ABSTRACT

Unit hydrograph methods are applied by TxDOT designers to obtain peak discharge and hydrograph shape for hydraulic design. Unit hydrographs are applied to watersheds that either are too large for application of the rational method or are sufficiently complex that the assumptions necessary for application of the rational method do not apply. Currently, the Natural Resources Conservation Service (NRCS) dimensionless unit hydrograph method is used by TxDOT to estimate unit hydrographs for ungaged watersheds in Texas.

The purpose of this project is to determine how TxDOT should apply unit hydrograph technology for drainage analysis in Texas. It is the intent of the proposed research to answer two questions. First, is the NRCS dimensionless unit hydrograph representative of observed unit hydrographs for Texas watersheds? The answer to the first question requires the assembly and review of a substantial database of paired rainfall-runoff measurements on small (less than 20 square mile) watersheds. Second, if the NRCS dimensionless unit hydrograph is not representative of unit hydrographs for Texas watersheds, then can an alternative method be developed that is representative of observed hydrographs in Texas? The answer to the second question requires a review of the literature to determine candidate procedures and comparison of the candidates with observed unit hydrographs for Texas watersheds.

Four tasks are required to complete the research:

- Review of current TxDOT unit hydrograph procedures and preparation of a literature review,
- Assembly of the database of measured rainfall-runoff responses for Texas watersheds,
- Development of unit hydrographs from the database,
- Comparison of the NRCS dimensionless unit hydrograph to observed unit hydrographs in Texas
- Regionalization of the observed unit hydrographs for purposes of estimating unit hydrographs for ungaged watersheds.

The proposed research fits within the TxDOT long-range research plan under RMC 3 to build on past and ongoing efforts in updating hydrologic techniques for TxDOT design practices. Results of the research will be implemented by incorporating results of the research into TxDOT design materials.

BACKGROUND AND SIGNIFICANCE OF WORK

Hydrologic analysis for development of hydraulic designs is a technical subject and requires considerable expertise. Hydraulic design in small watersheds is often approached using a simple procedure, known as the rational method, for estimating peak instantaneous discharges. Application of the rational method is generally limited to watersheds with drainage areas less than about 100ha (250ac). For watersheds that exceed 100ha, or for watersheds that have significant man-made runoff controls, hydrograph techniques are appropriate.

A unit hydrograph (or unitgraph) is the watershed hydrograph response to a unit pulse of effective precipitation. The duration of the unitgraph refers to the length of time of the effective precipitation. The unitgraph concept was developed more than 50 years ago (Sherman, 1932) and is still considered standard-of-practice for engineering hydrology. The unitgraph is generally applied in conjunction with either a design or a historical hyetograph (time-series of precipitation) and a rainfall-runoff model to compute the direct runoff hydrograph for a particular storm event. This procedure differs from the rational method in that (1) a complete hydrograph not simply a peak discharge is produced, and (2) the effects of variations in storm duration and temporal distribution are incorporated into the runoff hydrograph. Therefore it is generally thought that hydrographs produced using this procedure are more suitable for hydraulic design in larger watersheds or watersheds with significant man-made runoff controls. Furthermore, the unit hydrograph concept can be applied to integrated arrangements of sub-watersheds and combined with stream-routing or reservoir-routing technology to analyze reasonably complex problems using computational tools such as HEC-1 (1990).

The unitgraph for any given watershed should be determined through analysis of a substantially long rainfall-runoff history of the watershed. Two general approaches are available to derive the unitgraph using measured rainfall-runoff series. Both approaches require a direct runoff hydrograph, usually determined for a storm by using semilogarithmic baseflow separation (SCS, 1972; Barnes, 1940). The first approach uses the runoff expressed by integrating the direct runoff hydrograph and distributing the result over the watershed area to determine effective precipitation. A constant loss rate (phi-index) is assumed and storm duration is determined by superimposing the phi-index on the storm hyetograph. Ordinates of the direct runoff hydrograph are divided by the effective precipitation, thus determining both the unit response and the duration of the unitgraph (Viessman and Lewis, 1996). The second procedure involves the inverting, or deconvolution, of a measured rainfall-runoff response to arrive at a loss function, a distribution of effective precipitation, and a representative unitgraph associated with the effective precipitation (McCuen, 1998).

Unfortunately, most hydraulic design is performed for watersheds without both a stream gage and one or more rain gages that together provide rainfall-runoff history. In such cases, a synthetic unitgraph is estimated from statistical procedures. Synthetic unitgraphs refer to unitgraphs developed for a particular ungaged watershed using timing and shape parameters of the unitgraphs that are statistically transferred or regionalized from nearby gaged watersheds considered to be similar to the ungaged watershed.

Hydrologic regionalization is a common statistical practice that compensates for the lack of data for a given watershed. An example of hydrologic regionalization is flood frequency and magnitude estimation using regional regression equations (such as those developed for TxDOT Projects 0-1301 and 0-3301). Unitgraphs have two major components, a regionalized shape factor and a response time. Most methods for developing synthetic unitgraphs use a regionalized time component (time of concentration or lag time being most common) and a shape factor or shape component (NRCS dimensionless or triangular unitgraphs, Gray's method, and Snyder's method, for example).

