R.G. DRAGE CAREER TECHNICAL CENTER
2800 RICHVILLE DRIVE SW
MASSILLON, OH 44646

SWALE IMPROVEMENT CALCULATIONS REPORT

Prepared For:
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6677 Frank Ave NW, North Canton OH, 44720
August 2, 2018

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B. Rainfall data
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PART I – NARRATIVE

INTRODUCTION:
R.G Drage Career Technical Center in Massillon will rehabilitate an existing swale on their site that outlets into an existing ODOT ditch that runs along Richville Drive. The project entails regrading and re-shaping approximately 950 feet of the existing swale. The proposed work will eliminate existing erosion problems the swale is causing on the R.G. Drage campus as well as sediment buildup downstream of the swale. The swale services a drainage area of approximately 32 acres. The proposed rehabilitation will alleviate rutting within the swale and sediment buildup from the degradation of the swale. The proposed plan calls for a reshaping that will transform the existing rutted, v-shaped swale with variable slope to a trapezoidal swale with a 4 foot bottom and a consistent slope. The proposed swale will also include permanent erosion control matting to ensure erosion will not occur for high flows.

DESIGN CRITERIA:
The Ohio Rainwater and Land Development Manual and The Ohio Department of Transportation's *Location and Design Manual, Volume II: Drainage Design* was the basis for design, Chapter 1102.3. The depth of flow was determine using the 5 year storm. The shear stress was calculated using the 2 year storm. Rainfall data is taken from the NOAA 14. The SCS method was used to develop hydrographs. Manning's equation is used to determine swale flow parameters.

PRE-DEVELOPED CONDITIONS:
The pre-developed swale is in poor condition. Erosion over the years has caused large amounts of rutting and has created a "V" shape in the bottom of the swale, and the swale is no longer grassed. The approximate shape of the channel is a trapezoidal channel with no bottom width and side slopes of 3:1, with a varying depth. Erosion has transported sediment downstream.

POST-DEVELOPED CONDITIONS:
The post-developed swale will stabilize the erosion problems the current swale is experiencing. The entire length of the swale will be recut and reshaped, and grass will be planted along the bottom and sides. The swale will be widened to 4 feet on the bottom and the side slope will be normalized across the entire length of the swale, creating a trapezoidal swale with a 4 ft bottom and side slopes of 4:1, with a total depth of 1.5 ft. In addition to the shaping improvements, permanent erosion control matting will be added to the perimeter of the swale, and riprap will be added at pipe outlets. The matting and riprap will provide additional erosion control during large storm events.

SWALE IMPROVEMENT SUMMARY
Flows are summarized as follows:

FLOW SUMMARY						
	2 YR PEAK RUNOFF (CFS)	5 YR PEAK RUNOFF (CFS)	MANNING'S ROUGHNESS COEFFICIENT	DEPTH OF FLOW (FT)	AVERAGE VELOCITY (FT/S)	SHEAR STRESS (LBS/FT^2)
PRE-DEVELOPED SWALE	43.16	59.20	0.02	1.46	9.18	2.01
POST-DEVELOPED SWALE	43.16	59.20	0.05	1.42	4.28	1.89

By widening the channel, changing the side slopes, and stabilizing the wetted perimeter, the depth of flow is decreased, the water is slowed down, and the shear stress against the swale is reduced. These changes will drastically improve the performance of the swale while also preventing future erosion and sediment washout downstream. With a shear stress of 1.88 lbs/ft^2 on the proposed swale, a type 1 turf reinforcing mat will be added to the perimeter of the swale. The type 1 mat is rated to withstand up to 2 lbs/ft^2 of shear stress, so the swale will be protected adequately.

CONCLUSION:
The proposed swale drastically improved existing conditions and meets all the ODOT regulations for ditch design. All state and local ditch design and erosion & sediment control requirements have been met.

PART II – SWALE FLOW CALCULATIONS

Hydraulic Analysis Report

Project Data

Project Title: RG DRAGE SWALE IMPROVEMENT

Designer:

Project Date: Wednesday, August 01, 2018

Project Units: U.S. Customary Units

Notes:

