STREAM ANALYSIS
AND
OPPORTUNITIES FOR REHABILITATION
OF TRURO CREEK IN BRUCE PARK

By

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STREAM ANALYSIS AND OPPORTUNITES FOR REHABILITATION OF TRURO CREEK IN BRUCE PARK

BY

DUANE E. KELLN

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCES MANAGEMENT

ABSTRACT

The Friends of Bruce Park is a local neighbourhood group interested in preserving and enhancing the historic and natural heritage of Bruce Park in the City of Winnipeg. Truro Creek flows through the Park just before entering the Assiniboine River. The group is concerned about the apparent erosion of the creek's bed and banks and the low flow water levels in the creek which have put stress on the vegetation bordering the creek. In addition, poor fish spawning habitat exists in the creek.

The existing and historic hydrology and geomorphology of Truro Creek in Bruce Park were investigated and analyzed to determine a rehabilitation measure for the creek based on natural stream principles.

The conclusion is that the creek is in disequilibrium due to the land use changes which have occurred in the catchment upstream of the park. Flows in the creek are double those under natural conditions; the channel has enlarged by the process of erosion and is still eroding based on recent evidence.

The construction of pools and riffles in the park, which uses natural materials and is based on natural channel principles, is a feasible and cost effective rehabilitation measure. The proposed nine riffle design will stabilize the creek channel by reducing erosion of the bed and banks, provide some spawning habitat for fish, and improve moisture conditions for the riparian plant community in the Park by raising low flow water levels by an average

of one foot. The cost of construction has been estimated at $4100, which includes the supply, hauling and placing of the aggregate material; the estimate excludes the cost of mitigating any environmental disruption caused by construction activities.

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GLOSSARY OF TERMS

Abiotic - Non-living, basic elements and compounds of the environment.

Acre-foot (ac-ft) - A volume of water which is equal to an acre in area one foot deep (or 43,560 cubic feet). Can be calculated by multiplying a flow rate by the time over which the flow occurs to fill that volume. For example, 1 cfs flowing for one day is equivalent to about 2 acre-feet, or 1 cfs flowing for one month is equal to about thirty times that, or 60 ac-ft.

Alluvial - Pertaining to material that is transported and deposited by running water.

Baseflow - The stream discharge composed of groundwater flow and delayed surface flow.

Basin - see Drainage basin.

Benthic - Pertaining to the bottom of a body of water; benthos or benthic organisms are the plant and animal life whose habitat is the bottom of a sea, lake, river, or stream.

Biota (Biotic) - Flora and fauna of a region (*or* pertaining thereto).

Catchment - See Drainage basin.

Confluence - The location where two water courses meet.

Cfs - Units of flow rate in cubic feet per second, i.e. a volume of flow over a period of time.

Detritus - Disintegrated matter, such as organic debris, accumulated in pond water.

Drainage basin - The topographic area contributing water to a selected point along a stream channel; synonymous with catchment or watershed (American). The boundary of the drainage basin is termed the drainage divide or watershed line or catchment boundary.

Ecosystem approach - An ecosystem is a system composed of interacting organisms and their environments; in this approach humans are a component of the system and human intervention works with nature rather than against it.

GLOSSARY OF TERMS (continued)

Extremal Hypothesis - Hypothesis wherein it is assumed that a channel achieves stability or equilibrium when a specified function of some variables describing channel flow is a maximum or minimum (e.g. minimum stream power, maximum friction factor, etc).

Fauna (faunal) - The animal life of a region (*or* pertaining thereto).

Flora - The plant life of a region.

Fluvial - Pertaining to flowing bodies of water, such as rivers, streams or creeks.

Frequency Curve Analysis - A statistical analysis of peak flows of a stream record to determine the probabilities of peak flow occurrence.

Geomorphology - The study of landforms including their history and processes of evolution (in the current context, a main concern is with the action of the water flows in the creek which erode, transport and deposit sediment).

Habitat - The place upon which an animal depends directly or indirectly to carry out its life processes; includes, in the case of fish for example, spawning grounds and nursery, rearing, food supply and migration areas.

Hydraulics - The field of study (usually engineering) concerned with mathematically describing the flow of water in natural or artificial channels and over or through structures, such as pipes and weirs.

Hydrology - The field of study dealing with the properties, distribution, and circulation of water on the Earth, including runoff from the land to and through water courses to other bodies of water; also includes the study of evaporation and precipitation.

Invertebrates - Animals without an internal skeletal structure (e.g. insects, mollusks, crayfish).

Lotic - Pertaining to flowing water, such as streams and rivers (lentic pertains to standing waters such as lakes, ponds, and swamps).

Macroinvertebrates - Those invertebrates visible to the naked eye.

Morphology (Morphological) - See Geomorphology.

GLOSSARY OF TERMS (continued)

Point Bar - The landform on the inside of a meander of a stream formed by deposition of sediment.

Reach - A stretch of river or stream channel.

Rehabilitation - The process of restoring a disturbed site to a desired condition within a specific period of time; in the report, restoration, reclamation, and rehabilitation are used synonymously.

Restoration - See Rehabilitation.

Riparian - Pertains to land bordering the creek.

Sedimentological - Pertaining to the study of the formation, structure and movement of sediments.

Sinuosity - The meandering tendency of a stream; may be measured by the ratio of the length of the centreline of the stream to the length of a straight line connecting the same points along the channel.

Stochastic - Having to do with random variables and processes.

Thalweg - In a flowing stream, the line following the deepest part of the channel; the line following the lowest part of a valley whether under water or not (in other words, the creek bed).

Water course - A flowing body of water, such as a creek, stream, or river.

Watershed - See Drainage basin.

CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

An increasing interest and activity in recent years has developed in the naturalization, reclamation, restoration or rehabilitation of land and water areas in North America and Europe (Williams, 1990; Brookes, 1987; Bolliger *et al,* 1984; Binder *et al,* 1983).

The driving force behind many of these projects is the public, through volunteer organizations, schools and public interest organizations which have been actively involved in the identification and development of sites (Fitzgibbon, 1992). Examples of such activity include the restoration of trout streams (Jackson, 1992) and parklands (Anonymous, 1993) in small urban and suburban areas. As pointed out by one author: "...many of these organizations promote the restoration of drainage systems and the development of natural areas in the urban environment" (Fitzgibbon, 1992).

The development of naturalized drainage systems, including pool and riffle constructions, has taken place as a result of these circumstances. As stated by Fitzgibbon:

> The form of these naturalized or 'soft' systems ranges from the planting of a diverse range of vegetation, to the construction of channels which emulate the properties of a natural water course. These techniques contribute to an increase in infiltration, a reduction in pollution loads, and the stabilization of banks. It has meant the inclusion of natural woodlands and wetlands in the urban environment for hydrologic, aesthetic,

and ecological purposes. (Fitzgibbon, 1992)

1.2 BACKGROUND

The Friends of Bruce Park (FBP) is one such local neighbourhood group in the city of Winnipeg with an interest in preserving, enhancing and maintaining the natural setting and historical heritage of Bruce Park in Winnipeg. The group was established in 1992 by a few concerned citizens after the severe drought period of the late 1980s. The group was initially concerned about the loss of mature trees in Bruce Park, which were under great stress due to the prolonged drought conditions and apparent erosion of the banks along Truro Creek. Many of the trees are oaks which are over one hundred years old. Since 1992, the group has grown to represent over 50 households in the neighbourhood and is still growing in numbers.

Bruce Park is located in the St. James area of Winnipeg at the mouth of Truro Creek where it enters the Assiniboine River, as shown on Figure 1. (The locations, from which some of the photographs contained in the report were taken, are also shown on the figure.)

1.3 PROBLEM STATEMENT

One of the goals of the Friends of Bruce Park is to naturalize the southern half of Bruce Park. In view of the goal, one of its stated objectives is to "examine the water flow through the park" (FBP, 1993). From a discussion with the FBP's executive, the intent of the objective is to investigate the condition of Truro Creek in the Park and in the catchment upstream of the

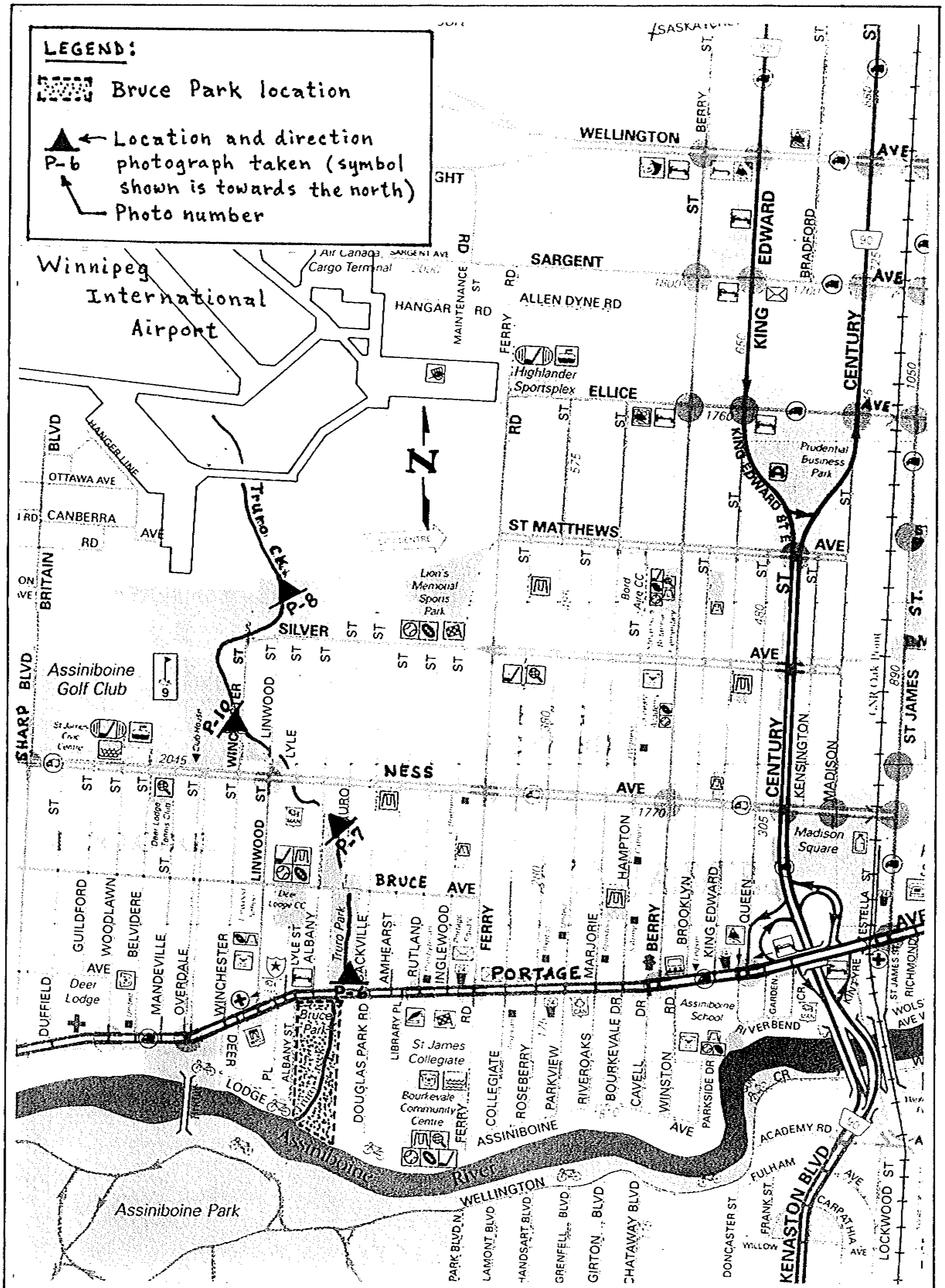


Figure 1. Map showing location of Truro Creek and Bruce Park south of the Winnipeg International Airport (from Sherlock 1991).

park to determine what can be done to rehabilitate the creek within the overall naturalization goal. The primary focus is to slow runoff in order to reduce erosion and to improve moisture conditions for the plant community in the Park. A parallel concern is the improvement of fish habitat in the creek.

1.4 SPECIFIC OBJECTIVES OF THE STUDY

The specific objectives for this study of Truro Creek, in light of the naturalization goal of the FBP, were the following:

(1) To analyze the existing hydrology and geomorphology of the Truro Creek catchment;

(2) To investigate the historical stream morphology and hydrology of Truro Creek;

(3) To determine the natural flow and geomorphic regimes through the park using the results from (1) and (2) and the principles for natural channels;

(4) To propose a design through the Park using a natural channel morphology and flow regime to stabilize the creek channel, enhance fish habitat, and improve moisture conditions for the plant community; and

(5) To assess the costs for the structural components identified in objective (4).

1.5 METHODS

The methods which have been employed to achieve the specific objectives included the following:

. *Review of the literature* pertaining to: hydrology and geomorphology, in particular as it relates to erosion and streambank and bed stabilization in a natural context; habitat rehabilitation of stream and riparian environments for fish; federal and airport, provincial, and city legislation and policies on stream, land drainage developments and water management practices in the catchment; city and airport land use and water management developments and plans as it affects runoff to Truro Creek;

. *Personal interviews and meetings* with: city and airport officials; a local resident concerning the historic biophysical and other related conditions of Truro Creek in Bruce Park and upstream; experts in the fisheries and water management fields;

. *Field inspections* of the creek and catchment;

. *Collection of engineering and geomorphic survey data* to complement existing data to enable a stream analysis to be accomplished; and

. *Review and analysis* of historic and current data as it pertains to the hydrology and geomorphology of the creek and its catchment including: hydrologic records and other related information on Truro Creek and the Assiniboine River; watershed maps and air photographs; other maps showing land use, drainage developments, and ownership; Truro Creek engineering survey data (profiles, cross-sections); field inspection information and other data collected during the course of the study.

1.6 DEFINITION OF TERMS

The following definitions are used in the report.

The use of the word *natural* in an urban setting is difficult to define. But, for the purposes of the report, *pre-settlement* conditions were considered to be representative of *natural* conditions. The basis for the natural or pre-settlement condition was information available from *historic* records, primarily the late 1800s.

Rehabilitation, restoration, and naturalization are considered to be synonymous terms.

The *catchment* is the land area which is sloped such that it contributes water overland to a creek, stream or river. The water may emanate from snowmelt in the spring or rainfall in the summer or autumn. The water is also called *runoff* because it *runs off* the land surface.

A *reach* is a stretch of a water course between two locations. A *water course* is a flowing body of water, such as a creek, stream or river.

Pools and riffles are naturally occurring undulations in the creek bed in which the coarse bed materials accumulate at specific intervals. Upstream from an accumulation a shallow *pool* is formed. Downstream from the crest of the accumulation, a local increase in slope causes the flow to accelerate, forming a *riffle* or rapids. Under low flow conditions, the pool and riffle profile stores water in the channel and re-aerates the flow.

The reader is referred to the Glossary of Terms for an explanation of other unfamiliar terms.

1.7 STUDY SCOPE AND LIMITATIONS

The primary focus of the study was to investigate and assess the hydrology and geomorphology of Truro Creek as it relates to the FBP's concerns in Bruce Park. Regarding the hydrologic focus, the emphasis was on the water quantity aspects of the problem. Therefore, the water quality aspects were generally beyond the scope of the current study and were not addressed directly.

1.8 UNITS OF MEASURE

Metric is the currently accepted system of measurement units for studies of this nature, however, the imperial system was adopted for this study for a number of reasons. The reasons are: previous survey and map information was performed under the imperial system, making comparisons easier; the size of the creek and its flow data is more amenable to the imperial system; and the client preferred imperial to metric units. A conversion table of equivalents between the two systems is provided in Appendix 1.

1.9 REPORT OUTLINE

A detailed description of the methods used in the study is given in *Chapter 2*.

A description of the existing Truro Creek and its catchment, including airport development is provided in *Chapter 3*. Erosion in Bruce Park is highlighted. Historic information, primarily in the form of pre-settlement maps, is also presented.

The principles of natural stream channels, and how riffles act as energy dissipators to reduce erosion and provide fish habitat are reviewed in *Chapter 4*. The stability of riffle formation by conforming to stream characteristics is also included. Erosion of stream channels caused by urbanization is presented in this chapter as well.

An analysis of the hydrology and geomorphology of Truro Creek in Bruce Park is provided in *Chapter 5*. Estimates of the increase in flow in the creek and the concomitant erosion due to urbanization are made. An analysis of the characteristics of the Natural Reach in the park which are useful in designing stream modifications is presented.

A pool and riffle design using natural materials and based on natural channel principles is proposed in *Chapter 6*. The design reduces erosion, provides habitat for fish and retains water in the creek for the riparian plant community. In addition, flows in the creek are analyzed to determine the hydrologic feasibility of an upstream storage reservoir to provide flows longer into the summer and to emulate natural conditions.

The importance of land use in the catchment is reviewed in *Chapter 7*. Riparian management and future development in the catchment are highlighted. Relevant jurisdictional and administrative considerations are also covered.

A summary of the study as well as the conclusions and recommendations emanating from the study are given in *Chapter 8*.

CHAPTER 2

DETAILED DESCRIPTION OF METHODS

The following is a more detailed description of the methods which will be used to achieve each of the specific objectives which are described in Chapter 1. The field methods and analysis as described by Newbury and Gaboury in their recent (1993) field manual entitled 'Stream Analysis and Fish Habitat Design' (henceforth designated SAFHD) will be utilized.

Objective 1: To analyze the existing hydrology and geomorphology of Truro Creek, the first five steps from SAFHD will be employed. These five steps are outlined briefly in the following:

a) Trace the watershed lines on a topographical map to identify the existing Truro Creek Basin and the existing land uses within the catchment. Consultation with city and airport staff will be required to ascertain the exact contributing area for the built-up portions of the basin.

b) Draw a longitudinal profile along the main course of the Creek by using contour maps and field surveys to identify discontinuities which may cause abrupt changes in stream characteristics (falls, former base levels, etc.)

c) Prepare a flow summary for the rehabilitation reach using existing and nearby hydrologic records (flood frequency, minimum flows, historical mass curve). Included in the analysis will be current licensed water use from the Creek. Also, possible contributions from groundwater sources will be investigated by consulting with Manitoba Water Resources Branch staff.

d) Survey in the field and/or extract from maps information on the Bruce Park reach to establish the relationship between the channel geometry, drainage area, and bankfull discharge. Include the stream bed material in the survey.

e) Plot the survey information for the Bruce Park reach in sufficient detail so that construction drawings may be prepared and survey reference markers may be established.

Objective 2: To investigate the historical stream morphology and hydrology of Truro Creek, archival maps, air photographs, and other information will be searched. From this information and in consultation with other sources, the natural drainage basin boundary and channel geometry may be determined.

Objective 3: To determine the natural geomorphic regime through the park, the principles for natural channels will be applied along with the data obtained under Objectives (1) and (2). In addition, the enlargement of the natural channel due to changes in land use will be applied to the existing condition to aid in assessment. In this way, a natural channel shape may be developed. In addition, the natural hydrologic regime will be estimated by applying hydrologic principles and understanding.

Objective 4: To propose a design for a natural channel morphology and flow regime through the Park, steps 6,7, and 8 from SAFHD for fish habitat enhancement and channel stabilization will be followed. These steps entail the following:

a) Using available physical data plus a survey of local residents concerning use of the creek by fish and in consultation with fisheries experts, a target species for which the reach should be rehabilitated will be chosen (preferred habitats).

b) Rehabilitation works will be selected and sized.

c) Instream flow requirements will be assessed. Upstream storage will be included in the assessment. The potential for utilizing the detention pond upstream on the airport property for storage of runoff with release later into the stream will be investigated. Also, other possible storage sites west of the airport boundary will be included in the assessment. Current plans for future development in the catchment will be included in the investigation. These investigations will require consultation with airport and city personnel.

Objective 5: To assess the costs for the structural components identified in objective 4, standard engineering approaches will be employed.

CHAPTER 3

DESCRIPTION OF TRURO CREEK AND ITS CATCHMENT

3.1 EXISTING CONDITION

3.1.1 Overall View of Bruce Park

Figure 2 is a base map of Bruce Park showing the route which Truro Creek takes through it. As shown on the figure, Truro Creek in Bruce Park has been subdivided into four reaches for purposes of analysis, namely the South, Natural, Playground and North Reaches. One of the reaches has been termed the Natural Reach, since it is the most natural of all and provides the basis for the design presented later. The main features of the park, such as the wading pool, the bridges which cross the creek, and the parking lot are shown. In addition, the locations, from which the photographs contained in the report were taken, are shown on the figure.

Photo P-1 and P-2 show the contrasting features of the park. Photo P-1 is a view of the South Bridge over Truro Creek in mid-summer with its beautiful shade trees, some being one hundred or more years old. In contrast, Photo P-2 shows the north part of the park with its open lawn area and Portage Avenue in the background. Just visible in the middle of the photograph is the culvert under Portage Avenue which conveys Truro Creek flows into the Park. A view of the Natural Reach is given in Photo P-3. One of the projects, which the FBP (Friends of Bruce Park) have been engaged in recently, has been to maintain a 'buffer strip' alongside the creek, in keeping with their naturalization goal. The group is working with

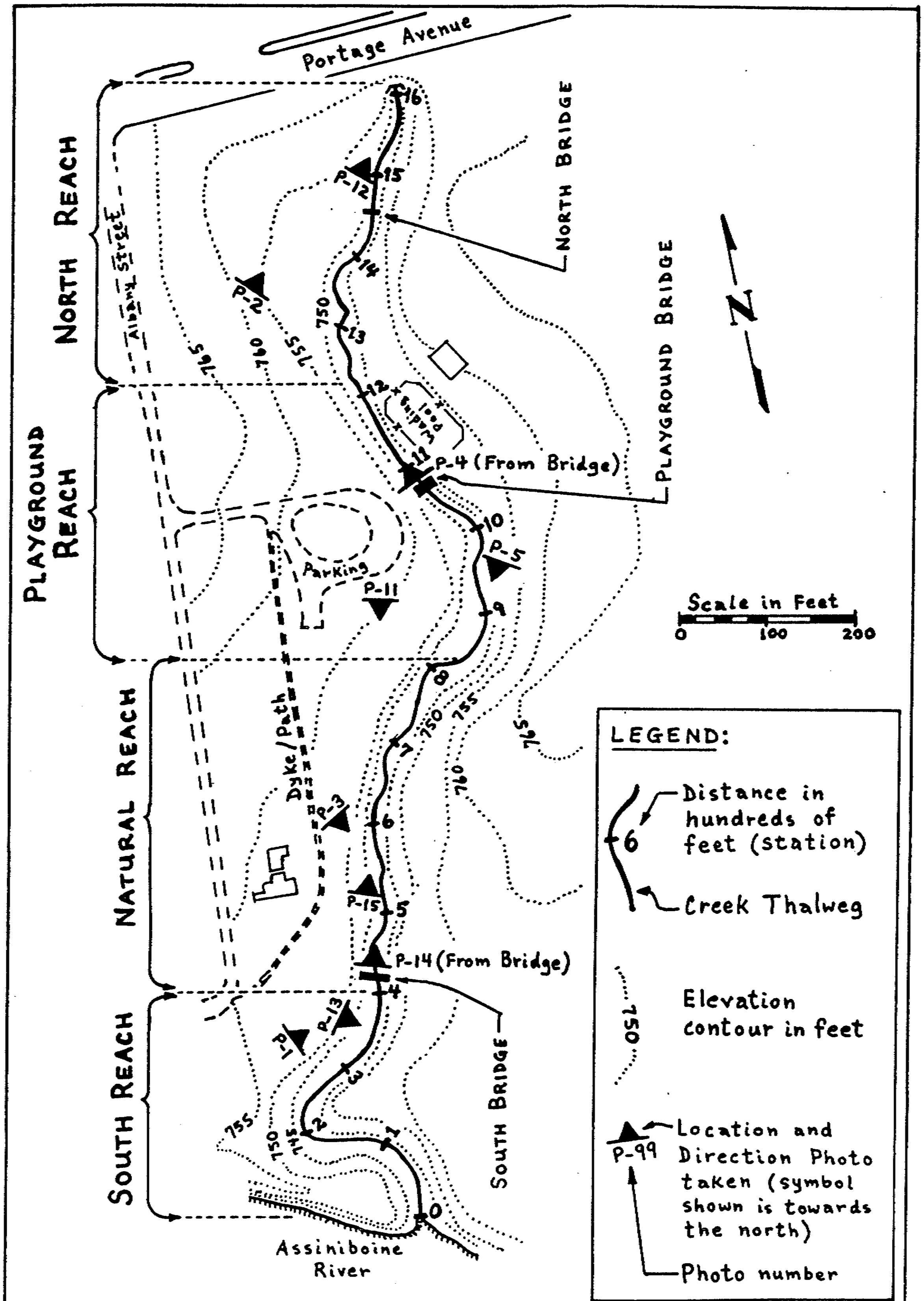


Figure 2. Base map of Bruce Park showing the location of Truro Creek and where photographs were taken.

Photo P-1. South end of Bruce Park showing the South Bridge over Truro Creek (July 14, 1993).

Photo P-2. North end of Bruce Park with the Portage Ave. culvert in the distance (Jul 14/93).

Photo P-3. 'Natural Reach' showing the creek valley and buffer (July 14, 1993).

the City of Winnipeg's Parks Department, marking off where city crews should not mow the grass. The buffer is visible in Photo P-3.

Photographs P-4, P-5A, and P-5B illustrate the erosive power of the creek. Both Photos P-4 and P-5A were taken in the spring of 1993 close to the time of peak flow on Truro Creek. The flow in the creek when the photographs were taken has been estimated at 30 cfs. Photo P-4 shows the creek flowing beside the wading pool area with the asphalt pathway on the left and the tiered retaining wall on the right. Photo P-5A was taken downstream of the playground bridge at the same time. Photo P-5B is an identical view to P-5A except it is under low flow conditions. (See Figure 2 for location.) Photo P-5B illustrates the erosive power of the creek as evidenced by the scour in the middle of the photograph. The city has attempted to halt the erosion by installing some concrete works along the bank and by placing concrete rubble and rocks on the creek bed. The bank works are visible just below the fence posts, which appear at the top of the photograph.

3.1.2 Catchment Upstream of Bruce Park

Some of the water which flows through the Bruce Park portion of Truro Creek originates over 6 creek miles upstream of the Park. Figure 3 is a map of the Truro Creek catchment. As can be seen in Figure 3, the Truro Creek catchment is 6.8 square miles in total area and extends west to the Perimeter Highway.

The catchment has been divided into three segments for study purposes as

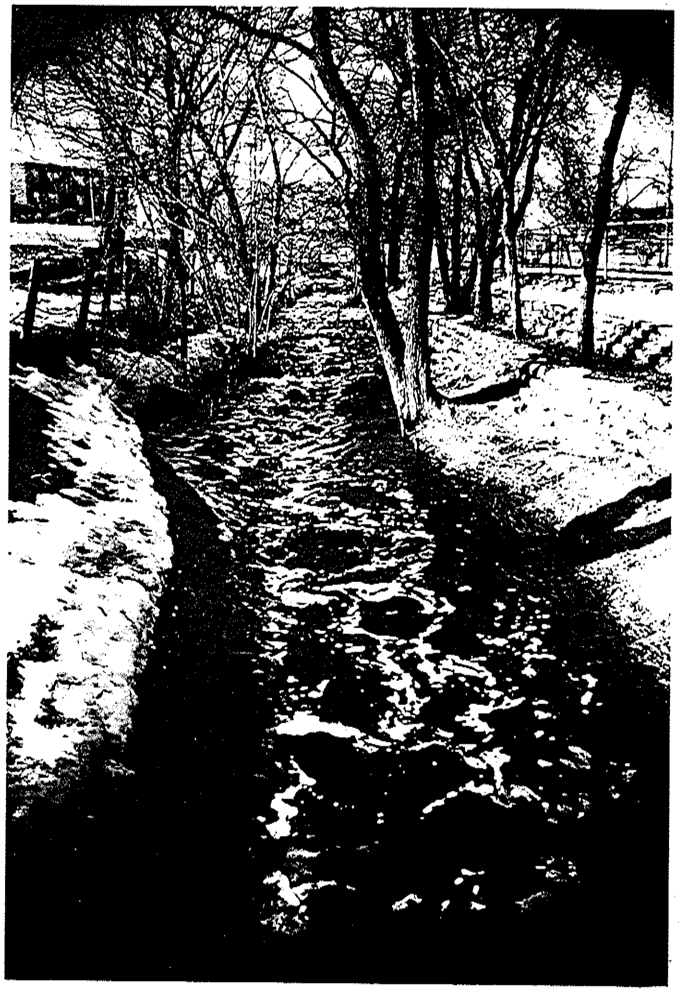


Photo P-4. Truro Creek alongside wading pool in spring (Apr 2/93).