OBJECTIVES

There are two main objectives for the proposed research. The first objective is to determine if the NRCS dimensionless unit hydrograph procedure is representative of observed unitgraphs in Texas. The measured unitgraphs will be derived from large regional databases of paired rainfall and runoff data in Texas. If, as expected, the NRCS dimensionless unitgraph procedure is not a reasonable representation of observed unitgraphs in Texas, then the second objective is to use the observed unitgraph data bases to select and calibrate one or more synthetic unitgraph procedures.

IMPLEMENTATION

Implementation of the resulting calibrated synthetic unitgraph procedure will be to include the technology in TxDOT design procedures. A possible implementation project could be to develop training materials to be used in TxDOT training courses.

WORK PLAN

Task 1 - Review of literature: The literature dealing with unitgraphs and estimation of unit hydrographs is rich. Topics range from historical development of the unitgraph procedure through the linear systems analysis approach to development of unitgraphs. Of particular interest to the proposed research is development of observed unitgraphs from measured rainfall-runoff time series, and the subsequent regionalization of the observed unitgraphs for development of procedures to estimate synthetic unitgraphs. A significant effort is required to assemble and evaluate the data and to review the relevant research literature. A synthesis report of the data and research literature review will be prepared and delivered to TxDOT near the end of the first project year.

The literature review will take two major directions: First is a review and assessment of techniques for analyzing data for gaged watersheds. A gaged watershed has both rainfall gaging and stage-discharge gaging information. Unitgraphs can be developed from these records using several methods. Most straightforward is separating the direct runoff hydrograph from the runoff hydrograph, using a phi-index to determine effective precipitation, then dividing the direct runoff hydrograph by the effective precipitation. However, alternative approaches involve a form of hydrograph deconvolution (often based on matrix computations) to "back out" both the loss-rate function and the unitgraph from measured rainfall-runoff series.

Based on this portion of the literature review, one or more approaches will be selected for analyzing Texas data to produce observed unitgraphs.

The second major direction for the literature review will be the review and assessment of methods for ungaged watersheds. An ungaged watershed is missing either rainfall or stage-discharge information. Methods for ungaged watersheds are usually called synthetic unitgraphs because of the emphasis on statistically transferring unitgraph responses from gaged watersheds (observed unitgraphs) through watershed physical/hydrologic characteristics of the watersheds such as contributing drainage area. For ungaged watersheds, a synthetic response is usually based on a timing parameter and shape parameter. Existing methods for estimating synthetic hydrographs will be examined and evaluated for use in Texas.

The research literature review will be divided between researchers at Texas Tech University (Thompson), Lamar University (Fang), and University of Houston (Cleveland). The USGS (Asquith) will take the lead in the data literature review, and finally, Tech will take the lead and will be responsible for preparation of the synthesis report.

Task 2 – Data Assembly: For TxDOT Project 0-2104, rainfall-runoff responses of small rural watersheds (watershed areas generally less than 10 square miles) are in review. During the course of data review for 0-2104, many studies of Texas small watershed hydrology by Texas District USGS were identified. There are a significant number of individual storm events contained within these studies. USGS small watershed studies were conducted largely during the period spanning the early 1960's to the middle 1970's, although longer periods are available for some stations. TTU and USGS are currently using some of the results from these studies in ongoing TxDOT project work. Unfortunately, no data pertinent to unitgraph research from these studies are digitally available and the USGS reports represent the sole data source. Furthermore, the USGS Texas District library might represent the only comprehensive archive of these data.

The storms documented in the USGS studies can be used to evaluate unit hydrographs and these data are critical for unit hydrograph investigation in Texas. Candidate stations for hydrograph analysis for less than 20 square mile rural watersheds are listed in Table 1. This list is not entirely complete because some stations used in USGS urban studies (discussed below) could be considered rural. However, the list comprises those stations that are most important for computing observed unitgraphs for small watersheds in Texas. Pair-wise records of rainfall and direct runoff exist for each storm and often more than one precipitation gage exists in the watershed. Of additional benefit to the research, the runoff record documented in the reports often includes pre-computed direct runoff values.

Approximately 860 events are documented for the stations in about 100 annual data reports. These data reports are not the usual and familiar annual data reports that are published annually for the statewide hydrologic data collection network of the USGS. The reports are instead annual data compilation reports specifically for the small watershed study areas. This represents about 35 events per watershed, which corresponds to about 30,000 lines of data. For each line of data, the time, precipitation, and direct runoff values are needed, which implies that in total about 90,000 individual data values require digital storage. USGS will be responsible for the development of this portion of the database, as these data are a natural extension of USGS work on TxDOT Project 0-2104. Optical-character recognition scanning software and hardware will be investigated; however, it is unknown to what extend this technology will facilitate rapid database development.