Channel Analysis: EXISTING CHANNEL 2 YR FLOW

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 3.0000 ft/ft

Side Slope 2 (Z2): 3.0000 ft/ft

Channel Width: 0.0100 ft

Longitudinal Slope: 0.0248 ft/ft

Manning's n: 0.0200

Flow: 43.1600 cfs

Result Parameters

Depth: 1.3001 ft

Area of Flow: 5.0841 ft^2

Wetted Perimeter: 8.2328 ft

Hydraulic Radius: 0.6175 ft

Average Velocity: 8.4892 ft/s

Top Width: 7.8109 ft

Froude Number: 1.8543

Critical Depth: 1.6654 ft

Critical Velocity: 5.1769 ft/s

Critical Slope: 0.0066 ft/ft

Critical Top Width: 10.00 ft

Calculated Max Shear Stress: 2.0120 lb/ft^2

Calculated Avg Shear Stress: 0.9557 lb/ft^2

Channel Analysis: EXISTING CHANNEL 5 YR FLOW

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 3.0000 ft/ft

Side Slope 2 (Z2): 3.0000 ft/ft

Channel Width: 0.0100 ft

Longitudinal Slope: 0.0248 ft/ft

Manning's n: 0.0200

Flow: 59.2000 cfs

Result Parameters

Depth: 1.4642 ft

Area of Flow: 6.4466 ft^2

Wetted Perimeter: 9.2706 ft

Hydraulic Radius: 0.6954 ft

Average Velocity: 9.1831 ft/s

Top Width: 8.7954 ft

Froude Number: 1.8903

Critical Depth: 1.8897 ft

Critical Velocity: 5.5161 ft/s

Critical Slope: 0.0064 ft/ft

Critical Top Width: 11.35 ft

Calculated Max Shear Stress: 2.2659 lb/ft^2

Calculated Avg Shear Stress: 1.0761 lb/ft^2

Channel Analysis: PROPOSED CHANNEL 2 YR FLOW

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 4.0000 ft/ft

Channel Width: 4.0000 ft

Longitudinal Slope: 0.0248 ft/ft

Manning's n: 0.0500

Flow: 43.1600 cfs

Result Parameters

Depth: 1.2274 ft

Area of Flow: 10.9361 ft^2

Wetted Perimeter: 14.1217 ft

Hydraulic Radius: 0.7744 ft

Average Velocity: 3.9466 ft/s

Top Width: 13.8195 ft

Froude Number: 0.7818

Critical Depth: 1.0822 ft

Critical Velocity: 4.7881 ft/s

Critical Slope: 0.0420 ft/ft

Critical Top Width: 12.66 ft

Calculated Max Shear Stress: 1.8995 lb/ft^2

Calculated Avg Shear Stress: 1.1984 lb/ft^2

Channel Analysis: PROPOSED CHANNEL 5 YR FLOW

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 4.0000 ft/ft

Side Slope 2 (Z2): 4.0000 ft/ft

Channel Width: 4.0000 ft

Longitudinal Slope: 0.0248 ft/ft

Manning's n: 0.0500

Flow: 59.2000 cfs

Result Parameters

Depth: 1.4240 ft

Area of Flow: 13.8070 ft^2

Wetted Perimeter: 15.7425 ft

Hydraulic Radius: 0.8770 ft

Average Velocity: 4.2877 ft/s

Top Width: 15.3919 ft

Froude Number: 0.7978

Critical Depth: 1.2716 ft

Critical Velocity: 5.1234 ft/s

Critical Slope: 0.0402 ft/ft

Critical Top Width: 14.17 ft

Calculated Max Shear Stress: 2.2037 lb/ft^2

Calculated Avg Shear Stress: 1.3573 lb/ft^2

PART III – APPENDIX

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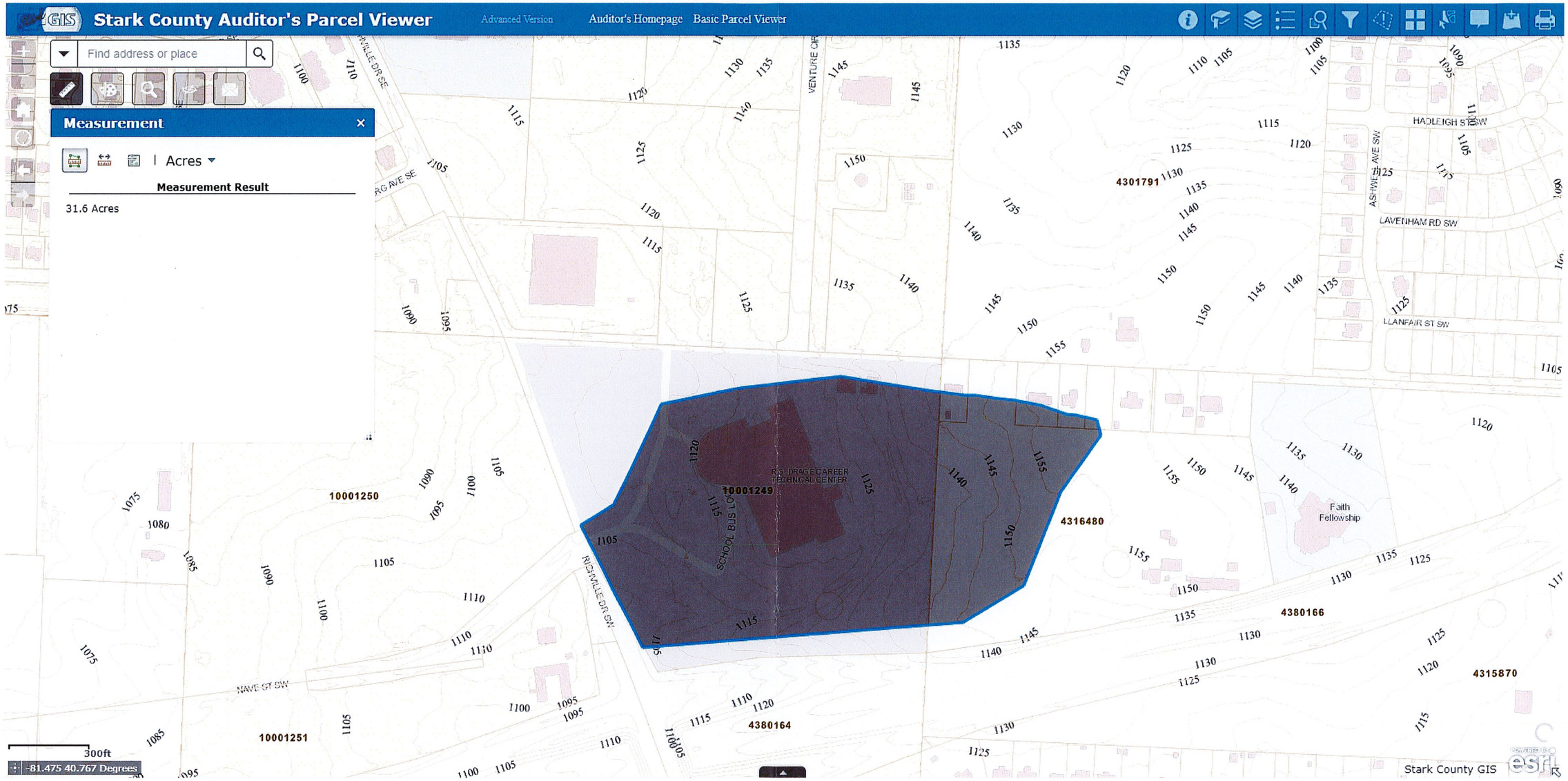
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Advanced Version
Auditor's Homepage
Basic Parcel Viewer
Find address or place
Measurement
Acres
Measurement Result
31.6 Acres
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HADLEIGH ST SW
LAVENHAM RD SW
LLANFAIR ST SW
ASHWELL AVE SW
VENTURE CIR
RIGSVILLE DR SE
RIGSVILLE DR SW
SCHOOL BUS LOOP
R.G. DRAGE CAREER TECHNICAL CENTER
10001249
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10001251
4316480
4380166
4315870
4380164
Faith Fellowship
NAVE ST SW
300ft
-81.475 40.767 Degrees
Stark County GIS
esri

