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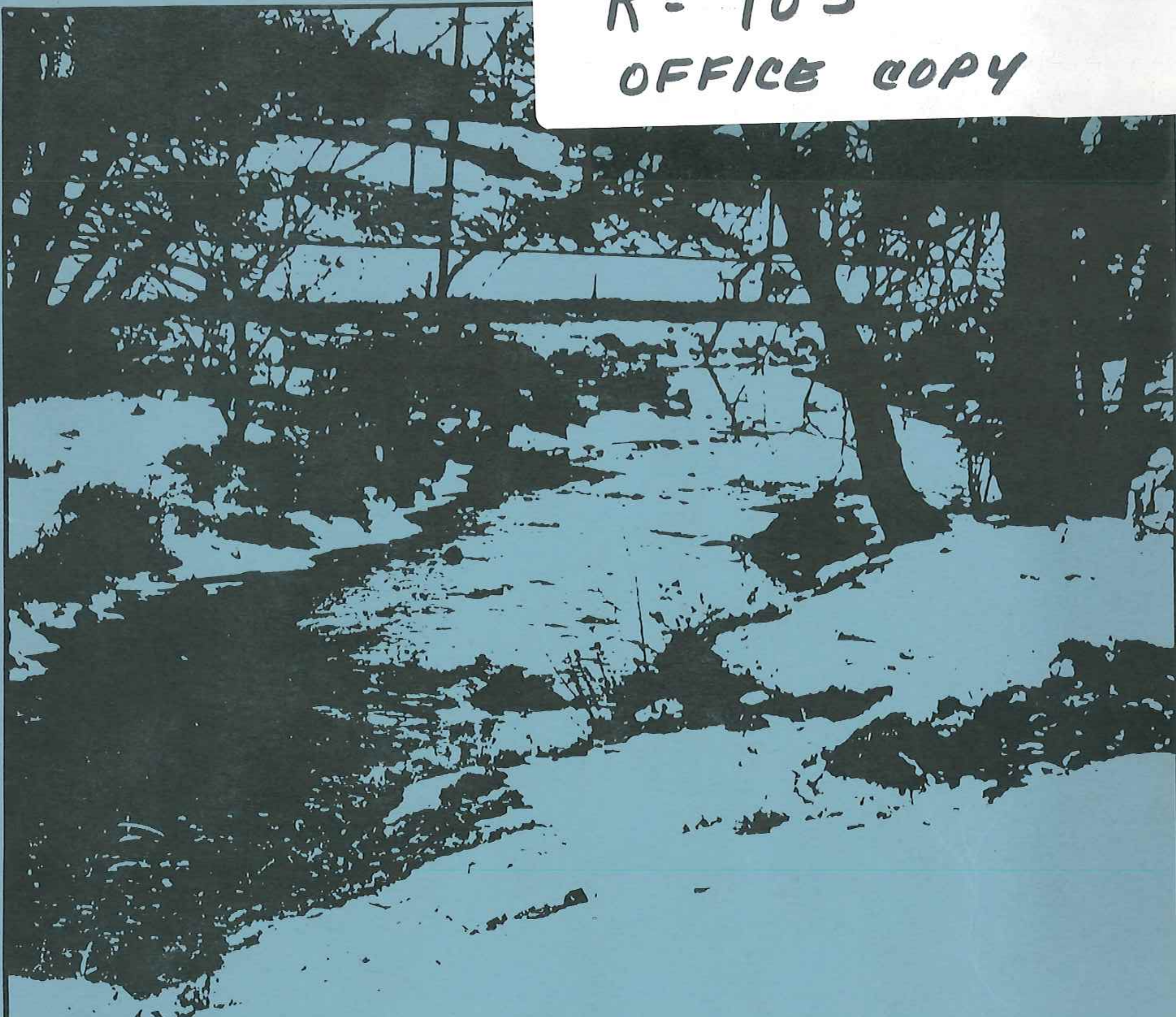

FLOOD LINE MAPPING STUDY

LITTLE RIVER WATERSHED

ESSEX REGION CONSERVATION AUTHORITY

DILLON

M. M. DILLON LIMITED

consulting engineers and planners

BOX 219, STN. K, TORONTO, ONT. M4P 2G5 • (416) 482-5656 • CABLE: DILLENG, TORONTO, CANADA

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28 January 1977

Essex Region
Conservation Authority
10 Talbot Street South
P.O. Box 400
Essex, Ontario

Attention: Mr. R.C. Read
Secretary Treasurer

Flood Plain Mapping Study
Little River Watershed

Gentlemen:

We take pleasure in submitting the results of our flood plain study on the Little River Watershed.

The report contains flood elevations resulting from a Hurricane Hazel and a 1 in 100 year type flood centered over the watershed.

Although these elevations indicate that a large portion of the land would be inundated by these two storms, a test section selected along the River proved that improvements to the channel could substantially reduce the levels of flooding.

It is hoped that the information provided in this report will assist the Authority in adopting a suitable watershed management program for the Little River.

We acknowledge with gratitude the co-operation and assistance received from the Authority and City of Windsor representatives.

Yours truly,

M.M. DILLON LIMITED

L.G. Eansor, P.Eng.
Project Director

F.I. Lorant, P.Eng.
Project Manager

LITTLE RIVER FLOOD PLAIN REPORT

1. INTRODUCTION

The following study was commissioned by the Essex Region Conservation Authority and carries out a flood plain investigation on the Little River extending from the Detroit River (Lake St. Clair) to the southern boundary of the City of Windsor.

The purpose of the flood plain study is to determine the effect of specified storms within the Little River watershed. The results of the study will provide input into future studies to investigate the alternatives to reduce or possibly eliminate danger of flooding at existing developments, and prevent flooding at proposed new developments. Flood plain studies are the essential first step in preparing long-term plans to regulate development within areas susceptible to flooding. Such long-term planning is carried out in co-operation with municipal and provincial authorities. In Ontario, under the Conservation Authorities Act, only Conservation Authorities can regulate flood plain development. This Act states that an Authority, such as the Essex Region Conservation Authority, may make regulations applicable to the areas under their jurisdictions as follows:

> "Prohibiting or regulating or requiring the permission of the Authority for the construction of any building or structure in or on a pond or swamp or in any areas susceptible to flooding during the regional storm, and defining regional storms for the purposes of such regulations".

"Prohibiting or regulating or requiring the permission of the Authority for the placing or dumping of fill of any kind in any defined part of the area over which the Authority has jurisdiction in which in the opinion of the Authority the control of flooding or pollution or the conservation of land may be affected by the placing or dumping of fill".

The main items in the Terms of Reference are as follows:

1. Identify developed areas and the areas of potential development that are in the flood plain.

2. Investigate available information on hydrology and geology for the study area.

3. Carry out an inspection of existing structures to determine their effects on high flows.

4. Investigate future development plans and their effect on runoff.

5. Establish design flood criteria and obtain Conservation Authorities Branch approval (the larger of 1 in 100 or Hurricane Hazel).

6. Carry out backwater calculations based on the design flood data with the use of a computer.

7. Prepare flood plain maps at scale 1" = 100' showing water levels derived from routing the design flood for existing conditions.

8. Advise the Authority of the areas requiring possible flood control works and the effect of such works relative to existing developed areas.

2. PAST STUDIES

In June 1966, M.M. Dillon Limited carried out a preliminary storm drainage report for the City of Windsor on the Little River drainage area. The Report indicated dike height and minimum channel sizes for the lower portion of the Little River. In 1969, G.V. Kleinfeldt and Associates prepared a plan of channel improvement from the CNR tracks to E.C. Row. In 1975 construction of channel improvements from the CNR tracks to Lauzon Road was carried out.

