ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Physical Description of the Selected Tributary Mouths and Sheltered Backwaters of the Athabasca and Clearwater Rivers

Project WS 1.5.1

July 1980

Sponsored jointly by

Alberta ENVIRONMENT

Environment Canada Environnement Canada

15th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, Alberta, Canada
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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program, which was established by agreement between the Governments of Alberta and Canada in February 1975 (amended September 1977). This 10-year program is designed to direct and co-ordinate research projects concerned with the environmental effects of development of the Athabasca Oil Sands in Alberta.

A list of research reports published to date is included at the end of this report.

Enquiries pertaining to the Canada-Alberta Agreement or other reports in the series should be directed to:

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The Hon. J.W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

and

The Hon. John Roberts
Minister of the Environment
Environment Canada
Ottawa, Ontario

Sirs:

Enclosed is the report "Physical Description of Selected Tributary Mouths and Sheltered Backwaters of the Athabasca and Clearwater Rivers".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Water System, under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

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Western and Northern Region

PHYSICAL DESCRIPTION OF SELECTED TRIBUTARY MOUTHS AND SHELTERED BACKWATERS OF THE ATHABASCA AND CLEARWATER RIVERS

DESCRIPTIVE SUMMARY

With the threat posed to fish communities by the development of the Athabasca Oil Sands, the baseline states of fish resources of the Athabasca and Clearwater rivers have been detailed by various projects of the Alberta Oil Sands Environmental Research Program (Reports 36, 84, and 89). These projects looked at the habitat and biology of the major spring-spawning fish populations (residency, spawning and rearing areas, overwintering, age and fecundity, food habits, etc.). A survey of the physical characteristics of the habitats utilized by these populations was needed to gain a more complete picture of the fisheries habitat. The present project, conducted during August 1978, looked at five parameters: current velocity and direction, depth, Secchi disc visibility, substrate composition, and temperature.

The report has been reviewed by scientists at the University of Alberta and Alberta Environment and a fisheries biologist. The Alberta Oil Sands Environmental Research Program accepts this report as a valid document and thanks the researchers for their contribution.

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Research Manager
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W.R. MacDonald, Ph.D
Director (1980-81)
Alberta Oil Sands Environmental
Research Program

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ABSTRACT

A survey of the physical characteristics of the aquatic habitats at 25 locations on the Athabasca and Clearwater rivers was conducted during August 1978. The parameters determined at each site were current velocity and direction, depth, Secchi disc visibility, substrate composition, and temperature. The survey sites included sheltered areas downstream of points of land or islands, as well as tributary confluences. Downstream of points of land or islands, current velocity and flow direction were altered markedly and substrates were typically sands or silts. Physical changes evident at tributary confluences were Secchi visibility, current velocity, and flow direction. At the tributary mouths, sand and silt substrates were predominant in sheltered areas of low current velocity while coarser rock substrates occurred in other areas of the confluences.

ACKNOWLEDGEMENTS

The authors would like to thank Dave Berry, Alberta Fish and Wildlife, for his assistance in the selection of study sites. William Griffiths assisted with the design of this study.

This research project WS 1.5.1 was funded by the Alberta Oil Sands Environmental Research Program, a joint Alberta-Canada research program established to fund, direct and co-ordinate environmental research in the Athabasca Oil Sands area of northeastern Alberta.

PHYSICAL DESCRIPTION
OF
SELECTED TRIBUTARY MOUTHS
AND
SHELTERED BACKWATERS
OF THE ATHABASCA AND CLEARWATER RIVERS

by

M. M. PSUTKA
B. W. HARVIE

LGL Limited
Environmental Research Associates

for

ALBERTA OIL SANDS
ENVIRONMENTAL RESEARCH PROGRAM

Project WS 1.5.1

July 1980

1. INTRODUCTION

Present and future development in the Alberta Oil Sands Environmental Research Program (AOSERP) study area may pose serious threats to fish communities in the adjacent Athabasca River as well as contiguous downstream and upstream areas. AOSERP has funded various studies to detail the baseline state of fish resources (e.g., relative species abundance, movements, spawning, behaviour) in the Athabasca and Clearwater rivers both upstream (Jones et al. 1978; Tripp and McCart 1980) and downstream (Bond 1980; Bond and Berry 1980a, b) of Fort McMurray.

The intent of this study is to supplement the available fish catch information for the AOSERP study area by providing detailed physical descriptions of some sites at which fish collections have been made in previous studies. Five characteristics (water depth, current velocity and direction, substrate composition, temperature, and turbidity) were determined for 25 selected locations on the Athabasca and Clearwater rivers, between the Fort McMurray area and the Firebag River confluence.

Field work was conducted in August 1978 by personnel employed by Renewable Resources Consulting Services Ltd. (RRCS). The report was written by the same personnel after the disbanding of RRCS and their transferral to LGL Limited.

2. RESUME OF CURRENT STATE OF KNOWLEDGE

There are large amounts of fish catch data available for many locations along the Athabasca and Clearwater rivers. Upstream of Fort McMurray, the extent of spring and autumn spawning have been determined in the Athabasca and Clearwater rivers (Jones et al. 1978; Tripp and McCart 1980). The Athabasca River downstream of Fort McMurray was studied in 1976 and 1977 to obtain baseline data (relative species abundance, movements, and spawning behaviour) on fish populations (Bond 1980; Bond and Berry 1980a, b). In addition, there have been numerous studies of Athabasca River tributaries where fish catches near tributary mouths have been recorded. The following tributaries have been studied: (1) Beaver River (Robertson 1970; RRCS 1971, 1973); (2) MacKay River (Machniak et al. in prep.; McCart et al. in prep.); (3) Muskeg River (RRCS 1974; Bond and Machniak 1977); (4) Poplar Creek (RRCS 1975); and (5) Steepbank River (Machniak and Bond 1980). In an extensive preliminary survey, Griffiths (1973) recorded fish catches at many of the junctions of the Athabasca River and its tributaries. Lutz and Hendzel (1977) also described fish at mouths of tributaries to the Athabasca, as well as at other locales in the Athabasca River. Most of the above studies concentrated on collection of fish abundance and distribution information. Generally, little discussion of the physical features at fish collection locations accompanies the reports.

3. DESCRIPTION OF THE STUDY AREA

The AOSERP study area encompasses 28 000 km^2 and is located in northeastern Alberta (Figure 1). In the present study, detailed physical information was collected at two locations on the Clearwater River and at 23 locations on the Athabasca River between Fort McMurray and the Firebag River mouth (Figure 2). These are the two major rivers flowing through the AOSERP study area.

In its lower reaches near Fort McMurray, the Clearwater River is characterized by a low gradient (0.2 m/km). River banks are composed of sands, silts, and clays and are generally low and eroding. River substrate is predominantly sand with some gravel bars. The channel pattern is straight or meandering and the river is bounded within a v-shaped valley with an entrenchment of 140 m. The mean flow rate of the Clearwater River, monitored at Draper (Guage 07CD001), was 136 m^3/s from 1957 to 1976 (Inland Waters Directorate 1977). Flows are usually highest in May, when the monthly mean is 266 m^3/s. Daily flow rates as high as 790 m^3/s have been recorded. Minimum monthly flows occur in March, when the mean is 51 m^3/s. The Clearwater River has a slight brown organic stain and has a low suspended sediment load relative to the turbid Athabasca River.

Immediately above Fort McMurray, the Athabasca River is characterized by many large meanders and a moderate gradient of 1.0 m/km. The river is confined within steep banks, some as high as 160 to 180 m. The river substrate is primarily coarse gravels, although there are also many limestone bedrock sills and rapids which can extend almost across the entire width of the river.

Downstream from Fort McMurray, the Athabasca River has developed a straight or sinuous channel pattern. In this region, the stream gradient is 0.2 m/km, the velocity averages 1 m/sec, and the river width varies from 300 to 600 m (Northwest Hydraulics Consultants Limited 1975). The river is bounded by gradually sloping banks and occasionally old meanders are noticeable. The river entrenchment gradually retreats from 180 m (near Fort McMurray) to almost 0 (at the Peace-Athabasca delta). Downstream

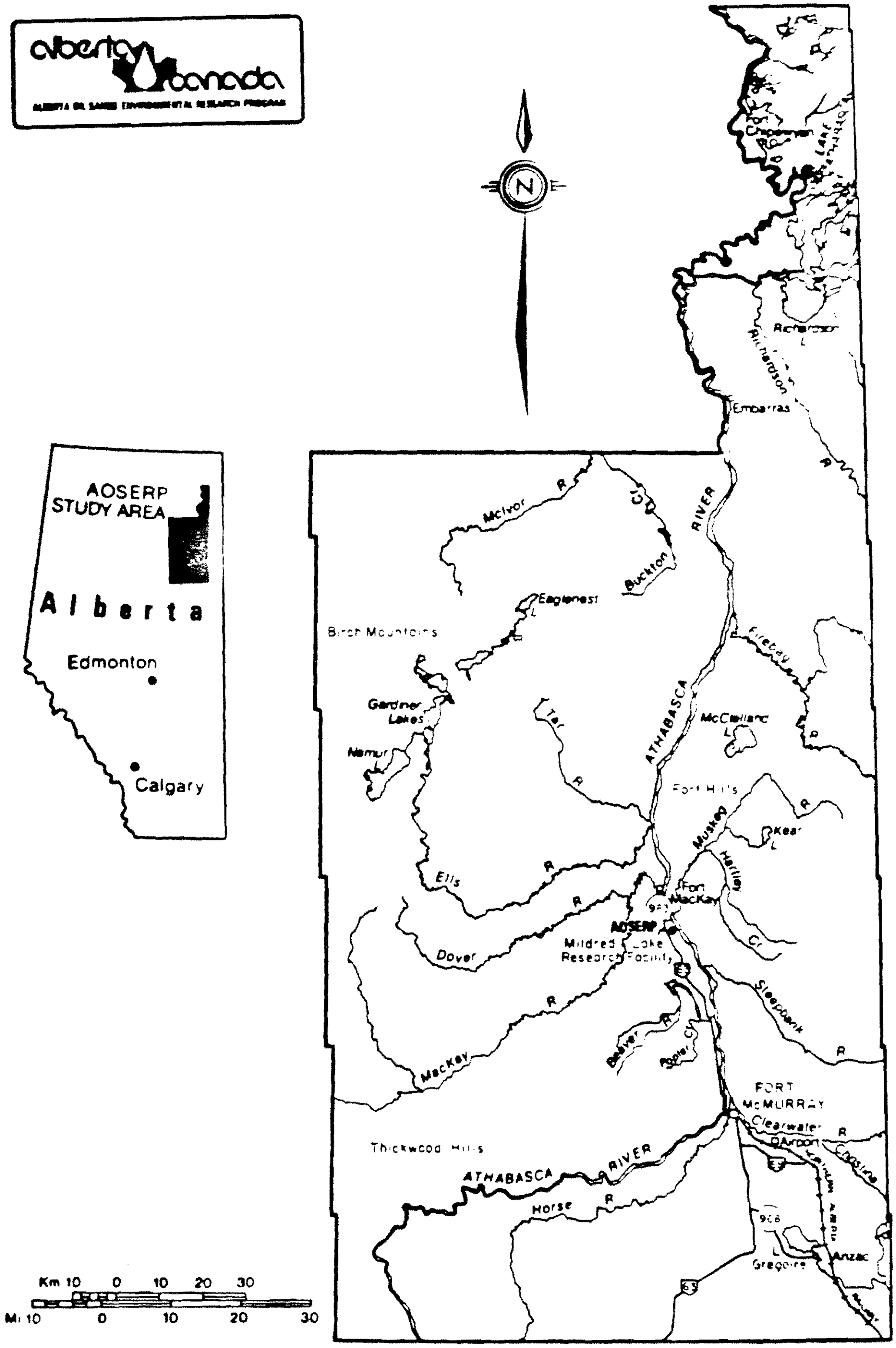


Figure 1. The AOSERP study area.

of Fort McMurray, the Athabasca River is occasionally deflected by cliffs of limestone, bitumen, or clay, which usually create backeddies. Downstream of Fort MacKay there are numerous islands and unstable mid-channel sand bars which are exposed in low water (Bond 1980). The mean Athabasca River flow, monitored near Fort McMurray (Guage 07DA001), was 691 m^3/s for the period 1957 to 1976 (Inland Waters Directorate 1977). The highest flow rates occur in July, when the monthly mean is 1467 m^3/s, and daily flows as high as 4700 m^3/s have been recorded. The mean flow rate for the month of March, when the river flow is minimum, is 165 m^3/s. The Athabasca River is turbid throughout the ice-free season and water temperatures as high as 23°C have been recorded (Bond 1980). Numerous brown water tributaries enter the Athabasca River throughout the present study area.

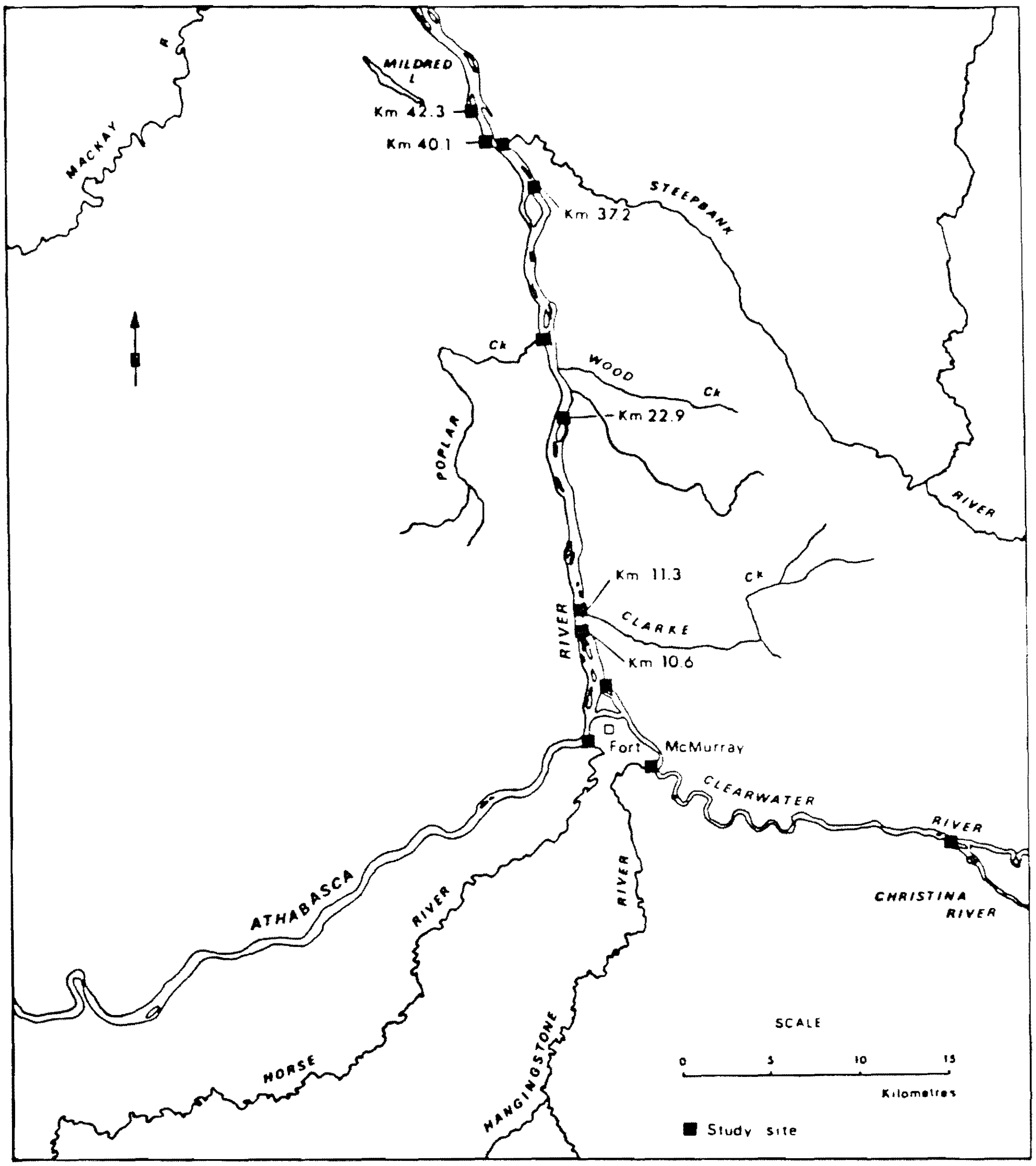


Figure 2. Study sites for the physical inventory (continued).

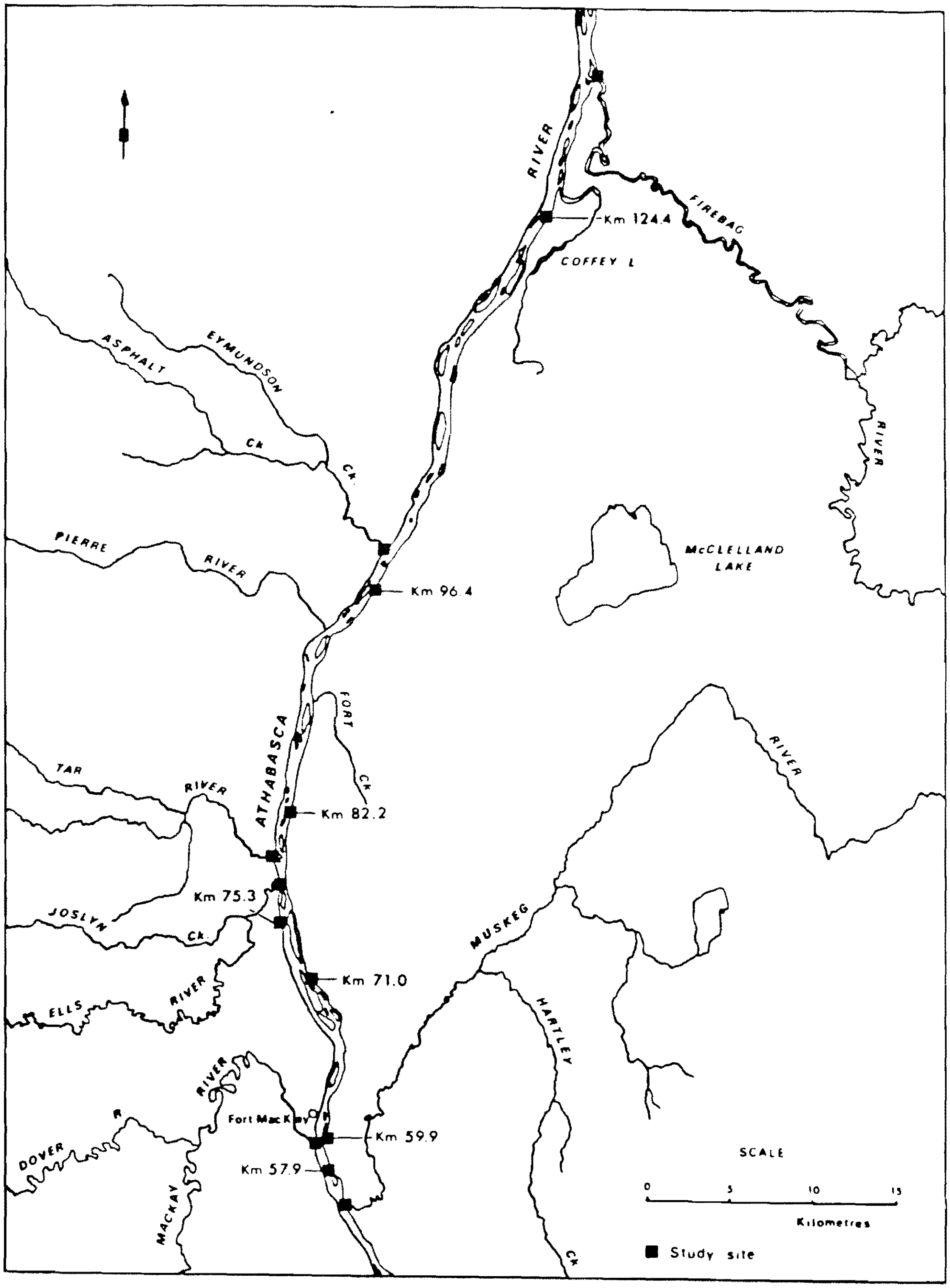


Figure 2. Concluded.

4. MATERIALS AND METHODS

4.1 SELECTION OF STUDY SITES

In reviews of studies on fish in the AOSERP study area, Bond (1980) and Bond and Berry (1980a, b) noted that fishing was normally attempted only at certain river habitat types (i.e., where conventional methods of collection are successful). These included sites associated with islands and mid-channel sand bars, eddies, sites associated with tributary streams, and areas of slack current along point bars, side bars, and bank indentations. After consultation with D.K. Berry, 25 sites were selected on the Athabasca and Clearwater rivers, generally between the Fort McMurray area and Firebag River (Figure 2). The 25 study sites included 12 tributary confluences, 10 areas of backwater eddies, and three regions of mid-channel sand bars or islands. Fish have been collected at most of these sites in previous studies. The sites were identified with the aid of the barge navigation maps for the Athabasca River which are published by Canada Department of Transportation.

4.2 TIMING AND ACCESS

The present study was conducted from 31 July to 13 August 1978. This time period was chosen because logistical and measurement problems are minimized in summer and because August flow rates best typify the average flow regime of the Athabasca River. Access to study sites was by an inboard jet powered riverboat of shallow draught. The boat was launched from Fort McMurray. Two or three stations were sampled per day by the field crew, generally in a downstream progression.

4.3 PROCEDURE AT EACH STUDY SITE

The zone of influence of each tributary entering the Athabasca River was evaluated by noting the length of the eddy line and colour and turbidity differences between the tributary and mainstem rivers.

As many as 10 transects were established by sightings from wooden stakes on the river bank. The primary transect traversed the length of the eddy line. Other transects usually included a "zero" line (straight across the mouth of the input tributary) and several transects perpendicular to the banks of the mainstem river. Sample sites were established at 5 or 10 m intervals along each transect.

Eddies downstream of stone bars or outcrops of limestone bitumen were sampled along numerous (4 to 10) transects through the eddy line and perpendicular to the river bank. Several sample sites were located at measured intervals (5 to 10 m) along each transect.

Three mid-channel islands or sand bars were sufficiently exposed in early August to allow evaluation of their physical characteristics. As for the above habitat types, transects were lined into the mixing waters and along eddy lines.

4.4 PARAMETERS

At each point along each transect, current velocity and direction, depth, Secchi disc visibility (turbidity), substrate, and temperature were measured.

4.4.1 Current Velocity and Direction

Current velocities were measured at 0.5 m depth using a Scientific Instruments Model 1210 Current Meter (Gurley type) and wading rod. The current meter was operated by a person in the stream, as it was usually not possible to measure velocity from the boat. Velocities of tributaries and the mainstem Athabasca River were measured. When water was too deep to operate the current meter, approximate measures of velocity were taken by timing a surface float over a pre-determined distance. Current direction was determined by visual observation and plotted by reference to points where current velocity was measured.

4.4.2 Depth

Depth was measured with a sounding line marked at 10 cm intervals.

4.4.3 Secchi Visibility (Turbidity)

A black and white Secchi disc, 20 cm in diameter and nailed to a holding dowl, was used to estimate light penetration into the water.

4.4.4 Substrate

Substrate samples were collected with a Peterson dredge (grab area 650 cm^2). The dredge was modified by attaching two additional weights (each 5 km) to the jaws so that a deeper bite might be achieved in compacted sediments. In substrates consisting of large material, the amounts of bitumen, limestone, boulder, and rubble were estimated in the field by soundings taken with a steel rod, since the Peterson dredge cannot sample such large substrates. Samples obtained by the dredge were passed through a seive series for determination of substrate composition. Substrate fractions were weighed on a Chatillon weigh scale (±20 g). Substrates were divided into the following categories:

1. Bedrock or bitumen - solid substrate;
2. Boulder - rocks over 30 cm in diameter;
3. Rubble - rocks 7 to 30 cm in diameter;
4. Gravel - rocks 0.2 to 7 cm in diameter;
5. Sand-Silt - particles less than 0.2 cm; and
6. Other - specified individually (e.g., sand over bedrock).

4.4.5 Temperature

Surface temperature was measured with a pocket thermometer (±0.5°C).

5. RESULTS

5.1 CONFLUENCES OF ATHABASCA RIVER AND CLEARWATER RIVER TRIBUTARIES

5.1.1 Clearwater and Christina Rivers

At the confluence of the Clearwater River with the Christina River, a large swirling eddy extended for 75 m downstream from a shallow gravel bar located 5 m upstream of the confluence (Figure 3). Areas of calm, upwellings, and persistent counter-currents were noticeable. Water depths along the eddy line were generally 0.5 to 1.0 m with a maximum of 3 m in the confluence area. Secchi visibility in the Christina River (0.5 m) was less than in the Clearwater River (0.9 m). Mixing of waters was almost complete within 180 to 200 m downstream of the confluence. Bottom substrates varied from fines in the Christina River to gravels and rubble in the Clearwater River proper. Water temperatures were similar in both rivers. Physical parameters along each transect are listed in Appendix 8.1 (Table 1).

