"An ideal solution to the problem of determining the LTC would be to derive general equations for computing it from the basin and/or regional characteristics that control its magnitude."

General Equations for the Lag Time Coefficient

by

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and
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Introduction

Flood hydrograph models (FHM's) require the estimation of a lag time coefficient (LTC) for the drainage area for which the hydrograph is being computed. The significance of the LTC is derived from its relationship to the hydrograph peak, i.e., the flood hydrograph peak is inversely proportional to the LTC from which it was derived. General formulas are available for the computation of the lag time from the unique physiographic characteristics of the basin, but they require the estimation of an LTC. However, there is no general formula or objective procedure for estimating this parameter, even though it is known to vary in practice from 0.4 to 8.0 for a range of 2000 percent as shown in reference 1. Furthermore, there is disagreement as to whether flatter terrain means a larger coefficient than does steeper terrain. The fundamental disagreement of authoritative sources on this matter is illustrated by the dichotomy between the Taylor and Swartz formula and the U.S. Corps of Engineers study shown in reference 1. Whereas, the Taylor and Swartz formula for the LTC as shown below assigns the higher coefficient to the flatter basins, the Corps study assigns a coefficient of .35 to valley areas and 1.2 to mountainous terrain.

$$C_t = .6/S^{1/2}$$

But even the above formula is not general and was derived as indicated in reference 1 from twenty basins in the North and Middle Atlantic States. Certainly, experience has shown that it does not apply in most hydrologic regions. The narrow range of its application indicates that equations for the LTC are regional and apply only in areas hydrologically similar to those for which they are derived. Also, basin and/or regional characteristics other than the slope of the main stream may be controlling influences for this parameter. An ideal solution to the problem of determining the LTC would be to derive general equations for computing it from the basin and/or regional characteristics that control its magnitude.

In the course of this study it was found that the magnitude of the LTC did indeed depend on both regional and basin characteristics other than the slope and that for hydrologically similar areas, equations for computing the LTC could be derived from the unique physiographic characteristics of the drainage areas. Furthermore, these studies revealed that the constant term and coefficients of these regional LTC equations could be derived from quantifications of the meteorologic, physiographic and antecedent condition characteristics of the region of similarity. From the results of this study, an LTC can be objectively determined for any drainage area in the Philippine Archipelago by starting with the controlling regional

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characteristics from which the parameters of the regional equation were derived by a general equation developed in this study; and from these regional equations, the LTC of any basin in the region of similarity can be computed. At this time, the geographic scope of this general equation has not been determined but its area of applicability probably includes all areas in Southern Asia and the South Pacific with meteorologic, physiographic, and antecedent condition characteristics comparable to those found in any of the regions in the Philippine Archipelago.

Regional Equations for the Unique Basin LTC

The flood hydrograph model (FHM) utilized in this study used the following equation for computing the lag time of a drainage area.

$$T_L = C_T (LL_C / S^{1/2})^{.38}$$

Hereafter, in this study, LTC will refer exclusively to the LTC of this formula. This is the formula for lag time developed by the U. S. Corps of Engineers for Southern California as explained in reference 1. For this equation as mentioned above, the LTC is larger for mountainous terrain compared to valley terrain. This somewhat contradictory development is explained as a compensation by the LTC for the over response of the remainder of the formula to the characteristics of a basin with efficient peaking characteristics, i.e., it dampens this over response.

The principal tasks involved in the development of a regional lag time equation are the following:

* Determination of the intrinsic values of the dependent variable, i.e., the basin LTC.
* Identification and measurement of the independent variables which control the variation of the intrinsic basin LTC.
* Selection of the method for deriving the equations.
* Application of the above method, i.e., deriving the regional LTC equations.

Determination of Intrinsic Values

The intrinsic value of the basin LTC is defined as the LTC required, everything else remaining fixed, for the FHM to arrive at the same peak as a peak annual flow (PAF) analysis for the same drainage area and frequency. Since the hydrograph peak from an FHM is inversely proportional to the time base of the hydrograph for a given volume of rainfall excess and hydrograph shape and the time base of the flood hydrograph is directly proportional to the unit hydrograph time base which is directly proportional to the LTC, the flood hydrograph peak is inversely proportional to the LTC. Hence, the intrinsic LTC for the basin is inversely proportional to the ratio of the PAF and the FHM peak for the same drainage area and frequency.

Then, to determine the intrinsic LTC for a given drainage area, an FHM peak for the given basin and frequency must be computed. But this computation requires the estimation of an LTC for the basin. Therefore, from experience gained by trial, regional LTCs were estimated that would result in an average ratio of PAF to FHM peak of near unity for the region from which an intrinsic LTC for each basin was then computed. The resulting magnitude of the variation of these intrinsic LTCs from basin to basin within the region of hydrologic similarity clearly demonstrated that the LTC was a basin and not a regional parameter.

Statistically, if we compute a flood hydrograph by the FHM using this estimated LTC and then divide this LTC by the ratio of the FHM and the PAF peak for the same drainage area and frequency, we have an unbiased estimate of the intrinsic value of the basin LTC. In this study, the LTCs were computed in this manner for all the sample drainage areas of each region using the results of a regional PAF frequency analysis of each region to estimate the basin PAF for the same drainage area and frequency. The frequency of the FHM flood hydrograph peak was considered to be the same frequency as the maximum rainfall depth duration frequency data from which it was derived using the arrangement of rainfall increments which would produce the maximum hydrograph peak from the unit hydrograph utilized in the hydrograph synthesis. For the method used in the PAF analysis for each region, see Stevens and Templo in reference 4.

Since the basin PAF utilized was estimated from the regional PAF analysis using the drainage area only, it represents the runoff efficiency of a basin with average physiographic characteristics for the region. But the unique characteristics of each basin are accounted for in the FHM model so that the basins with greater runoff efficiency result in a smaller PAF to FHM peak ratio which means that for these basins the LTC required to match the average PAF for that drainage area would be larger.