NOAA Atlas 14, Volume 2, Version 3
Location name: Massillon, Ohio, USA*
Latitude: 40.7695°, Longitude: -81.4829°
Elevation: 1102.3 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

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/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	3.88 (3.53-4.26)	4.62 (4.21-5.06)	5.60 (5.10-6.14)	6.35 (5.76-6.96)	7.31 (6.60-7.99)	8.03 (7.24-8.77)	8.74 (7.84-9.53)	9.44 (8.44-10.3)	10.4 (9.25-11.3)	11.1 (9.82-12.1)
10-min	3.01 (2.75-3.31)	3.61 (3.29-3.95)	4.36 (3.96-4.78)	4.90 (4.45-5.37)	5.59 (5.05-6.11)	6.09 (5.48-6.65)	6.57 (5.89-7.17)	7.05 (6.30-7.69)	7.65 (6.80-8.32)	8.08 (7.15-8.80)
15-min	2.46 (2.24-2.70)	2.94 (2.68-3.22)	3.57 (3.24-3.91)	4.02 (3.65-4.40)	4.60 (4.16-5.03)	5.02 (4.52-5.49)	5.44 (4.88-5.94)	5.84 (5.22-6.38)	6.36 (5.66-6.92)	6.74 (5.95-7.33)
30-min	1.63 (1.48-1.79)	1.97 (1.79-2.16)	2.44 (2.22-2.68)	2.79 (2.53-3.06)	3.25 (2.93-3.55)	3.59 (3.23-3.92)	3.93 (3.52-4.29)	4.27 (3.81-4.65)	4.71 (4.19-5.13)	5.05 (4.46-5.49)
60-min	0.993 (0.906-1.09)	1.21 (1.10-1.32)	1.53 (1.39-1.68)	1.78 (1.61-1.95)	2.11 (1.90-2.30)	2.37 (2.13-2.58)	2.63 (2.36-2.87)	2.89 (2.59-3.16)	3.26 (2.90-3.55)	3.55 (3.13-3.86)
2-hr	0.568 (0.516-0.626)	0.690 (0.624-0.762)	0.888 (0.804-0.978)	1.05 (0.948-1.15)	1.28 (1.16-1.41)	1.48 (1.33-1.62)	1.69 (1.51-1.85)	1.92 (1.71-2.10)	2.26 (2.00-2.45)	2.54 (2.23-2.76)
3-hr	0.402 (0.363-0.445)	0.487 (0.441-0.539)	0.625 (0.565-0.691)	0.740 (0.667-0.817)	0.907 (0.814-0.998)	1.05 (0.937-1.15)	1.20 (1.07-1.32)	1.37 (1.21-1.50)	1.62 (1.42-1.76)	1.83 (1.59-1.99)
6-hr	0.243 (0.220-0.273)	0.293 (0.265-0.328)	0.373 (0.337-0.417)	0.441 (0.396-0.491)	0.542 (0.485-0.602)	0.627 (0.559-0.695)	0.722 (0.640-0.797)	0.827 (0.728-0.911)	0.982 (0.856-1.08)	1.12 (0.964-1.22)
12-hr	0.144 (0.130-0.161)	0.172 (0.156-0.193)	0.217 (0.196-0.243)	0.256 (0.231-0.285)	0.314 (0.281-0.348)	0.364 (0.324-0.403)	0.419 (0.372-0.463)	0.481 (0.424-0.530)	0.574 (0.501-0.630)	0.654 (0.566-0.716)
24-hr	0.085 (0.077-0.094)	0.101 (0.093-0.112)	0.127 (0.115-0.140)	0.148 (0.135-0.163)	0.181 (0.163-0.199)	0.209 (0.187-0.229)	0.240 (0.213-0.262)	0.274 (0.241-0.300)	0.325 (0.282-0.355)	0.369 (0.316-0.403)
2-day	0.049 (0.045-0.054)	0.058 (0.054-0.064)	0.072 (0.066-0.079)	0.084 (0.076-0.092)	0.101 (0.092-0.111)	0.116 (0.104-0.127)	0.132 (0.118-0.144)	0.149 (0.132-0.164)	0.175 (0.153-0.192)	0.197 (0.169-0.217)
3-day	0.035 (0.032-0.038)	0.042 (0.038-0.046)	0.051 (0.047-0.056)	0.059 (0.054-0.064)	0.071 (0.064-0.077)	0.080 (0.073-0.088)	0.091 (0.082-0.099)	0.102 (0.091-0.112)	0.119 (0.105-0.130)	0.134 (0.116-0.146)
4-day	0.028 (0.026-0.030)	0.033 (0.031-0.036)	0.041 (0.037-0.044)	0.047 (0.043-0.051)	0.055 (0.051-0.060)	0.063 (0.057-0.068)	0.070 (0.064-0.077)	0.079 (0.071-0.086)	0.091 (0.081-0.099)	0.102 (0.089-0.111)
7-day	0.019 (0.018-0.021)	0.023 (0.021-0.025)	0.027 (0.025-0.030)	0.031 (0.029-0.034)	0.037 (0.034-0.040)	0.042 (0.038-0.045)	0.047 (0.042-0.050)	0.052 (0.047-0.056)	0.059 (0.053-0.064)	0.065 (0.058-0.071)
10-day	0.015 (0.014-0.017)	0.018 (0.017-0.020)	0.022 (0.020-0.024)	0.025 (0.023-0.027)	0.029 (0.027-0.031)	0.032 (0.030-0.035)	0.035 (0.032-0.038)	0.039 (0.035-0.042)	0.044 (0.040-0.047)	0.048 (0.043-0.052)
20-day	0.011 (0.010-0.011)	0.013 (0.012-0.014)	0.015 (0.014-0.016)	0.017 (0.016-0.018)	0.019 (0.018-0.020)	0.021 (0.019-0.022)	0.023 (0.021-0.024)	0.025 (0.023-0.026)	0.027 (0.025-0.029)	0.029 (0.026-0.031)
30-day	0.009 (0.008-0.010)	0.011 (0.010-0.011)	0.012 (0.012-0.013)	0.014 (0.013-0.015)	0.015 (0.014-0.016)	0.017 (0.016-0.018)	0.018 (0.017-0.019)	0.019 (0.018-0.021)	0.021 (0.019-0.022)	0.022 (0.020-0.024)
45-day	0.008 (0.007-0.008)	0.009 (0.008-0.010)	0.010 (0.010-0.011)	0.011 (0.011-0.012)	0.013 (0.012-0.013)	0.014 (0.013-0.014)	0.014 (0.014-0.015)	0.015 (0.014-0.016)	0.016 (0.015-0.017)	0.017 (0.016-0.018)
60-day	0.007 (0.007-0.007)	0.008 (0.008-0.009)	0.009 (0.009-0.010)	0.010 (0.010-0.011)	0.011 (0.011-0.012)	0.012 (0.011-0.013)	0.013 (0.012-0.013)	0.013 (0.012-0.014)	0.014 (0.013-0.015)	0.015 (0.014-0.016)