5.1.2 Clearwater and Hangingstone Rivers

At the confluence of the Clearwater River with the Hangingstone River, the bottom substrate varied from entirely fines in the Hangingstone River to gravels and rubble in the Clearwater River (Figure 4). Waters of depth 0.25 m extended across a shallow sand bar at the mouth of the Hangingstone River and depths quickly increased in the Clearwater River. No swirling eddies were present at the confluence. Secchi visibility and water temperature were similar in both rivers. Physical parameters along each transect are listed in Appendix 8.1 (Table 2).

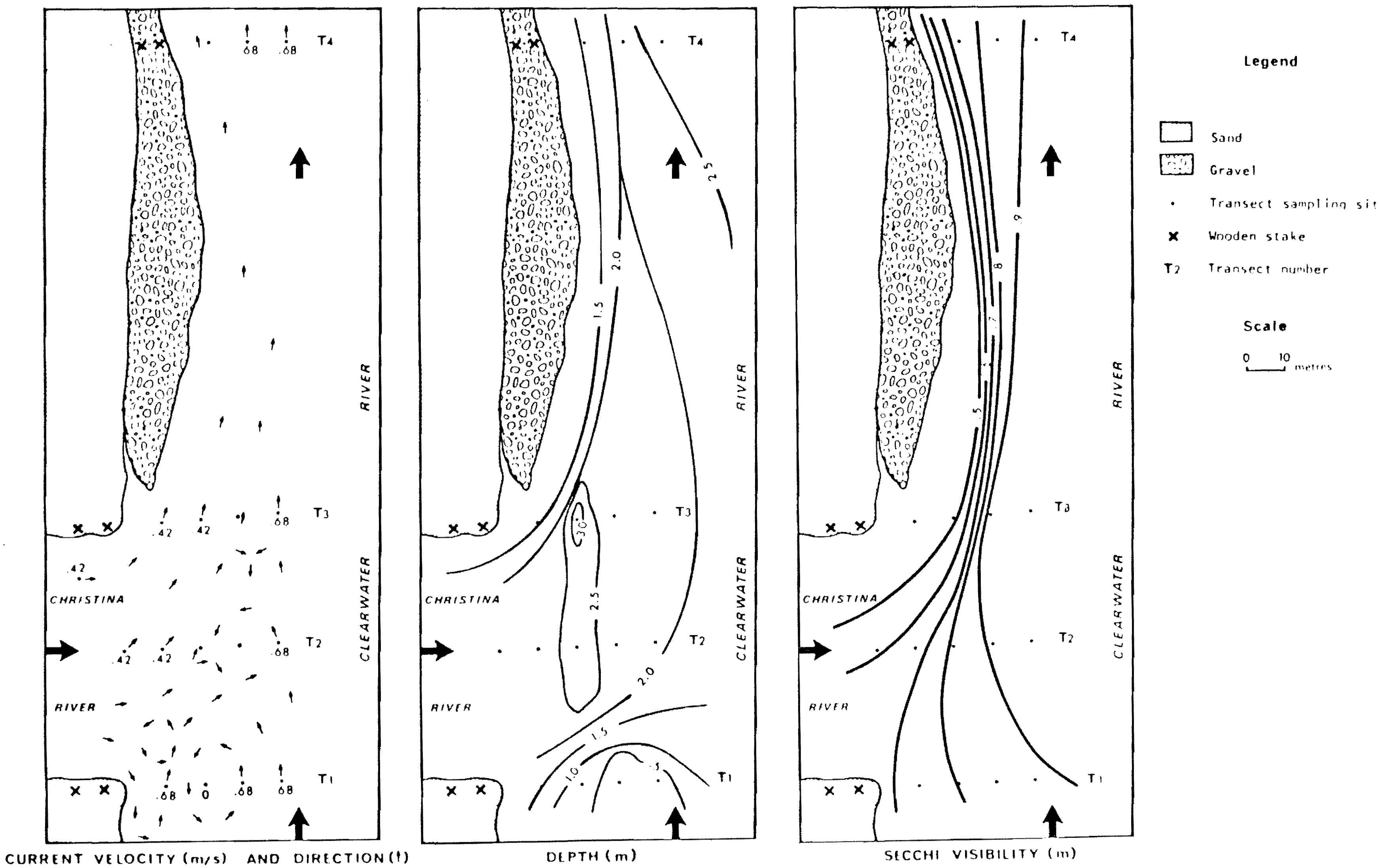


Figure 3. Confluence of the Clearwater and Christina rivers (continued).

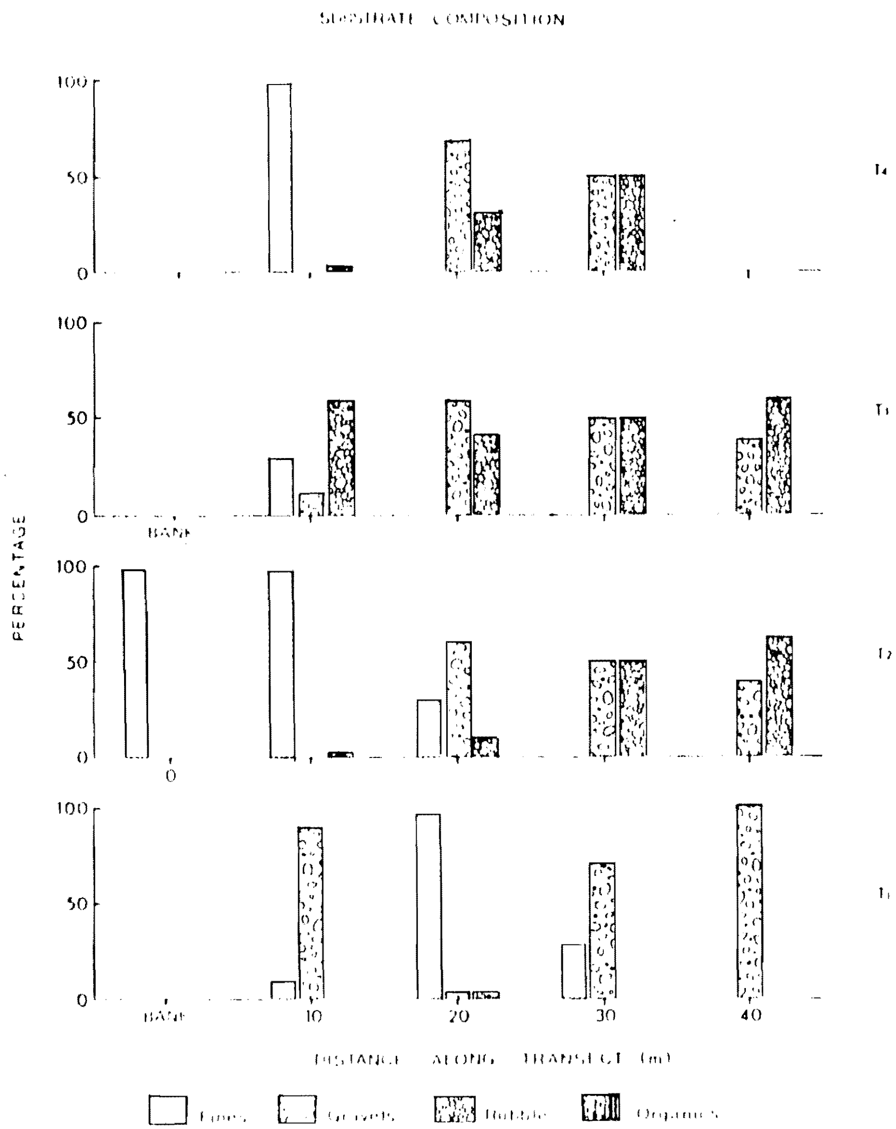
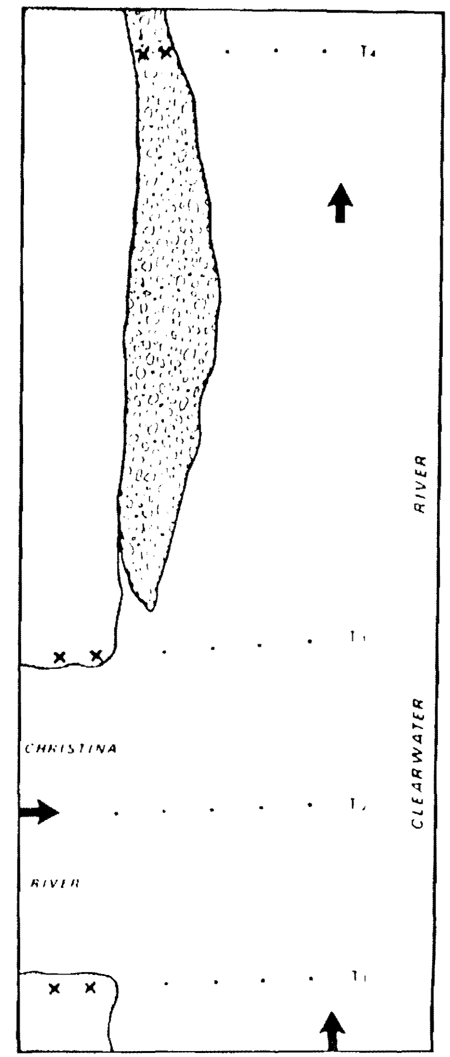


Figure 3. Concluded.



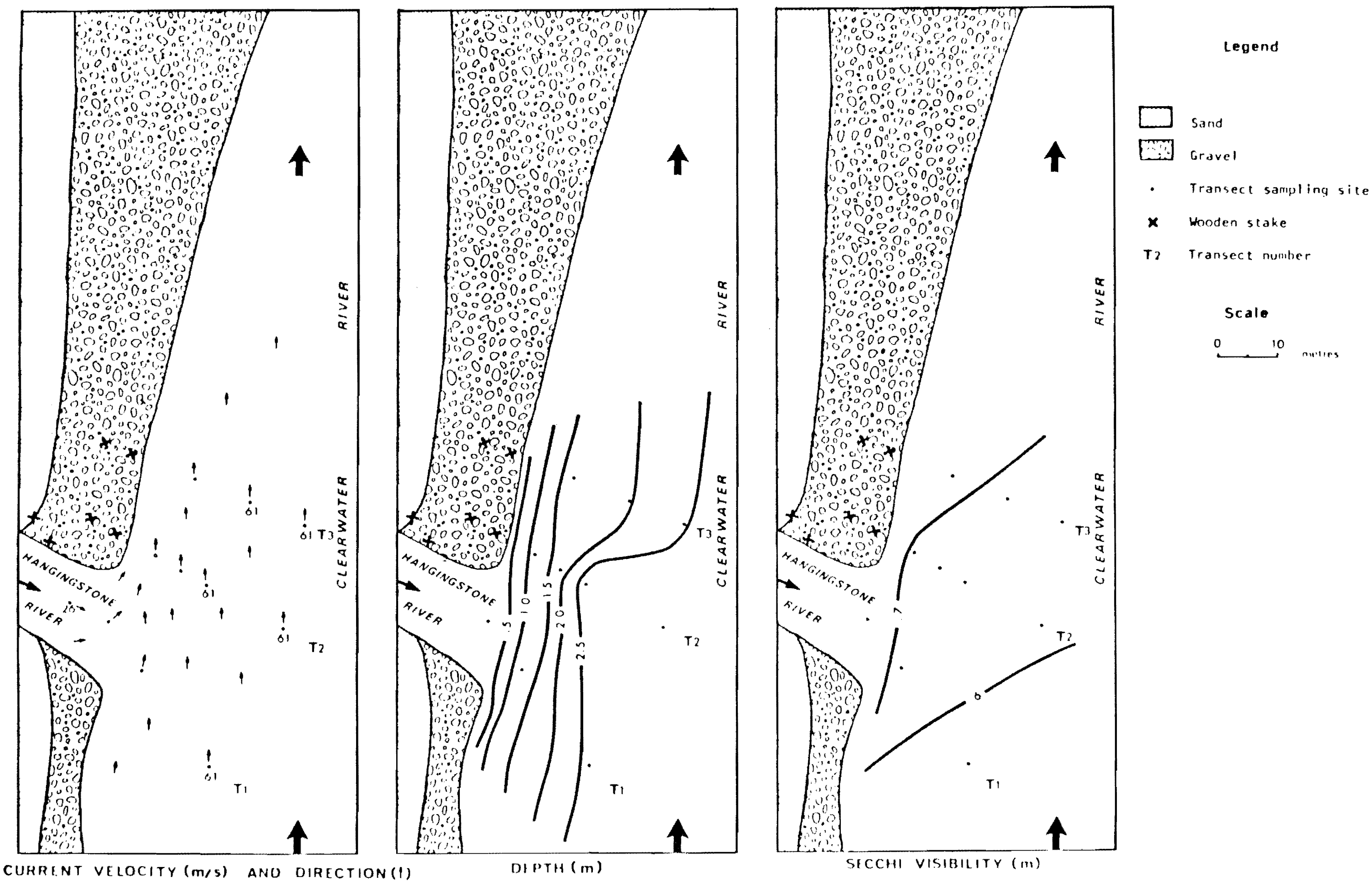
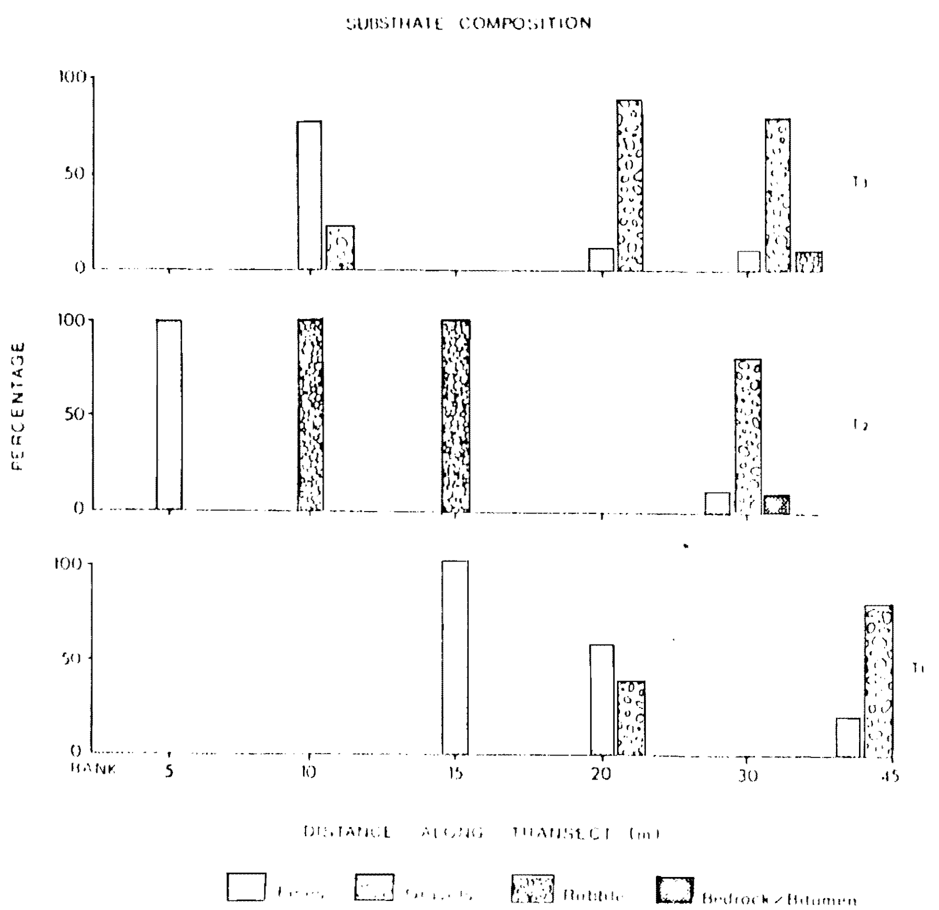


Figure 4. Confluence of the Clearwater and Hangingstone rivers (continued).



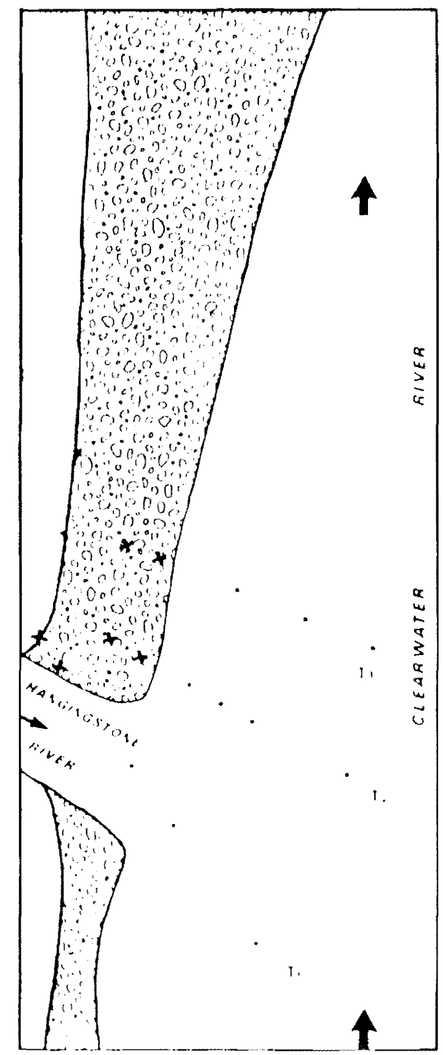


Figure 4. Concluded.

5.1.3 Athabasca and Horse Rivers

Waters from the turbid Athabasca River intruded into a slack water area at the mouth of the Horse River, as evidenced by the abrupt differences in Secchi visibility in the humic-stained Horse River (Figure 5). No eddies were apparent. Humic waters from the Horse River were not completely mixed with the Athabasca River 200 m downstream from the confluence. Substrates at the confluence were deep silts in the slack water area, or a thin layer of silt over bedrock, or bare bedrock in the Athabasca River proper. Depths were irregular throughout because of limestone and silt deposits. Water temperatures in the Horse River were slightly warmer (2°C) than the Athabasca River. Physical parameters along each transect are listed in Appendix 8.1 (Table 3).

5.1.4 Athabasca and Clearwater Rivers

The Clearwater River confluence with the Athabasca River is characterized by a large swirling eddy extending for 200 m across the mouth of the Clearwater River (Figure 6). Swirling pools, upwellings, and countercurrents existed along the eddy line and into the Clearwater River proper. Substrates were silt and sand in sheltered areas of the Clearwater River mouth and limestone bedrock in the Athabasca River itself. Depths were generally less than 2 m in the Clearwater River, increasing to 4 m in the Athabasca River. Differences in Secchi visibility between the two rivers were readily apparent and mixing of waters was not complete for several kilometres downstream. Physical parameters along each transect are listed in Appendix 8.1 (Table 4).

5.1.5 Athabasca River and Poplar Creek

At the confluence of the Athabasca River with Poplar Creek, a small eddy extended across the Poplar Creek mouth and for 20 m downstream (Figure 7). At the discharge volumes encountered during the study, the zone of influence of Poplar Creek was confined to the immediate creek mouth. Waters of Poplar Creek quickly mixed with the Athabasca River, as evidenced by rapid changes in Secchi visibilities. Neither water depths nor temperature in the Athabasca River were modified by Poplar Creek. Substrates in both Poplar Creek and Athabasca River were almost entirely soft silts and sands. Physical parameters along each transect are listed in Appendix 8.1 (Table 5).

5.1.6 Athabasca and Steepbank Rivers

The zone of influence of the Steepbank River at its confluence with the Athabasca River was considerable. A large oval-shaped vortex persisted in the Athabasca River 200 m downstream of the Steepbank River mouth (Figure 8). The centre of the vortex appeared calm and upwellings and countercurrents were noticeable. No eddies were present near the mouth of the Steepbank River. The bottom substrate adjacent to the river bank was either sand (2 cm) over bitumen or gravel embedded into bitumen. Further from shore, the substrate was entirely compacted bitumen, similar to the riverbanks in the area. Water depths were generally shallow on the extensive bitumen shelf. The differences in Secchi visibility between the two rivers was readily apparent; semi-stagnant waters from the Steepbank River persisted alongside the bank of the Athabasca River for 2 to 3 km downstream. Water temperatures in the Steepbank River (20.5°C) were only slightly warmer than in the Athabasca River (18.5°C). Physical parameters along each transect are listed in Appendix 8.1 (Table 6).

5.1.7 Athabasca and Muskeg Rivers

No swirling eddies or complex current patterns were observed at the confluence of the Athabasca and Muskeg rivers (Figure 9). The Secchi visibility difference between the two rivers

