DEVELOPMENT OF A DRAINAGE AND FLOOD CONTROL MANAGEMENT PROGRAM FOR URBANIZING COMMUNITIES — PART I

by

Eugene J. Riordan
Neil S. Grigg
Robert L. Hiller

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by

EUGENE J. RIORDAN
Department of Civil Engineering
Colorado State University

NEIL S. GRIGG
Director, Water Resources Research Institute
University of North Carolina

and

ROBERT L. HILLER
Department of Agricultural and Chemical Engineering
Colorado State University

submitted to

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Colorado Water Resources Research Institute
Colorado State University
Fort Collins, Colorado 80523

Norman A. Evans, Director

ABSTRACT

Urbanization causes an alteration of the stormwater runoff response of the urbanizing watershed which, in turn, increases stormwater damages downstream. Few communities have successfully implemented programs for managing these development induced drainage impacts due in part to the uncertainties associated with any drainage management program. Which rainfall-runoff model should be used, how sensitive is project analysis to poor discharge prediction, how should project cost be allocated, and so on.

The objective of this research is to clarify these uncertainties and develop a readily implementable drainage and flood control management program for the mitigation of development-induced drainage impacts. These objectives are realized through a detailed examination of and recommendation on the three major elements of a drainage management program: the Technical element which establishes the method of flood hydrology calculation, the Financial element which establishes the methods for drainage and flood control cost calculation and cost allocation, and the Regulatory element which establishes the enforcement mechanism of the drainage management program.

The recommended Technical element is based on the sensitivity of project analysis to poor runoff prediction, and on the predictive capability of various rainfall-runoff models. This predictive capability was evaluated for some of the more popular rainfall-runoff models through a statistical analysis of published results from those models.

The recommended Financial element is based on a thorough review of the legal issues regarding: 1) municipal and developer liability

with respect to development-induced drainage impacts, 2) project cost calculation, and 3) project cost apportionment. A new approach for apportioning drainage and flood control facility costs between developers and the municipal government is presented. The approach utilizes existing engineering analysis techniques to divide project costs in proportion to the reduced liability attributable to the developers and to the municipal government.

Two Regulatory elements are proposed for the drainage management program. The changes to existing legislation that are necessary to enforce the drainage management program under the proposed regulatory component are discussed and sample legislation is included for each.

The report is divided into two parts. Part II is the complete project report with detailed discussions of the methods and data used, and of the research findings. Part I is written as a user publication. It summarizes the research methods and results, and discusses the recommended drainage management program.

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CHAPTER 1

INTRODUCTION TO THE STUDY

Summary of the Drainage Problem in Urbanizing Communities

Suburban development produces a rather noticeable effect on the character of a watershed, transforming it from a system of pervious soil and natural swales to one of impervious pavements and houses, and man-made channels. This transformation alters the storm water runoff response of the urbanizing watershed which, in turn, causes a reduction in the adequacy of downstream stormwater drainage facilities. This reduction in adequacy puts a strain on the fiscal resources of the community. The fiscal impact is felt either as increased flood damages (public and private) or as costs of constructing drainage facilities to reduce these damages.

How does the community government absorb these costs? Some 2,000 rapidly growing communities across the country are beginning to recognize the relevance of this question. Unfortunately, they have had limited success in developing and implementing programs for accommodating these development-induced drainage costs. More than just a few communities have found themselves studying and restudying the same drainage basins without ever establishing any kind of drainage cost recovery or management program. In the writers' opinion, the great number of unknowns in managing development-induced drainage impacts precipitate this stall in implementing drainage management programs. These unknowns include:

1. The questions of liability -- Does the city insure property from flooding when issuing a building permit? Are developers liable for their actions in reducing the amount of pervious land area?

2. The questions of benefit -- Who are the true beneficiaries of urban drainage works? Can benefits be realistically assigned to remote areas of the community simply on the presumption that urban drainage provides general city-wide benefits?
3. The questions of hydrologic criteria -- What design storm should be used? What method of computing changes in watershed runoff should be used?
4. The questions of interjurisdictional responsibility -- Can an effective drainage program be developed for a multijurisdictional watershed? What regulation techniques (regional planning, intergovernmental agreements) are necessary to implement a multi-jurisdictional program?
5. The questions of financing -- Where will the initial funding come from to begin the drainage management program? How will the major and minor facilities be financed?

Objective

The objective of this report is to develop a readily implementable drainage and flood control management program for the mitigation of development-induced drainage impacts. To accomplish this objective the uncertainties listed above must be clarified. The writers have grouped these uncertainties into the three major elements of any drainage management program: 1) the Technical element which establishes the method of flood hydrology calculation, 2) the Financial element which establishes the methods for drainage and flood control cost calculation and cost allocation, and 3) the Regulatory element which establishes the enforcement mechanism of the drainage management program.

The objective of this report, then, is realized through a thorough examination of each of these program elements.

Scope and Limitations

In this report, the writers bring together the research efforts in the technical, financial, and regulatory areas to develop a program for managing development-induced drainage impacts. The management program does not address the actual design and construction of drainage and flood control facilities, nor does it rely on a newly developed flood hydrology model. The program is developed for the appropriate allocation of costs for drainage and flood control facilities using existing cost effective rainfall-runoff models, abbreviated yet reasonable planning procedures, and effective regulatory mechanisms.

The program is converted into sample legislation that can be incorporated within local subdivision regulations or state subdivision enabling legislation. This research clarifies those uncertainties in the three element areas of drainage management listed earlier. It represents a comprehensive effort to develop a drainage management program that is legal, equitable, and most importantly, implementable within the resource and sociopolitical constraints of small to medium sized communities.

Definitions

In order to clarify many points in this paper, the following definitions and explanations are presented:

1) Drainage basin/subbasin - A community can be divided into major drainage basins ranging from 10 to 100 square miles. These major basins are composed of individual drainage subbasins ranging from 1 to 5 square miles as illustrated in Figure I-1. The writers