However, since any relationship developed from these intrinsic LTCs for estimating their value from characteristics of the basin would be in some sense an average, the algorithm for computing the LTCs would only partially compensate for the difference, i.e., the efficient physiography would be only partially masked out and this residual efficiency in the lag time equation would still be greater for the more efficient basins. Hence, even though the computed values of the LTC for the efficient basins are larger than the average regional LTC, they will still result in a lag time shorter than the average for drainage areas of their size when used in the above lag time equation, because of the effect of their efficient characteristics on the remainder of the lag time formula, i.e., the computed LTC only dampens the effect of the basin characteristics as opposed to nullifying or reversing them.

Identification of the Basin Characteristics

Since the rainfall for the storm utilized in computing the flood hydrograph by the FHM is assumed to be uniformly distributed over the basin, the runoff of the rainfall excess is subject to the principles of hydraulics whose precise solution for a basin is a relatively complex problem. However, certain relatively simple aspects of this solution are representative of the average effect of other more numerous and harder to quantify aspects. For example, the time required for the runoff to assemble at the hydrograph site from the upstream drainage area into a peak flow for a given storm depends to some extent on the length and slope of the main stream channel. Also, the time to peak is dependent on the size of the basin and the distribution of its area in terms of its distance from the hydrograph site. The precise degree of this dependency was determined later in the study. Hence, for each drainage area in this study the above characteristics were quantified by the following measurements.

* The length of the mainstream channel
* The slope of this channel below the centroid
* The length of this channel below the centroid
* The drainage area of the basin

These, of course, are the very characteristics utilized in the lag time formula. However, the intent here is to compensate through the LTC the lack of precision in the representation of the effect of these characteristics by the lag time formula for the particular regions of hydrologic similarity covered by this study.

The Method of Derivation

Since we have determined the intrinsic LTC for each basin and measured the basin characteristics that generally control the hydraulics of the basin, further progress depends upon the choice of a method for establishing the relationship.

After the method to be derived has been applied, there should still remain the effect of the efficient or inefficient characteristics on the lag time of the basin. Furthermore, this dampening or magnifying effect should go as far as needed in moving the FHM peak toward the PAF to establish true effect of the unique basin characteristics on the lag time as measured by the peaking efficiency of the basin.

In other words, if when using an average regional LTC the efficient characteristics of the basin will produce a peak that is too large, the effect of these extreme characteristics on the lag time formula should be dampened by increasing the LTC. However, since the use of the intrinsic LTC would completely eliminate the effect of the efficient characteristics and would make the results identical to those of the regional PAF analysis which did not account for difference in the peaking characteristics of the basins, a method is sought that will optimize both the dampening effect on the efficient characteristics and the magnifying effect on the inefficient characteristics.

Since the ratio of the PAF and FHM peaks for the sample basins must have an average of approximately one over the region, the magnitudes of the residual efficiency contained in these computed lag times must be constrained to meet this requirement. In fact, the technique used should derive the lag time equation parameters (LTCEP's) so that the regional LTC equation not only dampens the effect of efficient peaking characteristics on the remainder of the lag time formula but also magnifies the effect of the inefficient characteristics, i.e., the LTC for steeper terrain must be larger than for flatter terrain. In other words, the derivation should treat the efficient and inefficient characteristics with an even hand, i.e., there should be one formula for all conditions to be encountered in the region. This even-handed requirement should result in a formula for the LTC that compensates for the inappropriate response of the remainder of the formula to the basin characteristics. Hence, the response that would remain after the computed LTC has been applied would represent the true response of the intrinsic basin lag time to these characteristics.

It is desirable that the method chosen results in a single equation for each region which can be used to compute the LTC for a given basin from its own unique characteristics. Also, application of this method should, if possible, produce a measure of the degree of relationship between the dependent and independent variables. The method of regression analysis has all these desirable features plus the guaranteed minimization of the deviations between the measured and computed values of the dependent variable.

Application

To maximize the degree of relationship between the dependent and independent variables, the log of the log of these variables was taken before the regression. This is justified since the non-transformed regression is a special case of the log transformation, i.e., the non-transformed equation without the constant term, and the least squares computation is free to arrive at the non-transformed case if it is truly the best fit. Furthermore, by the same reasoning the log transformation is a special case of the log-log transformation, i.e., the log transformation without the constant term. Also, the non-transformed and the log transformation were tested in every region and the log-log transformation gave the best results not only statistically but also from a technical standpoint.

To obtain the true correlation coefficient, a secondary correlation was made. In this study, the differences between the two correlation coefficients were negligible and the results of the secondary correlation as shown in Table 1 can be ignored. Also, the variation of the constant term and coefficients of the equations for the basin lag time from region to region clearly shows that a separate equation for each of these regions of hydrologic (and political) similarity is required. The high degree of correlation, as represented by the correlation coefficients of these regressions which range from 73 to 96 percent, is proof not only of the internal similarity of these regions but also of the significance of the relationship between the LTC and the basin characteristics. Figures 2 and 3 show a comparison of the PAF and FHM results when these equations are utilized for the sample basins of a representative region.

Formulae for the LTC Equation Parameters

Since the values of the LTC parameters have already been determined, only the following tasks remain.

- Identification of the regional characteristics that control these variations.
- Selection of the method of relating the LTCEP to these characteristics.
- Application of that method.

Regional Regression Equations
For
The Lag time Coefficient
USING LOG – LOG TRANSFORMATION

Region	No. OBS	Secondary Regression Detransformed – OBS Vs. Company			Primary Regression with Transformed Variables					
		Cons 7	Comp-y CF.	Trir Con CF.	Con CF	Cons 7	A – CF	L. CF	C – CF	S CF
I	28	.025904	.987932	.959411	.952585	.595367	.030404	–.329802	–.045934	1.319330
II	20	–.067379	1.029670	.962463	.962560	.571087	.030113	–.016077	–.304744	.769789
III	58	.030129	.990598	.801426	.816287	.481283	–.172330	.006618	–.009538	.243108
IV	180	.095628	.978902	.791704	.804976	.593095	.043434	– .029060	–.321531	1.223670
V	134	.053322	.979634	.922571	.924292	.646024	.016162	–.306078	–.013875	.329077
VI	126	–.029786	1.04950	.778544	.734268	.403760	.043871	–.202916	–.020381	1.489200
VII R	102	.064218	.976355	.953713	.963226	.680798	.027759	–.372853	.034827	2.650830
VII Y	219	–.087313	1.044090	.971659	.970258	.795750	.039450	–.499498	–.018198	2.086040
VIII	76	–.032199	1.046480	.949698	.948761	.089410	.099834	–.698826	–.036974	2.983000
IX	148	–.029454	1.040230	.961221	.966603	.313450	.020629	–.006919	–.194375	1.481290
X	151	–.044290	1.070410	.940873	.944544	.328608	.021942	–.237826	–.011160	1.153940
XI	240	.268301	.927022	.897649	890122	.791351	.017602	–.426805	–.007437	.815117
XII	74	–.090546	1.090060	.951477	.946485	.656590	.000159	–.422831	–.061841	3.526430
	1556				*Means	.611752	.016848	–.272563	–.068271	1.543910

