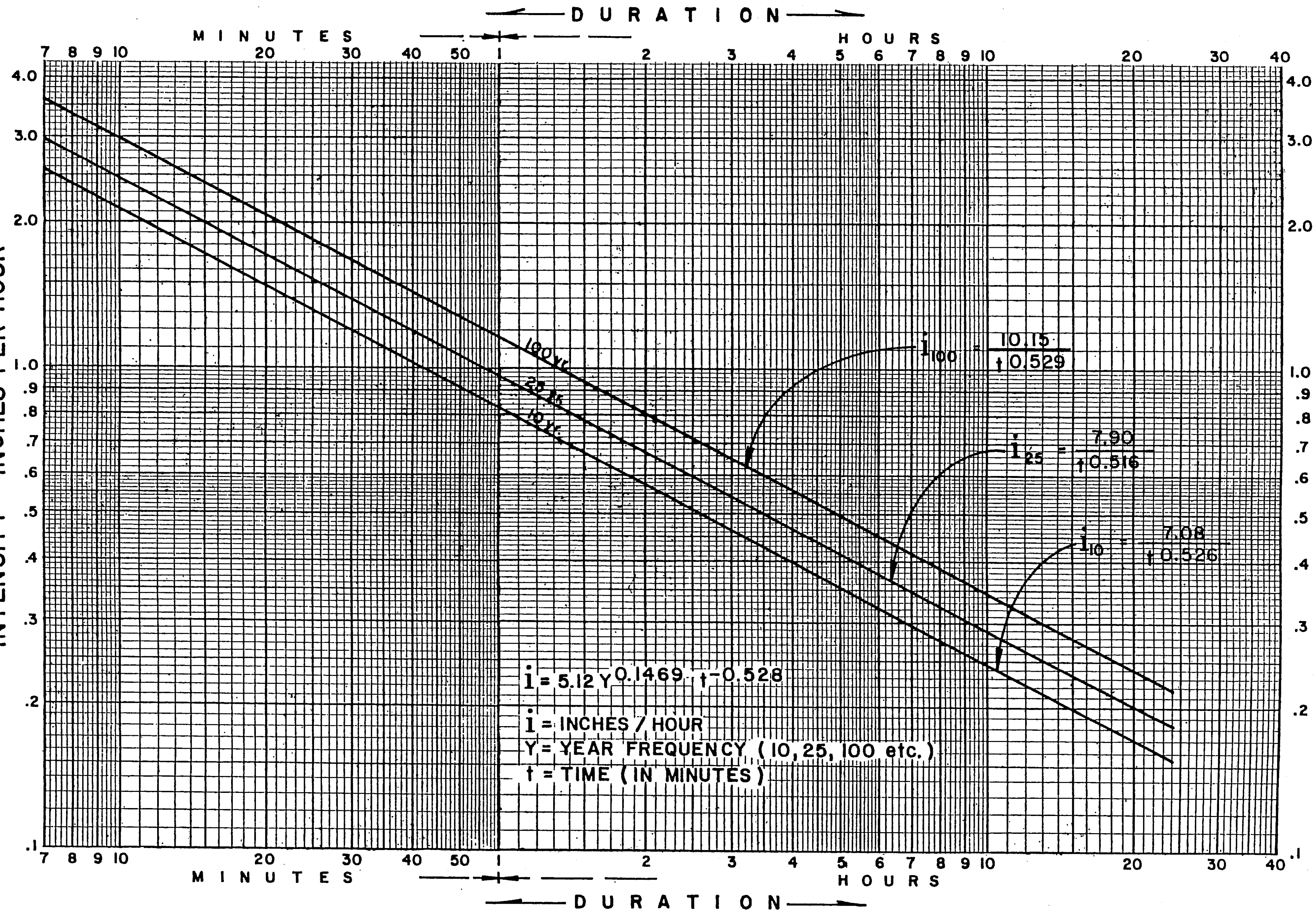
NOTE: Commercial, Industrial & Multiple Residential Areas

C_P = 0.9 (Based on paving, roofs, etc.)