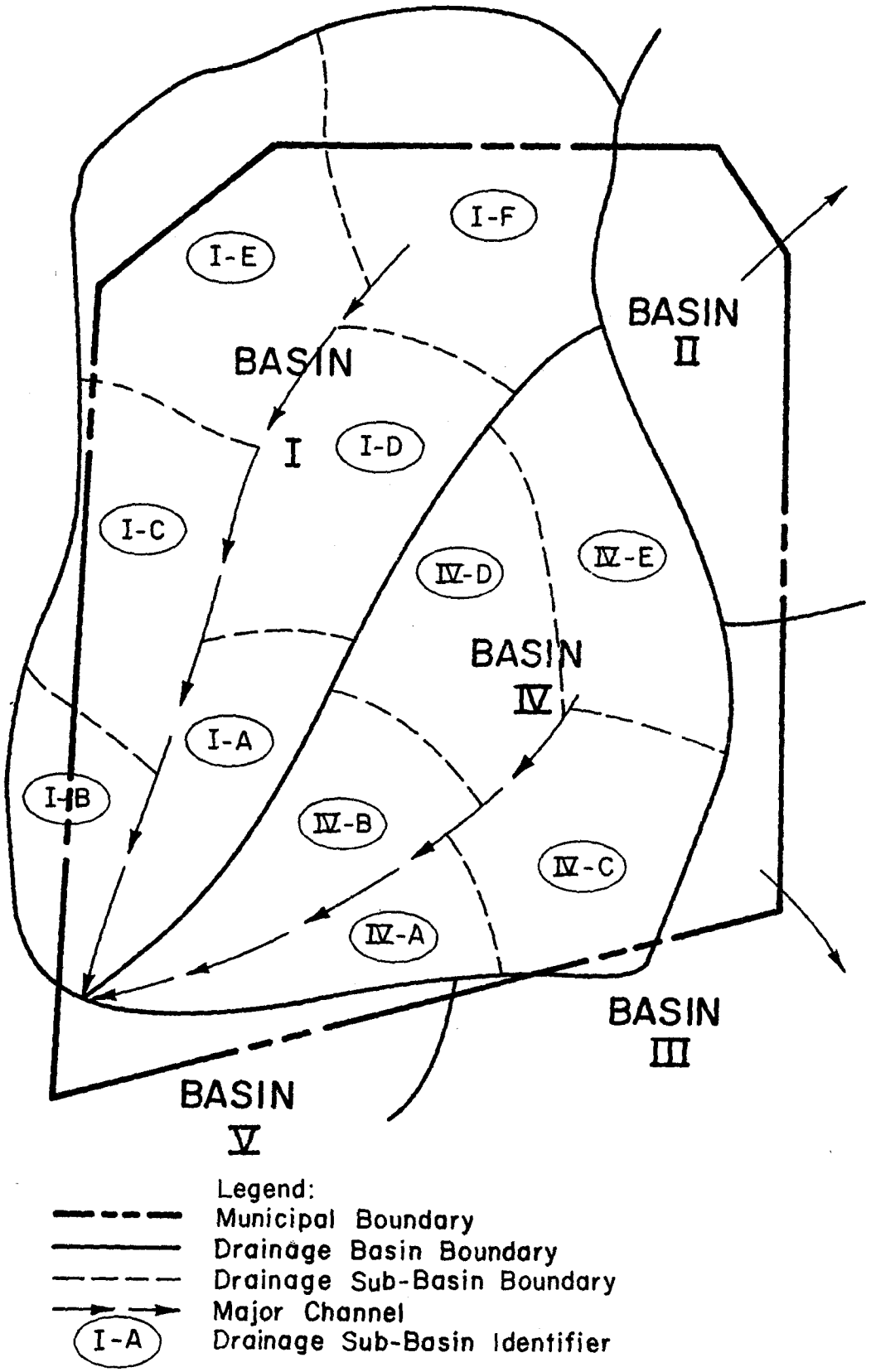

Figure I-1. Drainage Basin/Sub-basin Configuration.

feel this division creates logical drainage units for planning and management at the local level. The division separates the overall basin planning process from the detailed subbasin planning process, yet provides for coordination between these planning efforts. The major basins are studied to plan central drainage and flood control facilities, such as major channels and retention ponds. The individual subbasins are then studied to plan the trunk drainage facilities (minimum size of 36" to 54" pipe or channel equivalent) from the major channel to the upper reaches of the subbasin. Each property within the community is overlain by at least one basin and one subbasin and subject to the requirements of each.

2) Drainage and flood control - Control of surface and subsurface stormwater runoff. In this paper, the writers will use "drainage" or "flood control" alone to mean the same thing. The writers are not referring to drainage of marshy lands for reclamation purposes, nor to the hydraulic flow processes per se.

3) Drainage and flood control management program - A management program enforced under some regulatory scheme for the equitable financing of drainage and flood control facilities. The system consists of:

a) a Technical element which establishes the method to be used for calculating flood hydrology, and

b) a Financial element which establishes the method to be used for calculating the costs of urban drainage and flood control facilities, and for allocating those costs among the beneficiaries of the facility.

4) Medium-size community - Throughout this paper, the writers are addressing drainage management for small to medium-sized rapidly growing communities with populations under 200,000 persons.

CHAPTER II

SUMMARY OF PROJECT RESULTS

Technical Element of the Drainage Management Program

The development of an appropriate Technical element begins with a description of the requirements for flood hydrology calculation in urbanizing basins. Management of development-induced drainage impacts requires an estimate of the growth-related changes to all aspects of runoff response. The tools for estimating these changes are rainfall-runoff models; models that predict the runoff response for some rainfall input, and for various levels of basin development.

These rainfall-runoff models can be classified into two categories: Physically-based models and Conceptual models. The Physically-based models simulate the physical processes involved in transforming rainfall into runoff. They are supposed to be more accurate but their requirements (data, support personnel, and technology) make them relatively time-consuming to initiate and expensive to support. The Conceptual "black-box" models, on the other hand, can be initiated rather quickly and are cheaper to support.

In order to recommend an appropriate rainfall-runoff model class, the writers tested the predictive capability (both peak discharge and hydrograph shape) of the more popular models within each category. The data for these tests were taken from published reports. The tests indicate that the Physically-based models (as a group) do not provide significantly better runoff response predictions than the Conceptual models. Further, the predictive capability of the Conceptual models seems to be less sensitive to the model user than the predictive capability of the Physically-based models.

With the availability of better data and improved simulation algorithms, the relative capabilities of response prediction may change. Intuitively, the detailed Physically-based models should be able to better simulate the runoff response if adequate verification and calibration data are available. The advantage of this improved predictive capability is taken for granted. It is believed that drainage facility analysis improves as the accuracy of response prediction increases. Just how important is prediction accuracy?

The writers answer this question by examining the economic sensitivity of poor discharge prediction. The examination revealed that the cost of urban drainage and flood control facilities generally follows the "two-thirds power rule", and is not very sensitive to poor predictions of discharge. Project analyses such as Benefit Cost analysis and Minimum Cost analysis, on the other hand, are quite sensitive to errors in discharge prediction. This sensitivity was determined by estimating project benefits using damage frequency curves for various distributions of flood discharge.

The writers note, however, that the sensitivity of these project analysis techniques may not be as important as one might think. If a community uses a single rainfall-runoff prediction tool for evaluating all basins within that community, the analyses for each project will have a consistent basis. That is, the predicted benefit-cost ratio for each project may not be accurate, but it will precisely define the relative economic merits of each project. In the urban drainage and flood control area, where the benefit-cost ratios for politically justified projects are not always greater than one, this relative consistency can be more important than truly accurate benefit-cost ratios.

Thus, the Conceptual models appear to be the more appropriate rainfall-runoff models for use in small to medium size rapidly growing communities. Their predictive capability is as good as the Physically-based models, yet they are generally less expensive to initiate and support. Just as important, the Conceptual models are more likely to yield consistent runoff response predictions regardless of model user. This consistency is extremely important when the chosen model will be accessed by various model users in the community such as municipal staff personnel and engineering consultants. As a final consideration, the community should endeavor to select a flood hydrology calculation method that is consistent with other rainfall-runoff prediction models used in the area.

Financial Element of the Drainage Management Program

The recommended Financial element provides for a sharing of the costs to provide necessary drainage facilities. This method of financing raises three questions which were answered through an analysis of pertinent case law:

1. Among whom should the costs be shared?

   The costs can be shared among the municipal government and land developers. The developers' responsibility for a portion of the costs arises because they actually construct the houses and roads that modify the hydrologic response of the basin. The municipal government's responsibility stems from its actions on subdivisions and annexations which allow development to occur.

2. How shall costs be calculated?

   The dearth of legal doctrine in this area and the practical problems of cost estimating suggest that it is not mandatory to use comprehensive master plans when estimating project costs. A reasonable drainage plan that can be inexpensively prepared in a relatively short period of time is an appropriate cost calculation document.

3. How shall costs be allocated among beneficiaries?

   Allocation of project costs is generally under legislative control. However, to avoid judicial attack, the allocation method adopted by the municipal government should insure that:

   a) Project benefits are greater than project costs,
   b) Project benefits accrue to the area being assessed,
   c) The allocation of cost schedule has a reasonable basis,
   d) The regulation contains specific language regarding developer construction in excess of his responsibility, and
   e) A viable cost adjustment mechanism is developed for reimbursing front-end construction and for adjusting cost allocation errors.

In keeping with this criteria, the writers developed a procedure for computing the amount of the flood control project cost for which the developers are liable (Special Costs) and for which the municipal government is liable (General Costs). The procedure is based on the reduction in average annual damages, or benefit, that can reasonably be assigned to the developers (Special Benefit) and to the municipal government (General Benefit).

The recommended Financial element developed from these legal requirements is represented by a flow of decisions and money as illustrated in Figure II-1. The element is divided into two functional components: Cost Apportionment and Cost Adjustment.

Cost Apportionment -- The apportionment process begins after a reasonable drainage plan has been prepared. From this plan, the project costs are estimated and the special and general benefits are computed. If the total benefits are less than the total costs, and the nonquantifiable aspects of the project (aesthetics, political issues, etc.) do not override the economic analysis, the project is not viable and the process is terminated. If the project is viable, the process divides into financial actions and planning actions.

1. Financial actions:
    a) The special and general portions of project cost are computed.
    b) The general portion is apportioned to the community through encumbrances on the general fund, issuance of general obligation bonds, etc. (see Ref. 12 for a review of the various general financing alternatives).
    c) The special portion is apportioned to developers as they request subdivision plat approval using any one of a number of allocation formulas (see Ref. 22 and 23). The writer recommends an allocation formula based on land area and land use. It includes the major hydrologic factors, yet is simple enough for easy computation and administration.

