Report No. FHWA-RD-77-23

ASSESSMENT OF NATIONAL SMALL RURAL WATERSHEDS PROGRAM. EXECUTIVE SUMMARY

June 1977

Final Report

Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D. C. 20590

Foreword

This report describes an economic assessment of the utility of hydrologic data collection networks which support the development of procedures for the design of highway culverts.

The report presents the results of FCP study No. 35H3-092 "Assessment of National Small Rural Watersheds Program." The study was conducted for the Federal Highway Administration, Office of Research, Washington, D.C. under Contract DOT-FH-11-8605. This final report covers the period of research from March 10, 1975, to August 10, 1976.

The research results are presented in two volumes which will be of interest to managers concerned with the planning of hydrologic data collection networks and economical design of drainage structures. An Executive Summary supplements the report, describing briefly the results of the study in non-technical language. The report is intended to assist highway administrators in determining the need and level of effort for continuation of the small rural watershed data collection program.

Acknowledgment is given to those selected States which cooperated in the search for data on culvert design necessary for economic analyses.

Sufficient copies of the Executive Summary are being distributed to provide a minimum of one copy to each FHWA Regional office, one copy to each FHWA Division office, and one copy to each State highway agency. Volumes 1 and 2 are available upon request. Direct distribution of the Executive Summary is being made to the Division offices.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

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16. Abstract

A State-by-State assessment is made of the current status of the National Small Rural Watersheds Program with regard to adequacy of data collection and analysis. Methodology is recommended for flood frequency estimation to replace currently used biased approaches. Concepts of risk aversion are discussed, and decision criteria based on economic considerations are incorporated into the hydrologic evaluation. Stream gaging programs of various gaging densities for 48 States are evaluated and recommendations made for continuation or termination of the programs based on FHWA objectives of drainage culvert design.

Volumes 1 and 2 of the report are available upon request.

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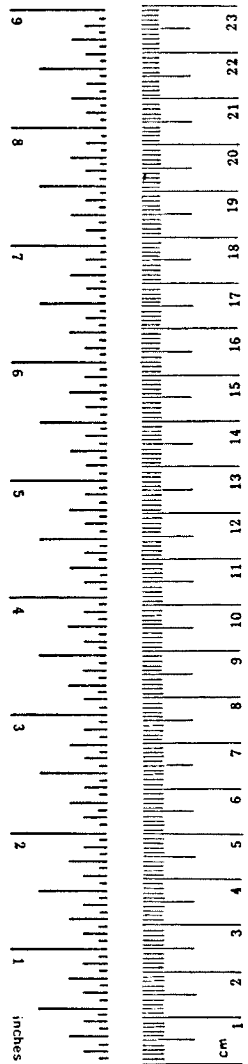
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

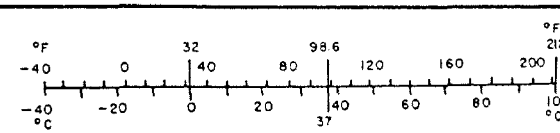
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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MANAGERIAL SUMMARY

This summary serves four principal requirements: (1) to explain in non-technical language the statistical arguments which form the basis of the decision analysis contained in the Technical Report; (2) to list the assumptions and limitations of this formal analysis so it can be implemented by the States, the FHWA and other interested institutions; (3) to display results based on a marginal economic analysis of the value of statistical information; and (4) to recommend new design procedures and research investigations. In addition, it will be shown that all the tasks in the Scope of Work have been accomplished or, if they could not be accomplished as written, how and why they were approximated.

The contractual statement of work is included in detail in Appendix A. The study objective was to make a comprehensive independent assessment of the National Small Rural Watershed Program in keeping with long-range goals of the FHWA and State highway agencies. The assessment was on a State-by-State basis of the current status of the National Small Rural Watershed Program with regard to adequacy of data collection and analysis as well as data dissemination. These objectives were achieved through various task accomplishments, namely (A) a literature review including two major nation-wide reports concerning Small Watersheds Program; (B) to establish criteria, define specific terms, promulgate guidelines and/or choose guidelines from available information which were used for program assessment and future development; (C) assess the Highway Planning and Research Small Watershed Studies and the programs of other agencies with respect to established criteria, definitions, and guidelines; (D) based on data availability determine the recommended method of peak flow estimation for each region, status of hydrologic recording stations in region and assessment of adequacy of that status; (E) suggest a method for data analysis in each region based on the above and (F) estimate useful life of the gaging program for each region.