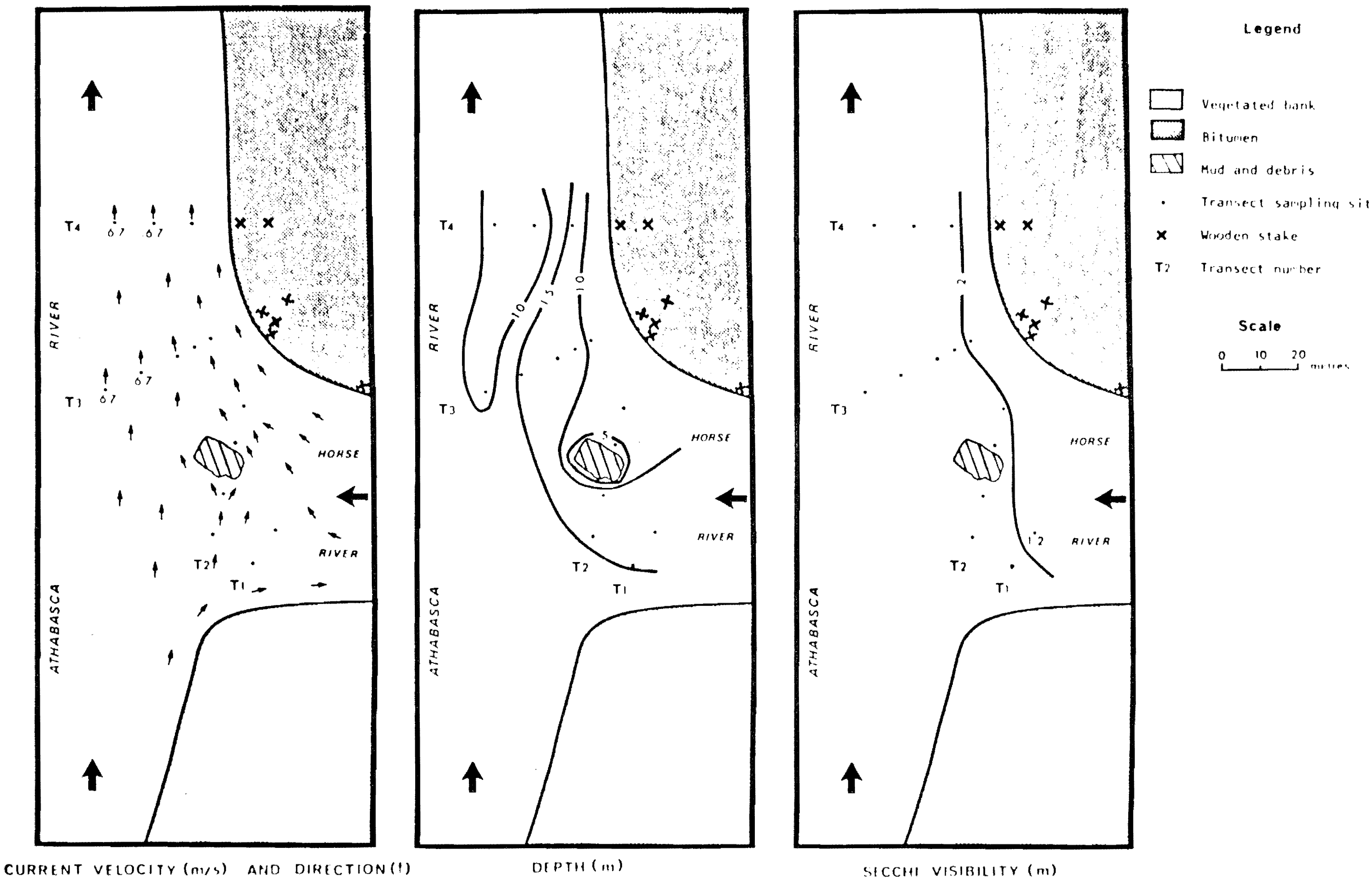
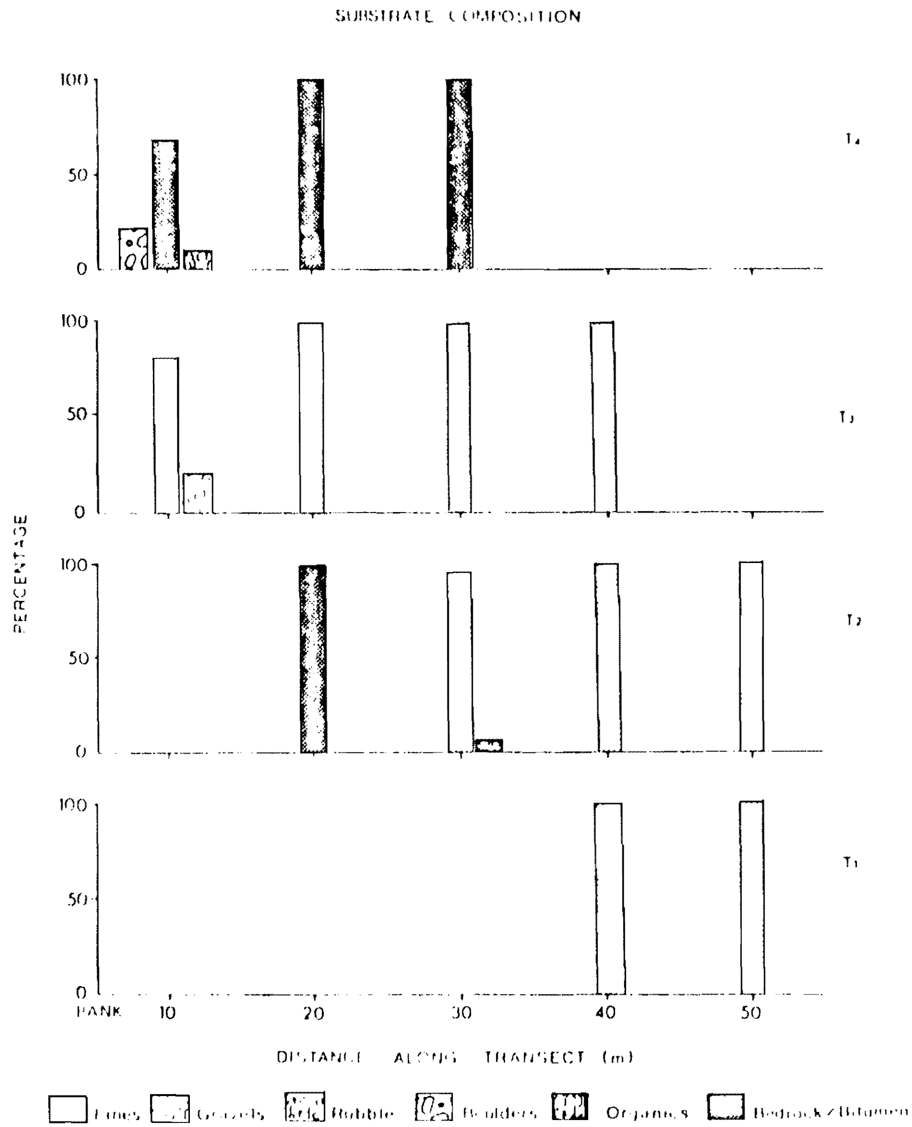
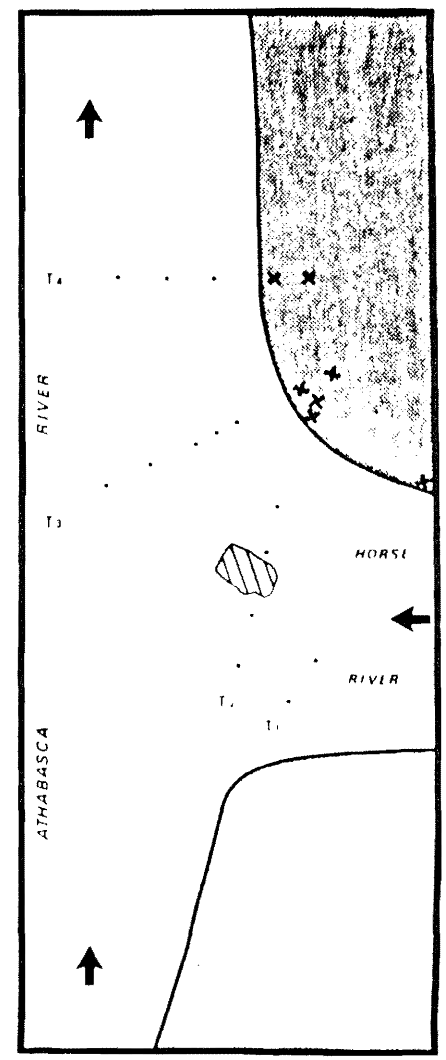


Figure 5. Confluence of the Athabasca and Horse rivers (continued).





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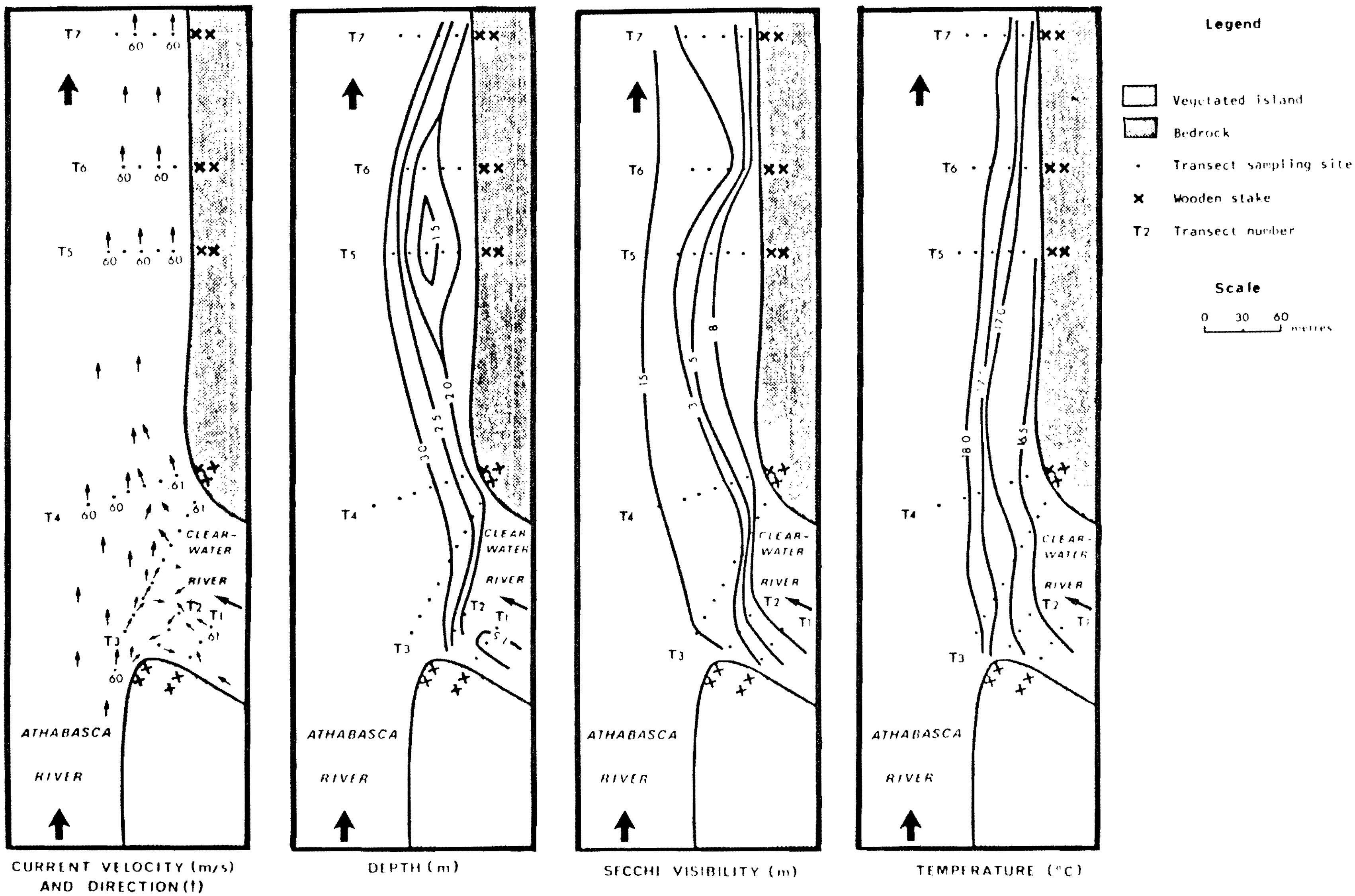
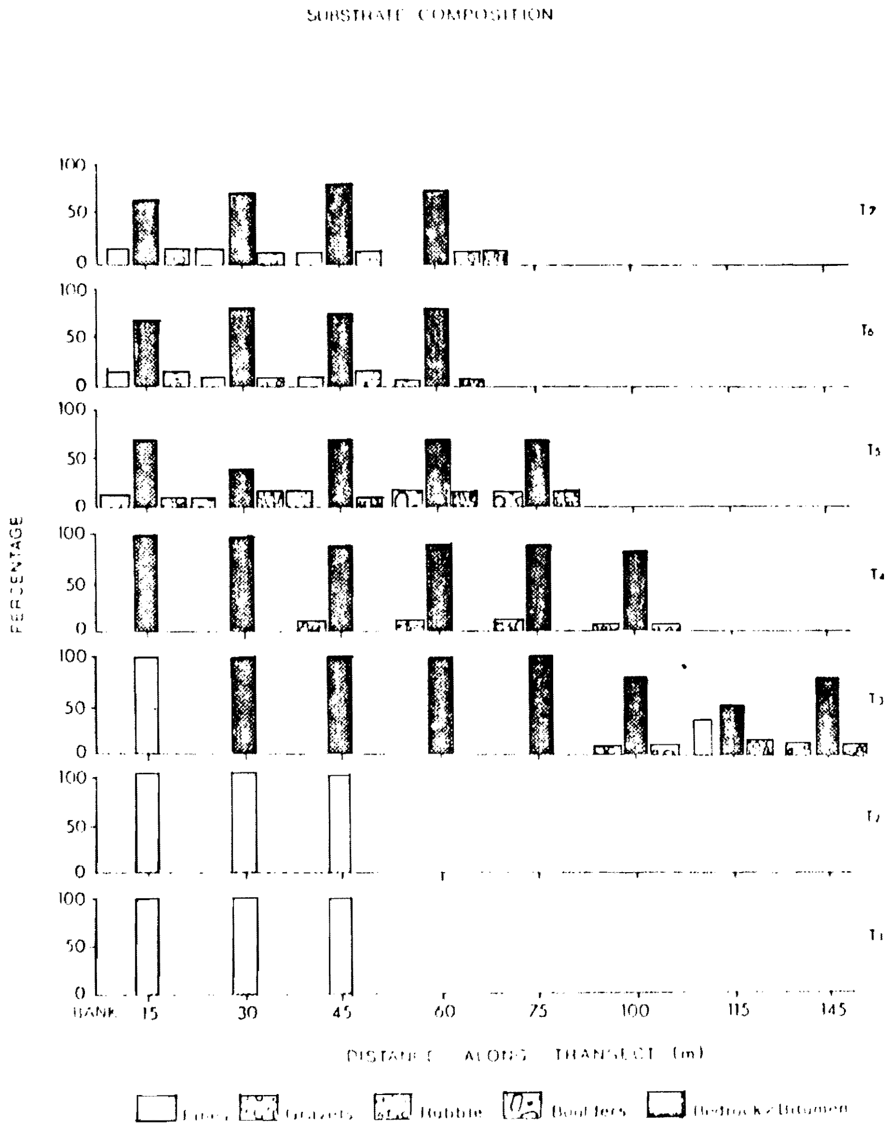
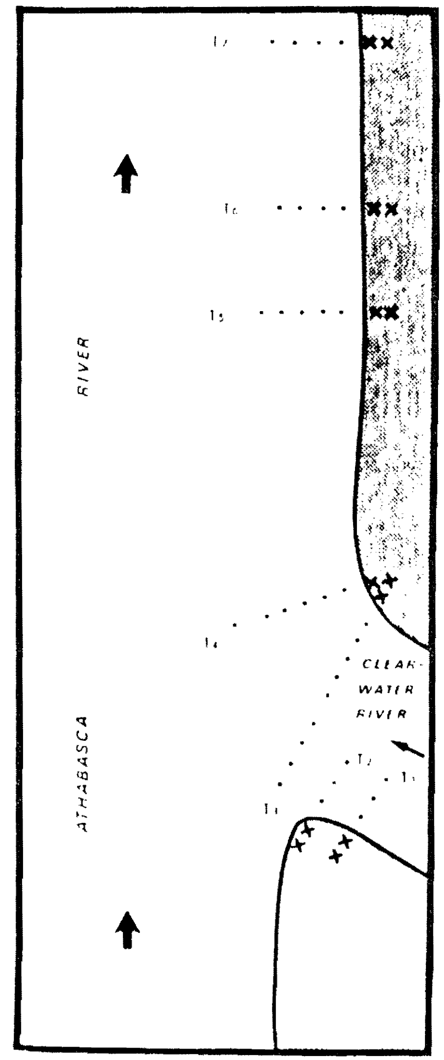


Figure 6. Confluence of the Athabasca and Clearwater rivers (continued).





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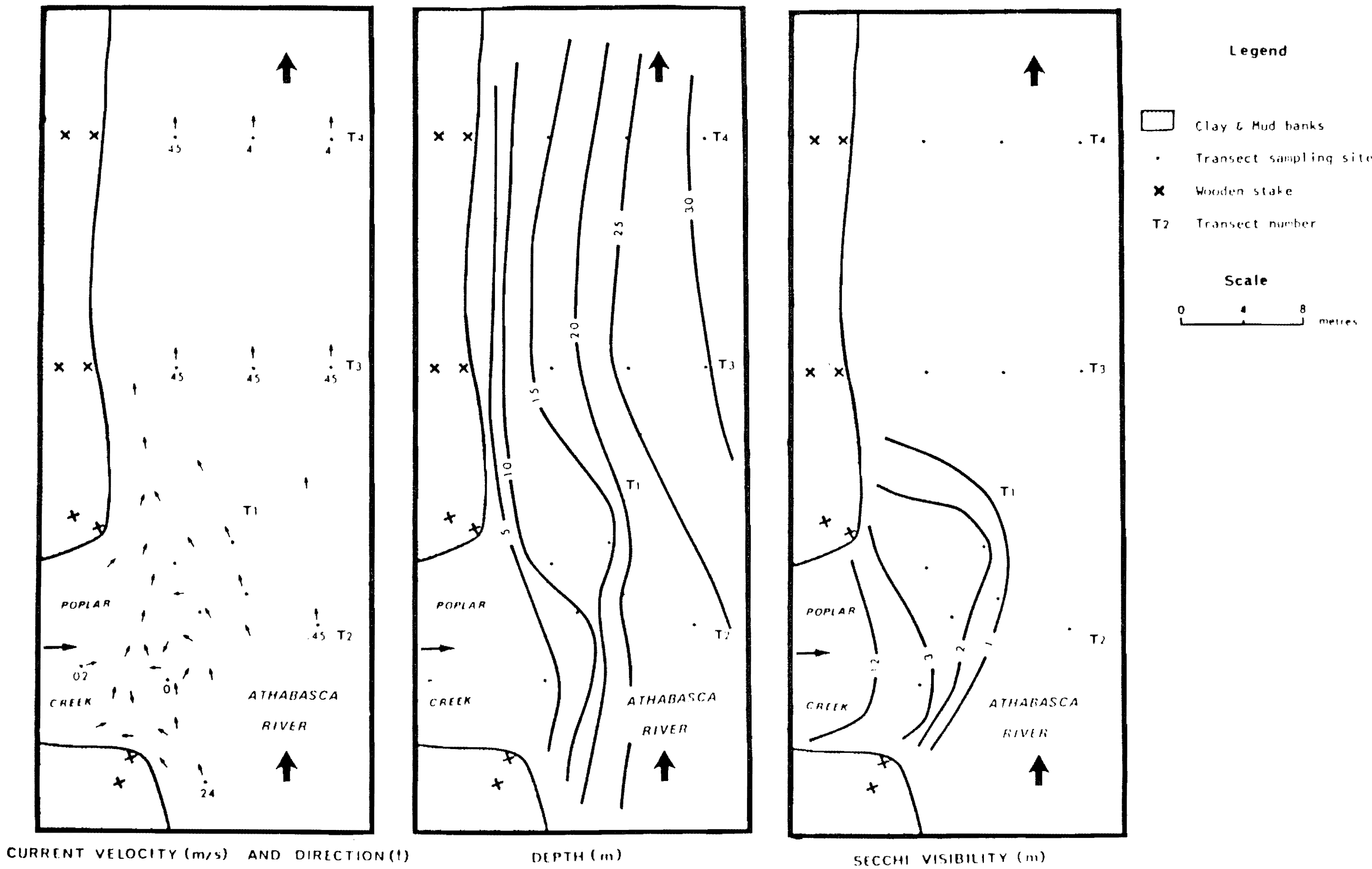


Figure 7. Confluence of the Athabasca River and Poplar Creek (continued).

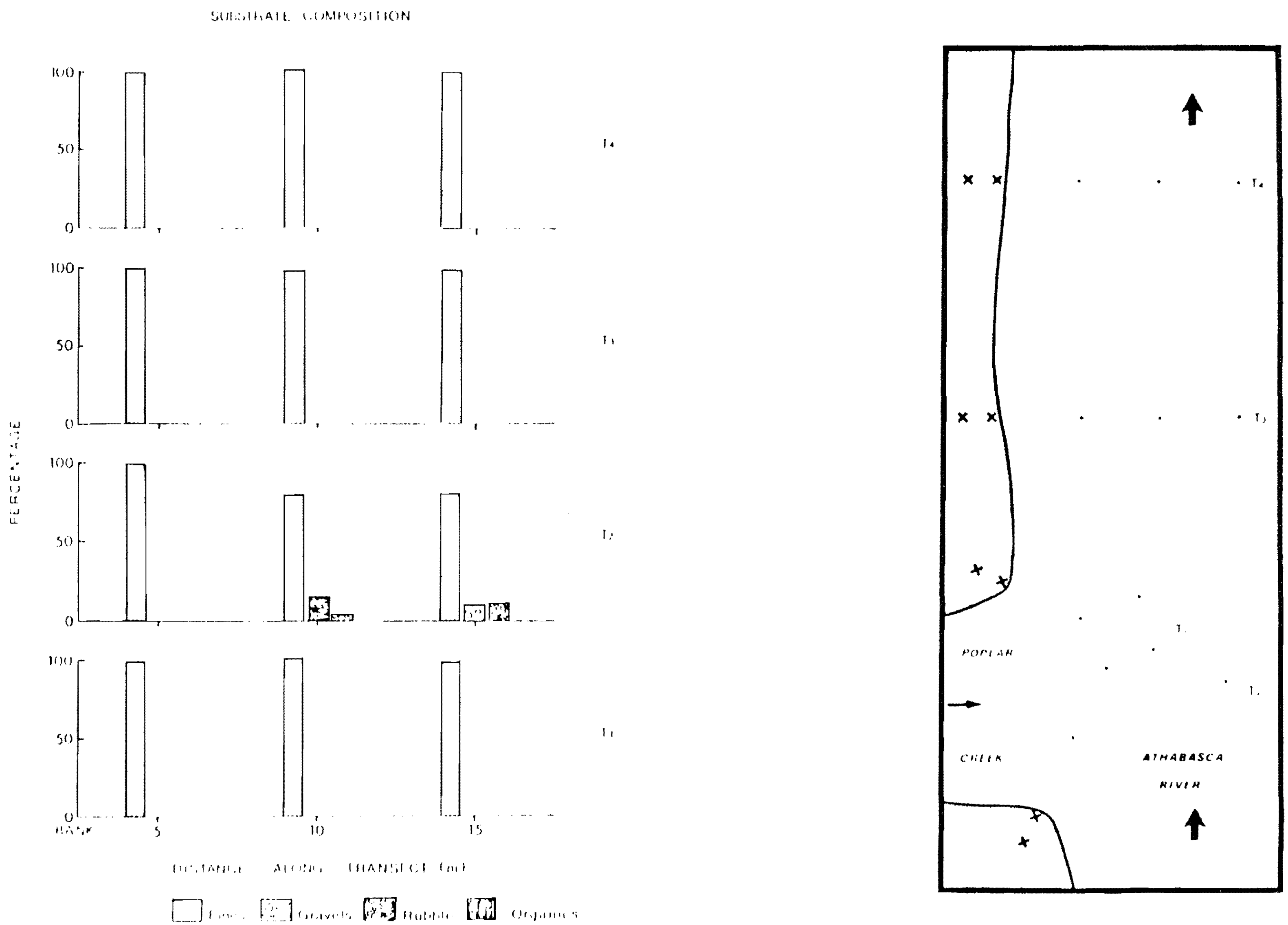
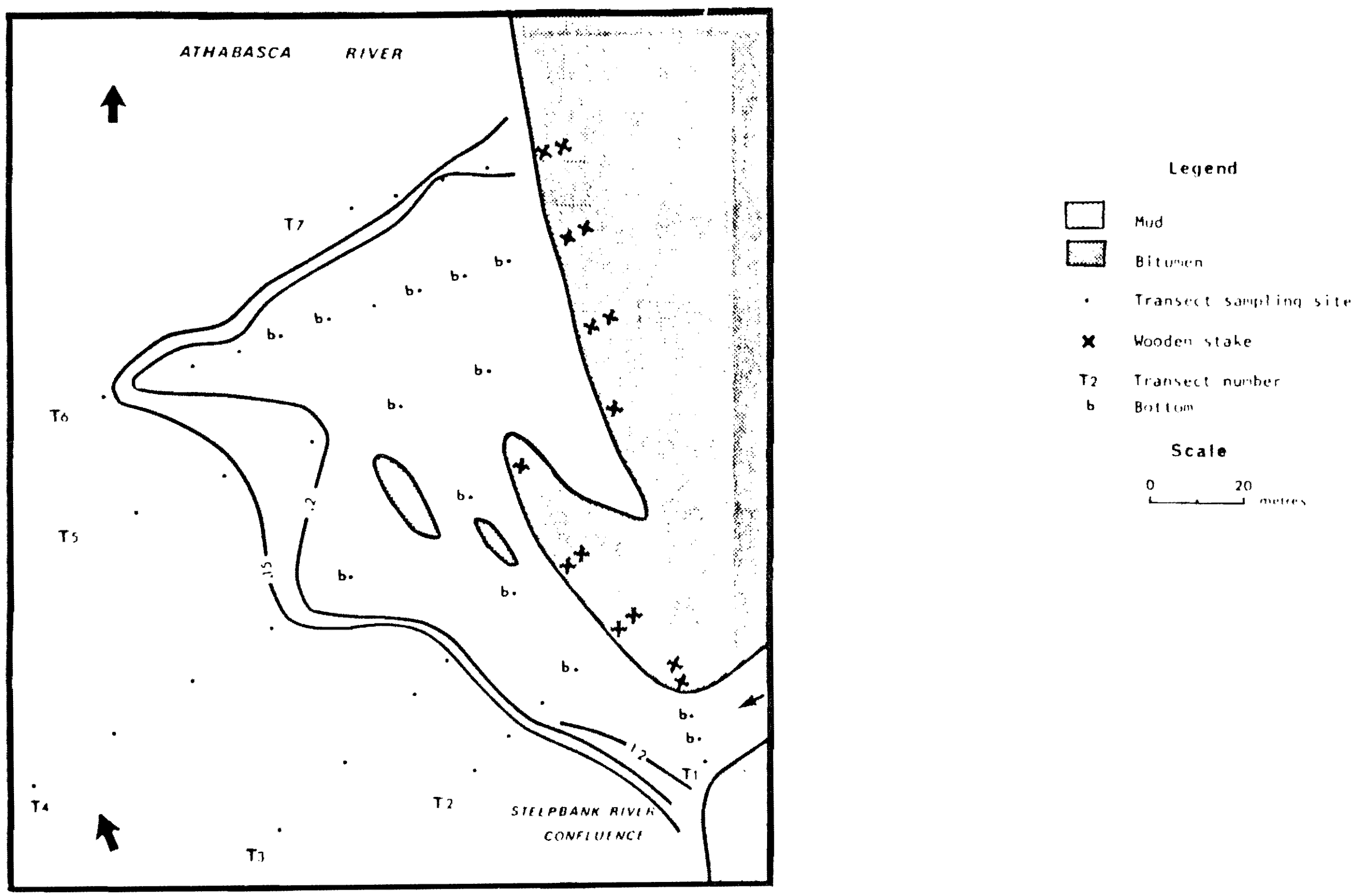


Figure 7. Concluded.

CURRENT VELOCITY (m/s) AND DIRECTION(↑)

DEPTH (m)

Figure 8. Confluence of the Athabasca and Steepbank rivers (continued).



