USING GIS IN MASTER PLANS OF DRAINAGE

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Abstract

A Graphics Data Base Management System is developed for use with computerized Master Plans of Drainage. The Master Plans are prepared according to particular governing agency specifications involving multiple hydrologic and hydraulic modeling options, integrated into a single software package. Data bases are prepared for graphical representation of streets, land uses, hydrologic soil groups, rainfall, master plan system elements, topographic, and other data, as well as computational results developed from the Master Plan of Drainage computer model. Two applications are available; an integrated package enabling editing and upgrading of the Master Plan, and another package designed to publish and distribute the Graphics and the Master Plan of Drainage data bases to the public in an access-only data base retrieval environment. The opportunities provided by such public information programs are significant, in that the entire Master Plan becomes available to the public in an easy-to-read and easy-to-use environment. The public therefore becomes an integral and important member of the Master Plan team, exchanging input and easing the way for acceptance of the project.

INTRODUCTION

In urbanized areas, where development patterns are essentially uniform with respect to drainage to streets, the flood damage potential may be related to the flood depth in the adjacent street section. For a particular street geometric cross-section, a given flood depth may be correlated to different levels of flood damage potential depending upon the contiguous developmental land use. Additionally, the greater the flood depth in the street section, the higher the flood damage potential to the adjacent property. The flood damage potential can be estimated if there exist relationships between the street section flood depth and the various associated land use designations. By a master plan study of the flood control system, a cost to reduce the flood damage potential (according to local agency standards) can be estimated.

Dividing the flood damage potential by the associated cost to upgrade the appropriate flood control system determines a cost-to-benefit index. A higher cost-to-benefit index value indicates that a higher benefit can be achieved with the associated cost to upgrade the local flood control system. A prioritization of the master plan of drainage system elements can then be developed based upon a ranking of each master plan system element's cost-to-benefit index. A computer model, called "CBI", was prepared to perform the above described tasks. Use of the CBI approach enables a prioritization of master plan system improvements in order to increase utilization of agency funds to remove system deficiencies. By graphically displaying CBI values, prioritization becomes more visually apparent in that systems demonstrating a more efficient use of agency funds (in removing deficiencies) are graphically identified. The CBI mapping approach draws upon well-known experience in plotting other phenomenon, such as earthquakes, as geometric symbols (such as hexagons) whose diameters reflect, for example, the magnitude of the earthquake and the symbol's centroid is located at the earthquake's epicenter. In the CBI graphical display, the geometric symbol's diameter reflects the CBI magnitude and the symbol's centroid is located at the point at which the CBI value applies.

COUPLED STREET AND STORM DRAIN SYSTEM DEFICIENCY CATEGORIES

A typical drainage system element in a master plan of drainage consists of the combined capacity of a particular street section, with an underlying pipe or box flood control system. For evaluation purposes, three types of coupled street and storm drain deficiency model classifications are used in the CBI analysis; these categories reflect the varying storm-flow carrying capacity of each street section used in the study. The categories are:

Deficiency Category I (Roadway Sumps): For street grades equal to zero, deficiencies typically correlate to the volume of runoff ponded at the particular vicinity, for the selected design storm event.

Deficiency Category II (Arterial Streets): For any street with a maximum allowable design flow depth less than or equal to the street top-of-curb. A typical case is when it is required to maintain one or more lanes of traffic flood-free during a design storm event. Generally, such a criterion applies to major or arterial streets.

Deficiency Category III (Residential Streets): For any street with a maximum allowable design flow depth greater than or equal to top-of-curb, for the selected design storm event. Generally, residential streets fit into this category.

DEFINITION OF FLOOD DAMAGE POTENTIAL

A set of flood damage potential curves (see Figure 1) are needed for each deficiency category. The flood damage potential curves define a street flow depth versus flood damage potential relationship, for various land use designations. In order to define flood damage potential for a particular system element, damage potential versus street flow depth data are needed. Generally, flood damage of habitable structures can be estimated to occur at a specific depth of flow above street top-of-curb (such as a one-foot depth above top-of-curb). At this depth, it is assumed that flood flows are damaging property, and actual damage costs can be computed. For greater depths, higher damage potential values may be assigned. For lesser flow depths, where property damage might not occur, a "penalty" may be assigned that generalizes "damage" due to traffic obstruction, risks to emergency services, among other factors. For example, assuming a ten-percent damage potential, for flow depths 0.5-foot above top-of-curb, may be appropriate. As shown in Figure 1, a continuous damage potential versus flood depth relationship is defined. Although actual costs may be computed, they are not necessary in the CBI approach as a subsequent normalization of CBI values is used for prioritization purposes. Consequently, the key to the CBI analysis is a relative flood damage potential definition, with respect to both flood depth in the street and land use designation. The ranking of master plan system elements with respect to CBI values is analogous to the more standardized cost-to-benefit ratio approach such as is used by the U.S. Army Corps of Engineers (Sheaffer et. al., 1982).