NON-TECHNICAL SUMMARY OF THE STRATEGY

Analyses of programs for collecting meteorological information depend on statistical criteria alone for their evaluation. Information is collected until the parameter being estimated has a sufficiently small sampling error or degree of uncertainty. The main thrusts of this study are to place an economic benefit on improved information by noting that it typically allows for the reduction of construction costs and to identify the point at which increased information costs just balance decreased construction costs. If the cost of collecting information is very high, substantial benefits must be realized to justify the data collection program; conversely, if the cost of collection is low, modest gains in information and small consequent reductions in construction costs might justify continuation of the information program.

This study is divided into two major parts. The first is a statistical section which deals with specification of how the potential error in design flow estimation (and consequently the margin of safety required to accommodate unlikely extrema) might be reduced as a function of increased information. It should be noted that expanding the information base by using more stations does not necessarily increase precision in estimating design flows. This is because some of the extended measurements may introduce so much statistical noise into the estimating procedure that the designer is better advised to use only the original information without augmentation.

The second part of the analysis deals with economic benefits associated with reductions in the design flow for culverts serving small drainage areas. Bridges, although they can represent up to half the drainage structures in a drainage basin, are ignored in this analysis because (1) their cost-capacity functions (which are difficult to estimate for small bridges) represent straightforward extensions of those for culverts and (2) because the costs of hydrologic data collection turn out to be so small (even though they represent a substantial investment in the aggregate) that modest improvements in information applied even to relatively inexpensive culverts can be shown to justify continuation of gaging programs. Therefore an extension of the economic analysis to encompass a broader range of structures is not indicated.

Consider the statistical issues associated with estimating some extreme event Q_T, where T is the expected or average return period, which for purposes of this study is taken to be 50 years. Suppose a record covering n years of annual floods is available, from which the event Q_T can be estimated. Leave aside for the moment the choice of technique for estimating Q_T; it is assumed that the Water Resources Council (WRC) identifies standard methods and that one of these is chosen. For most hydrological records, the length n is a small fraction of the hydrological history of the stream, so it is easy to concede that many other sequences of length n years might also represent the actual record. Because n tends to be small, the estimates of Q_{50} tend to range widely, forming thereby a distribution of estimates rather than a single number $\hat{Q}_{50}$. Because all the n-year sequences are equally likely, each $\hat{Q}_{50}$ derived therefrom is equally likely, so one is faced immediately with the question of which estimate is the "best estimate" of Q_{50}. It follows trivially that if the record length is increased, each estimate is, in some statistical sense, a better estimate of the true value of Q_{50}. In the extreme, if n is increased until it spans the entire history of the stream, the sample estimate is the population or true value. This study is concerned with how rapidly the distribution of estimates $\hat{Q}_{50}$ changes as n increases, and with adjustments to the gaging program which might be made to increase n. For the case in which information is transferred from gaged to ungaged locations, it is not a simple matter to increase n if the increase is occasioned by the use of regression estimates (on basin characteristics) which transfer the information from gaged to ungaged locations. The transfer process is typically a weak one in that major increases in record length at gaged locations might produce only very small increases in record length, or equivalent record length, at ungaged locations. There is uncertainty associated with the inadequacy of the record length at any gage and with the transfer of information from gaged to ungaged locations. This report deals systematically with these errors, and from them seeks to evaluate the reduction in design flow which could be attained by extending the data network.

The economic analysis is founded on less secure theoretical grounds due to current data inadequacies. There is developed for each State or region an average design flow for culverts in that State. This value is based on extrapolation to the entire State of representative culvert sizes and densities, and this assumption is one of the weaker arguments in the analysis. Nonetheless, it is a way to introduce economic considerations into the gaging decision process, and it happens that the benefit from increased precision exceeds the program cost in any State with a net gain in hydrologic information, thereby making more acceptable the reality that the economic calculations are very coarse.