Photo P-5A Creek in spring flood stage downstream of Playground Bridge (April 2, 1993).

Photo P-5B. Same view as above but at low flow. Note concrete bank works and scours (Nov 3, 1993).

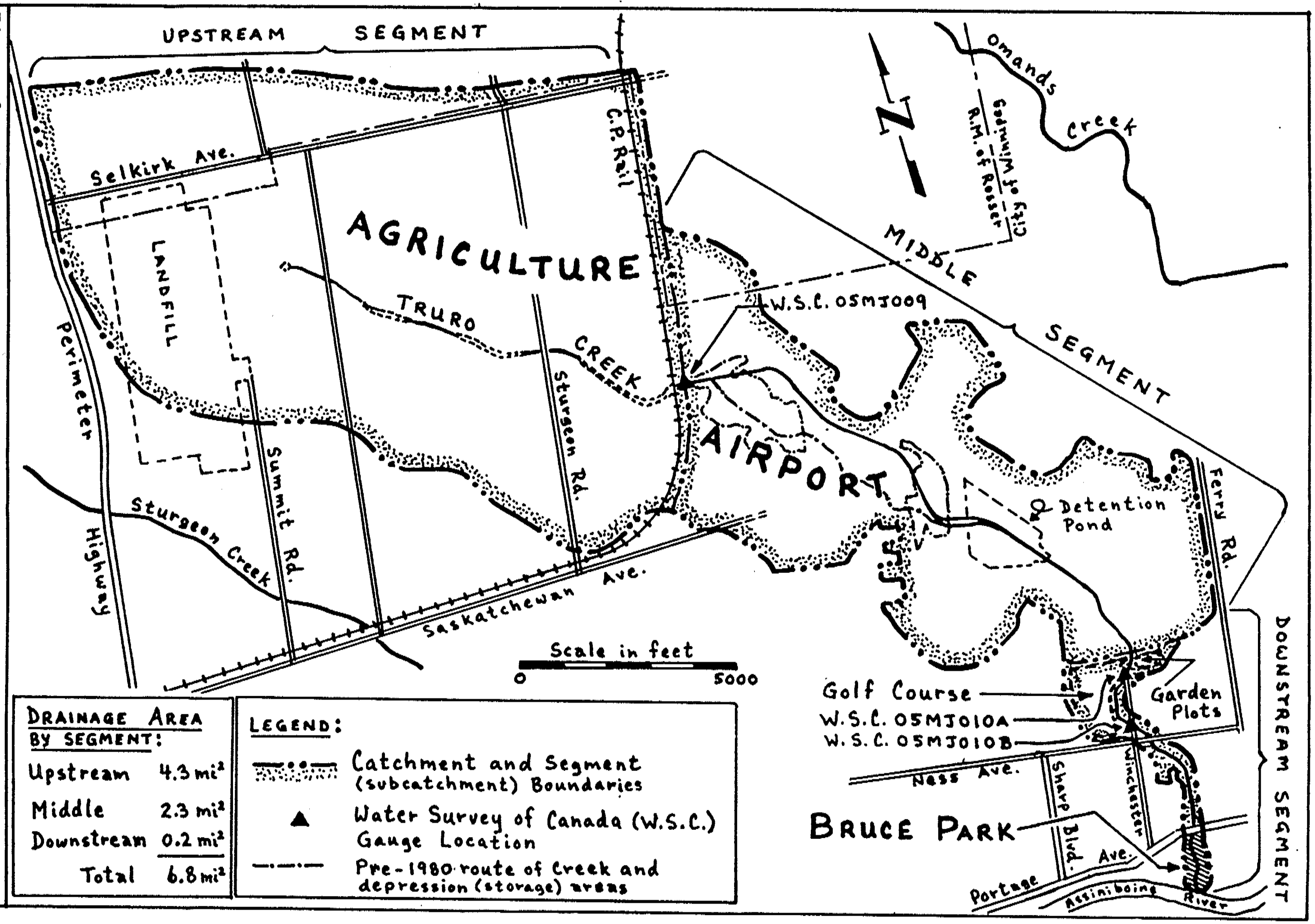


Figure 3. The Truro Creek Catchment.

shown on Figure 3: upstream, middle and downstream. Within the catchment boundary are a number of land uses, by far the predominant ones being agriculture (upstream segment) and the airport (middle segment), with areas of 3.7 and 2.3 square miles respectively. The third largest land use is the Summitt Road Landfill site at 0.7 square miles (upstream segment). In other words, the upstream and middle segments, that is, from the perimeter highway to the south boundary of the airport, account for 97% of the catchment area. The contributing area from the airport boundary south to Bruce Park (downstream segment) is relatively insignificant in size at only 0.2 square miles, or 3% of the total catchment area. The downstream segment would be a little larger but is not because the residential area south of the airport is serviced by a combined sewer system which drains surface runoff water away from Truro Creek. The only contributing areas in the downstream segment are the garden plots just north of Silver Avenue, the Assiniboine Golf Course, and a small riparian strip along the creek.

Photos P-6 to P-9 inclusive show views of the creek as one moves in an upstream direction from Bruce Park. The locations from which the first three of these shots were taken are shown on Figure 1 (Chapter 1); the location of the last one (P-9) is not shown on any map. Photo P-6 is a view of Truro Park where the creek is restricted to a well-engineered straight channel. In spite of its condition, the creek still shows a tendency to meander with some pool and riffle development occurring. Photo P-7 shows the Albany Street crossing just south of Ness Avenue. The crossing is quite often over-topped (once every two years on average) as its capacity is less than one-

Photo P-6. The creek looking north from Portage Ave. in Truro Park (Nov 3, 1993).

Photo P-7. The Albany St. Crossing looking northwest (Nov 3, 1993).

Photo P-8. The Pollution Control Structure at airport outlet (Nov 3, 1993).

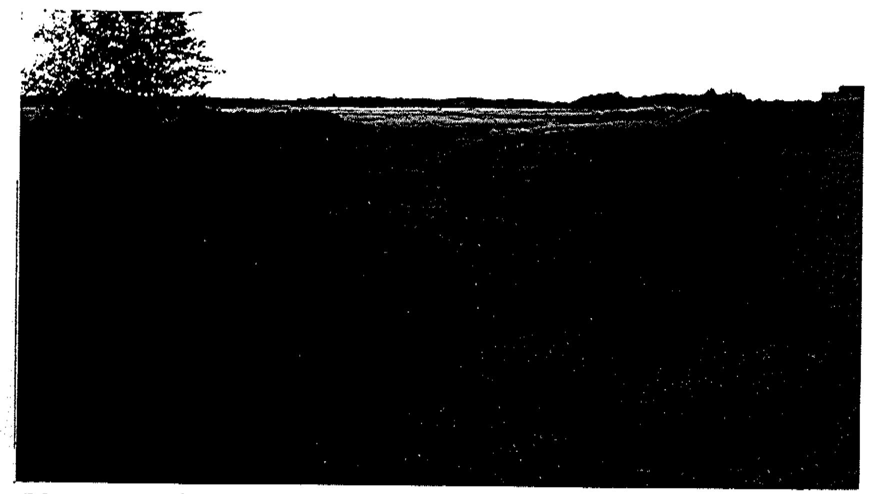


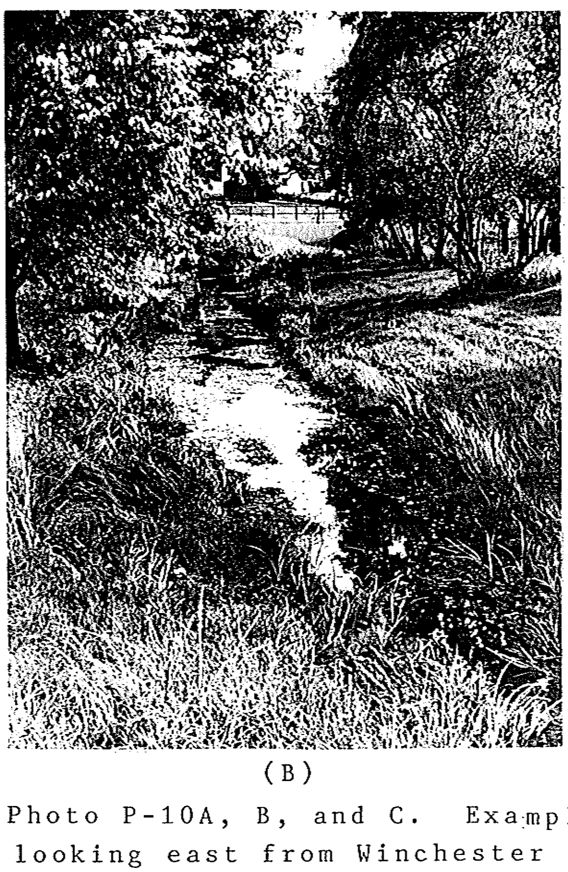
Photo P-9. Pilot channel looking east from Sturgeon Road (July 14, 1993).

half the capacity which generally exists in the reach downstream of the airport. Photo P-8 is a view of the so-called Pollution Control Structure (P.C.S.) at the south boundary of the airport property. The structure is simply a gated culvert controlling the creek flow, which may be closed in the event of an environmental emergency, such as a fuel spill at the airport, following which cleanup may commence. Photo P-9 shows the so-called 'pilot channel' in the upstream segment looking east from Sturgeon Road (photograph location is not shown on any map). Being primarily a swale, the creek channel is not well defined in this segment.

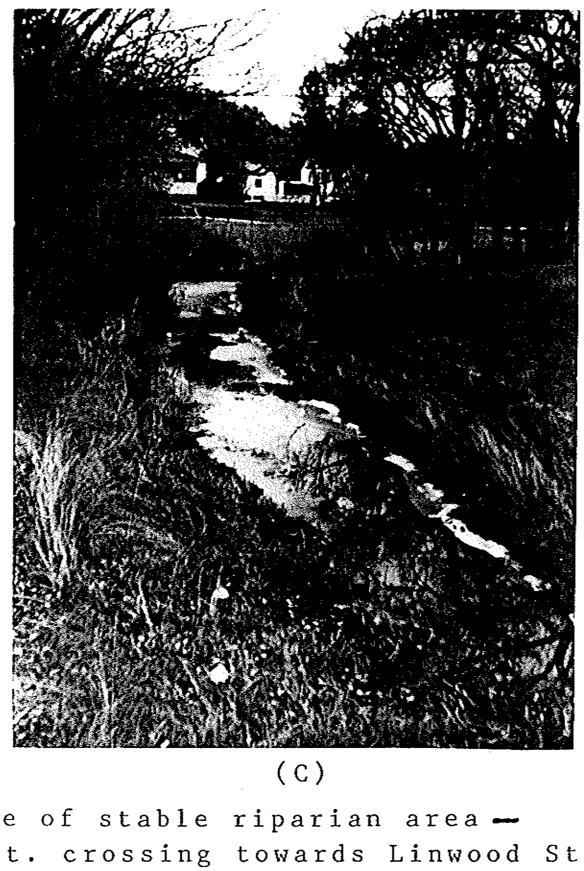
3.1.3 Example of Riparian Area

The series of photographs contained in Photos P-10(A), (B), and (C) were taken during the course of 1993 in the reach between Winchester and Linwood Streets just north of Ness Avenue. (See Figure 1 for location.) The photographs provide a pictorial example of a stable riparian area along the creek. Photo (A) was taken in summer. It shows the grass buffer zone which is intended to trap nutrients from runoff and keep them out of the creek which otherwise could be detrimental to the aquatic life. The buffer may also aid somewhat in retarding peak flow runoff to the creek. A fair amount of shade is provided by the mature trees to help cool the water in the creek. In addition, the buffer appears to be amenable habitat for ducks by possibly providing some nesting cover; on May 5, 1993, a pair of mallards (male and female) were observed dabbling in the pool at the site. Photo (B) was taken in September and shows the long grass of the buffer having been mowed and the leaves from the trees having fallen into the

(A)



(B)



(C)

Photo P-10A, B, and C. Example of stable riparian area — looking east from Winchester St. crossing towards Linwood St.
(A) Summer (July 14, 1993)
(B) Autumn (Sept 25, 1993)
(C) Late Autumn (Nov 3, 1993)

creek. The debris will become detritus and ultimately become part of the aquatic food chain. Photo (C) shows the site in late autumn when ice has formed on the creek surface. Unfortunately, this site is *not* typical of most of the reaches of Truro Creek outside Bruce Park.

3.1.4 Airport Area

The area occupied by the airport (middle segment) is about one-third of the entire catchment, however its impact upon flows in Truro Creek is considerably greater. In light of this circumstance, the airport drainage area is discussed in this subsection, particularly with respect to recent developments.

The course of Truro Creek through the airport is generally an open channel with some flow occurring through culverts under roads, runways and taxiways; the creek exits at the P.C.S. (Photo P-8).

The areas of the airport contributing surface runoff to Truro Creek are drained by a complex system of pipes, manholes and catchbasins which ultimately drain into the main channel of Truro Creek. The complex system has been simplified and summarized on Figure 4. The main flow inputs to Truro Creek are indicated by arrows showing the direction of flow from each area. The major built-up portions of the airport property are shown as shaded areas, and being primarily pavement, are about 80% impervious (Radzius, 1979).

Major changes of the airport drainage system were undertaken during the

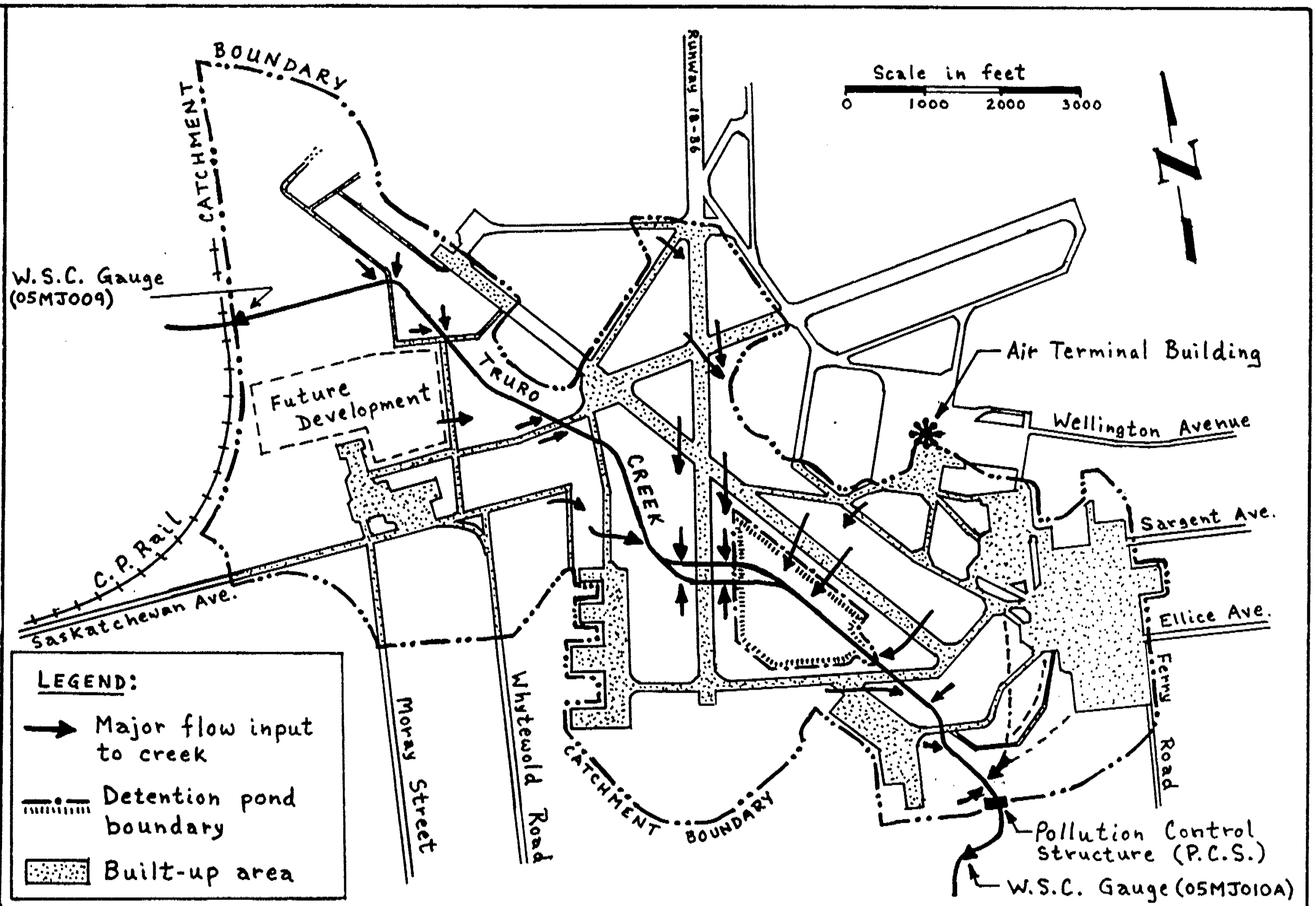


Figure 4. Major features of the existing drainage system of the airport property (middle segment of Figure 3).

1980s, in the anticipation of future development on the western side of the airport property (as shown on Figure 4) and to alleviate existing flooding problems on the airport site (Radzius, 1979). The changes included re-routing a portion of Truro Creek and the construction of a detention pond east of Runway 18-36. The route of Truro Creek through the airport prior to 1980 is shown on Figure 3 as a dash-dot-dash line; the existing creek course is a solid line. Prior to 1980, the creek flowed through some shallow depressions (old borrow pits) which are also shown on Figure 3. The extreme western depression is currently being filled in to accommodate the future development shown on Figure 4. The fill which was excavated to form the detention pond was hauled and placed in this former depression to accommodate the future development.

The detention pond on the airport property has a moderating effect by reducing the peak flows of major flood events on Truro Creek downstream of the airport. The pond and outlet works were designed so that the capacity of the creek channel in the downstream segment would not be exceeded. (The existing outlet capacity of the detention pond is just over 100 cfs. Water is not captured and stored in the pond until the flow exceeds 100 cfs, below which inflow passes through the detention pond as if it did not exist). If the detention pond had not been constructed, the proposed development and other construction on the east side (Radzius, 1985) would have increased flows on Truro Creek downstream of the airport to over double the existing capacity of most of the channel (Radzius, 1979) when major runoff events occur. The existing capacity is approximately 175 cfs, except for the Albany Street crossing (Photo P-7) which is 70 to 90 cfs.

Transport Canada's practice for many years has been to construct detention ponds for the *temporary* storage of runoff water resulting from storms of high intensity and volume (Radzius, 1979). As the flood peak from the storm recedes, the water which was stored in the detention pond during the runoff event is emptied into the storm drainage system. The peak rate of the outflow from the pond is less than that which would have occurred if the detention pond had not existed. Although the peak flow is less, the length of time over which flow occurs is somewhat greater.

Detention ponds differ from retention ponds, as *retention* ponds have a permanent water surface whereas *detention* ponds are normally dry. Retention ponding is usually discouraged from airports, because it attracts waterfowl, which interfere with aircraft movements. Detention ponds have always been part of the drainage systems at Winnipeg International Airport and at many other Canadian airports (Radzius, 1979).

3.1.5 Streamflow and Water Use in the Catchment

Water Survey of Canada (WSC) flow data has been collected on Truro Creek for a few years at two locations, or stations. The two stations are 05MJ009 and 05MJ010 and are shown on Figure 3. One was located at the west side of the airport property (WSC 05MJ009) and the other one was located just south of the airport property (WSC 05MJ010A and B). The latter station was moved from its Silver and Winchester location (05MJ010A) in the early 1980s when the bridge crossing the creek at that location was removed; it was moved to the Winchester Street crossing just north of Ness Avenue (05MJ010B). The incremental drainage area between the two stations is minimal. (In fact, Water Survey of Canada did not even change the location identifier or contributing area; the 'A' and 'B' designations are the author's.) Therefore, the data collected at stations WSC 05MJ010A and 05MJ010B have been combined into one station, hereafter known as 05MJ010. Incidentally, the establishment of the stations was prompted by the recent drainage re-construction which occurred on the airport property as described in the previous sub-section.

Truro Creek is an intermittent stream. Figure 5 shows the daily flows for a couple of months which were recorded at station 05MJ010 during a typical year (1978). Because the incremental drainage area between the station and Bruce Park is small, the flows recorded at station 05MJ010 may be considered representative of flows in Bruce Park. The flows in March and April resulted primarily from the melting of the snowpack, whereas the large flows in May resulted from a two-and-a-half inch rainstorm which occurred on May 25th. As the figure shows, snowmelt runoff may occur over a period of two or more weeks, whereas rainfall events yield higher peaks with a shorter duration of streamflow in the order of a week or so. The flow between events is generally very minimal. Of course, rainfall events can occur at any time during the summer or autumn and produce streamflows of the magnitude shown in Figure 5. In 1993, for example, three major downpours occurred in July and August, producing a considerable duration of streamflow in Truro Creek. Unfortunately, the Water Survey of Canada (WSC) had discontinued operating the stations on Truro Creek in 1989 and therefore no recorded streamflows of the 1993 runoff events are available.

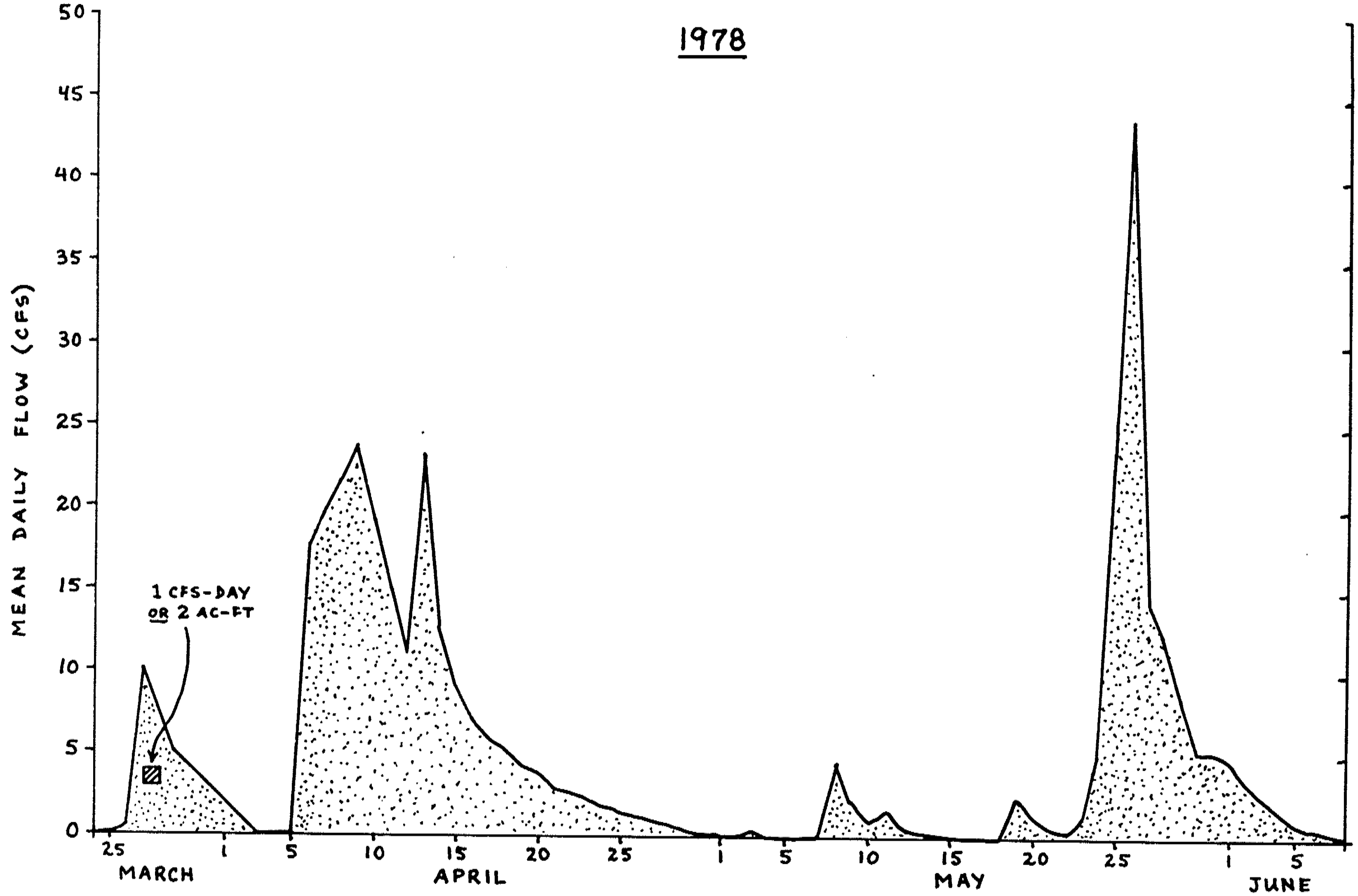


Figure 5. Daily flows in Truro Creek through Bruce Park during the spring and early summer of a typical year (1978).

The area under the line plotted on Figure 5 represents a volume of water since it is a flow rate over time. The volume can be described as either a flow rate in cfs (cubic feet per second) times time in days (86,400 seconds) yielding cfs-days, or in more direct volume units such as acre-feet (ac-ft). A volume of one cfs-day is equivalent to a volume of 2 acre-feet. A volume of two acre-feet is shown on the figure as a cross-hatched area at the 3 to 4 cfs flow level in the month of March; it is labelled as '1 cfs-day'. (The streamflow in a stream is analogous to the flow of water from the tap in one's bathtub in their home. If the tap is opened, the water will flow at a certain rate, say at one gallon per minute. In streams, flow rate is measured in cubic feet per second rather than in gallons per minute. If the tap is left open for an hour, the bathtub will fill up and hold a certain volume of water; at a rate of one gallon per minute the volume would be 60 gallons. Similarly, if a stream flows at one cfs (rate) for a day and that water could be captured, it would fill a volume equivalent to one acre to a depth of two feet. In other words, one cfs flowing for a day (one cfs-day) equals a volume of two acre-feet.)

Tables 1 and 2 provide the monthly streamflow data for stations 05MJ009 and 05MJ010, respectively. A monthly value is the average of the daily flows, as illustrated on Figure 5, for a month. WSC (Water Survey of Canada) records began in 1978 and were discontinued in 1988/89 with a gap in the 1979 to 1982 period. To provide sufficient data for analysis, the flow data for the missing years were determined using flow data from station 05MJ011 (Sturgeon Creek near Perimeter Highway).

Table 1

WSC Station 05MJ009 - Truro Creek at Western Airport Boundary

Year	Monthly Mean Flows (cfs)												Annual Volume (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1978	-	-	0.0	6.2	1.6	0.67	0.0	0.0	0.0	0.0	-	-	504.
1979*	-	-	0.0	10.9	4.2	0.32	0.1	0.0	0.0	0.0	-	-	940.
1980*	-	-	0.0	1.4	0.04	0.0	0.0	0.04	0.07	0.0	-	-	92.
1981*	-	-	0.7	0.14	0.04	0.04	0.04	0.0	0.0	0.04	-	-	63.
1982*	-	-	0.35	2.0	0.07	0.0	0.04	0.0	0.04	0.07	-	-	162.
1983	-	-	0.21	6.6	0.0	4.5	0.5	0.0	0.0	0.0	-	-	704.
1984	-	-	0.04	0.0	0.0	6.1	0.25	0.0	0.0	0.0	-	-	379.
1985	-	-	4.7	0.81	0.0	0.0	0.0	1.8	0.28	0.0	-	-	465.
1986**	-	-	2.0	2.2	1.7	0.24	0.34	0.01	0.12	0.02	-	-	399.
1987	-	-	0.0	1.4	0.0	0.0	0.0	0.53	0.0	0.0	-	-	120.
1988	-	-	0.0	0.11	0.0	0.0	0.0	0.0	0.0	0.0	-	-	7.
												Average	349.

Notes:

* Flows for this year based on station 05MJ011 (Sturgeon Creek near Perimeter Highway).

** Flows for this year based on station 05MJ010 (Truro Creek near Assiniboine Golf Course).

Drainage area is 4.3 square miles.