Table 1. Gaging stations for small rural watersheds in Texas.

Station	Description	Drainage Area (Square Miles)	Number Events	of Period of Record
08042700	North Creek #28A	6.82	14	1973-1979
08050200	Elm Fork Creek #6	0.77	35	1961-1971
08052600	Little Elm Fork #10	2.1	29	1966-1976
08057500	Honey Creek #11	2.14	108	1953-1970
08058000	Honey Creek #12	1.26	111	1953-1970
08063200	Pin Oak Creek	17.6	22	1957-1962
08094000	Green Creek	3.18	29	1959-1971
08096800	Cow Bayou #4	5.25	51	1959-1975
08137500	Mukewater Creek	4.02	47	1961-1973
08139000	Deep Creek #3	3.42	156	1953-1971
08140000	Deep Creek #8	4.32	159	1953-1971
08182400	Calaveras Creek	7.01	42	1957-1971
08187000	Escondido Creek #1	3.29	32	1960-1971
08187900	Escondido Creek #11	8.43	22	1962-1970

In addition to the strictly rural data (Table 1), many records for less than 20 square mile watersheds exist for five urban areas in Texas (Austin, Dallas, Fort Worth, Houston, and San Antonio). Candidate watersheds are listed in Tables 2, 3, 4, and 5. Like the rural data, much of the urban data comprises historical reports in which hyetographs and hydrographs are presented in hand written or typeset tables documented in over 100 USGS urban-study annual data-compilation reports. At this time, no comprehensive summary of the number of events per station exists; however, from preliminary review of the USGS reports suggests that from 2 to 4 storms per year per station are documented and that the length of record is usually about 10 years. It is estimated that about 1,800 storms events are available from the USGS urban studies. The total number of data values to be digitally stored is about 150,000.

Table 2. Gaging stations for Austin, Texas

Station	Drainage Area (Square Miles)	Description
08156650	2.79	Shoal Creek at Steck, Austin, Texas
08156700	6.52	Shoal Creek at Northwest Park, Austin, Texas
08156800	12.3	Shoal Creek at 12th Street, Austin, Texas
08157000	2.31	Waller Creek at 38th Street, Austin, Texas
08157500	4.13	Waller Creek at 23rd Street, Austin, Texas
08159150	4.61	Wilbarger Creek near Pflugerville, Austin, Texas
08155550	3.12	West Bouldin Creek at Riverside Drive, Austin, Texas
08158050	13.1	Boggy Creek at US183, Austin, Texas
08158300	1.63	Ferguson Branch at Springdale Road, Austin, Texas
08158380	5.22	Little Walnut Creek at Georgian Drive, Austin, Texas
08158810	12.2	Bear Creek below FM1826 near Driftwood, Texas
08158880	3.58	Boggy Creek (south) at Circle S Road, Austin, Texas
08158920	6.3	Williamson Creek at Oak Hill, Texas
08158930	19	Williamson Creek at Manchaca Road, Austin, Texas

Table 3. Gaging station for Dallas-Ft. Worth.

Station	Drainage Area (Square Miles)	Description
08048530	0.97	Sycamore Creek tributary above Seminary South Shopping
08048540	1.35	Sycamore Creek tributary IH35-W, Fort Worth, Texas
	0.38	Seminary South Shopping Center and associated residential area
08048600	2.15	Dry Branch at Fain Street, Fort Worth, Texas
08048850	12.3	Little Fossil Creek at Mesquite Street, Fort Worth,
08048550	1.08	Dry Branch at Blandin Street, Forth Worth, Texas
08048820	5.64	Little Fossil Creek IH820, Fort Worth, Texas
08048520	17.7	Sycamore Creek at IH35-W, Fort Worth, Texas
08049565	1.73	Trigg Branch at DFW Airport near Euless, Texas
08055590	9	Joe's Creek Outfall at Denton Drive, Dallas, Texas
08055600	7.51	Joe's Creek at Dallas, Texas
08055700	9.58	Bachman Branch at Bluff View Blvd, Dallas, Texas
08057020	4.75	Coombs Creek at Sylvan Avenue, Dallas, Texas
08057050	9.42	Cedar Creek at Bonnie View Road, Dallas, Texas
08057120	6.77	Spanky Branch at McCallum Lane, Dallas, Texas
08057140	8.5	Cottonwood Creek at Forest Lane, Dallas, Texas
08057160	4.17	Floyd Branch at Forest Lane, Dallas, Texas
08057320	6.92	Ash Creek at Highland Road, Dallas, Texas
08057340	1.84	Forney Creek at Lawnview Avenue, Dallas, Texas
08057420	13.2	Fivemile Creek at U.S. Highway 77, Dallas, Texas
08057425	11.5	Woody Branch at U.S. Highway 77, Dallas, Texas
08061620	8.05	Duck Creek at Buckingham Road, Garland, Texas
08061920	13.4	South Mesquite Creek at State Highway 352, Mesquite,

Most of the watersheds for some of the urban gages identified in Tables 2, 3, 4, and 5 are highly urbanized. However, several could be considered rural. The USGS reports generally provide description of the land use practices in the basin. Each of the identified stations has one or more storms documented storm events. That is, the data includes pair-wise precipitation and resulting runoff values. The precipitation is usually calculated from appropriate areal weighting of rainfall from two or more precipitation gages in the respective watersheds because the USGS-operated dense precipitation networks during the duration of the urban studies.