[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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NOAA Atlas 14, Volume 2, Version 3
Location name: Massillon, Ohio, USA*
Latitude: 40.7695°, Longitude: -81.4829°
Elevation: 1102.3 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

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	0.323 (0.294-0.355)	0.385 (0.351-0.422)	0.467 (0.425-0.512)	0.529 (0.480-0.580)	0.609 (0.550-0.666)	0.669 (0.603-0.731)	0.728 (0.653-0.794)	0.787 (0.703-0.859)	0.867 (0.771-0.944)	0.925 (0.818-1.01)
10-min	0.501 (0.458-0.551)	0.602 (0.548-0.659)	0.726 (0.660-0.796)	0.817 (0.741-0.895)	0.931 (0.841-1.02)	1.01 (0.913-1.11)	1.10 (0.982-1.20)	1.18 (1.05-1.28)	1.27 (1.13-1.39)	1.35 (1.19-1.47)
15-min	0.615 (0.561-0.676)	0.736 (0.671-0.806)	0.892 (0.810-0.977)	1.00 (0.912-1.10)	1.15 (1.04-1.26)	1.26 (1.13-1.37)	1.36 (1.22-1.48)	1.46 (1.31-1.59)	1.59 (1.41-1.73)	1.68 (1.49-1.83)
30-min	0.813 (0.742-0.894)	0.985 (0.897-1.08)	1.22 (1.11-1.34)	1.40 (1.27-1.53)	1.62 (1.47-1.78)	1.80 (1.62-1.96)	1.97 (1.76-2.14)	2.13 (1.91-2.33)	2.36 (2.10-2.57)	2.52 (2.23-2.75)
60-min	0.993 (0.906-1.09)	1.21 (1.10-1.32)	1.53 (1.39-1.68)	1.78 (1.61-1.95)	2.11 (1.90-2.30)	2.37 (2.13-2.58)	2.63 (2.36-2.87)	2.89 (2.59-3.16)	3.26 (2.90-3.55)	3.55 (3.13-3.86)
2-hr	1.14 (1.03-1.25)	1.38 (1.25-1.52)	1.78 (1.61-1.96)	2.10 (1.90-2.31)	2.57 (2.31-2.82)	2.96 (2.66-3.24)	3.39 (3.03-3.70)	3.85 (3.43-4.19)	4.51 (3.99-4.91)	5.08 (4.47-5.52)
3-hr	1.21 (1.09-1.34)	1.46 (1.32-1.62)	1.88 (1.70-2.08)	2.22 (2.00-2.45)	2.72 (2.44-3.00)	3.15 (2.81-3.45)	3.61 (3.21-3.95)	4.12 (3.65-4.50)	4.86 (4.26-5.30)	5.48 (4.79-5.96)
6-hr	1.46 (1.32-1.63)	1.76 (1.59-1.97)	2.24 (2.02-2.50)	2.64 (2.37-2.94)	3.24 (2.91-3.61)	3.76 (3.35-4.16)	4.32 (3.83-4.77)	4.95 (4.36-5.45)	5.88 (5.12-6.45)	6.68 (5.77-7.32)
12-hr	1.73 (1.57-1.94)	2.08 (1.88-2.33)	2.61 (2.37-2.92)	3.08 (2.78-3.43)	3.78 (3.39-4.20)	4.38 (3.91-4.86)	5.05 (4.48-5.58)	5.80 (5.11-6.38)	6.91 (6.03-7.59)	7.88 (6.82-8.63)
24-hr	2.03 (1.86-2.25)	2.44 (2.22-2.69)	3.04 (2.77-3.36)	3.56 (3.23-3.92)	4.34 (3.91-4.77)	5.01 (4.49-5.49)	5.75 (5.11-6.29)	6.57 (5.79-7.19)	7.80 (6.76-8.53)	8.85 (7.57-9.68)
2-day	2.35 (2.15-2.59)	2.81 (2.57-3.09)	3.46 (3.17-3.81)	4.02 (3.67-4.42)	4.86 (4.41-5.32)	5.56 (5.01-6.09)	6.33 (5.66-6.94)	7.17 (6.35-7.87)	8.41 (7.34-9.23)	9.46 (8.14-10.4)
3-day	2.51 (2.31-2.75)	3.00 (2.76-3.28)	3.68 (3.38-4.02)	4.25 (3.89-4.64)	5.09 (4.63-5.55)	5.79 (5.24-6.31)	6.55 (5.89-7.14)	7.37 (6.57-8.04)	8.59 (7.55-9.38)	9.62 (8.36-10.5)
4-day	2.68 (2.47-2.92)	3.19 (2.94-3.47)	3.89 (3.59-4.24)	4.47 (4.11-4.86)	5.32 (4.86-5.78)	6.02 (5.47-6.53)	6.77 (6.11-7.35)	7.57 (6.79-8.22)	8.76 (7.77-9.53)	9.78 (8.57-10.7)
7-day	3.21 (2.97-3.48)	3.81 (3.53-4.13)	4.61 (4.26-4.99)	5.27 (4.86-5.70)	6.22 (5.71-6.73)	7.00 (6.40-7.56)	7.83 (7.11-8.45)	8.70 (7.86-9.40)	9.94 (8.88-10.8)	10.9 (9.69-11.9)
10-day	3.70 (3.44-3.98)	4.38 (4.07-4.72)	5.25 (4.87-5.65)	5.95 (5.51-6.40)	6.92 (6.39-7.44)	7.71 (7.08-8.28)	8.52 (7.79-9.16)	9.35 (8.52-10.1)	10.5 (9.49-11.3)	11.4 (10.2-12.4)
20-day	5.16 (4.83-5.51)	6.10 (5.71-6.52)	7.19 (6.72-7.69)	8.04 (7.51-8.60)	9.17 (8.55-9.81)	10.0 (9.34-10.7)	10.9 (10.1-11.7)	11.8 (10.9-12.6)	12.9 (11.8-13.8)	13.7 (12.6-14.8)
30-day	6.47 (6.06-6.90)	7.63 (7.15-8.14)	8.89 (8.32-9.48)	9.86 (9.21-10.5)	11.1 (10.4-11.8)	12.1 (11.2-12.9)	13.0 (12.1-13.9)	13.9 (12.9-14.8)	15.1 (13.9-16.1)	15.9 (14.6-17.1)
45-day	8.28 (7.78-8.79)	9.71 (9.13-10.3)	11.2 (10.5-11.9)	12.2 (11.5-13.0)	13.6 (12.8-14.5)	14.7 (13.7-15.6)	15.6 (14.6-16.6)	16.5 (15.4-17.6)	17.7 (16.4-18.9)	18.5 (17.1-19.8)
60-day	10.00 (9.44-10.6)	11.7 (11.1-12.4)	13.3 (12.6-14.1)	14.6 (13.7-15.4)	16.1 (15.2-17.0)	17.2 (16.2-18.2)	18.2 (17.1-19.3)	19.1 (18.0-20.3)	20.3 (19.0-21.5)	21.0 (19.7-22.4)