When vegetated area exceeds 20% of total, C_V from vegetated curve may be used to reduce above C_P as follows:

$$C_T = C_V \frac{A_V}{A_T} + C_P \frac{A_P}{A_T}$$

SONOMA COUNTY WATER AGENCY



NOTE: THE INFORMATION SHOWN IS SUBJECT TO ANNUAL REVISION AS ADDITIONAL RAINFALL DATA BECOMES AVAILABLE

RAINFALL
INTENSITY vs DURATION

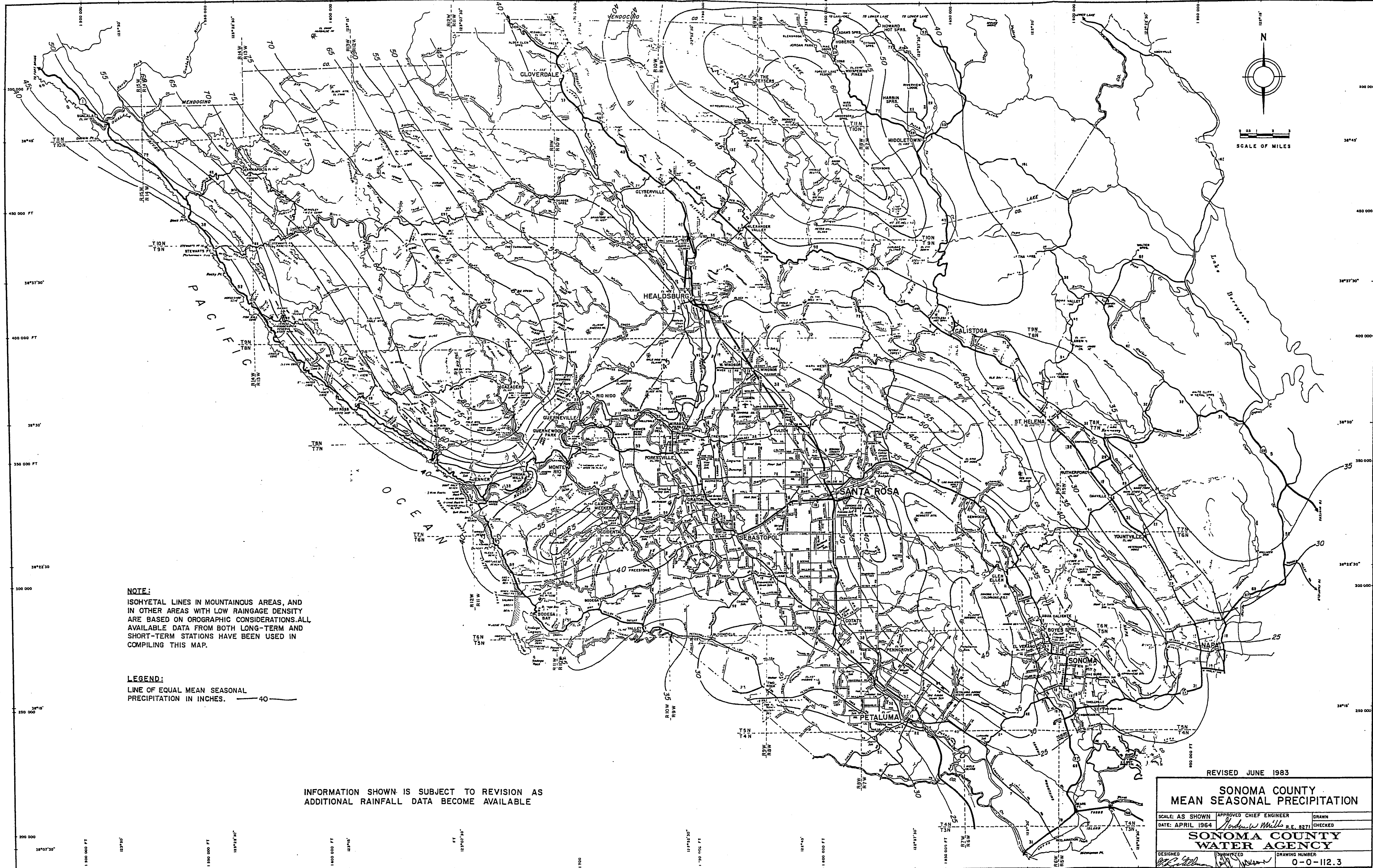
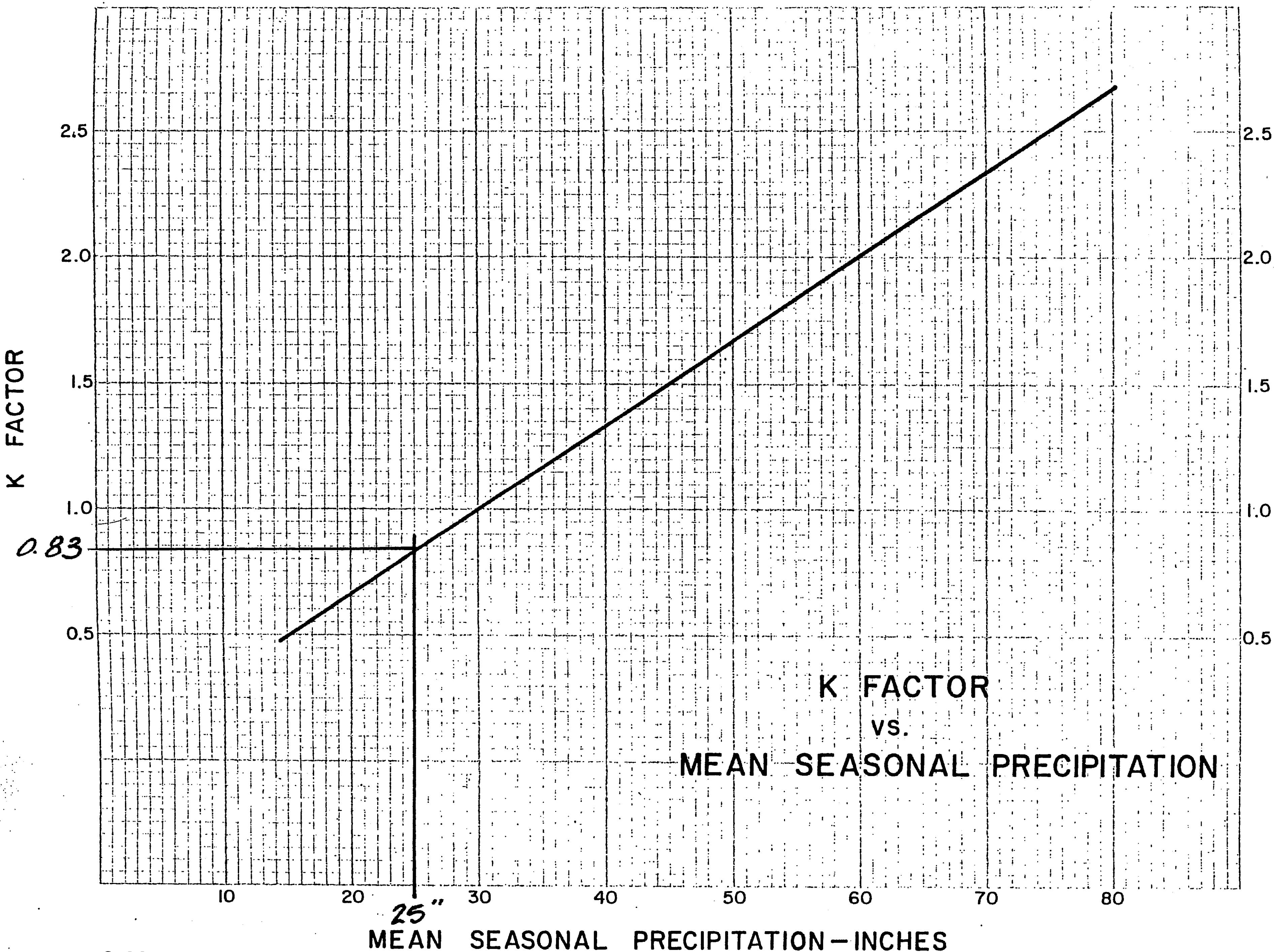