Table 2

WSC Station 05MJ010 - Truro Creek Near Assiniboine Golf Course

Year	Monthly Mean Flows (cfs)												Annual Volume (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1978	-	-	0.95	7.2	4.3	0.64	0.52	0.21	0.95	0.04	-	-	899.
1979*	-	-	0.0	27.9	10.9	0.85	0.28	0.0	0.0	0.0	-	-	2400.
1980*	-	-	0.0	3.5	0.07	0.0	0.0	0.04	0.18	0.07	-	-	235.
1981*	-	-	1.8	0.35	0.07	0.07	0.07	0.04	0.04	0.07	-	-	162.
1982*	-	-	1.1	5.3	0.14	0.0	0.07	0.04	0.07	0.18	-	-	413.
1983	-	-	3.9	7.3	0.14	4.9	0.57	0.46	0.11	0.04	-	-	1049.
1984	-	-	1.2	1.0	0.60	13.3	0.88	0.14	0.92	2.5	-	-	1232.
1985	-	-	9.2	2.0	0.71	1.2	0.53	5.9	0.35	1.2	-	-	1286.
1986	-	-	6.1	6.5	5.0	0.74	1.0	0.04	0.35	0.07	-	-	1198.
1987	-	-	6.9	11.9	0.11	0.39	1.8	2.0	0.21	0.42	-	-	1437.
1988	-	-	0.14	1.2	0.11	0.35	0.21	0.0	0.21	0.07	-	-	133.
												Average	949.

Notes:

* Flows for this year based on station 05MJ011 (Sturgeon Creek near Perimeter Highway).

Drainage area is 6.7 square miles.

The monthly flows for station 05MJ010 were analyzed to determine the pattern of monthly flows which would occur during an average (median) spring and summer period in Bruce Park. The results of the analysis are shown graphically as monthly flows on Figure 6. Each of the flows is the median value for that month from the study period 1978 to 1988. Similar to Figure 5, the cross-hatched area representing one cfs-day (or 2 ac-ft) is shown. As the figure illustrates, the bulk of the runoff volume occurs from the spring snowmelt period (March and April) with a much lesser volume being contributed by rainstorms in the summer (May to August). Although the peaks are generally higher from rainstorm events compared to snowmelt ones (Figure 5), the volumes are usually lower.

Discussions with experts at the provincial Water Resources Branch were undertaken. From the discussions and other information, baseflow from groundwater contributions to the creek are most unlikely, since the creek bed lies well above both the piezometric surface of the carbonate aquifer underlying Winnipeg and the bedrock surface (Render, 1970). In addition, there are no licensed uses of either surface or ground water in the catchment.

3.1.6 Longitudinal Profile of Truro Creek and Erosion in Bruce Park

Figure 7 provides a longitudinal profile of the creek bed from the headwaters just east of the landfill site to the creek mouth at the Assiniboine River. Viewing Figures 7 and 3 together reveals the relationship between the bed

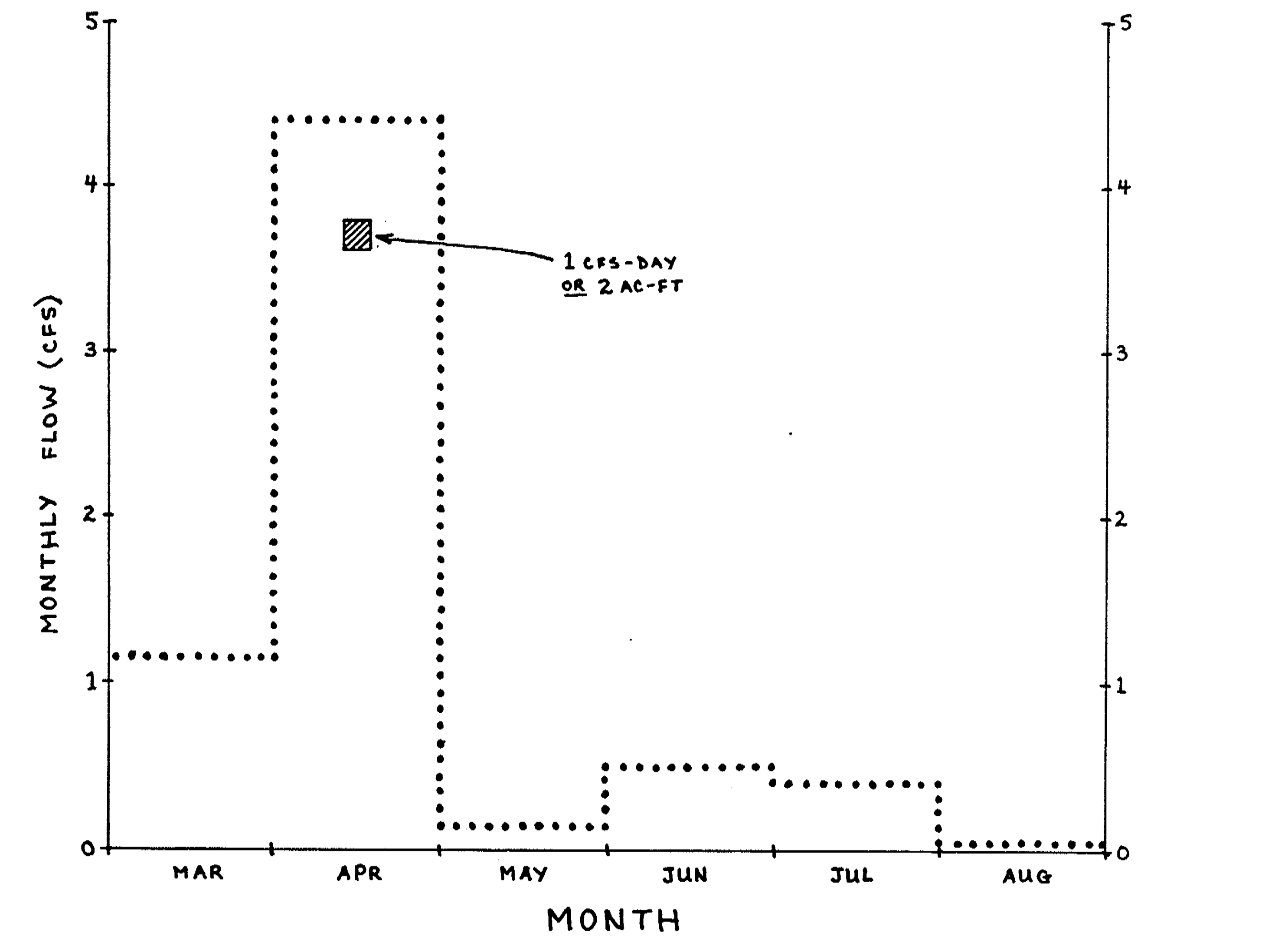


Figure 6. Monthly flows in Truro Creek through Bruce Park during an average (median) year.

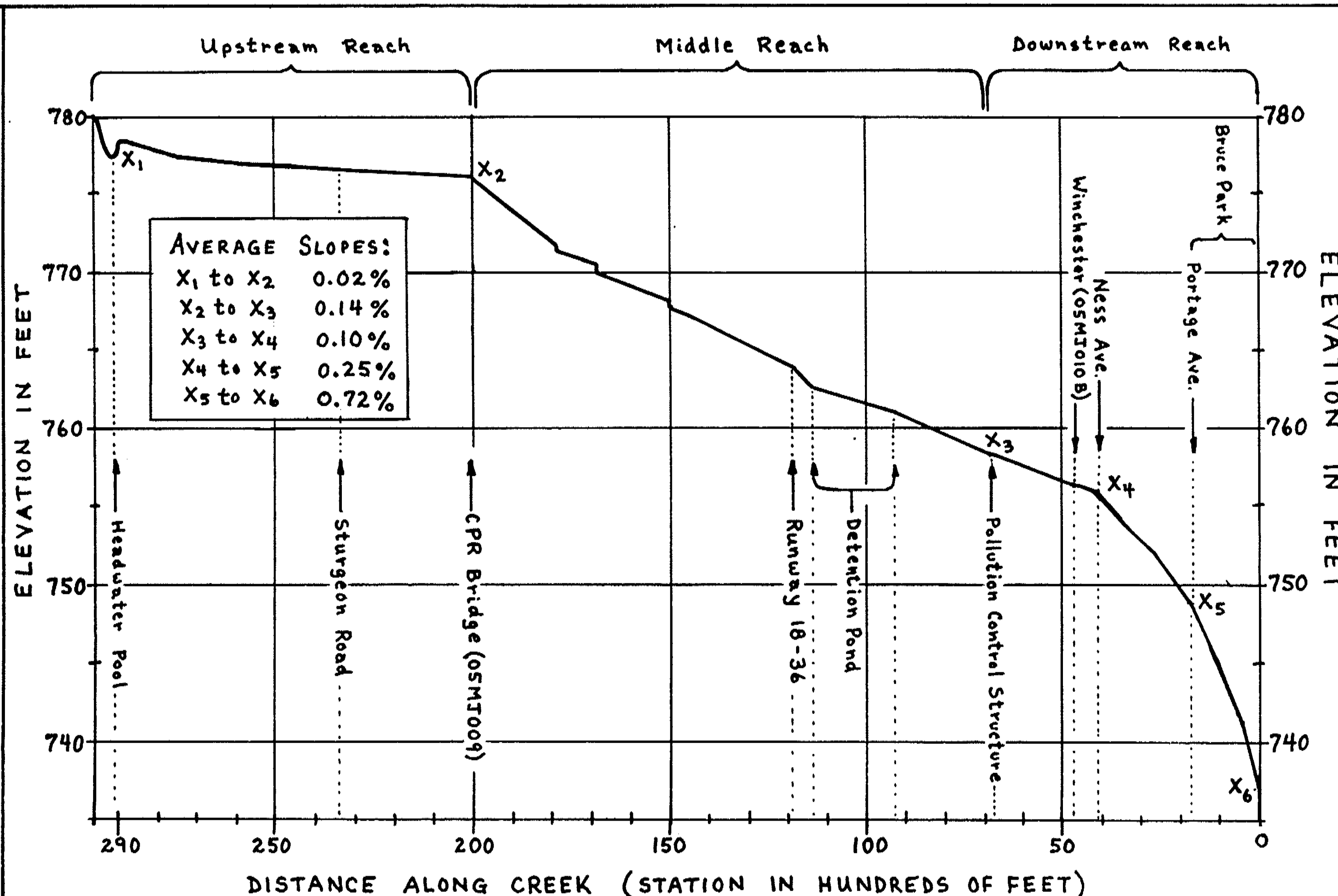


Figure 7. Longitudinal profile of the bottom of Truro Creek throughout its catchment.

of Truro Creek and the catchment. The headings at the top of the profile of Figure 7 (Upstream Reach, Middle Reach, and Downstream Reach) correspond to the *segments* of the catchment identified on Figure 3. (In other words, the downstream *reach* of the creek in Figure 7 corresponds to the downstream *segment* of the catchment in Figure 3. The middle and upstream reaches and segments are similarly designated.) As can be seen from Figure 7, the slope of the creek is generally increasing in a downstream direction with its greatest slope being in the Bruce Park subreach. The slope increases from 0.02% in the headwaters to 0.72% through Bruce Park. On the other hand, in natural basins, the slope generally *decreases* in the downstream direction forming a concave profile (Newbury, 1993). By contrast the Truro Creek profile is more or less convex. Whether the convex attribute is a natural occurrence or is due to urban developments, such as road crossings, is unknown.

3.1.6.1 Bruce Park Reach

Figure 7 shows that the total drop of Truro Creek from its headwaters to Portage Avenue is in the order of 30 feet over five miles, whereas the drop through Bruce Park alone is an additional 10 feet over just one-third of a mile. Such an extreme slope in the Bruce Park reach provides tremendous power to the creek under high flow conditions. Associated with the 10 foot drop through the Park is an incised valley.

Profiles of the creek bed and water levels under high and low flow conditions in Bruce Park are presented on Figure 8. The creek bed and low

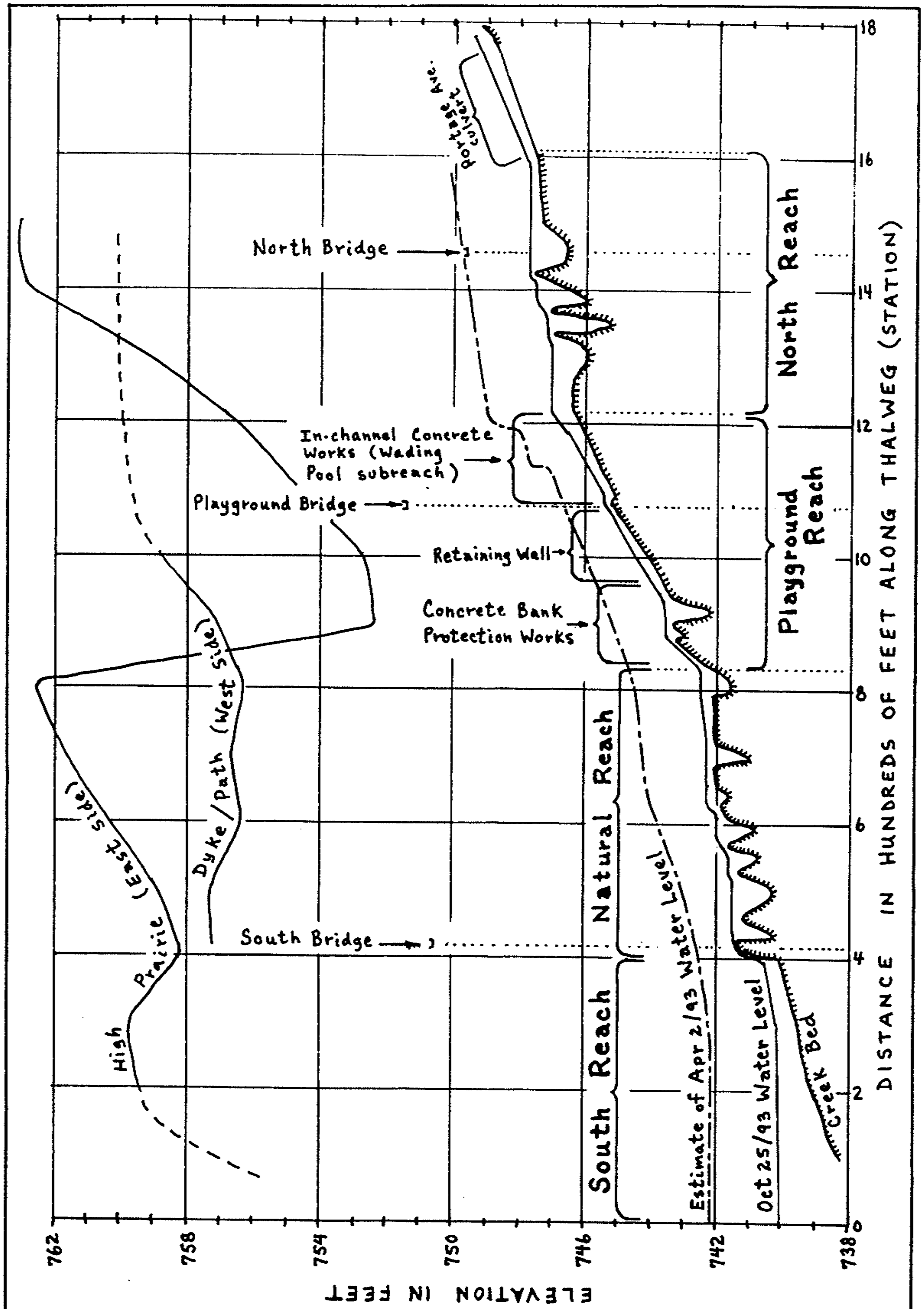


Figure 8. Creek bed and high and low water level profiles of Truro Creek through Bruce Park.

flow profiles are the results of an engineering survey performed on October 25 and 26, 1993 when the flow was less than one cfs. The high water profile is based on pictorial evidence presented subsequently, field observations on April 2 and an understanding of the hydraulics of stream channels. The two discontinuities in the April profile near station 12 account for temporary channel obstructions (debris) which were observed.

The average slope of 0.72% through Bruce Park is significant and is an important factor contributing to the erosion in the park. Although 0.72% is the average slope through the park as shown on Figure 7, it is even higher locally. As seen on Figure 8, the creek drops four feet over 400 feet through the Playground Reach, equivalent to a slope of one percent. A one per cent slope is comparable to that of a sub-escarpment stream in the western region of the province, where streambank and bed erosion of the shale substrate is a major problem (Newbury and Gaboury, 1993: 133).

The incised valley and drop through the park are shown pictorially in Photos P-11, P-12 and P-13. Photo P-11 is an overall view of the incised creek valley in the Natural Reach. Photo P-12 is a shot of the creek on the Bruce Park side of the Portage Avenue culvert. Photo P-13 is a view of the eroded east bank south of the South Bridge. The person in the photograph is standing on a point bar at the edge of the creek when the creek is in a low flow condition. The eroded bank appears to be about 15 feet in height. The reader is referred to Figure 2 for the exact location from which these pictures were taken.

Photo P-11. Creek valley in the 'Natural Reach' with South Bridge in distance. Taken from parking lot. (Nov 3, 1993)

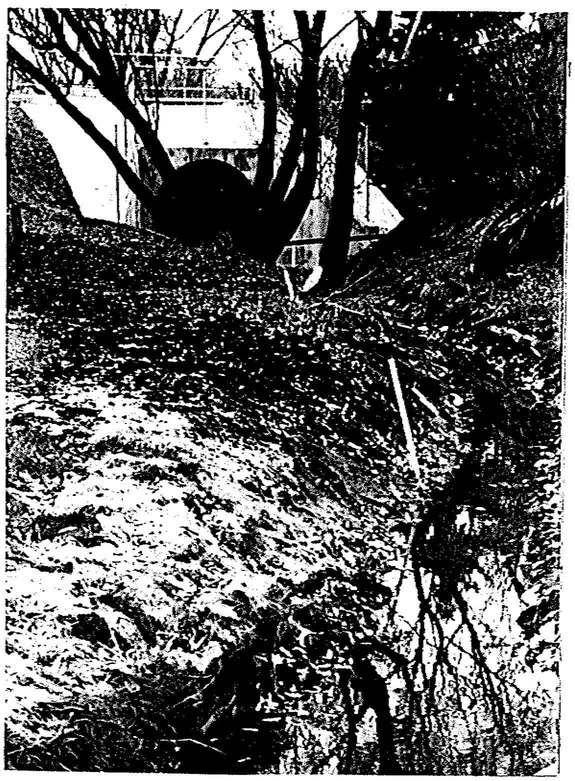


Photo P-12. Portage Avenue culvert (Nov 3, 1993).

Photo P-13. Erosion south of South Bridge (Sept 25, 1993).

3.2 HISTORIC INFORMATION

A number of sources were searched to ascertain what Truro Creek would have looked like in its pre-settlement or natural state. Archival material such as maps, field books and air photographs were studied as well as discussions with knowledgeable people were undertaken to obtain this information. In particular, an hour-long interview was conducted with Jack Benedict, a lifetime resident of St. James who lives in the house which he built in 1962 at 38 Deer Lodge Place. His residence is situated on the lot immediately adjacent to the west boundary of Bruce Park and backs onto the Assiniboine River. This section discusses what was discovered during the search process.

Sinclair and McPhillips (1874) identify three creeks in the Bruce Park area. One creek is shown in River Lot 16 proceeding north to a point just past the current Portage Avenue. To the east, on the boundary between River Lots 24 and 25, another creek is identified and is shown as being truncated before reaching north to the current Portage Avenue. A third creek mouth (not truncated) is shown in River Lot 27 where the current Bruce Park is located. Peter Bruce is identified in the field book as owning lot 27. All the creeks are unnamed.

The most detailed archival information which was discovered was a map produced in 1888 by Ruttan (found at the City of Winnipeg Archives). The map is in remarkably good condition considering that it is over 100 years old. A photocopy of the original portion of the map pertinent to the study is shown on Figure 9. Only the southern portion of the figure (the creek

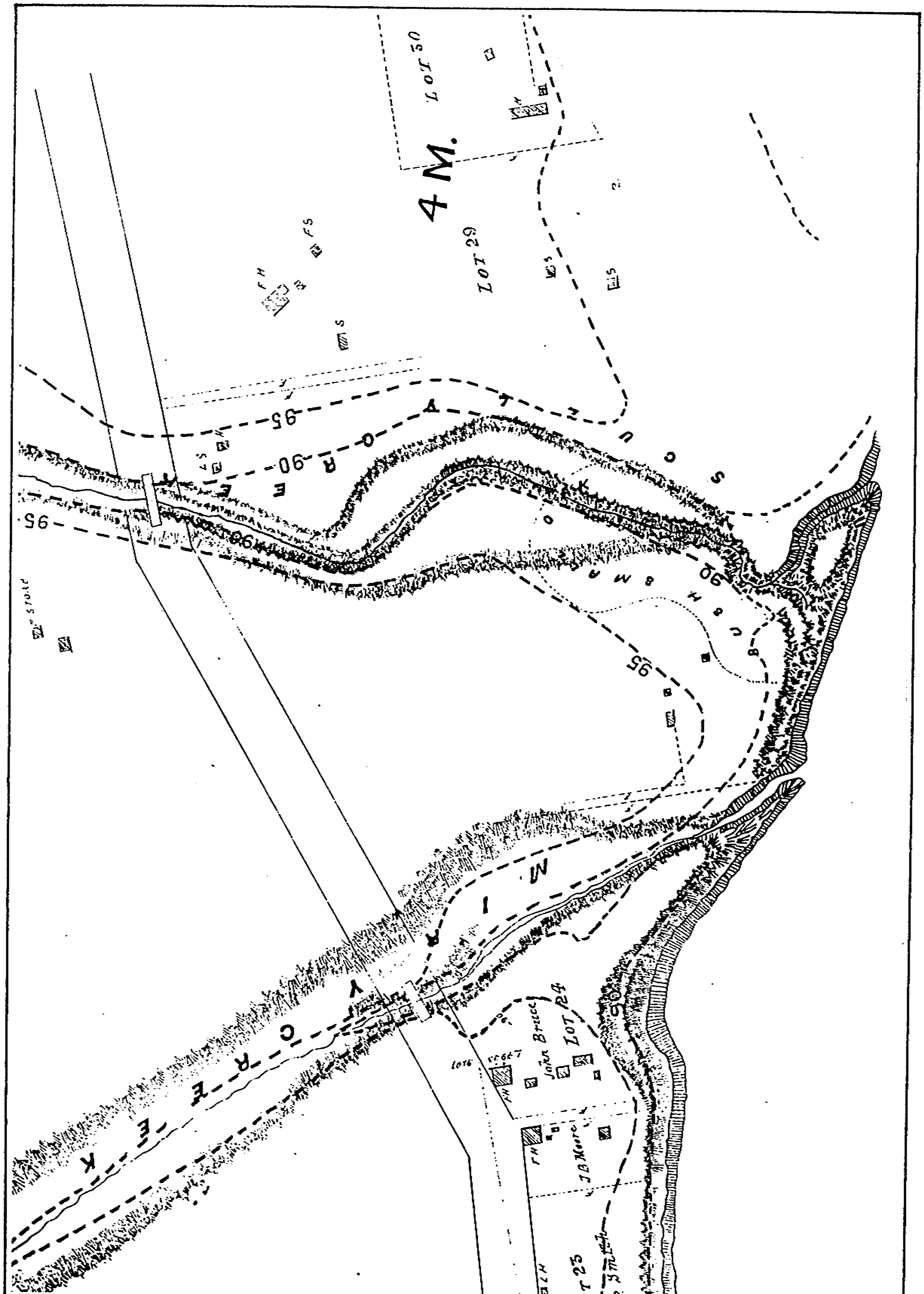


Figure 9. Ruttan Map of 1888 showing Scully and Miry Creeks in the Bruce Park area.

mouths) is not photo-original and had to be traced because this section could not be captured in the photocopy process; the map could not be folded due to its fragility. The two creeks are identified as Scully and Miry. The contour intervals of 90 and 95 feet, which are shown as dashed lines on the figure, are in blue ink on the original.

Figure 10 shows the creeks of Figure 9 reduced and overlaid on a City of Winnipeg Right-of-way Street Map. As can be seen, Scully Creek fits extremely well with the shape of the current Truro Creek. Miry Creek is just to the west having once flowed through the Deer Lodge Place area.

Other archival information was discovered and some is shown on Figure 10 as well. From air photographs taken in 1927, Truro Creek in the airport area may have taken a slightly different route. In addition, although inconclusive from 1927 air photographs, a low lying area may have existed on the current airport property just to the west of the creek. From air photographs taken during the 1950 flood, when the Red and Assiniboine flood level backed up water in Truro Creek to Ness Avenue, a possible alternate channel along Lyle Street became apparent. The channel may have been used as an overflow in times of high flow on Truro Creek. Other interesting information which was uncovered includes the existence of the golf course on the current airport property and an eroded Assiniboine River bank just west of the former Miry Creek mouth.

Some information which was discovered was erroneous. Graham (1984) inadvertently identified the current Truro Creek with the old Miry Creek and had Scully Creek originating at St. Matthews Avenue and Parkview Street

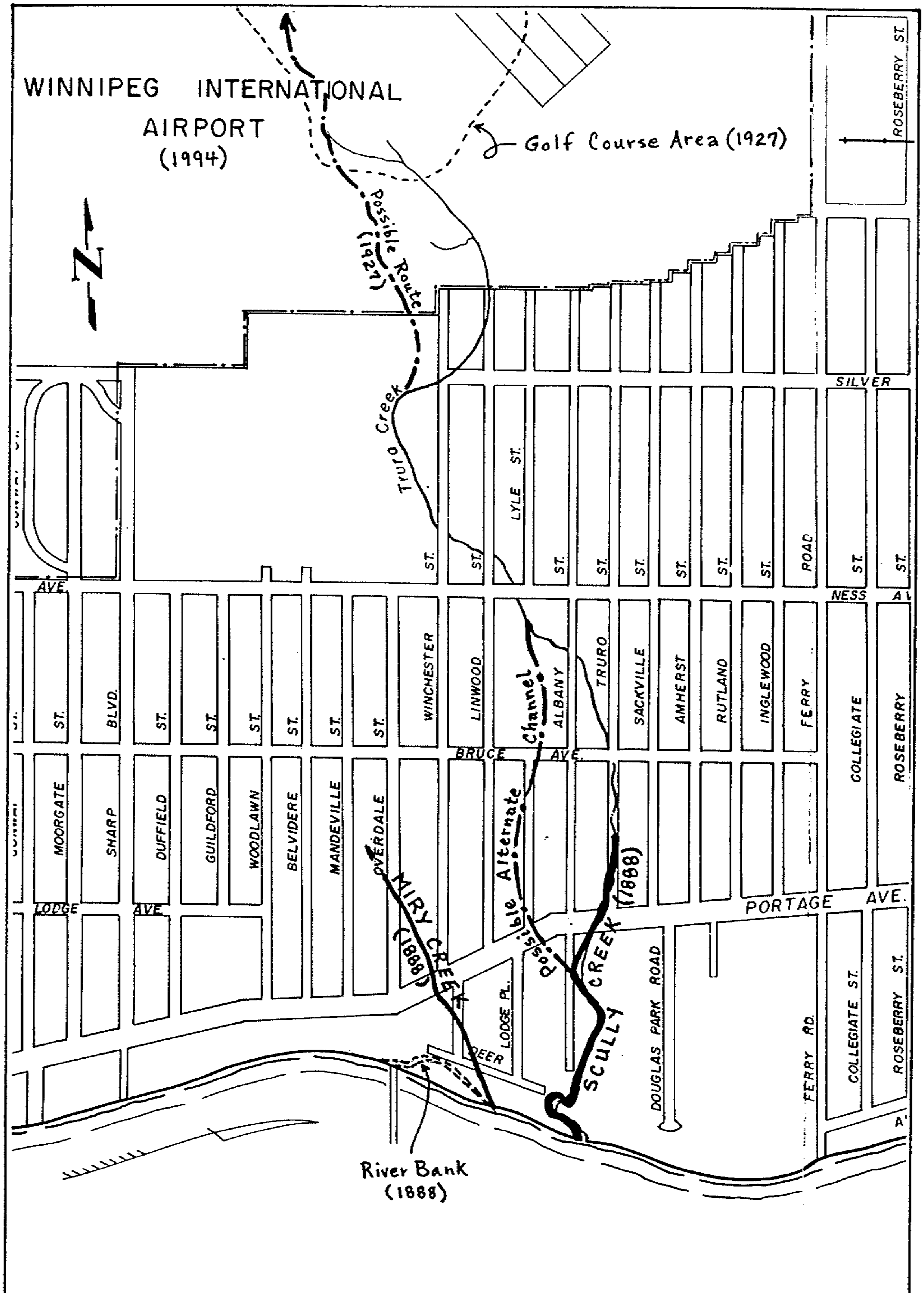


Figure 10. Historic creek information overlaid on a city street (right-of-way) map.