[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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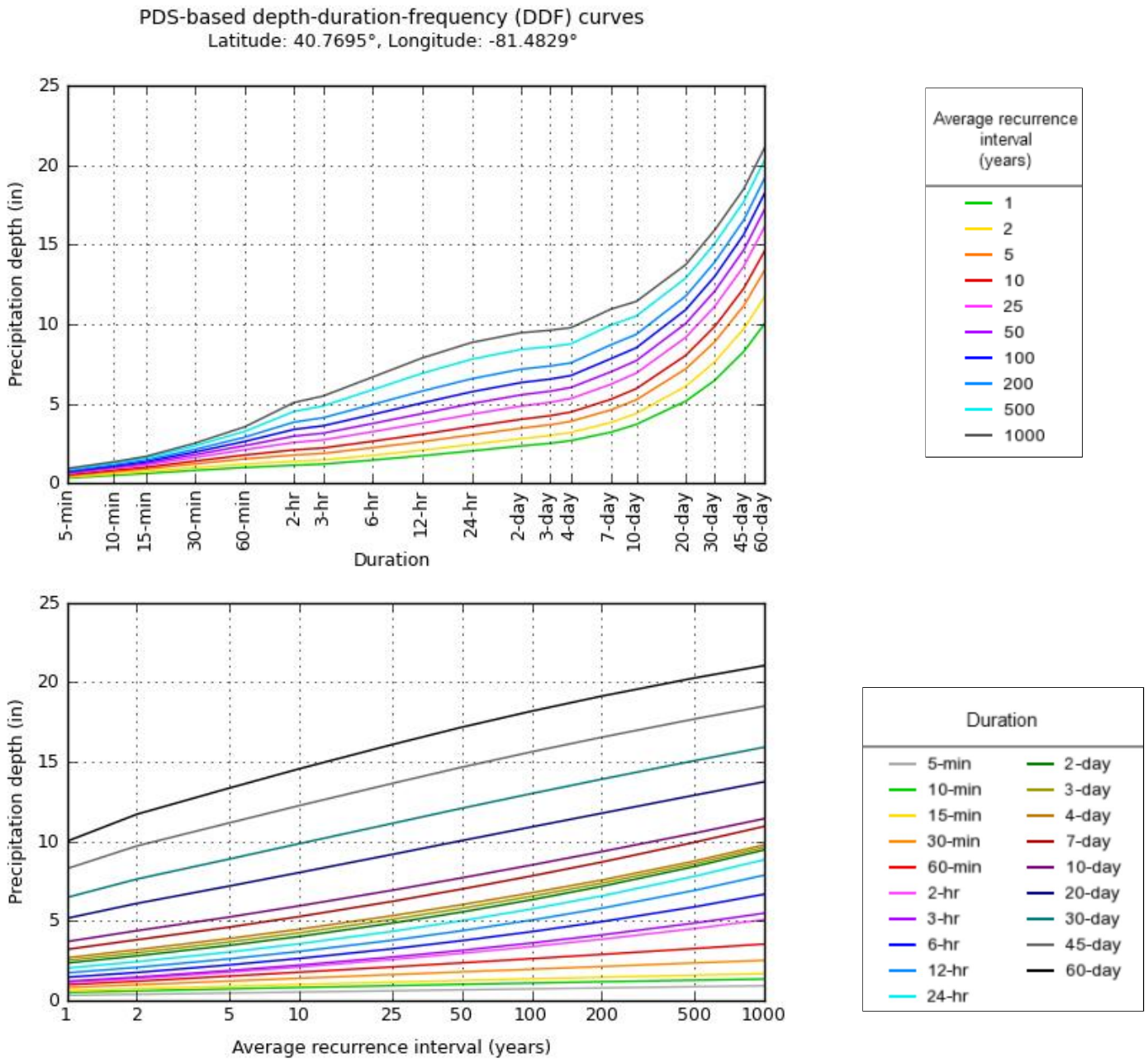
PF graphical