LEGEND
A – DR. Area
L – Length of Storm
C – L to Centroid
S – Slope of Stormy

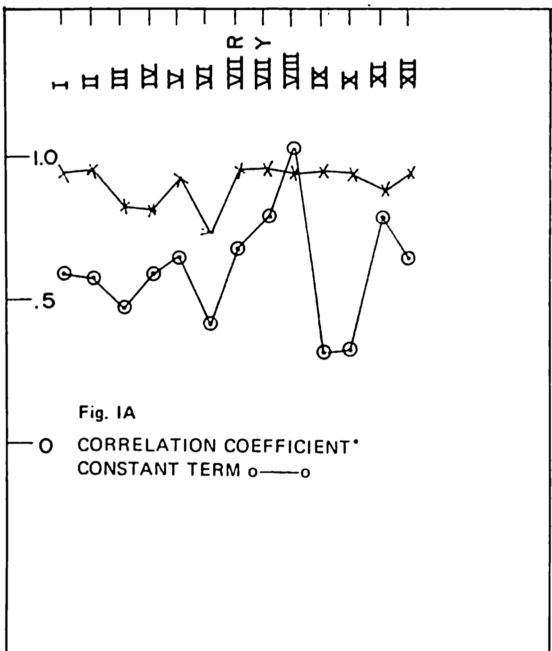

Fig. IA

CORRELATION COEFFICIENT'
CONSTANT TERM o——o

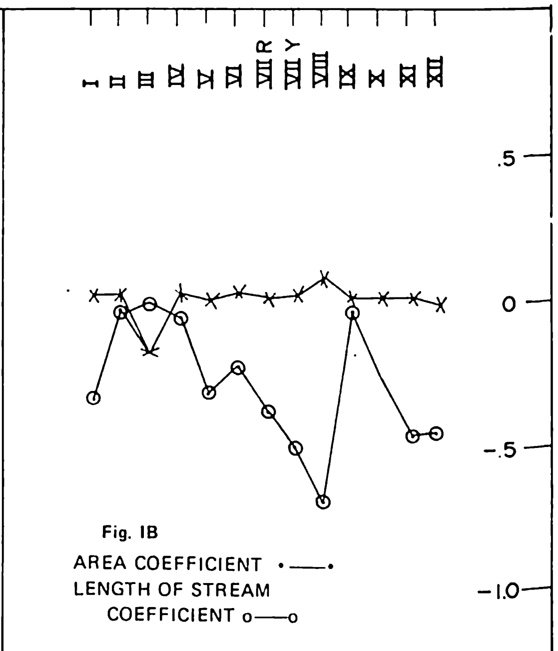

Fig. IB

AREA COEFFICIENT •——•
LENGTH OF STREAM
COEFFICIENT o——o

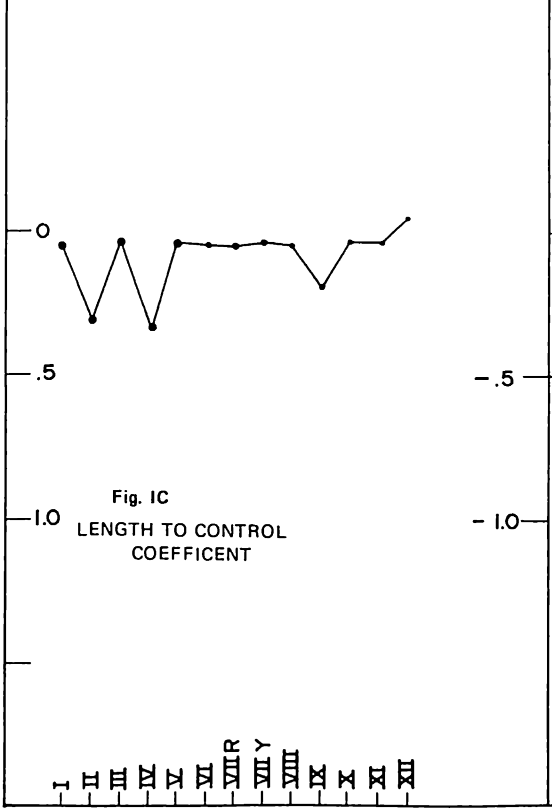

Fig. IC

LENGTH TO CONTROL
COEFFICENT

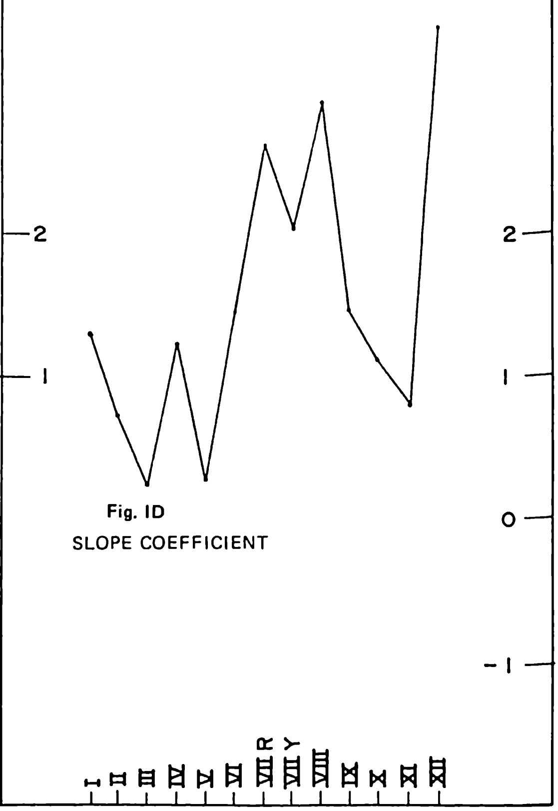

Fig. ID

SLOPE COEFFICIENT

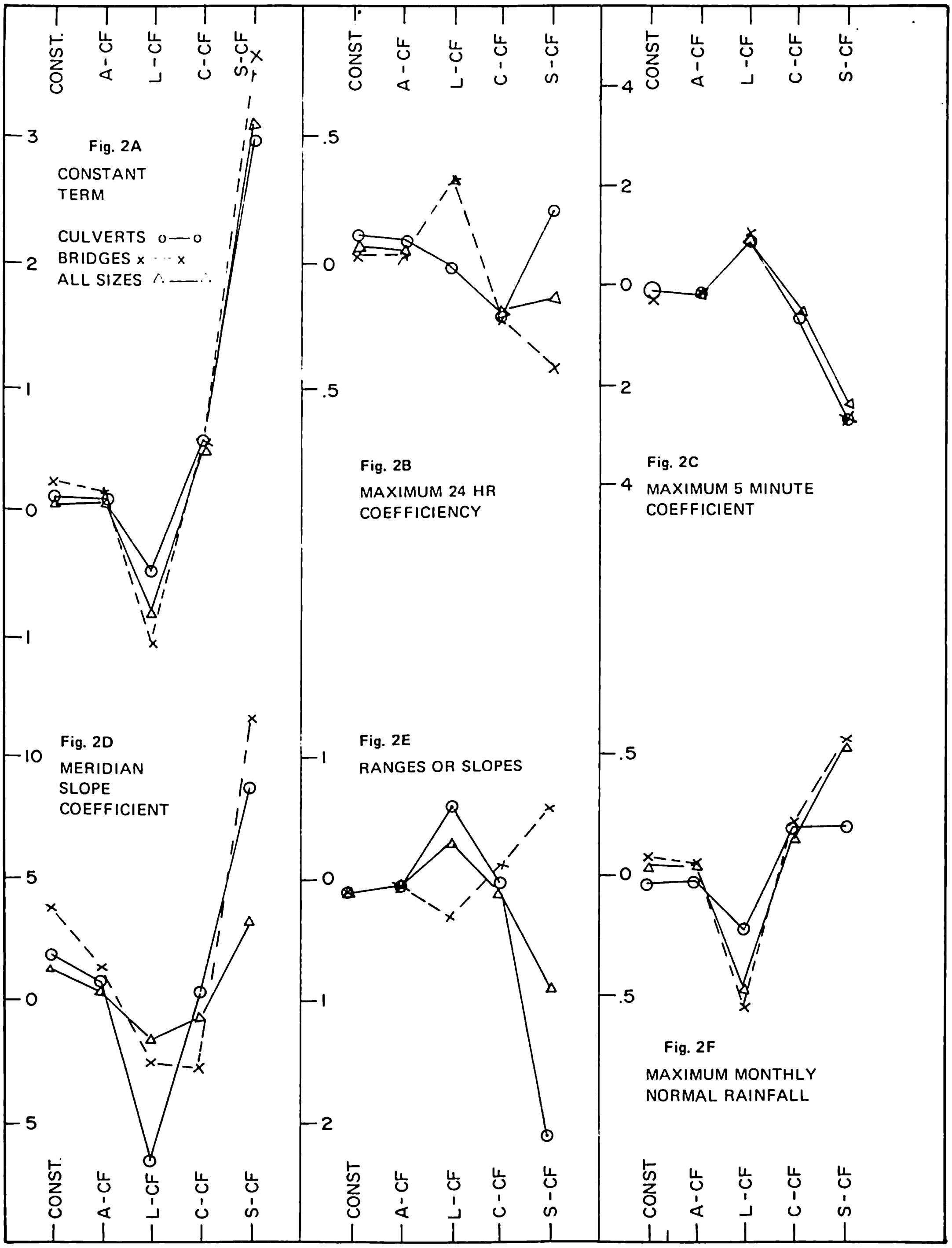

Fig. 2A

CONSTANT TERM

Fig. 2B

MAXIMUM 24 HR COEFFICIENCY

Fig. 2C

MAXIMUM 5 MINUTE COEFFICIENT

Fig. 2D

MERIDIAN SLOPE COEFFICIENT

Fig. 2E

RANGES OR SLOPES

Fig. 2F

MAXIMUM MONTHLY NORMAL RAINFALL

Identification of Regional Characteristics

The variation of the LTC equation parameters from region to region as shown in Figure 1 and the high correlation coefficients for these equations within their regions of similarity confirm that these parameters are truly regional in nature. Therefore, there exist characteristics within each region that cause this variation. It is speculated that the same factors that cause the average PAF for the same drainage area and frequency to be larger in one region than another cause these parameters to vary from region to region.

Rainfall is a characteristic that varies from region to region and has a controlling effect upon the mean PAF for a given size drainage area. From the hydraulics of runoff, it is known that more intense rainfall run off faster simply because the channels and riverlets that make up the basin drainage network become more efficient conveyances as the depth of water in them increases, i.e., the basins become more efficient as peak flow generators. From the previous section it has been pointed out that this efficiency has a lot to do with the LTC equation parameters. Therefore, since rainfall characteristics are meaningful regional characteristics in that they vary from region to region and since they are one of the controllers of basin peaking efficiency which in turn controls the intrinsic LTC of the basin, it is a likely candidate as a controlling characteristic for the LTC equation parameters of the region. There remains only the quantification of this characteristic and the testing of its relationship to the LTC equation parameters for the region.