Development of this portion of the database will be divided between researchers at Lamar University (Fang), University of Houston (Cleveland), and the USGS. Database development will be coordinated by the USGS (Asquith) to help ensure that the other researchers are provided with the necessary data sources and independently developing databases remain parallel and format consistent.

Table 4. Gaging stations for Houston.

Station	Drainage Area (Square Miles)	Description
08073750	0.5	Stoney Brook Street Ditch at Houston, Texas
	7.05-8.29	Cole Creek at Guhn Road, Houston, Texas
08074150	8.81	Cole Creek at Deihl Road, Houston, Texas
08074200	2.05	Brickhouse Gully at Clarblak, Houston, Texas
08074250	10.5	Brickhouse Gully at Costa Rica Street, Houston, Texas
08074780	5.77	Keegans Bayou at Keegan Road near Houston, Texas
08074800	9.28	Keegans Bayou at Roark Road near Houston, Texas
08074850	4.29	(Unknown at this time)
08074900	11.2	Willow Waterhole Bayou at Landsdowne Street, Houston, Texas
08075300	4.99	Sims Bayou at Carlsbad Street, Houston, Texas
08075400	20.2	Sims Bayou at Hiram Clarke Street, Houston, Texas
08075550	3.26	Berry Bayou at Gilpin Street, Houston, Texas
08075600	1.58	Berry Bayou tributary at Globe Street, Houston, Texas
08075650	11.1	Berry Bayou at Forest Oaks Street, Houston, Texas
08075700	4.86	Berry Creek at Galveston Road, Houston, Texas
08075730	8.21	(Unknown at this time)
08075750	1.03	Hunting Bayou tributary at Cavalcade Street, Houston, Texas
08075760	3.42	Hunting Bayou at Falls Street, Houston, Texas
08075770	14.4	Hunting Bayou at US90A, Houston, Texas
08075780	8.73	Greens Bayou at Cutten Road near Houston, Texas
08076100	0.1	Reinhardt Bayou trib near Houston, Texas
08076200	6.31	Halls Bayou at Deertrail Street near Houston, Texas
08077100	1.33	Clear Creek tributary at Hall Road, Houston, Texas

Table 5. Gaging stations for San Antonio.

Station	Drainage Area (Square Miles)	Description
08177600	0.33	Olmos Creek tributary at Farm Road 1535, Shavano Park, Texas
08178300	3.26	Alazan Creek at St. Cloud Street, San Antonio, Texas
08178600	9.54	Panther Springs Creek at Farm Road 2696 near San Antonio, Texas
08178690	0.26	Salado Creek tributary at Bitters Road, San Antonio, Texas
08178736	0.45	Salado Creek tributary at Bee Street, San Antonio, Texas
08181000	5.57	Leon Creek tributary at Farm Road 1604, San Antonio, Texas
08181200	1.08	French Creek tributary near Helotes, Texas
08181400	15	Helotes Creek at Helotes, Texas

Data sheets from USGS reports are in several formats. One is a dot matrix printout, similar to the form presented on Figure 1. A second form is a handwritten sheet, similar to Figure 2. Many of the reports that contain data represented by Figure 1 and Figure 2 have hydrographs similar to that presented on Figure 3.