The representative culvert size of each region is an average derived from a regional design flow based on a sample within the region and extrapolated to cover the entire area. The regional design flow is thus related directly to culvert construction cost, for which assumptions concerning fill height and culvert length are made. The cost of culvert failure is not included in these calculations because a basic assumption is that the risk of failure, and its consequent costs, is constant under the existing data program and its potential extensions. Thus the marginal cost of risk, or the cost of culvert failure, is unchanged so that it need not be explicitly considered.

Construction savings which might be effected through the use of improved information are compared to the cost of obtaining that information. There is a rich literature associated with the average or expected value of sample information; this has been developed in the discipline known as decision theory, a branch of applied mathematics and operations research. Applications of the theory have been made to the acquisition of data in industrial and commercial decisions, but there seems to be no previous application of this analysis to the collection of hydrological data.

ASSUMPTIONS AND LIMITATIONS

The principal assumptions of the statistical analysis, and some discussion of their implications and limitations, are given below.

- Drainage areas up to 50 square miles are considered. This definition accords with that of the Water Resources Council (WRC), and is convenient for this study because there are relatively few sites which qualify for inclusion so that a limitation to (say) 25 square miles would sharply curtail the available data base.

- Only those sites with records of annual floods and basin characteristics were utilized. There are many other sites for which the basin characteristics are measured and somewhere available, but not on the tape files of the U.S. Geological Survey (USGS).

- States and hydrologic regions are identical. In fact, any State can be divided into a number of hydrologically homogeneous regions, in each of which the analysis described here can be performed. The reason for such gross aggregation in this study is the paucity of complete data files, as described above. Thus the decision calculus is applied to States rather than to regions within States, so that the gaging programs are evaluated for States which are vastly different in area. But it must be remembered that the identity of States and regions is an artifact of this analysis, and that large and hydrologically diverse States are subject to multiple applications of this methodology. Because of the lack of data adequate to perform the tasks as specified in the Scope of Work, there are some minor modifications occasioned by the realities of this study.

- Extreme events, $\hat{Q}_{50}$, are drawn from distributions of such events which are independent (with respect to time), log-normally distributed, and which express a regional correlation coefficient among estimates of Q_{50} at other locations in the region. This study departs from WRC recommendations in that estimates of parameters of the distributions of $\hat{Q}_{50}$ contain a correction to remove bias.

- There is no way of knowing the true Q_{50} because the population parameters of the distribution of annual floods can not be known but merely estimated. Techniques for defining a design flow Q_d select one element of the distribution of all possible events $\hat{Q}_{50}$, with the choice being based on a formal or informal factor of safety which represents the decision-maker's risk aversion. It is assumed invariant from time period to time period.

- Modal model errors are unchanged by incremental gaging (or extended records) at independent sites.

- Techniques for generating unbiased parameter estimates of the distribution $\hat{Q}_{50}$ are embodied in tables which are derived for mean annual floods but which are assumed applicable to extremes Q_T because the tables themselves are indifferent to the name (or label) of the statistic to be unbiased. Log-normality can be applied to the tables for $\hat{Q}_{50}$ as well as for the mean annual flood.

- Outliers among the record of annual floods can not routinely be disregarded because they govern the skew coefficient of the distribution of events, and are of fundamental importance in utilizing the tables for unbiased parameter estimates.

- Regression formulations for transferring information from gaged to ungaged locations are based on exponential functions.

- Incremental gaging programs are based on five-year extensions because of the coarseness of the grid that the tables utilize to evaluate the regression procedure. Finer subdivisions would involve interpolation at a degree of resolution which is not warranted in this analysis.

- The cost of maintaining a gage is $242 per year, the marginal cost of a crest stage recorder. Its capital cost is not included because it is a sunk cost and can not be retrieved under the available options; only an O&M cost is considered. The cost is therefore very small, suggesting that the program be continued in those areas where hydrologic information is improved (independent of the actual construction savings). If the program were run with continuous recorders, which require frequent maintenance and inspection, the results would be different (e.g., at $5,000, almost no programs should be continued).