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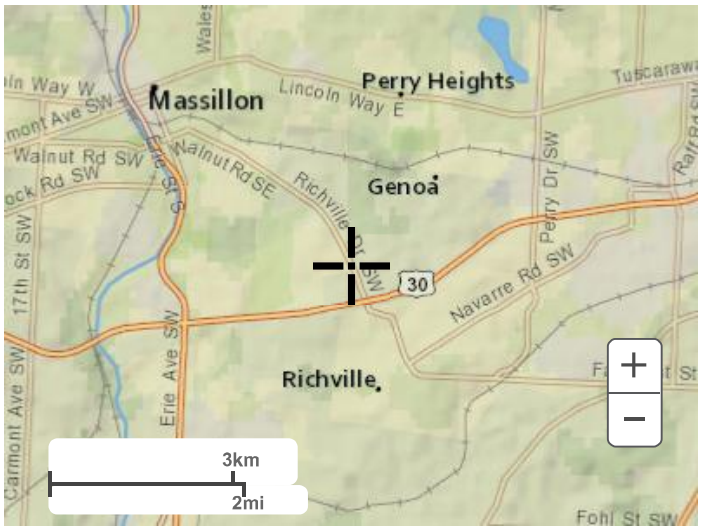
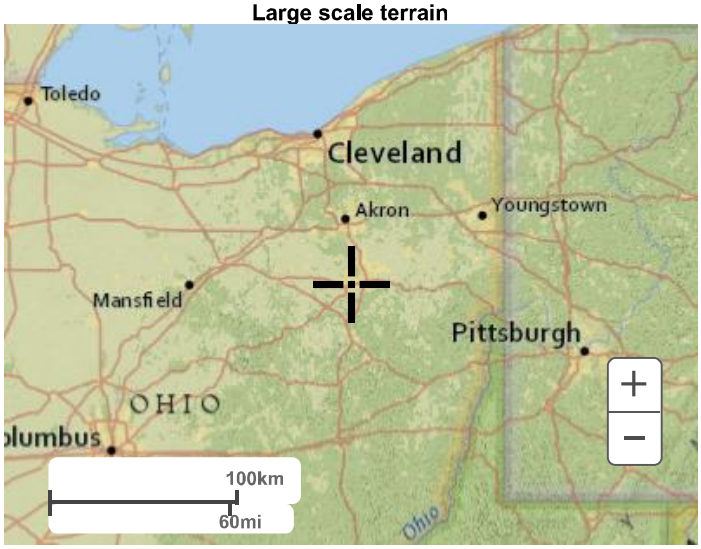
Maps & aerials

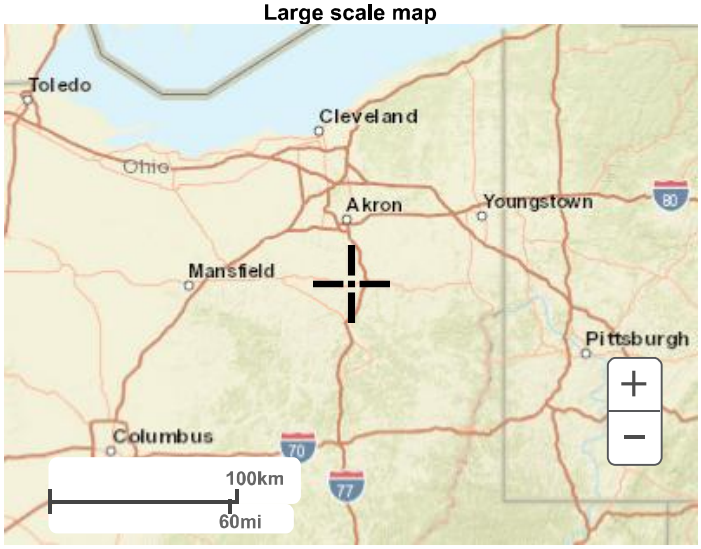
Small scale terrain



Large scale terrain



Large scale map



Large scale aerial

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Disclaimer

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2018 by Autodesk, Inc. v12

Hyd. No. 1

RG Drage Ditch

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.150		0.011		0.011		
Flow length (ft)	= 200.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 2.44		0.00		0.00		
Land slope (%)	= 1.50		0.00		0.00		
Travel Time (min)	**= 21.92**	**+**	**0.00**	**+**	**0.00**	**=**	**21.92**
Shallow Concentrated Flow							
Flow length (ft)	= 475.00		0.00		0.00		
Watercourse slope (%)	= 5.46		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=3.77		0.00		0.00		
Travel Time (min)	**= 2.10**	**+**	**0.00**	**+**	**0.00**	**=**	**2.10**
Channel Flow							
X sectional flow area (sqft)	= 48.00		0.00		0.00		
Wetted perimeter (ft)	= 20.00		0.00		0.00		
Channel slope (%)	= 2.50		0.00		0.00		
Manning's n-value	= 0.015		0.015		0.015		
Velocity (ft/s)	=28.24						
			0.00				
					0.00		
Flow length (ft)	({0})1150.0		0.0		0.0		
Travel Time (min)	**= 0.68**	**+**	**0.00**	**+**	**0.00**	**=**	**0.68**

Total Travel Time, Tc ..... 24.70 min

Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2018 by Autodesk, Inc. v12

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	32.56	43.16	-------	59.20	72.69	92.62	109.52	127.49	RG Drage Ditch

APPENDIX A - HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF CONDUITS AND CHANNELS

