The undersigned has approved this document for and on behalf of Carollo Engineers, P.C.

Partner

City of Lincoln, Nebraska

STEVENS CREEK BASIN TRUNK SEWER

TECHNICAL MEMORANDUM NO. 1
DESIGN FLOW EQUATION

FINAL

May 2004

REGISTERED PROFESSIONAL ENGINEER
BRIAN D. CLOW
E-8538
STATE OF NEBRASKA
5-5-2004

901 EAST 104TH STREET • SUITE 660 • KANSAS CITY, MISSOURI 64131 • (816) 942-5027 • FAX (816) 942-4025

City of Lincoln, Nebraska

STEVENS CREEK BASIN TRUNK SEWER

TECHNICAL MEMORANDUM NO. 1

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

DESIGN FLOW EQUATION

1.0 INTRODUCTION

The purpose of this Technical Memorandum is to identify methodologies utilized by the City of Lincoln (City) and other Midwest communities for the determination of trunk sewer peak design flow, and to recommend a peak design flow calculation methodology for the Stevens Creek Basin Trunk Sewer.

2.0 PEAK DESIGN FLOW EQUATIONS

Four cities and wastewater districts, including Lincoln, were surveyed to obtain their respective peak design flow calculation methodologies. The other three entities contacted include Johnson County Wastewater (Johnson County, Kansas), the City of Lee's Summit, Missouri, and the City of Wichita, Kansas.

Peak design flow consists of three components: dry weather flow, infiltration, and inflow. Each entity surveyed included these components in their peak flow determination, but the magnitude of each component was found to vary by location.

2.1 Lincoln, Nebraska

The City has adopted, and currently utilizes, an equation that relates tributary area in the basin/subbasin to peak flow. The peak flow design equation takes the form:

Q = 0.01726 * A^0.8 + 0.003 * A.

Where, Q = the peak hourly design flow in cfs,

and A = the developable land area in the basin/subbasin.

The peak flow from each cumulative tributary area is determined using this design flow equation. The calculated peak flow is then used to determine the pipe size at a specified minimum velocity, usually 3 fps.

The underlying data used to support this design flow equation is as follows:

- Equation form is by Babbitt & Bauman, "Sewerage and Sewage Treatment".[1]
- Dwelling unit density is 2.79 dwelling units per acre.
- Population density is 2.48 persons per dwelling unit.

[1] 7th Edition, John Wiley & Sons, Inc., 1953.

- Average per capita flow rate is 119 gallons per capita per day (gpcd), including dry weather wastewater flow.
- Peak to Average Ratio is 5.
- Inflow and infiltration flow is 1,935 gpd per acre.

The aforementioned equation was developed by City staff after analyzing data obtained from the watershed tributary to the Theresa Street WWTP as well as corresponding flow monitoring records.

2.2 Johnson County Wastewater, Kansas

Johnson County Wastewater (JCW) has adopted and currently utilizes a graphical methodology for determining peak wastewater flow in new sewers. This graph is presented in Figure 1.

Peak flow is defined as the sum of peak dry weather flow, infiltration, and peak inflow. The underlying data used to support the peak dry weather flow and infiltration components are as follows:

- Dwelling unit density is 2.6 customers per acre.
- Average per capita flow rate is 279 gpcd.
- Peak to Average Ratio is 1.5.

JCW utilizes a 10-year design storm to determine peak inflow. The peak inflow component takes the form:

$Q = kiA.$

Where, Q = the peak hourly design flow in cfs,

k = is the inflow coefficient (k = 0.01 for JCW),

i = the rainfall intensity for a 10-year storm,

and A = the developable land area in the basin/subbasin.

Based on the design flow graph, the maximum peak design flow rate for small tributary areas is 0.025 cfs/acre, and the minimum peak flow rate at the maximum tributary area is 0.01 cfs/acre.

The data which supports the JCW Design Flow Curve was generated through intensive flow monitoring for relatively small basins/subbasins. These basins/subbasins were typically in the range of 250 to 700 acres. This range of basin/subbasin area was studied so that the peak instantaneous flow could be accurately determined.

2.3 Lee's Summit, Missouri

The City of Lee's Summit has adopted and currently utilizes an equation that relates tributary area in the basin/subbasin to peak flow. The peak flow design equation takes the form:

$$Q = 1500 + 500 + kiA.$$

Where, Q = the peak hourly design flow in cfs,

k = the inflow coefficient (k = 0.006 for Lee's Summit),

i = the rainfall intensity for a 50-year storm,

and A = the developable land area in the basin/subbasin.