(one block east of Roseberry Street). He also reported McMillans Creek as flowing where Miry was. In other words, he had the creeks in the correct order from west to east but had them all shifted geographically to the east.

CHAPTER 4

PRINCIPLES OF NATURAL CHANNELS, URBANIZATION AND EROSION

4.1 PRINCIPLES OF NATURAL STREAM CHANNELS

4.1.1 Introduction

The flow in natural stream channels is highly complex and in many ways defies quantitative analysis even to the present day. As recently as 1990, this complexity has been demonstrated by Phillips (1990: 39) who states: "...it is also shown that hydraulic variables may not always respond to changing discharge in the expected direction." The reason for this complexity has been summed up in a Dutch textbook on river engineering by Jansen *et al.* They state:

> ...a physical-mathematical description of various morphological processes will be hindered by the complex combinations present in nature. The largely stochastic nature of the processes also present problems. Consequently, the relations put forward are rather empirical and conclusions drawn from different empirical relations can quite easily contradict each other. (Jansen *et al,* 1979: 130)

A case in point is the comparison made by combining the extremal hypotheses popular a few years ago with the conventional sediment transport and flow resistance equations in use at the time. The results were compared with data from laboratories (flume channels) and with observations from 'stable' natural rivers. The conclusion was that progress in this field was 'illusory' since the theory "...lead to conclusions incompatible with observations" (Griffiths, 1984: 113).

Another well-known researcher, in his review of the last 50 years of sediment research, concluded: "...we still cannot predict with adequate certainty the velocity and sediment discharge in a channel for a given water discharge. Nor can we predict if the channel will be stable." (Vanoni, 1984: 1048). Still other authors comment: "Over the last several decades, stream morphology research has been undertaken by scientists in a wide variety of disciplines, yet our understanding of channel features and the factors influencing them is still incomplete" (Beschta and Platts, 1986: 377).

These circumstances have led Newbury and Gaboury to develop an approach which is based on a study of natural stream systems holistically. The basic design principle which they have employed in their recent work on stream rehabilitation to enhance fish habitat is to simply "mimic natural conditions" (Newbury and Gaboury, 1993: 72). The resultant biological habitats created are "... a complex combination of the flow hydraulics and physical characteristics of the streambed, banks, and riparian vegetation that defies complete analysis" (Newbury and Gaboury, 1993: 91).

4.1.2 Natural Channel Factors

Hasfurther (1985: 22-23) has summarized the basic natural factors which govern the delicate balance of all streams. He has broken them down into four categories: geologic, hydrologic, hydraulic and geometric. Together, these factors interact to develop the stream system. Each of them is described briefly below.

Geologic factors include soil type and topography. Both these factors influence the type and amount of sediments entering a stream and can greatly affect the formation of meanders in a stream channel. Soil type and slope will affect the degree of meandering through the alluvium.

Hydrologic factors influence the variations in flow and runoff, which in turn affect the meander system developed by the stream. Hydrologic conditions in a watershed are affected by climatic fluctuations and changes in land use. In particular, land use changes such as urbanization or vegetal cover could have a dramatic effect on the morphology of the receiving stream.

Hydraulic factors include depth, slope and velocity of a stream. These factors directly control sediment transport and erosion of the stream bank which is reflected in the changes in channel cross-sections, pool and riffle formation and meander shape. The hydraulics of flow in natural channels is very complex, resulting in complex processes which affect its morphology.

Geometric factors consist of the channel cross-sectional shape, stream pattern (straight, meandering or braided) and the pool-riffle pattern. On many alluvial streams, significantly different channel dimensions, shapes and patterns are associated with the amount of flow and sediment load, indicating that changes in these variables can cause significant adjustments to the geometric factors.

4.1.3 Geomorphological Concepts — Energy and Dynamic Equilibrium

Two inter-related concepts aid in the understanding of stream geomorphology, namely energy and dynamic equilibrium. A stream is said to be in dynamic equilibrium when the sediment loads entering a stream reach are equal to those leaving it (Heede, 1986: 352). The energy of the stream is what gives the stream the capacity to transport a sediment load.

Energy is dissipated as a stream carries sediment. Although if a stream is in disequilibrium, unexpected changes can occur due to an imbalance in the energies. Heede summarizes these concepts in the following:

> Under conditions of dynamic equilibrium, a stream's energy is at a level that allows sediment loads entering a stream reach to equal those leaving it. The available energy is not only determined by the discharge and the morphology of the channel, controlling the hydraulic variables, but also by the sediment load. Indeed, discharge and sediment load are the most important variables. The sediment load requires energy expenditures by the flow; hence, a stream determines its own ultimate load. Loads larger than the ultimate cannot be transported and will be deposited. On the other hand, if more free energies are available than expended by the flow, the principle of continuity requires changes in some or all hydraulic variables, such as width and depth of flow, or morphologic changes leading to additions of sediment load. Whatever process occurs, it is directed toward attainment of a new equilibrium between available and expended energy. (Heede, 1986: 352)

Therefore dissipation of excess energy in a stream is important, particularly if unwanted erosion is to be controlled in an urban catchment where land use changes have significantly altered the equilibrium of the outlet stream. Energy dissipation can be accomplished in a variety of ways (Beschta and Platts, 1986: 370) including: alternating pools and riffles to encourage turbulent mixing, increasing the sinuosity (adding meanders) and increasing bank resistance with large roughness elements (e.g. woody root systems, logs and other organic debris, boulders, or bedrock outcrops).

4.1.4 Riffles as Energy Dissipators

Riffles, due to their natural hydraulic design, act as important dissipators of stream energy, particularly at intermediate and lower flow (Newbury, 1984: 336ff; Newbury and Gaboury 1993: 86). Pools, on the other hand, result from localized scour during moderate to high flows (Keller and Melhorn, 1978: 730). As has been pointed out, "...the fact that a pool has formed indicates that the location is one of intense turbulence and energy dissipation" (Beschta and Platts, 1986: 372). Pools and riffles also aerate the water which is important for fish survival. As noted by Newbury and Gaboury (1993: 75): "The pool and riffle profile creates the diverse hydraulic habitat conditions that are required in streams with healthy habitats."

Figure 11 illustrates schematically how excess energy is dissipated by riffles in a natural stream system. The views are of the stream in profile with the water flowing from left to right. The specific energy or head (H) of a flowing stream has two components: the depth (d) and the velocity head. The velocity head is the kinetic portion of the specific energy and is equal to

$v^2/2g$ as shown on Figure 11(A). The specific energy line, or simply 'Energy Line', is shown as a series of short and long dashes on the figure. Figure 11(B) shows how energy is dissipated by an engineered structure. The flow at location 1 (on the top of the drawing) is in a state termed subcritical and at location 2 the flow is passing through a point where the flow velocity is critical. At location 3 the flow becomes supercritical and is accelerating. At location 4, a phenomenon, known as a hydraulic jump, occurs. In order for the flow to return to a subcritical state (the second location 1), the water must pass through a very turbulent and noisy state where it decelerates. The turbulent and noisy mixing state (hydraulic jump) dissipates a certain amount of energy (noted as Energy Loss in the drawing), over and above the normal friction losses along the sides and bottom of the channel. Figure 11(C) illustrates these principles for a riffle in a natural stream system: the flow over the rock-boulder riffle accelerates (location 2 to 3); the hydraulic jump dissipates energy (location 4); and the flow returns to a subcritical state (location 1), with an associated energy loss. Figure 11(D) shows a schematic of a natural stream system for two riffles in sequence with a pool being formed between the riffles. (The spacing between riffles is actually much greater. The schematic is for illustrative purposes only.) The location numbers, indicating the various states of flow, are shown above the drawing as in (B) and (C).

4.1.5 Stability of Riffle Formations

Evidence exists showing the geomorphologic stability of a pool-riffle configuration in streams, in particular its resistance to disruption by major

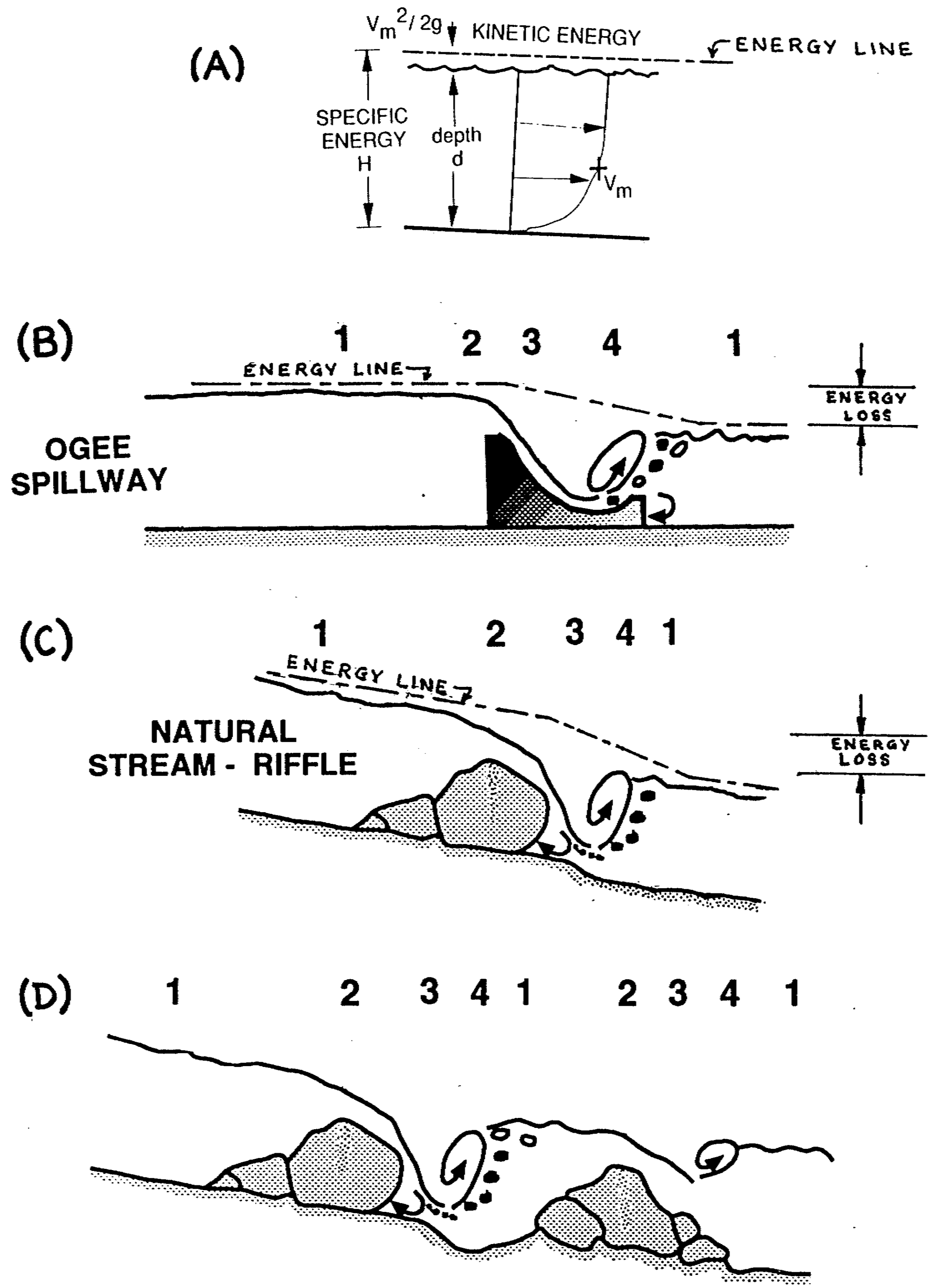


Figure 11. Dissipation of excess stream energy illustrated (adapted from Newbury and Gaboury, 1993):
(A) Specific energy equals depth plus kinetic energy,
(B) Energy loss over an engineered structure,
(C) Energy loss over a natural stream riffle, and
(D) Pool-riffle-pool-riffle natural stream sequence.

floods. This is in direct contrast to many man-made stream obstructions which frequently are washed out by such events.

One case study in the United States illustrates the point (Babcock, 1986). On a stream, pools and riffles were constructed and 'unnatural' engineered fish enhancement structures were also built. During the study period, a 4% chance flood occurred in the project area. This event rendered 75% of the enhancement structures ineffective, however, pool-riffle ratios and the quantity and quality of fish spawning areas remained essentially unchanged. On one reach it was observed that "...the lower gradient areas (less than 1.5%) were little affected; in fact, they may have experienced some improvement as the sediments were rearranged giving a somewhat better pool-riffle ratio... Despite all the material relocation caused by the flood, the area still exhibits many features that are associated with a good trout stream" (Babcock, 1986: 410).

A recent flood event in the escarpment area of Manitoba substantiates the stability of a natural pool-riffle construction in Canada. On July 3-4, 1993 record flash-flooding occurred on many streams in the area due to torrential rains. The flood event was in the order of one percent probability (or even more extreme), however, virtually no damage occurred to the constructed pools and riffles on the streams in the area (Gaboury, 1993).

4.1.6 Pools, Riffles, and Channel Geometry

Various researchers have reported on the relationships between pools, riffles and channel geometry based on the study of natural streams (Leopold, Wolman and Miller, 1964; Dunne and Leopold, 1978; Keller and Melhorn, 1978; Beschta and Platts, 1986; Roy and Abrahams, 1980; Newbury and Gaboury, 1993).

Dunne and Leopold describe a pool-riffle sequence in the following way:

> ...Even within a given reach, the channel is not uniform, rather the bed undulates in elevation in quite a regular repeating pattern. Shallow parts that we have called *riffles* alternate with deeps or *pools*. These terms we drew from our vocabulary as fishermen. The riffles differ from pools in the concentration or density of larger rock sizes. The bed of a pool may be mostly sand or sand mixed with a few cobbles, whereas the riffle nearby will be mostly gravel or cobbles. The riffle is a topographic high, or a local hillock on the bed, and water leaving the pool and approaching the riffle must converge...that is, bed water must actually rise upward and converge with water near the surface. Because of the restricted cross-sectional areas over the riffle, the mean velocity over the riffle must be greater than in the pool. (Dunne and Leopold, 1978: 622)

Just such a typical pool-riffle sequence is shown schematically on Figure 12.

Dunne and Leopold continue:

> This convergence and increased velocity over the riffle are more pronounced at low flow than at high. With increase in discharge accompanied by increase in mean velocity and in depth, the water surface slope, which is the measure of the rate of energy expenditure, also changes. Over the pool the surface slope increases with discharge, and over the riffle it decreases. At high stage the gradients become equal, the water

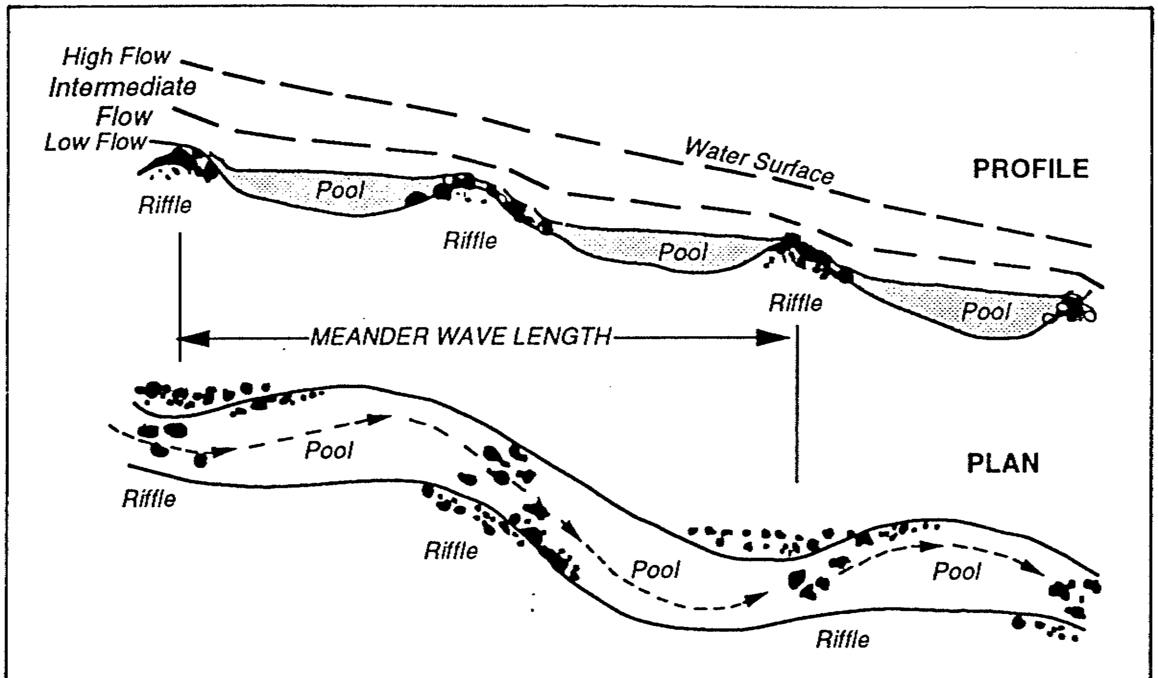


Figure 12. Longitudinal profile and plan view of a pool-riffle sequence (from Newbury and Gaboury, 1993)

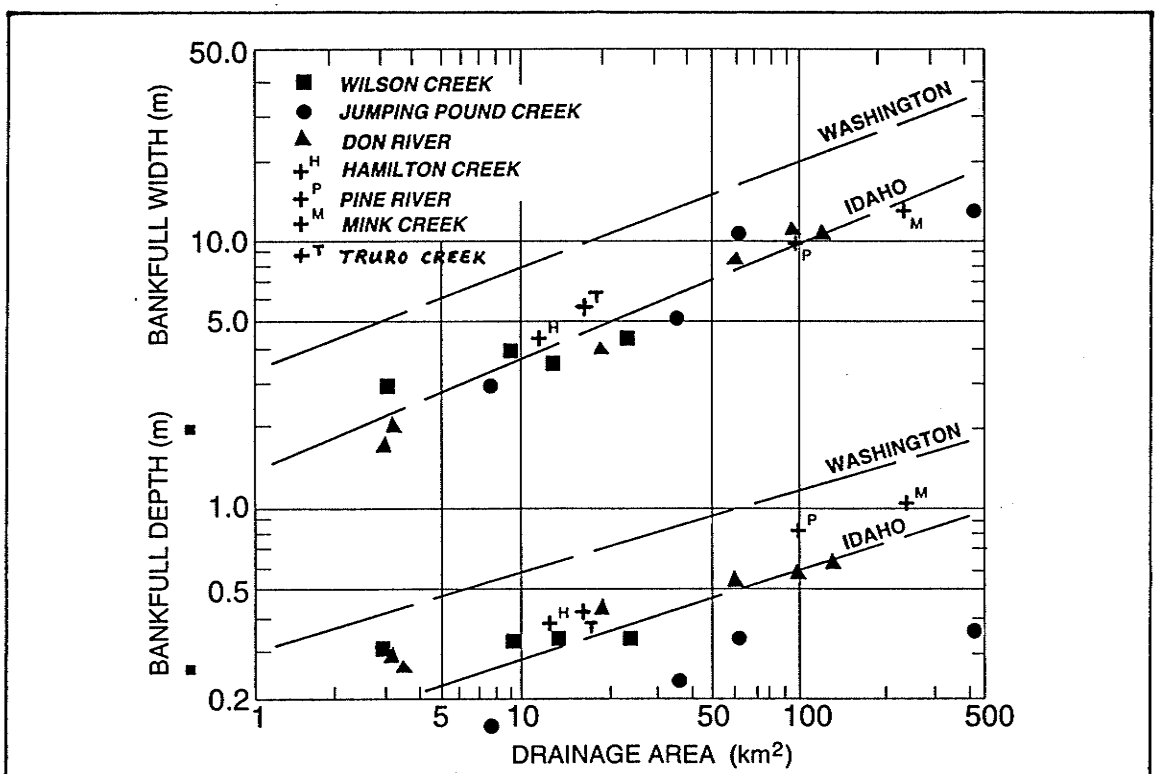


Figure 13. Bankfull channel geometry and drainage areas for several Canadian streams. The dashed lines bracket the relationship for U.S. streams (from Newbury and Gaboury, 1993).

> surface appears smooth rather than stepped, and all visual indications of the presence of pool and riffle are obliterated. In stream-gauging parlance, the riffles 'drown out'.
>
> ...
>
> The riffles are caused by the deposition and maintenance of a gravel bar that characteristically occurs alternately on one side and then on the other side of the channel. The distance between successive bars averages five to seven channel widths. (Dunne and Leopold, 1978: 622)

The distance between successive pools (or 'bars') for alluvial channels has been reported as varying between 2 and 15 channel widths with nearly 90% falling in the 3 to 9 range (Beschta and Platts, 1986: 371). Roy and Abrahams (1980) report a mean value of 5.58. Generally in applications, five to seven channel widths is used as a guide to the spacing of riffles in a stream; six channel widths may be used for channels with very uniform geometry.

Pools tend to scour at high flow and fill at low flow, whereas riffles may scour at low flow and fill at high flow. This pattern of scour and fill is important in maintaining the morphology of the pool-riffle sequence and in providing a natural sorting of the bed material such that the coarser material is deposited on riffles and point bars (Keller, 1978: 120).

Pool-riffle development is closely associated with the meander pattern. In fact, even a relatively straight reach of stream or man-made channel will tend towards meandering (Henderson, 1966: 468; Leopold *et al,* 1964: 203). Leopold, Wolman and Miller have suggested that the orderly appearance of a pool-riffle sequence in all patterns of river from straight to meandering is based on a latent form of wave phenomenon. They state:

> ...The similarity in spacing of the riffles in both straight and meandering channels suggests that the mechanism which creates the tendency for meandering is present even in the straight channel and that this mechanism is associated with some form of wave phenomenon.
>
> The alternating pool and riffle is present in practically all perennial channels in which the bed material is larger than coarse sand, but it appears to be most characteristic of gravel-bed streams — whether the gravel is pea-size or the size of a man's head. There appears to be a latent tendency for the development of pools and riffles even in boulder-bed channels. (Leopold, Wolman and Miller, 1964:203)

The waveform hypothesis has also been suggested by others (Keller and Melhorn, 1978; Baird and Lanken, 1993) and has been most recently articulated by Newbury and Gaboury who state:

> The geometry of meanders and the pool and riffle profile for all river patterns in erodible materials may be related to the bankfull width. A full meander wavelength, that is, the distance between two riffles or two similar points along the channel where the wave form is repeated, has been observed to occur between 7 and 15 times the bankfull width for rivers ranging from 0.3 to 300m wide. The mean spacing of pools, half a meander wavelength, has been measured as 5.6 and 6.7 times the bankfull width for alluvial and bedrock streams, respectively... (Newbury and Gaboury, 1993:76)

The wavelength relationship is depicted on Figure 12.

4.1.7 Bankfull Width in the Design of Natural Channels

Another important concept in the geomorphology of natural stream channels is the bankfull stage, which has been alluded to previously. The *bankfull stage* determines the *bankfull width* (or sometimes called channel width) upon which much of the design of natural channels rests. This stage, or water level, corresponds to the discharge at which "channel maintenance" is most effective, that is, "the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels" (Dunne and Leopold, 1978: 608). Other names include the characteristic flow or maintenance flow (Newbury and Gaboury, 1993: 66) or dominant channel-forming flow (Dunne and Leopold, 1978: 609). Relationships between the drainage area and the depth and width of streams at bankfull have been developed. Newbury and Gaboury have combined data from Canada with that for the United States. The relationships are shown on Figure 13.

4.1.8 Bank Erosion Processes

Natural channels change their cross-sections by the process of erosion and deposition. Straight channels migrate laterally most slowly, whereas meandering channels tend to move by erosion along concave banks with deposition on convex banks (Dunne and Leopold, 1978: 626). The deposits formed are called riffle bars or point bars as shown on Figure 14. Riffle bars on alternate banks characterize straight channels and point bars on convex

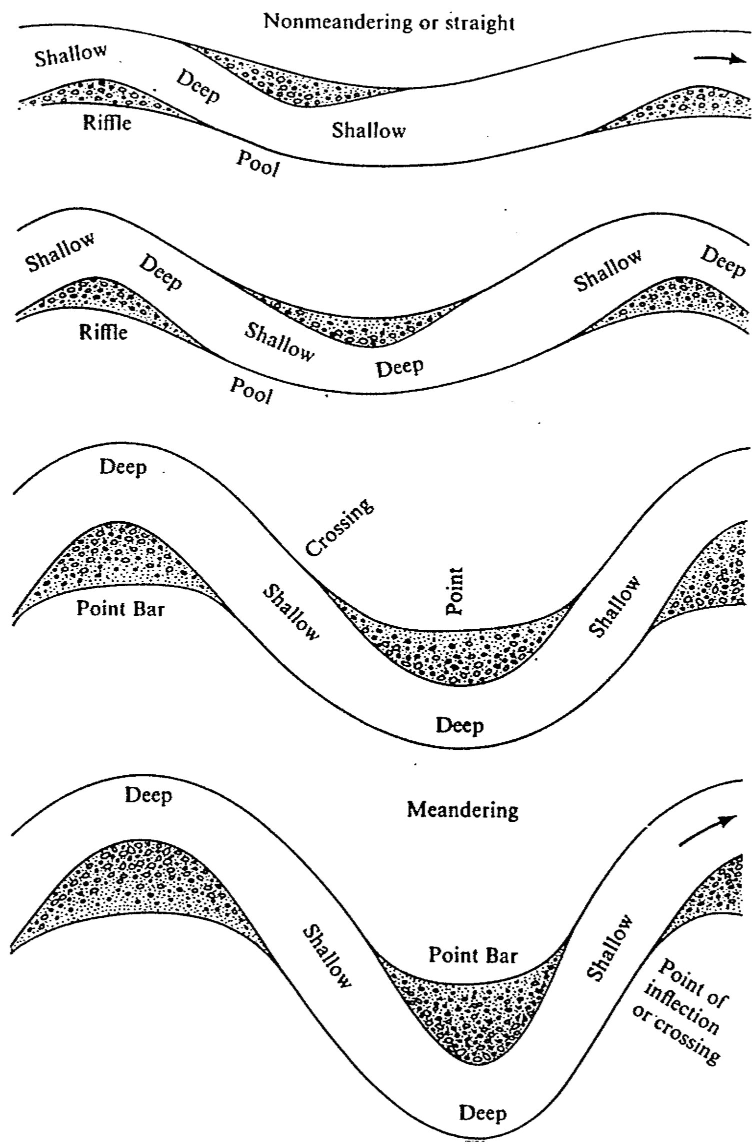


Figure 14. Schematic showing sediment deposits as riffle bars and point bars. Riffle bars on alternate banks characterize straight channels, whereas point bars on convex banks characterize meander bends (from Dunne and Leopold 1978).

banks characterize meander bends. Therefore, erosion of streambanks is quite a natural process.

Streams tend to move to a position of dynamic equilibrium, in which the bankfull width is uniform throughout the reach (Andrews, 1982). The process includes erosion of those banks which are narrower than the mean width and to a certain extent deposition on those banks which are wider. In this way, the channel is adjusting to a more uniform bankfull width which is slightly wider than the present mean reach width. Although such adjustment is the tendency, the pool-riffle sequence and lateral migration of the stream maintain the variability of the channel width (Andrews, 1982: 1192). In other words, opposing forces are at work on the channel banks.

4.2 EFFECT OF URBANIZATION ON STREAM CHANNELS

Urbanization is generally considered to be "the most radical change in land use" (Harvey and Watson, 1986: 360) in a basin leading to major hydrologic and sedimentological changes which are reflected in the outlet stream's morphology.

The change begins primarily with the change in runoff processes resulting from covering parts of the catchment with impervious roofs, sidewalks, roadways, and parking lots (Dunne and Leopold, 1978: 275). In addition, gutters, drains and storm sewers are laid in the urbanized area to convey runoff more rapidly than natural to stream channels. Due to these changes, the flood wave moves downstream more quickly with less storage in the basin. Stormwaters can therefore accumulate more quickly downstream than in natural stream systems and produce higher flood peaks with a concomitant increase in channel erosion (Dunne and Leopold, 1978: 693).

The increase of storm runoff has many costly consequences in urban areas (Dunne and Leopold, 1978: 276-277), two of which are of particular interest in the current Truro Creek situation. One consequence is that channels become enlarged in response to the larger floods. The other consequence is that increased amounts of water that generate storm runoff are not available for recharging the groundwater to supply baseflow during dry weather.