SECCHI VISIBILITY (m)

Figure 8. Continued.

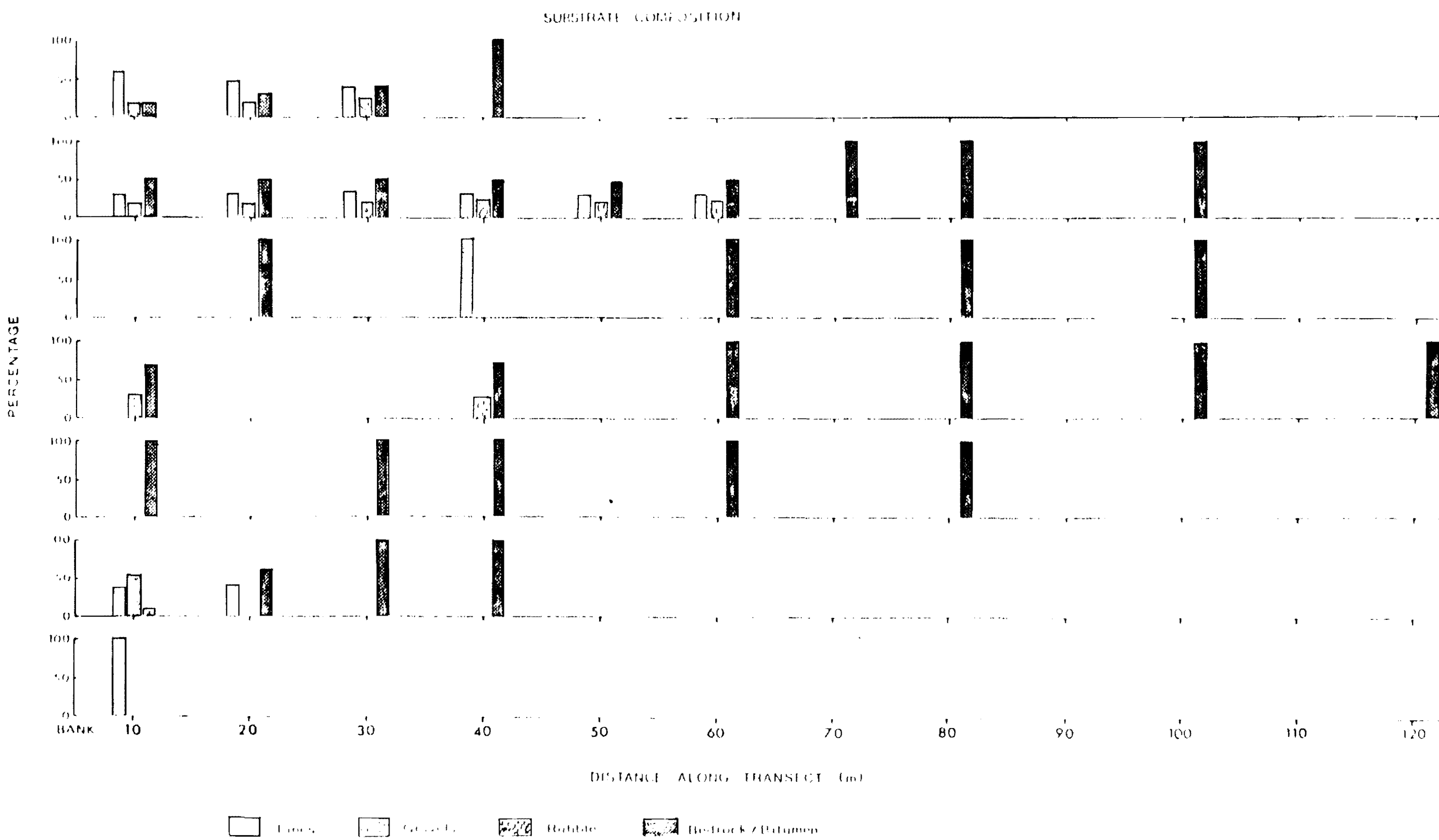


Figure 8. Concluded.

was marked and the colour difference persisted for 1 km downstream. Water depths across the river mouth and downstream of the confluence were generally shallow. The bottom substrate was entirely fines in the Muskeg River and gravels in the Athabasca River. The water temperatures in the Muskeg River were 4°C lower than in the Athabasca River. Physical parameters along each transect are listed in Appendix 8.1 (Table 7).

5.1.8 Athabasca and MacKay Rivers

At the confluence of the Athabasca River with the MacKay River, a large eddy with countercurrents and upwellings extended for 30 m across the river mouth (Figure 10). Waters of the Athabasca River intruded for 200 m along the left bank (facing downstream) of the MacKay River proper. Water depths in the confluence were irregular with deepest areas being present along the eddy line. The differences in Secchi visibility between the two rivers were apparent and mixing was almost immediate. Soft sand-silts prevailed throughout the river mouth with gravels and bitumen becoming evident further into the Athabasca River. Physical parameters along each transect are listed in Appendix 8.1 (Table 8).

5.1.9 Athabasca and Ells Rivers

Two swirling eddies were evident at the confluence of the Athabasca and Ells rivers; one across the Ells River mouth and another associated with a nearby sand island (Figure 11). Water depths at the mouth of the Ells River reflected flow patterns, varying from shallows with sand deposits to deeper areas coincident with increased flow velocities. The differences in Secchi visibility between the Athabasca and Ells rivers were readily apparent and mixing was complete within 0.5 km downstream. A soft sand-silt substrate prevailed throughout. Physical parameters along each transect are listed in Appendix 8.1 (Table 9).

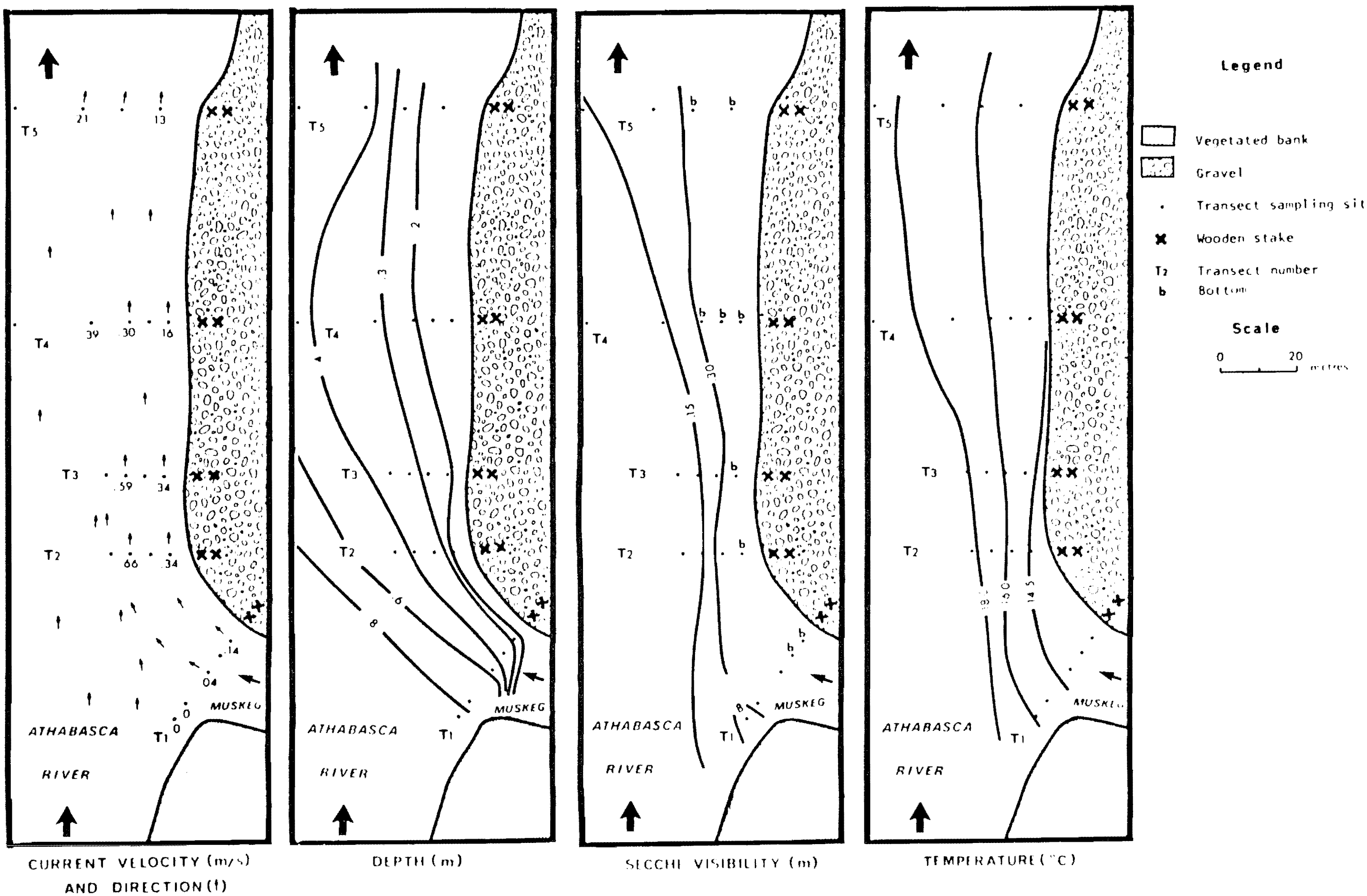
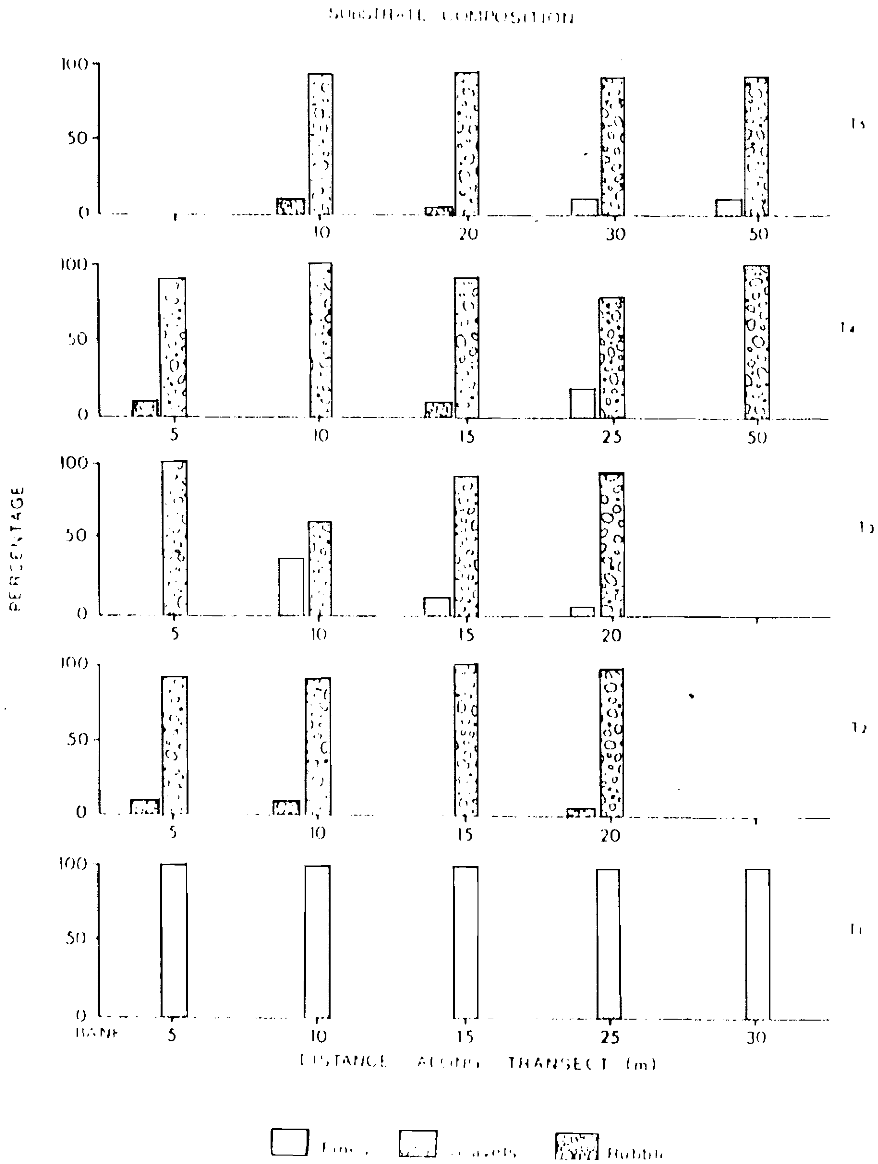


Figure 9. Confluence of the Athabasca and Muskeg rivers (continued).



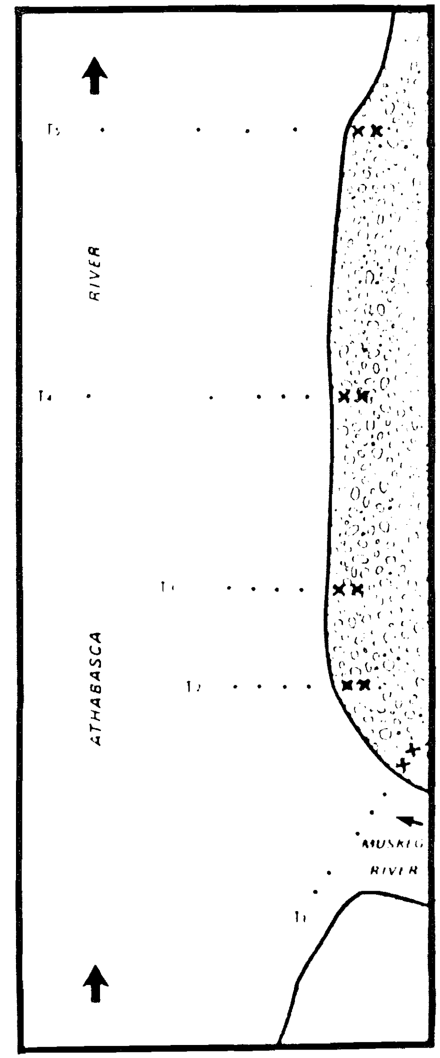
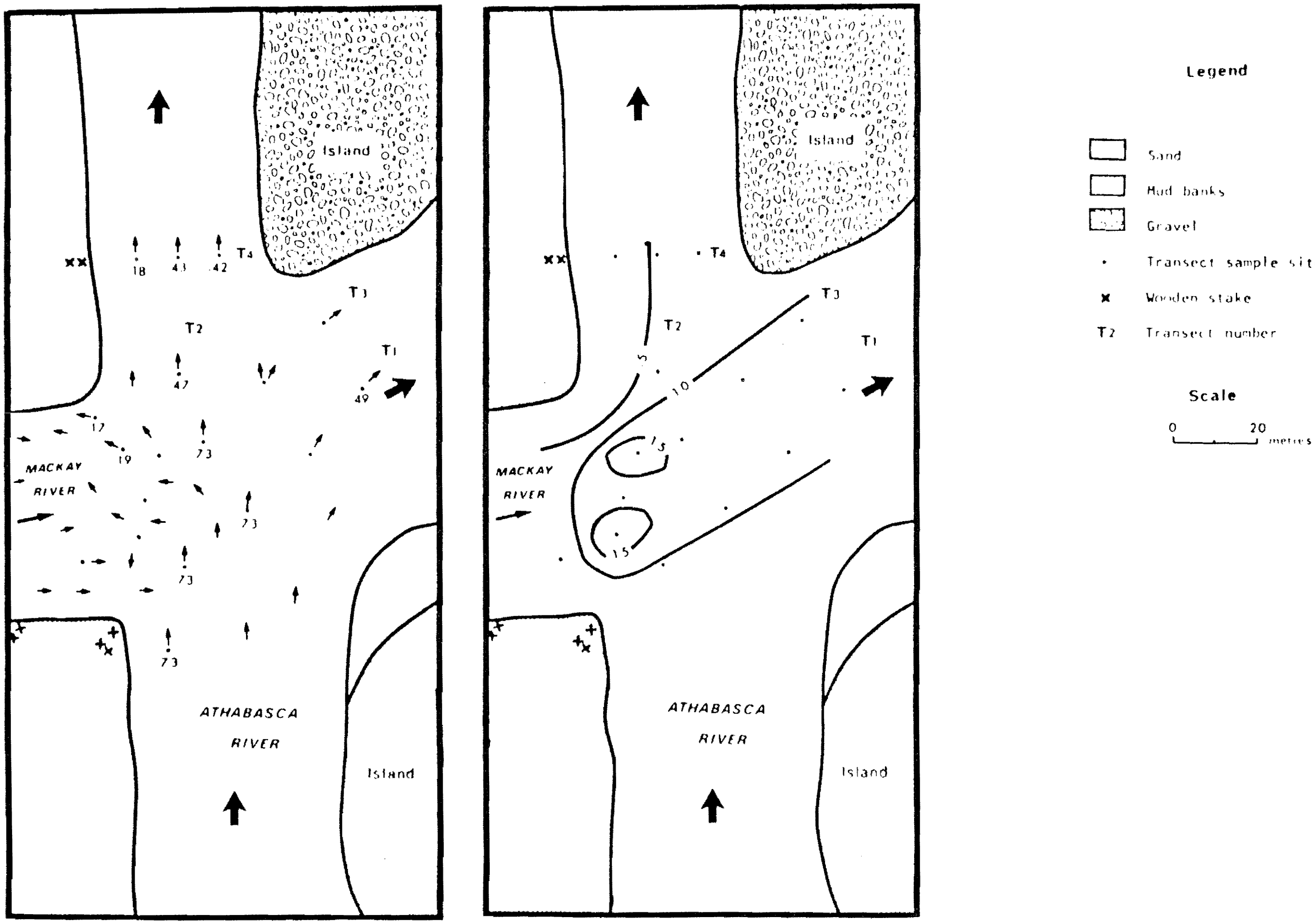


Figure 9. Concluded.



CURRENT VELOCITY (m/s) AND DIRECTION (↑)

DEPTH (m)

Figure 10. Confluence of the Athabasca and MacKay rivers (continued).

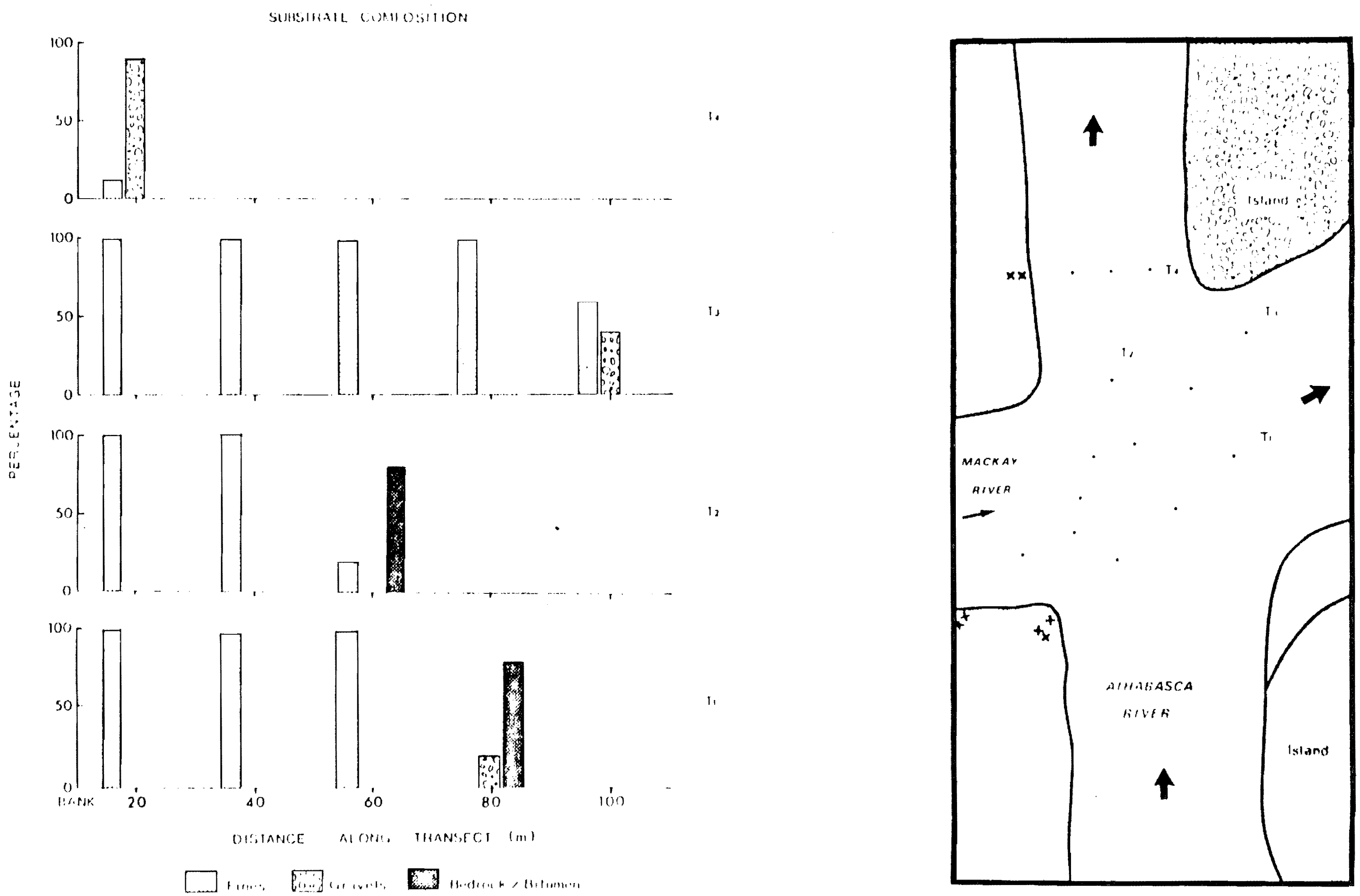


Figure 10. Concluded.

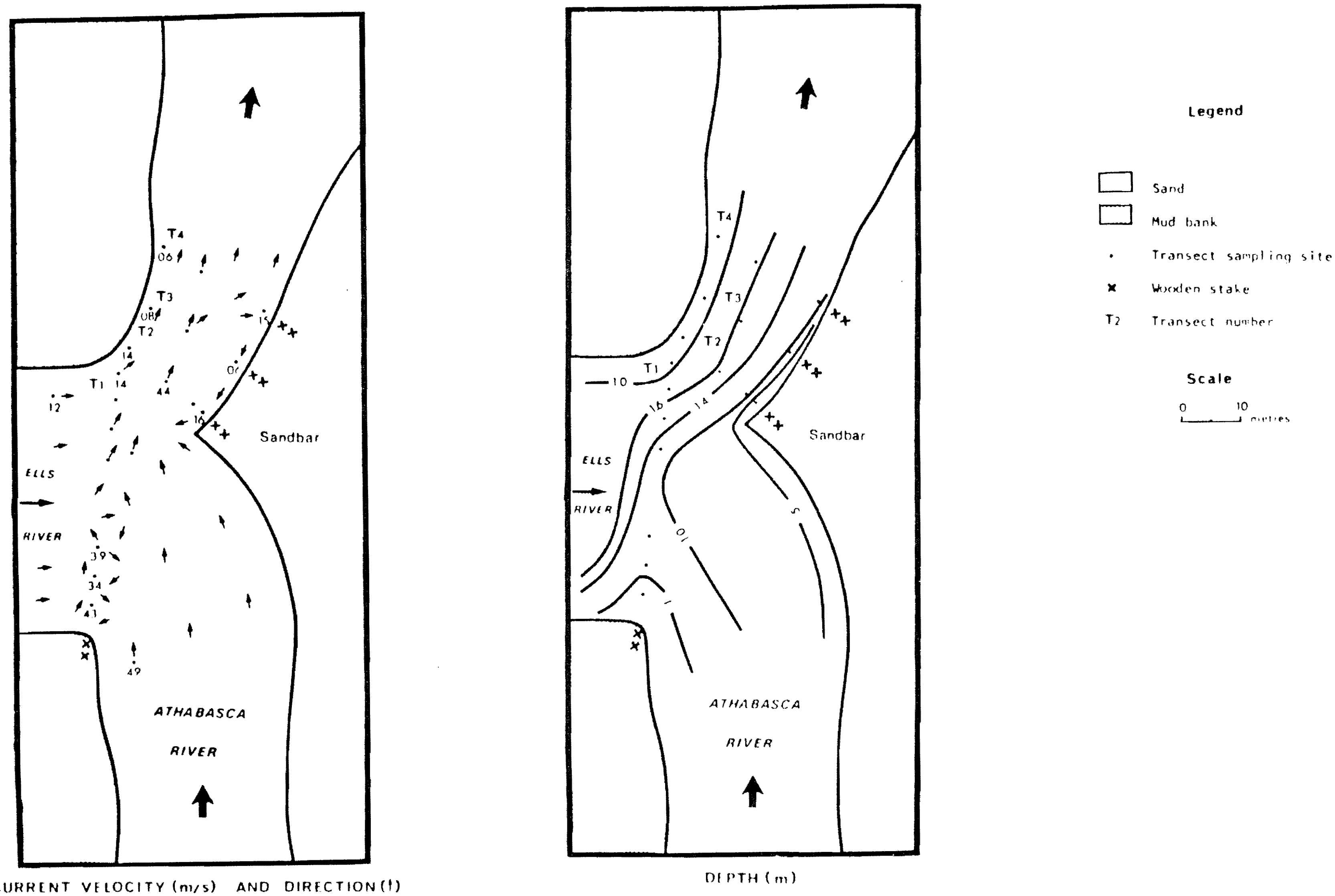


Figure 11. Confluence of the Athabasca and Ells rivers (continued).