The assumed cost of $242 per year (personal communication, USGS) presumes the States pay only for crest stage type gages and that the cost is divided equally between the States and the USGS. Other programs such as an FHWA participating program could change the States' share to only 20 percent. It should be noted that there may be institutional constraints under which the USGS might reasonably feel if it is going to the trouble of installing and maintaining a gage, it might prefer one that would provide maximal information, thereby precluding crest gages. The cost sharing arrangement between the State and USGS may result in other than a $242 per year cost. Under such a situation, new benefit analysis must be done to evaluate the program.

The principal assumptions underlying the economic analysis are given below.

- On the basis of a small sample, each hydrologic region and therefore each State is associated with a design flow Q_d

appropriate for that area, from which a culvert capital cost can be deduced on the basis of generalized functions.

- The capital cost dominates the maintenance and failure costs, where failure costs include repair, diversions, traffic delays, and direct flooding damages to surrounding lands. Therefore the capital cost alone is used as the criterion for establishing the value of information.
- The capital cost is based on standard fill height, culvert length, headworks, and other hydraulic assumptions.
- No bridges are considered in this analysis, which is limited to box and pipe culverts. Multiple-barrel box culverts closely resemble small bridges in terms of cost per unit capacity, and are considered. Moreover, large bridges over major floodways, for which the cost functions are not merely extrapolations of the culvert functions given here, typically fall outside the realm of drainage facilities on small watersheds and are beyond the scope of this study.

PRINCIPAL RESULTS

1. In no State or region is it reasonable to expect that a target of 10 equivalent years of record can be met through the transfer of information from gaged to ungaged areas. This is because the model error is shown to dominate other sources of error, so that however good the estimation of flow parameters might be at a gaged location, the act of transferring that information dilutes the information to such an extent that 10 equivalent years can not be attained.

2. The introduction of economic assessments to supplement statistical evaluation suggests that gaging programs can fruitfully be extended even though the institutional target of 10 equivalent years can not be reached. Thus even though the gains in information are small at best, they may be sufficient to justify continuation of the gaging programs.

3. The results in the tables of Section 4 are based on a very coarse aggregation of basins, under which a single State is taken as representative of a region which includes several States. Thus the calculations must be viewed with care; they are certainly not made casually, but are not necessarily applicable to such wide regions. As stated several times in the Technical Report, the paucity of hydrologic basin characteristics is responsible for this aggregation into large regions. Additional hydrologic basin data, if already collected, must be made available for the USGS tape file; if it is not collected, it must be collected so that analyses can be performed and regional decisions made. This study imposes limitations of 50 and then of 25 gages per State because the regressions are not strong enough to accommodate a larger number of gages without significant loss of information; that is, the model error dominates the data transfer. The gages are spread throughout the State, although in subsequent applications they may be more intensely located to cover smaller areas.

4. The optimal return period, at which the total structural and failure costs for culverts is minimized, is of the order of 15 years. If biased estimates of the 50-year flood are made, this turns out to be approximately the unbiased 15-year flood. Thus current design techniques, utilizing WRC methods for estimating the 50-year event, seem by chance to give adequate results in that the expected return interval is very close to the optimal value. This conclusion is based on a detailed economic analysis of culvert costs in Virginia, which for reasons detailed in the Technical Report is presumed applicable over a wide range of hydrologic regimes.

5. The cost of maintaining a single crest gage is so small ($242 per year) and the potential savings in construction costs so large, that continuation of a crest stage gaging program can be justified in any region where there is a net gain of hydrologic information. Calculations show that if on the other hand continuous flow recorders are utilized, and if the installation is capitalized over the course of the program, the annual cost of maintaining a gaging location is approximately

$5,000, whereupon virtually no gaging program should be maintained if its sole justification is reduction in drainage construction costs.