COST APPORTIONMENT

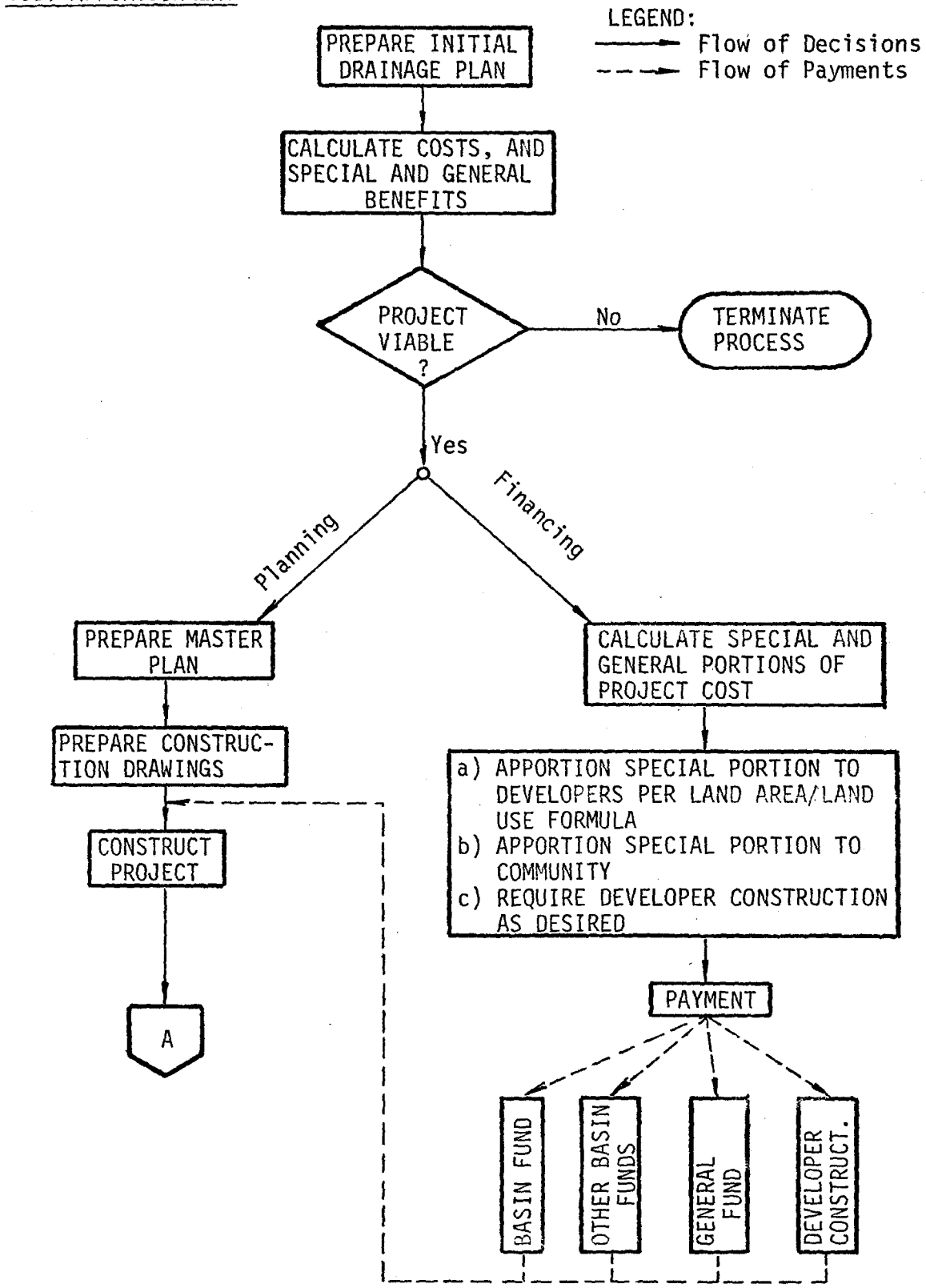

Figure II-1. Procedural Flow Chart for the Recommended Financial Element.

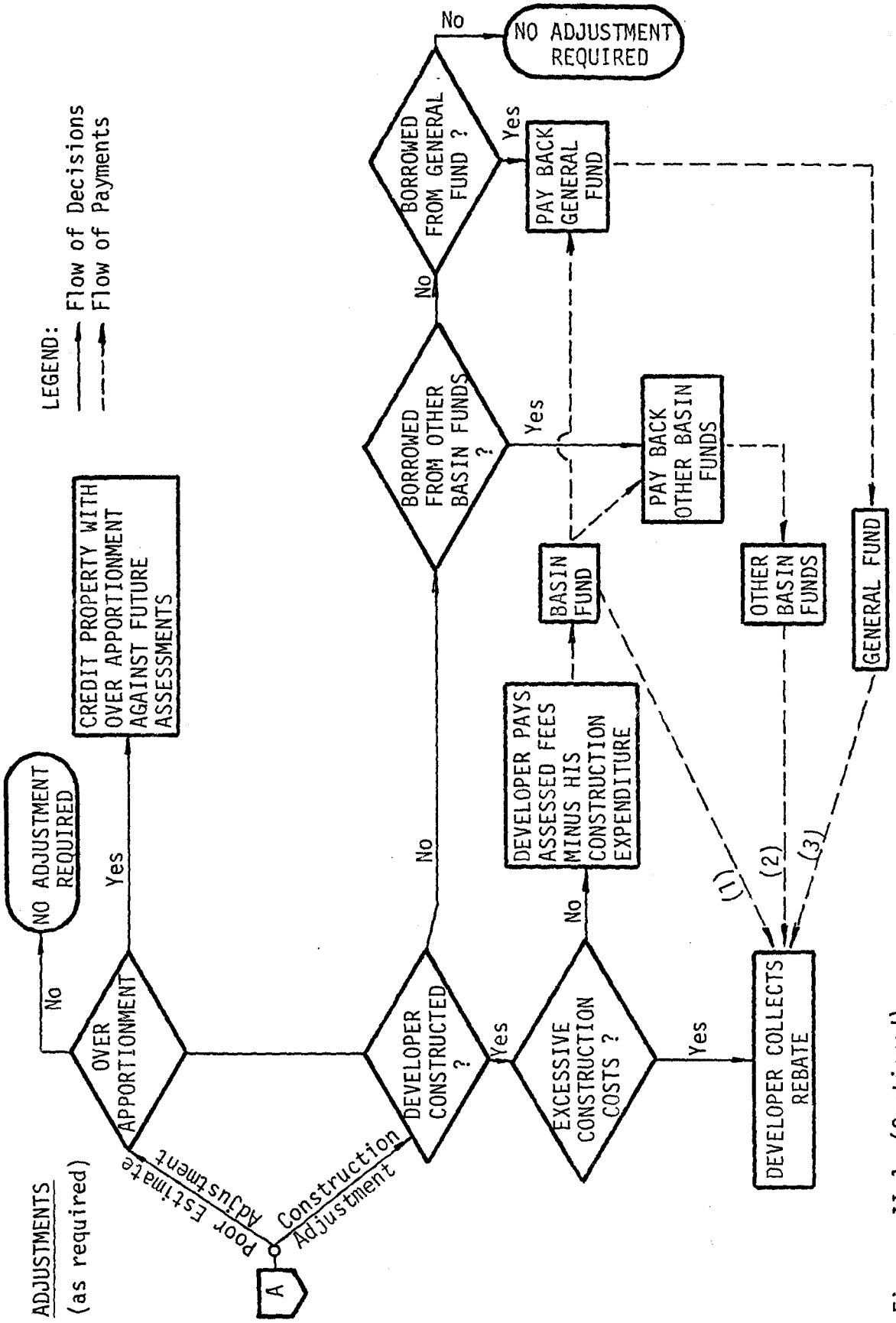

Figure II-1. (Continued).

d) As an alternative or in addition to Item (c), the developer may be requested to install some of the planned facilities during the construction of his development.

2. Planning actions:

a) The master planning process continues for a viable project. The Alternative Plan Phase expands the Initial Study Phase to include alternative basin plans. The alternative plans are reviewed by the community and various agencies, and a recommended Final Plan is developed.

b) From the Final Plan, construction drawings of the basin facilities are prepared. These are let out for bid, a contract is awarded, and the project is constructed.

c) The funds for the construction of the project are generated from one or a combination of the funding sources shown on the financial side: the basin fund, other basin funds, the general fund, or developer construction funds.