3. REGIONAL DESIGN STORM

The regional storm used to establish flood lines has been determined by the Ministry of Natural Resources based on a probable meteorological occurrences. The regional storm assigned within the Essex Region Conservation Authority is the Hurricane Hazel storm except for areas which are susceptible to flooding from Lake St. Clair, Detroit River or Lake Erie. The design criteria adopted for the lakes combined the water level due to the occurrence of mean monthly lake levels and wind setup having a total probability of being equalled or exceeded during any year of 1 per cent. The design criteria adopted for the Detroit River is the instantenous water level having a 1 per cent probability of being equalled or exceeded during any year.

The regional storm (Hurricane Hazel) has been analyzed by the

Conservation Authorities Branch of the Ministry of Natural Resources. The total duration of the design storm is 12 hours while the total precipitation is 8.31 inches. During the first 36 hours, the total precipitation is 2.90 inches. The distribution for the last 12 hours is set out in the following table:

37th hour	0.25 inches
38th hour	0.17 inches
39th hour	0.25 inches
40th hour	0.50 inches
41st hour	0.66 inches
42nd hour	0.50 inches
43rd hour	0.91 inches
44th hour	0.50 inches
45th hour	0.50 inches
46th hour	2.08 inches
47th hour	1.49 inches
48th hour	0.50 inches

The above rainfall values refer to a drainage area of 10 square miles or less. The total drainage area of Little River is 23.6 square miles. The regulations states that when the equivalent circular area upstream of a point of interest on the watercourse exceeds 10 square miles, the total Hurricane Hazel rainfall should be reduced as shown in the following table:

Equivalent Area	Total Rainfall
0 - 10 square miles	8.31 inches
11 - 17 square miles	8.24 inches
18 - 25 square miles	8.16 inches
26 - 35 square miles	8.07 inches
36 - 45 square miles	8.00 inches

At present, three watershed classes are recognized by the Ministry of Natural Resources when applying the regional storm regulations to urban development. These three classes are:

1. Watershed less than 0.5 square miles in area. Drainage is considered to be a municipal responsibility.

2. Watersheds of 0.5 to 1.0 square mile in area. These are considered low hazard areas.

3. Watershed of more than 1.0 square mile in area. These areas are considered high hazard lands.

In low hazard watersheds, subdivision lot lines may extend into the regional storm flood plain. This is not permitted in high hazard watersheds. For drainage areas of one square mile or greater, no line in a subdivision is allowed to encroach beyond the regional storm flood lines. No fill may be placed inside the flood line unless done in such a way that the existing stage storage and hydraulic characteristics are maintained taking fill out to the same elevation as it was put in.

4. DESCRIPTION OF THE WATERSHED

The Little River watershed covers an area of 23.6 square miles and stretches southerly from Lake St. Clair for a distance of 8.5 miles. The boundaries of the watershed are shown on Figure 1.

The gradient of the stream is flat, and has a uniform slope of 2 feet per mile throughout. Lake St. Clair levels frequently extend from the mouth up to the Canadian National

Railway bridge. This area is extremely flat with local drainage being provided by pumping from the developed area and by gravity from the undeveloped portion. In the past, the creek from the mouth to the Canadian National Railway was dredged to an approximate dimension of 50 feet in width and 10 feet in depth. The spoil was then dumped on either side of the banks forming rather substantial dikes. South of the CNR tracks, the land rises gradually from elevation 580 to 625 providing drainage to the Little River. The north-eastern half of the watershed between the CPR and Lake St. Clair has been urbanized at a rapid pace. South of the CPR the primary land use is agricultural.

In the past, flooding on the Little River from high lake levels has been confined chiefly to flooding north of the Canadian National Railway. A brief survey of residents living adjacent to the Little River south of the Canadian National Railway revealed that the Little River frequently overflowed its banks during spring runoffs and summer thunder-storms. This flooding has been relatively minor due to the small amount of development adjacent to the river south of the Canadian National Railway.

Flood peaks south of the Canadian National Railway have been reduced, in part, because of ponding of excess rain waters on agricultural lands and constrictions caused by inadequate channel capacities and bridge sizes.

The watershed boundary of Little River as shown on Figure 1 was determined by a combination of 1" = 100' contour maps and air photo interpretation. In order to calculate the design flows the watershed was divided into 36 sub-areas that make up the various internal drain systems. Table 1 summarizes the subdrainage areas used in the calculations.

5. SOIL AND LAND USE

Generally the watershed consists of a stone free clay or sandy clay type soil having high runoff potential. However, there is an area of well drained gravelly loam soil running approximately parallel to Walker Road through the south portion of the basin.

Presently, the watershed has two major land use areas. Land to the south of the Canadian Pacific Railway is generally used for agricultural purposes while the area between the Canadian Pacific and Lake St. Clair is rapidly being developed into residential areas with some industrial sites in the north. For the purposes of estimating runoff, it was assumed that the entire drainage basin will be developed according to the Official Plan of the City of Windsor and the Zoning By-laws for the Township of Sandwich South.

The estimate of runoff from the specified rainfall was carried out by the hydrologic soil complex method developed by the United States Department of Agriculture Soil Conservation Service. In this method the direct runoff is estimated by the use of runoff curve numbers which are related to soil groups and land use. Four hydrologic soil groups have been defined by the Soil Conservation Service. These are:

- A Low Runoff Potential
- B Soils With Moderate Infiltration Rates
- C Soils With Slow Infiltration Rates
- D High Runoff Potential

The combination of land use description and hydrologic soil group provides a curve number which in turn determines the amount of runoff from the selected design storm.

An important factor in the determining of runoff from a particular storm is the condition of the ground on which the rain falls. This antecedent rainfall condition for unpaved areas can significantly influence the amount of runoff. Antecedent rainfall is defined as the amount of rainfall in the 5 day period preceeding the particular storm used for design purposes. The Soil Conservation Service has identified three classes of antecedent conditions:

Conditions I, II and III

In the Little River watershed study, Conditions II and III have been used which are defined as follows:

Condition II: the average case for floods including the 1 in 100 year flood.

Condition III: the condition when heavy rainfall occurs during the 5 days previous to the given storm.

Using the parameters of land use and soil type, runoff curve numbers were calculated for each subdrainage area in the Little River drainage basin. Most of the soil groups within the watershed fall either under group C or group D, while the land use varies from industrial to parks and residential. Table #2 indicates the typical curve numbers recommended by the Soil Conservation Service which were used in the Little River study. The table refers to Condition II for average floods. Table #3 is included to convert Condition II curve numbers to Condition III.

A detailed calculation of runoff curve numbers for all subdrainage areas is shown in Table #4. This table shows the subdrainage area number, the soil complex type and percentage, the land use type and percentage and the resulting curve numbers for Condition II and Condition III. These curve numbers are summarized in Table #1.

6. MAPPING AND SURVEY

Aerial photography was taken during the spring of 1975 by Kenting Earth Sciences Limited at a scale of 1:5000. This scale is suitable to produce fairdrawn topographic maps at a scale of 1" = 100' with 2 foot contours and 1 foot machine interpolations.

The topographic mapping was carried out in October 1975, after a decision was made to exclude Sandwich South from the Flood Plain Mapping Project. At this time J.D. Barnes Limited, Surveyors, started the mapping and completed delivery of the pencil manuscripts by mid January 1976.

During our routine checking of the mapping, it was discovered that some spot elevations on the maps were outside the tolerances allowed by the Canadian Association of Aerial Surveyors. These specifications require that 90% of all contours be accurate within ± 50% of the 2 foot contour intervals and that spot elevations be accurate within 6".

Consequently, in May 1976, new aerial photographs were prepared at the same scale. The revised contour maps were prepared by Kenting Earth Sciences Limited and completed in June 1976. The new recompiled mapping meets the specifications.

More than 60 structures have been surveyed and photographed within the watershed.

The inventory which was handed over to the Authority includes the following items for each structure:

Location
Type
Size
Road Elevation
Invert Level
Obvert Level
Average depth of Flow

Other observations which would assist the designer in calculating the hydraulic performance of the structure have also been included. It is noted that most structures would be overtopped by a Hurricane Hazel type storm.