STA. NO. 08057130 — STORM RAINFALL AND RUNOFF RECORD — 1974 WATER YEAR

RUSH BRANCH AT ARAPAHO ROAD, DALLAS, TEX. — STORM OF OCT. 30-31, 1973

DATE & TIME	GAGE NUMBER 1-RH	ACCUM. WEIGHTED PRECIP. IN.	DISCHARGE IN FT³/S	ACCUM. RUNOFF IN.
OCT. 30				
1530	0.97	0.97	4.4	0.1136
1600	0.97	0.97	3.2	0.1151
1615	0.97	0.97	2.6	0.1160
1630	0.97	0.97	2.1	0.1170
1700	0.97	0.97	1.7	0.1180
1730	0.97	0.97	1.1	0.1185
1740	0.97	0.97	1.1	0.1187
1745	0.98	0.98	1.1	0.1188
1750	0.98	0.98	1.1	0.1190
1800	1.33	1.33	1.7	0.1192
1805	1.42	1.42	2.1	0.1195
1810	1.51	1.51	20.0	0.1216
1815	1.81	1.81	45.0	0.1263
1820	2.05	2.05	83.0	0.1351
1825	2.28	2.28	159.0	0.1520
1830	2.36	2.36	260.0	0.1795
1835	2.48	2.48	350.0	0.2165
1840	2.51	2.51	400.0	0.2589
1845	2.53	2.53	412.0	0.3025
1850	2.55	2.55	420.0	0.3469
1855	2.56	2.56	392.0	0.3884
1900	2.57	2.57	368.0	0.4274
1905	2.58	2.58	334.0	0.4629
1910	2.58	2.58	304.0	0.5112
1920	2.60	2.60	254.0	0.5650
1930	2.62	2.62	221.0	0.6001
1935	2.64	2.64	203.0	0.6215
1940	2.65	2.65	188.0	0.6514
1950	2.67	2.67	167.0	0.6868
2000	2.67	2.67	151.0	0.7267
2015	2.67	2.67	143.0	0.7721
2030	2.67	2.67	132.0	0.8140
2045	2.67	2.67	119.0	0.8518
2100	2.68	2.68	119.0	0.8896
2115	2.69	2.69	117.0	0.9206
2125	2.69	2.69	109.0	0.9436
2135	2.68	2.68	102.0	0.9652
2145	2.68	2.68	95.0	0.9904
2200	2.69	2.69	83.0	1.0167

-131-

Figure 1. Dot matrix printout of measurements from USGS watershed.

TX-65
(Rev.6-68)

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY-TEXAS DISTRICT

RUNOFF COMPUTATIONS

Station 8-1786.90 Salado Creek trib. at Bitters Road, San Antonio, Tex
Period of Record Jan. 16, 1969 Drainage Area 0.26 sq mi.

Time	G. Ht. Feet	Sh. Adj.	Discharge c.f.s.	Inc.	In/hr.	Runoff Inches	Acc. In.
Jan 16, 1969							
0000	—		0	1		0.0000	0.0000
0005	—		(5.0)	2	0.0299	.0025	.0025
0010	3.32	0	22	2	.1312	.0109	.0134
0015	3.57		32	2	.1908	.0159	.0293
0020	3.66		36	2	.2146	.0179	.0472
0025	3.51		29	2	.1729	.0144	.0616
0030	3.34		23	2	.1371	.0114	.0730
0035	3.21		17	2	.1014	.0084	.0814
0040	3.12		14	2	.0835	.0070	.0884
0045	3.05		12	2	.0715	.0060	.0944
0050	2.96	0	9.1	3	.0543	.0068	.1012
0100	—		(5.5)	5	.0328	.0068	.1080
0115	—		(2.6)	6	.0155	.0039	.1119
0130	—		(1.0)	9	.0060	.0022	.1141
0200	—		(0)	18	0	.0000	.1141
0300	—		(0)	24	0	.0000	.1141
2400	—		(0)	252	0	.0000	.1141
			459.4)	576			
			0.80				
Total Runoff =			1.58 ac-ft				
( ) Estimated data							

Computed by LEL Date 2/18/70 Checked by W.E.R. Date 02/19/70

-65-

Figure 2. Runoff computations in handwritten form.