Leopold, in 1968, drew together the results of various studies on the hydrologic impact of urbanization. The results are reported in Dunne and Leopold (1978: 328). Figure 15 shows the effect of urbanization on the size of the mean annual flood from one-square-mile basins. Two parameters are used to describe the extent of urbanization: the percentage of area served by storm sewers and the percentage of the area urbanized. As the figure shows, flood peaks increase substantially as urbanization progresses.

A number of authors have cautioned about making predictions or interpreting channel changes due to changes in land use such as urbanization, grazing, vegetation clearing and agriculture, or additions such as instream structures (Dunne and Leopold, 1978: 693; Beschta and Platts, 1986; Heede, 1986: 353; Petts and Foster, 1985: 171) since the predictions are not that reliable. However, based on the available evidence, urbanization generally causes channel erosion and enlargement downstream of developments, due to increases in frequency and magnitude of high flows and even moderate

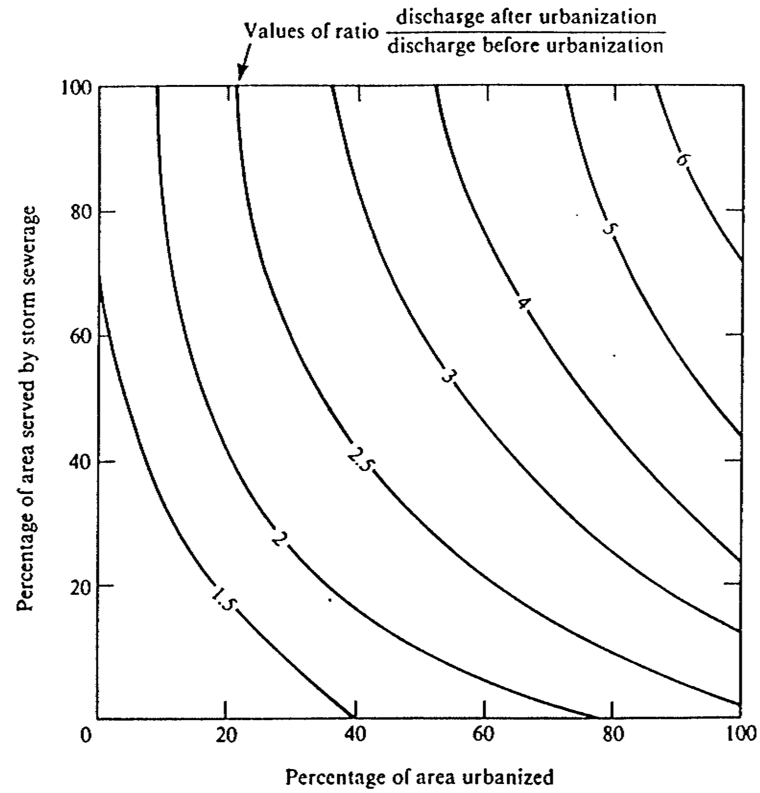


Figure 15. Effect of urbanization and storm sewerage on mean annual flood for a one-square-mile basin (from Dunne and Leopold, 1978).

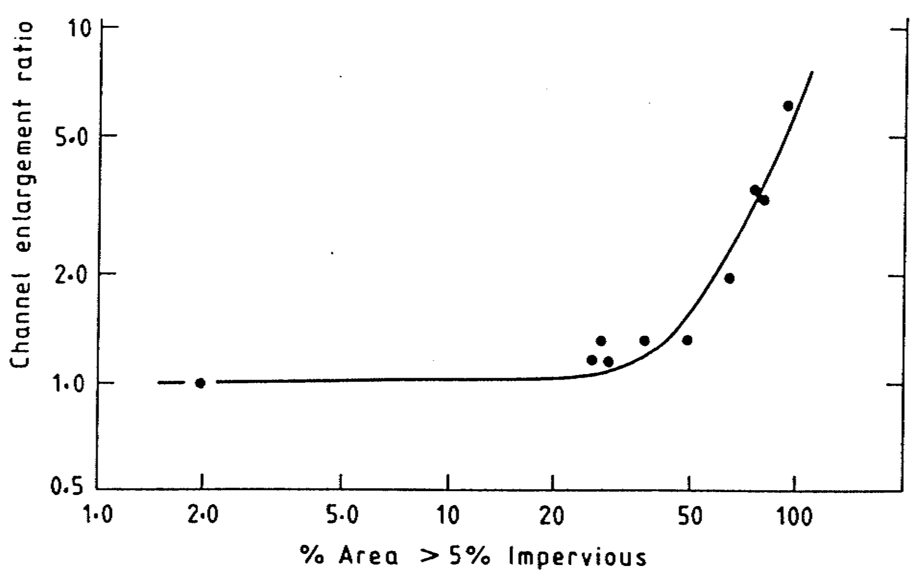


Figure 16. Relationship between impervious area in an urban area and channel enlargement, east coast, U.S.A. (from Petts and Foster, 1985).

flows (MacRae and Rowney, 1992). It has been reported that along rivers draining urban catchments, channel capacity may be more than double that of natural channels at a given drainage area (Petts and Foster, 1985: 170).

Certain thresholds may have to be crossed before significant change in a channel occurs because of urbanization. For example, Morisawa and LaFlure identified a threshold value of urbanization for catchments on the east coast of the U.S.A. (Petts and Foster, 1985: 171). Twenty-five percent of the catchment area with 5 percent impermeability was required before significant channel enlargement occurred, and once the area had risen to 30-40 percent, the rate of channel enlargement was accelerated. This relationship is shown graphically on Figure 16.

Wolman and Schick, who studied sediment records and made measurements in natural, urbanizing and urban areas in Maryland, found that areas under construction produce 10 to 100 times more sediment than is found in otherwise comparable rural or natural areas (Dunne and Leopold, 1978: 684). An increase in sediment load will generally cause a channel to decrease in depth and increase in width (Beschta and Platts, 1986: 371).

Dunne and Leopold have concluded, from the studies by Wolman and Schick and by others on urbanization, that the effect of an increase in discharge which causes the channel to enlarge overrides the effect of an increase in sediment which causes the channel to decrease in size. They state:

> From basins of drainage area less than 10 square miles, urbanization apparently tends to increase, on the average, the cross-sectional area of a channel at bankfull level. Though this

> enlargement may lag in time the changes of basin surface that cause it, the implication is that for small drainage areas the increase in flood peaks overcompensates for concurrent increases in sediment yield. This conclusion follows from the fact that enlargement means more channel erosion than deposition. (Dunne and Leopold, 1978:695)

Hammer (1972) studied 78 small catchments near Philadelphia to determine the relative effect of different land uses on channel enlargement. Fifty of the sample catchments contained some degree of urbanization in the form of large-scale residential, commercial, or industrial development; 28 catchments contained only rural land uses. The results from Hammer's study are shown in Table 3 as ratios of enlarged channel area to natural channel area in a catchment of one-to-five square miles in area. A weighting procedure

Table 3. Ratio of enlarged channel area to natural channel area in a catchment of one- to five-square-mile area if all the catchment were in use as specified (from Hammer 1972).

LAND USE	RATIO
Wooded	0.75
Previous developed land	1.08
Impervious area less than 4 years old; unsewered streets and houses	1.08
Cultivation	1.29
Houses more than 4 years old fronting on sewered streets	2.19
Sewered streets more than 4 years old	5.95
Impervious areas more than 4 years old	6.79

based on drainage area can be used for basins which have more than one land use.

A limited amount of data exists which relates the *relative* change in widths and depths of the stream channel which occurs when a channel enlarges. The available information generally indicates that downcutting usually occurs and narrowing is also possible (Dunne and Leopold, 1978: 698ff).

4.3 CONCLUDING COMMENT

Pools and riffles are inherent features of natural streams. The pool-riffle formation dissipates excess energy, which otherwise would be used to erode the channel bed and banks. To maintain a stable riffle formation, the spacing between riffles must be based on the wavelength of the stream which is reflected in its morphology, namely the bankfull width. A spacing of five to seven (average six for uniform morphology) bankfull widths between riffles provides a stable system.

Keller has concluded from his rehabilitation work on urban streams that pools and riffles may be developed on urban streams using natural stream morphology. He states:

> Statistical comparison of pool spacing with channel width in natural streams and those affected by limited human use suggests that there is no significant difference. This supports the tentative conclusion that the tendency for pools and riffles to develop is a fundamental aspect of stream channel morphology that is relatively insensitive to limited environmental stress. (Keller, 1978: 125)

Keller's conclusion, however, is dependent upon the availability of appropriately sized bed material. If such alluvial material is unavailable in the stream bed, locally available stones, rocks, and boulders may need to be imported to construct the riffles to compensate for the disequilibrium brought on by the change in land use from natural conditions to urbanization.

CHAPTER 5

ANALYSIS OF THE HYDROLOGY AND GEOMORPHOLOGY OF TRURO CREEK IN BRUCE PARK

5.1 THE HISTORIC (PRE-SETTLEMENT) CONDITION

5.1.1 Historic (1888) Information

Figure 17 shows an enlargement of that portion of Figure 9 where the current Bruce Park is situated. The current and 1888 locations of Truro Creek are shown. A number of things are worth noting from this figure. They are: the creek migration since 1888, the steep Assiniboine River banks, the meander loop cutoff, and the possible floodplain. Each one is discussed briefly below.

The creek has probably migrated over time, particularly in the southern portion near the mouth. Such migration would at least partially account for the inordinately high steep east bank near the South Bridge, as the creek cut into the bank over time. (See Photo P-13.) The migration as envisaged would have undermined the bank, causing bank sloughing to occur. Furthermore, successive rises in the Assiniboine River water levels during flood events and subsequent de-waterings of the banks upon recession of flood flows would have exacerbated the condition. However, since 1970 flood control works on the Red and Assiniboine Rivers have controlled flood flows on the rivers. The control has reduced the extremes of high water levels which historically had occurred. In this way, the control works have lessened the watering-dewatering effect during the last 24 years.

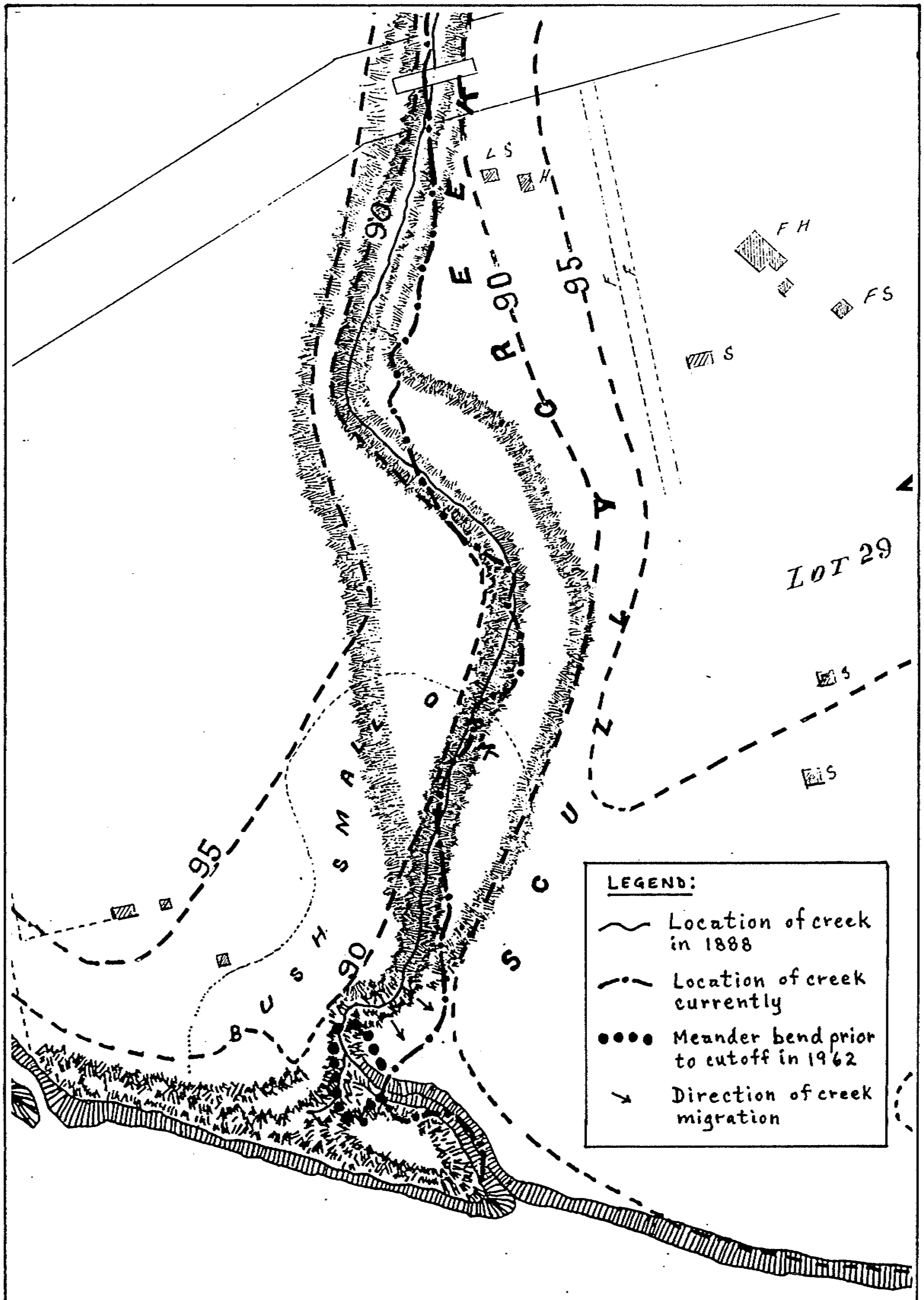


Figure 17. Ruttan map (1888) of Bruce Park showing the 1888 and current locations of Truro Creek.

The map shows that the high banks, characteristic of the Assiniboine River, extend for over 200 feet upstream of the confluence, suggesting that the high banks in this reach of Truro Creek have existed for over one hundred years. From discussion with Jack Benedict (1994), the high east bank has been there as long as he can remember.

The creek possessed, prior to 1962, a major meander loop whose location is shown near the mouth of Truro Creek. In 1962, when Jack's house was built, a cut of 20 to 25 feet to allow the creek to flow straighter was made and the cutoff meander bend was filled in. The envisaged migration would account for the meander loop which the Benedicts cut off and filled in.

Along both sides of Truro Creek in 1888, a floodplain or terrace appears to have existed. Evidence for such a landform is the following. Immediately adjacent to the thalweg of the creek are markings indicative of the banks of the creek. Varying between 50 and 150 feet on either side of the creek are what appear to be another set of 'banks'. This second set of 'banks' could possibly signify the extent of a former floodplain. The 'floodplain' extends the entire length of Truro Creek in Bruce Park from what is now Portage Avenue to the South Bridge. The existence of a flood plain in this reach would indicate that the creek valley was not as incised in 1888 as it is today, allowing flood waters to spill over the banks quite regularly. In addition, the gradient of the creek through the widest part of the 'floodplain' was relatively mild, not steep as it is today.

No information was uncovered to reveal if pools and riffles existed in Truro

Creek in 1888. As can be seen on Figure 17, meanders were not part of the general morphology of the creek, outside of the one large meander loop near the confluence.

5.1.2 Hydrology and Geomorphology of the Natural Stream Channel

Urbanization, as pointed out in Chapter 4, can have a severe impact on the creeks which are used to carry away stormwaters from urban areas. This section discusses these aspects with respect to Truro Creek and the change in the creek from natural conditions.

No historical information was discovered which suggested that any major diversions into or out of the catchment has occurred. Therefore, although the boundary of the catchment has been modified somewhat, especially in the middle segment (Figure 3), the current area of the catchment does not appear to be significantly different from natural conditions.

The available streamflow records allow for an estimate of the hydrologic effects that urbanization, primarily in the form of airport development, has had. The basic assumption for the runoff analysis is that the upstream segment is currently hydrologically similar to the natural condition. The assumption is sound since, in pre-settlement time, the vegetative cover was most probably tall grass prairie. The primary agricultural use now is grain crops and pasture, which provides a hydrologic response similar to tall grass.

Runoff volumes were compared using the data contained in Tables 1 and 2. The median unit runoff at station 05MJ009 (Table 1) is 88 ac-ft/mi^2 which corresponds very closely to the value for the area from regional studies which produced a value of 84 ac-ft/mi^2 (Mowchenko, 1978). The median value for station 05MJ010, calculated from the data in Table 2, is 160 ac-ft/mi^2. The analysis suggests that, on average, runoff volumes through the park have doubled over natural because of airport development.

A similar analysis for peak flows of the mean flood was undertaken. A frequency analysis of peak flows for data at station 05MJ009 produced a value of 18 cfs. The procedure to transpose peak flows to a downstream location (Durrant and Blackwell, 1961; Gray *et al*, 1970) produced a value of 24 cfs for natural conditions at station 05MJ010, which is half the value of 50 cfs for existing conditions (Figure 23). Figure 15 produced a similar result. Utilizing 35% for both axes on the graph of Figure 15, which is representative of the proportion of airport area in the catchment, the ratio of peak flows for after and before urbanization is about 2.2. The conclusion is that peak flows through the park have doubled due to airport development.

The geomorphologic effects on the channel, however, are not as easy to ascertain, being that no archival channel cross-section information was uncovered which described the cross-sectional shape of the channel under natural conditions. Therefore, estimates, based on studies primarily from the eastern United States, were made. The estimates are somewhat tenuous since the hydrologic regimes and other conditions, such as soils, are undoubtably different from the Truro Creek situation.

One approach utilized the work of Hammer (1992) as described in Chapter 4 (Table 3). Enlargement of the natural channel due to changes in land use in the catchment (primarily airport development) could range from a factor of 1.5 to 3 depending upon how the ratios from Table 3 are applied. Airports are just one of a number of land uses in Hammer's category entitled 'Impervious areas more than 4 years old'. The ratio in the table for this category is 6.79. Hammer is not clear in his article (Hammer, 1972) about the application of the ratio. Whether the 6.79 ratio applies to the entire airport area, which in the Truro Creek case is 2.3 square miles, or just to the *impervious portions of the area*, which are one-third to one quarter of the area, is unclear. If the latter case applies, then the enlargement ratio for Truro Creek is about 1.5; if the former case applies, then the enlargement ratio is 3.0.

A different enlargement ratio is determined if the work of Morisawa and Laflure is applied by using the graph on Figure 16. The portion of the Truro Creek catchment which has impervious area greater than five percent is approximately 35% (middle segment). This value places the Truro catchment in the transition stage, beyond which enlargement would accelerate with additional development in the catchment. At the current stage of development, according to the curve on Figure 16, the enlargement ratio should be about 1.3.

A doubling of flow, as the hydrologic analysis indicates, would intuitively suggest that an enlargement ratio in the order of two would be appropriate.

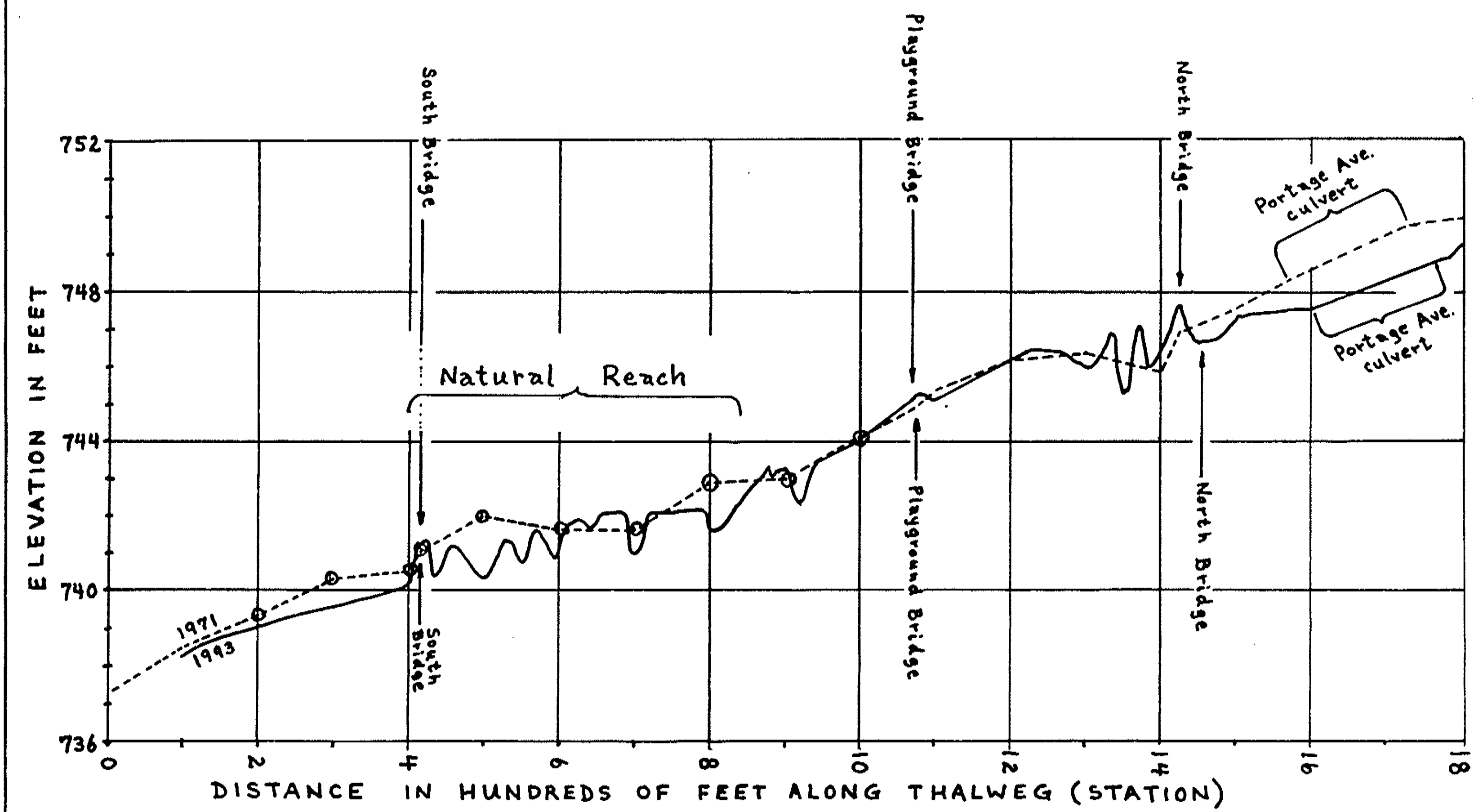
The conclusion is that the channel has enlarged by erosion due to an increase in flow over natural conditions. The exact enlargement ratio is indeterminable but appears to be somewhere in the one-and-a-half to two range.

The channel, although it has enlarged, still exhibits a width-to-depth ratio at bankfull consistent with data from natural channels. Such a condition suggests that the enlargement has proceeded proportionally in width and depth, preserving the width to depth ratio. This aspect is discussed further in Section 5.2.1.1.

5.2 EXISTING CONDITION

An engineering field survey of the Bruce Park reach of Truro Creek was performed on October 25 and 26, 1993. A profile of the thalweg is plotted on Figure 18. (The thalweg is the lowest point in the channel at any cross-section of the creek, in other words the creek bed.) Fortuitously, the provincial Water Resources Branch had performed a survey of the creek 22 years earlier in December, 1971. For comparison, the 1971 survey information (Manitoba, 1971) is plotted on Figure 18 as well. From a comparison of the two surveys a number of observations can be made, which are:

1. From station 2 to station 9 (primarily Natural Reach) erosion of the creek bottom has occurred. The amount of erosion ranges from 0.24 feet to 1.62 feet with an average value of 0.68 feet. The estimate is based on nine measurements, since the 1971 survey took measurements at only 100 foot intervals (station 1, station 2, etc) which are identified by circles on the profile. The 1993 survey was far more detailed with elevations taken at



NOTE: Profile of 1971 Survey shown as dashed line; 1993 Survey is solid line. Bridge and culvert notations for the 1971 Survey are above the profile lines; for the 1993 survey, notations are below the profile lines.

Figure 18. Comparison of the 1993 survey to the 1971 survey of the Truro Creek thalweg through Bruce Park.

each one hundred foot station and at many more locations in between.

2. From station 9+50 (read as nine plus fifty in surveying jargon) to station 12 (twelve plus zero zero in surveying jargon) the creek has remained fairly stable. This stability is due in great part to the rocks and rubble which line the channel in this section of the creek and have been there for quite some time.

3. The 1971 surveyed channel is somewhat shorter than that of the 1993 survey, especially in the sub-reach between the playground bridge and the Portage Avenue culvert. It is suspected that, since the 1971 survey was probably performed with snow and ice on the creek, the true thalweg may not have been measured in this sub-reach.

A detailed plan and profile view of Truro Creek for each of the reaches in Bruce Park (identified on Figures 2 and 8) are provided in the series of Figures numbered 19 to 22. The figures were based on a combination of the 1:2400 Flood Risk maps (Metropolitan Corporation of Greater Winnipeg, 1975), the engineering survey conducted on October 25-26, 1993, and free-hand drawing and field observations and measurements performed by the author on October 21 to 23, 1993. These data are also the basis for the map contained on Figure 2 (base map).

5.2.1 Study of the Natural Reach

Subsequent analyses focused on a study of the Natural Reach as described

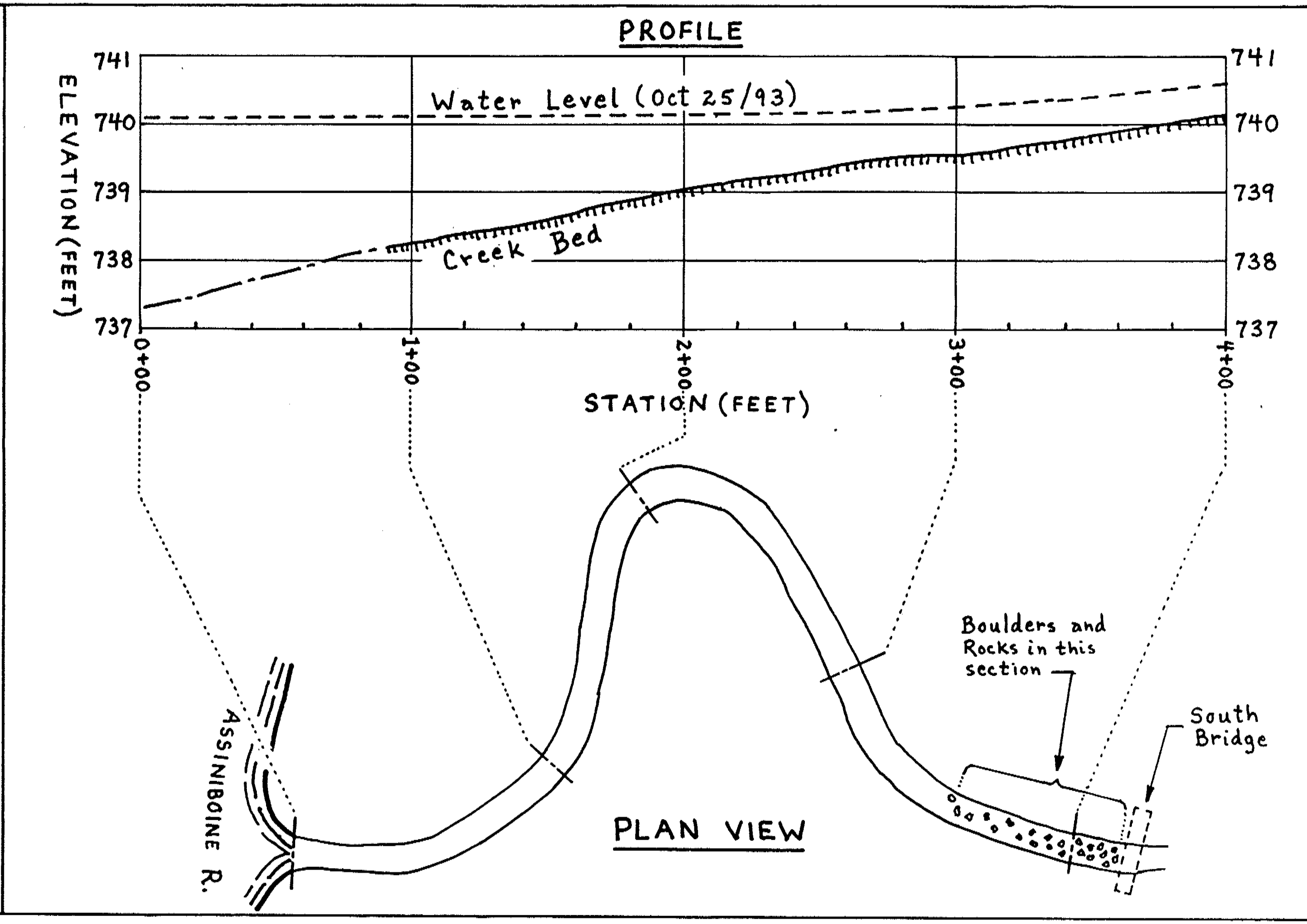


Figure 19. Detailed plan and profile views of the South Reach of Truro Creek in Bruce Park.