7. FLOOD CALCULATIONS

7.1 Introduction

All flow calculations were carried out using the HYMO hydrological modelling program on the latest IBM 370 computer. This computer model incorporates the effect of available storage within the drainage basin. The program develops runoff hydrographs using the Soil Conservation Service method of triangular unit hydrographs. These hydrographs are routed through the watercourse using the variable storage coefficient flood routing method revised to account for variation in water surface slope during the flood. In establishing the regional flood elevation, criteria were adopted from the Conservation Authorities Branch as follows:

1. Regional flood calculations were based on future land use in the watershed. This provides significantly higher flows due to the future urbanization, drainage and deforestation.

2. Flow calculations at any point assume that the flows are unrestricted, and no allowance has been made for retardation behind bridges and other structures. This was assumed in case existing structures are removed or replaced by a structure with sufficient capacity to pass the regional storm.

The effects of two different floods have been estimated for the study: 1) Hurricane Hazel and 2) 1 in 100 Year Flood.

The return period of the Hurricane Hazel storm is not known, but a comparison of total precipitation indicates that the

Hazel value is approximately twice as much as the 1 in 100 year precipitation value.

By definition, the 1 in 100 year storm could occur once every 100 years on the average. However, given a particular return period, it is not at all clear what risk is being undertaken in a specified engineering project. The design return period cannot be realistically discussed without the description of the following three components:

1. Design Return Period
2. Design Life
3. Risk of Failure During Design Life

The design life depends on social and economic factors rather than on hydrological ones. If loss of life is not expected, and all benefits and losses can be expressed in monetary terms, the literature recommends a design life of 50 years as a realistic figure. Assuming, therefore, that the development along the flood plain has an expected project life of 50 years the following table indicates the design return period and corresponding risk of failures:

Risk	Design Return Period
1% risk	4,977 years
10% risk	475 years
22% risk	200 years
25% risk	174 years
39% risk	100 years
50% risk	73 years
62% risk	50 years

For example, assuming that development in the flood prone areas is designed for a 50 year life, and that a 10% risk of failure of that development is permissible, then we would require a 475 year return period design flood to meet the specified risk. Similarly, a 100 year design return period would provide a 39% risk of failure for an expected project life of 50 years. Even a 1000 year design return period flood hazard has a 5% risk of being equalled or exceeded in a 50 year period. Risk cannot be eliminated in practice. It can only be reduced to an acceptable level.

For the 1 in 100 year flood calculations, the Windsor airport rainfall data were used. A total of 4.18 inches is the estimated 1 in 100 year rainfall. The rainfall distribution of the 12 hour duration storm was prepared as set out in Design of Small Dams. The rainfall values recorded from 1946 to 1973 at Windsor A Station were used, and are shown in the following table:

Rainfall in Inches

Return Period In Years	5 Min.	10 Min.	15 Min.	30 Min.	1 Hr.	2 Hr.	6 Hr.	12 Hr.	24 Hr.
2	0.40	0.59	0.70	0.94	1.18	1.39	1.71	1.96	2.15
5	0.52	0.75	0.91	1.28	1.57	1.82	2.28	2.55	2.73
10	0.60	0.86	1.04	1.51	1.83	2.09	2.65	2.95	3.12
25	0.70	0.99	1.22	1.80	2.16	2.45	3.13	3.45	3.61
50	0.77	1.09	1.34	2.01	2.40	2.71	3.48	3.82	3.97
100	0.85	1.19	1.47	2.22	2.65	2.97	3.83	4.18	4.33

7.2 Time of Concentration

The time of concentration values necessary for the flow and flood line calculations were calculated first by the formula $T = \left(\frac{11.9\ L^3}{H}\right)^{.385}$. The results appeared to be too short when compared to observed values. Corresponding peak flows were as high as 580 cfs per square mile.

After the presentation of the draft report to the Water Management and Land Use Advisory Board of the Essex Region Conservation Authority in July 1976, the Board approved the setting up of a small technical review committee to review the study and its implications in details. This committee was made up of representatives from the Essex Region Conservation Authority, the City of Windsor, the Ministry of Natural Resources and the Consultant.

At the first meeting of the steering committee held in August 1976, the Consultant was instructed to carry out two further studies on the Little River; 1) to derive time of concentration values from recorded hydrologic data and 2) to investigate the feasibility of containing the regional flood within an improved channel and/or by allowing placing of fill on both sides of the flood plain.

7.3 Analysis of Grand Marais Gauging Station Data

The recorded flow data was analyzed to obtain time lag and time of concentration values. In the original flood plain study, theoretical values were calculated by using the above formula. While this is an accepted method in Ontario, it was felt that the formula would yield rather unrealistically low values for time of concentration in the flat Essex terrain.

Three gauging stations were in operation during the period 1967 - 1971 in the City of Windsor to record river levels. Two of those stations were located at South Cameron Boulevard and Huron Church Road along the Turkey Creek (Grand Marais Drain). The third one was located at Malden Road and installed to measure flood levels at the major tributary. Out of the two gauging stations - both of which stopped operating after 1971 - Station #1 (South Cameron Boulevard) was selected for the analysis. Unfortunately, only a limited number of low flow current meter measurements was available for the station, which was inadequate to provide a rating curve. For this reason a theoretical rating curve was extrapolated beyond the observed low flow data. The extrapolation was carried out after separating the cross-section area from the velocity component of the discharge formula $Q = AxV$. This method allowed the use of actually measured cross-section areas at the gauging station and extrapolated the velocity values only. By then multiplying the cross-section areas and the extrapolated velocity values, a rating curve was developed for the gauging station at South Cameron Boulevard.

A search of all available flow charts identified two storms which were most suitable for hydrograph analysis. The calculated lag time values were approximately four times greater than the values given by the empirical formula. When these new results were compared with the lag curves prepared by the Conservation Authorities Branch more than 10 years ago, lag values were found to be within the average Ontario lag values shown on Figure 2. This confirmed that the calculated lag values using the formula are not as appropriate for the flat low lying Essex watersheds.

7.4 Flood Calculations

A new set of Little River flow calculations was prepared using the lag time relationships shown on Figure 2.

Flow summaries including Hazel and 100 year flood peaks are shown on Table 5. Generally, Hazel peak flow values are 2 to 3 times larger than the 1 in 100 year flood peak flow values.

Backwater elevations for the Hazel and 100 year floods are shown on Table 6. The difference in the two water levels is generally 2 to 3 feet except in the vicinity of bridges where Hazel levels can be 5 feet higher than the 1 in 100 year flood levels.

7.5 Channelization of Little River

The original flood plain calculations indicated a uniqueness of the Little River flood plain: although the flood limits based on Hurricane Hazel flows are extremely wide, and in some instance merge with adjacent watersheds, the efficiency of the flow over the flooded land is extremely low due to the low velocities and high friction factors.

A test section of 6,700 feet in length was selected between Lauzon Road and E.C. Row to investigate the effect of future channelization. Two improved channel sections were tested. These were both unlined with three to one side slopes: alternative A with a 50 foot bed width; alternative B with a 100 foot bed width.

The 50 foot bed width would not contain the Hazel flow but it would provide for the conveyance of Hurricane Hazel flows at a surface water elevation approximately 2 feet below the Hazel surface elevation based on existing conditions. This proves that filling outside the improved channel does not create higher flood levels than if the land is left at its present elevation. A wider, 100 foot, improved channel would still not be able to contain the Hazel flow, but it would lower the Hazel flood surface elevation by approximately 3 feet below the flood surface elevation under existing conditions. Generally, the flood elevations of the 50 foot and 100 foot channels are within 1 to 4 feet above the existing ground levels.

The same bed width channels have also been tested with dikes to investigate the possibility of reducing the flood plain width. This resulted in a slightly higher Hazel flood level, but still below the Hazel elevation based on existing conditions. Figure 3 indicates alternative A and alternative B for diked and non-diked sections.