CBI MODEL INTERFACE WITH OTHER COMPUTER PROGRAMS

The CBI model is written to interface with the Advanced Engineering Software (AES) RATCAD/GIS hydrology model and the Boyle Facility Management System (BFMS) data base application. The RATCAD program provides the peak flow rates for each coupled street/storm drain element (i.e., link) within the catchment master plan. The BFMS utilizes the RATCAD peak flow rates to identify the deficient reaches within the entire drainage system and provide improvement options based upon the Agency's standards. Next, another data base file is created by the BFMS for use with the CBI analysis. After determining the cost-to-benefit index for each element in the entire master plan of drainage, a graphics data base file is created for use in preparing CBI mapping.

COST-TO-BENEFIT INDEX (CBI) PROCEDURE

A flow chart of the cost-to-benefit index (CBI) analysis procedure is depicted in Figure 2. Descriptions of the specific procedures shown in Figure 2 are given below.

Determine Element Deficiency Category

The element deficiency category under study can be determined by using the master plan system element's street cross-section information (contained in the data base) and the element's deficiency category definitions as described previously.

Determine Existing Condition Street Flow Depth

Manning's equation for normal depth flow is used to determine the existing condition (i.e., no new drainage improvements) street flow depth, for each system element, by using the peak flow rate, existing storm drain capacity, and street cross-section information. This flow depth corresponds to the condition where storm drain improvements have not yet been made to remove deficiencies, for the selected design storm event.

Determine Flood Damage Potential

After determining the existing condition street flow depth, the flood damage potential is determined from the flood damage potential curves, based upon the proper street deficiency category and the adjacent land use. If the system element under study contains mixed land uses, the flood damage potential for each land use is calculated, and an area-averaged value is used to represent a composite flood damage potential, for the selected design storm event.

Determine Improvement Costs to Remove Deficiencies

Improvement costs, for each deficient street/storm drain reach, is provided by the master plan of drainage results. These costs reflect the cost to remove deficiencies, consistent with agency standards, for the selected design storm event.

Calculate the Cost-to-Benefit Index (CBI) Value

The cost-to-benefit index is calculated as follows:

CBI (cost-to-benefit index)

= (Flood Damage Potential)/(Improvement Costs) (1)

Store CBI Values

The CBI value computed by Equation.(1) for each street/storm drain reach is then stored in the computer data base with respect to its deficiency category.

Normalize CBI Values

After completion of the CBI analysis for the entire master plan of drainage, statistical calculations of mean value and standard deviation, for each of the three different deficiency categories, are prepared. By dividing the entire CBI range of values by the maximum CBI value (based upon the deficiency category), normalized CBI values are computed with a range of zero to one. These normalized values are written to another data file for subsequent graphics display purposes. Note that a CBI value of zero corresponds to a zero deficiency pursuant to Agency standards and the selected designed storm event. A CBI value of 1. corresponds to the maximum value of the CBI per Equation (1).

CBI GRAPHICS DISPLAY

A graphical representation of the CBI values can then be prepared by plotting graphics symbols onto the storm drain system maps. The composite CBI map will have three different symbols to represent each deficiency category:

Deficiency Category I : triangle

Deficiency Category II : hexagon

Deficiency Category III: circle

The standard unit plot (e.g., see map legend) for each symbol represents the mean CBI value, for each respective deficiency category. From the map, the larger the symbol, the greater the CBI value, proportional to the symbol diameter. In other words. the larger the symbol, the higher the ranking of the prioritization within the associated deficiency class.

APPLICATION

The City of Santa Ana encompasses approximately 29 square miles and is located in Orange County, California. The CBI analysis is applied to the City's latest master plan of drainage system to provide prioritization for the recommended improvements. A graphical map that displays the CBI analysis results has been compiled. Figure 3 depicts the legend used to represent different deficiency categories. The diameter of each symbol represents the mean CBI value for each deficiency category. In this application, the mean CBI values are 0.25, 0.29, and 0.30 for Deficiency Category I (Roadway Sumps), Deficiency Category II (Arterial Streets), and Deficiency Category III (Residential Streets), respectively.