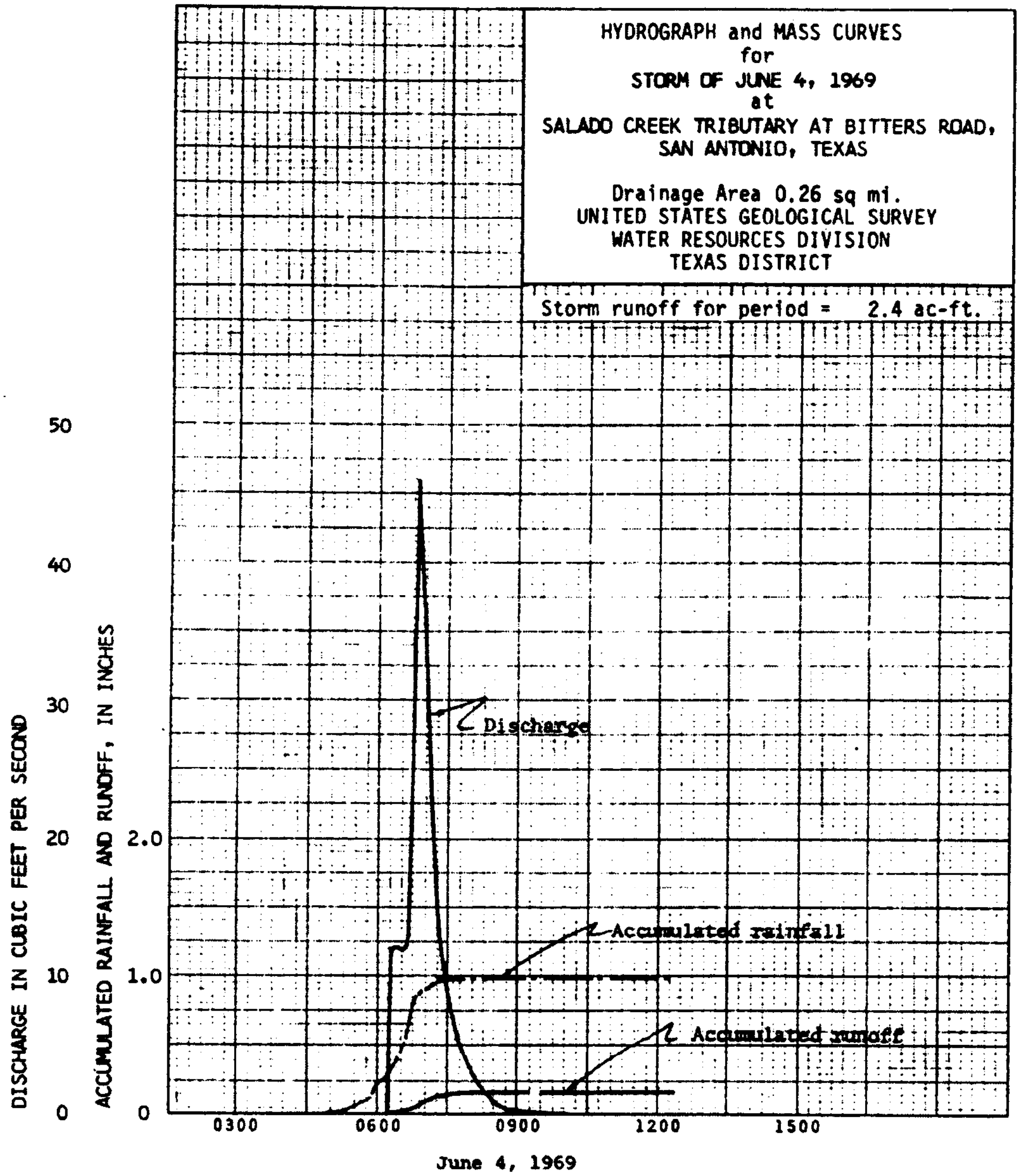

Figure 3. Hydrographs from typical USGS report.

Finally, Agricultural Research Service (ARS) datasets have been identified for the Reisel and Sonora experimental watersheds in Texas. These data will be assembled into the database by researchers at Tech (Thompson). The ARS data are important because they represent an additional sample from small watersheds that includes pair measurement of rainfall and runoff.

Task 3 - Data analysis: The dataset assembled in Task 2 will be subjected to analysis. Each rainfall-runoff series represents the possibility for extracting a unit hydrograph for the watershed. From this set of runoff events, hydrographs with obvious errors will be deleted from further consideration. Reasons for removing the hydrograph from the dataset include having more runoff than rainfall, multiple-peaked hydrographs, and precipitation sequences that are not approximately uniform in time distribution. Storms for which more runoff than rainfall is observed are easily filtered. It is possible that automated procedures could be used for identifying unacceptable multiple-peaked hydrographs or uniform precipitation.

Although the exact procedure used for extracting the unit hydrograph from the measured time series will be determined during the literature review, there are only two fundamental approaches for this computation. Fortunately, much of the runoff data identified is actually direct runoff and limited hydrograph separation is needed.

The first (and oldest) approach is to separate baseflow from the hydrograph using (most commonly) semilogarithmic plots of discharge versus time to extract baseflow recessions from the runoff hydrograph. Baseflow is subtracted from the runoff hydrograph to produce the direct runoff hydrograph. The time integral of the direct runoff hydrograph distributed over the watershed drainage area represents the depth (or volume) of effective precipitation. The hyetograph is separated into losses and effective precipitation using a phi-index (constant loss rate) such that the depth above the phi-index corresponds to the depth of effective precipitation computed from the direct runoff hydrograph. The length of time over which effective precipitation occurs is the duration of the unit hydrograph. The unitgraph itself is obtained by dividing the ordinates of the direct runoff hydrograph by the depth of effective precipitation.

The second approach is to apply a form of deconvolution to either the direct runoff hydrograph (after baseflow separation) or to the runoff hydrograph itself to "back out" loss-rate and unitgraph parameters. One method is built into HEC-1 in which loss-rate parameters and Clark synthetic unitgraph parameters are optimized by iteration. Basically, the parameters are changed and a runoff hydrograph is simulated. Deviations between the predicted and observed hydrographs are used to direct subsequent modification of loss-rate and unitgraph parameters. A second method uses a matrix inversion to deconvolute unitgraph and loss-rate parameters from the input hyetograph and output runoff hydrograph in a one-pass approach.

Most likely that an exploratory approach will be required to determine which of the available methods will work best for Texas hydrology. Based on the literature review, several approaches will be tried and evaluated before a commitment to a particular method is made.

The result of the data analysis will be a set of observed unitgraphs. Each gaged watershed will have multiple replications of the unitgraph for that watershed. The unitgraphs will be converted to a common duration (time of effective precipitation) most likely using the S-hydrograph for the watershed. An appropriate duration for the unitgraph is about 20 percent of time of concentration of the watershed. The resulting unitgraph for each watershed will have a characteristic shape and a timing parameter. The lag time will be extracted from the unitgraph for each watershed.