6. If the upper limits on the number of crest gage sites is set at 50 (30 for Rhode Island and 18 for South Carolina), continuation of the gaging program would improve design flow estimates (i.e., provide a net gain of hydrologic information or reduce the estimated design flow variance) in Connecticut, Rhode Island, Vermont, Indiana, Utah, Kansas, Nebraska, South Dakota and Wyoming (in nine states). If all gaging networks are reduced to 25 (except South Carolina with 18), a net gain of hydrologic information is experienced in Indiana, Ohio, Wisconsin, Pennsylvania, Tennessee, Colorado and West Virginia (in seven states). Once again it must be emphasized that these results are merely guidelines to policy; detailed recommendations, on a region-by-region basis within the individual States, must await the development of better hydrologic information. This does not mean more and better flood records but a more complete file of hydrologic basin characteristics at those gages for which flood records are already available. The need for better hydrologic basin characteristics data is exemplified by our 25 and 50 gage site example. Only the State of Indiana is common to both lists of States for which continuation of the gaging program is recommended. The river basin characteristics are not independent but are strongly correlated; changing the number of gaging sites from 50 to 25 did not preserve this intercorrelation so the model error changed. The result of the reduced network analysis is a net gain of hydrologic information for a different set of gaging programs, or States. The instability of the regression of basin hydrology to river basin characteristics reinforces our recommendation to improve the USGS data file with respect to these basin characteristics. According to sources in the USGS, these data are available in several States but have not been inserted in the current tape files. It is regrettable that this information was not available during the course of this study so that all the tasks of the Scope of Work could be completed in their requisite detail.

7. Despite the shortcomings of the existing program, and despite the difficulty with which information can be added to the current data base through the use of regression techniques, there is no question that the cooperative program has provided data on which reasonable estimates of design flows can be based. This is true even though the return interval associated with that design flow is chronically overestimated; as indicated above, this overestimation is fortuitously close to the optimal return interval.

RECOMMENDATIONS FOR DESIGN, RESEARCH, AND POLICY

Six recommendations are given in order of increasing complexity and cost. It is explicitly recognized that a responsibility associated with criticizing an existing design methodology is that of providing something in its place. This is attempted below although it should be emphasized that the design methodology itself is not under attack but rather the assumption that the methodology is significantly improved by further collection of information without regard to its cost effectiveness. Therefore we are not suggesting immediate abandonment of current design techniques, but a phased program whereby current techniques are used during collection of a large empirical data base for more sophisticated design procedures which might well revolutionize drainage design.

1. The WRC technique for fitting annual flows to a log-Pearson function should be modified by the procedure introduced by the USGS to remove bias. Even if nothing else is changed, this modification will give better estimates of return intervals associated with design flows, and will enable a more valid economic analysis to be performed.

2. The Systems Group at the USGS should be consulted periodically to assist in assessing the gaging program, in whatever form it is continued.

3. The basin characteristics file of the USGS should be updated so that the analyses performed here for the several States could be

executed on meaningfully small regions in which individual decisions concerning continuation or termination of gaging might be made.

4. Initiate the collection, in a disciplined and systematic way, of data on existing culverts. In particular, information on failures is important. This includes the cause of the failure, the hydrologic description of the area (including precipitation intensities and land forms), the cost of failure (including repair, flooding, detour and interruptions, etc.), and updated measures for estimates of frequency of such events. It might not be necessary to do this on a nation-wide scale because the ultimate use of such a data base is the development of a new design methodology for which a relatively complete data array in a few States might be adequate.

5. Consider a large-scale research effort devoted to multinomial logit analysis. This is a form of multivariate analysis in which the dependent variable is divided into discrete classes rather than represented on a continuous scale, and from which the analysis gives the <u>probability</u> p_i that each of the discrete classes will be realized for a given set of independent variables. The data for this analysis, on which the p_i are based would include all the relevant hydrologic information such as the moments of the annual floods, the basin characteristics, and some measure of economic assessment and risk aversion; the index i ranges over the set of potential culvert designs.

6. Undertake a major hydrological study to replace existing empirical techniques and rules-of-thumb with a sound theoretical science of design for drainage structures. This is an ambitious undertaking, representing a major research venture over two or three years, whose funding might appropriately be shared by the National Science Foundation or other similar organizations. Details of the proposed research program are given in Section 5 of the Technical Report. Existing gaging programs and design methodology would be continued until replaced by new techniques developed under the suggested research plan. If undertaken, such a program would constitute a monumental advance in

that drainage design would become a scientific discipline rather than a black art.