Similar calculations were carried out based on the 1 in 100 year flood. These flood levels are approximately 2 to 3 feet above the existing ground level. An improved 50 foot bed width channel would lower the 1 in 100 year flood level by approximately 5 feet and contain the flow within the channel. Similarly, a 100 foot wide channel would reduce the 100 year flood by more than 6 feet and contain the flow within the channel. Figure 4 shows the 50 foot and 100 foot alternatives with 100 year flood levels. For the 1 in 100 year flood no dikes are needed to contain the flood levels.

The reduction in flood plain storage due to channel improvements could influence the downstream discharges. The test section showed that, for Hurricane Hazel values, the reduction in flood plain storage resulted in an average of 5 per cent increase in flow. The effect of this small increment on flood elevations is insignificant.

7.6 Two Zone Concept

The construction of the improved channel with or without dikes would permit fill outside the flood limits. This solution is very similar to the two zone concept used in the United States and in some Ontario locations and is shown on Figure 5.

Basically, this method accommodates the need for retaining sufficient flood carrying capacity while allowing development outside on the fringe areas. The first need is accommodated by retaining the channel of the stream and as much of the flood plain adjacent to the stream as is needed to convey the regional design flood. This area is commonly called the floodway. Typical land uses permitted in these areas include open space, agriculture, recreation and sometimes limited parking. Filling and structures not associated with open space use are not permitted in the flood plain.

The needs of man can be accommodated by acquiring areas of flood protection outside the flood plain which could be subject to inundation. However, in times of flooding, these higher areas are associated with shallow flooding depth and slow velocities. These areas, sometimes called flood fringe areas, can be filled above the elevation of the design flood to permit development.

Although any filling or building on the flood plain will result in increased flood heights, if such development is limited to areas outside the natural floodway, the increases in flood heights are generally too small to calculate. When existing development, comprehensive land use plans, social and political considerations require use of part of the flood plains, it is necessary to determine the changes in flood elevations which will be attributable to the planned encroachment. Increases in flood elevations resulting from filling and developing within the flood fringe areas, are usually limited to increases between 0.2 and 1.0 foot.

Engineering calculations for the design of a floodway are carried out in two stages. In the first phase, the water surface elevation due to the selected design storm is calculated before any encroachment is permitted on the flood plain. A second set of calculations assumes a limit of encroachment and the entire area outside the encroachment limits is assumed to be filled. A new design water surface elevation is calculated which will now be confined between the new encroachment lines. This new elevation reflects the flood stage that would be created by the same flood in the future.

The design frequency used for floodway calculations should provide adequate safety for the residents situated in or adjacent to the flood plain. Experience showed that, in the United States, the design frequency is at least the 1 in 100 year flood with 1 to 3 feet of freeboard added as a factor of safety in determining the minimum level required for flood proofing measures. Little River flood plain calculations indicated that the difference between the 1 in 100 year flood and Hurricane Hazel flood can vary from a few inches to as much as four feet. The large differences are usually immediately upstream of structures such as culverts and bridges with inadequate openings.

8. DESCRIPTION OF FLOOD PLAIN AREAS

8.1 Detroit River - Riverside Drive

Flood levels in this section are controlled by the Detroit River levels. These design water levels are based on the combined occurrence of mean monthly lake levels and wind setup having a total probability of being equalled or exceeded during any year of 1%. The estimated 1 in 100 year level for this location is 578.8. Road elevations along Riverside Drive east and west of the Little River Bridge are below this elevation. Therefore, high lake levels will back up upstream along Little River.

8.2 Riverside Drive to Little River Road

Although there is diking along the entire length of this reach, some flooding could occur on either side of the river during a Hazel flood. This is due to the fact that some portions of the dikes are not constructed high enough to prevent overtopping.

Available contour maps indicate that the dikes will contain the 1 in 100 year flood.

Flooding behind the dikes could still occur, because the general ground elevation is 576 to 577.5 which is below the 1 in 100 year Detroit design level.

8.3 Little River Road to the CN Railway

This reach is also diked along both banks.

Flooding during Hazel could occur behind the dikes due to overland flow and due to dike overtopping at four or five locations.

The dikes would contain the 1 in 100 year flood.

8.4 CNR - Tecumseh Road

This section has been improved recently but even the new section cannot take the Hazel flood. High flood levels are aggravated by the inadequate opening at the CN railway crossing.

The 1 in 100 year flood is contained within the improved section.

8.5 Tecumseh Road to Lauzon Road

This section has a partially improved channel but even the improved section cannot take the Hazel flood.

The 1 in 100 year flood is contained within the improved section and almost contained along the rest of the sections.

8.6 Lauzon Road to E.C. Row

This section of the Little River has not been improved and the capacity of the river is less than either the 1 in 100 year flood or the Hazel flood. Both floods would overtop the banks and spread along both sides of the river. The flood would cross Lauzon Road flowing east.

8.7 E.C. Row to CP Railway (Study Limit)

This section of the Little River has a very small capacity to discharge floods; consequently, both the 1 in 100 year and Hazel floods would overtop the banks.

Tributaries

All tributaries investigated have discharge capacities below the 1 in 100 or the Hazel flood; consequently, these floods overtop the banks.

9. RECOMMENDATIONS

Results of the flood plain calculations showed that large portions of the mapped area in the Little River watershed are flood prone. Preliminary investigation of alternative flood prevention methods such as diversion or storage showed that these are not suitable for the flat drainage area characterized by the Little River.

Channel improvements including widening, deepening, realignment, diking and the enlargement of existing structures are the most feasible corrective flood prevention methods recommended for the Little River.

For areas where the extent of flooding is minimal, the two zone development concept and flood proofing should be considered.

The main objective of this flood plain mapping study is to assist the Essex Region Conservation Authority and its member municipalities in reducing possible future flood damages. In order to help the Authority in achieving this goal, a list of suggestions and recommendations was prepared.

1. New development within the flood plain limits should conform to criteria laid down by the Ministry of Natural Resources and which is consistent with the uniqueness of the watershed.

2. The Conservation Authority and municipal officials should attempt to regulate runoff from new development outside the flood plain limit. This can be achieved by encouraging the use of new techniques

for controlling storm water runoff such as the use of porous concrete, on-site storage, etc.

3. Flood proofing of new and existing developments could be considered in some areas provided that stage - storage characteristics of the channel were not adversely affected. Such flood proofing measures have been tried successfully in other locations where low velocities (approximately 2 ft. per sec.) and shallow depths (approximately 1.5 feet) were predicted.

4. The Authority should advise Municipal, Railway and Highway Officials on the backwater effects of existing structures. Before the replacement of these structures is undertaken, the Authority should be given an opportunity to make comments on the size and arrangement of any new structures.

5. Annual inspection and cleaning of debris from the creek bed and culverts should be carried out.

6. Residents living near the creeks should be made aware of the possibility of floods occurring with magnitude greater than the capacity of the creek through an organized information and education program.

7. The Authority should continue its present efforts to study complete watersheds rather than just tributaries of each watershed. Aspects of flooding, low flow, water quality, soil erosion, urban and rural drainage should be considered in the watershed studies.

8. It is suggested that the flood plain maps and reports be reviewed annually in light of the extent of new upstream development, changes in bridge or culvert structures and the current guidelines provided by the Ministry of Natural Resources on regional storm design criteria.

9. A flood contingency plan for the Windsor area should be prepared in conjunction with municipal officials to reflect any new information arising from this flood plain study.