This appendix lists Manning's roughness (n) values for various conduits and channels, as follows:

Sources:
- Chow, Ven Te, "Open-Channel Hydraulics," 1959
- FHWA, "Design of Urban Highway Drainage, The State of the Art," 1979
- FHWA, "Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow," 1961
- FHWA, "Hydraulic Engineering Circular No. 15, Design of Roadside Channels with Flexible Linings," 1988
- FHWA, "Hydraulic Engineering Circular No. 22, Urban Drainage Design Manual," 1996
- ODOT, "Memo to Designers, Helical Corrugated Pipe," 1992

TABLE 1: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF CONDUITS

Conduit	Minimum	Normal	Maximum
A. Concrete or asbestos-cement pipe	0.011	0.013	0.015
B. Metal pipe or pipe-arch with annular corrugations			
1. 2-2/3-inch x ½-inch corrugations			
a. Plain or fully coated	. . . . .	0.024	. . . . .
b. Paved invert (range represents 25 and 50 percent of circumference paved, with larger n value representing 25 percent paved)			
1. Full flow depth	0.018	. . . . .	0.021
2. Flow 80 percent of depth	0.016	. . . . .	0.021
3. Flow 60 percent of depth	0.013	. . . . .	0.019
2. 3-inch x 1-inch corrugations	. . . . .	0.027	. . . . .
3. 6-inch x 2-inch corrugations	. . . . .	0.032	. . . . .
C. Smooth walled helical spiral rib pipe	0.012	. . . . .	0.013
D. Corrugated metal subdrain	0.017	0.019	0.021
E. Plastic pipe			
1. Smooth	0.011	. . . . .	0.015
2. Corrugated	. . . . .	0.024	. . . . .

TABLE 1: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF CONDUITS

Conduit	Minimum	Normal	Maximum
Conduits, continued			
F. Metal pipe or pipe arch with helically wound corrugations			
1. Smaller pipes			
12 inch	. . . . .	0.013	. . . . .
15 inch	. . . . .	0.014	. . . . .
18 inch	. . . . .	0.015	. . . . .
21 inch	. . . . .	0.016	. . . . .
24 inch	. . . . .	0.017	. . . . .
27 inch	. . . . .	0.018	. . . . .
30 inch	. . . . .	0.019	. . . . .
33 inch	. . . . .	0.020	. . . . .
36 inch	. . . . .	0.021	. . . . .
42 inch	. . . . .	0.022	. . . . .
48 inch	. . . . .	0.023	. . . . .
2. Diameters larger than 48 inches with 2-2/3-inch x 1/2-inch corrugations	. . . . .	0.024	. . . . .
3. Diameters larger than 48 inches with 3-inch x 1-inch corrugations	. . . . .	0.027	. . . . .
G. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017

TABLE 1: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF CONDUITS

Conduit	Minimum	Normal	Maximum
Conduits, continued			
H. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
I. Steel pipe, welded	0.010	0.012	0.014
J. Brick			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
K. Common clay drainage tile	0.011	0.013	0.017
L. Vitrified clay sewer	0.011	0.014	0.017
M. Sanitary sewer, coated with sewage slime, with bends and connections	0.012	0.013	0.016
N. Monolithic concrete			
1. Wood forms, rough	0.015	0.017	0.020
2. Wood forms, smooth	0.012	0.014	0.016
3. Steel forms	0.012	0.013	0.014
O. Rubble masonry, cemented	0.018	0.025	0.030
P. Laminated treated wood	0.015	0.017	0.020

TABLE 2: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF GUTTERS AND PAVEMENTS

	Channel	Minimum	Normal	Maximum
A.	Concrete gutter, troweled finish *	. . . . .	0.012	. . . . .
B.	Asphalt pavement			
	1. Smooth texture	. . . . .	0.013	. . . . .
	2. Rough texture	. . . . .	0.016*	. . . . .
	3. ODOT Standard Curb, Low Profile Mountable Curb, Monolithic Curb and Sidewalk, and Mountable Curb	. . . . .	0.016*	. . . . .
C.	Concrete gutter with asphalt pavement			
	1. Smooth	. . . . .	0.013	. . . . .
	2. Rough	. . . . .	0.015	. . . . .
	3. ODOT Curb and Gutter, Mountable Curb and Gutter, and Valley Gutter	. . . . .	0.014	. . . . .
D.	Concrete pavement			
	1. Float finish	. . . . .	0.014	. . . . .
	2. Broom finish	. . . . .	0.016	. . . . .
	3. ODOT Standard Curb, Low Profile Mountable Curb, Monolithic Curb and Sidewalk, and Mountable Curb	. . . . .	0.016*	. . . . .
E.	Brick	. . . . .	0.016	. . . . .
F.	For gutters listed above with small slope, where sediment may accumulate, increase above values of n by	. . . . .	0.002	. . . . .

* Flow contained within gutter.
* The most common value used for gutters with pavement bottoms on ODOT project is 0.016

TABLE 3: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF SMALLER ARTIFICIAL CHANNELS

Values are for artificial channels with flows of 50 cubic feet per second or less. Roughness values vary with depth, as follows:

- Minimum values are for flow depths greater than 2 feet.
- Normal values are for depths between 6 inches and 2 feet.
- Maximum values are for flow depths less than 6 inches.

Channel	Minimum	Normal	Maximum
A. Rigid Linings			
1. Concrete	0.013	0.013	0.015
2. Grouted riprap	0.028	0.030	0.040
3. Stone masonry	0.030	0.032	0.042
4. Soil cement	0.020	0.022	0.025
5. Asphalt	0.016	0.016	0.018
B. Unlined			
1. Bare soil	0.020	0.020	0.023
2. Rock cut	0.025	0.035	0.045

TABLE 3: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF SMALLER ARTIFICIAL CHANNELS

Channel	Minimum	Normal	Maximum
Smaller Artificial channels, continued.			
C. Temporary			
1. Woven paper net	0.015	0.015	0.016
2. Jute net	0.019	0.022	0.028
3. Fiberglass roving	0.019	0.021	0.028
4. Straw with net	0.025	0.033	0.065
5. Curled wood mat	0.028	0.035	0.066
6. Synthetic mat	0.021	0.025	0.036
E. Grass (See Figures 8-12 through 8-16 of this chapter.)			
F. Riprap			
1. ODOT Class 50	0.036	0.070	0.106
2. ODOT Class 100	0.039	0.075	. . . . .