Cost Adjustment -- The decisions for adjustments are divided into poor estimate adjustments and developer construction adjustments. The poor estimate adjustments consist of crediting properties with any overapportionment. The developer construction adjustments consist of collecting additional fees from the developer or reimbursing him as necessary. The reimbursement comes from the basin fund, other basin funds, and the general fund, in that order. The adjustments also illustrate the reimbursement of the other basin funds and the general fund from the "borrowing" basin fund.

Regulatory Element of the Drainage Management Program

The advantages of the recommended Technical and Financial elements cannot be realized unless the entire drainage management program is packaged within effective regulation. Regulatory legislation that insures the consistent, equitable, and reasonable application of these program elements must be developed. The legislation must be carefully drafted to minimize legal uncertainties that might subject the regulatory program to interpretative court actions.

The nature of the hydrologic problem suggests that the regulatory mechanism be invoked at the time that the land alteration is approved, and that the regulatory legislation be drafted to provide for a watershed management approach. This latter suggestion must be tempered with the prevalent socio-political climate. At the present time, the politically practical approach to drainage management is based on local control without any regional or state intervention. In this situation, the writers feel that the first suggestion is best accomplished by incorporating legislation for drainage management within local subdivision regulations. The division of land marks the beginning of the alteration of the land; the developer should at this stage, be required to internalize the drainage-related costs that his land alteration is creating.

The writers also suggest a regulatory mechanism that would be appropriate under a more cooperative local/regional/state organization. The mechanism would provide for stronger regional and state control over land development. This approach would combine statewide expertise to the benefit of each local community, and would bring to fruition management of entire watersheds. It does, however, require considerable relinquishment of local control to regional or state governments.

CHAPTER III

RECOMMENDED DRAINAGE MANAGEMENT PROGRAM

The product of this research is a viable drainage management program. The program draws each of the recommended elements into a management tool to be used for mitigating development-induced drainage impacts. The program is based on:

1. Simple response prediction models that are consistent with other rainfall-runoff models used in the area.
2. A cost sharing approach for financing needed drainage facilities, and
3. Management control at the local level through subdivision regulations.

Sample regulatory language for implementing the recommended drainage management program is included in Appendix A. This legislation was drafted to supplement existing local subdivision regulations. It is divided into four subsections: Definitions, General Provisions, Drainage Basin Studies, and Off-site Drainage Fee. The important features of the legislation are discussed below.

Definitions

The sample regulation is based on the drainage basin/subbasin concept as discussed in Chapter I. Each development is overlain by at least one drainage basin and at least one drainage subbasin. That development is then partially responsible for all drainage facilities required within the applicable subbasin and basin. The extent of this responsibility is represented by an Off-site Drainage Fee (ODF) charged to that development. This fee is the development's proportionate

share of providing off-site drainage facilities required, at least in part, because of that development.

General Provisions

This subsection prescribes the general drainage requirements under the regulation. The subsection requires subdivision disapproval unless the developer adequately provides for both on-site and off-site drainage and flood control facilities. The on-site facilities include all the drainage facilities physically within the development for the conveyance of potential stormwater resulting from the planned ultimate upstream development. To obtain subdivision approval these facilities must be installed, or the installation must be suitably guaranteed by a performance bond.

The off-site facilities are those drainage facilities not actually within the development but required, at least in part, to transport the stormwater from the proposed development to the subbasin and basin outlet. These facilities are generally provided through a cash payment of the Off-site Drainage Fee (ODF). However, the regulation allows for developer construction of off-site facilities in situations where such construction is practicable and desirable. Any money expended for this off-site construction in excess of the applicable ODF for the development is subject to reimbursement under the regulation. If off-site facility construction is required, it will also have to be installed or suitably guaranteed prior to subdivision approval.

Procedurally, the developer is required to retain a registered professional engineer to prepare construction drawings for the required drainage facilities. The facilities are to be designed in accordance with local design standards and criteria. The developer then constructs

or suitably guarantees construction of the required drainage facilities in order to obtain subdivision approval. Upon completion of the construction, the municipal government accepts the facility for maintenance unless the developer wants to utilize the facility within his development. For example, a developer may want to utilize the subdivision detention pond as a Common Area park. In this case, the developer or the homeowners' association controlling the Common Area is subject to the proper maintenance of the drainage facility.

The regulation recognizes that some monetary adjustment will have to be made. All front-end money apportioned to the developer in excess of his "fair share" must be reimbursed. This subsection sets up a timely reimbursement mechanism. The differences between the developer's actual expenditure and his "fair share" shall be paid back in the following order:

1. First, from the available funds in the particular drainage basin fund in which the development is located;
2. Second, from money available in other drainage basin funds; and
3. Third, from the municipal government's general funds specifically earmarked for drainage construction reimbursement.

If these three sources are not sufficient, then the municipal government shall include money sufficient to complete the reimbursement in their next suceeding annual appropriation.

This payback provision can be used as an effective growth management tool. For example, if a proposed development creates or adds to a situation requiring substantial off-site drainage facility construction, the community can deny subdivision approval if it is

unable to make the timely reimbursements required by this subsection. This is like a timed-development management approach. The community's denial of subdivision approval indicates its inability to handle the proposed development at the present time. The developer can either wait until the community is able to accommodate his development, or he can waive the timely reimbursement section of the ordinance and authorize the city to reimburse him over an extended period of time (5-10 years) in order to proceed with his development.

Any errors in overestimating a developer's "fair share" must also be rebated in order to avoid arbitrary and capricious actions against the regulation. The reimbursements for poor estimates can't generally be made to the developer because it will usually be some time before an estimate is determined to be in error. Therefore, the refund is made to the homeowners who presumably paid for the excess apportionment when purchasing their home. The refund is in the form of a credit for any future public works assessments.

Drainage Basin Studies

This subsection describes the multi-step drainage planning process of the drainage management program. There are three steps:

1. Initial Drainage Study -- This study shall be made to determine one viable plan for drainage and flood control within the basin or subbasin. The plan is viable if either the estimated costs of the planned drainage facilities are less than the estimated benefits from the facility, or there exist overriding socio-political considerations that warrant the construction of the facilities regardless of the benefit to cost relationship. The plans will be the

basis for calculating project costs and developing a cost allocation schedule. The importance of this initial step is that it allows a community to study the entire jurisdiction in a relatively short period of time and at a reasonable cost.

2. Alternative Plan Study -- After the Initial Drainage Study has been completed, the basin will be examined in more detail (at a greater cost and over a longer period of time) to determine other viable drainage and flood control schemes. Each of these schemes will be evaluated in a consistent manner. The viable alternatives developed during this study will be presented in a report for public review and comment. The study will focus on factors other than strict economic ones such as environmental issues and legal constraints.
3. Final Plan Study -- The purpose of this study is to prepare the Master Drainage Plan that has been identified as the best drainage scheme for the basin or subbasin during the Alternative Plan Study. This final Master Drainage Plan may be quite different from the plan prepared under the Initial Drainage Study; a difference that may introduce errors into the previously prepared cost allocation schedule. The regulation provides for this through a "Poor Estimate Adjustment" mechanism discussed earlier.

It should be realized that development will occur prior to the preparation of the final Master Drainage Plan. The regulation recognizes this and allows for divergence from the three-step planning process. The regulation requires that at a minimum the Initial Drainage Study plan for the applicable basins and subbasins must be completed

prior to subdivision approval. If these plans have not been completed the developer is required to pay for their completion. The cost of this planning is subject to reimbursement under the regulation. The planning costs incurred by the developer will be deducted from the ODF charged to his development. If these plans are completed but the Master Drainage Plans for each of the applicable basins and subbasins have not been prepared, the developer can usually proceed with his development. He shall design all of the required drainage facilities in accordance with the latest adopted drainage facility plans.

Off-Site Drainage Fee

This subsection of the drainage management program regulation describes the procedure for calculating the Off-site Drainage Fee (ODF). This fee, as stated earlier, is the fee that is charged to a developer as his proportionate share of providing off-site drainage facilities. It is based on the particular subdivision's land area and land use. The ODF charged to a particular subdivision is computed by multiplying the land area (LA) of the proposed development times the applicable Development Factor (F) as tabled in the regulation, and then multiplying this product by the sum of the Base ODF of the basin (BODFB) and subbasin (BODFS) within which the subdivision lies. Or:

$$ODF = [(LA) \times (F)][BODFB + BODFS] \qquad (1)$$

If the proposed development lies within two or more subbasins or basins, it is separated in accordance with the basin and subbasin divides and the ODFs for the various portions of the development within each subbasin/basin are calculated. The ODF charged to the entire development is the sum of each of these individually computed ODFs.