FINDINGS BY TASK

Task A

The literature review, with particular emphasis on documents cited in the Scope of Work, was completely fulfilled and is reported in Section 2 of the Technical Report. Additional references cited in the Technical Report (Section 5) relate to alternative design proposals.

Task B

1. The selection of representative watersheds is based on the availability of flood records coupled with basin characteristics. Criteria for selecting the representative watersheds were simply those of identifying States with an adequate number of sites which met the data needs for regression. This is covered in Section 3.

2. The second part of Section 3 of the Technical Report deals with economic criteria which form the basis of defining the adequacy of data networks.

3. A small watershed is identified in terms of drainage area, with the criterion being 50 square miles (128 square kilometers) or less; the justification is a matter of data availability.

4. This sub-task could not be handled in its entirety because the lack of data in the several States and regions made it impossible to develop a sufficiently large gaging base from which to select sites for subsequent analysis.

Task C

1. The small watershed studies were included among the 48 Statewide studies whose analysis appears in the tables of Section 4.

2. The master plot of hydrologic data network and related large format maps were prepared for use as visual aids for presentation of the gaging program.

Task D

1. Due to the unreliability of rainfall-runoff methods and other "rational" analyses, as described in Section 5 of the Technical Report, and to the tabulation by the USGS of an enormous amount of information on runoff models, it has been elected to utilize runoff only to estimate flood peaks and design flows. Section 5 suggests modifications to this scheme as an area for further research.

2. The criteria developed earlier suggest that only crest stage information is necessary for the analyses subtended by this study.

3. Tables 36 and 37 of the Technical Report indicate those States in which the gaging program should be continued and those in which it might be terminated. These determinations are not based on network density because in each State the density is trivially calculated as a constant (25 or 50) divided by the area of the State. This sub-task could not be completed as specified in the Scope of Work because the data availability does not permit an adequate sub-division of each State or region into smaller, hydrologically homogeneous decision modules. The methodology for making this determination was demonstrated for each State, and by multiple usage of the methodology within each State, this sub-task could be completed by field implementation. It would be necessary, of course, to make available to the several cooperating or regional offices copies of the USGS tables on which these decisions are based.

4. A complete gaging profile, giving optimal record lengths for each watershed, could not be developed because there appears to be no meaningful criterion against which to measure the value of information. In other words, the cost of information is so small relative to its potential benefit that information should continue to be collected so

long as it contributes to a net gain of information, or to a situation to which the information obtained exceeds the noise introduced by more measurements. It is clear that by BIGBASIN applications, each State can establish an upper limit to the region within which regression analyses are meaningful.

Task E

The required data analyses are indicated in Tables 36 and 37.

Task F

1. For those States or regions in which additional hydrologic information does not contribute a net gain through regression analyses, no further collection can be justified. For those States or regions in which there is a net gain of information due to continuing data collection, the time to program termination can not be estimated properly because the regression coefficients and correlation values will continue to change as more data are collected, thereby changing the way in which information is accumulated and significantly changing the time to program termination.

2. It is recommended that program continuation depends on criteria other than economic justification for drainage structures, whereupon negotiation with the USGS should produce continuation of the program in areas where model improvement seems most likely -- leading to urgently needed reduction in model error. It is further recommended that a substantial research program be undertaken, definitively to settle the hydrologic issues involved and to improve the Small Watersheds Program as recommended in Section 5 of the Technical Report.

3. Because it is impossible to estimate the total future data program on the basis of the methodology introduced here, it is impossible to calculate the costs of the program from this point onward. This question could be answered if it were to be assumed that all the regression coefficients remain unchanged (or that the model error does not

change as more data are accumulated), but this is unrealistic as a basis for fiscal commitment. It should be noted that this same assumption is used in applying the decision tables from year to year, but it is clearly stipulated that new information collected each year changes the decision outlook for the five following years in a dynamic framework. It was decided not to make such a projection for the total cost of a program because such projections are so variable and may be accorded more nobility than they are worth.

FHWA

R&D