Note: Roughness values vary with depth. See previous page.

**TABLE 4: HYDRAULIC ROUGHNESS (MANNING'S n)
VALUES OF LINED ARTIFICIAL CHANNELS**

Channel	Minimum	Normal	Maximum
A. Concrete, with surfaces as indicated:			
1. Formed, no finish	0.014	0.017	0.020
2. Trowel finish	0.011	0.013	0.015
3. Float finish	0.013	0.015	0.016
4. Finished, with gravel on bottom	0.015	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	. . . . .
8. On irregular excavated rock	0.022	0.027	. . . . .
B. Concrete, bottom float finished, sides as indicated:			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry	0.020	0.025	0.030
4. Cement rubble masonry, plastered	0.016	0.020	0.024
5. Dry rubble or riprap	0.020	0.030	0.035

Note: Values are for straight alignment.

TABLE 4: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF LINED ARTIFICIAL CHANNELS

Channel	Minimum	Normal	Maximum
Lined artificial channels, continued.			
C. Gravel bottom, sides as indicated:			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
D. Glazed brick	0.011	0.013	0.015
E. Brick in cement mortar	0.012	0.015	0.018
F. Asphalt			
1. Smooth	. . . . .	0.013	. . . . .
2. Rough	. . . . .	0.016	. . . . .
G. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
H. Cemented masonry rubble	0.017	0.025	0.030
I. Dry masonry rubble	0.023	0.032	0.035

Note: Values are for straight alignment.

TABLE 5: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF EXCAVATED ARTIFICIAL CHANNELS

Channel	Minimum	Normal	Maximum
A. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
B. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
C. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060

Note: Values are for excavated or dredged channels with natural linings.

TABLE 5: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF EXCAVATED ARTIFICIAL CHANNELS

Channel	Minimum	Normal	Maximum
Excavated artificial channels, continued.			
D. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
E. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Clean bottom, brush on sides, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

Note: Values are for excavated or dredged channels with natural linings.

TABLE 6: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF HIGHWAY CHANNELS AND SWALES WITH MAINTAINED VEGETATION

Channel	Minimum	Normal	Maximum
Range of roughness values represents flow velocities from 2 to 6 feet per second with the higher roughness values representing the 2 feet per second flow velocity.			
A. Depth of flow up to 0.7 feet			
1. Grass			
a. Mowed to 2 inches	0.045	. . . . .	0.07
b. Length 2 inches to 6 inches	0.05	. . . . .	0.09
2. Grass, good stand			
a. Length about 12 inches	0.09	. . . . .	0.18
b. Length about 24 inches	0.15	. . . . .	0.30
3. Grass, fair stand			
a. Length about 12 inches	0.08	. . . . .	0.14
b. Length about 24 inches	0.13	. . . . .	0.25
B. Depth of flow 0.7 feet to 1.5 feet			
1. Grass			
a. Mowed to 2 inches	0.035	. . . . .	0.05
b. Length 2 inches to 6 inches	0.04	. . . . .	0.06

TABLE 6: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF HIGHWAY CHANNELS AND SWALES WITH MAINTAINED VEGETATION

Channel	Minimum	Normal	Maximum
Highway channels and swales with maintained vegetation, continued.			
2. Grass, good stand			
a. Length about 12 inches	0.07	. . . . .	0.12
b. Length about 24 inches	0.10	. . . . .	0.20
3. Grass, fair stand			
a. Length about 12 inches	0.06	. . . . .	0.10
b. Length about 24 inches	0.09	. . . . .	0.17

TABLE 7: HYDRAULIC ROUGHNESS (MANNING'S n)
VALUES OF NATURAL CHANNELS AND FLOODPLAINS

Channel	Minimum	Normal	Maximum
A. Minor streams (top width at flood stage less than 100 feet)			
1. Streams on plain			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, irregular slopes and sections with more ineffective flow area	0.040	0.048	0.055
f. Same as d, but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

TABLE 7: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF NATURAL CHANNELS AND FLOODPLAINS

Channel	Minimum	Normal	Maximum
Natural channels and floodplains, continued.			
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070
B. Floodplains			
1. Pasture, no brush			
a. Short grass	0.025	0.030	0.035
b. High grass	0.030	0.035	0.050
2. Cultivated areas			
a. No crop	0.020	0.030	0.040
b. Mature row crops	0.025	0.035	0.045
c. Mature field crops	0.030	0.040	0.050

TABLE 7: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF NATURAL CHANNELS AND FLOODPLAINS

Channel	Minimum	Normal	Maximum
Natural channels and floodplains, continued.			
3. Brush			
a. Scattered brush, heavy weeds	0.035	0.050	0.070
b. Light brush and trees, in winter	0.035	0.050	0.060
c. Light brush and trees, in summer	0.040	0.060	0.080
d. Medium to dense brush, in winter	0.045	0.070	0.110
e. Medium to dense brush, in summer	0.070	0.100	0.160
4. Trees			
a. Dense willows, summer, straight	0.110	0.150	0.200
b. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
c. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
d. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
e. Same as above, but with flood stage reaching branches	0.100	0.120	0.160

TABLE 7: HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF NATURAL CHANNELS AND FLOODPLAINS

Channel	Minimum	Normal	Maximum

Natural channels and floodplains, continued.

C. Major streams (top width at flood stage more than 100 feet). The n values are less than those of minor streams with similar description because banks offer less effective resistance.

1. Regular section with no boulders or brush	0.025	. . . . .	0.060
2. Irregular and rough section	0.035	. . . . .	0.100