The peak flow from each cumulative tributary area is determined using the design flow equation. The peak flow is then used to determine the size of pipeline based on the pipe flowing full at a specified minimum velocity, usually 2 fps.

The underlying data used to support this design flow equation was established through extensive dry weather and wet weather flow monitoring and, as such, is specific to the City of Lee's Summit. The dry weather flow monitoring data correlated well with historic design values of 2.8 persons per dwelling unit and 125 gpcd.

2.4 Wichita, Kansas

The City of Wichita has performed monitoring and modeling to identify peak wastewater flow in each basin/subbasin.

The underlying data used to determine the peak design flow is as follows:

- Dwelling unit density is 3 dwelling units per acre.
- Population density is 3 persons per dwelling unit.
- Average per capita flow rate is 100 gpcd.
- Peak to Average Ratio is 6 for a 10-year rain event.

State design guidelines recommend that sanitary sewer pipes carry design flows at 2/3 pipeline depth, or 79 percent of full capacity. This design recommendation provides additional "reserve" capacity in the sanitary sewer system.

3.0 SUMMARY

Each entity surveyed utilized a peak design flow based on developable land area within a basin/subbasin, results of system modeling or evaluation of existing data and consideration of dry weather, infiltration and inflow sources.

For a 2000 acre basin, design flow equations predict that the peak wastewater flow in Lincoln would be 8.24 mgd, while the JCW flow would be 18.89 mgd.

Since peak flow values are greatly influenced by local conditions (age and condition of pipelines, rainfall, groundwater, etc.), the methodology from one entity would not likely be applicable to another. For example, the average annual precipitation for the City of Lincoln is 28.3 inches, Wichita is 29.33 inches and Johnson County (JCW) and Lee's Summit is 37.62 inches (based on Kansas City, Missouri weather data). For basins of equal area served by these four entities, it would be expected that peak wastewater flow would be greater at JCW and Lee's Summit than Lincoln or Wichita since the average annual precipitation is greater.

Since the design flow equation for the City of Lincoln has been successfully used for many years, it is recommended that the locally developed equation should be employed to determine the peak wastewater flow projections for the Stevens Creek Basin Trunk Sewer.

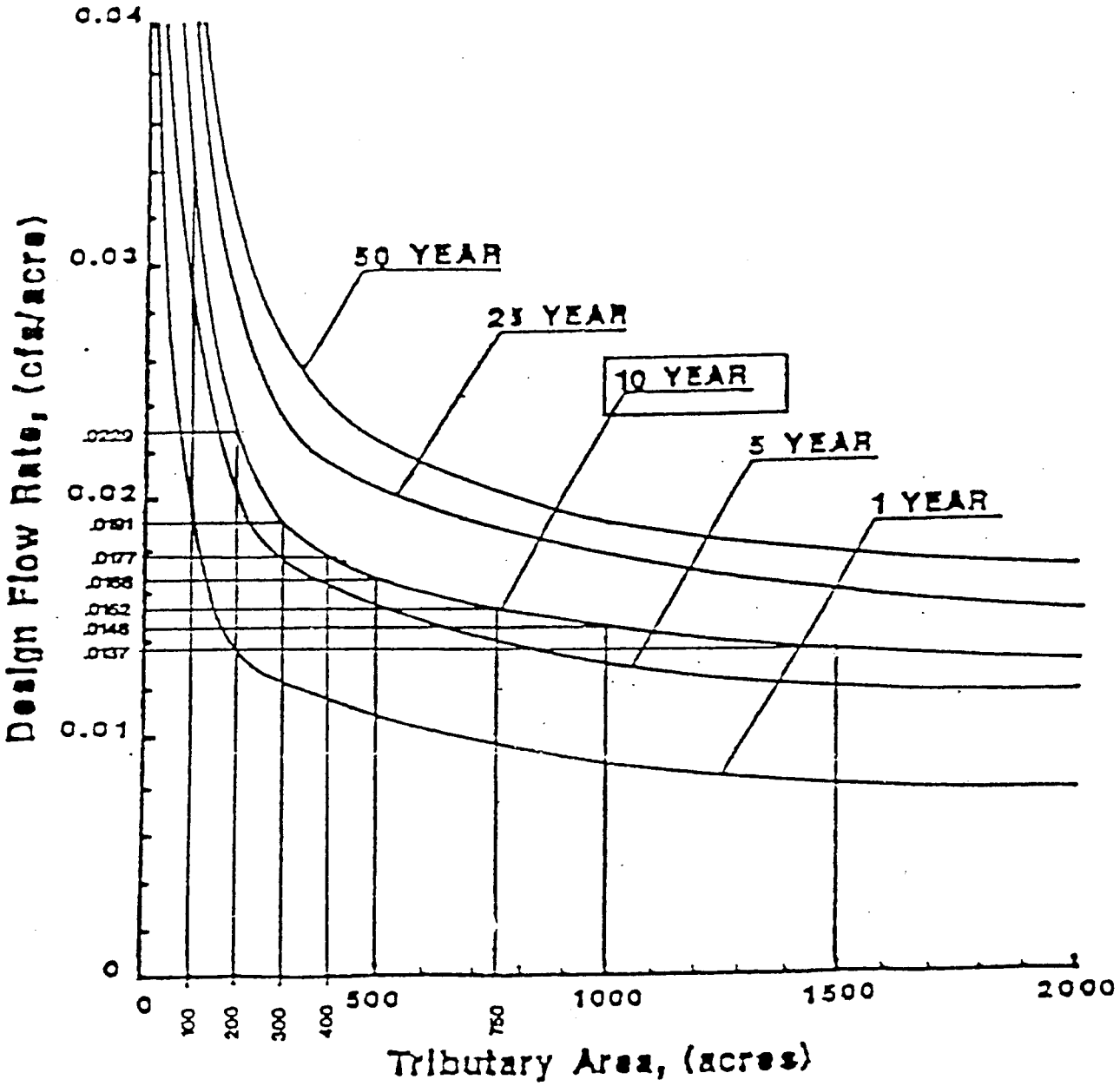
A summary of peak wastewater flow, determined by each entities respective methodology, is presented in Table 1. A graphical representation of this data is presented in Figure 2.