This allocation formula is not particularly unique, but the calculation of the Base ODF (BODF) is. In the past the BODF was computed by dividing the total flood control project costs (TC) of each subbasin and basin by the sum of the projected acreage for each of the various land uses (LU) times its respective development factor. That is:

$$BODF = TC \Big/ \sum_{i=1}^{n} (LU_i) \times F_i \qquad (2)$$

where n = number of land use categories.

In keeping with the suggested dual liability concept, the writers feel that the Base ODF should not be figured on the total project cost. Rather the Base ODF should be based on the costs of the project that can reasonably be assigned to new developments. The writers split the total project cost into a Special Cost and a General Cost, the former being used to compute Base ODF.

This division of costs is part of the Initial Drainage Study. One should recall that during that study a viable plan is developed. One of the measures of viability is the benefit cost ratio. Thus two items are estimated during the Initial Drainage Study: the cost of the project, and the economic benefit of the project. Cost is estimated using standard construction estimating methods and does not concern use here.

The benefit of a drainage and flood control facility is estimated as the reduction in average annual damages provided by that facility. These damages include direct damages such as structural and content losses, and indirect damages such as maintenance and cleanup costs, and loss of sales. Grigg (40) has detailed the procedure for constructing

the curves necessary to evaluate average annual damage reduction. The method consists of computing the flood damages for particular storm events with and without a proposed drainage facility. The computed damages are then plotted against the return interval (or frequency) of their respective storms. The two sets of damage frequency plots (with and without the facility) are connected to yield two damage frequency curves as shown in Figure III-1. The area between these two curves is the reduction in average annual damages.

This then is the total benefit of the proposed project. However, it is not necessarily the total benefit that will accrue to new developments. Two other damage frequency curves are needed to estimate the proportionate benefit of the facility that accrues to new development. These two curves are also to be constructed during the Initial Drainage Study. They are the damage frequency curves for existing conditions with and without the proposed drainage facility. The damage frequency plotting positions are computed in exactly the same manner as the previous two curves except the hydrology used and the damages estimated are those for existing conditions with and without the proposed drainage facility. These two curves are plotted with the "ultimate" development curves as shown in Figure III-2. The special and general portions of the project cost are then computed as follows:

Step 1 -- Calculate average annual damage reduction (AADR) of the project.

The economic benefit of a drainage project is computed as the average damage reduction expected each year (or AADR) after the project is constructed and after the basin reaches ultimate development. It is the area in Figure III-2 between the U1 and the U2 curves.

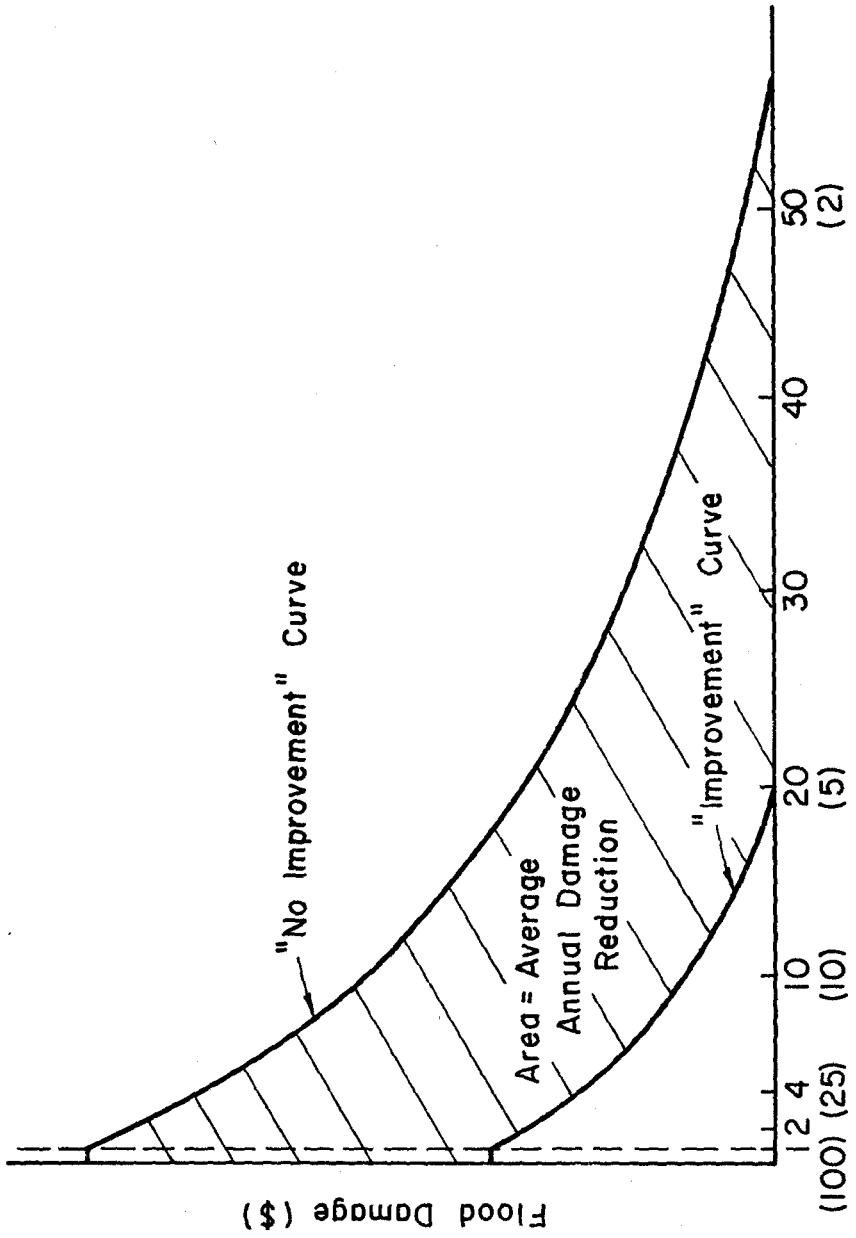

Figure III-1. Sample Damage-Frequency Curves and Computation of Reduced Average Annual Damages.