Part of the City's CBI graphical display is shown in Figures 4a and 4b. Figure 4a illustrates that System A, which entirely falls within Deficiency Category II, has higher priority than other systems within the same deficiency category. System B, which primarily falls within Deficiency Category I, has higher priority than other systems within the same deficiency category. Figure 4b shows System C, which is included in Deficiency Category III, has higher priority than other systems within the same deficiency category. Prioritization for the City of Santa Ana master plan of drainage system can be determined by ranking from the largest to the smallest cluster size of symbols for each deficiency category.

CONCLUSIONS

The Cost-to-Benefit Index (CBI) method is developed as a graphical means to communicate important information regarding master planning prioritization of flood control system elements targeted for improvement. Using the CBI approach, decisions can be made regarding which system reach or system elements may be ranked as having the highest priority in scheduling construction. Additionally, a CBI map aids in communicating to the public the relative importance of any particular element with respect to the overall master plan.

REFERENCES

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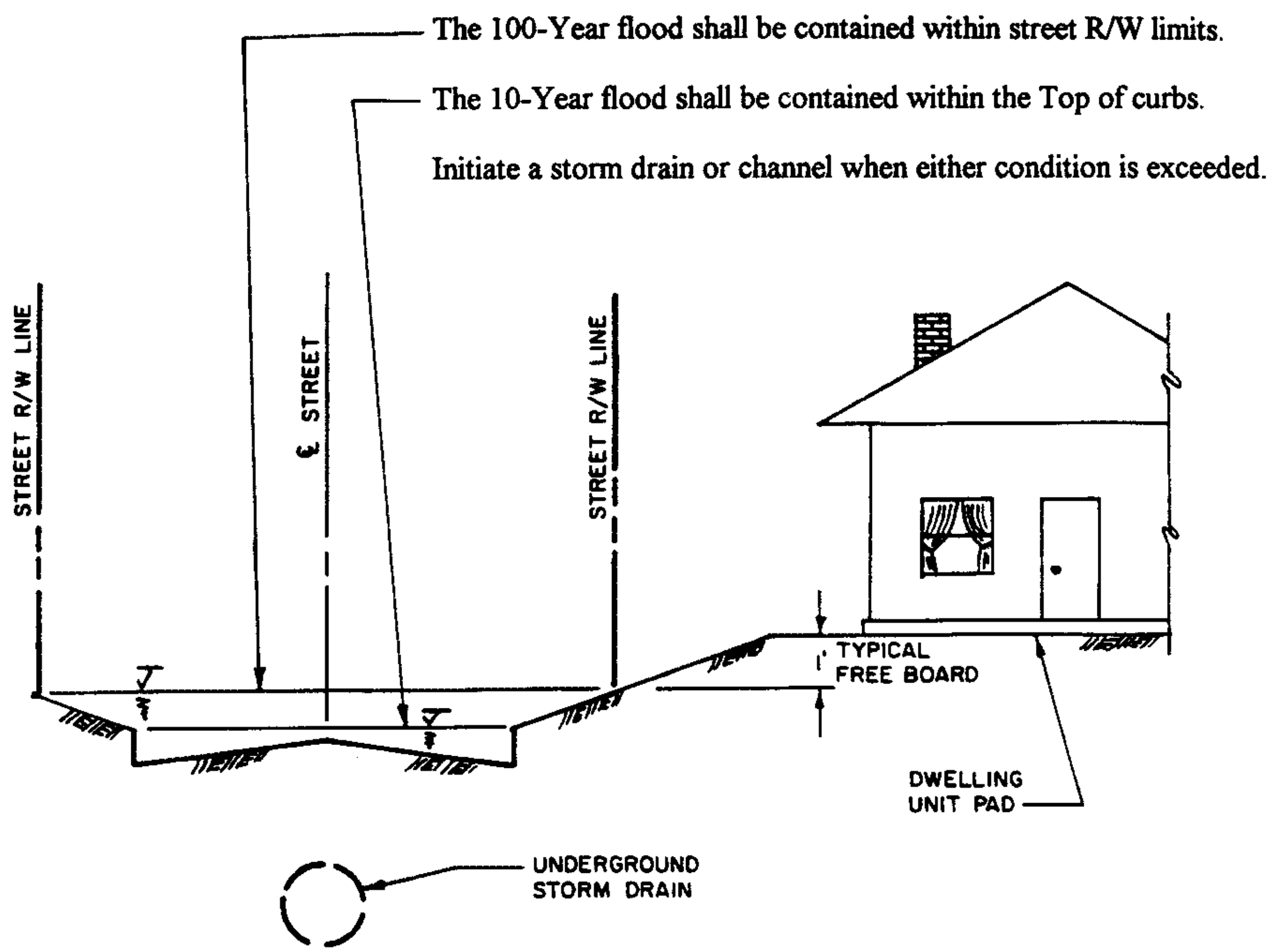

Notes:

Protection criteria shown are District typical minimum requirements. Special conditions, or other authorities may require stricter controls; i.e.; for reasons of traffic or pedestrian safety, maintenance problems behind curbs, etc., lower maximum depths of flow in streets may be required.

(Reference: Riverside County Flood Control And Water Conservation District, Hydrology Manual, 1978.)

FIGURE 1. TYPICAL DEFICIENCY CATEGORY III

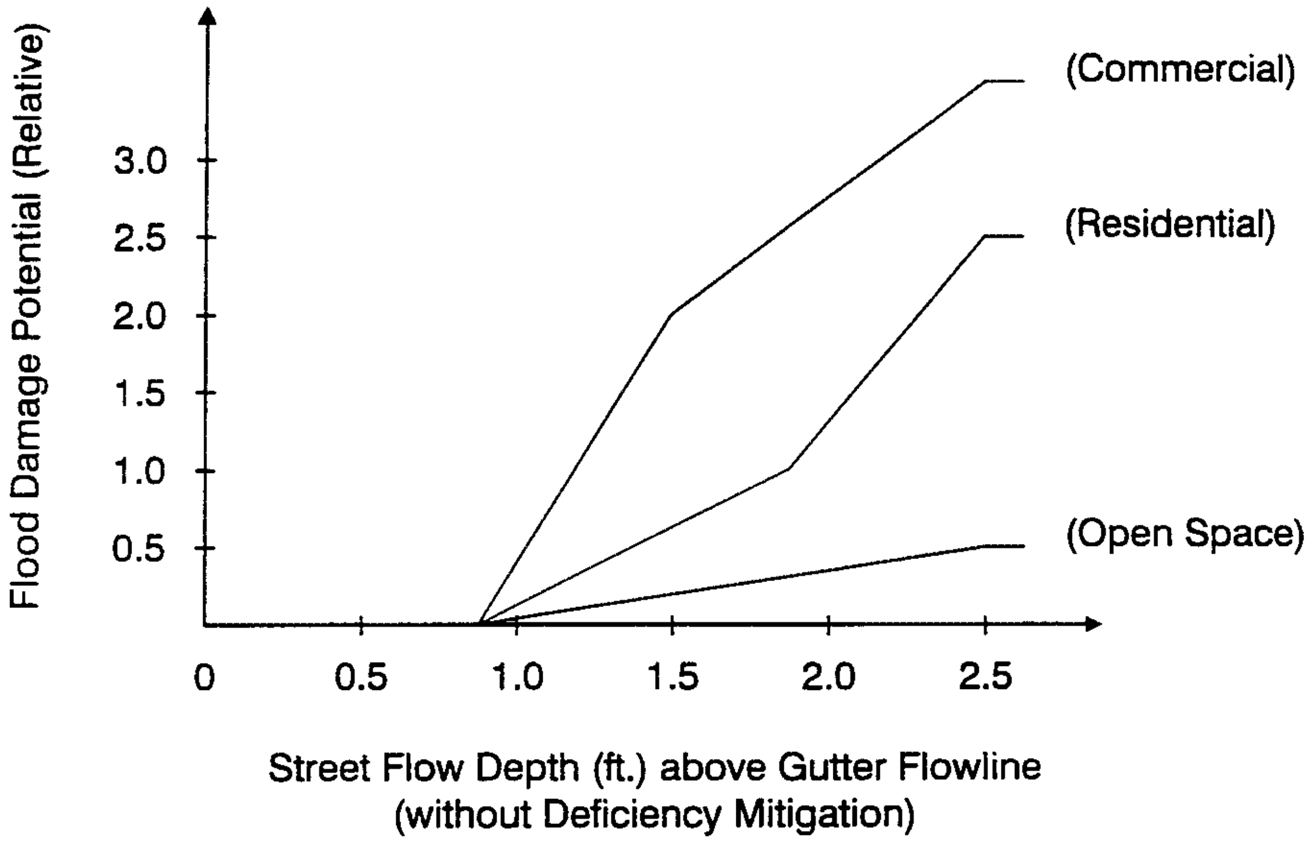

FIGURE 2. FLOOD DAMAGE VS. STREET FLOW DEPTH

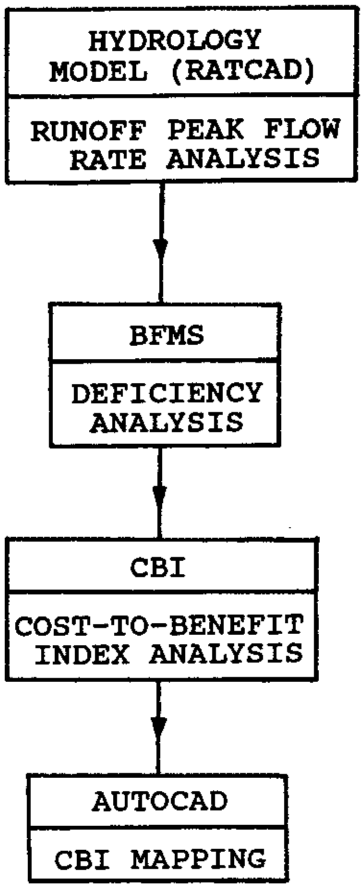

FIGURE 3. CBI MODEL INTERFACES WITH OTHER PROGRAMS

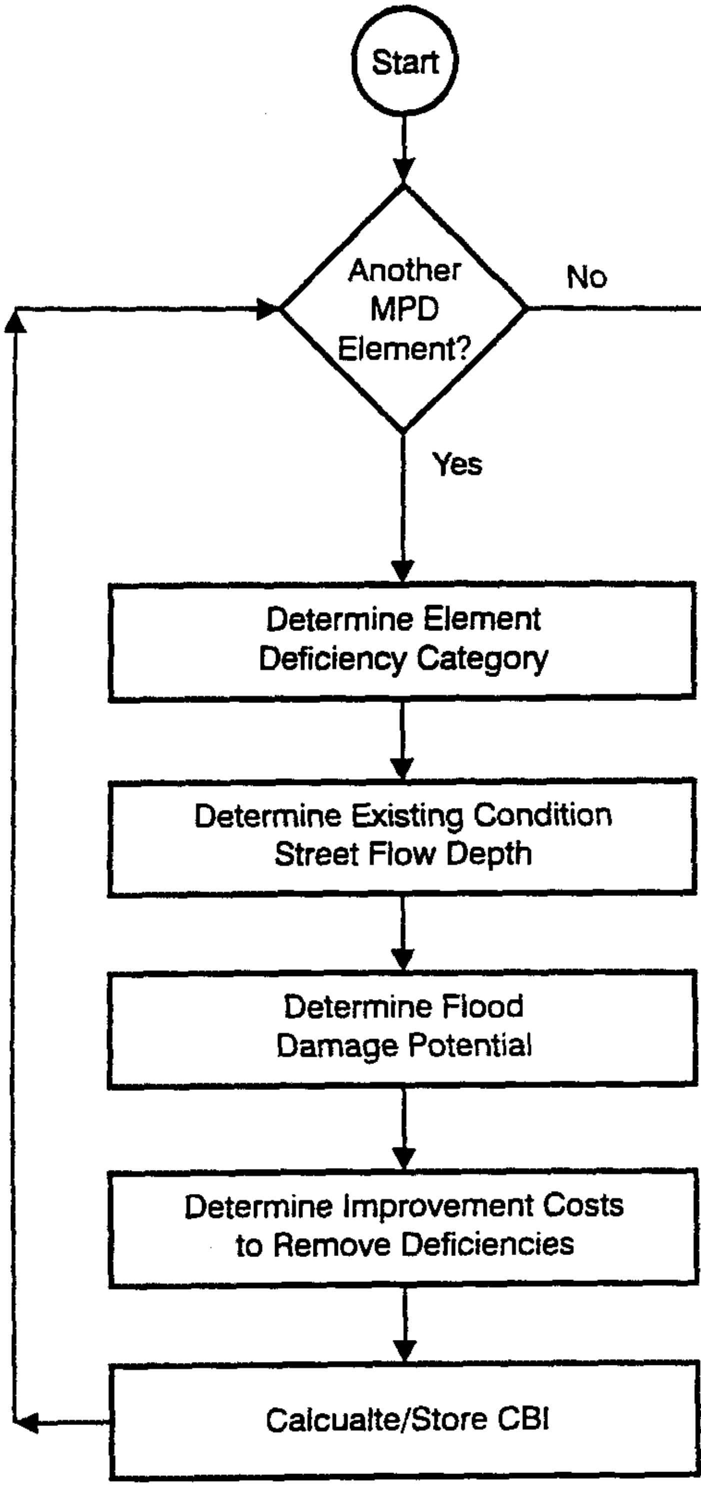

FIGURE 4. FLOW CHART OF CBI ANALYSIS PROCEDURE

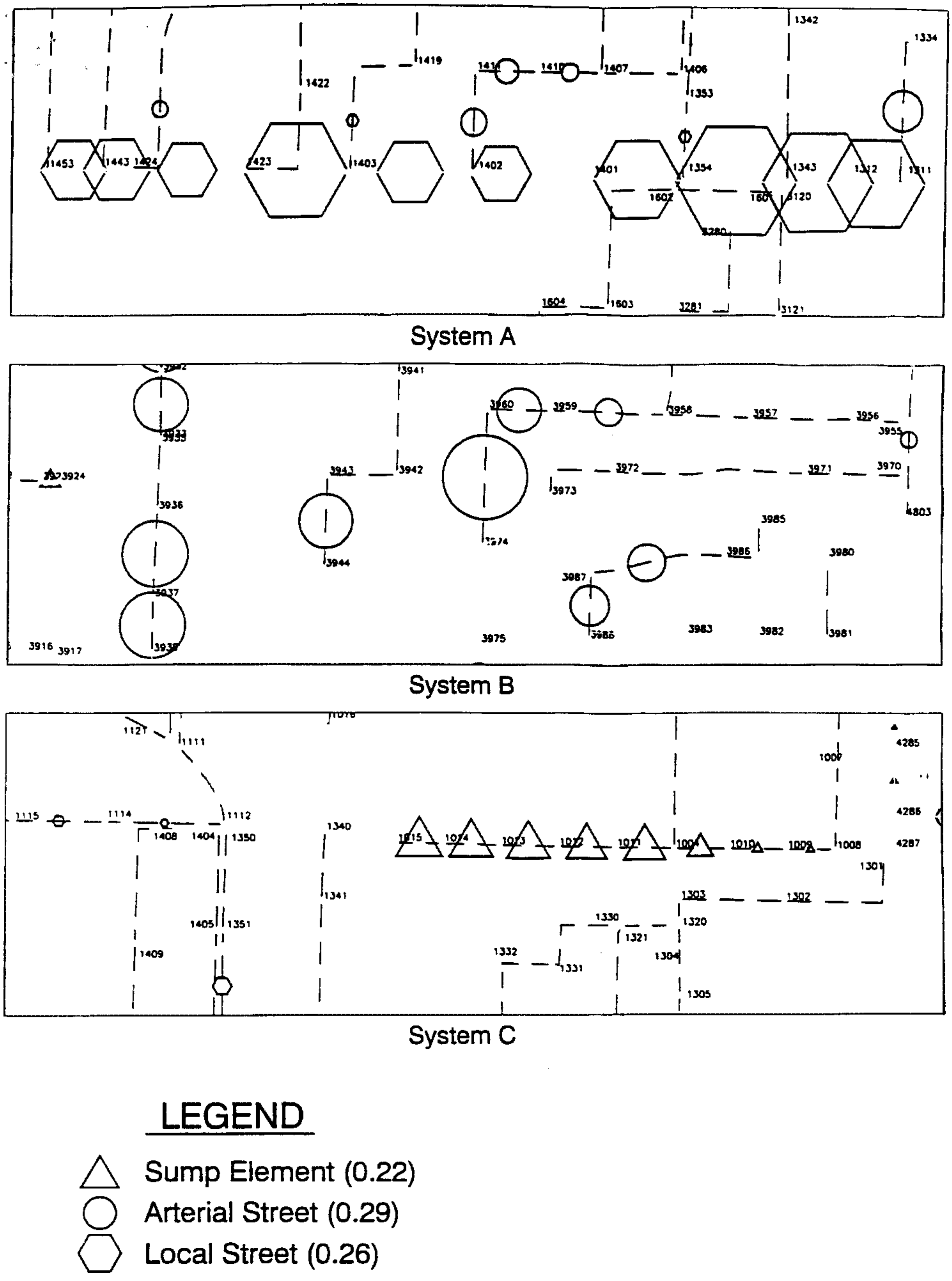

FIGURE 5. CBI INDEX, LEGEND AND GRAPHICAL DISPLAY