Table 1 Peak Wastewater Design Flow Comparison
Stevens Creek Basin Trunk Sewer
City of Lincoln, Nebraska

	Peak Wastewater Flow (mgd)			
Area	**Lincoln, NE**	**Johnson Co. WW, KS**	**Lee's Summit, MO**	**Wichita, KS**
100	0.64	1.87	1.49	0.54
200	1.16	3.04	2.75	1.08
300	1.65	4.04	3.92	1.62
400	2.12	4.95	4.99	2.16
500	2.57	5.79	6.00	2.7
600	3.02	6.58	6.97	3.24
700	3.46	7.33	7.87	3.78
800	3.89	8.05	8.74	4.32
900	4.31	8.75	9.55	4.86
1000	4.73	9.42	10.37	5.4
1100	5.15	10.07	11.28	5.94
1200	5.56	10.71	12.12	6.48
1300	5.97	11.32	13.04	7.02
1400	6.37	11.93	13.88	7.56
1500	6.77	12.52	14.75	8.1
1600	7.17	13.10	15.54	8.64
1700	7.57	13.67	16.38	9.18
1800	7.96	14.23	17.21	9.72
1900	8.35	14.78	18.10	10.26
2000	8.74	15.33	18.89	10.8
2100	9.13	15.86	19.59	11.34
2200	9.51	16.39	20.44	11.88
2300	9.90	16.91	21.28	12.42
2400	10.28	17.42	22.02	12.96
2500	10.66	17.93	22.84	13.5
2600	11.04	18.43	23.55	14.04
2700	11.42	18.93	24.45	14.58
2800	11.79	19.42	25.26	15.12
2900	12.17	19.90	26.15	15.66
3000	12.54	20.38	26.94	16.2
3100	12.92	20.85	27.83	16.74
3200	13.29	21.33	28.61	17.28
3300	13.66	21.79	29.50	17.82
3400	14.03	22.25	30.28	18.36
3500	14.39	22.71	31.16	18.9
3600	14.76	23.17	32.05	19.44
3700	15.13	23.62	32.79	19.98
3800	15.49	24.06	33.68	20.52
3900	15.86	24.51	34.41	21.06
4000	16.22	24.95	35.30	21.6

JCUWD Design Flow Curves

$$\text{cfs/acre} = (0.11385) \times \left[(\text{tributary acres})^{(-0.29735)} \right]$$