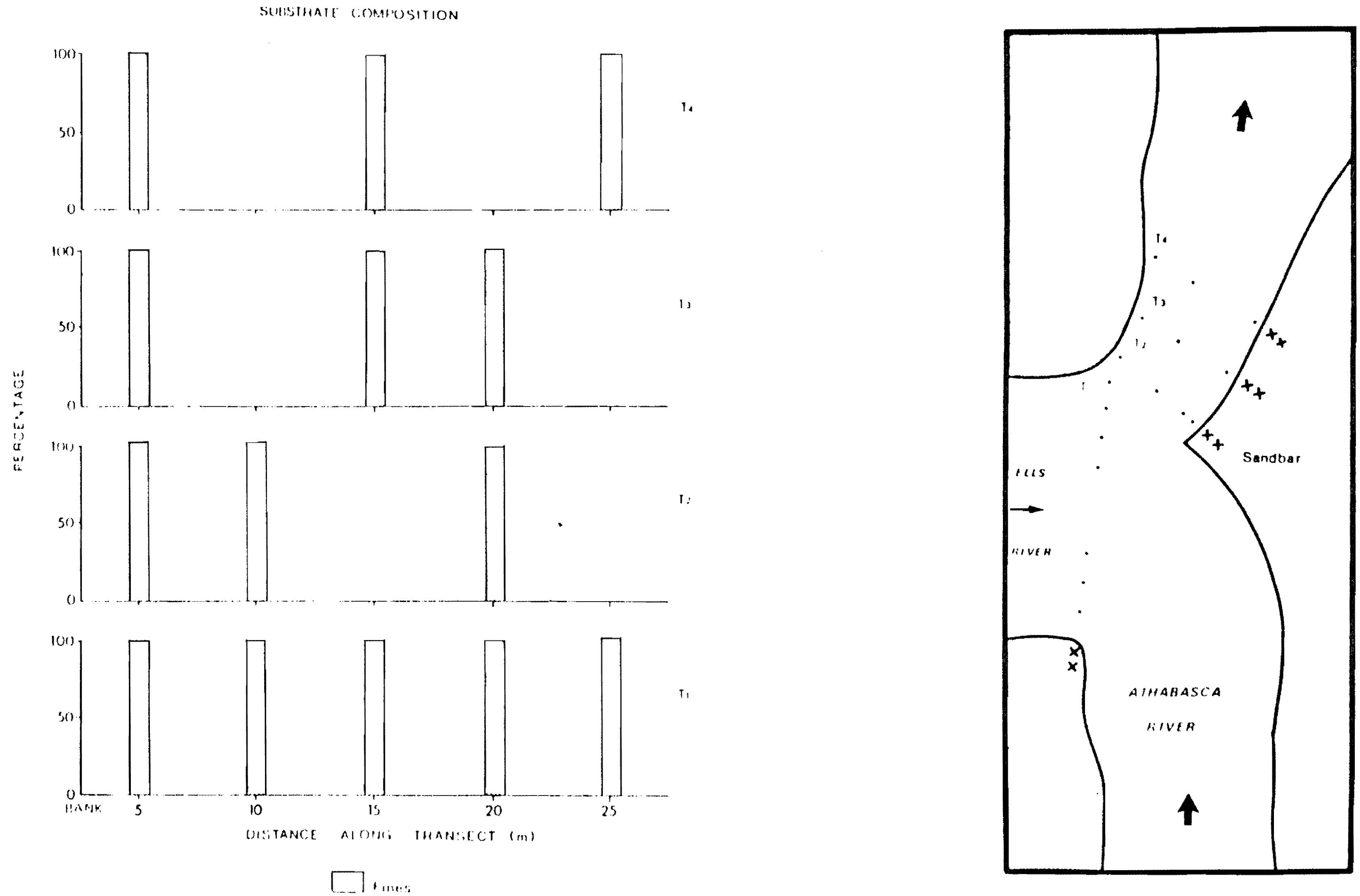


Figure 11. Concluded.

5.1.10 Athabasca and Tar Rivers

The Tar River confluence with the Athabasca River was characterized mainly by changes in Secchi visibility and temperature. Mixing of waters was almost immediate as evidenced by the abrupt disappearance of the humic-stained waters of the Tar River. Water temperatures were 15°C in the Tar River, increasing quickly to 19°C in the Athabasca River. There were no noticeable changes in current velocity or direction (Figure 12). There was a submerged sand bar across the Tar River mouth. Bottom substrates throughout this confluence were entirely a soft mud silt. Physical parameters along each transect are listed in Appendix 8.1 (Table 10).

5.1.11 Athabasca River and Eymundson Creek

An eddy extended for 20 m across the mouth of Eymundson Creek. Also present was a slowly revolving vortex with slack waters and countercurrents immediately downstream from the creek mouth (Figure 13). These changes in current direction are probably due to the presence of a bitumen outcrop immediately upstream. Bottom substrates changed abruptly from soft sands and muds in the creek mouth and river bank to compacted bitumen and gravels 20 m into the Athabasca River. Unlike all other Athabasca River tributaries, Eymundson Creek was more turbid than the Athabasca River. Water temperatures (16.5°C) were lower than in the Athabasca River (18°C). Physical parameters along each transect are listed in Appendix 8.1 (Table 11).

5.1.12 Athabasca and Firebag Rivers

The Firebag River confluence with the Athabasca River is characterized by a large swirling eddy extending for 150 m across the mouth of the Firebag River (Figure 14). Countercurrents and upwellings along the eddy line created a mixing zone between waters of the turbid Athabasca River and humic-stained waters of the

Firebag River. Mixing of waters was not complete for several kilometres downstream. A sand bar of irregular depth stretched across the mouth of the Firebag River. Downstream from the confluence, depths increased quickly with distance from the riverbank. Bottom substrates were sands in the Firebag River mouth and gravels and rubble in downstream areas. Physical parameters along each transect are listed in Appendix 8.1 (Table 12).

5.2 EDDIES DOWNSTREAM OF POINTS OF LAND

5.2.1 Athabasca River at km 11.3

A large low velocity vortex was observed at km 11.3 immediately below a large gravel delta extending out from Clarke Creek (Figure 15). Immediately downstream of this point of land, the water was shallow (0.5 m) and the substrate was a mixture of sands, gravels, and boulders. At the tail of the vortex, waters were deeper (1 to 2 m) and a silt substrate was present near the river bank. Physical parameters along each transect are listed in Appendix 8.1 (Table 13).

5.2.2 Athabasca River at km 37.2

At km 37.2, a limestone bluff deflected waters of the Athabasca River, resulting in the formation of a narrow backwater eddy (Figure 16). Downstream of the bluff, current velocities decreased and countercurrents and vortices became apparent. Water depths were generally shallow throughout with no irregular changes. The bottom substrate was primarily gravels and rubble immediately downstream of the bluff and sands in the vortex area. Physical parameters along each transect are listed in Appendix 8.1 (Table 14).

5.2.3 Athabasca River at km 40.1

At km 40.1 of the Athabasca River, the only noticeable physical change was the formation of an elongated eddy resulting from waters being deflected off a shallow gravel and bitumen point

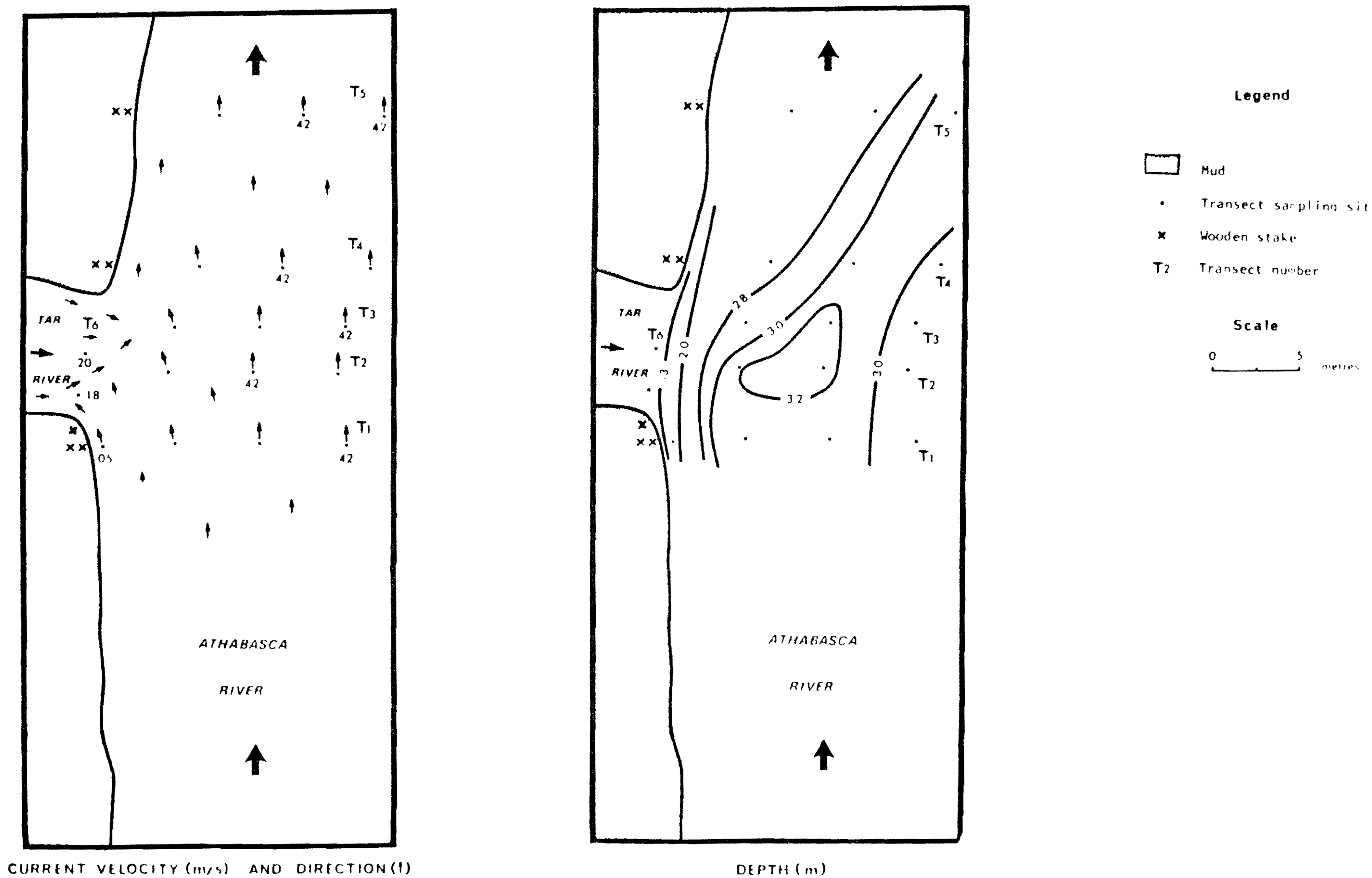
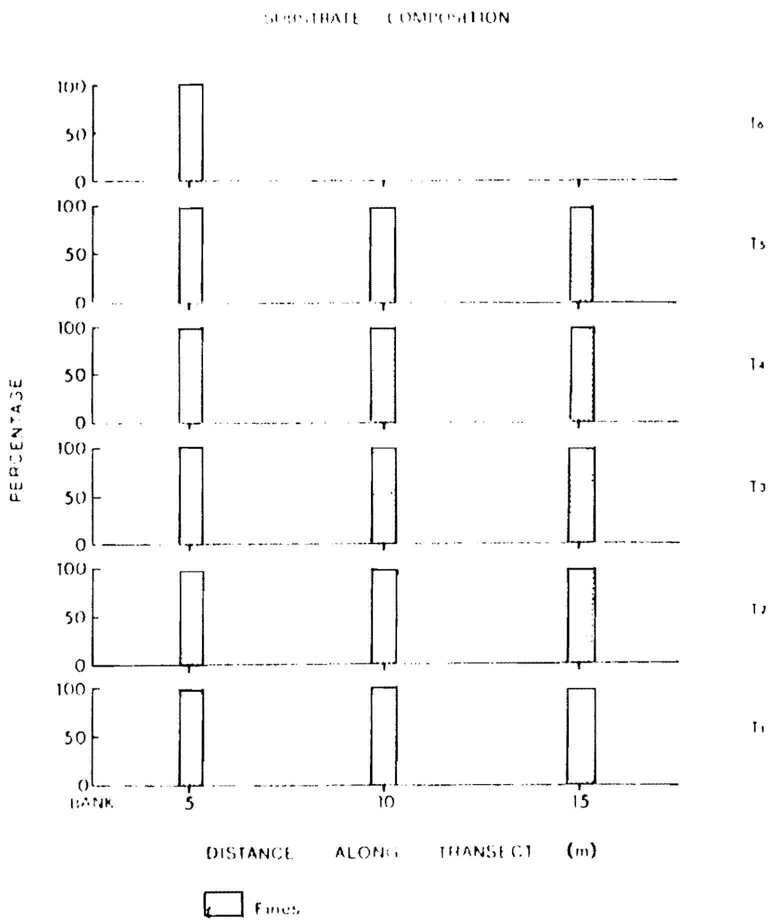


Figure 12. Confluence of the Athabasca and Tar rivers (continued).



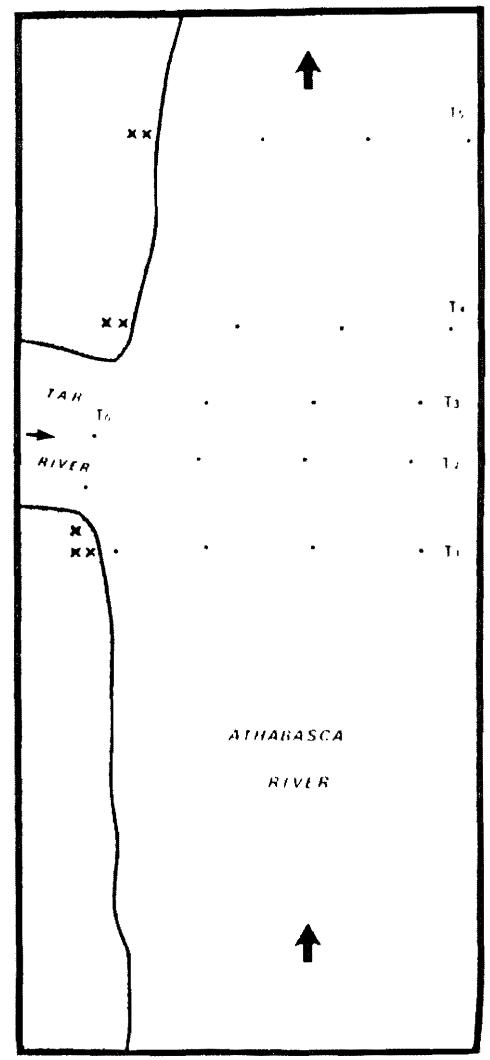


Figure 12. Concluded.

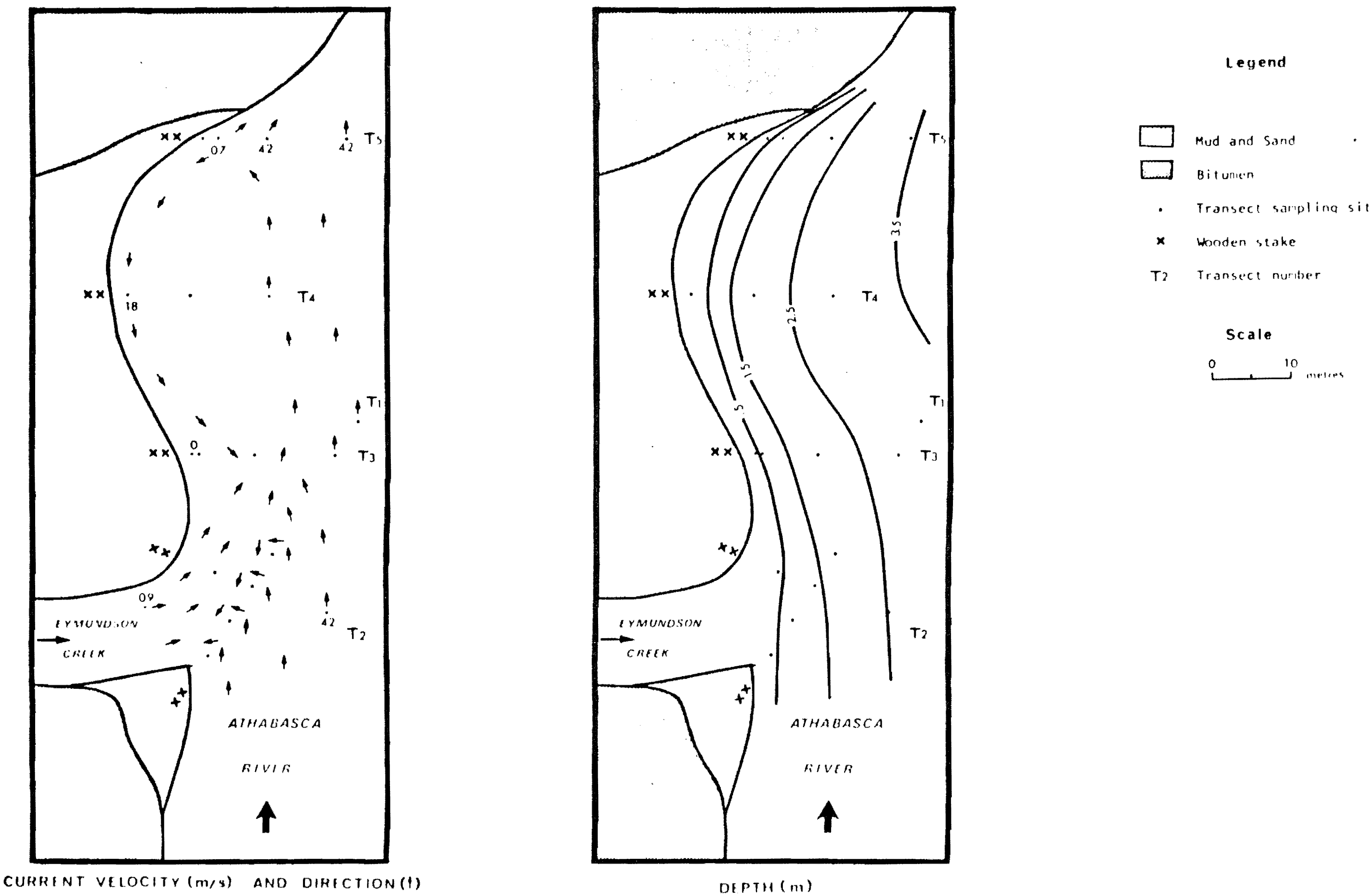
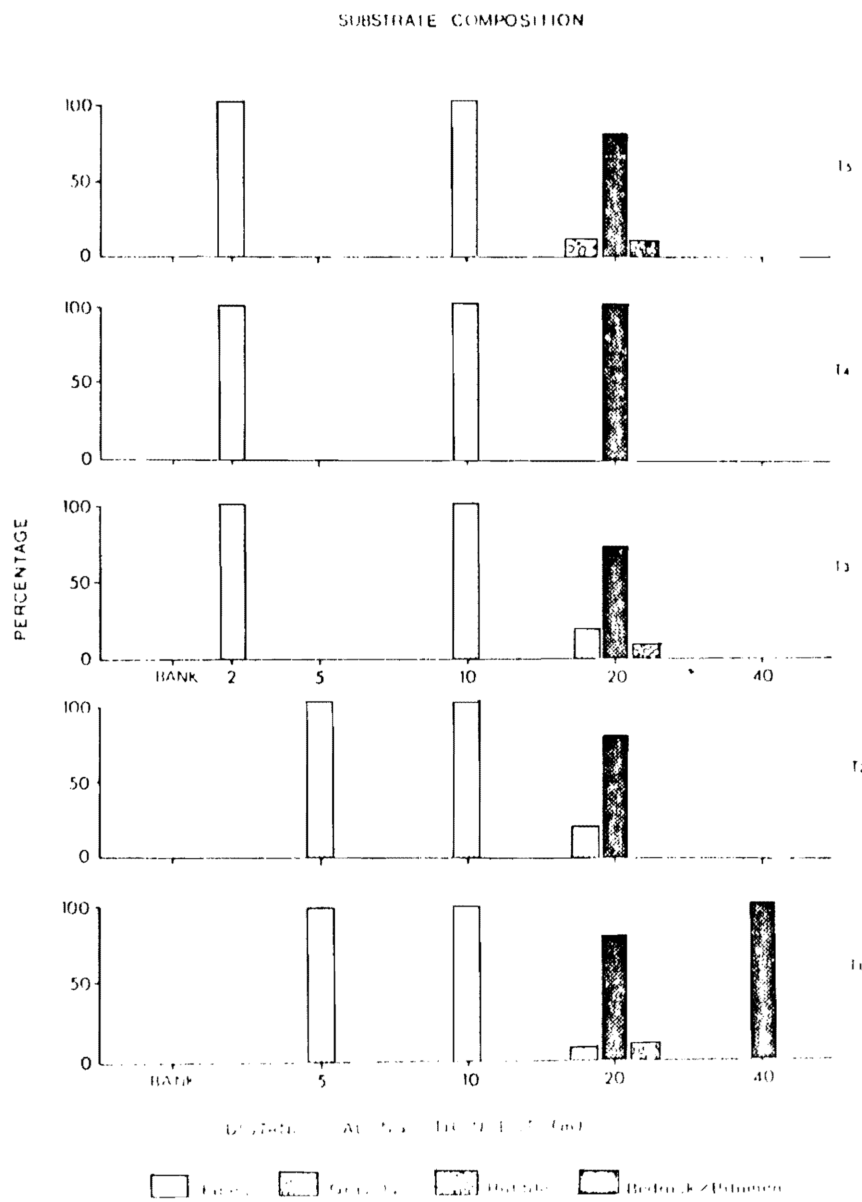


Figure 13. Confluence of the Athabasca River and Eymundson Creek (continued).



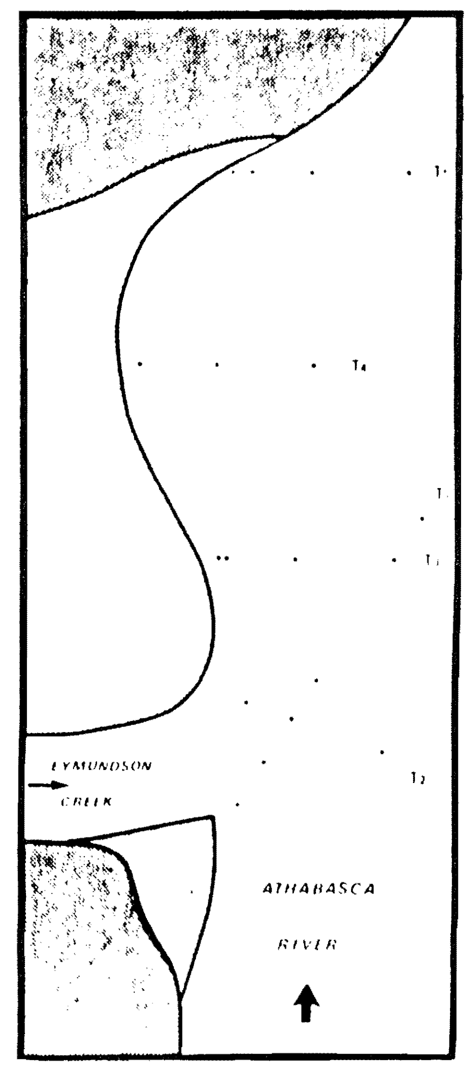


Figure 13. Concluded.