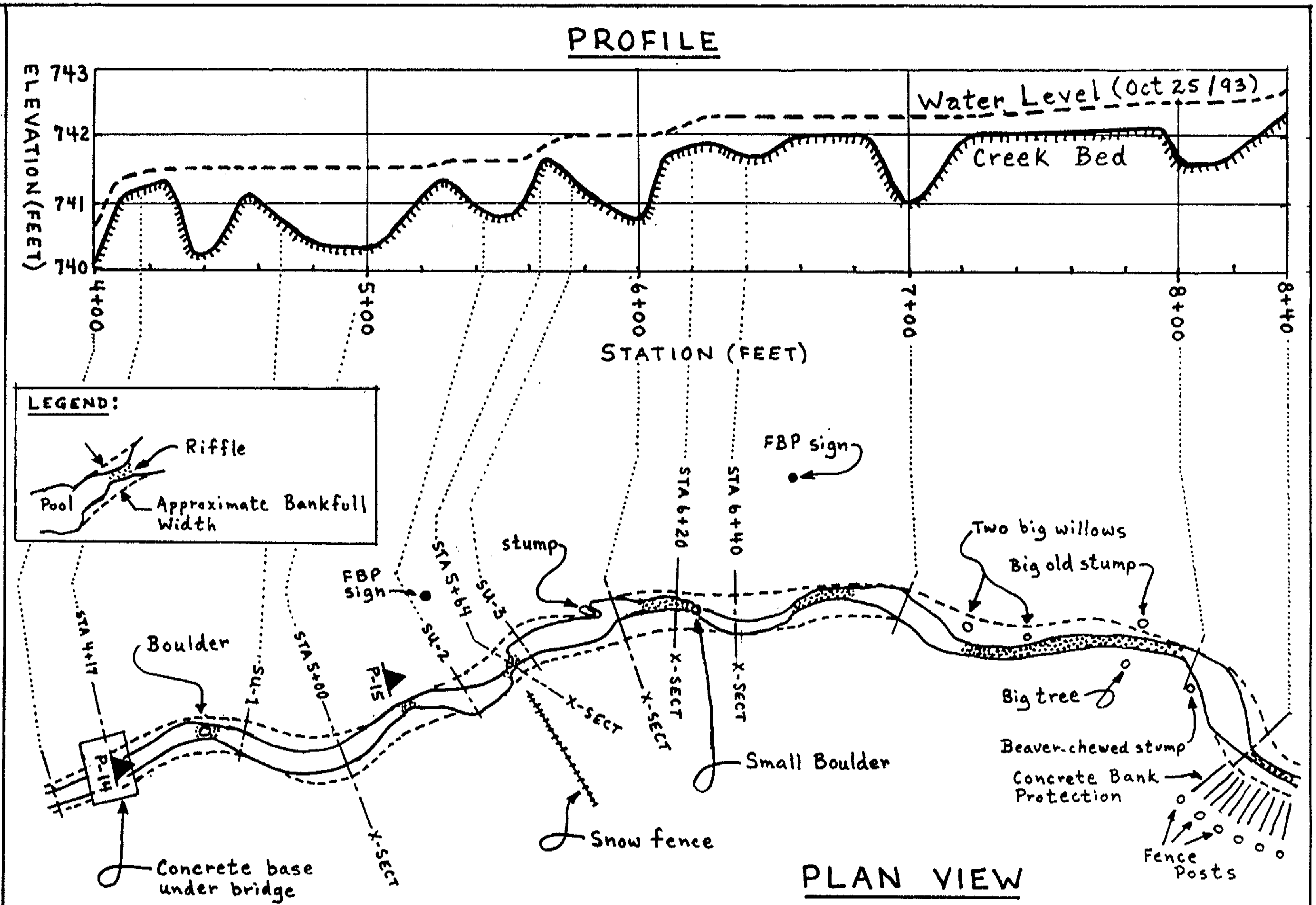


Figure 20. Detailed plan and profile views of the Natural Reach of Truro Creek in Bruce Park.

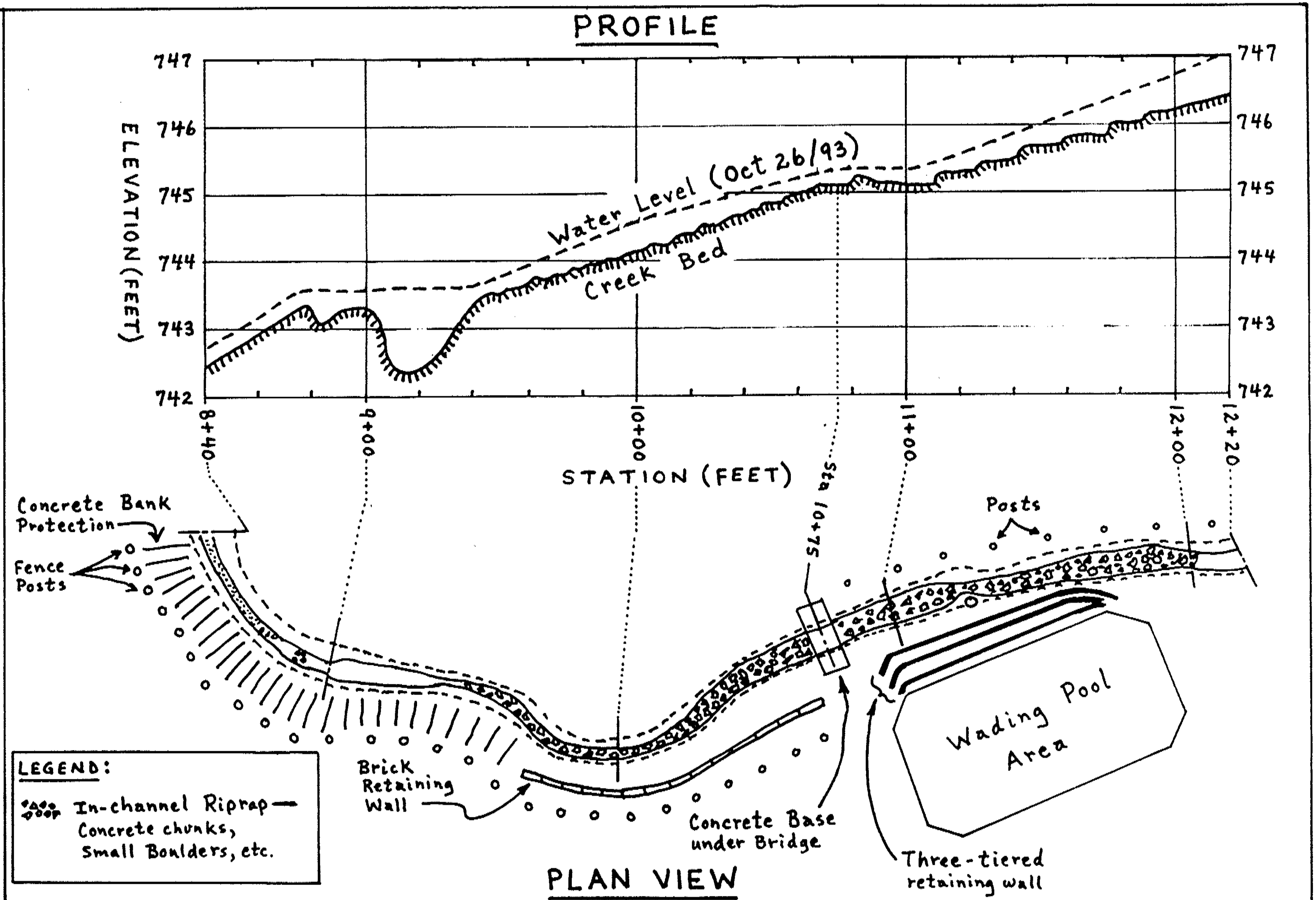


Figure 21. Detailed plan and profile views of the Playground Reach of Truro Creek in Bruce Park.

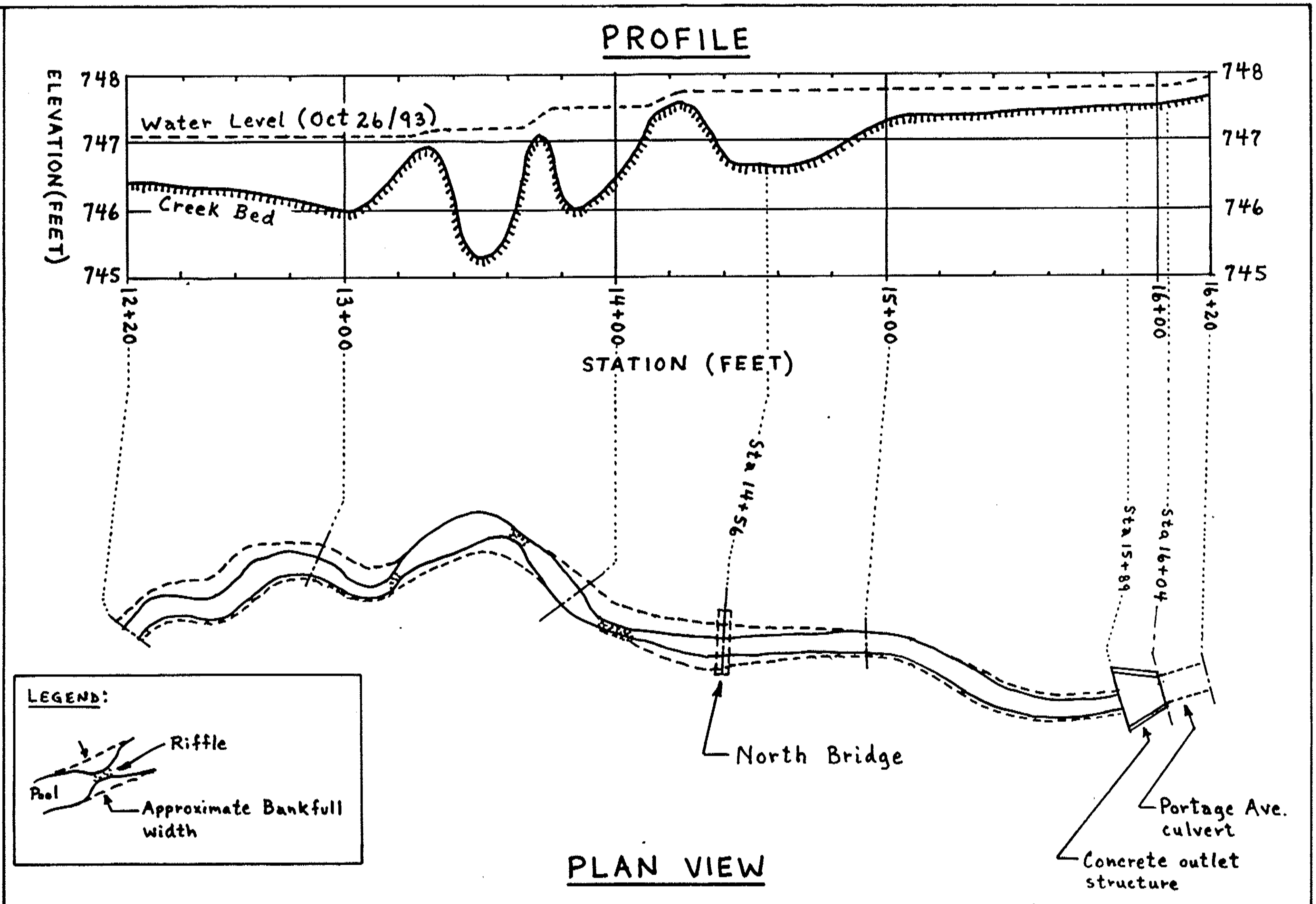


Figure 22. Detailed plan and profile views of the North Reach of Truro Creek in Bruce Park.

by Figure 20, since it exhibited the most natural characteristics of all the reaches.

The similarity between the plan and profile views of Figure 20 and the top two diagrams of Figure 14 and Figure 12 should be noted. From a comparison of the figures, the reach of Truro Creek can be identified as being primarily a straight channel exhibiting riffle bar (plan view) and shallow pool and riffle (profile view) formations.

The creek bed material was not sampled and analyzed in detail. But, from simple visual field observation, the creek bed material was identified as sandy silt mixed with clay and the riffles had collected some larger sized material, mostly flat rocks generally one-half inch in diameter. Outside of the few small boulders identified on Figure 20, no large sized sediment material is available in the alluvium from which sizable riffles could be formed.

Photos P-14(A) and(B) and P-15(A) and (B) were taken during 1993 from the locations shown on Figure 20 (same as the triangles on Figure 2). The photographs show the creek at the two flow conditions of high flow (30 cfs) and low flow (less than 1 cfs) which relate to the water level profiles shown on Figure 8.

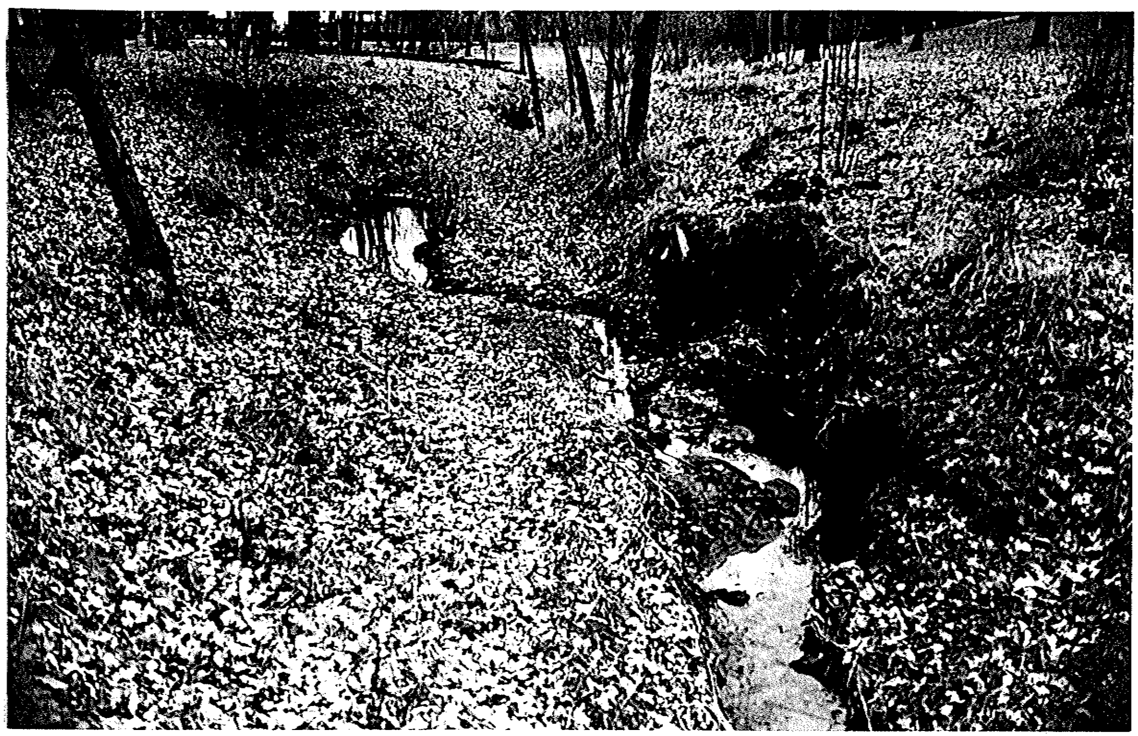
5.2.1.1 Bankfull Width Determination

The bankfull (or channel maintenance flow) width of the channel is the key to determining stream behaviour, as discussed in Chapter 4, particularly

(A) (B)

Photos P-14A and B. 'Natural Reach' from South Bridge under two flow conditions:
(A) Flow approximately 30 cfs (April 2, 1993).
(B) Flow less than 1 cfs (Nov 3, 1993).

(A)



(B)

Photos P-15 A and B. 'Natural Reach' looking north from station 5+20 under two flow conditions:

(A) Flow approximately 30 cfs (April 2, 1993)

(B) Flow less than 1 cfs (Nov 3, 1993)

if channel modifications based on natural stream principles are being considered. Therefore, a great deal of effort was expended to determine what this value is for Truro Creek in Bruce Park.

The first step was to conduct a frequency curve (statistical) analysis of peak flows using recorded and estimated data for WSC station 05MJ010. A number of severe rainstorms had produced significant flows in the summer of 1993 on Truro Creek. Since the WSC stations were no longer in operation, estimates of the peak flows were made based on miscellaneous readings at the gauge location and field observations. The recorded and estimated flow data are given in Table 4. The result of the frequency curve analysis is presented on Figure 23.

The bankfull flow (or maintenance flow) of a stream is not determined using a 'hard and fast' rule. The bankfull flow can vary from stream to stream and even from continent to continent (Newbury and Gaboury, 1993; Newbury, 1993). From the literature (Newbury and Gaboury, 1993; Leopold, Wolman, and Miller, 1964; and others), the bankfull flow was reasoned to lie somewhere in the box bounded by the instantaneous peak flow curve, the mean daily (spring) peak flow curve and the 50% (1:2 year) and 67% (1:1.5 year) probability lines. However, the flows represented by these bounds on the graph of Figure 23 ranges, as shown in the inset, from 20 cfs to 113 cfs.

Further field information was gathered after the engineering survey had been completed to aid in the assessment and to narrow in on what the 'true' bankfull flow and associated width might be. On November 13, 1993, the

Table 4

Peak Flow Data for Station 05MJ010

	Peak Flows (cfs)		
Year	**Instantaneous**	**Mean Daily (Annual)**	**Mean Daily (Spring)**
1978	149.	43.	24.
1983	84.	35.	27.
1984	194.	60.	4.
1985	143.	70.	33.
1986	87.	43.	43.
1987	74.(e)	50.	50.
1988	11.	11.	11.
1989*	-	-	16.
1993	170.(e)	71.(e)	30.(e)

Notes: (e) - Estimated flow value
* - The station was discontinued after the spring freshet (May 2, 1989)

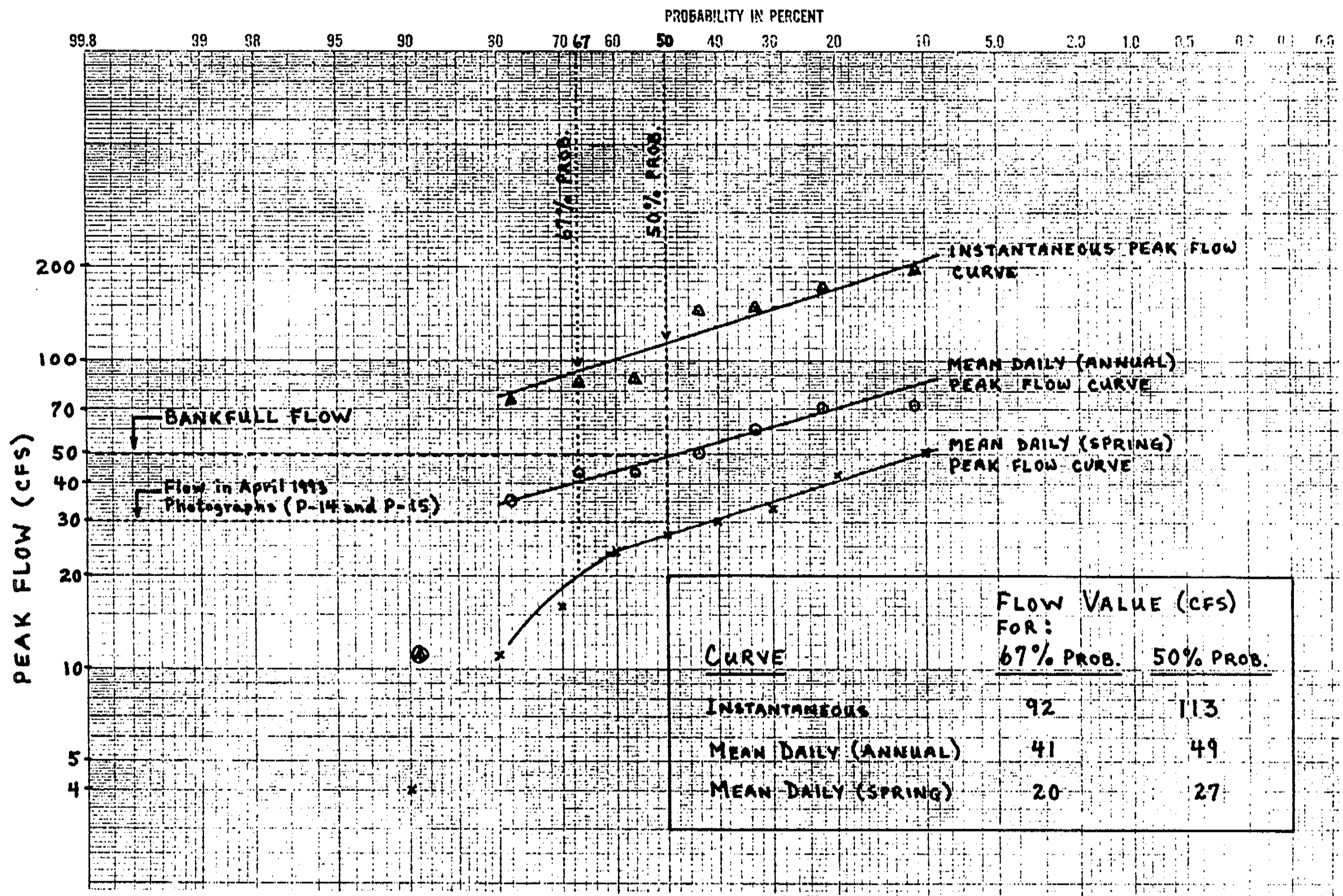


Figure 23. Frequency curve (probability) analysis of flood peaks using data from WSC station 05MJ010.

April 2/93 flood level widths were determined in the field at three of the surveyed cross-section locations using Photos 14(A) and 15(A) as a guide. As well, supplemental measurements were taken at the locations shown on Figure 20 as SU-1, SU-2 and SU-3. At this time also, measurements of bankfull width were taken at each of the aforementioned locations. The measurements were based solely on observations (and measurements) in the field at some level above the April 2/93 flood level. The observations included looking at the channel form and visualizing where the bankfull flow level might be. Generally, they were a foot or so above the 1993 flood level as seen in Photos P-14(A) and P-15(A). All the measurements were then compiled and related to the cross-sections plotted from the engineering survey. In addition, hydraulic calculations were done as required at each of the surveyed cross-sections to determine the water levels and associated widths for the various flows. All the above measurements and calculations have been compiled and are summarized in Table 5.

The creek bed form was analyzed in addition to the above data. Looking at the profile view of Figure 20, a definite pattern of pool spacing appeared to exist: a pool was located at 110 foot intervals beginning at station 4+80 and proceeding upstream. In fact, if the pattern is followed upstream to the 'untrained' part of the North Reach, where natural pools and riffles had been allowed to develop, pools are found at stations 13+60 and 14+70. (See Figure 22.) The 110 foot spacing is equivalent to six times a bankfull width of 18.3 feet.

A value of 18 feet seemed appropriate for the bankfull width. The value

Table 5

Summary of Results from Investigation of the Bankfull (Channel Maintenance) Width and Depth Values in the Natural Reach

Location (Station)	April 2/93 Width in Feet (Flow = 30 cfs)	Width in Feet at 49 cfs Flow	Field Measurements of Bankfull width in Feet	Width in Feet at 113 cfs Flow
SU-1	10.5	-	17.0	-
5+00	14.5	16.0 (1.5)[1]	17.00	20.0
SU-2	17.8	-	21.0	-
5+64	16.2[2]	20.0 (1.1)	-	23.5
SU-3	15.3	-	21.3	-
6+20	17.2[3]	19.7 (1.2)	21.0	23.0
6+40	15.0	16.0 (1.8)	18.0	18.0
Averages	15.2	17.9 (1.4)	19.2	21.1

Notes:

1. Value in parentheses is the average depth of flow at the cross-section. Overall average for the four cross-sections shown at bottom of column.

2. Interpolated from data for SU-2 and SU-3.

3. Value shown is taken from surveyed cross-section. Field measurement taken at that location was 16.8 feet.

corresponds to the 49 cfs flow level (column 3) of Table 5 whose average bankfull width is 17.9 ft. The values in parentheses shown alongside column 3 in Table 5 are the average depths of flow corresponding to a flow level of 49 cfs. The average width of 17.9 feet and average depth of 1.4 feet have been converted to metric and plotted on Figure 13 (Chapter 4). As can be seen, the values fall a little above the line for Idaho but generally very close to the range of data for Canadian streams. In fact, the width-to-depth ratio is 13:1; the range for natural streams has been observed to be between 10:1 and 15:1 (Newbury and Gaboury, 1993: 71).

The values for the natural bankfull width and depth for Truro Creek would lie below the line for Idaho on Figure 13, if the channel has enlarged as described in Section 5.1.2. Assuming the channel has enlarged by a factor of two over natural conditions and has progressed proportionally to maintain the 13:1 ratio, the values for the natural bankfull width and depth would be 12.8 ft (3.9 m) and 1.0 ft (0.3 m), respectively. The values are not shown on Figure 13 but would lie roughly an equal distance below the Idaho line as the current values lie above it. As can be visualized from the figure, these natural values are very much in line with the bankfull widths and depths for other streams in Canada.

The bankfull flow level of 49 cfs is indicated on Figure 23. As the drawing shows, the flow level corresponds quite closely to the mean daily peak flow (annual) curve at 50% probability. For a catchment of Truro Creek's size and nature, the floods which comprise this particular curve occur from short-duration high intensity rainfalls. Resulting streamflows typically peak rapidly and recede quickly with the instantaneous peak level being very short-lived. One would think that the average flow for a day (the mean daily peak flow) would be required to perform the required "channel maintenance".

The surveyed cross-sections used in the analysis are plotted on Figures 24 and 25. Also plotted on the cross-sections are the elevations corresponding to the low-flow water level of October 25, 1993 and the flood level of April 2, 1993. The bankfull level corresponding to 49 cfs is also shown. As can be seen, the bankfull level is about one-half foot above the April 2/93 water level. Referring back to Photos 14(A) and 15(A), the bankfull level would appear to be just a bit below the 'scour' level which is in concurrence with Newbury (1993). The 'scour' level is the level below which permanent vegetation, such as trees, are prevented from growing due to the scouring action of regular flood flows.

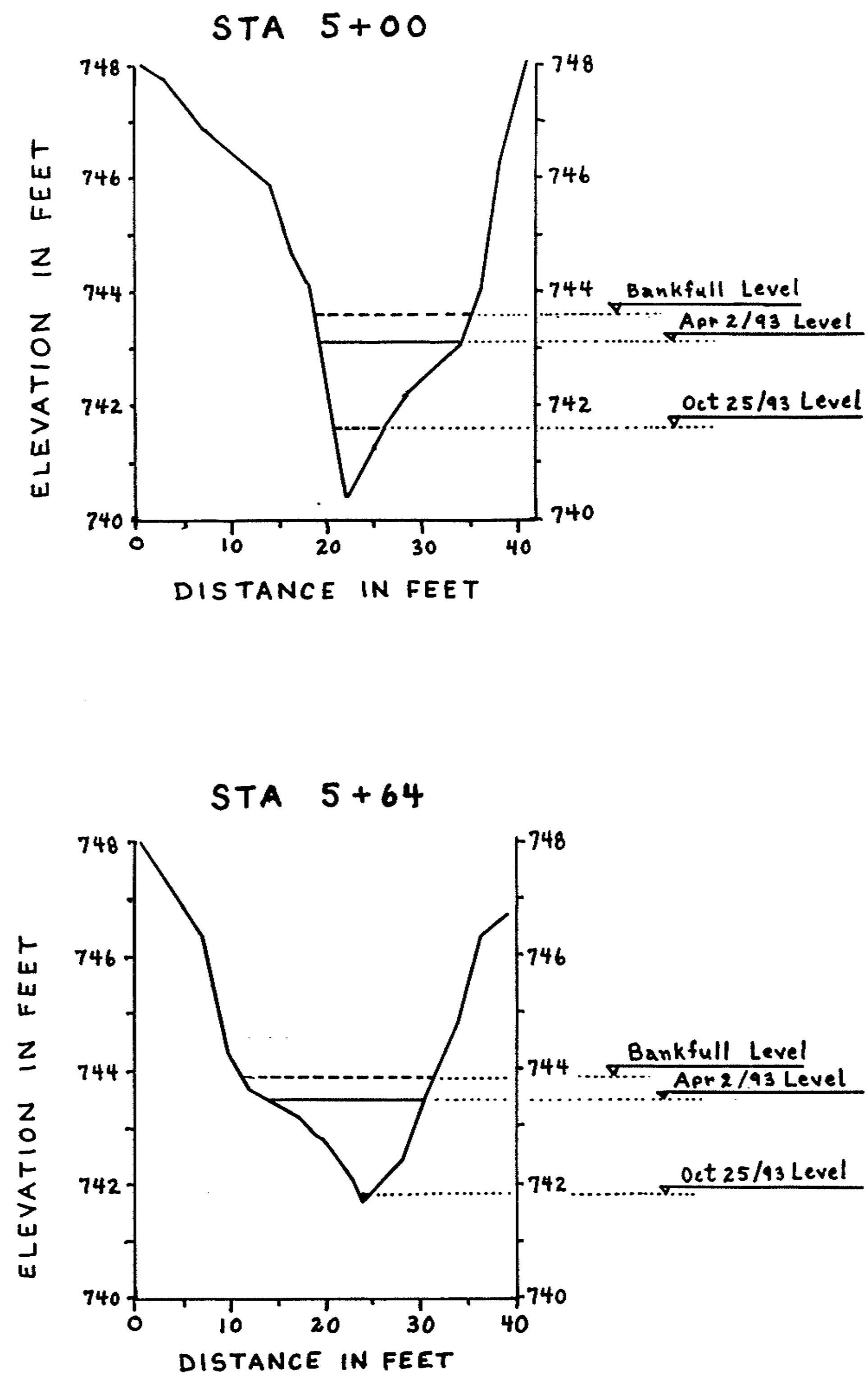


Figure 24. Cross-sections 5+00 and 5+64 used in the bankfull analysis.