Design flow for areas less than 164 acres need not exceed .025 cfs/acre and shall be at least .010 cfs/acre (for areas larger than 3568 acres)

FIGURE 1
JCUWD DESIGN FLOW CURVES
STEVENS CREEK TRUNK SEWER
CITY OF LINCOLN, NEBRASKA

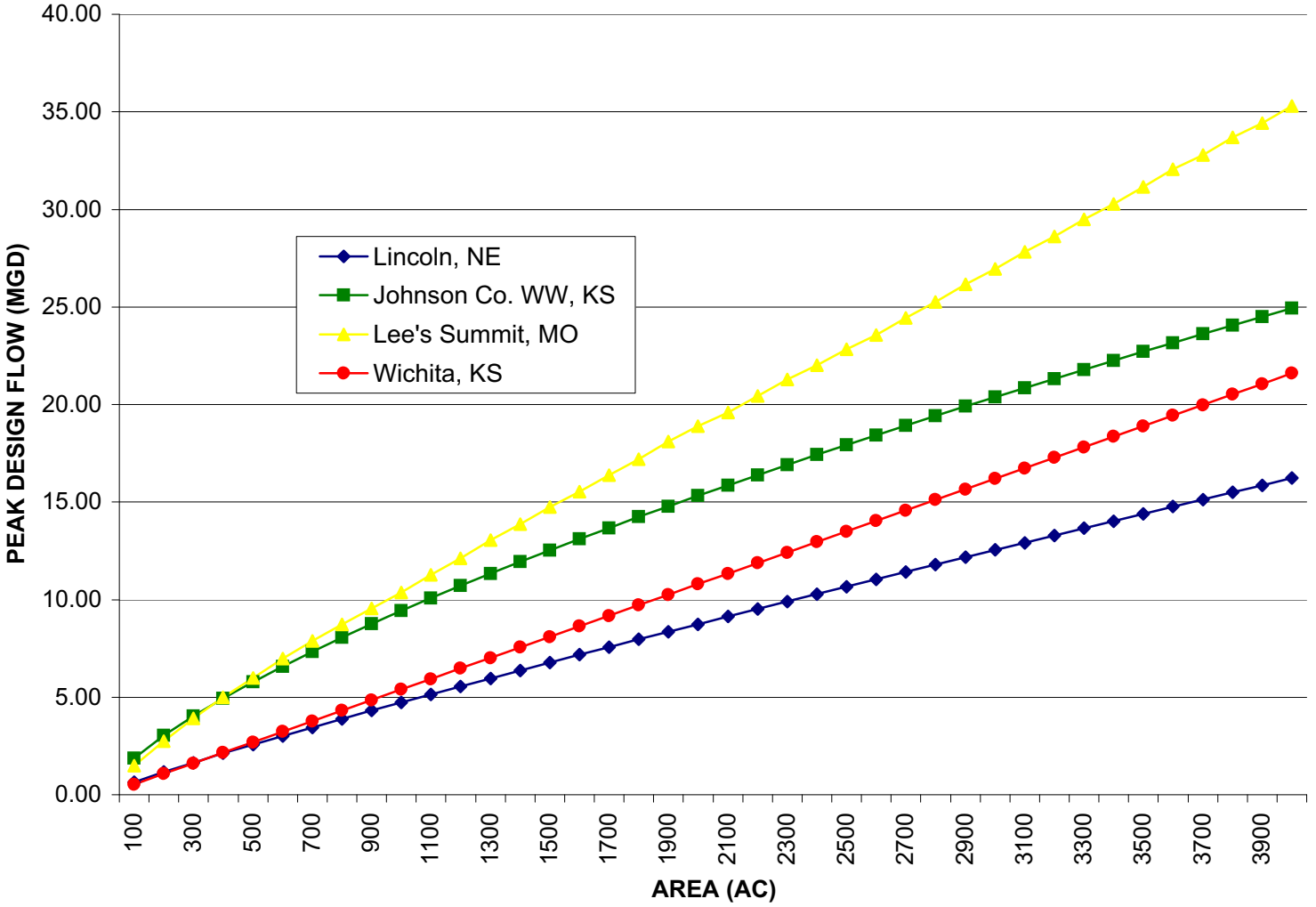


FIGURE 2
PEAK DESIGN FLOW COMPARISON
STEVENS CREEK BASIN TRUNK SEWER
CITY OF LINCOLN, NE