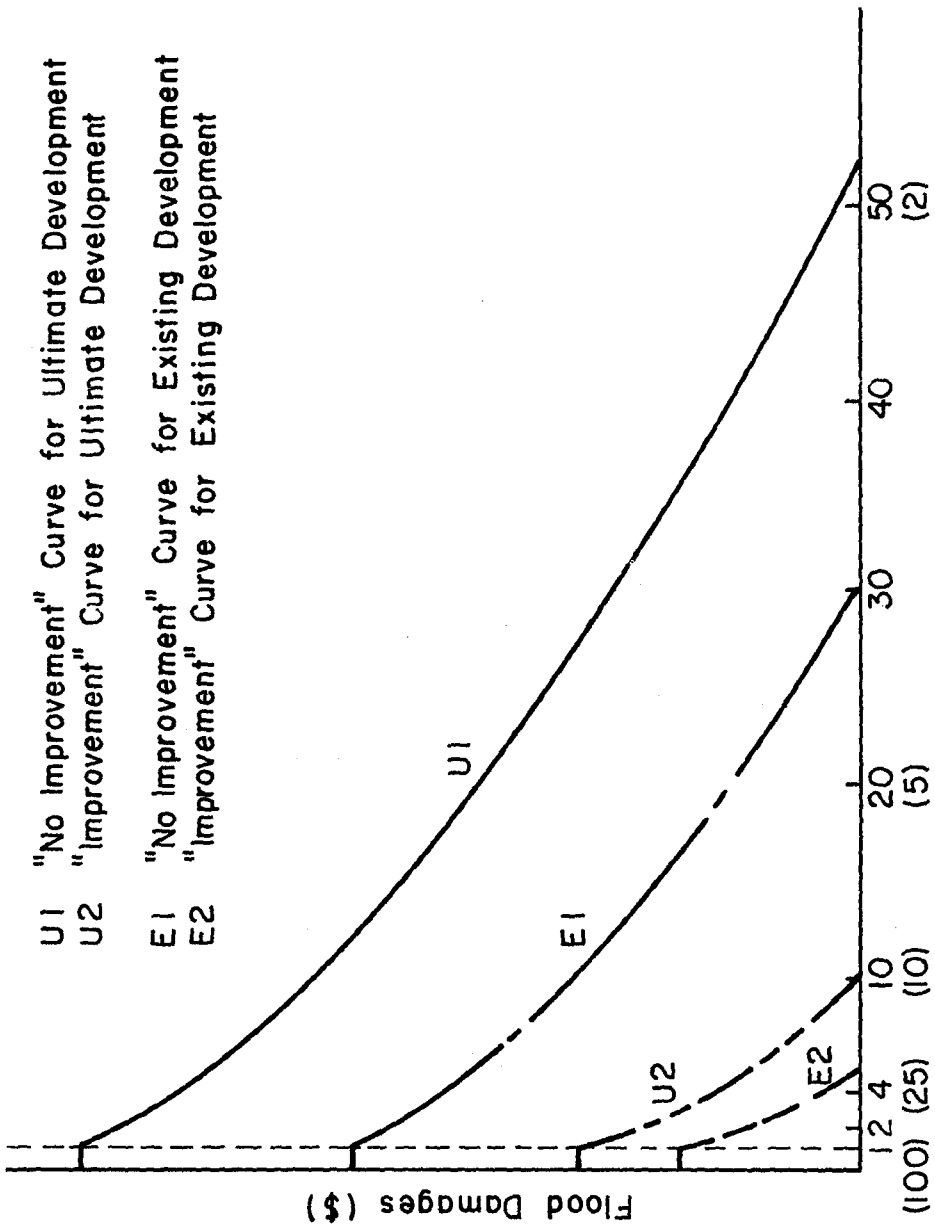

Figure III-2. Sample Damage-Frequency Curves Generated from the Initial Drainage Study.

Step 2 -- Calculate special benefit portion of project (B_S).

The special benefit portion of the project is the reduction in liability for development-induced impacts. It is the AADR measured from ultimate development without new drainage facilities to the existing conditions. It is the area in Figure III-2 between the U1 and the E1 curves.

In Chapter II of this report the writers stated that both the municipality and the developer were responsible for increased damages due to new developments. This implies that the AADR from curve U1 to curve E1 is a benefit to both, and each should contribute in proportion to that benefit. The writers feel that the municipal government is contributing its portion of this benefit by implementing and administering the drainage management program. That is, the municipal government's responsiblity is taking positive management actions to mitigate development-induced drainage impacts. For this reason, the entire area between curve U1 and curve E1 is assigned as special benefit to be allocated among developers.

Step 3 -- Calculate general benefit (B_G).

There are two elements of the general benefit. The first is the reduction in liability that the community has incurred through past actions of its elected officials. This element is the AADR from existing conditions to the conditions that existed when the municipal government began exercising authority over land development. This latter condition might be difficult to ascertain and the writers suggest that a practical substitute for it is the existing conditions with the new drainage facilities. The AADR measured from curve E1 to E2 in Figure III-2 reasonably establishes the portion of the new facility that reduces municipal responsibility.

The second element of general benefit is the non-quantifiable aspects of urban drainage and flood control facilities. These are important in dividing project costs when the benefit to cost ratio (BCR) of a viable project is less than 1.

Step 4 -- Compute special and general fractions of project cost.

1. BCR is greater than 1. When the BCR is greater than 1, the sum of the special benefit and the general benefit will be greater than or equal to the total project cost (C_T). That is:

$$B_S + B_G = B_T \geq C_T \tag{3}$$

where B_T = sum of the special and general benefits. Therefore:

$B_S/B_T = F_S$ = special fraction of project cost, and

$B_G/B_T = F_G$ = general fraction of project cost.

Thus, the cost allocated to developers (C_S) is:

$$C_S = (F_S)C_T \tag{4}$$

and the cost allocated to the general fund (C_G) is:

$$C_G = (F_G)C_T \quad . \tag{5}$$

2. BCR is less than 1. In this case, the project is viable only with the addition of the non-quantifiable element of the general benefits. This element is assigned a minimal economic value to equitably divide the project costs. To calculate the special and general portions in this case, the BCR is expressed in the following form:

$$B_T/C_T = 1 - R \tag{6}$$

where R = the non-quantifiable fraction of project benefit to economically justify the project, and B_T, C_T are as defined above.

Expanding and rearranging equation 6 yields:

$$B_S/C_T + (B_G + RC_T)/C_T = 1 \tag{7}$$

From equation 7, we see that

$$B_S/C_T = F_S \tag{8}$$

and

$$\frac{B_G + RC_T}{C_T} = F_G \cdot \tag{9}$$

The costs allocated to the developers and to the general fund are as before:

$$C_S = (F_S)C_T \tag{10}$$

$$C_G = (F_G)C_T \tag{11}$$

This Special Cost (C_S) is then used to compute the basin or subbasin Base ODF as described earlier. The General Costs (C_G) are borne by the general community for the reasons stated in Chapter II.

Closure

The features of the recommended drainage management program enable a community to quickly and inexpensively initiate a procedure for mitigating development-induced drainage impacts with confidence that the procedure is not arbitrary and open to judicial overrule. The program is based on an abbreviated planning methodology for calculating project costs and establishing a cost apportionment schedule. The abbreviated procedure can reduce the front-end drainage planning costs by approximately 75-80 percent. This is a substantial reduction in light of the keen competition for municipal funds.

The community's financial situation with regard to drainage management is further improved through the program's cost apportionment method. The method utilizes existing project analysis techniques to equitably divide the responsibility for mitigating drainage problems between the actors causing the impacts--the municipal government and the developers. This shared responsibility results in the collection of project revenues from both actors and can double the money available for drainage facility construction.

The recommended drainage management program is packaged within local subdivision regulations. The writers acknowledge that this approach will fall short of addressing comprehensive basin-wide planning and management because of its parochial nature. However, it is favored over any regional approach because of the socio-political problem with implementing regional programs. The local government should, however, strive for some type of regional approach. After gaining credibility through the local program they must impress upon the community the importance of basin-wide planning with regard to drainage and flood control.

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    c) California, State of

d) Chicago, IL, Metropolitan Sanitary District of

e) Colorado Springs, CO, City of

f) Dekalb, GA, County of

g) Fairfax, VA, County of

h) Ingham, MI, County of

i) Lakewood, CO, City of

j) Larimer, CO, County of

k) Los Angeles, CA, City of

l) Los Angeles, CA, County of

m) Pueblo, CO, City of

n) Tampa, FL, City of.

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APPENDIX A

SAMPLE LEGISLATION

APPENDIX A

SAMPLE ORDINANCE SECTIONS FOR LOCAL SUBDIVISION REGULATIONS

The sample ordinance sections presented in this appendix illustrate how the philosophical approaches to drainage management proposed in this report might be put into law. The sections represent additions to or modifications of the drainage related sections of local subdivision ordinances. The ordinance sections are not intended to be used verbatim, but rather to be used as a guide to state governments or local communities in preparing their own regulations. The legislative bodies must obtain such legal, engineering, and planning assistance as is necessary to tailor the proposed ordinance sections to the local situations.

Local Subdivision Ordinance Sections

21.05 Drainage and Storm Sewers

21.05.01 Definitions

21.05.02 General Provisions

21.05.03 Drainage Basin Studies

21.05.04 Off-Site Drainage Fee

21.05.01 Definitions

(a) Drainage Basin:

An area of land - generally between 10 and 100 square miles - defined by physical boundaries such that all precipitation falling upon this area will drain by gravity toward a common watercourse such as a natural stream, river, or man-made channel and will ultimately exit the area at a specific point known as the outfall (also referred to as basin).

(b) Drainage Sub-basin:

An area of land - generally between 1 and 10 square miles - contained within a drainage basin. Each drainage sub-basin has its own physical characteristics and has all the qualities of a drainage basin. The drainage basin is divided into several drainage sub-basins in order to more carefully analyze each portion of the drainage basin (also referred to as sub-basin).

(c) Off-site Drainage Facilities:

Drainage facilities physically located outside of the subdivision in question, or the excess capacity portion of drainage facilities physically located within or adjacent to the subdivision in question. These facilities are not the sole responsibility of the owner/developer of the subdivision in question; the cost of these facilities shall be shared with the owner/developer and the (name of city or county).