Since physiographic characteristics vary from region to region and since this variation is reflected in the mean PAF's for equal size drainage areas, these characteristics are likely candidates for controllers of the LTC equation parameters. The previous section stated that basin characteristics control the intrinsic LTC and the nature of the regression technique tells us that the LTCEP's are controlled by the values of the LTC for the basin since the characteristics of that basin do not change. Although basin characteristics vary widely within the region, especially the drainage area, length of stream and length to centroid, one region might be generally steeper than another and we know from the hydraulics of runoff that slope is one of the controllers of peak flow. Therefore, since basin slope is one of the controllers of the LTCEP's and since slope is a meaningful regional characteristics, it is logically speaking, a suitable regional characteristic for testing with regard to its relationship to these parameters.

Basin antecedent conditions affect the peaking efficiency of the basin in several ways in that the peak produced by a given storm on a given basin is closely related to the dryness of the basin on which it falls. Also, they are a measure of the frequency of flooding which is important in the hardening of stream bed sediments which might otherwise go into suspension during flood flows and increase the depth of flow in the channel and therefore its conveyance efficiency. Also, the frequency of flushing the windblown debris from the riverlets affects the average peaking efficiency of a basin. Therefore, since peaking efficiency is one of the controllers of the LTC equation parameters as shown in the previous section and since antecedent conditions are a meaningful regional characteristic, it is suitable for testing against these parameters.

From the above reasoning the following regional characteristics were chosen as representative of the characteristics of a region that control the LTC equation parameters for that region.

- Meteorologic Characteristics
  - Maximum 24-Hour Rainfall
  - Maximum 5-Minute Rainfall
- Physiographic Conditions
  - Median Slope of Mainstream of Sample Basins
  - Range of Slopes of Mainstream
- Antecedent Conditions
  - Maximum Monthly Rainfall Normal
  - Days of Rain during Maximum Rainfall Month

The quantification of these values are shown in Table 2.

Selection of a Method of Relating

The method selected for relating the regional LTC equation parameters to the characteristics of the region should be one that results in an equation for computing the parameters from the regional characteristics and for which there are measures of the degree of correlation between these characteristics and parameters. Since regression analysis fulfills these conditions in the regression equation and the correlation coefficient, this method was chosen for establishing and testing this relationship.

Application

When the LTC equation parameters (LTCEP's) were regressed against the regional characteristics of culvert, bridge and all drainage sites, the resulting constant terms and coefficients are shown in Table 3 and plots of these parameters are shown in Figure 3. Statistical measures of the degree of correspondence are shown in Table 4 and the order of importance is shown in Table 5.

From an overview of Figure 2 we see that the greatest variation between the culvert, bridge and all sites LTCEP's occur in the length and slope coefficients. The three types of drainage sites track fairly well for the other LTCEP's. The correlation coefficients for the three types of sites vary in unison with that of the culvert sites being somewhat larger than for the bridge sites and that of the bridge sites being larger than for all sites. The lowest correlation coefficient was for the constant term. However, the estimate of the constant term was best as measured by the root mean square. But, the root mean square broke down as a measure of goodness of fit in the case of the area and centroid coefficients in all three types of sites, because the mean of these coefficients is near zero, exaggerating the effect of the measurement error. The standard error of the LTCEP's at each site is of course the cause of the variation in the correlation coefficients at the three types of sites. Since the correlation can be defined as the improvement of a line estimate over the mean as an estimate, deficiencies of the correlation coefficient at these sites are largely due to the relative lack of deviation of these parameters, i.e., the relative sufficiency of the mean as an estimate of these LTCEP's. Even so, the correlation coefficients, which ranged from 37 to 87 percent for the characteristic coefficients and 24 to 34 percent for the constant terms, were statistically significant for all LTCEP's at each of the three types of drainage sites.

With regard to the order of precedence or degree of relationship between the various regional characteristics and the LTCEP's, Table 5 reveals that for the constant terms the median slope is always the most important, but for the coefficients of the characteristics, the mean maximum 5-minute rainfall is the most important characteristic except in the case of the length coefficient at the culvert sites where it is second yielding to the median slope. Even so, second place is not as clearly dominated by any one of the characteristics until we group them under the headings of maximum rainfall, slope and antecedent conditions. Under these headings, antecedent conditions hold second place for 10 of the 15 LTCEP's and for the bride and all site cases, the only exception to this precedence of antecedent conditions is the length to centroid coefficient which yields to slope. However, second place for the culvert sites is held by antecedent conditions only for the length to centroid coefficient with maximum rainfall and slope splitting the other four LTCEP's for these sites.

The Meaning of this Correspondence

If the LTC equations are regional, the variation of the LTCEP's should be caused by the differing characteristics from region to region. If the LTCEP differences are caused by these characteristics then the degree of variation in the LTCEP's from region to region should correspond to the variation in the regional characteristics, i.e., they should correlate with them. Also, the converse of this is true, i.e., if the regional LTCEP's correlate with the regional characteristics, the LTC equations are regional. Therefore, from the correlation coefficient within the region we know that the LTC is an intrinsic basin parameter which within the

Table 2
Regional Characteristics

	AVERAGE MAXIMUM RAINFALL				SLOPES				ANTECEDENT		REPRESENTATIVE
Region	25 Year Return PD.		50 Years Return PD.		Culvert Sites		Bridges Sites		Max Month Rainfall		Station
		5 Min.	24 Hrs.	5 Min.	Median	Range	Median	Range	Normal	Day of Rain	
I	576	21.4	660	23.6	.0039	.1653	.0050	.2775	566	21	Laoag
II	410	27.0	474	30.6	.0240	.2025	.0051	.0268	281	15	Tuguegarao
III	368	24.0	420	26.7	.0140	.3205	.0073	.1027	394	24	Cabanatuan
IV	400	22.1	461	24.4	.0312	.3562	.02440	.0952	336	19	Baler
V	400	25.4	455	28.8	.0480	.3761	.0098	.0723	478	23	Legaspi
VI	271	18.8	312	20.6	.0219	.4490	.0051	.0191	333	20	Iloilo
VII R	212	18.5	244	20.1	.0150	.1694	.0183	.0340	204	19	Tagbilaran
VII Y	212	18.5	244	20.1	.0396	.1852	.0190	.0740	209	18	Cebu
VIII	331	20.4	377	22.0	.0680	.3418	.0198	.2136	670	26	Borobon
IX	196	18.0	223	19.7	.0300	.2249	.0114	.0825	178	15	Zamboanga
X	328	19.7	372	22.0	.0540	.3253	.0259	.2359	607	30	Surigao
XI	289	18.3	325	19.6	.230	.4343	.0110	.0856	226	21	Davao City
XII	179	19.7	200	20.8	.0770	.1809	.0026	.0234	257	8	Cotabato