TABLE 1: LITTLE RIVER SUBDRAINAGE AREA DATA

Area Number	Area Square Miles	Time of Concentration (hrs.)	Soil Complex Curve Number Cond. II	Soil Complex Curve Number Cond. III
1	1.36	3.05	84	93
2	0.75	0.77	85	94
3A	0.16	1.85	92	97
3B	0.60	1.46	92	97
4	0.12	0.43	83	93
5	0.43	1.43	83	93
5A	0.46	1.24	83	93
6	0.31	1.24	89	96
6A	0.20	0.89	89	96
7A	0.04	0.61	79	91
7B	0.02	0.03	75	88
7C	0.01	0.20	78	90
8A	0.51	2.30	83	93
8B	0.12	1.10	83	93
8CA	0.81	2.09	83	93
8CB	0.90	2.35	83	93
9A	0.20	0.14	75	88
9B	0.30	0.50	80	91
9C	0.05	0.62	74	88
9D	0.05	0.42	74	88
10	0.19	1.15	90	96
10A	0.31	0.89	90	96
11A	0.35	1.23	91	97
11B	0.41	1.35	83	93
12	0.29	1.60	81	92
13A	0.33	2.16	78	90
13B	0.42	1.68	78	90
14	0.71	5.86	81	92
15A	0.42	2.08	78	90
15B	0.27	1.48	78	90
16	0.23	1.83	78	90
17A	0.77	2.11	78	90
17B	0.45	1.55	78	90
18C	0.58	1.75	78	90
18DA	0.64	2.57	78	90
18DB	0.64	2.17	78	90
18DC	0.48	2.02	78	90
19A	0.94	1.74	78	90
19B	0.63	3.52	78	90
19C	0.85	1.21	78	90
20	0.43	1.68	78	90
21A	1.02	9.58	76	89
21B	1.13	7.40	76	89
21C	0.88	5.29	76	89
22A	1.99	7.41	72	89
22B	0.90	3.71	77	89
23	0.02	0.52	78	90

TABLE 2: TYPICAL RUNOFF CURVE NUMBERS

(Condition II)

LAND USE DESCRIPTION	HYDROLOGIC SOIL GROUP A	B	C	D
Cultivated lands:				
without conservation treatment	72	81	88	91
with conservation treatment	62	71	78	81
Pasture or range land:				
poor condition	68	79	86	89
good condition	39	61	74	80
Meadow:				
good condition	30	58	71	78
Wood or Forest land:				
thin stand, poor cover, no mulch	45	66	77	83
good cover	25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.				
good condition: grass cover on 75% or more of the area	39	61	74	80
fair condition: grass cover on 50% to 75% of the area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential: Av. lot size / Av. % Impervious				
1/8 acre or less / 65	77	85	90	92
1/4 acre / 38	61	75	83	87
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Streets and roads:				
paved with curbs and storm sewers	98	98	98	98
gravel	76	85	89	91
dirt	72	82	87	89

For a more detailed description of agricultural land use curve numbers refer to National Engineering Handboook, Section 4, Hydrology, Chapter 9, Aug. 1972.

TABLE #3: CONVERSION OF CURVE NUMBERS

Curve Number for Condition II	Curve Number for Condition III
100	100
95	98
90	96
85	94
80	91
75	88
70	85
65	82
60	78
55	74
50	70
45	65
40	60
35	55
30	50
25	45
20	39
15	33
10	26
5	17
0	0

TABLE 4: DETAILED CALCULATIONS OF RUNOFF CURVE NUMBERS

Subdrainage Area (1)	Soil Complex Type (2)	Soil Complex % of Sub-Area (3)	Land Use % of (3) (4)	Land Use Type (5)	Curve Number (6)	(4) x (6) (7)
1	C	100	25	Industrial	91	2275
			15	Parks	74	1110
			60	Residential	83	4980
						8365/100
					CN II	84
					CN III	93
2	C	100	20	Industrial	91	1820
			75	Residential	83	6225
			5	Commercial	94	470
						8515/100
					CN II	85
					CN III	94
3A+3B	C	100	80	Industrial	91	7280
			20	Commercial	94	1880
						9160/100
					CN II	92
					CN III	97
4	C	100	95	Residential	83	7885
			5	Parks	74	370
						8255/100
					CN II	83
					CN III	93
5+5A	C	100	100	Residential	83	8300
						8300/100
					CN II	83
					CN III	93
6+6A	C	100	20	Residential	83	1660
			80	Industrial	91	7280
						8940/100
					CN II	89
					CN III	96
7A	C	100	40	Parks	74	2960
			60	Residential	83	4980
						7940/100
					CN II	79
					CN III	91
7B	C	100	96	Parks	74	7104
			4	Parking Lot	98	392
						7496/100
					CN II	75
					CN III	88

continued

Subdrainage Area (1)	Soil Complex Type (2)	Soil Complex % of Sub-Area (3)	Land Use % of (3) (4)	Land Use Type (5)	Curve Number (6)	(4) x (6) (7)
7C	C	100	60 40	Parks Residential	74 83	4440 3320 7760/100
					CN II CN III	78 90
8A	C	100	100	Residential	83	8300 8300/100
					CN II CN III	83 93
8B	C	100	100	Residential	83	8300 8300/100
					CN II CN III	83 93
8C	C	100	100	Residential	83	8300 8300/100
					CN II CN III	83 93
9A	C	100	85 15	Parks Residential	74 83	6290 1245 7535/100
					CN II CN III	75 88
9B	C	100	30 70	Parks Residential	74 83	2220 5810 8030/100
					CN II CN III	80 91
9C	C	100	100	Parks	74	7400 7400/100
					CN II CN III	74 88
9D	C	100	100	Parks	74	7400 7400/100
					CN II CN III	74 88
10+10A	C	100	90 10	Industrial Residential	91 83	8190 830 9020/100
					CN II CN III	90 96

continued

Subdrainage Area (1)	Soil Complex Type (2)	 % of Sub-Area (3)	Land Use % of (3) (4)	 Type (5)	Curve Number (6)	(4) x (6) (7)
11A	C	100	100	Industrial	91	9100
						9100/100
					CN II	91
					CN III	97
11B	C	100	100	Residential	83	8300
						8300/100
					CN II	83
					CN III	93
12+14 combined	C	65	100	Agriculture	78	5070
		35	15	Agriculture	78	410
			45	Residential	83	1307
			40	Industrial	91	1274
						8061/100
					CN II	81
					CN III	92
13A+13B	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90
15A+15B	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90
16	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90
17A+17B	C	100	100	Agricultune	78	7800
						7800/100
					CN II	78
					CN III	90
18C+18D	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90
19A+19B+19C	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90

continued

Subdrainage Area (1)	Soil Complex Type (2)	Soil Complex % of Sub-Area (3)	Land Use % of (3) (4)	Land Use Type (5)	Curve Number (6)	(4) x (6) (7)
20	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90
21A+21B+21C	AB	15	100	Agriculture	67	1005
	C	85	100	Agriculture	78	6630
						7695/100
					CN II	76
					CN III	89
22A+22B	AB	10	100	Agriculture	67	670
	C	90	100	Agriculture	78	7020
						7690/100
					CN II	77
					CN III	89
23	C	100	100	Agriculture	78	7800
						7800/100
					CN II	78
					CN III	90

TABLE 5: LITTLE RIVER WATERSHED

FLOW SUMMARY FOR WATERCOURSES WITHIN THE STUDY AREA

MAIN BRANCH OF LITTLE RIVER

Outflow From Area(s) Number	Total Upstream Area Sq. Mi.	Hazel Total Rainfall (in.)	Hazel Peak Flow (cfs)	100 Year Peak Flow (cfs)
Little River at Detroit River	23.66	7.93	7060	3020
Little River at CN Railroad	21.56	8.07	7560	2640
7C+5	20.67	8.07	7640	2750
7C	19.78	8.07	7230	2580
7B+6	19.77	8.07	7230	2580
7B	19.26	8.07	7030	2510
7A+10	19.24	8.07	7160	2510
7A	18.74	8.07	6940	2410
9B+8B+8CB+11A	18.70	8.16	7190	2550
9B, 9D, 12+14	15.60	8.16	5650	1880
9C+9A	14.25	8.16	5300	1730
9C	11.63	8.16	4210	1360
16C+13B	11.58	8.16	4200	1380

TABLE 5: (continued)

FLOW SUMMARY FOR WATERCOURSES WITHIN THE STUDY AREA

TRIBUTARIES TO LITTLE RIVER STARTING AT DOWNSTREAM END OF STUDY AREA

Outflow From Area(s) Number	Total Upstream Area Sq. Mi.	Hazel Total Rainfall (in.)	Hazel Peak Flow (cfs)	100 Year Peak Flow (cfs)
6	0.51	8.31	350	180
6A	0.20	8.31	150	90
10	0.50	8.31	307	150
10A	0.31	8.31	230	130
8B	0.63	8.31	337	130
8A	0.51	8.31	290	110
11A	0.76	8.31	480	230
11B	0.41	8.31	270	120
9A	2.62	8.31	1150	370
19C	2.42	8.31	1160	370

TABLE 6: LITTLE RIVER

SUMMARY OF BACKWATER CALCULATIONS

MAIN BRANCH OF LITTLE RIVER

Location/Chainage[1]		Hazel Flow (cfs)	Hazel Elev.	100 Year Flow (cfs)	100 Year Elev.
Little River at Lake St. Clair 0+00		7060	578.8	3020	578.8
Riverside Drive East 3+90	D/S[2] U/S[3]	7082	578.8 579.3	3000	578.8 578.8
Little River Road 47+70	D/S U/S	7330	580.9 580.9	2810	578.8 578.8
C.N. Railroad 88+10	D/S U/S	7560	582.9 586.7	2640	582.4 582.4
Tecumseh Blvd. East 99+50	D/S U/S	7580	587.5 588.0	2670	583.5 583.7
Lauzon Road 122+50	D/S U/S	7630	589.0 590.5	2740	584.9 584.9
Little River at Confluence with Area 6 128+80		7230	592.6	2580	588.5
Little River at Confluence with Area 10 145+60		7160	593.5	2510	590.4
Little River at Confluence with Areas 8B+11B 171+00		7190	595.0	2550	592.6
E.C. Row Avenue East 191+50	D/S U/S	5430	595.5 595.8	1790	593.1 594.0
Little River at Confluence with Area 9A 203+80		5300	596.4	1730	594.4
Little River at Confluence with Area 13B 216+30		4200	597.1	1380	595.2

1 *All chainages refer to distance along channel from the mouth of Little River at Lake St. Clair*

2 *Downstream*

3 *Upstream*

TABLE 6: LITTLE RIVER

SUMMARY OF BACKWATER CALCULATIONS

TRIBUTARIES TO LITTLE RIVER WITHIN STUDY AREA

Location/Chainage		Hazel Flow (cfs)	Hazel Elev.	100 Year Flow (cfs)	100 Year Elev.
Confluence of Little River and Area 6 128+80		7230	592.6	2580	588.5
Meadowbrooke Lane 133+00	D/S	340	592.7	180	588.9
Lauzon Parkway 145+50	U/S	295	592.8	155	592.1
Kew Drive 156+40	D/S U/S	250	593.0 593.0	140	592.6 592.6
C.N. Railroad 178+00	D/S U/S	170	598.8 601.3	100	598.7 599.5
Jefferson Blvd. 181+45	D/S U/S	150	601.3 601.3	90	599.5 601.1
Little River at Confluence with Area 10 145+60		7160	593.5	2510	590.4
Lauzon Parkway 167+00	D/S U/S	280	593.8 593.8	140	591.0 591.3
C.N. Railroad 199+50	D/S	230	595.1	130	592.8
Little River at Confluence with Area 8B 171+00		7190	595.0	2550	592.6
Lauzon Road 177+50	D/S U/S	330	595.1 595.1	130	592.6 592.6
E.C. Row Avenue East	D/S U/S	290	595.2 595.2	110	593.8 593.8
Little River at Confluence with Area 11B 171+00		7190	595.0	2550	592.6
~~C.N~~ CP. Railroad 230+00	D/S U/S	310	601.2 602.5	140	600.7 602.3

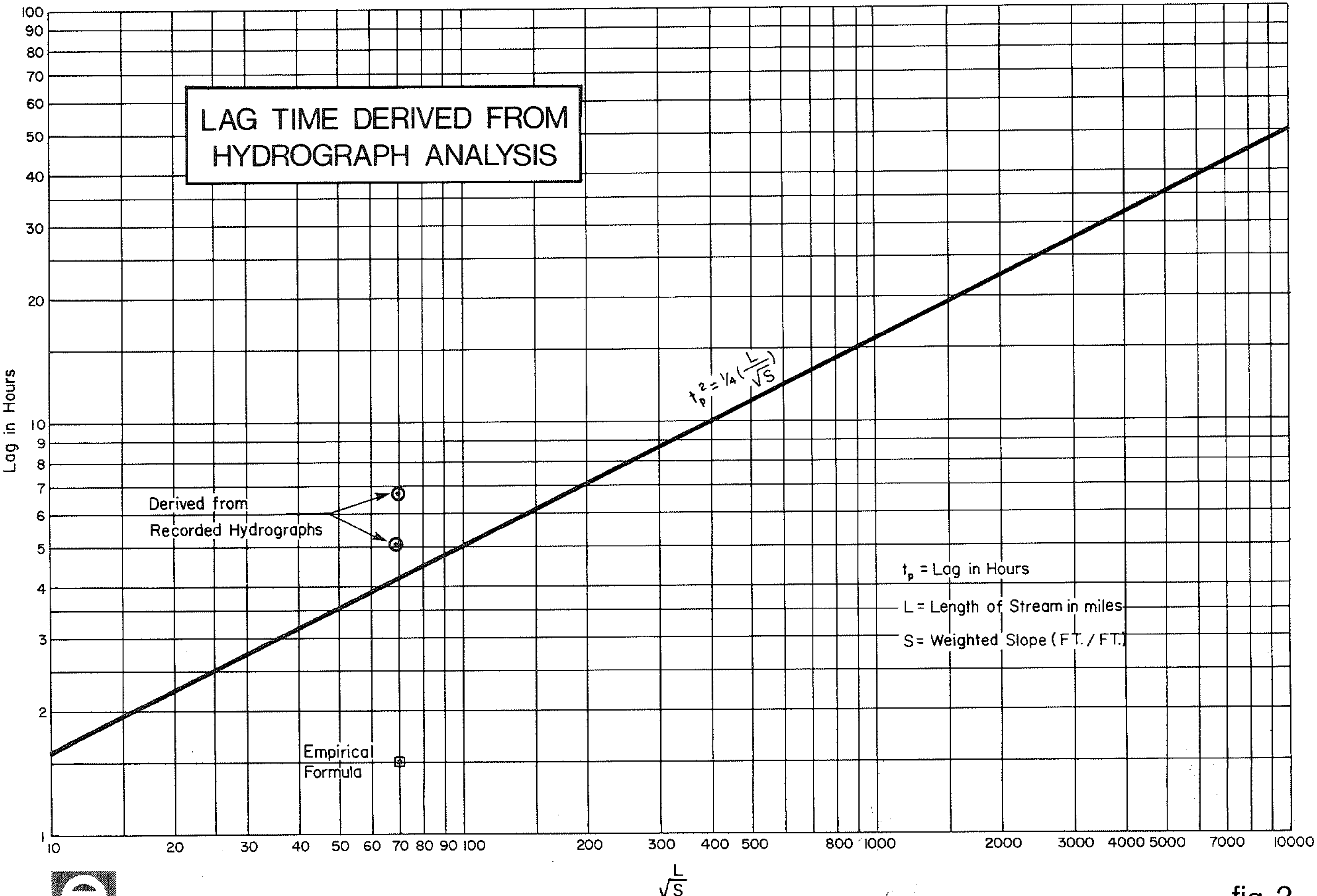
LAG TIME DERIVED FROM HYDROGRAPH ANALYSIS
Lag in Hours
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
100
200
300
400
500
800
1000
2000
3000
4000
5000
7000
10000
$\frac{L}{\sqrt{S}}$
$t_p^2 = 1/4\left(\frac{L}{\sqrt{S}}\right)$
Derived from Recorded Hydrographs
Empirical Formula
t_p = Lag in Hours
L = Length of Stream in miles
S = Weighted Slope (FT./FT.)