(d) Off-site Drainage Fee (ODF):

The fee charged to the owner/developer of the subdivision in question for sharing in the cost of providing off-site drainage facilities. The ODF represents the owner's/developer's proportionate share of providing these facilities based on the land area and land use of the subdivision in question.

(e) Project Cost:

The cost of providing the drainage facilities for a particular basin or sub-basin as recommended under the Initial Drainage Study. The cost shall include the cost of installing the facilities; all right-of-way costs, all mapping and planning costs; design, inspection, and administration costs; and appropriate contingency costs.

(1) General Costs: That fraction of the project cost that is proportional to the project benefits that accrue to the general community. These general benefits shall include the reduction in the community's flood damage liability as computed from the basin or sub-basin damage-frequency curves as well as the non-quantifiable benefits that accrue to the community such as prevention of life loss, aesthetic improvements, improved public convenience, improved land values, alleviation of health hazards, and provision for recreational opportunities.

(2) Special Costs: That fraction of the project cost that is proportional to the project benefits that accrue to new developments. These special benefits are computed as the reduction in new development flood damage liability from the basin or sub-basin damage-frequency curves.

21.05.02 General Provisions

(a) Requirements:

No subdivision of land shall be approved in the (name of city or county) until the owner/developer has suitably guaranteed the provision for both on-site and off-site drainage and storm water runoff.

(1) On-site Drainage Facilities: The owner/developer of land to be subdivided shall provide drainage facilities within his development as determined by the city (or county) engineer to be necessary for the drainage and control of stream and surface waters within his development. These facilities shall in each case be large enough to accommodate potential upstream runoff from areas inside and outside of the city (or county) and of the subdivision in question without altering existing flood elevations as shown in the city's (or county's) Flood Hazard Boundary Map. The size of the facility shall be determined by the city (or county) engineer, who shall base his determination on the applicable basin and sub-basin plans, the (name of city or county) Master Land Use Plan and any other appropriate land use planning documents. The cost of constructing drainage facilities to accommodate potential upstream runoff from land other than that being subdivided shall be shared by the owner/developer and the city (or county) in accordance with Section 21.05.02(c).

(2) Off-site Drainage Facilities: The owner/developer of land to be subdivided shall contribute to the provision of off-site drainage facilities required to convey potential runoff from his development and all areas upstream of his development to such outfall or discharge point(s) as shall be indicated on the applicable drainage basin and sub-basin plans for the drainage basin and sub-basin

within which the devleopment is located. The proportionate contribution for off-site drainage facilities shall be determined by the (name of city or county) and shall be based on an estimate of the hydrologic impact of the development as outlined in Section 21.05.04. The city (or county) may require the owner/developer to pay an off-site drainage fee (ODF) as determined under Section 21.05.04 for the proposed subdivision, or it may require the construction of necessary off-site drainage facilities that traverse through, are adjacent to, or extend beyond the proposed subdivision in lieu thereof, or it may require some combination of fee payment and facility construction. The decision to require off-site construction in lieu of payment shall be based on the construction practicability, the need for the facility, and the ability of the city (or county) to share in the cost of construction as required. The cost of constructing off-site drainage facilities shall be shared by the owner/developer and the city (or county) in accordance with Section 21.05.02(c).

(3) Location: All on-site and off-site drainage facilities shall be located in street right-of-way where feasible, or in perpetual unobstructed easements of appropriate width. The city (or county) shall cooperate with and assist owners/developers subject to the provisions of this ordinance in such matters as the exercise of its power of eminent domain for obtaining easement rights for drainage facilities.

(b) Procedures:

(1) Plans and Specifications: Prior to final approval of a subdivision plat, detailed plans and specifications for the construction and installation of the on-site and off-site drainage facilities as required under this Section 21.05 shall be prepared in accordance

with the criteria set forth in Section 21.05.02(d) by a registered professional engineer retained by the owner/developer, and shall be approved by the city (or county) engineer. A copy of the hydrologic and hydraulic design calculations and the itemized estimate of the costs of constructing the planned facilities shall be submitted along with the plans. The city (or county) engineer shall not approve the plans and specifications unless they are in substantial conformance with the applicable basin and sub-basin drainage plans. However, if the plans and specifications for the proposed drainage facilities subject to adjustment under Section 21.05.02(c) are determined not to be the most economical alternative available, and the developer elects to provide a more expensive alternative, the city (or county) engineer shall approve the plans and specifications if the developer agrees to waive his eligibility for any credit in excess of the city's (or county's) estimate of the cost of the most economical alternative available.

(2) On-site Drainage Facility Guarantee: Prior to final approval of a subdivision plat, the on-site drainage facilities required under this Section 21.05 shall either be constructed by the owner/developer and accepted by the city (or county), or shall be suitably guaranteed by the execution of a performance bond as provided in Section (number of section in ordinance that discusses requirements for performance bonds).

(3) Off-site Drainage Facility Guarantee: Prior to final approval of a subdivision plat all off-site drainage fees applicable to the proposed subdivision as required under Section 21.05.04 and as adjusted under Section 21.05.02(c) shall be paid in full, and any

off-site drainage facilities required under this Section 21.05 shall either be constructed by the owner/developer and accepted by the city (or county), or shall be suitably guaranteed by the execution of a performance bond as provided in Section (number of section in ordinance that discusses requirements for performance bonds).

(4) Facility Acceptance: Except as provided below, all drainage facilities and appurtenant structures constructed or provided under this Section 21.05 shall upon written acceptance by the (name of city or county) become the property of the city (or county) and the city (or county) thereafter shall be responsible for the operation and maintenance of same. The city (or county) may allow title of an off-site drainage facility that is designed for combined flood control and park purposes to remain with the owner/developer if the owner/developer establishes or agrees to establish a homeowners' association for the continued maintenance and operation of that facility. The organizational documents of such a homeowners' association shall allow the (name of city or county) to assume maintenance and/or operation of the on-site drainage facility should the homeowners' association fail to properly maintain and/or operate the facility, as determined by the city (or county) engineer, for flood control and/or other designated purposes. The documents shall further declare that all costs incident to such city (or county) maintenance and/or operation shall be the responsibility of the homeowners' association and shall become a lien on the property held by each homeowner in the association until paid.

(c) Adjustments:

(1) Planning and Construction Cost Adjustments: The planning and construction cost adjustment is the adjustment for differences between the off-site drainage fee (ODF) as computed under Section 21.05.04 and the sum of the planning fees required under Section 21.05.03(c.1) plus the cost of off-site drainage facilities either inside or outside of the subdivision constructed by the owner/developer. Off-site drainage facilities include facilities outside of the subdivision boundary, and excess capacity drainage facilities inside the subdivision boundary. The cost of these facilities shall be computed by adding the construction cost of the outside facilities to the cost of the excess portion of the inside facilities. The excess portion shall be computed by multiplying the cost of the excess capacity drainage facility by the ratio of inflow from areas upstream of the subdivision to the total flow accommodated by the facility. The city (or county) engineer can define "inflow" and "total flow" in terms of peak discharge rate, volume of discharge, or a combination of both depending on the function of the inside facilities. If the sum of the required planning fees plus the off-site drainage facility cost is less than the ODF, the owner/developer shall pay the difference prior to subdivision plat approval as required under this Section 21.05. If the sum of the required planning fees plus the off-site drainage facility cost is greater than the ODF, the owner/developer shall be entitled to the difference. The owner/developer may elect not to be reimbursed this difference and may direct the city (or county) to apply the sum of money he would be reimbursed to pay for ODF's for which he is liable in other subdivisions he is developing within the city (or

county); or, upon approval by the city (or county), the owner/developer may direct the city (or county) to apply the sum of money to pay for other facility costs for which he is liable within the city (or county). If the owner/developer elects to be reimbursed, the city (or county) shall, except as provided below, pay such difference to the owner/developer from the following sources and in the following order:

i) First, from the available funds in the particular drainage basin fund in which the development is located;

ii) Second, from available funds in other drainage basin funds;

iii) Third, from the city (or county) general funds specifically earmarked for drainage construction reimbursement. If these three sources are not sufficient, then the city (or county) shall include money sufficient to complete the reimbursement in the next succeeding annual appropriation ordinance. For purposes of budgeting, the cut-off date for being included in the "next succeeding annual appropriation ordinance" shall be the first day of September.