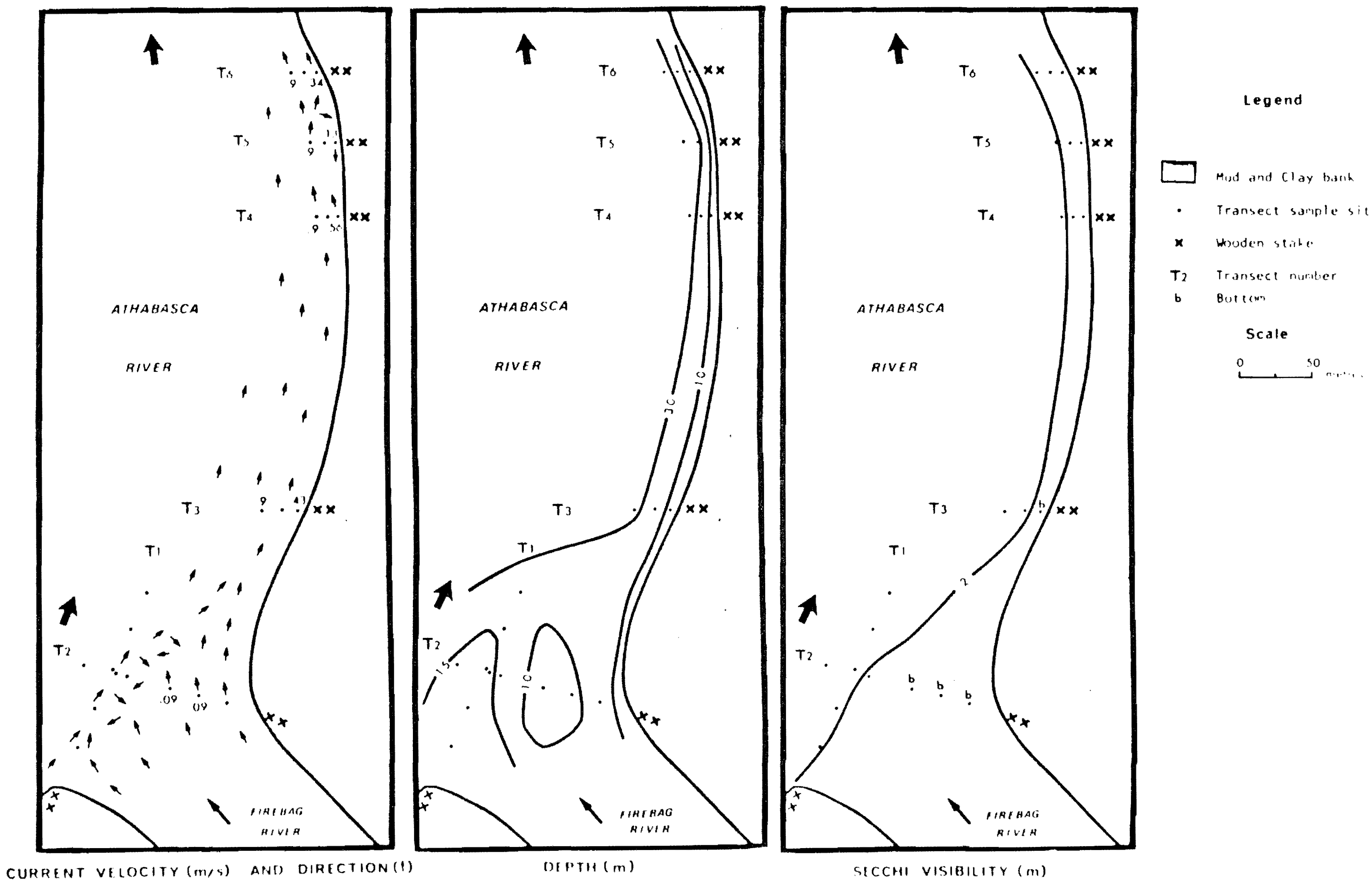


Figure 14. Confluence of the Athabasca and Firebag rivers (continued).

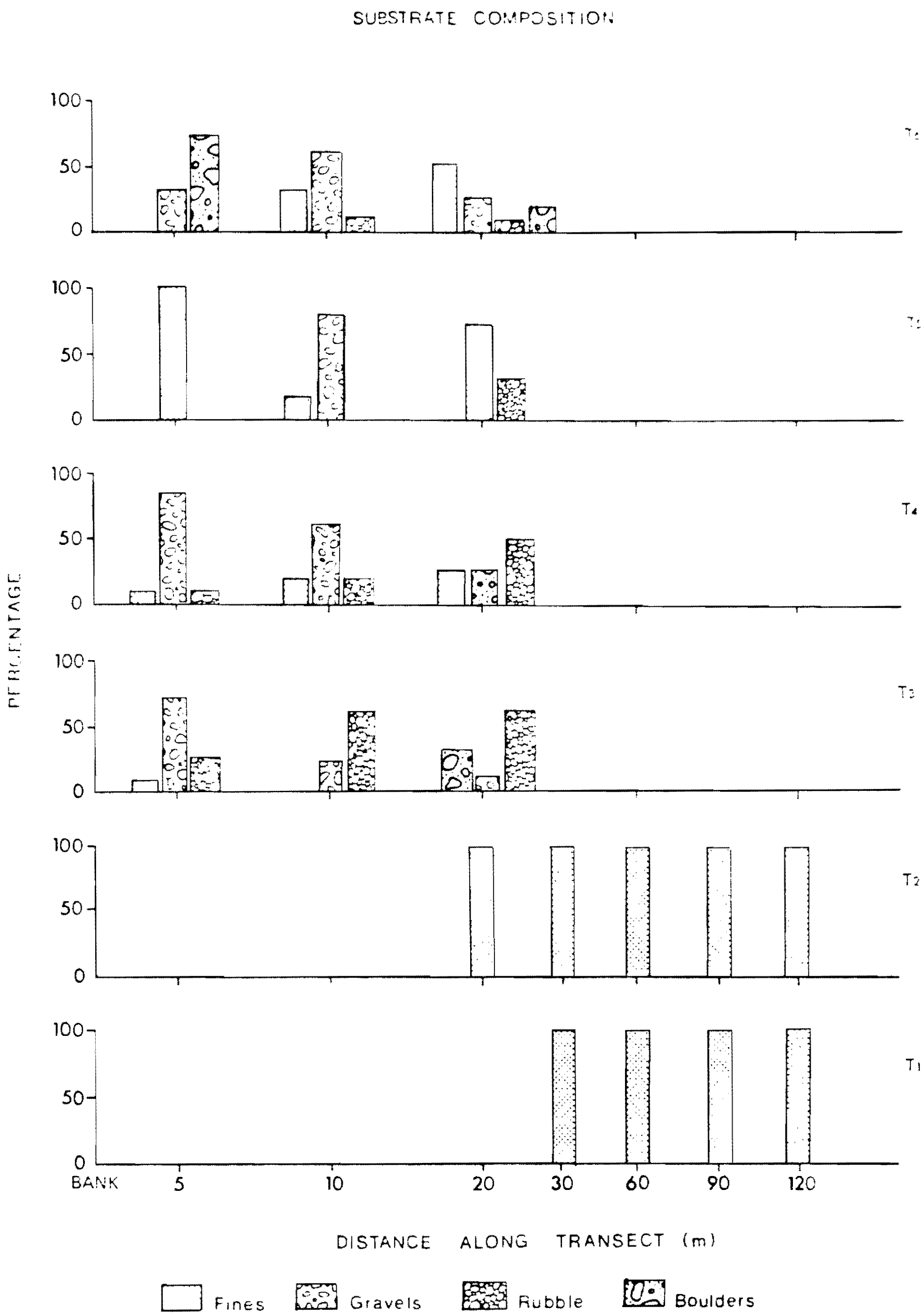
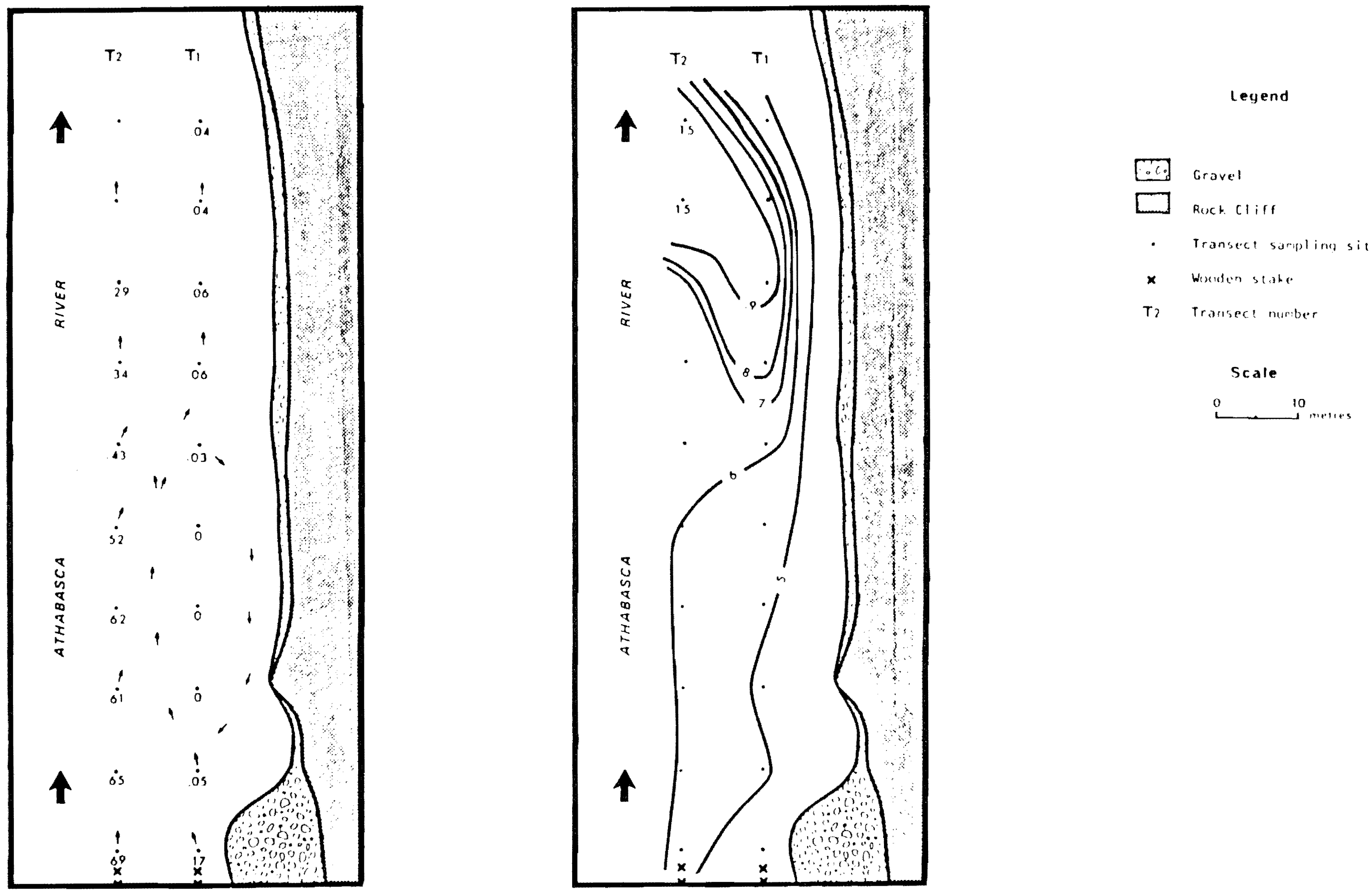


Figure 14. Concluded.



CURRENT VELOCITY (m/s) AND DIRECTION (↑)

DEPTH (m)

Figure 15. Athabasca River at km 11.3 (continued).

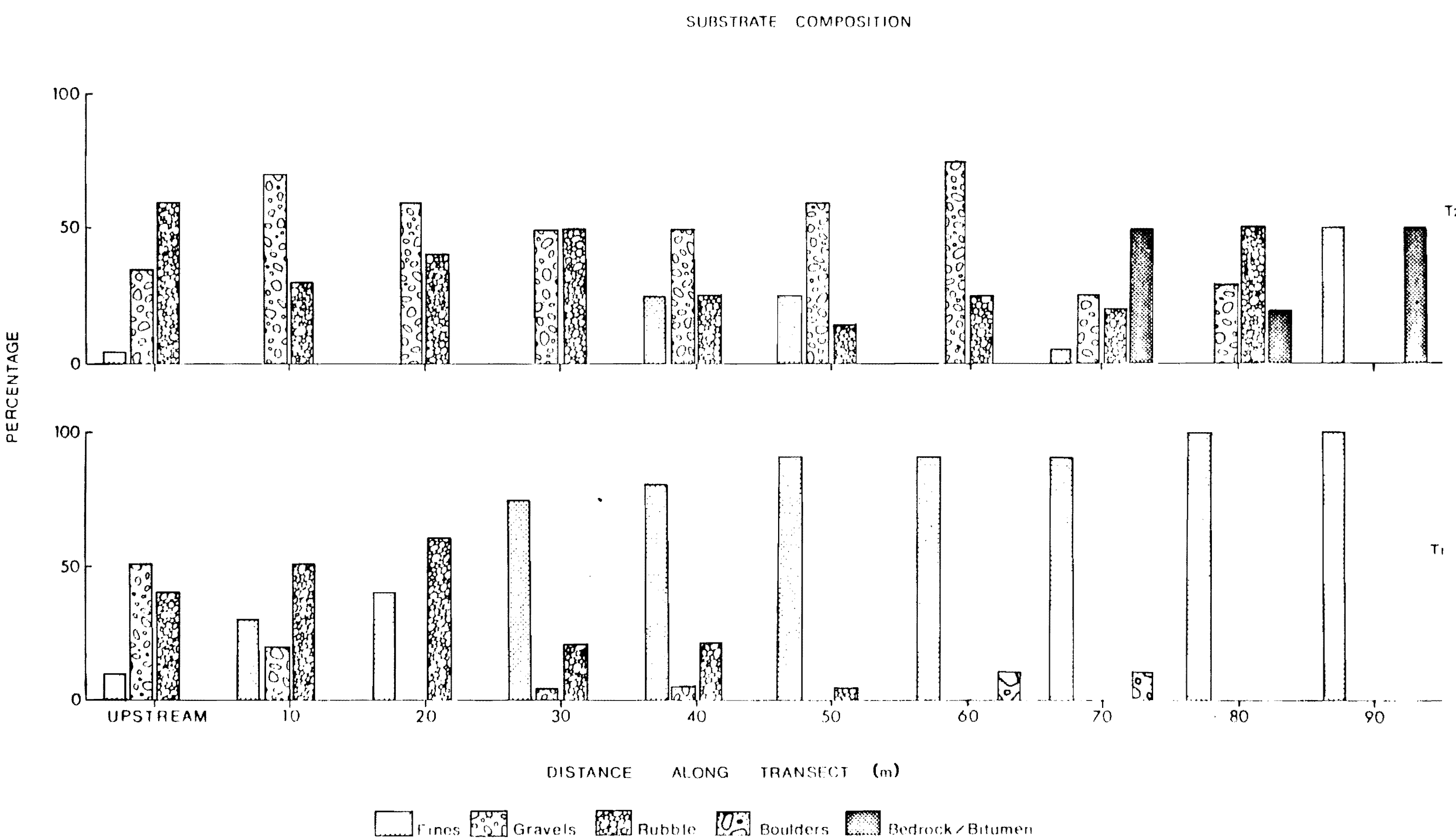


Figure 15. Concluded.

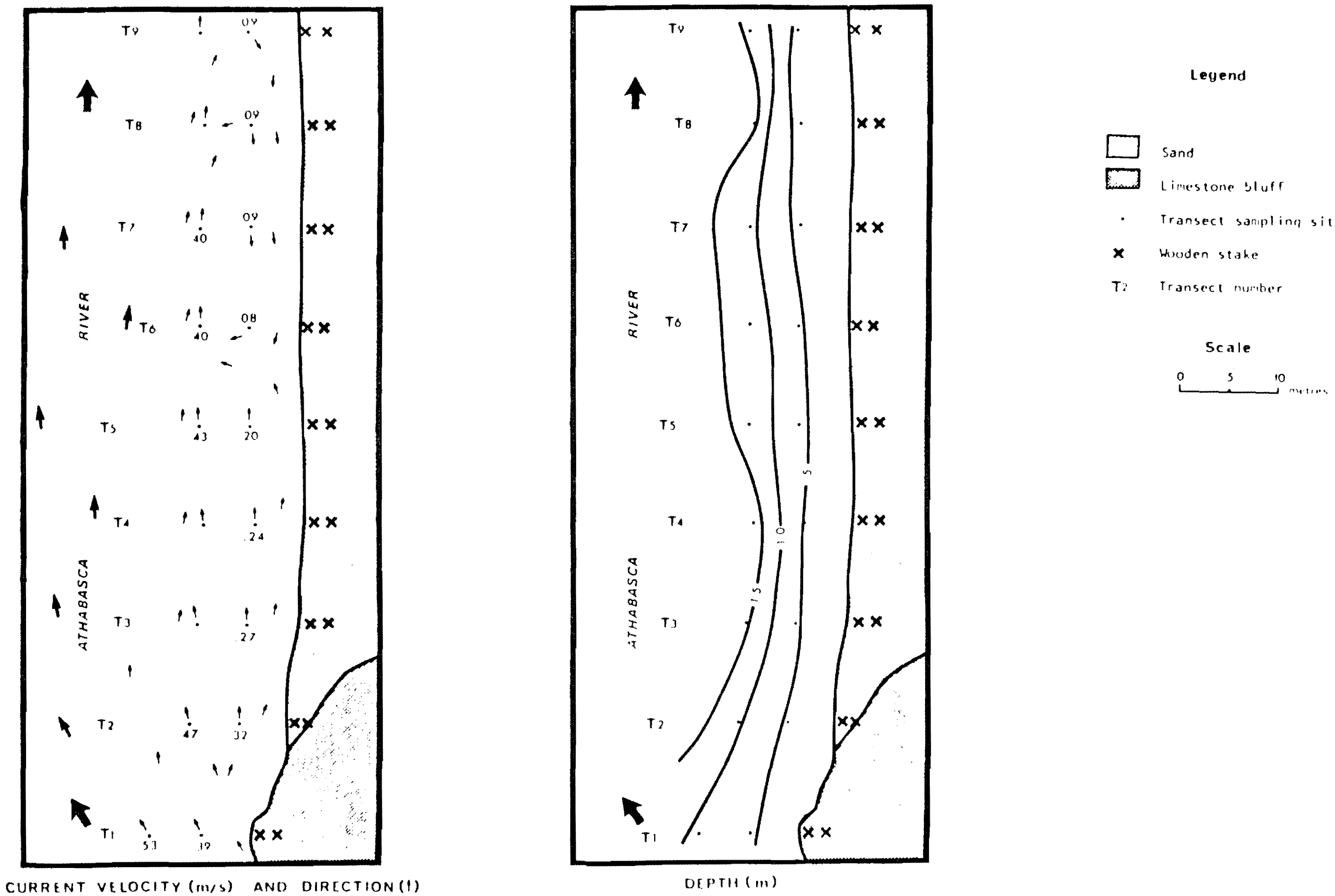


Figure 16. Athabasca River at km 37.2 (continued).

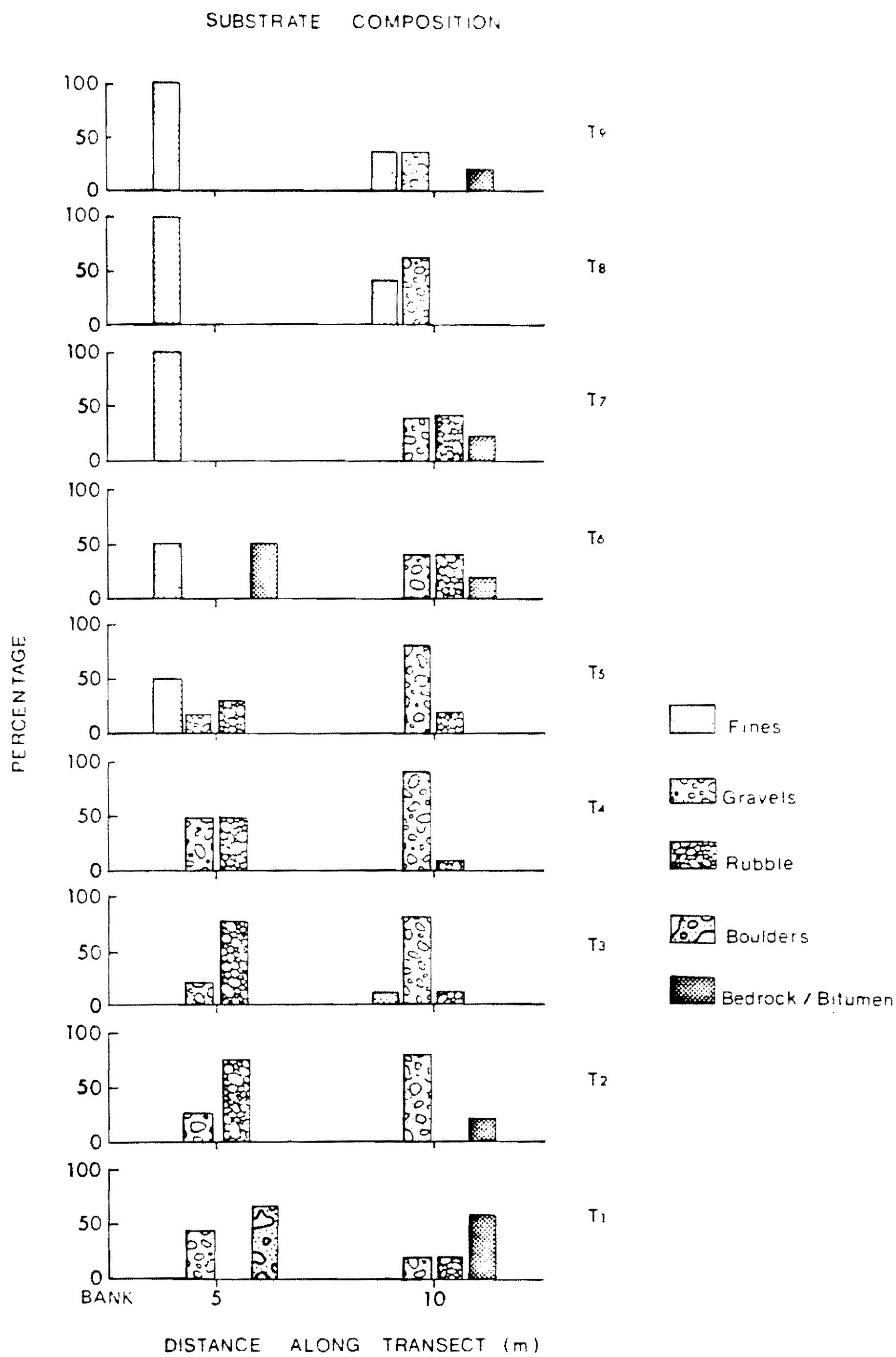


Figure 16. Concluded.

bar (Figure 17). This vortex was approximately 25 m long and 4 m wide. Depths in the area were shallow and regular. The river substrate was similar throughout and consisted of a mixture of gravels and muds. Physical parameters along each transect are listed in Appendix 8.1 (Table 15).

5.2.4 Athabasca River at km 42.3

A large eddy and area of becalmed waters was formed at km 42.3 as a consequence of the deflection of the Athabasca River off a limestone bluff (Figure 18). The vortex was located 30 m downstream of the deflection. Calm areas of negligible water velocity persisted for 150 to 200 m alongside the river bank. Water depths were uniformly shallow. The bottom substrate was primarily muds along the river bank and gravels over limestone bedrock in deeper (1 m) areas. Physical parameters along each transect are listed in Appendix 8.1 (Table 16).

5.2.5 Athabasca River at km 59.9

The formation of a small eddy at km 59.9 of the Athabasca River was the most apparent physical change caused by a limestone cliff jutting into the Athabasca River (Figure 19). The eddy was relatively small and composed mostly of becalmed waters. The bottom substrate adjacent to the limestone cliff was entirely limestone or gravels and rubble of limestone origin. Immediately downstream, substrates consisted of muds in the shallows, and gravel and rubble in deeper waters. Water depths gradually increased with distance from the river bank in a regular fashion, except for deep areas opposite the limestone cliff. Physical parameters along each transect are listed in Appendix 8.1 (Table 17).