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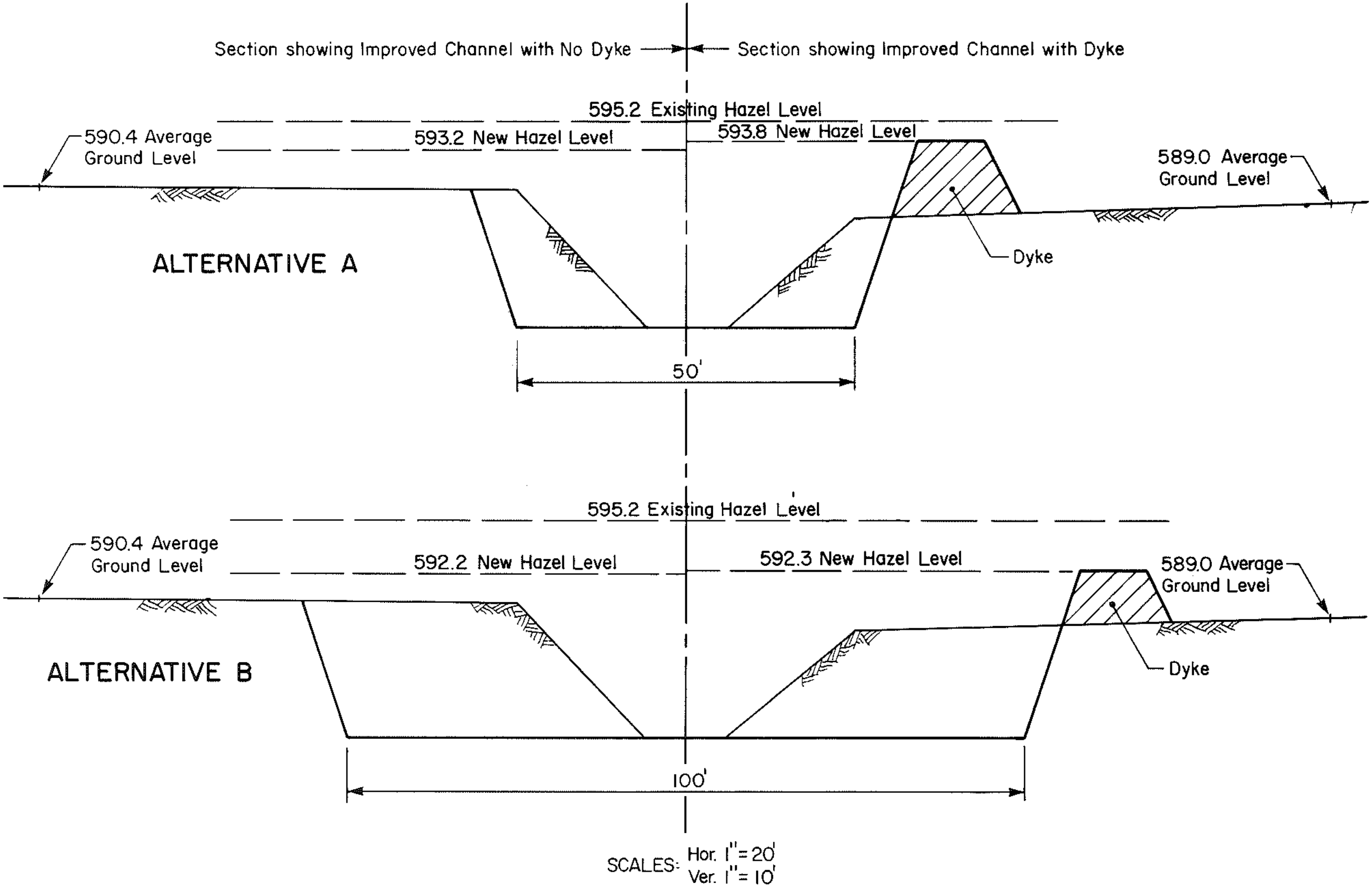
fig. 2



Little River

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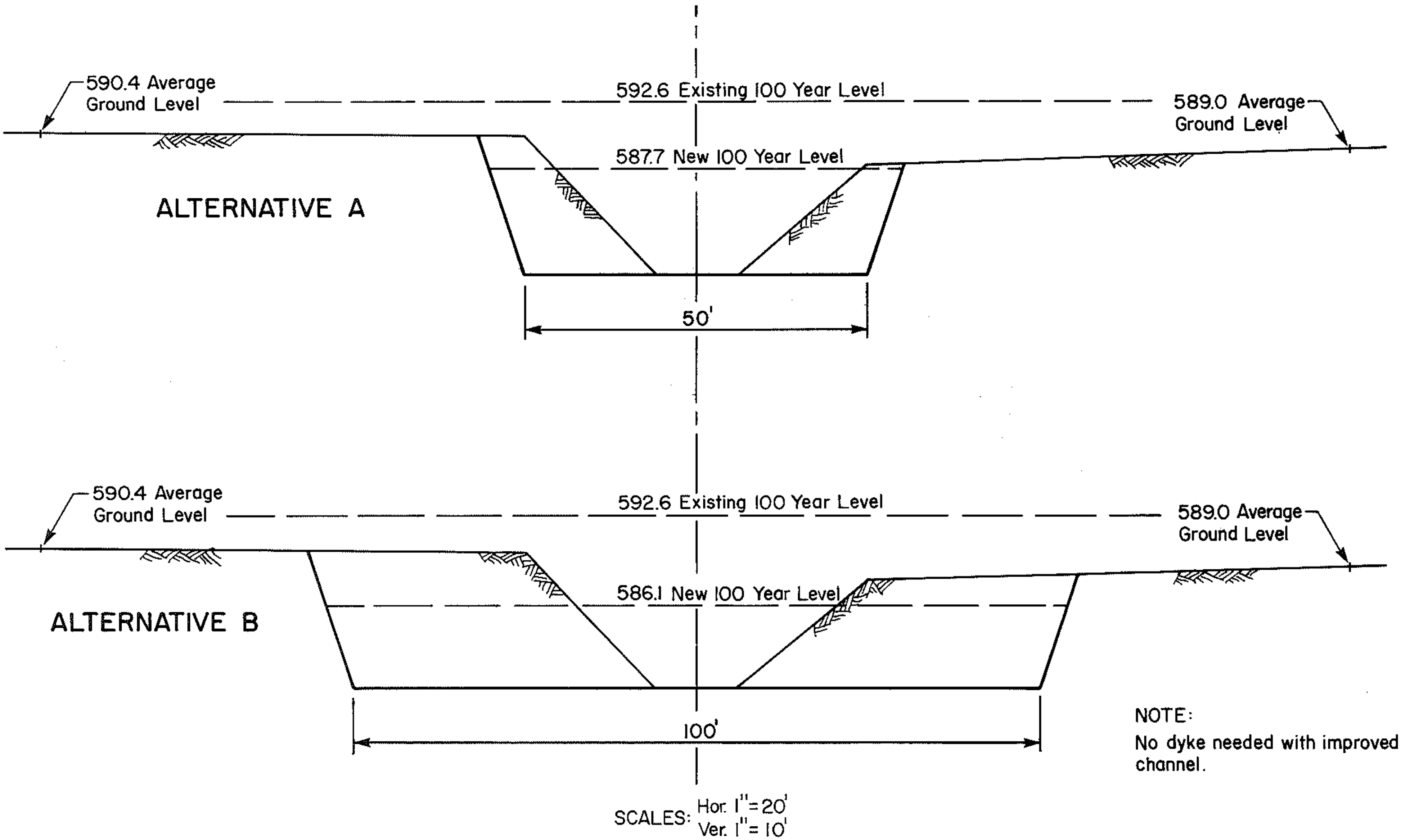
TYPICAL SECTIONS SHOWING HAZEL CONDITION

fig. 3



Little River

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TYPICAL SECTION SHOWING 100 YEAR FLOOD CONDITION

fig. 4

THE TWO ZONE FLOODWAY - FLOOD FRINGE CONCEPT

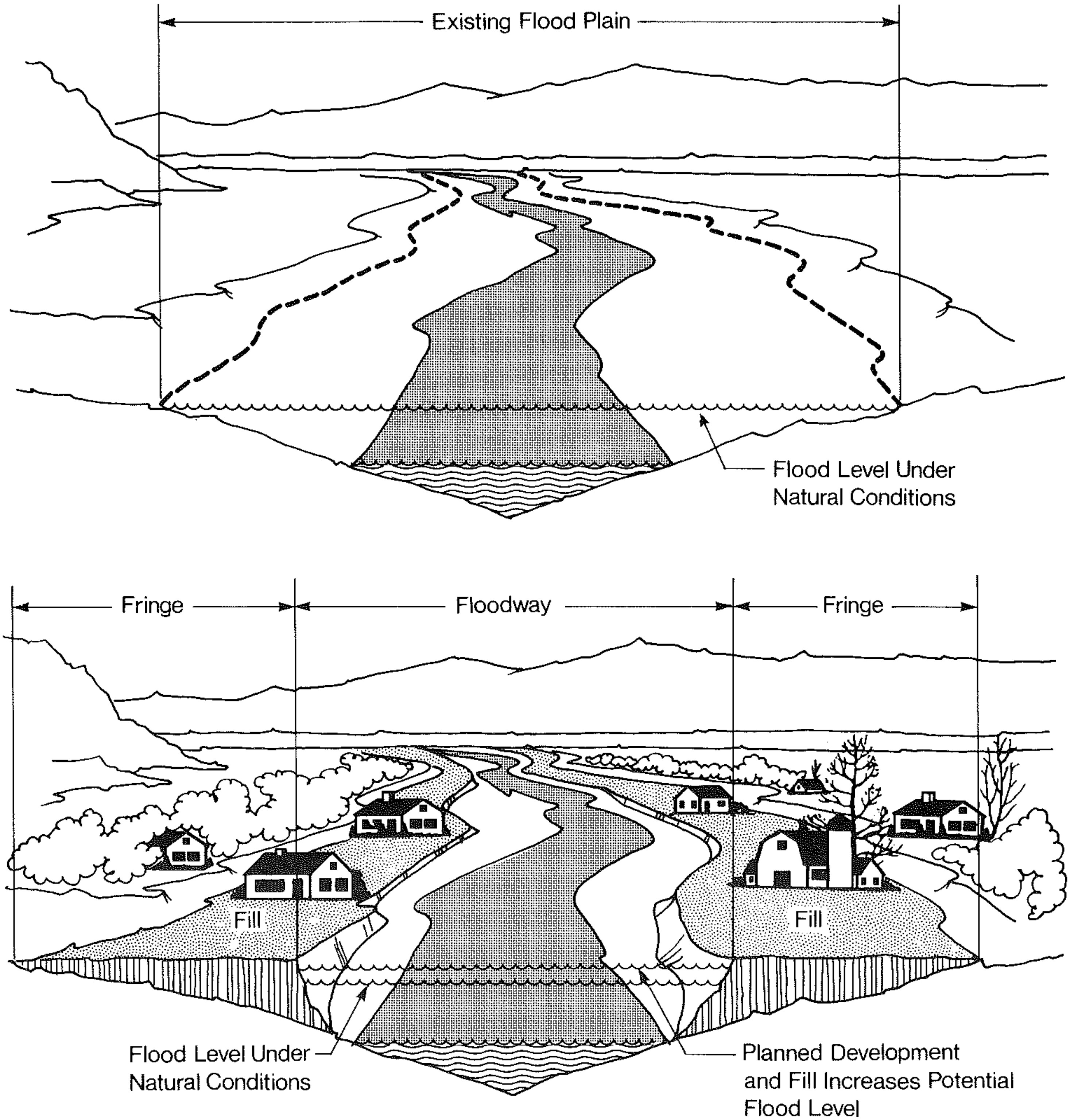
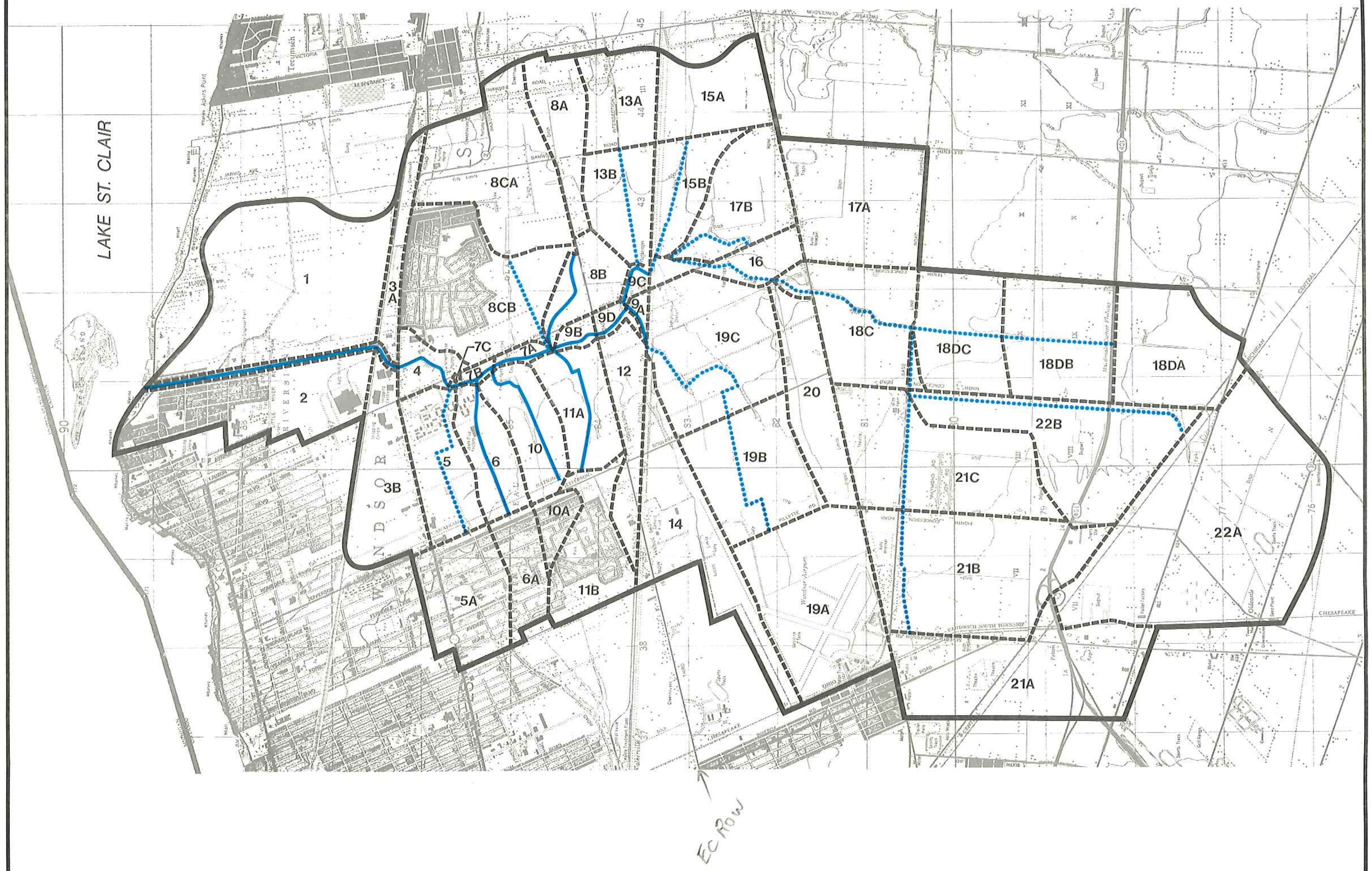


fig. 5



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ESSEX REGION CONSERVATION AUTHORITY

FIGURE·1

Little River Watershed