Table 5
PARAMETERS OF LAG TIME EQUATION
VS
REGIONAL CHARACTERISTICS
USING LOG-LOG TRANSFORMED REGRESSION

LTC EQ. Parameters	Secondary Regression Detransformed Fm vs. Fc			Primary Regression with Transformed Variables								
							25/50 years RP					
	Const Term	Const CF	STO ERR.	$Trir^2$ Cons CF	Const CF	Const Term	Max R 24	Max R 5	Median Slope	Range Slopes	Max No. Normal	Range Days/R
						CULVERT SITES						
Const	–.424478	1.723010	.185002	.405456	.346403	.092258	.10983	.08724	1.95956	–.12541	–.03175	.03712
A–CF	–.011407	1.809560	.049132	.555961	.489534	.080274	.09442	–.19586	.84588	–.05983	–.01250	.00249
L–CF	.039917	1.097240	.153107	.684821	.686334	–.490963	–.01089	.94609	–6.72760	.57511	–.21155	–.26345
C–CF	.007155	1.041780	.097502	.570407	.580895	.581414	–.21715	–.55851	.33611	–.07515	.20367	.04937
S–CF	.050129	.997854	.494489	.859047	.870272	2.97797	.20439	–2.64158	8.88597	–2.10625	.20269	–.20117
						BRIDGES SITES						
Const	–.237658	1.412530	.192244	.312563	.301696	.227962	.01414	–.16789	3.97205	.10488	.08833	–.03944
A–CF	–.004676	1.378220	.053450	.426995	.400152	.123107	.01068	–.17444	1.25378	.07265	.05134	–.02435
L–CF	–.053259	1.134360	.166074	.612551	.607587	–1.062170	.32462	1.07081	–2.73418	–.34363	–.52735	.05142
C–CF	.008096	1.057780	.093598	.615070	.629261	.540621	–.21638	–.53088	–2.94649	.07282	.21013	–.15746
S–CF	–.323159	1.281330	.526918	.838132	.833702	3.634650	–.41708	–2.54812	11.69260	.54387	.58946	–.58127
						ALL DRAINAGE SITES						
Const	–.313217	1.538740	.195049	.266781	.242024	.052115	.05096	–.05048	1.27110	–.12569	.05561	–.00016
A–CF	–.009897	1.717740	.053662	.419321	.374499	.084131	.02830	–.16487	.28448	–.06957	.04710	–.01519
L–CF	.068665	1.185380	.169681	.589733	–.575665	–.841494	.31309	.95447	–1.70253	.26865	–.48931	–.07262
C–CF	.020492	1.218880	.097061	.575728	.573022	.513143	–.20262	–.48578	– .83042	–.10648	.19405	.04523
S–CF	.008487	1.048420	.591217	.790834	.807048	3.098250	–.15951	–2.31577	3.26424	–.92550	.54315	–.62831