5.2.6 Athabasca River at km 71.0

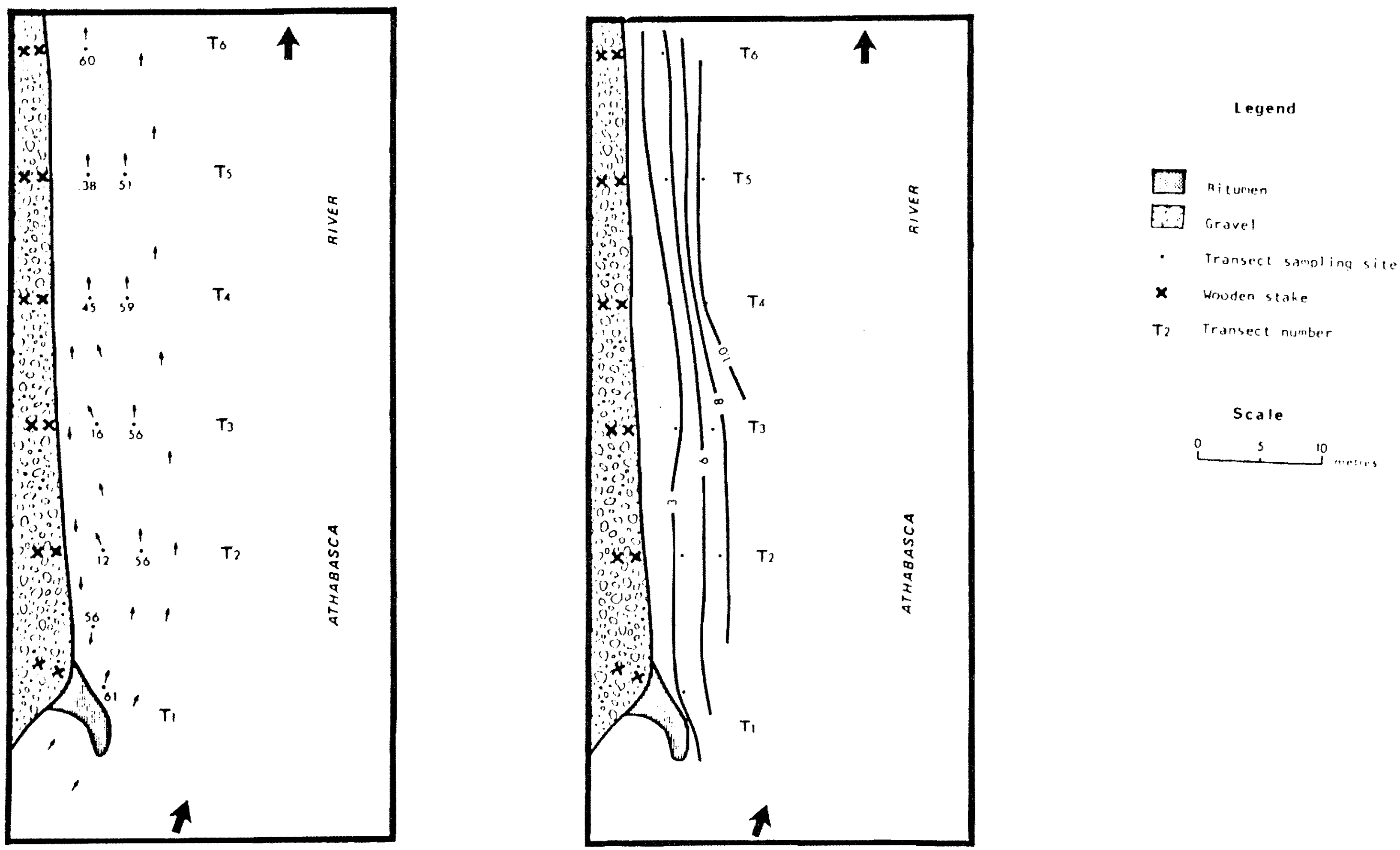
A series of vortices, becalmed waters, and countercurrents were located immediately downstream of an unused docking site at km 71.0 (Figure 20). This sheltered area was approximately 80 m long and 12 m wide. Water depths in the area were regular and increased quickly away from the river bank. Bottom substrates were primarily a thin layer of sands or silts overlying bitumen. Physical parameters along each transect are listed in Appendix 8.1 (Table 18).

5.2.7 Athabasca River at km 75.3

At km 75.3, the only noticeable physical change was an area of sheltered, low velocity waters resulting from part of the Athabasca River being deflected off a mud bank. In this area, water velocities ranged from 0.08 to 0.49 m/s (Figure 21). There were no eddies or countercurrents present. Depths were generally shallow with no abrupt changes. The bottom substrate was soft mud-silt throughout. Physical parameters along each transect are listed in Appendix 8.1 (Table 19).

5.2.8 Athabasca River at km 82.2

Backwater eddies and becalmed waters at km 82.2 were the result of the Athabasca River being deflected slightly from a bank slump (Figure 22). The area of vortices extended downstream for 60 m and was 20 m wide. Water depths increased to 4.5 m within a short distance from the river bank. Bottom substrates were similar to river bank materials. Gravels and rubble were predominant at the upstream end, while sands and muds only were present downstream near the protruding sand bar. Physical parameters along each transect are listed in Appendix 8.1 (Table 20).



CURRENT VELOCITY (m/s) AND DIRECTION (↑)

DEPTH (m)

Figure 17. Athabasca River at km 40.1 (continued).

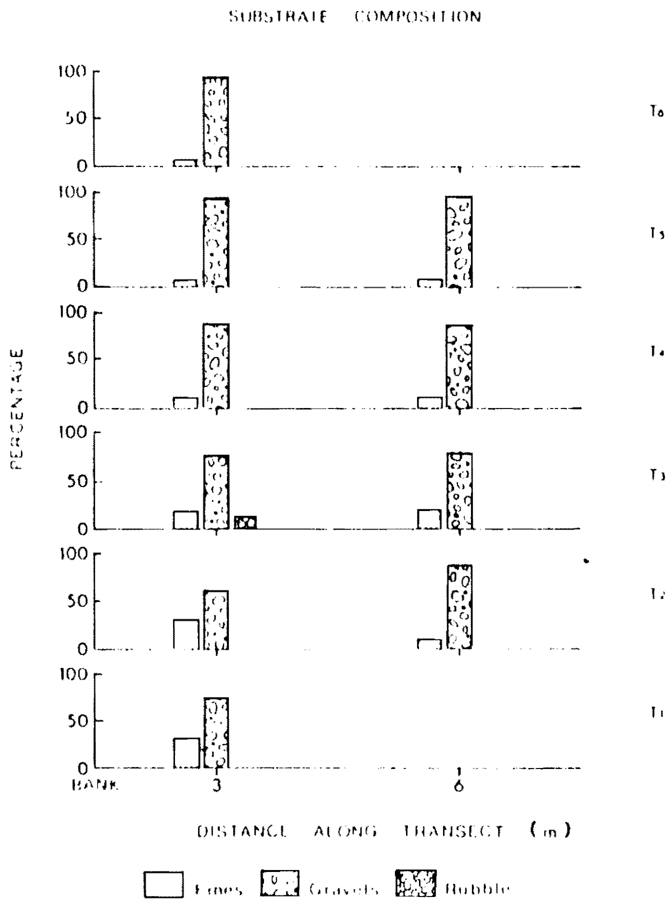
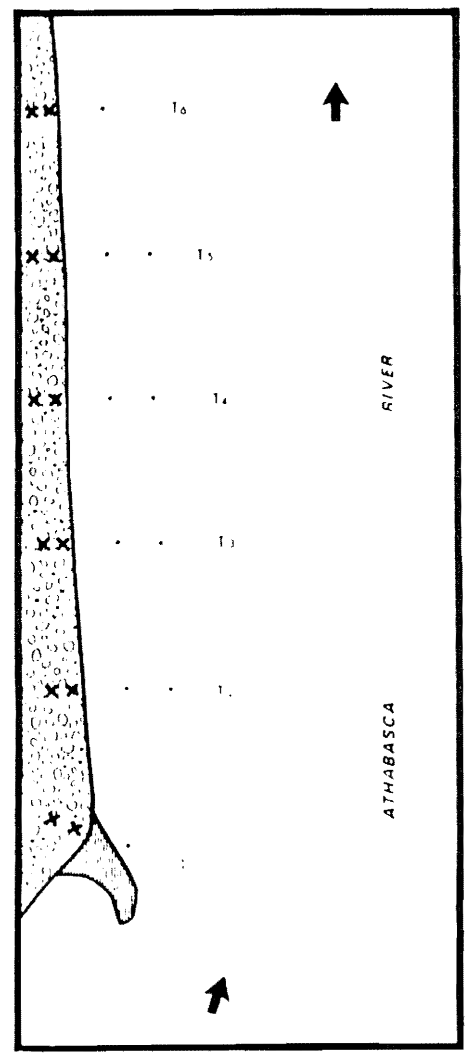


Figure 17. Concluded.



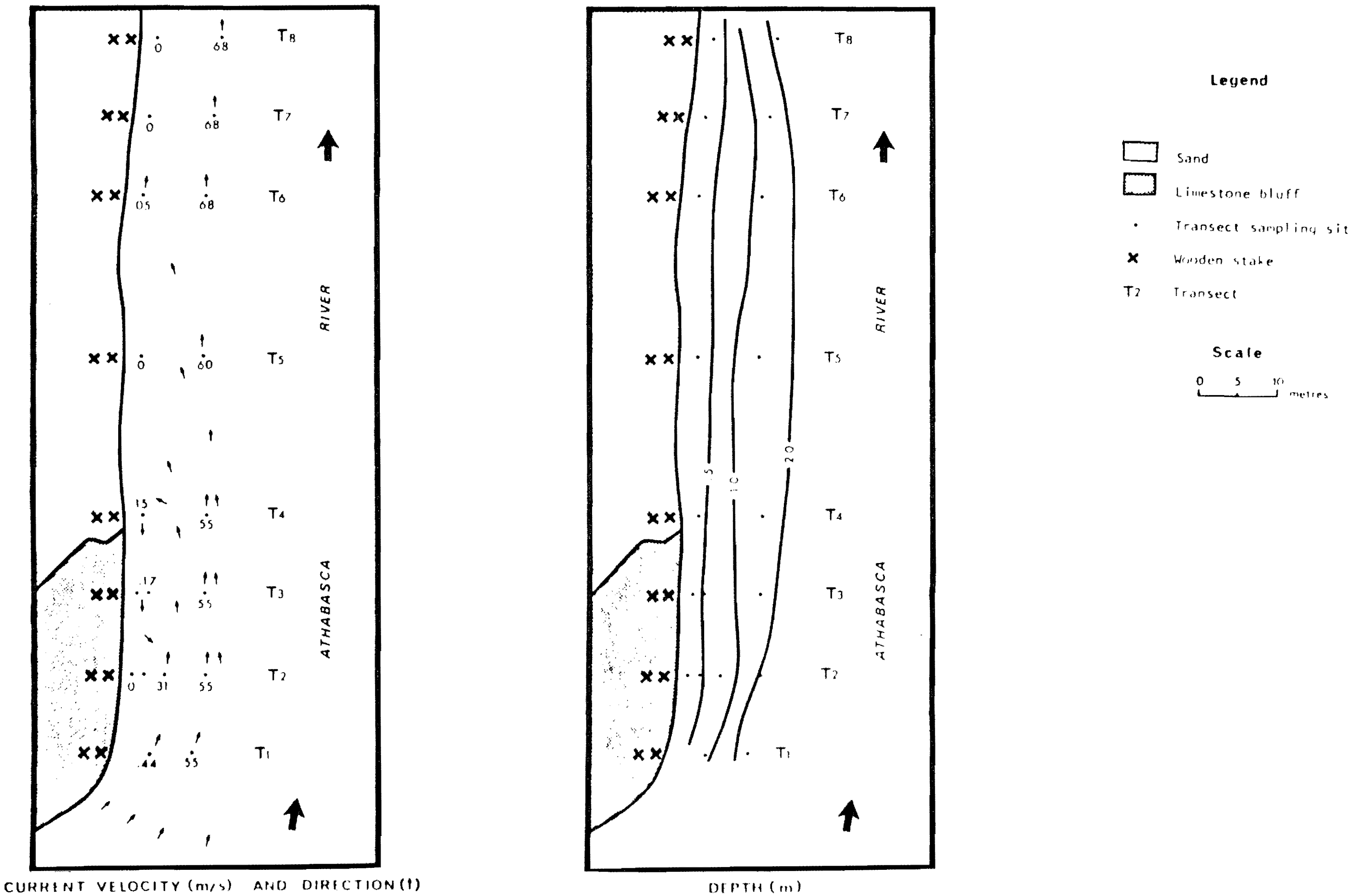
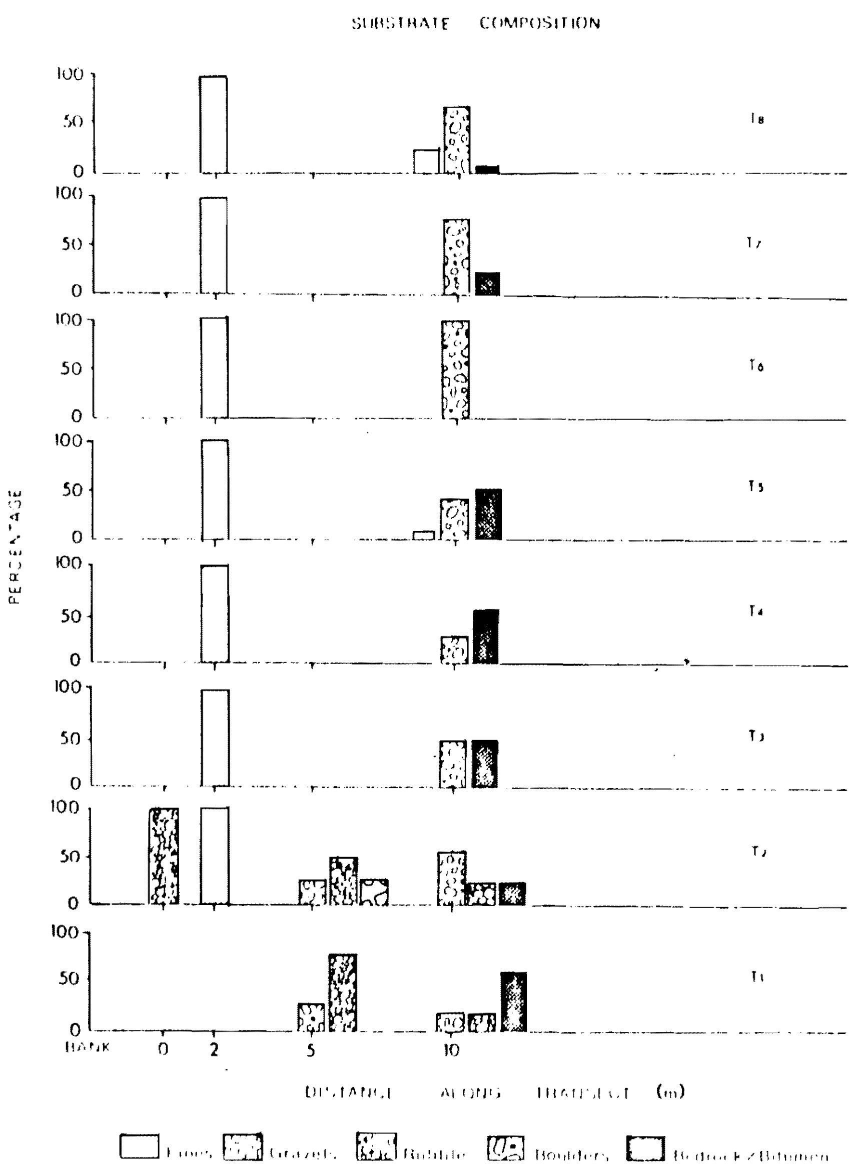


Figure 18. Athabasca River at km 42.3 (continued).



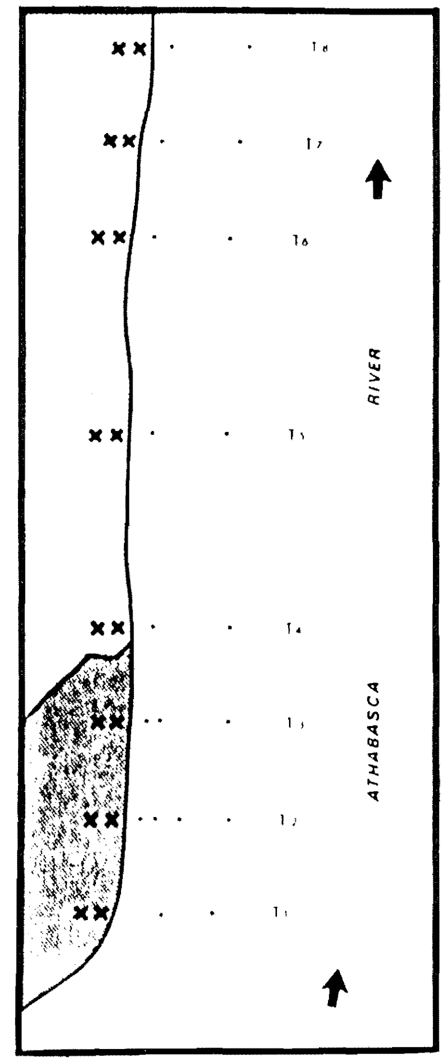
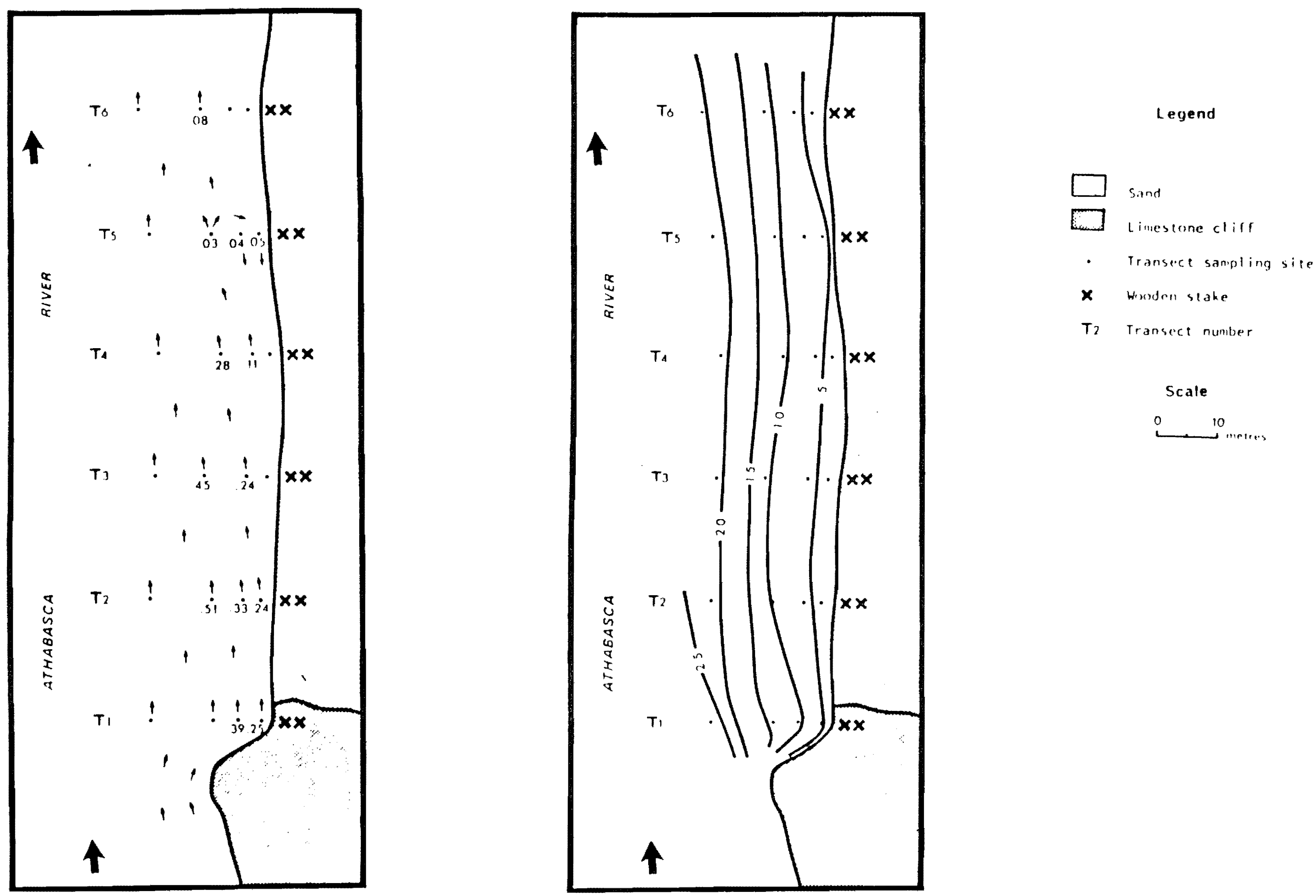


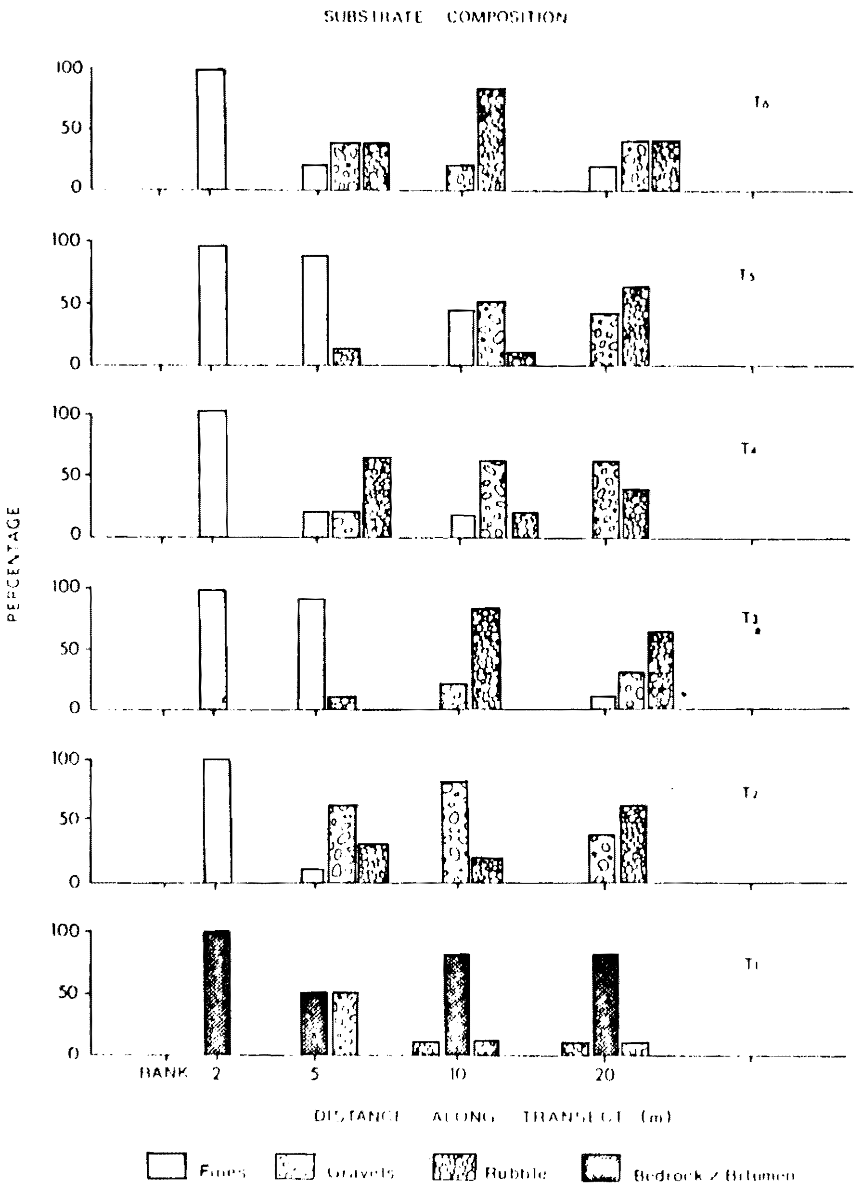
Figure 18. Concluded.



CURRENT VELOCITY (m/s) AND DIRECTION (↑)

DEPTH (m)

Figure 19. Athabasca River at km 59.9 (continued).



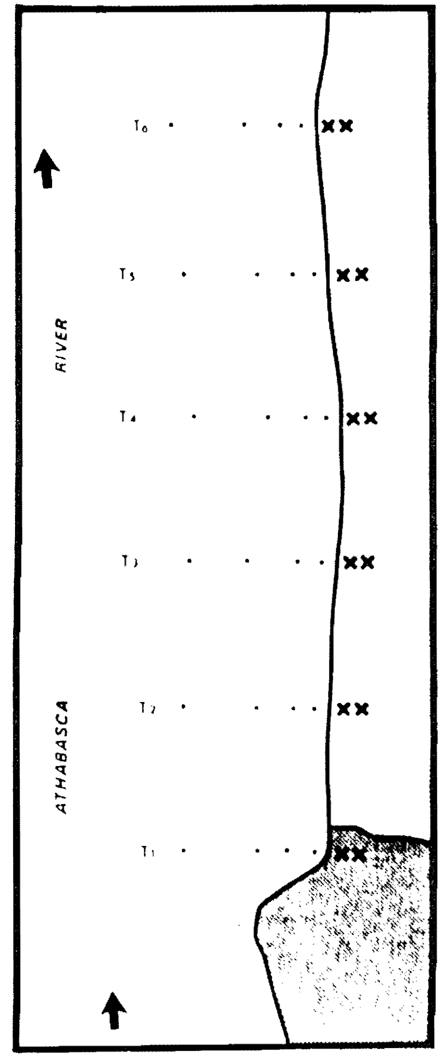


Figure 19. Concluded.