PACIFIC
OCEAN
MENDOCINO
CO.
LAKE
CO.
CLOVERDALE
GEYSERVILLE
HEALDSBURG
THE GEYSERS
MIDDLETOWN
HARBIN SPRS.
CALISTOGA
ST. HELENA
RUTHERFORD
OAKVILLE
YOUNTVILLE
NAPA
SANTA ROSA
SEBASTOPOL
GUERNEVILLE
RIO NIDO
FORESTVILLE
MONTE RIO
JENNER
CAZADERO
OCCIDENTAL
FREESTONE
BODEGA
BODEGA BAY
VALLEY FORD
BLOOMFIELD
COTATI
PENNGROVE
PETALUMA
KENWOOD
GLEN ELLEN
EL VERANO
AGUA CALIENTE
BOYES SPRS.
SONOMA
FULTON
WINDSOR
Lake Berryessa
N
SCALE OF MILES
NOTE:
ISOHYETAL LINES IN MOUNTAINOUS AREAS, AND IN OTHER AREAS WITH LOW RAINGAGE DENSITY ARE BASED ON OROGRAPHIC CONSIDERATIONS. ALL AVAILABLE DATA FROM BOTH LONG-TERM AND SHORT-TERM STATIONS HAVE BEEN USED IN COMPILING THIS MAP.
LEGEND:
LINE OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES. —40—
INFORMATION SHOWN IS SUBJECT TO REVISION AS ADDITIONAL RAINFALL DATA BECOME AVAILABLE
REVISED JUNE 1983
SONOMA COUNTY
MEAN SEASONAL PRECIPITATION
SCALE: AS SHOWN
DATE: APRIL 1964
APPROVED CHIEF ENGINEER
R.E. 8271
DRAWN
CHECKED
SONOMA COUNTY
WATER AGENCY
DESIGNED
SUBMITTED
DRAWING NUMBER
0-0-112.3

PLATE No. B-3


K FACTOR
vs.
MEAN SEASONAL PRECIPITATION
K FACTOR
2.5
2.0
1.5
1.0
0.83
0.5
10
20
25"
30
40
50
60
70
80
MEAN SEASONAL PRECIPITATION-INCHES

2-66

Table 4: Weighted Runoff Coefficients

Basin 1D

Total Area	101.49	ac
Open Space Area	94.20	ac
Developed Area	7.29	ac
C, Open space	0.45	
C, Developed	0.68	
C, Weighted	**0.47**	

Basin 3

Total Area	1.60	ac
Open Space Area	0.95	ac
Developed Area	0.65	ac
C, Open Space	0.45	
C, Developed	0.68	
C, Weighted	**0.54**	

Basin 4

Total Area	7.11	ac
Open Space Area	6.44	ac
Developed Area	0.67	ac
C, Open Space	0.45	
C, Developed	0.68	
C, Weighted	**0.47**	

All Other Basins

C, Open Space	0.45
C, Developed	0.68

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 5: Peak Runoff, 10 Year Storm, Existing Condition