The funds from which the money is drawn to reimburse the developer shall be paid back by the drainage basin fund in which the development is located as money is collected from other developers in that drainage basin. If the city (or county) determines that the subdivision will create a new flooding problem or aggravate an existing flooding problem without the installation of off-site drainage facilities, and further determines that the city (or county) is unable to guarantee sharing the cost of constructing these facilities with the owner/developer as prescribed above, the city (or

county) shall deny approval of the subdivision unless the owner/ developer agrees to an extension of the adjustment period that shall not exceed ten (10) years.

(2) Poor Estimate Adjustment: Upon completion and acceptance of entire basin and sub-basin facilities, the city (or county) engineer shall determine whether the base ODF calculated pursuant to Section 21.05.04 was overestimated or underestimated. In the event of an overestimate, the properties that contributed to ODF shall receive a credit against future public works assessments for the amount of overestimate in proportion to their contribution. The city (or county) shall bear the burden of ODF underestimation.

(d) Criteria:

The design and construction of required on-site and off-site drainage facilities shall be in accordance with sound engineering practices and shall be in accordance with the criteria contained in the (name of local or regional storm drainage criteria manual) as amended and applied by the city (or county) engineer. The city (or county) engineer is responsible for developing and maintaining the amended criteria and he shall endeavor to coordinate his efforts with other jurisdictions within the same drainage basin.

21.05.03 Drainage Basin Studies

(a) Basin and Sub-basin Plans:

As soon as possible after the adoption of this ordinance, the boundaries of the drainage basins and sub-basins within the city (or county) and surrounding the city (or county) shall be delineated upon a map or maps by the city (or county) engineer. There will also be shown upon said map or maps the area in said basins which have been platted,

subdivided or developed and not subject to the provisions of this ordinance, and those areas therein which are presently not subdivided and subject to the provisions of this ordinance. The recommended drainage facilities shall be shown on said maps as studies for the individual sub-basins and basins are completed pursuant to Section 21.05.03(b) and adopted by the city (or county) council. The maps shall be adopted by the city (or county) by resolution after a public hearing and shall serve as official designations of the respective sub-basins and basins. The maps will be subject to revision from time to time to conform with and show existing conditions, the results of additional studies, and other information obtained. Major revisions shall be adopted by the city (or county) only after a public hearing has been held.

(b) Drainage Study Methodology:

(1) General: Pursuant to the Multiple Planning Process described in this section, the city (or county) engineer shall cause to be made engineering studies of drainage basins and sub-basins within the city (or county) and those surrounding the city (or county) which either extend into the city (or county) or which affect or may affect present or future city (or county) territory and drainage therein. The larger basin studies shall precede the individual sub-basin studies within that basin. The city (or county) shall in all ways and within the limits of its powers solicit the (names of adjoining jurisdictions) to cooperate in the drainage basin planning process and in carrying out the drainage plan in drainage basins and sub-basins that extend outside the city (or county) limits. The engineering studies will provide an interdisciplinary investigation of the drainage basins and sub-basins with the idea of

putting drainage facilities to multiple uses. Retention sites and green strips shall, when practicable, be designed for park and recreation as well as drainage and flood control uses. In the event that such sites and strips are so used for park and recreational purposes, the owner/developer making available and granting these areas for the aforesaid uses shall be credited for Park and Recreation fees payable under this subdivision ordinance (if such fees are required under this subdivision ordinance) to the extent of the appraised value of the land within the boundaries of each area. The studies shall be based upon land uses and developments as projected by the (name of city or county) Comprehensive Plan. The studies will develop a plan which designates the necessary conduits, open channels, natural drainage courses, greenbelts, retention ponds, and other drainage facilities, and the necessary easements and rights-of-way for these facilities required to provide for the drainage and control of storm runoff within said sub-basins and basins. Every effort shall be made to promote economies in the proposed drainage schemes by the selection of materials, structure, and methods which minimize costs. Previous studies made by the city (or county) or others shall be considered in whole or in part where applicable. The studies shall include a current estimate of the cost of providing the recommended drainage facilities. The computation of such costs shall include the cost of installing the recommended drainage facilities; all right-of-way costs; all mapping and planning costs; design, inspection, and administration costs; and appropriate contingency costs. These studies shall be authorized

as finances become available and as allocated by the city (or county) Council except as provided in Section 21.05.03(c).

(2) Multiple Planning Process: The following three studies shall be prepared for each basin and sub-basin except as provided in Section 21.05.03(c).

i) Initial Drainage Study -- This study shall be made to determine one viable plan for drainage and flood control within the basin or sub-basin and to determine the base ODF for that basin or sub-basin in accordance with Section 21.05.04. The plan is viable if either the estimated costs of the plan are less than the estimated benefits from the plan, or there exist overriding sociopolitical considerations that warrant the construction of the plan regardless of the benefit to cost relationship. If a viable plan cannot be developed, the planning process for that basin or sub-basin shall be terminated.

ii) Alternative Plan Study -- The purpose of this study shall be to consistently investigate all feasible alternative drainage schemes so that the best drainage and flood control plan for the basin can be determined and justified. The investigations shall be presented in a report to the public for their review and comment.

iii) Final Plan Study -- The purpose of this study is to prepare the master drainage plan that has been identified as the best drainage scheme for the basin or sub-basin during the Alternative Plan Study.

(c) Modifications:

(1) Planning: In the event that a proposed development lies within a sub-basin and basin that has not been studied as provided in Section 21.05.03(b), the owner/developer shall in addition to other fees required by these subdivision regulations and this Section 21.05, pay to the city (or county) one hundred percent (100%) of the estimated cost as calculated by the city (or county) engineer of completing the drainage basin and sub-basin Initial Drainage Study for the basin and sub-basin in which the subdivision is located. The owner/developer shall be entitled to an adjustment for this planning fee as provided in Section 21.05.02(c).

(2) Construction: In the event that a proposed development lies within a sub-basin and basin that does not have a master drainage plan and the adoption of a master drainage plan for that sub-basin and basin is not scheduled for within six months from the time of subdivision application, the owner/developer shall design and construct all required on-site and off-site drainage facilities in accordance with the latest adopted drainage facility plan.

21.05.04 Off-Site Drainage Fee (ODF):

(a) Project Cost Calculation:

The cost estimate prepared in the Initial Drainage Study for the viable drainage plan for the sub-basin or basin shall be the "project cost" of the necessary sub-basin or basin drainage facilities.

(b) Division of Project Cost:

The "project costs" for the sub-basins calculated in the Initial Drainage Study for each shall be divided into Special Costs and General Costs in proportion to the reduction of flood damage liability that

accrues to new development and that accrues to existing development. The Special Costs shall be financed by the owners/developers of subdivisions requesting approval after adoption of this ordinance and the General Costs shall be financed through the city (or county) general fund. The method of division shall be based on the relationship between the computed reduction in average annual damages for new developments, and the computed reduction in average annual damages for existing development plus the minimum monetary equivalent of non-quantifiable considerations to make the project benefits equal the project cost. The exact method for dividing the project costs using the damage-frequency plots of the Initial Drainage Study shall be detailed in the amended criteria maintained by the city (or county) engineer.

(c) Fees:

The projected amount and type of new development shall be used to allocate the Special Costs of the sub-basin and basin Initial Drainage Study plans. The base ODF for a particular basin or sub-basin shall be computed by dividing the Special Costs of that basin or sub-basin by the sum of the projected development acreage times its development factor as specified in the following table:

Land Use	Development Factors*
Single-family Residential	1.0
.	.
.	.
List of other city (or county) zone classifications	.
.	.
Commercial/Industrial	2.0

*Note: The Land Use/Development Factor Table is based on the relative percentages of imperviousness for each zoning classification and should be developed by the city (or county) engineer.

This base ODF shall be set for each sub-basin and basin by resolution of the city (or county) Council. The ODF for a particular development shall be determined by multiplying the applicable basin and sub-basin base ODF's by the appropriate Development Factor and then by the total gross acreage of that particular development including portions dedicated to the city (or county).

(d) Revision:

The city (or county) shall reestablish the basin and sub-basin base ODF's in accordance with changes in construction and other costs at its first regular meeting in (month of first annual meeting) of each year.

(e) Sub-basin and Basin Funds:

All ODF's paid to the city (or county) or other revenue received by the city (or county) for the construction of drainage facilities under this ordinance shall be placed into the applicable basin fund in which the development is located. The money collected in each fund shall be used for the provision of drainage facilities within that basin except as provided in this Section 21.05.02(c).