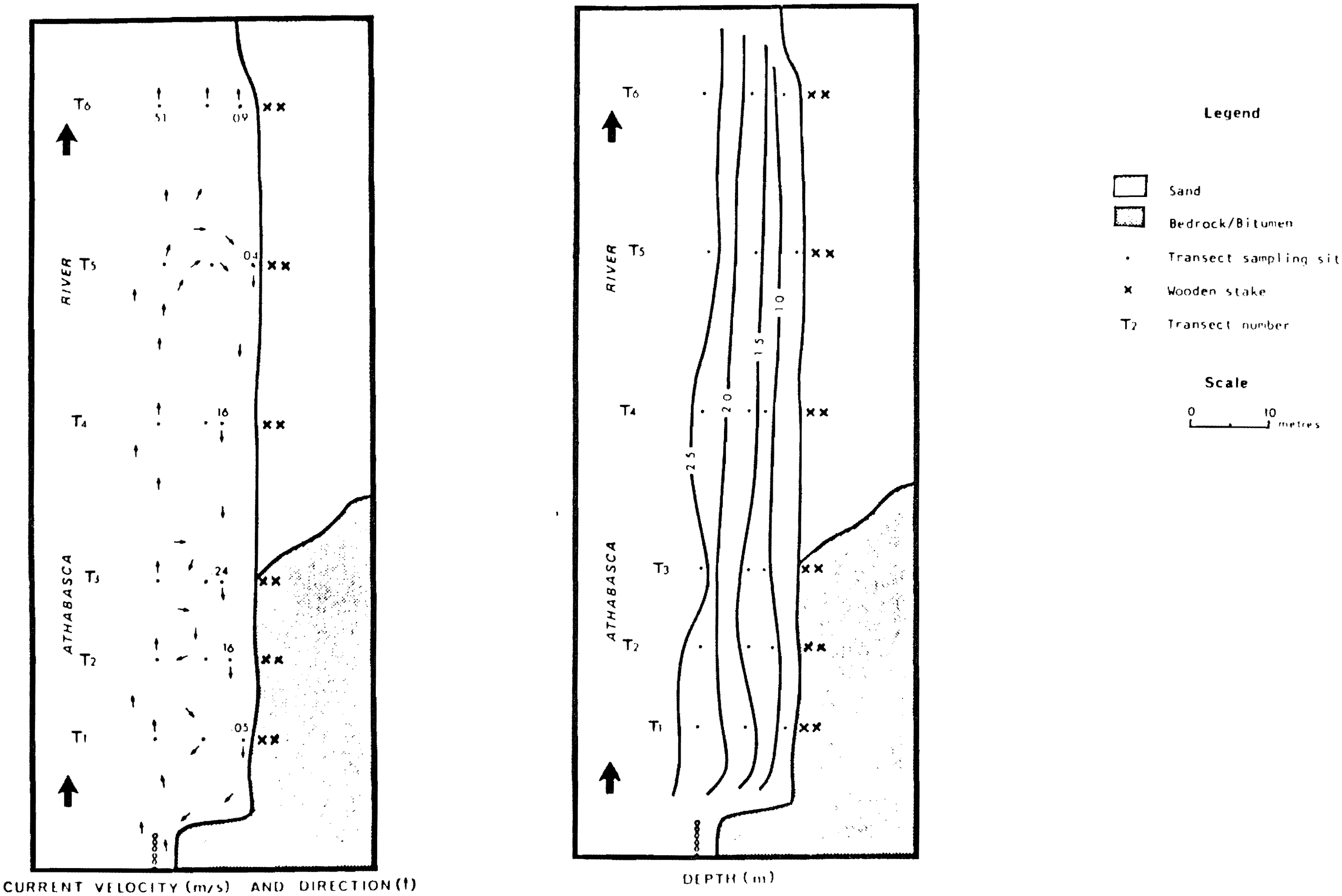
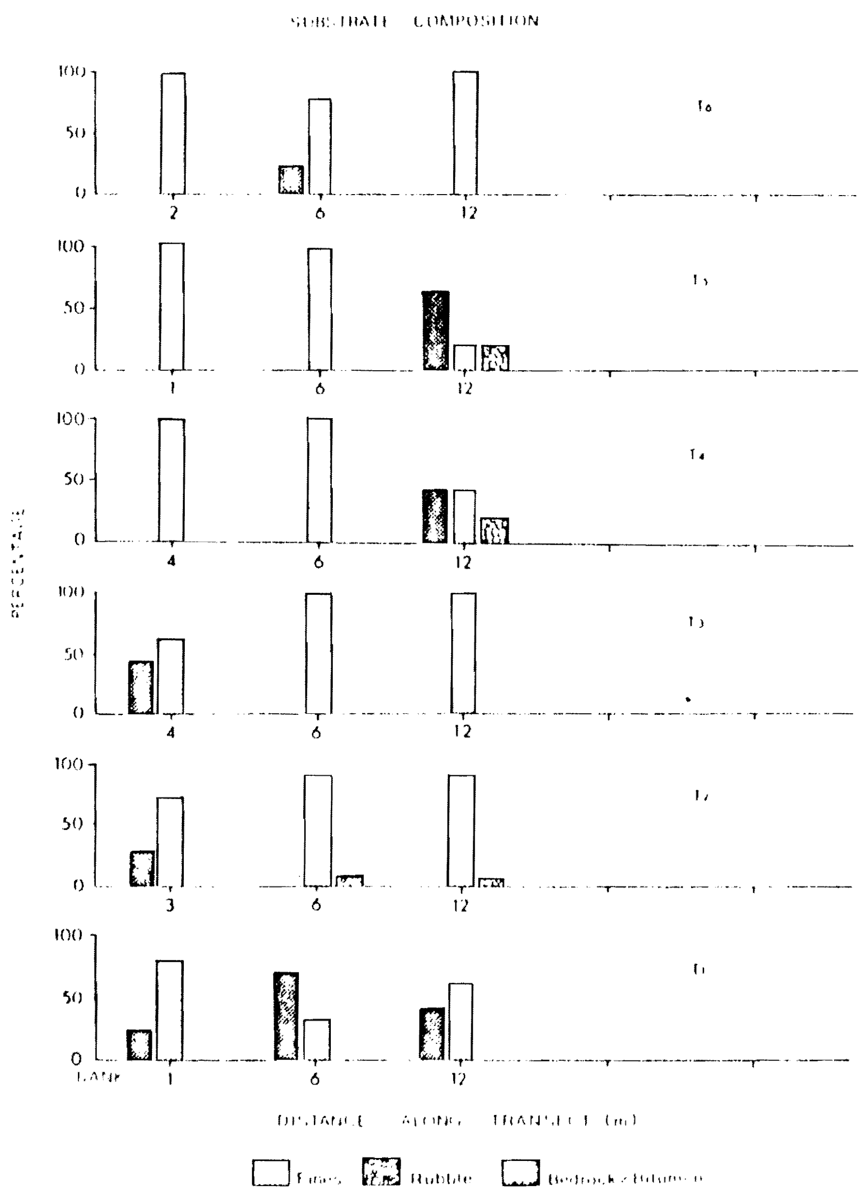


Figure 20. Athabasca River at km 71.0 (continued).



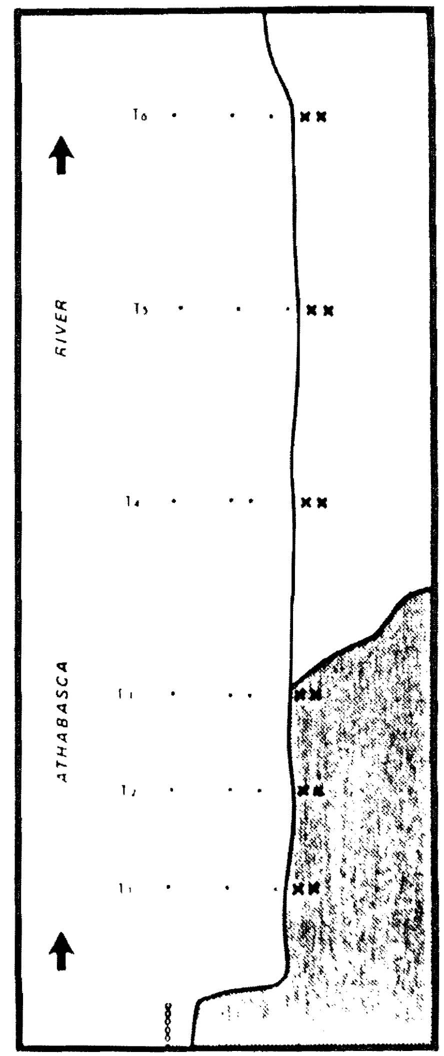
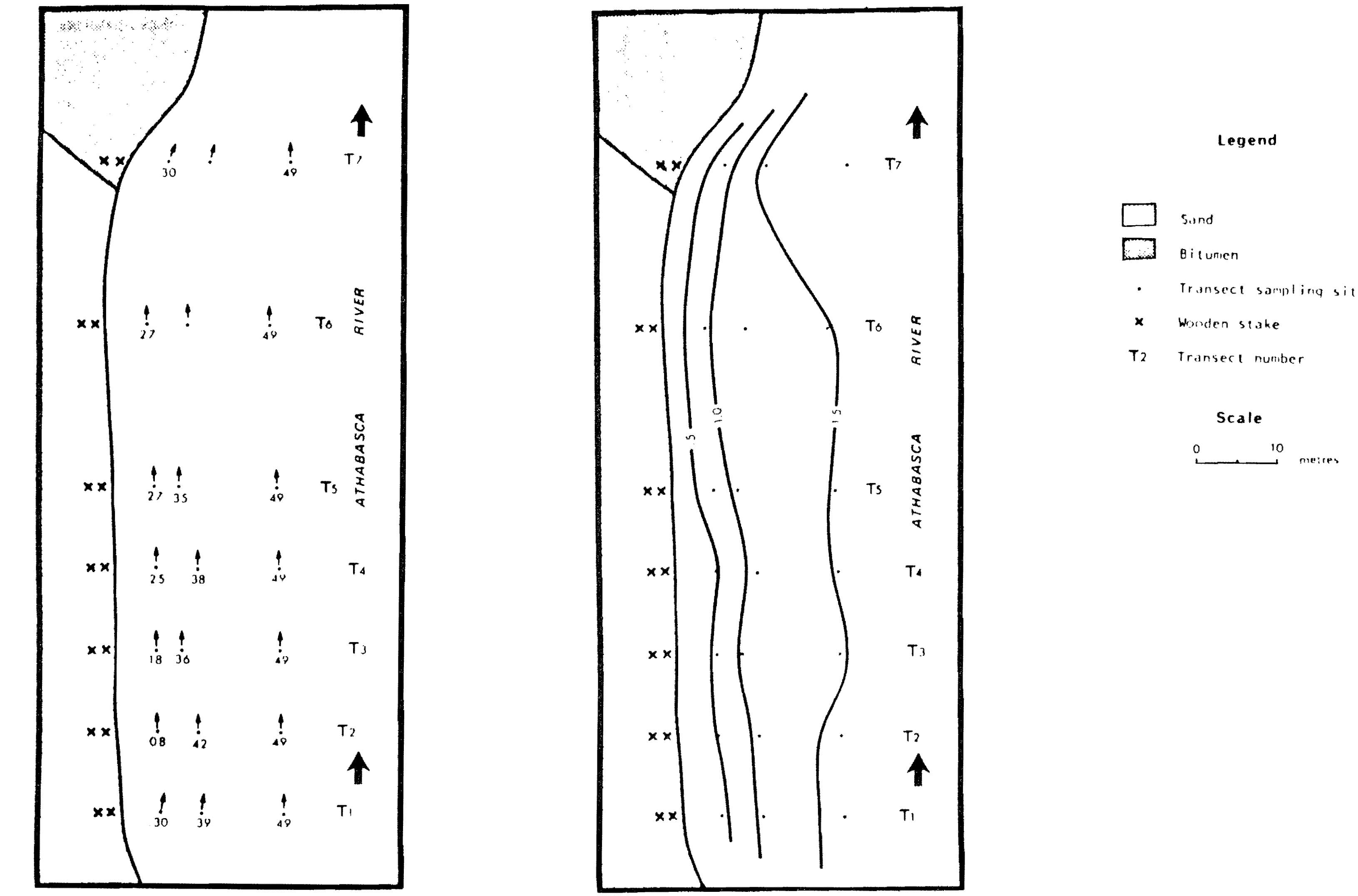


Figure 20. Concluded.



CURRENT VELOCITY (m/s) AND DIRECTION (↑)   DEPTH (m)

Figure 21. Athabasca River at km 75.3 (continued).

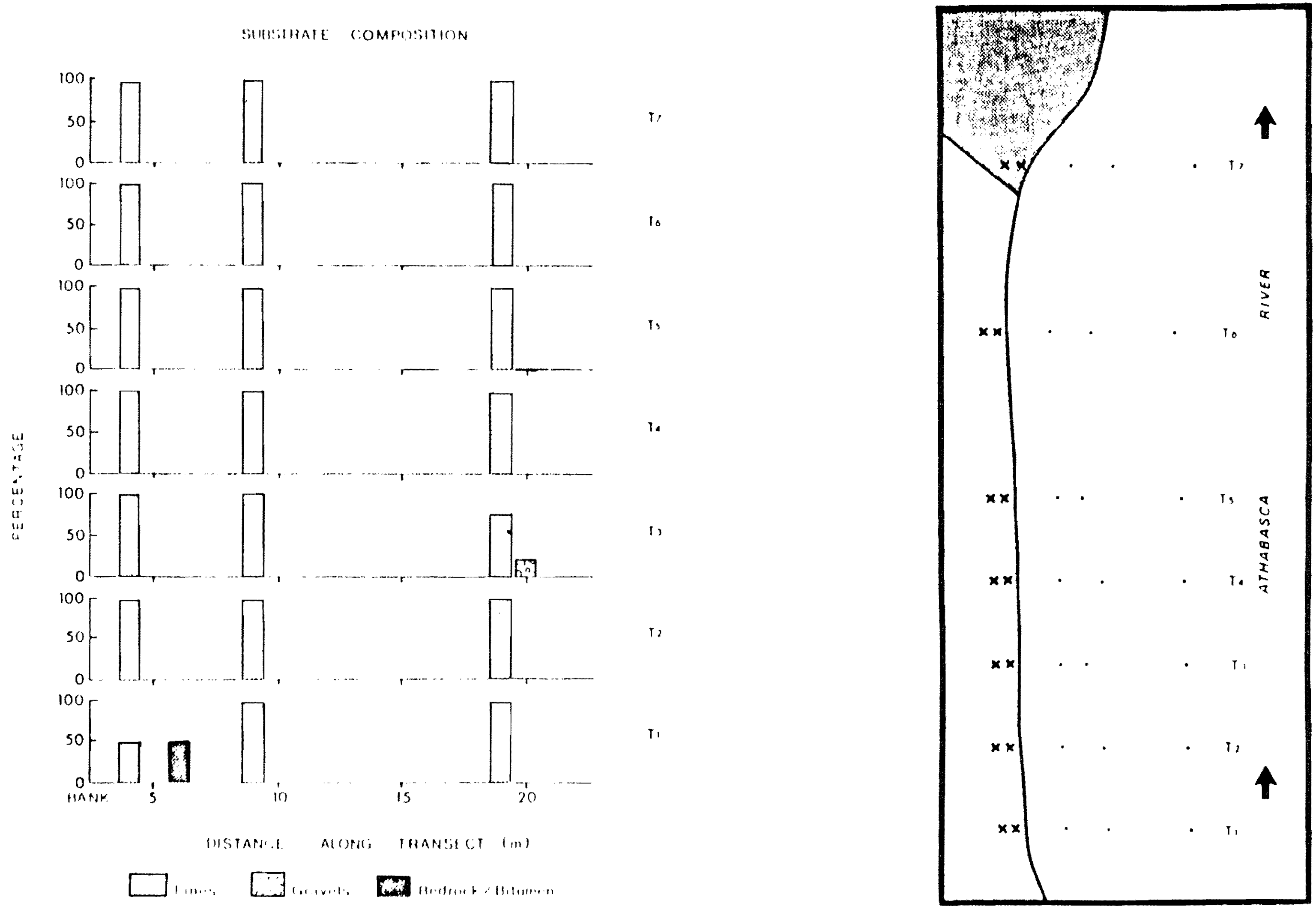


Figure 21. Concluded.

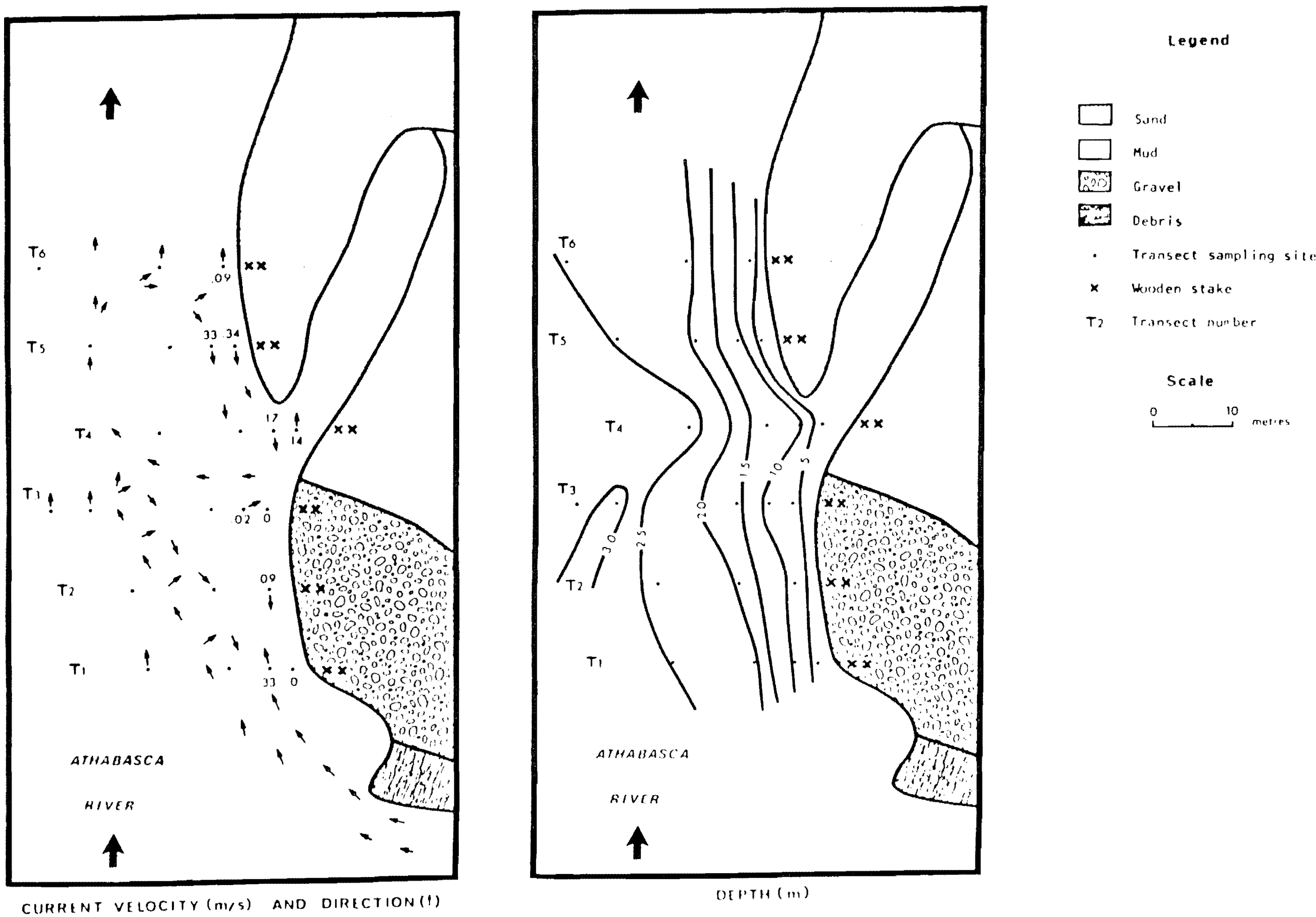


Figure 22. Athabasca River at km 82.2 (continued).

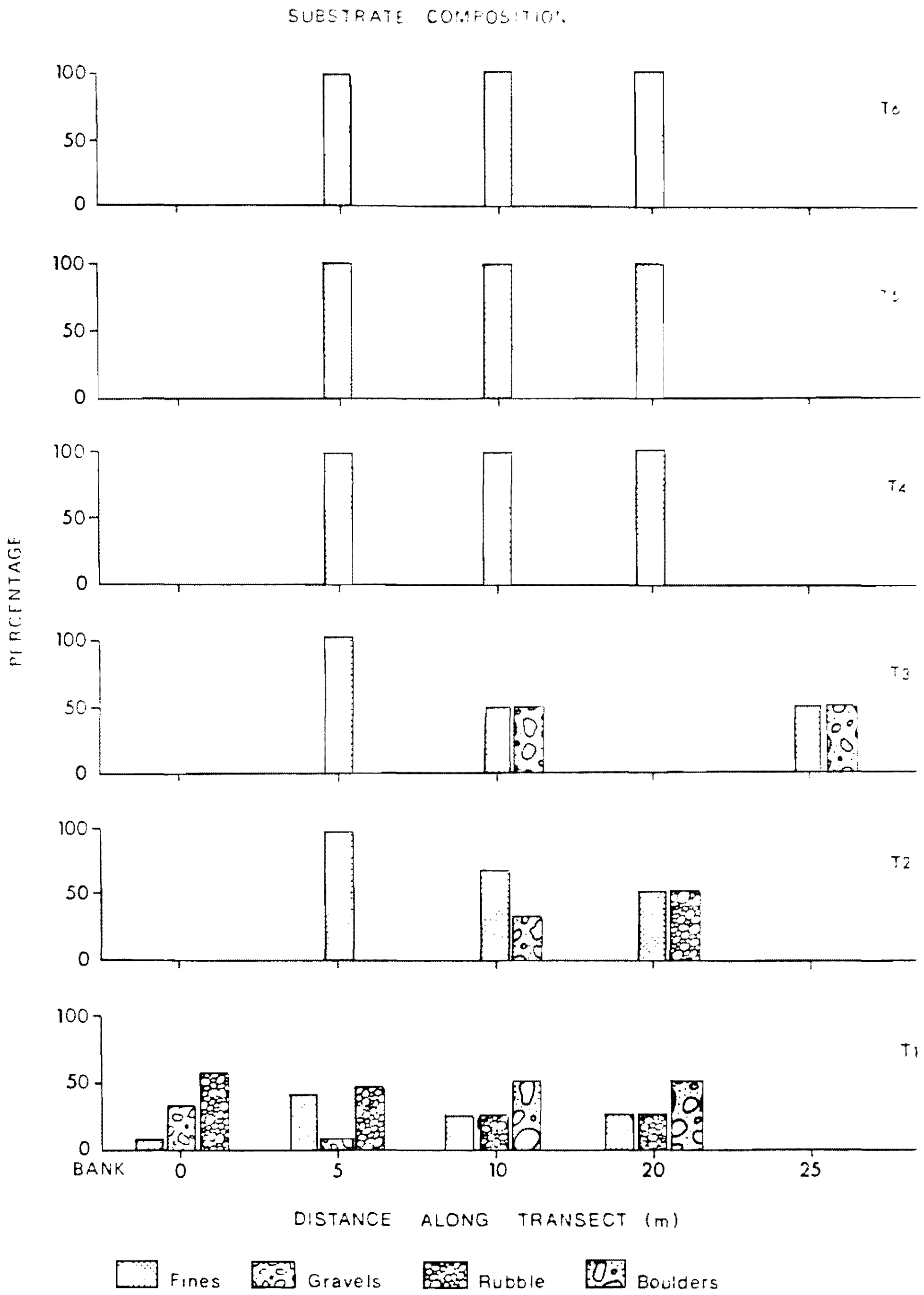


Figure 22. Concluded.

5.2.9 Athabasca River at km 96.4

An indentation between two bitumen cliffs at km 96.4 resulted in the formation of series of vortices in an area 40 m by 15 m (Figure 23). A small stream appeared to have little effect on the eddy. Water depths increased quickly away from the river bank. Substrate composition throughout the eddy was predominantly soft muds, similar to the river bank material. Bitumen was more widespread in deeper waters. Physical parameters along each transect are listed in Appendix 8.1 (Table 21).

5.2.10 Athabasca River at km 124.4

A grassy muskeg bank deflected part of the Athabasca River at km 124.4 creating an area of sheltered, low velocity, and still waters. