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APPLICATION OF COMPUTER PROGRAMMING IN THE DESIGN OF SEWER NETWORKS FOR BIG CITIES

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M. Sc. THESIS

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INTRODUCTION

The methods of designing sewers have changed very little in the past 50 yrs. Engineers still use design charts and special slide rules to a large extent to select the proper pipe slopes, diameters, and alinement. The emergence of the hand calculator in the past 15 yrs or so has helped facilitate design; however, sewer design remains a tedious and time-con suming chore. It is the writers' opinion that the most ecnomical design of sewer system is often not obtained because engineers can afford to investigate only a few different design alternatives due to the labor involved. Furthermore, designers rarely have the opportunity to investigate the effects that the chosen design criteria, flows, and diameters have on the cost of a sewer network.

Engineers often unknowingly select improper slopes and diameters for sewers, resulting in inadequate scouring velocities. When a pipe is laid at its minimum slope, the actual velocity in the conduit will be equal to, or greater than, the minimum scour velocity as long as the pipe is flowing at least half full. However, if the pipe is flowing less than half full, the velocity would be less than the specified minimum scour velocity. Since the actual velocity and depth of flow in a conduit cannot be found explicitly from hydraulic formula, designers have traditionally assumed that a sewer is flowing half full and have hence calculated the minimum slope solely by the simlified form of Manning's equation. This design approach can lead to deposition of solids, especially in the upper reaches of a sewer network where the flows and water depths are usually low or during early years of operation when peak flows are frequently less than design flows. Furthermore, engineers sometimes try to minimize excavation by choosing pipe diameters that are larger than necessary to convey the anticipated flows.Therefore, solids in oversized pipes may not be adequately scoured due to the low water depths and resulting low velocities if the pipes flow less than half full.

The difficulties in selecting the proper pipe slope and diameter can be overcome by designing sanitary sewers with a computer. Computer-aided design, unlike conventional sewer design, can easily calculate the actual velocity and depth of flow corresponding to any given flow, slope, pipe roughness, and pipe diameter. The exact velocity and depth cannot be determined even by a computer since two roots are found from Manning formula which indicates that the required diameter to carry a flow varies inversely with pipe slope; i.e., an increase in slope reduces the required diameter. Therfore, a trade-off between diameter and slope exists. Since excavation depth is generally associated with pipe slope, the basic cost trade-off in design is between diameter and excavation depth. If a small diameter pipe is selected, it must be laid on a steeper slope than a larger diameter pipe and thus requires deeper cuts.

Conversely, flatter slopes can be used to reduce excavation, but they requir larger pipe sizes.

Since pipe cost and excavation cost are not linearly related, there is no simple method to find the least-cost design for a sewer network. Becuse of the numerous combinations of pipe slopes, diameters, and water depths that can solve manning equation, engineers can investigate only a few combinations that would lead to feasible design without violating any of the constraints set by the design criteria. The major shortcoming with the traditional sewer design approach is that decisions are made on combinations of pipe slopes and sizes without fully analyzing the network cost implications. Since designers investigate only a few combinations, many superior and more ecnomical designs may be overlooked.

By using a heuristic computer program, an engineer can quickly investigate many different design alternatives in fraction of the time it would take using traditional methods. The designer can find the combination of pipe diameters which gives the most economical overall cost, without violating any of the design criteria.

These problems can be alleviated by using computers to design sanitary sewer networks.

The proposed program (SAYD) was used to evaluated, redesign and design of sewer network for existing city.

The ability analysis of (SAYD) program indicated that:

- Sewer design was relatively sensitive to area zone served or to flow variation.

- Save alot of design time.

A proposed program named (SAYD) for sewer network design has been developed for the personal computer HP86B

(SAYD) is a linear program that attempts to find the design of a sanitary sewer network or trunk pipeline.

The program computes min., max. velocities, water depths, pipe slopes, invert and ground elevations, max., min., av. flows, sewer lenghs and diameters.

CHAPTER ONE

REVIEW OF LITERATURE.

Recently , sewer design programs have been developed to operate on microcomputers. These programs attempt to find good but not necessarily globally optimal least costly designs.

Some of these programs are time-consuming to use since they can design only one pipe at a time instead of a whole network in a single computer run. To overcome these limitations, it would be highly desirable to develop a powerful program for microcomputers that can quickly accomplish an economical design of sewage network and study the effect of the parameters on the cost of a sewage network.

The simplest of computerized design procedure is design by trails. DeCicco et. al. [21] applied this technique in 1966 to the Merrick Harbor area in Nassan County, New York. The reported computerized procedure for the design of sanitary sewers collections system is believed to offer a significant improvement over traditional engineering approaches to such work.

DeCicco believes that the system developed and tested in the design of the Merrick Harbor Collection District has demonstrated that computerization of this kind of engineering work is not only feasible but may offer the only answer to the current need to balance increased work loads in this area and available technique man power.

Another trial procedure which tried to optimize the system link by link used for the trunk lines of the sewage network of Lao Panlo, Brazil. A computer program selected the min slope with the smallest sewer if could take flow at min. velocity. If the minimum slope was greater than the ground slope, then the program increased the pipe size, otherwise it laid out the sewer parallel to the ground. Many factors enter into the cost picture- depth, size, slope ... etc.

In South Africa, Barlow [6] used this technique to design the networks link by link. Using the Darcy-Weisbach equation, he "defined maximum and minimum slopes for different pipe sizes. Checking with the ground slope he searched for the optimal diameter. Having pipe sizes and assumed trench depths, he calculated the cost of each link, using a non-linear cost function. However, this method is the same as laying pipes parallel to the ground.

Therefore, problems would appear when designing a network on flat ground or other terrain where it is possible to have a pipe system parallel to the ground . Barlow [6] used another search technique, the shortest route algorithm, to trace the optimal layout of a waste water collection network. Both his objective (cost) function and the way the shortest route algorithm was utilized received much criticism. For example, Heggie [34] found the cost function "possibly incorrect" while templeman [75] suggested that this function could not be found unless the collection system was designed.

Another example of the search technique is liebman's [45] heuristic method for the generation of a layout. His method is based on a computer search technique which improves upon a given layout. He cited the major drawbacks of his method as being its lack of consideration of flow conditions and it's limitation to networks composed of links of equal capacity or diameter. He considered the selection of an optimal sewer layout from a network of interconnected nodes, but was unable to resolve this problem when various pipe sizes, or detailed hydraulic considerations, or both, were included.

A popular approach to the sewer problems using M.P. has been dynamic programming. Voorhees [3] developed D.P. algorithm for the design of wastewater collection networks. the algorithm generated two networks are downstream starting from the first manhole , one upstream starting from the sink. the available pipe sizes and costs were read in as inputs into a computer program.

Marrite and Bogan [44]. They defined the manholes (nodes) as stages, the conduit size, invert elevations and cumulative cost to the node as state variables; and the conduit size and existing invert elevation at the manhole as decision variables. The transformation between stages was given by the hydraulic model, a policy was feasible solution set for the system, and the optimal policy was the least-cost solution set.

Walsh [81] defined upper and lower boundaries for slopes and used increments between these boundaries as possible hydraulic slopes, while Merritt used minimum allowable hydraulic slopes for different pipe sizes. Walsh was less explicit in defining his dynamic programming terms.

He generated different trees downstream starting at the first manhole , with different invert elevations at the sink.

David Parr [2] considers in his study a method by which sewer discharge can be accurately determined at a flow section from a depth measurement and single velocity measurement along a vertical passing through the center line of the sewer for uniform open channel flow conditions. This method is called the point-velocity discharge measurement (P V D M) method and falls under the general classification of slope-area methods. A comprehensive of sense of laboratory experiments were performed to establish discharge equations based on Manning's formula for various degree of fullness. Two types of experiments were performed .

Experiment where in manning's "n" was measured for the pipe and experiments where in velocity distributions were measured along the vertical center line of the pipe.

The method proposed here, however, is based on a family of empirical velocity distribution curves that are dependent on the relative depth of flow. The distributions were used to formulate a general discharge relationship that can be used for all circular pipes with fully turbulent open channel flow.

The measurement method discussed here in should provide an accurate, economical method for monitoring sewer flow.

The purpose of this thesis is to discuss the advantages of computer aided design and illustrate the program's applicability and capability.

CHAPTER TWO

HYDRAULIC SEWER DESIGN

Sewage in sewer made up of 99.9% of water with only 0.1% of mineral or organic matter having specific gravity a little more than 1.0. In the hydraulic design of sewers, therefore, sewage and water considered identical.

The flow of sewage in sewers occurs under two conditions:

I) Under gravity (the flowing liquid which is thus exposed to atmosphere) as in open-channel, or in partially full pipe.

II) Under pressure as in closed channel or full pipe (rising main).

2.1 HYDRAULIC FORMULA:-

Gravity sewers are usually designed using hydraulic formula, which were originally developed for flow in open channels.

These formula that show the relation between the discharge, velocity and friction loss can be expressed(in metric units) as:

* $Q = AV$	(2/1)	CONTINUITY EQUATION
* $V = C(RS)^{(1/2)}$	(2/2)	Chezy formula