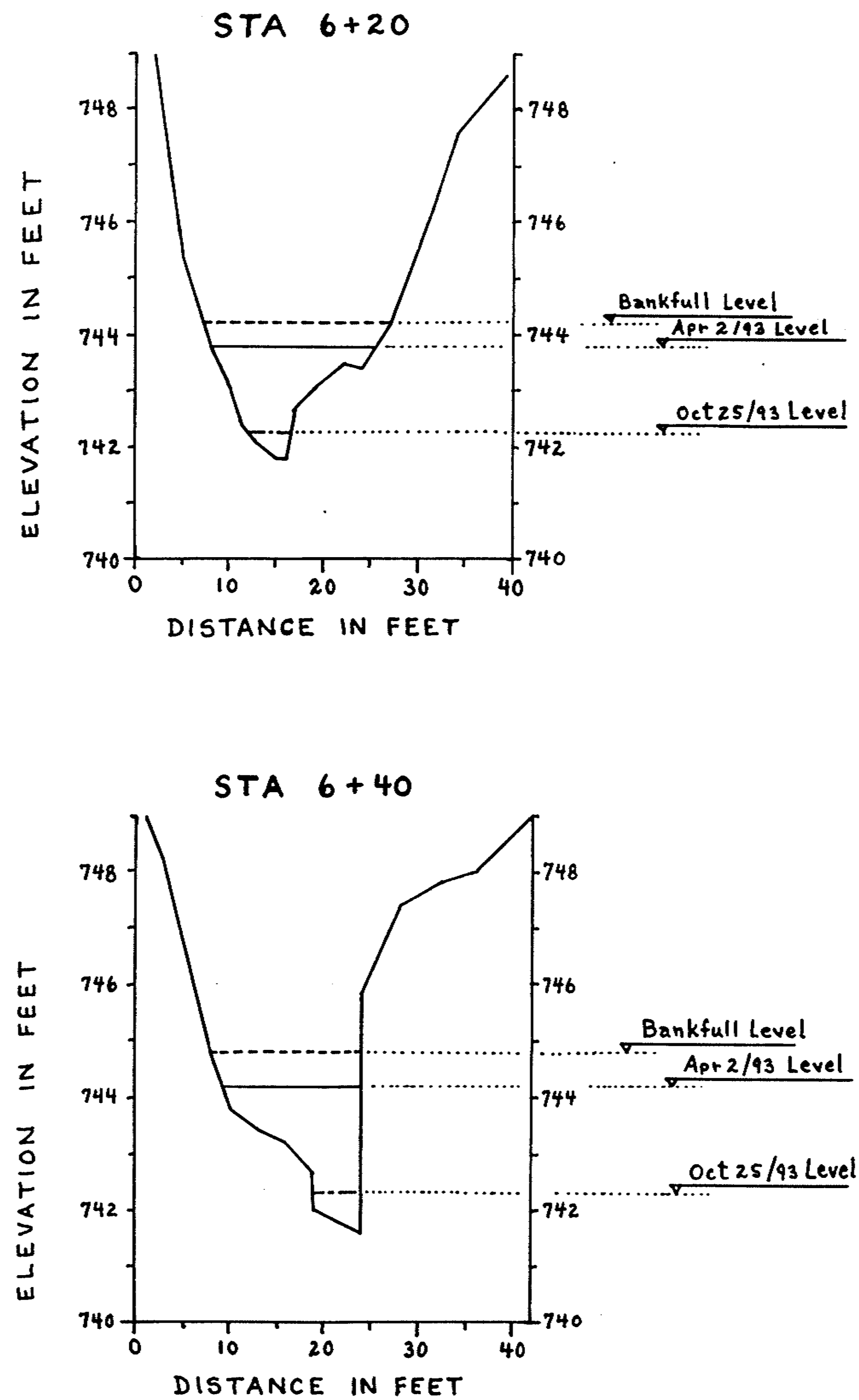


Figure 25. Cross-sections 6+20 and 6+40 used in the bankfull analysis.

CHAPTER 6

DESIGN PROPOSED FOR TRURO CREEK IN BRUCE PARK

A number of activities could be undertaken to rehabilitate Truro Creek in Bruce Park and move the creek towards a more natural condition. The activities are aimed at: reducing the erosive power of the creek; enhancing the habitat for fish and other aquatic life; improving moisture conditions for the plant community bordering the creek; and generally determining and, as necessary, improving the health of the creek's ecosystem. The list of activities includes:

a) constructing pools and riffles,

b) providing upstream storage facilities,

c) determining the water quality and health of the Truro Creek eco-system, and

d) improving the management of the riparian areas and guiding or controlling the land use activities and development in the catchment.

The first two remedial measures in the above list, namely constructing pools and riffles and providing upstream storage, were looked at in detail and are described in this chapter. The other two activities are discussed in broad terms in Chapter 7.

6.1 TRURO CREEK AS HISTORIC FISH HABITAT

Gore and Bryant (1988: 33) list the most important components for fish production as being: acceptable water quality, food production areas, spawning/egg incubation areas, and cover. Most of these physical requirements could be met in Truro Creek, particularly if pool and riffle sequences are developed in the stream.

However, the question remains: Has Truro Creek historically been a spawning area for certain species of fish? No direct sampling of fish populations which currently inhabit the creek was performed. Therefore, alternate means were used to answer the question, namely population survey data from a nearby stream and an interview with a long time local resident.

Omand's Creek, which is adjacent to Truro Creek and whose catchment is about four and a half times Truro's, provides evidence that fish habitat for certain species may exist in Truro Creek. In 1986, Collicut conducted an inventory of the plant and animal species found in and along Omand's Creek. In his survey, he encountered four species of fish which utilize Omand's Creek: northern pike, creek chub, white sucker and brook stickleback (Collicut, 1986: 30-31). The adults of the northern pike and white sucker species enter the creek from the Assiniboine River to spawn in the spring. Apparently, spawning runs of pike have been known to occur in the creek for many years. The chub and stickleback are smaller fishes which are year-round residents and, according to Collicut's survey, are quite prolific with an estimated population of 10,000 of each species in August.

Information was also gleaned from the interview with Jack Benedict (1994), a long time resident of the area. The following is a synopsis of the pertinent comments which he made:

He recalled that in the 1970s he saw pike (jackfish) and possibly walleye (pickerel) going upstream to spawn. He also remembers having seen the young return later on. The spawning took place as far upstream as Portage Avenue, maybe even further upstream than that. He recalls that in the 1970s there would typically be flow in the Creek until mid-July, after which the creek would 'dryup'. He suggested that the flow in the creek in the 1970s was similar to that which occurred during the summer of 1993. He also recalled walking down to the mouth of the creek on spring mornings in the 1970s and seeing 10 to 12 fish there. He also recalls people catching all sorts of fish from the Assiniboine River including jackfish, pickerel, sauger, catfish, bass and even goldeye. In particular, he remembers someone catching a one-and-a-half to two-foot long silver/white bass at the confluence of Truro Creek and the Assiniboine River.

Jack Benedict's reminiscences (1994) and Collicut's survey (1987) suggest that if the appropriate conditions are available in Truro Creek, then fish will migrate from the Assiniboine River to spawn in the creek. The target species chosen for the design was walleye, since it is a prized sport fish in Manitoba and indications are that walleye may use Truro Creek. However, the design will also accommodate other species of fish which may inhabit the shallow pools and riffles during low or no flow periods in the summer.

6.2 PROPOSED POOL AND RIFFLE DESIGN

The proposed natural pool and riffle design provides benefit to Bruce Park in three areas: fish habitat, creek stabilization, and improved moisture conditions for riparian habitat. The design criteria for fish habitat enhancement which was adopted for the riffle design is based on the natural approach of Newbury and Gaboury (1993). In addition to fish habitat, the design provides for creek bed and bank stabilization. As described by Newbury (1993), pools are unstable whereas riffles are stable. Finally, to a certain degree, the moisture condition for the plant community in the Park is improved by retaining water in pools above the current low-flow water elevations of the creek.

6.2.1 Design Criteria

The criteria adopted for the design were:

1. Riffle spacing between five and seven times the bankfull width;
2. Depths of pools to range between 2.0 and 2.6 feet;
3. Drops between riffles to range between 8 and 15 inches;
4. Assiniboine River design water level to correspond to the June level which has been exceeded 80% of the time since 1971 (when the flood control works on the Red and Assiniboine Rivers became completely operational); and
5. Riffle heights to be such that the pool created behind the riffle backfloods onto the upstream riffle.

The last criteria (number 5) is critical to maintaining the channel in its current course so that the tendency for the creek to meander is greatly retarded and erosion of the banks due to migration is minimized. If a pool backfloods onto the face of the upstream riffle, then the excess energy which normally would go into forming meanders is dissipated by having the water plunge into the pool. In this way, the current form of the channel is maintained (Newbury, 1993).

6.2.1.1 Adjustment of Riffle Spacing

The preferred riffle spacing of six times the bankfull width required adjustment to meet the conditions present in the Bruce Park reach of Truro Creek due to its non-uniformity. In designing the riffles, a strict application of the preferred six times the bankfull width (6 x 18.3 feet = 110 feet) in the Natural Reach proved very satisfactory. However, applying the criteria to the South and the Playground Reaches posed a difficulty.

The difficulty was that placement of the riffles at the locations dictated by the 110 foot spacing would have interfered with the secondary flow currents in the stream and may even have exacerbated the erosion problems in the creek. The problem was particularly prevalent in the meander bend of the South Reach, where the 110 foot spacing would have situated the riffle in the pool at the meander bend. The location would be working against the secondary rotational flow current, known as helical flows, for bends in a stream. The proper location for a riffle in a bend is at the cross-over point where the helical flow rises from the bottom of the channel to the surface and changes its rotation from clockwise to counter-clockwise. In plan view, the location is where the main flow is in the middle of the channel (thalweg) crossing over from one bank to the opposite bank. The flow pattern is illustrated on Figure 26. The helical flows and proper location of the riffles in bends are important in providing turbulent aeration and mixing, moving

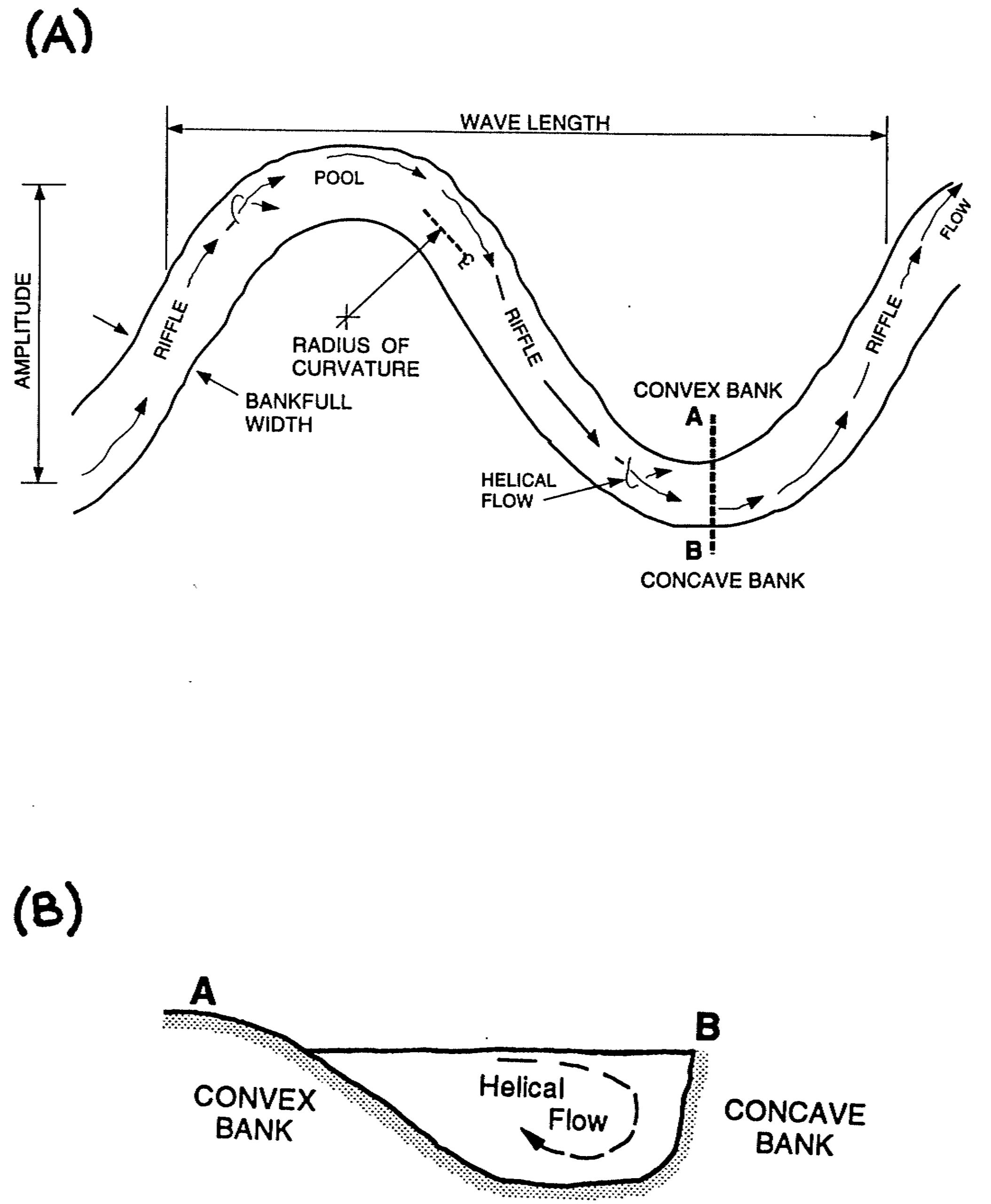


Figure 26. Riffle location in a meander bend to be compatible with helical flow pattern (from Newbury and Gaboury 1993),
(A) Plan view,
(B) Cross-section A-B showing helical flow pattern in pool.

detritus and benthic organisms from the bottom of deeper pools upwards to the water surface, and maintaining the pools clear of sediment (Newbury and Gaboury, 1993: 81; Gaboury, 1993). Therefore, the spacing throughout the entire reach from station 0+00 to station 12+00 required adjustment from the original preferred 110 foot spacing.

A variable riffle spacing of 110 feet to 135 feet with an average of 126 feet was adopted to provide compatibility with the helical flows present in Truro Creek. A spacing of 135 feet is equivalent to seven times a bankfull width of 19.3 feet. A review of Table 5 reveals that a bankfull width of 19.3 feet corresponds very closely to the average bankfull width determined from strictly field measurements, which was 19.2 feet. Utilizing a bankfull width of 21 feet, which corresponds to the 113 cfs flow level in Table 5, the acceptable range of spacings would be between 105 feet (5 times) and 147 feet (7 times) with an average of 126 feet. In light of the foregoing, a variable riffle spacing of 110 to 135 feet appears to be acceptable and well within the allowable range for Truro Creek.

6.2.2 Riffle Design

A final riffle design was ultimately derived by applying the criteria and being mindful of the numerous other constraints which are present in Bruce Park, namely the bridges crossing the creek, the top of bank elevations, and the bends in the creek. The profile view of the riffle design is shown on Figure 27 with the exact riffle crest heights and crest locations given in Table 6. A plan view of the design is given on Figure 28. As Figure 27 shows, the

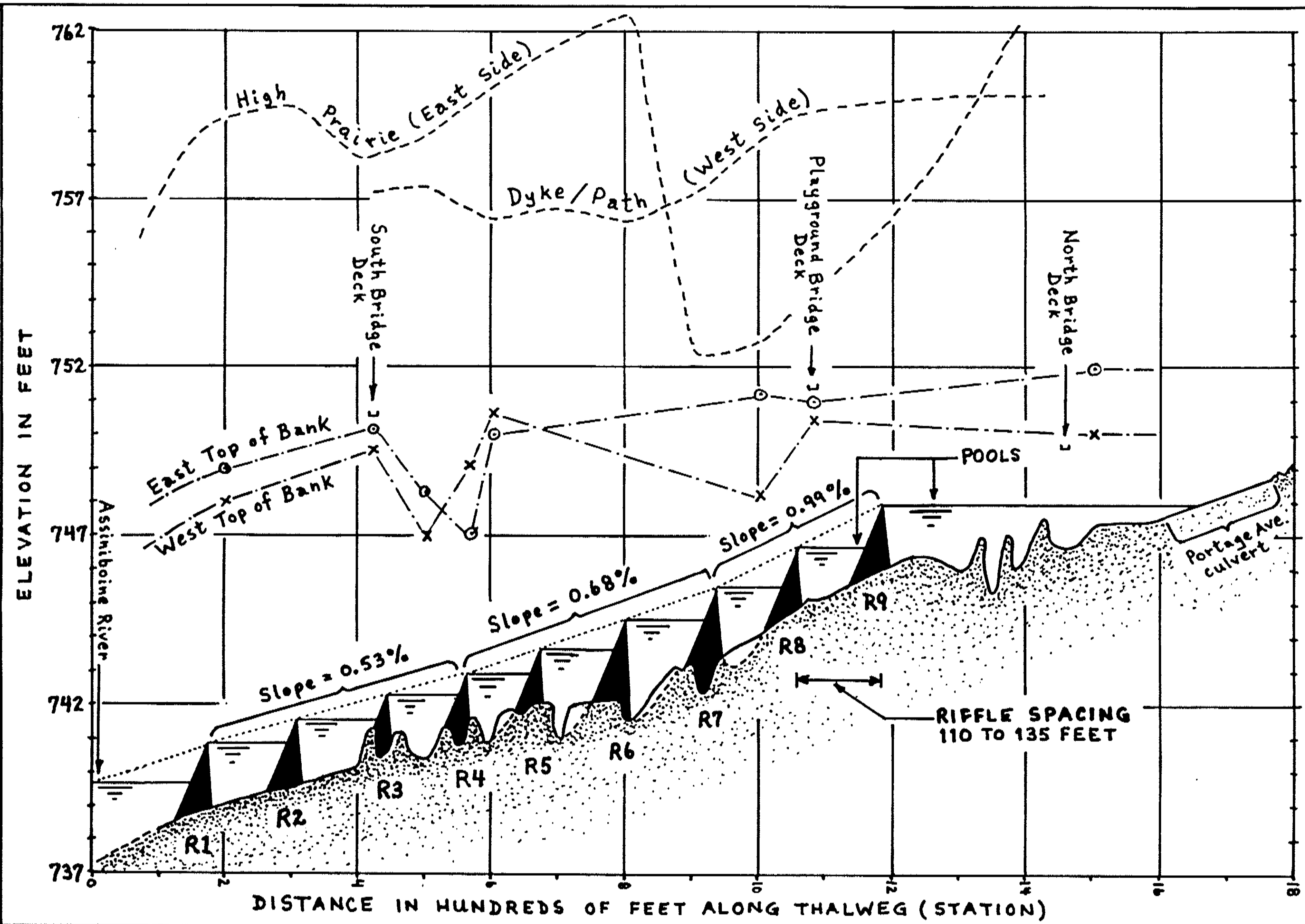


Figure 27. Profile view of proposed pool and riffle system for Truro Creek in Bruce Park.

Table 6

Riffle Heights of Proposed Design

Structure	Station Where Crest Located (ft)	Crest (or Pool) Elevation (ft)	Elevation Drop (inches)	Remarks
–	0+00	739.70		Assiniboine R. Design W.L.
			15	
R1	1+75	740.95		
			8.5	
R2	3+10	741.66		
			8.5	
R3	4+45	742.37		
			7.6	
R4	5+64	743.00		
			9	
R5	6+74	743.75		
			10.3	
R6	8+00	744.61		
			11	
R7	9+35	745.53		
			14.9	
R8	10+60	746.77		
			14.8	
R9	11+85	748.00		

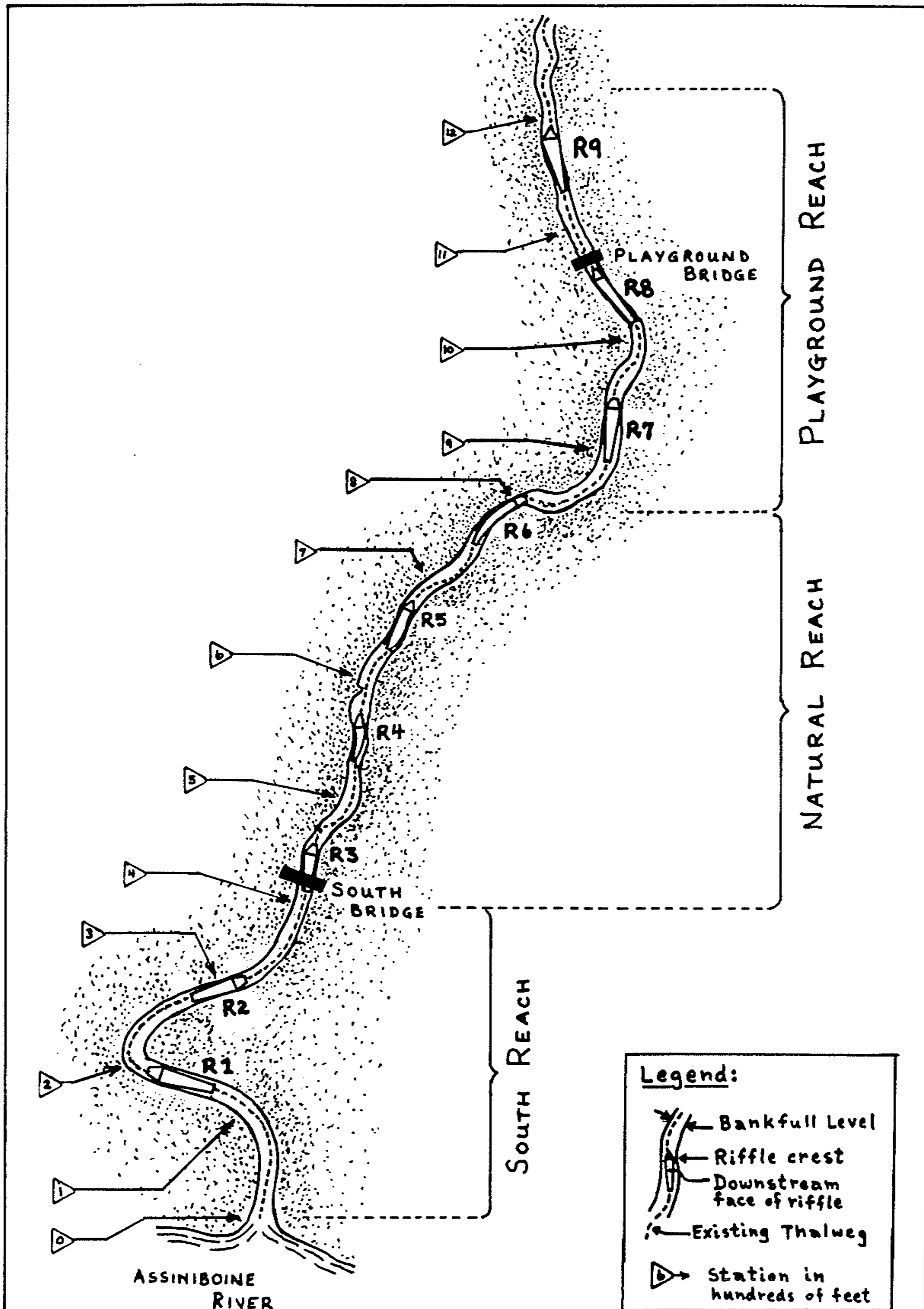


Figure 28. Plan view of proposed pool and riffle system for Truro Creek in Bruce Park.

spacing between riffle crests varies between 110 and 135 feet and the slope for the riffle crests follows the bed slope fairly closely changing from about 1% to one half per cent in a downstream direction. Sufficient clearance generally is provided under the bridges and to the tops of banks. Between riffles R7 and R8 on Figure 27 a dashed line is shown. The line represents an excavation which may be made during construction to make the pools more natural.

Figures 29 and 30 provide views of a typical riffle. Figure 29(A) shows a typical riffle with sections A-A and B-B through it. The upstream slope is 4:1 and the downstream slope is 20:1. The crest is V-shaped to provide sufficient depth of flow over the crest under low flow conditions. Section B-B of riffle R4 is shown on Figure 29(B), using roughly the same vertical to horizontal ratio for the scale (scale of one vertical to five horizontal) as on Figure 29(A). The elevation of the water level as seen in Photo P-15A (Apr 2/93) is also shown. Referring to the photograph, the riffle crest would be located in the stream beside the snow fence about 6 inches below the water surface. Of course, after construction the actual water level for a flow of the magnitude seen in the photograph (30 cfs) would be somewhat higher. Figure 29(C) shows the same view as Figure 29(B) but with the vertical scale compressed so that the vertical and horizontal scales are identical (ratio of one to one) as in the real world. In this way, the reader may obtain a sense of what the constructed riffle will look like in the creek and in relation to the surrounding land. Using these real-life ratios between vertical and horizontal scales, Figure 30(A) shows section A-A (of Figure 29A) through Riffle R4. The pools above and below the riffle are also shown.