Basin	Area		Elevation Difference	Distance	Slope	TC			i (base)+	K	C	KAC	Sum KAC	Q	Design Type
	Sub-Basin (ac)	Sum (ac)	(ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(in/hr)					(cfs)	
Tributary 1															
1A	9.55	9.55	70	550	0.13	15.00		15.00	1.70	0.83	0.45	3.57	3.57	6.08	Overland
1B	14.14	23.69	70	800	0.09		1.33	16.33	1.63	0.83	0.45	5.28	8.85	14.41	Creek
1C	51.12	74.80	90	1300	0.07		2.17	18.50	1.53	0.83	0.45	19.09	27.94	42.63	Creek
1D	97.90	172.70	130	2800	0.05		4.67	23.17	1.36	0.83	0.45	36.56	64.50	87.44	Creek
Total	172.70							23.17	1.36				64.50	87.44	Creek
Tributary 2															
2A	13.76	13.76	80	850	0.09	15.00		15.00	1.70	0.83	0.45	5.14	5.14	8.76	Overland
2B	34.06	47.82	60	1000	0.06		1.67	16.67	1.61	0.83	0.45	12.72	17.86	28.79	Creek
2C	23.12	70.94	50	1100	0.05		1.83	18.50	1.53	0.83	0.45	8.64	26.50	40.43	Creek
2D	14.38	85.33				15.00		15.00	1.70	0.83	0.45	5.37	31.87	9.15	Overland
2E	9.71	95.04				15.00		15.00	1.70	0.83	0.45	3.63	35.50	6.18	Overland
2F	16.95	111.99				15.00		15.00	1.70	0.83	0.45	6.33	41.83	10.79	Creek
2G	28.59	140.58	60	1700	0.04		2.83	21.33	1.42	0.83	0.45	10.68	52.50	74.33	Creek
2H	44.43	185.01	50	1500	0.03		2.50	23.83	1.34	0.83	0.45	16.59	69.10	92.28	Creek
Total	185.01							23.83	1.34				69.10	92.28	Creek
Tributary 3	4.10	4.10				15.00		15.00	1.70	0.83	0.45	1.53	1.53	2.61	
Tributary 4	8.22	8.22				15.00		15.00	1.70	0.83	0.45	3.07	3.07	5.23	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 6: Peak Runoff, 100 Year Storm, Existing Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin (ac)	Sum (ac)	Difference (ft)	(ft)	(ft/ft)	Sub-Basin (min)	Travel* (min)	Total (min)	(base)+ (in/hr)					(cfs)	Type
Tributary 1															
1A	9.55	9.55	70	550	0.13	15.00		15.00	2.42	0.83	0.45	3.57	3.57	8.64	Overland
1B	14.14	23.69	70	800	0.09		1.33	16.33	2.32	0.83	0.45	5.28	8.85	20.49	Creek
1C	51.12	74.80	90	1300	0.07		2.17	18.50	2.17	0.83	0.45	19.09	27.94	60.58	Creek
1D	97.90	172.70	130	2800	0.05		4.67	23.17	1.93	0.83	0.45	36.56	64.50	124.18	Creek
Total	172.70							23.17	1.93				64.50	124.18	Creek
Tributary 2															
2A	13.76	13.76	80	850	0.09	15.00		15.00	2.42	0.83	0.45	5.14	5.14	12.45	Overland
2B	34.06	47.82	60	1000	0.06		1.67	16.67	2.29	0.83	0.45	12.72	17.86	40.92	Creek
2C	23.12	70.94	50	1100	0.05		1.83	18.50	2.17	0.83	0.45	8.64	26.50	57.45	Creek
2D	14.38	85.33				15.00		15.00	2.42	0.83	0.45	5.37	31.87	13.02	Overland
2E	9.71	95.04				15.00		15.00	2.42	0.83	0.45	3.63	35.50	8.79	Overland
2F	16.95	111.99				15.00		15.00	2.42	0.83	0.45	6.33	41.83	15.34	Creek
2G	28.59	140.58	60	1700	0.04		2.83	21.33	2.01	0.83	0.45	10.68	52.50	105.58	Creek
2H	44.43	185.01	50	1500	0.03		2.50	23.83	1.90	0.83	0.45	16.59	69.10	131.04	Creek
Total	185.01							23.83	1.90				69.10	131.04	Creek
Tributary 3	4.10	4.10				15.00		15.00	2.42	0.83	0.45	1.53	1.53	3.71	
Tributary 4	8.22	8.22				15.00		15.00	2.42	0.83	0.45	3.07	3.07	7.44	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 7 Peak Runoff, 10 Year Storm, Proposed Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin	Sum	Difference			Sub-Basin	Travel*	Total	(base)+						Type
	(ac)	(ac)	(ft)	(ft)	(ft/ft)	(min)	(min)	(min)	(in/hr)					(cfs)	
Tributary 1															
1A	9.55	9.55	70	550	0.13	15.00		15.00	1.70	0.83	0.45	3.57	3.57	6.08	Overland
1B	14.14	23.69	70	800	0.09		1.33	16.33	1.63	0.83	0.45	5.28	8.85	14.41	Creek
1C	51.12	74.80	90	1300	0.07		2.17	18.50	1.53	0.83	0.45	19.09	27.94	42.63	Creek
1D	101.49	176.30	130	2800	0.05		4.67	23.17	1.36	0.83	0.47	39.30	67.24	91.14	Creek
Total	176.30							23.17	1.36				67.24	91.14	Creek
Tributary 2															
2A	13.76	13.76	80	850	0.09	15.00		15.00	1.70	0.83	0.45	5.14	5.14	8.76	Overland
2B	34.06	47.82	60	1000	0.06		1.67	16.67	1.61	0.83	0.45	12.72	17.86	28.79	Creek
2C	23.12	70.94	50	1100	0.05		1.83	18.50	1.53	0.83	0.45	8.64	26.50	40.43	Creek
2D	14.38	85.33				15.00		15.00	1.70	0.83	0.45	5.37	31.87	9.15	Overland
2E	9.71	95.04				15.00		15.00	1.70	0.83	0.45	3.63	35.50	6.18	Overland
2F	16.95	111.99				15.00		15.00	1.70	0.83	0.45	6.33	41.83	10.79	Creek
2G	28.59	140.58	60	1700	0.04		2.83	21.33	1.42	0.83	0.45	10.68	52.50	74.33	Creek
2H	44.43	185.01	50	1500	0.03		2.50	23.83	1.34	0.83	0.45	16.59	69.10	92.28	Creek
Total	185.01							23.83	1.34				69.10	92.28	Creek
Tributary 3	1.60	1.60				10.00		10.00	2.11	0.83	0.54	0.72	0.72	1.52	
Tributary 4	7.11	7.11				15.00		15.00	1.70	0.83	0.47	2.78	2.78	4.74	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Davidon Homes/UOP Property
Preliminry Storm Drain Analysis

Table 8: Peak Runoff, 100 Year Storm, Proposed Condition

Basin	Area		Elevation	Distance	Slope	TC			i	K	C	KAC	Sum KAC	Q	Design
	Sub-Basin	Sum	Difference			Sub-Basin	Travel*	Total	(base)+						Type
	(ac)	(ac)	(ft)	(ft)	(ft/ft)	(min)	(min)	(min)	(in/hr)					(cfs)	
Tributary 1															
1A	9.55	9.55	70	550	0.13	15.00		15.00	2.42	0.83	0.45	3.57	3.57	8.64	Overland
1B	14.14	23.69	70	800	0.09		1.33	16.33	2.32	0.83	0.45	5.28	8.85	20.49	Creek
1C	51.12	74.80	90	1300	0.07		2.17	18.50	2.17	0.83	0.45	19.09	27.94	60.58	Creek
1D	101.49	176.30	130	2800	0.05		4.67	23.17	1.93	0.83	0.47	39.30	67.24	129.44	Creek
Total	176.30							23.17	1.93				67.24	129.44	Creek
Tributary 2															
2A	13.76	13.76	80	850	0.09	15.00		15.00	2.42	0.83	0.45	5.14	5.14	12.45	Overland
2B	34.06	47.82	60	1000	0.06		1.67	16.67	2.29	0.83	0.45	12.72	17.86	40.92	Creek
2C	23.12	70.94	50	1100	0.05		1.83	18.50	2.17	0.83	0.45	8.64	26.50	57.45	Creek
2D	14.38	85.33				15.00		15.00	2.42	0.83	0.45	5.37	31.87	13.02	Overland
2E	9.71	95.04				15.00		15.00	2.42	0.83	0.45	3.63	35.50	8.79	Overland
2F	16.95	111.99				15.00		15.00	2.42	0.83	0.45	6.33	41.83	15.34	Creek
2G	28.59	140.58	60	1700	0.04		2.83	21.33	2.01	0.83	0.45	10.68	52.50	105.58	Creek
2H	44.43	185.01	50	1500	0.03		2.50	23.83	1.90	0.83	0.45	16.59	69.10	131.04	Creek
Total	185.01							23.83	1.90				69.10	131.04	Creek
Tributary 3	1.60	1.60				10.00		10.00	2.42	0.83	0.54	0.72	0.72	1.75	
Tributary 4	7.11	7.11				15.00		15.00	2.42	0.83	0.47	2.78	2.78	6.73	

* Travel time through the Basin is based on channel velocity of 10 feet per second
+ Base rainfall intensity for 30 inches annual rainfall. Corrected by K for locations with different annual rainfall amounts.'ex 10 yr storm'!

Table 9: Storm Water Detention Calculation

Basin	Storm Event	Tc (min)	Ex Peak Runoff (cfs)	Pr Peak Runoff (cfs)	Detention Required (cf)
1	10 Year	23.17	87.44	91.14	7,730
1	100 Year	23.17	124.18	129.44	10,977
2	10 Year	23.83	92.28	92.28	N/A
2	100 Year	23.83	131.04	131.04	N/A
3	10 Year	15.00	2.61	1.52	N/A
3	100 Year	15.00	3.71	1.75	N/A
4	10 Year	15.00	5.23	4.74	N/A
4	100 Year	15.00	7.44	6.73	N/A

Note: Detention volumes for basin 3 are based on proposed peak runoff.

REACH 1B

Man-Made Channels

CIVIL TOOLS PRO

English Units

07-06-2018 15:22:50

Results

Flow Depth	=	1.00 ft
Flowrate	=	20.49 cfs
Bottom Width	=	0.00 ft
Side Slope (H:V)	=	2.0000 H:V
Channel Slope (V:H)	=	0.0870 V:H
Manning's N	=	0.025
Wetted Area	=	2.00 sq ft
Wetted Perimeter	=	4.47 ft
Velocity	=	10.25 fps
Froude No.	=	2.56
Flow Regime	=	Super-Critical

UOP Kelly Creek Flow

100 yr flow, natural channel

Man-Made Channels

CIVIL TOOLS PRO
English Units
07-06-2018 15:26:34

Results

Flow Depth	=	5.86	ft
Flowrate	=	267.21	cfs
Bottom Width	=	2.00	ft
Side Slope (H:V)	=	0.5000	H:V
Channel Slope (V:H)	=	0.0200	V:H
Manning's N	=	0.035	
Wetted Area	=	28.88	sq ft
Wetted Perimeter	=	15.10	ft
Velocity	=	9.25	fps
Froude No.	=	0.85	
Flow Regime	=	Sub-Critical	

Reach 1D

Man-Made Channels

CIVIL TOOLS PRO
English Units
07-06-2018 15:27:29

Results

Flow Depth	=	2.31 ft
Flowrate	=	129.44 cfs
Bottom Width	=	0.00 ft
Side Slope (H:V)	=	2.0000 H:V
Channel Slope (V:H)	=	0.0400 V:H
Manning's N	=	0.025
Wetted Area	=	10.66 sq ft
Wetted Perimeter	=	10.32 ft
Velocity	=	12.14 fps
Froude No.	=	1.99
Flow Regime	=	Super-Critical