The final result of Task 3 will be a set of unitgraph shapes and timing parameters. Each watershed that was analyzed will have a lag time (or other timing parameter) and a characteristic unitgraph shape. These values will be used to evaluate existing approaches as used in current TxDOT design and synthetic unitgraph methods discovered during the literature review. Tech (Thompson) will provide leadership for Task 3.

Task 4 – Comparison with NRCS unit hydrographs: Detailed comparisons between the NRCS unit hydrograph method and the observed unit hydrographs in Texas (task 3) will be conducted. Because the dataset developed in Tasks 2 and 3 will be unique to Texas, it is anticipated that results from national approaches will differ from NRCS method. Results of Task 4 will be either validation of existing technology for development of synthetic unitgraphs, modification of existing technology, or development of a new formulation particular to Texas hydrology. Results of Task 4 will be presented in a final report. Tech (Thompson) will provide research leadership for Task 4; however, each of the supporting partners will have significant contributions.

Task 5 –Regionalization of observed unit hydrographs in Texas:

Given an unfavorable comparison of the NRCS unit hydrograph approach to the observed unit hydrographs in Texas, regionalization of the observed unit hydrographs is required. The regionalization is the statistical transference of observed unit hydrograph and watershed characteristic information for the gaged watersheds to any given ungaged watershed.

It is anticipated that before the final regionalization is performed that considerable data exploration is needed to determine the most scientifically based and efficient approach to relate watershed characteristics to the unitgraph timing parameter and shape. The approach could be manifested as a suite of tools for the designer that might include: regression equations, graphical charts, guidelines, and nomographs.

Results of Task 5 are the most important product of the project and will be presented in a final report and in the form of design guidance to be included in TxDOT design manuals. Tech (Thompson) will provide leadership for Task 4; however, each of the supporting partners will have significant contributions.

COMPUTER PROGRAMS

We do not anticipate development of computer programs as part of the deliverables for this project. Numerous computer programs will be developed during the research, but these will be useful only to the researchers and will require specific, detailed expertise for application.

ASSISTANCE OR INVOLVEMENT BY TxDOT

No direct involvement of TxDOT personnel is expected or required to complete the proposed research. However, technical advice and input on project direction will be sought from the PD and the PAC.

PROJECT DELIVERABLES

Project deliverables will be in the form of a series of task progress reports documenting work completed as tasks are completed following by a final project report, project summary report, and guidance document for inclusion in the TxDOT online manual system. A summary of deliverables is presented on the Deliverables Table below.

Deliverables Table
Project No. 0-4193
RMC 3

<u>Products</u> (e.g., specifications, guidelines, design procedures, devices, or software resulting from the project)

Product Description	**Required Submittal Date***	**Responsible Party for Multi-Agency Agreement**	**Comments**
Guidance for development and application of synthetic unit graphs for design applications	8/31/01	Research Supervisor (Tech)	In format for inclusion in TxDOT Online Manual System

<u>Reports</u> (This table will include a minimum of one Research Report that comprehensively documents the project and one Project Summary Report of maximum 6 pages. The requirements for reports in this table may be revised at a later date by mutual agreement of the Research Supervisor, the Project Director, and the Director of the Research and Technology Transfer Section of the Construction Division.)

No.	**Report Description**	**Required Submittal Date***	**Responsible Party for Multi-Agency Agreement**	**Comments**
1	Synthesis of Literature Review (Task 1)	8/31/201	Research Supervisor (Tech)	
2	Synthesis of Data Assembly (Task 2)	8/31/01	Research Supervisor (Tech)	
3	Synthesis of Data Analysis (Task 3)	8/31/01	Research Supervisor (Tech)	
4	Final Project Report	11/30/02	Research Supervisor (Tech)	
5	Project Summary Report	11/30/02	Research Supervisor (Tech)	

* If no required submittal date is indicated, it defaults to 60 days after project termination.

Date Updated: March 31, 2000

SCHEDULE OF RESEARCH ACTIVITIES

h Activity	FY 2001												FY 2002								
Description	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**
Literature Review	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
Data Assembly	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Data Analysis									■	■	■	■	■	■	■	■	■	■	■	■	■
Comparison w/NRCS																		■	■	■	■
Regionalization																		■	■	■	■

Research Project Statement
Fiscal Year 2001

Project Number: 0-4193 **Modification?** ☐ Yes ☒ No

Title: Regional Characteristics of Unit Hydrographs

RMC Number: 3 **LRRP Element(s):**

Developed By:

Project Statement Date: 1-7-00

TxDOT Project Personnel	Name	Office	Area Code/Phone Number	Fax Number
Program Coordinator (PC)	Anthony J. Schneider, P.E.	Bridge	512. 416. 2315	512. 416. 2354
Project Director (PD)	David Stolpa, P.E.	Bridge	512. 416. 2271	512. 416. 2354
Project Monitoring Committee (PMC) (Project Advisors Optional)				

Duration (# of years): 2 **Total Budget:** $

Budget by year:
First Year FY $
Second Year FY $
Additional FYs $

Other Funding Available? ☐ Yes ☐ No

Project Description:

Traditional techniques for developing storm and basin attributes for use in rainfall-runoff modeling depend on manual procedures that can be time consuming. However, recent advances in computer program and GIS technology have the potential for improving the cost-effective use of runoff modeling by TxDOT. The effectiveness and reliability of GIS methods for incorporation in TxDOT applications, however, are also dependent on improvement in hydrologic techniques and data.