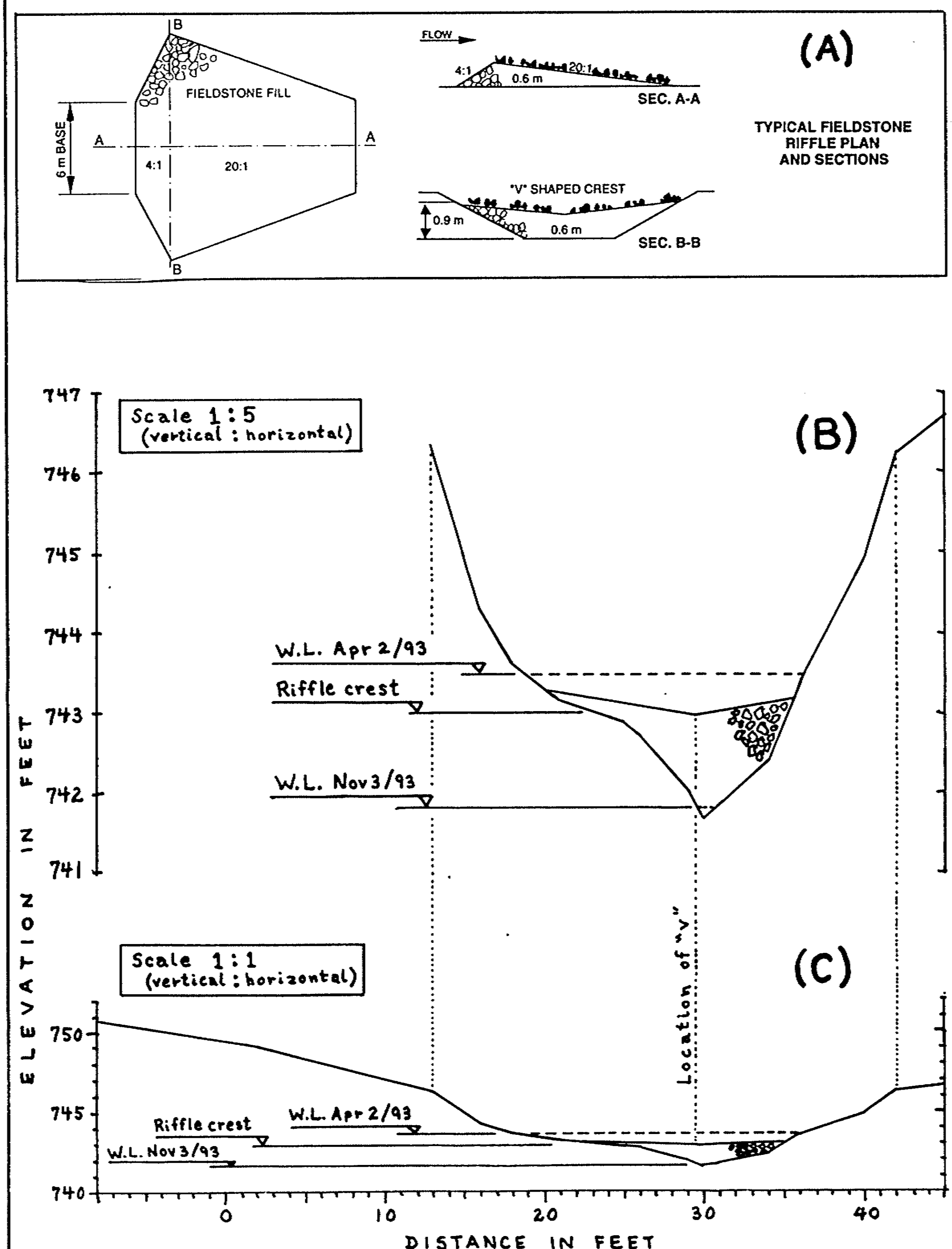


Figure 29. (A) Typical riffle design (Newbury and Gaboury, 1993), (B) and (C) Section B-B of Riffle R4.

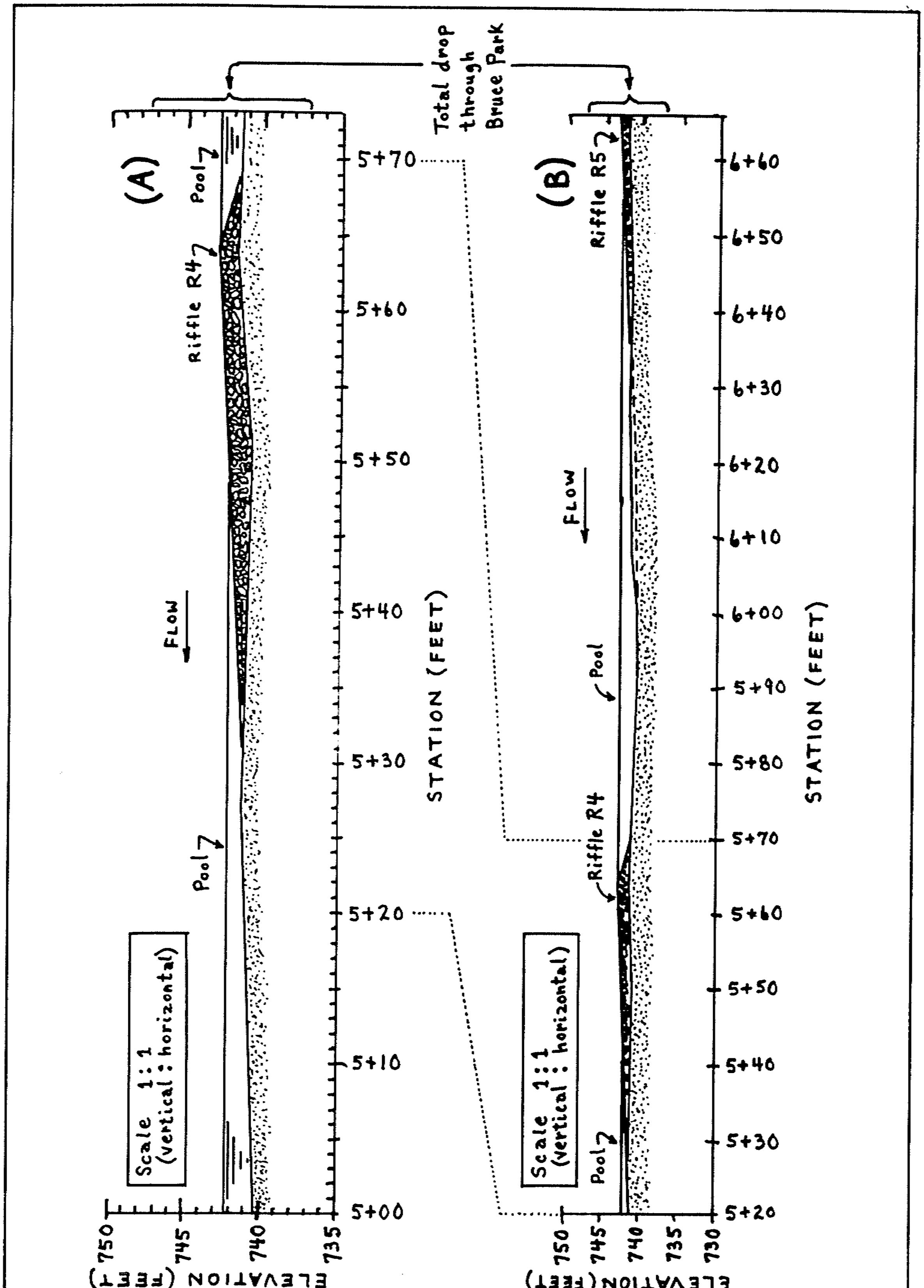


Figure 30. Profiles of a typical riffle: (A) Riffle R4; (B) Pool from Riffle R4 'backwatering' onto Riffle R5.

Figure 30(B) provides the same sort of view but at a somewhat smaller scale (so that the drawing fits on the page). The figure shows the pool-riffle-pool-riffle sequence for R4 and R5, which is repeated throughout the stream system from R1 to R9. The reader should note the backwater from the pool behind Riffle R4 onto the downstream face of Riffle R5.

6.3 RIFFLE CONSTRUCTION COST

A construction cost has been estimated at $4100 for the nine riffles for an average cost of $460 per riffle. The cost includes the supply, hauling and placing of the aggregate. A cost for mitigation of environmental damages resulting from construction activities in the area has not been included in the cost estimate. To obtain a licence from the City's Rivers and Streams Authority to construct the works should cost an additional $150.

Fieldstone has historically been used in Manitoba for this type of construction, however, fieldstone is generally difficult to find in the Winnipeg area. Therefore, limestone, which is more readily available, was assumed to be used for the construction. Each riffle on average would require about 28 metric tons of rocks ranging in size from a minimum of 4 inches to a maximum of 12 inches with a median diameter of 6 inches. These are preliminary estimates for planning purposes only. If the project does proceed, final hydraulic calculations would be required to ensure the chosen aggregate sizes are appropriate.

6.4 SUPPLEMENTAL UPSTREAM STORAGE

Hydraulic and hydrologic calculations were performed to determine the flow required to transport walleye juveniles from Truro Creek to the Assiniboine River. A flow of 3 cfs was calculated to provide a depth of flow of six inches at the 'V' in a riffle crest, which was deemed sufficient for the task (Gaboury, 1993). However, the timing of the flow rate is critical as the 3 cfs flow would have to occur at the end of May. In the 11-year study period of 1978 to 1988, the required flow condition occurred only twice, meaning that successful spawning of walleye could only occur about once in five years on average.

Flow enhancement provided by an upstream storage reservoir was investigated to improve the chances of successful walleye spawning and to more closely emulate a natural flow regime. Utilization of the detention pond on the airport property was not considered as a storage option due to Transport Canada's policy to empty the pond as quickly as possible after a runoff event. Therefore, the reservoir was assumed to be located immediately upstream of the railway bridge where the WSC station 05MJ009 is located. (See Figure 3 for location.) The reservoir was assumed to have a capacity of 180 acre-feet (3 cfs-mon).

Two simple schemes of operation of the reservoir were simulated: Scheme 1 strictly targets walleye production; Scheme 2 emulates more of a natural condition than currently exists. Each of the schemes and the resultant flow patterns are described below.

6.4.1 Scheme 1 (Walleye Production)

The rules of operation for Scheme 1 are simple: store all the flow from June 1 to April 30 of the following year up to the capacity of 180 ac-ft; then, during the month of May release all the stored water. The scheme maximizes storage of all the available water and releases it in May to transport the juvenile walleye to the Assiniboine River. The operation was applied to the flows for the study period 1978-88. The resulting monthly flows in Bruce Park were analyzed statistically just as they were as described in Section 3.1.5. The resultant median April and May monthly flows in Bruce Park are 2.7 cfs and 2.9 cfs, respectively. Both flow values are sufficiently close to 3 cfs to suggest that upstream storage would improve successful walleye spawning up to a level of one in two years from the current one in five years.

6.4.2 Scheme 2 (Natural Emulation)

The rules of operation for scheme 2 attempt to emulate natural conditions. During a snowmelt event, a great deal of the snowmelt water flows over the impervious surfaces of the airport and appears in the creek only hours after the snow has melted. Under pre-settlement conditions, much of the water is surmised to have run off into sloughs and similar storage areas. From the slough, the water would have drained slowly into the subsoil and eventually may have appeared as flow in the creek, weeks and even months later. To emulate such a condition, the following rules of operation for the 180 acre-foot upstream reservoir were devised: store all the flows in March and April up to 180 acre-feet; release the stored volume according to the following pattern: May 50%, June 25%, July 15% and August 10%. A statistical analysis of the resulting flows in Bruce Park was performed as described previously.

The resulting median flows in Bruce Park for each of Scheme 1, Scheme 2 and under existing conditions (Figure 6) are plotted together on Figure 31. As can be seen from Figure 31, over one third of the April flow under existing conditions would be stored in the upstream reservoir. The stored water would be released later, in May (Scheme 1) or in the summer (Scheme 2), to supplement existing flows in the creek.

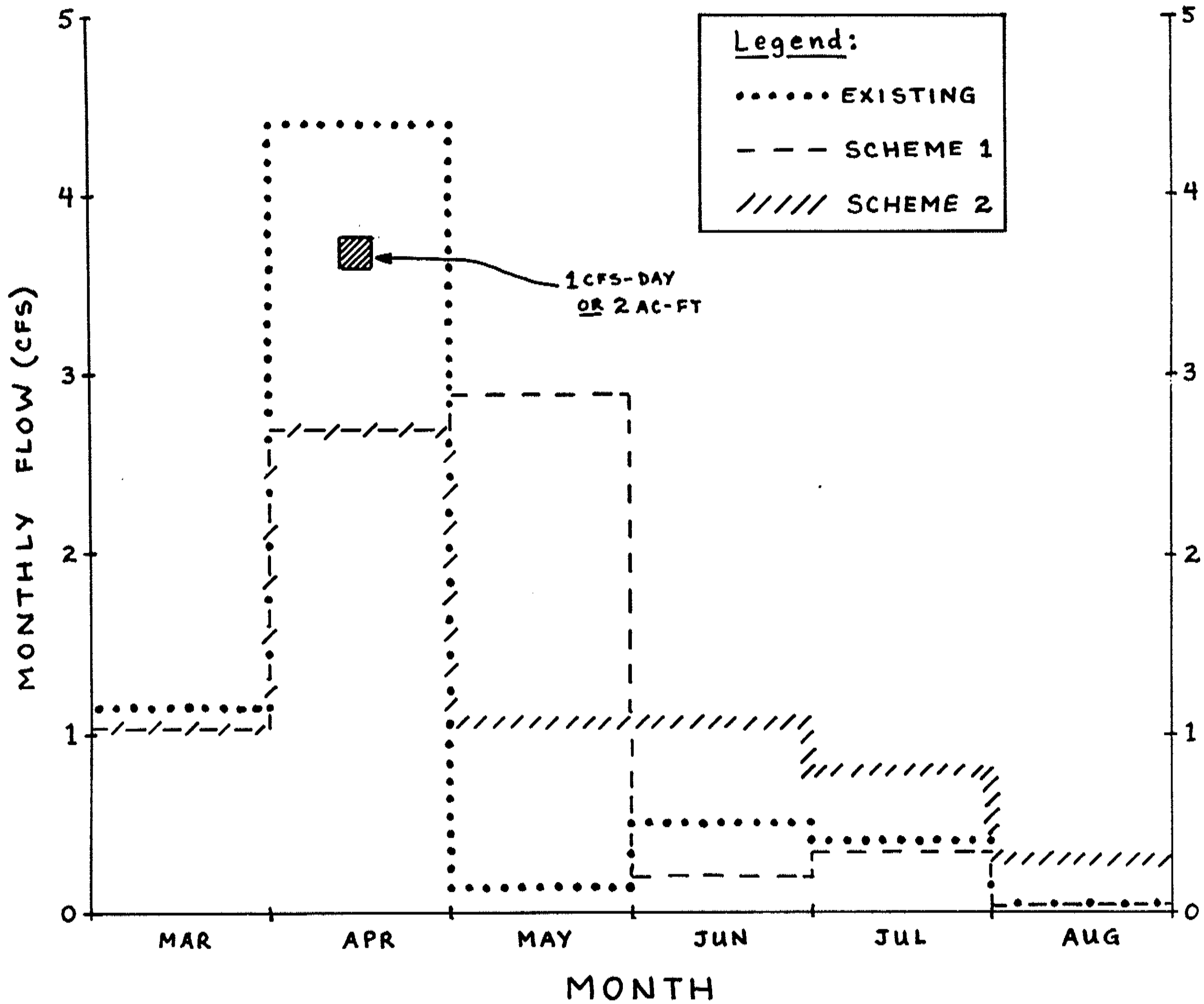


Figure 31. Median flows in Truro Creek through Bruce Park under existing conditions and with upstream storage (Schemes 1 and 2).

CHAPTER 7
OTHER CONSIDERATIONS

7.1 LAND USE IN THE CATCHMENT

Land use in the Truro Creek catchment has a major impact on the flows in the creek as the study has shown. Although the emphasis in the study was on water quantity, water quality is also affected by land uses. Land uses in the catchment which have been identified from upstream to downstream segments include: a landfill, a tire retreader, an airport, a golf course, a community garden plot, parks, and a community club. Runoff from any or all of these areas could be detrimental to the aquatic life and health of Truro Creek, including successful fish spawning, by affecting the water quality.

The management of the riparian area is probably the easiest to accomplish in the short term, being that south of the airport it is almost exclusively under only one jurisdiction (City Parks Department) and the FBP are currently preparing for a planning study aimed at this area. In addition, the FBP's input to the planning of new developments in the catchment is relatively easy to achieve. Therefore, in light of these circumstances, the impacts of the riparian zone and future development in the upstream segment are discussed in the following subsections with a view to areas of further research.

7.1.1 Riparian Area Management

The riparian zone is the "emerald thread" (Wallis, 1991: 116) which is the important link between the land and water environments (Karr and Schlosser, 1978). The proper management of riparian areas is important in maintaining or enhancing fish, bird and other wildlife populations, especially in urban areas. Suitable streamside vegetation can reduce water temperatures which ensures fish survival; provide organic matter to the stream ecosystem which is also important for fish survival; control erosion of streambanks; provide habitat for a variety of birds and other creatures; and improve water quality by tapping unwanted nutrients from surface runoff.

High water temperatures in summer are detrimental to some fish by reducing the oxygen available for them (Karr and Schlosser, 1978: 230). In fact, the water temperature difference between shaded and unshaded areas can be quite significant. For example, summer water temperature for a stream inside a small woodlot was measured at 19 degrees C, whereas in nearby unshaded areas the water temperature was 28 degrees C (Karr and Schlosser, 1978). As water temperature increases, its capacity to hold oxygen decreases and at elevated temperatures the ability of streams to assimilate organic wastes without oxygen depletion is reduced. It has also been noted that temperature control using vegetation such as trees and shrubs is much more effective on small streams than on larger ones due to the obvious scale factor. Streamside vegetation is also important in providing food for the aquatic invertebrates which feed on leaves and twigs which fall into the water. These invertebrates are part of the fish's food chain and therefore are important for fish survival (Karr and Schlosser, 1978: 231).

Small streams with well established grass and shrub vegetation protect channel banks from erosion and provide cover for fish. Furthermore, trees and other woody-rooted vegetation provide long-term stability to stream banks by resisting the erosive forces of water at high flow. Also, evidence suggests that unmown or ungrazed riparian areas are better able to handle flooding without habitat damage (Beschta and Platts, 1986: 375).

Vegetation complexity is clearly recognized to be associated with the structure of the bird community (Willson, 1974: 1017) and that manipulations increasing the structural diversity of the habitat would benefit the greatest number of species (Stauffer and Best, 1980: 13). DeGraaf (1986: 234) has noted: "...a common result of increased urbanization is a decline in the number of species and a simultaneous increase in total bird density as a relatively few species become very abundant. Habitat availability and complexity are important agents in these changes." The species richness of the suburban breeding bird community is dependent upon: the nearness of a woodlot and open field, smaller lawn areas, more "weedy" vegetation, and lower building density (DeGraaf, 1986: 242). In particular, natural woodlands and fields are extremely important because they are "elements of the pre-existing landscape" (DeGraaf, 1986: 244) and support insect-eating migrant species, which have been used as measures of the quality of the birds of a region (avifaunal quality).

Native vegetation is highly recommended (Croonquist and Brooks, 1993: 65; Beschta and Platts, 1986: 377; Gore and Bryant, 1988: 28; Dangerfield, 1993) for buffer zones but the width of the buffer zone along streams could vary depending upon the effect desired. Although even narrow 2m bands of woody vegetation along the stream channel seem to be enough to maintain portions of the bird community in disturbed areas (Croonquist and Brooks, 1993: 65), wider buffers in the order of 25 to 30m or greater are recommended to protect the water quality of the stream for the aquatic life (Gore and Bryant, 1988: 28) and to maintain bird populations sensitive to disturbance (Croonquist and Brooks, 1993: 69).

Gore and Bryant summarize the importance of riparian vegetation to a stream rehabilitation project in the following:

> A stable zone of riparian vegetation enhances the water quality of a stream by reducing erosion and the subsequent introduction of suspended solids. In low-order streams, riparian vegetation provides shading that reduces water temperature and primary production and also provides organic material in the form of detritus, which is important to stream community dynamics. Riparian vegetation also represents important habitat for terrestrial organisms, particularly in arid regions. Riparian vegetation functions in bank stabilization, which is of particular importance in stream reclamation efforts. (Gore and Bryant, 1988:28)

7.1.2 Future Development Upstream of the Airport

The only undeveloped portion of the Truro Creek catchment is the upstream segment as shown on Figure 3 which is primarily in agricultural use; the current plans for this area are not completely clear. The landfill site is scheduled to close within the next couple of years and the current plans are to direct the drainage of surface waters from this area out of the Truro Creek catchment into Sturgeon Creek (Hilderman *et al*, 1990). Early planning studies of drainage for the upstream segment, if developed, provide various alternatives, including the construction of stormwater detention ponds and directing the drainage of surface waters to Sturgeon Creek (Dillon, 1975 and 1976). A more recent initiative concerns developing the area for inter-modal facilities compatible with air cargo transport. However, servicing the land to full urban standards appears to be prohibitively expensive (Winnipeg, 1993). In any event, it is unclear what development, if any, will occur in the area. It should be kept in mind, however, that as flow is diverted out of the catchment, any upstream storage scheme would become less effective.

7.2 JURISDICTIONAL AND ADMINISTRATIVE CONSIDERATIONS

Strijack *et al* (1991: 8-9) point out that developments in rivers and streams and on their banks in the City of Winnipeg fall under the jurisdiction of all three levels of government: federal, provincial and city.

The province has jurisdiction over fish by virtue of the Resource Transfer Agreement of 1930, however, the federal government has some jurisdiction over 'inland fisheries' (Gibson, 1973). The federal Fisheries Act (Canada 1985) gives the federal government certain jurisdiction over fish habitat (S.35). As noted by Gibson (1973), "...the area of jurisdiction overlap is large, but problems have usually been avoided by federal-provincial co-operation."

A great deal of the province's responsibility regarding streams and streambank development within Winnipeg has been delegated to the City government. The two main legislative instruments to accomplish this task are the City of Winnipeg Act (Manitoba, 1990c) and The Rivers and Streams Act (Manitoba, 1988). Generally, the former governs developments in the watercourses themselves, whereas the latter is primarily concerned with developments on the riverbanks, particularly with regard to stability. However, both pieces of legislation have sections dealing with the restriction or impedance of flows or the prevention of a watercourse from being encumbered, damaged, interfered with or improperly used.

Strijack *et al* (1991 :9) list fourteen specific responsibilities which the City government has regarding the stream environment. Of the fourteen, the ones most pertinent to the Truro Creek situation are the following:

. flow impedance;

. land use policy on riverbanks;

. minimum standards of maintenance on private or public property;

. riverbank parks; and

. maintenance of publicly owned riverbank lands as it pertains to Dutch Elm disease, insect control, and weed control.

One other consideration exists, namely that an environmental assessment of proposed works *may* be required. By virtue of the Manitoba Environment Act and its associated regulations, "alterations to stream channels which affect fish mobility and fish habitat" are classified as Class 2 developments under the Act and may require assessment (Manitoba, 1988b: 1977).

CHAPTER 8

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 SUMMARY

The Friends of Bruce Park (FBP) is a local neighbourhood group in the city of Winnipeg with an interest in preserving, enhancing and maintaining the natural setting and historical heritage of Bruce Park in Winnipeg. One of the goals of the FBP is to naturalize the southern half of Bruce Park through which Truro Creek flows as it enters the Assiniboine River.

The initial concern of the group was the apparent erosion of the creek's banks and the low flow water levels in the creek which have put stress on the vegetation bordering the creek. In addition, poor fish spawning habitat appears to exist in the creek.

The purpose of the study was to investigate the hydrologic and geomorphologic condition of the creek and its catchment to identify opportunities for rehabilitation within a naturalization context.

A plan, which is embodied in the following conclusions and recommendations, is proposed to lead to a reversal of the apparent degradation process which is occurring in Truro Creek.

8.2 CONCLUSIONS

Truro Creek, with the entire catchment having been changed by human settlement, is far from being a natural 'pristine' stream. As a consequence, the runoff into the stream channel has been significantly altered with detrimental consequences to the creek, such as increased erosion in Bruce Park. A comparison between engineering surveys indicate that an average of 0.7 feet of erosion of the creek bed has occurred in the south half of Bruce Park over the 22 year period from 1971 to 1993; the creek bed will likely continue to erode with further upstream development. The creek and catchment require rehabilitation measures to move the creek *towards* a more natural condition.

Truro Creek in Bruce Park appears to have migrated by the process of erosion (and to some degree deposition), most notably in the region downstream of the south bridge which possesses a steep eroded east bank. The high steep banks, which are characteristic of the Assiniboine River and which extend for over 200 feet upstream from the confluence with the Assiniboine River, have existed for over one hundred years.

Truro Creek in Bruce Park currently possesses features somewhat representative of a natural stream, such as small riffles, pools, riffle bars and point bars, and a width to depth ratio in the range of natural streams. However, the creek is in disequilibrium with flow in the creek estimated to be *twice* what it would be under natural conditions due to changes in land use, primarily airport development. The runoff is occurring faster with higher peak flows due mostly to the impervious areas of the built-up portions on the airport property. The increased flow has enlarged the channel by the process of erosion from what it was naturally. The enlargement ratio appears to be in the one-and-a-half to two range.

The construction of pools and riffles is a feasible approach to rehabilitation of Truro Creek in Bruce Park to counteract the erosive energy of the creek brought on by the increased flows. Since appropriately sized material does not exist in the creek bed, riffles need to be constructed. A riffle system has been designed which uses naturally available materials and is based on natural stream principles. The proposed design entails constructing nine riffles on the creek bed which will enhance the natural values and appearance of the creek by: reducing the erosive power (energy) and migration tendency of the creek; improving moisture conditions for the riparian plant community along the creek in the Park by raising the low summer water levels in the creek an average of about one foot; providing some spawning habitat for fish; and retaining water in pools behind each riffle to improve the appearance of the creek. A more natural flow regime could be attained by the construction of an upstream reservoir, which is hydrologically feasible.

The proposed riffle design in Bruce Park is a cost effective rehabilitation measure. The actual construction cost for the supply, hauling, and placing of the aggregate material used to form the riffles is estimated to be $4100. The cost of measures to mitigate possible damage caused by the movement of construction machinery in the vicinity of the construction site has not been estimated and hence is not included in the cost estimate. Formal approval from The Winnipeg Rivers and Streams Authority is anticipated to cost less than $200.

8.3 RECOMMENDATIONS

The following recommendations are made in light of the study. Each may be acted upon independent of the others.

Recommendation 1. The pool and riffle system should be constructed once the appropriate approvals have been obtained and funding procured, since the pool and riffle system is a cost effective rehabilitation measure. Formal approval in the form of a licence to proceed from the City of Winnipeg's Zoning Development Branch and The Winnipeg Rivers and Streams Authority No. 1 are required. The Friends of Bruce Park should work with the City's Parks Department to obtain the necessary approvals. Approval from the provincial government by way of an environmental assessment may also be necessary; the provincial Departments of Natural Resources and Environment should be consulted in this regard.

Recommendation 2. Land use activities and developments in the catchment and riparian areas are of critical importance to the general health of Truro Creek and its ability to support aquatic life, including successful fish spawning. The current land uses in the catchment are quite diverse (Figure 3) and which, if any, are detrimental to the aquatic ecosystem is unknown at this time. Therefore,

a) Further research should be done to ascertain which land use activities are potentially harmful to the aquatic life of Truro Creek. The study could be in the form of a survey of stakeholders to discover what substances are currently being applied to the land areas which could run off into Truro Creek as well as what substances are being released directly into the creek. Objectives of the study could include the development of remedial land use measures and riparian management alternatives.

b) In addition, the FBP could request the provincial and/or federal Environment Departments to establish water quality monitoring stations on Truro Creek. In this way, a water quality data base would be developed to more adequately assess the health of the Truro Creek eco-system and monitor changes. Members of the FBP could possibly participate in the collection of some of the data by working in cooperation with the government agencies. In addition, Environment Canada should reactivate the water survey stations 05MJ009 and 05MJ010 in conjunction with the water quality monitoring stations. Using these two station locations for the collection of both water quality and water quantity data is highly recommended.

c) Further research in the form of an ecological study to determine the overall health of the Truro Creek ecosystem could be performed in conjunction with a) above. One of the objectives of the study could be to ascertain the preferred flow regime for the creek, so that operating rules for the upstream reservoir may be developed.

Recommendation 3. a) The FBP should continue to pursue discussions and consultations with the appropriate stakeholders in the catchment upstream of Bruce Park to communicate the group's concerns, goals, and objectives for Truro Creek. In this way, the detrimental land use activities of stakeholders may be changed.

b) The ultimate result of the exchanges could be a multi-stakeholder effort to manage the waters of Truro Creek as has been done for other catchments in Winnipeg and elsewhere (see Smith, 1993; Park, 1994). The FBP could approach the appropriate authorities to set up such a watershed management committee.

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APPENDIX 1

EQUIVALENTS OF MEASURE

The following list of convenient equivalents of measure includes the relationship between imperial units and the International System of Units (SI or metric).

1 statute mile (mi) = 1.6093 km (kilometres)
1 m (metre) = 3.2808 feet (ft)
1 km (kilometre) = 0.62137 mile (mi)

1 acre (ac) = 0.4047 ha (hectare)
1 square mile (mi^2) = 2.5900 km^2 (square kilometres)
1 km^2 (square kilometre) = 0.38610 square mile (mi^2)

1 cubic foot = 6.2288 imperial gallons
1 cubic foot = 0.028317 m^3 (cubic metre)
1 m^3 (cubic metre) = 35.315 cubic feet
1 dam^3 (cubic decametre) = 1000 m^3 (cubic metres)
1 dam^3 (cubic decametre) equals 1 millimetre over 1 square kilometre
1 acre-foot (ac-ft) = 1.2335 dam^3 (cubic decametres)

1 m^3/s (cubic metre per second) for one day equals 86.4 dam^3 (cubic decametres)

1 cfs (cubic foot per second) = 0.028317 m^3/s (cubic metre per second)
1 m^3/s (cubic metre per second) = 35.315 cfs (cubic feet per second)

1 tonne = 2204.6 pounds