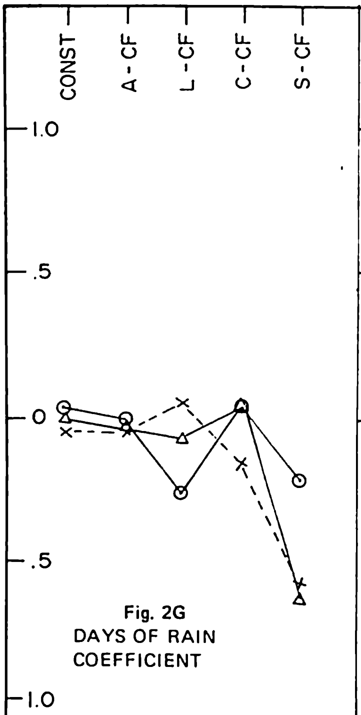

Fig. 2G
DAYS OF RAIN
COEFFICIENT

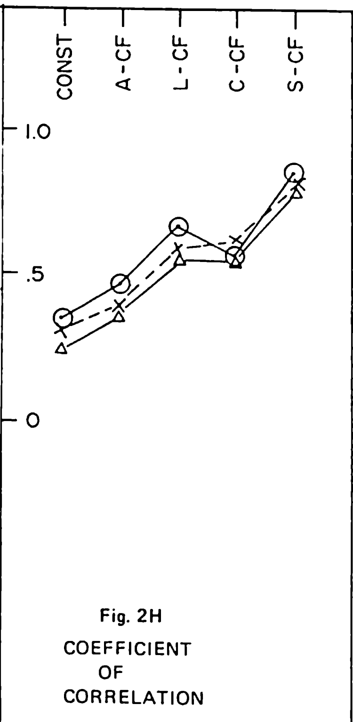

Fig. 2H
COEFFICIENT
OF
CORRELATION

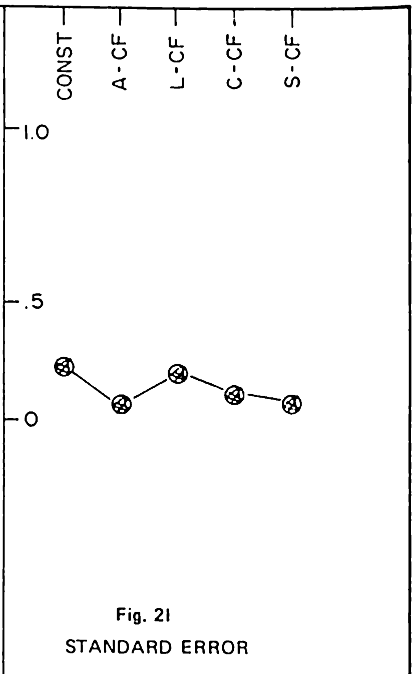

Fig. 2I
STANDARD ERROR

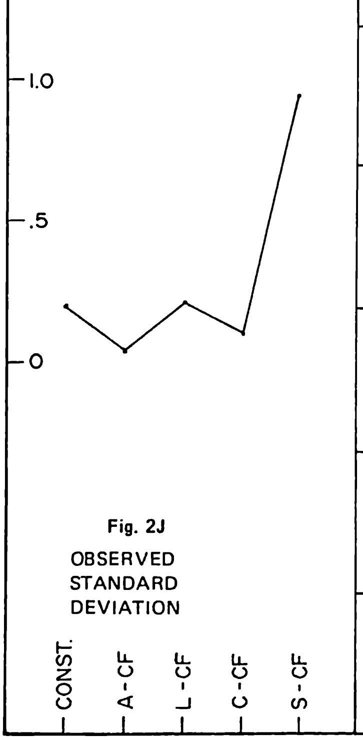

Fig. 2J
OBSERVED
STANDARD
DEVIATION

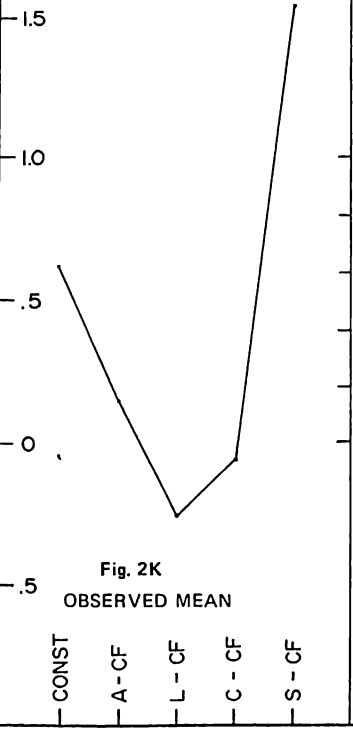

Fig. 2K
OBSERVED MEAN

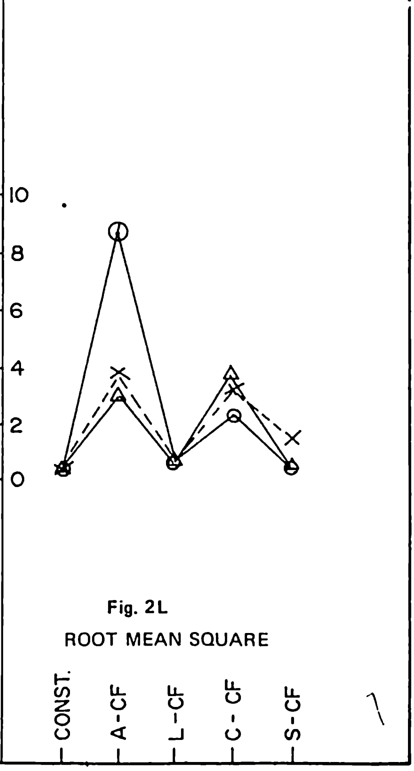

Fig. 2L
ROOT MEAN SQUARE

Table 4
REGIONAL LTC. EQ. PARAMETERS
VS
Regional Characteristics
Statistical Measures

Dependent Variable	Correlation Coefficient	Standard Error	Standard Deviation	Mean	Roof Mean Squares
		CULVERT SITES			
Const	.346403	.185002	.202384	.611752	.283181
A-CF	.489534	.049132	.059110	.016848	8.298500
L-CF	.686334	.153107	.210106	−.272563	.618689
C-CF	.580895	.097502	.118708	−.068271	2.146630
S-CF	.870272	.494489	.965993	1.543910	.350757
		BRIDGE SITES			
Const	.301696	.192244	.202384	.611752	.313294
A-CF	.400152	.053450	.059110	.016848	3.756220
L-CF	.607587	.166074	.210106	−.272563	.729050
C-CF	.629261	.093598	.118708	−.068271	3.156130
S-CF	.833702	.526918	.965993	1.543910	1.495390
		ALL DRAINAGE SITES			
Const	.242024	.195049	.202384	.611752	.316472
A-CF	.374499	.053662	.059110	.016848	2.993810
L-CF	.575665	.169681	.210106	−.272563	.694649
C-CF	.573022	.097061	.118708	−.068271	3.756250
S-CF	.807048	.591217	.965993	1.543910	.439970

Table 5

	ORDER OF SELECTION				ORDER OF SELECTION					
	Max Rain *		Slope		Antecedent Conditions		General Characteristics			Remarks
	24 Hr.	5 Min.	Median	Range	Max MO Normal	Max MO Days/12	1st	2nd	3rd	
	6	7	8	9	10	11				
				CULVERT SITES						
Const	2	4	1	3	6	5	S	R	A	
A-CF	3	1	2	4	5	6	R	S	A	
L-CF	6	2	1	4	5	3	S	R	A	
C-CF	3	1	5	6	2	4	R	A	S	
Sm-CF	6	1	3	2	4	5	R	S	A	
				BRIDGE SITES						
Const	6	3	1	5	2	4	S	A	R	
A-CF	6	1	3	5	2	4	R	A	S	
L-CF	3	1	5	4	2	6	R	A	S	
C-CF	3	1	4	6	2	5	R	S	A	
Sm-CF	5	1	4	6	3	2	R	A	A	
				ALL DRAINAGE SITES						
Const	5	4	1	3	2	6	S	A	R	
A-CF	5	1	3	4	2	6	R	A	S	
L-CF	3	1	5	4	2	6	R	A	S	
C-CF	3	1	2	4	6	5	R	S	A	
Sm-CF	6	1	5	4	3	2	R	A	S	

* Return Period is 25 years of Culvert Sites; 50 years for Bridge Sites; and 25 years for all Sites Combines.

region of similarity can be accurately computed from the unique characteristics of the basin, and from the correlation of the regional LTCEP's with the characteristics of the regions, we can conclude that the LTC equations are characteristic of the region for which they were derived.

Computing the Basin LTC

Within the Philippine Archipelago, the LTC equations are suitable for computing the LTC for any drainage area, within the region of similarity covered by that equation, from its own unique physiographic characteristics. However, the application of these equations outside the Archipelago is a matter of speculation, but it seems logical that a definite method of determining the LTC for a basin is preferable to making the intuitive leap into the unknown. With this in mind, for areas with comparable meteorologic, physiographic and antecedent conditions such as Southern Asia and the South Pacific Islands, the following method of application may prove useful.