Reach 2H

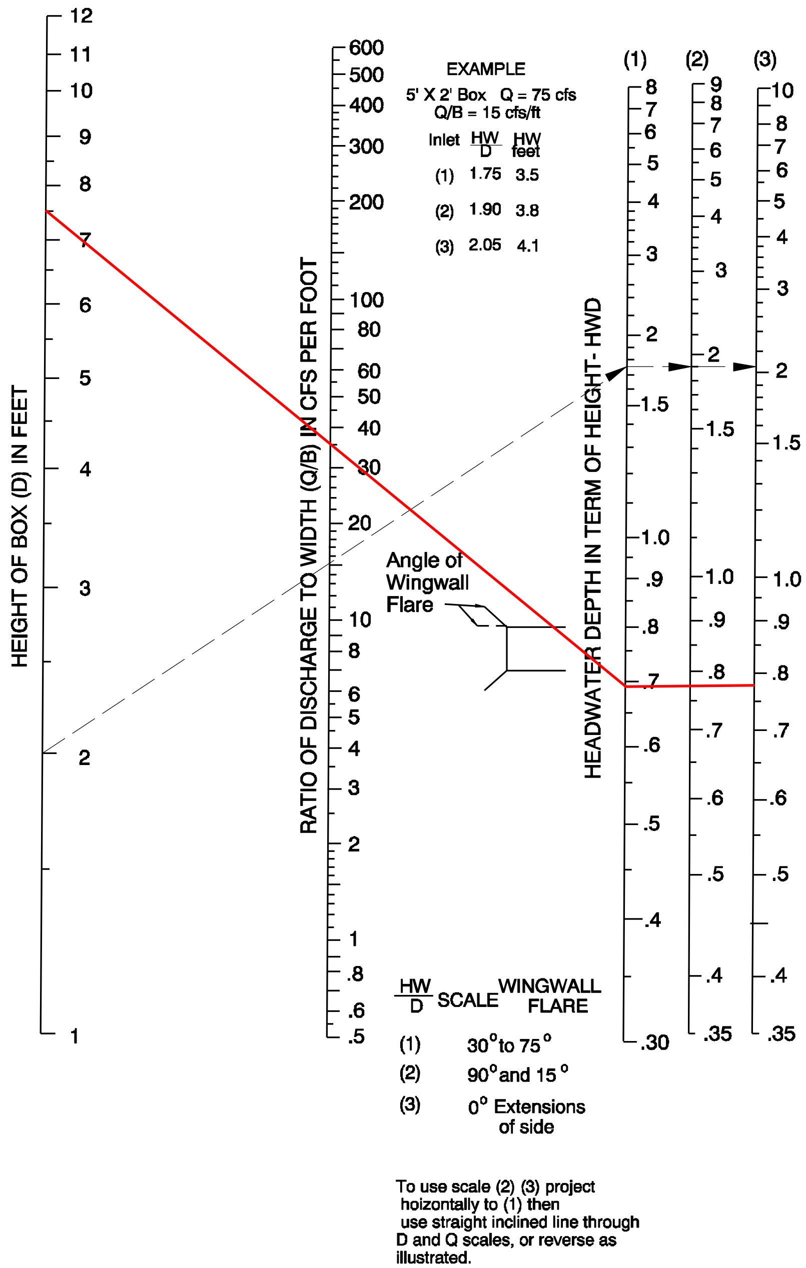
Man-Made Channels

CIVIL TOOLS PRO
English Units
07-06-2018 15:30:21

Results

Flow Depth	=	1.56 ft
Flowrate	=	131.04 cfs
Bottom Width	=	0.00 ft
Side Slope (H:V)	=	2.0000 H:V
Channel Slope (V:H)	=	0.3330 V:H
Manning's N	=	0.025
Wetted Area	=	4.86 sq ft
Wetted Perimeter	=	6.97 ft
Velocity	=	26.97 fps
Froude No.	=	5.38
Flow Regime	=	Super-Critical

HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL



7.5' X 7.5' Box
Q = 267.21 cfs
Q/B = 35.63 cfs/ft
HW/D = .78
HW = 5.9'

BUREAU OF PUBLIC ROADS JAN. 1963