TxDOT usually considers rainfall-runoff models for two reasons. The first use is to evaluate specific changes or controls within a watershed. Runoff modeling is also used as a check or alternative method to statistical approaches when gage records and results appear inadequate for a site. TxDOT application of rainfall-runoff modeling is typically used for projects having drainage basin of 10 square miles or less, and/or a time-of-concentration of less than six hours (however, sites as large as 100 square miles may be considered at times).

TxDOT currently relies on the Natural Resources Conservation Service (NRCS) dimensionless unit hydrograph procedure when using this methodology for design applications. Default NRCS unit graph characteristics represent values that have been adopted for an "average" watershed. In particular, for the peak rate equation "qp = KAQ/Tp," K is considered to be equal to 484 (English units). "K" is related to the internal storage characteristic of a basin and may vary considerably depending on the region characteristics and scale of a basin. For example, K may be closer to a value of 300 in the flat coastal plains of the state. In addition, the empirical relationship for lag is assumed to be lag = 0.6 Tc, where Tc is the time of concentration. Informal discussions with the NRCS indicates that the relationship may be closer to lag = 0.7 Tc in East Texas. General use of the NRCS procedure without consideration of actual regional or site characteristics can result in poor correlation with statistical expectation, inadequate design, or inefficient over-designed structures.

Ideally, unit hydrograph parameter development should involve calibration using actual events experienced at the site or nearby, similar watersheds. However, such calibration can be time consuming and many sites simply lack data. In lieu of calibration, generalized regional data has the potential to be a satisfactory option for parameter development. Research along the regional line of approach has recently been initiated on the climatic adjustment of NRCS curve numbers for rainfall loss modeling.

The proposed research is expected to build on and is an important continuation of past and current efforts in updating hydrologic techniques for TxDOT applications. Of particular interest are the regional characteristics of basins of ten square miles or less.

The research should include the following tasks:

Task 1: Review current TxDOT methodology in rainfall-runoff modeling., in particular, the use of the NRCS dimensionless unit hydrograph for design applications. Identify currently available alternatives to the use of the NRCS procedure and determine if the proposed research presents a potential for improvement relative to statistical expectation, etc. If so, determine if the research is properly sequenced. That is, if other issues need to be addressed before proceeding.

Task 2: If the sequencing, etc., is appropriate, perform a search and review of available rainfall and streamflow records to determine if there is adequate data to potentially provide guidance on regional unit hydrograph characteristics across Texas.

Task 3: If there is adequate data, recommend and develop procedures for modifying existing models to use the regional data or develop a new model.

Task 4: If the data appears to be generally inadequate or is inadequate for a region, estimate/describe the degree of effort required to acquire the necessary data.

Task 5: Present a methodology for TxDOT use, based on the regional data, for incorporation in the TxDOT *Hydraulics* Manual.. The methodology should include necessary guidance documentation. A computer program is not required, but may be a potential feature for final implementation.

Minimum Deliverables:	1. A methodology and tools to aid in the development of unit hydrographs for design applications for TxDOT use, with recommendations and guidance document for implementation. The document should be provided in a format appropriate for inclusion in the TxDOT Hydraulic On-line Manual system. 2. A synthesis report with recommendations at the end of each task. 3. A final research report that provides detailed documentation of all research performed, methods used, and that fully supports the recommendations and conclusions contained therein. 4. Project summary report outlining the research, findings and recommendations, in 4 to 6 pages. 5. Any other deliverables identified during the course of the research project.
Implementation:	The methodology and tools developed will be considered for incorporation into TxDOT hydraulics design procedures.
Pre-Proposal Meeting:	☒ Yes ☐ No February 22, 2000, 9:00 a.m., Bridge Division, Conference Room A, 118 Riverside Drive, Austin, Texas. Please contact David Stolpa at (512) 416-2271 if you plan to attend the meeting.
Sole-Source Project:	☐ Yes ☒ No
Additional Information:	
Deadlines (for CSTR use only):	1. All individuals interested in proposing are encouraged to contact the PD by February 18, 2000. 2. Proposals are due to CSTR by 5:00 p.m. on March 31, 2000.

T:Rmsdocs\Projstat\Fy2001\RMC3-0-4193-PST-rfp