This application begins by computing the LTCEP's from the general equation and comparing these parameters with those of the 13 regional LTC equations and using the regional equation it most resembles. Another, but less precise method, would be to compare the regional characteristics given in Table 2 with those of the region of interest and make the choice between the regional LTC equations on the basis of similarity of these characteristics. However, caution should be exercised in using the equation taken directly from the computed parameters since the equation for these LTCEP's were derived separately and the error to be expected from such computations may not compensate, i.e., the error in one LTCEP will not necessarily compensate for the error in another.

Conclusions

From this study we can safely draw the following conclusions.

Basin LTC

Within regions of hydrologic similarity, the LTC is a basin parameter whose variation from basin to basin is caused by the variation of the physiographic characteristics of the basin. This was demonstrated by the high degree of correlation between the intrinsic LTC for the basin and the logical choice of basin characteristics to cause such variation. Furthermore, the differences in the intrinsic LTCs for a given region of hydrologic similarity clearly demonstrated that the LTCs were not regional parameters. Therefore, since the LTCs were not regional and correlated well with basin characteristics, we were forced to conclude that the LTC is a basin parameter.

Regionality of LTCEP's

Within the Philippine Archipelago, the LTCEP's are regional and there is no reason to believe that they are not regional in other geographic locations. The regionality of the LTCEP's was established by their variation from region to region and by their correlation with the regional characteristics that should logically control them. The variation of these parameters are shown by their graphs in Figure 1 and their correlation as shown by the graph of the correlation coefficients of their regression against the characteristics of the regions. Since the meteorologic, physiographic, and antecedent condition characteristics in the Philippine Archipelago are not atypical, i.e., the terrain varies from mountainous to flood plain and the maximum depth duration rainfall data vary from season to season along with the antecedent conditions, and the principles of meteorology and hydraulics are applicable worldwide, there is no reason to believe that the regionality of the LTCEP's is not a worldwide phenomenon.

Transposition of Results

Although the LTCEP's shown in Table 6 are clearly regional, there are certain similarities between regions with comparable characteristics as shown in Table 3. This similarity indicates that the LTCEP's can be transposed to regions of similar characteristics without undue loss of accuracy, certainly with greater precision and consistency than by

Table 6
COMPUTED PARAMETERS FOR EQUATIONS
FOR
LAG TIME COEFFICIENTS
USING LOG – LOG TRANSFORMATION

CULVERT SITES						BRIDGE SITES					ALL SITES				
Const	~~Const~~ Term	Area Coef.	Length Coef.	Const Coef.	Slope Coef.	Const Term	Area Coef.	Length Coef.	Const Coef.	Slope Coef.	Const Term	Area Coef.	Length Coef.	Const Coef.	Slope Coef.
I	.55705	.01666	−.19709	−.096236	1.35410	.65737	.39400	−.31918	−.10570	1.31413	.62989	.04416	−.30466	−.04784	1.50314
II	.56671	−.03666	−.01387	−.22210	.67638	.50486	−.04437	.06760	−.21796	.12003	.60139	−.02513	−.03596	−.21034	.82473
III	.51483	−.04196	−.10340	−.13288	.50997	.56840	−.01188	.16306	−.12001	.50786	.56948	−.01634	−.20177	−.10506	.72977
IV	.60146	.01008	−.194084	−.12693	.93906	.73356	.03434	−23146	−.16812	1.43698	.61178	.00667	−.22125	−.12392	1.15364
V	.65532	−.00683	−.26072	−.14067	.68175	.58270	−.015987	−.13704	−.14286	.37305	.66265	−.00787	−23296	−,15552	.77748
VI	.56630	.00138	−.21427	−.02818	1.02415	.59307	.020271	−.33200	.00611	1.75112	.55876	.01858	−.35203	−.01140	1.56371
VII R	.53886	.00532	−.24744	−.02920	1.85017	.66755	.03197	−.31180	−.05376	2.20518	.56171	.02263	−33649	−.00503	1.90347
VII Y	.64844	.04082	−.37096	−.02182	2.39061	.68751	.03935	−.33178	−.06269	2.41556	.62980	.03498	−.37165	−.02042	2.17537
VIII	.77205	.06803	−.53898	.01157	2.0000	.65603	.04272	−.44005	.01238	1.74683	.75543	.05789	−.49785	−.02188	1.82625
IX	.57754	.02373	−.26994	−.03218	2.10144	.54307	.01095	−.28720	−.02032	2.03348	.57893	.02682	−.33182	−.02153	2.27662
X	.72548	.05843	.(.51099	.02036	1.86143	.62723	.03450	−.42092	.01558	1.47394	.71633	.05380	−.49291	.00502	1.67864
XI	.55562	.02143	−.21822	−.05802	1.1322	.54849	.01413	−.28377	−.01201	1.58095	.54789	.01180	−.28585	−.04694	1.41283
XII	.72380	.05862	−.40336	−.03123	3.56858	.58292	.02363	−.35267	−.01816	3.11180	.73151	.06078	−.40828	−.07506	4.00119

intuitively estimating the LTC without the aid of these formulae. For example, the LTCEP's for regions I and II are within a reasonable if not precise proximity except for the transposition of the length and centroid coefficients which are both in one sense measures of basin shape. The results from regions VIIR and VIIY fall in the same range of values, while those of IX and X bear a certain resemblance. Certainly, this indicates that although these LTCEP's are distinctly regional, they can be transposed from one region to another with better results that an intuitive choice from authoritative sources that differ by 2000 percent.

Limitations

Although the validity of using LTCEP's computed directly from the characteristics of the region is still to be tested, the 13 equations presented should be transposed only to those geographic areas with meteorologic, physiographic, and antecedent condition characteristics similar to those found in the Philippine Archipelago. Also, it goes without saying that the regional LTC equations should not be used for basin characteristics outside the range of values from which they were derived, and the application of the LTCEP equations are not recommended for regional characteristics outside the range of those for which their validity has been demonstrated.

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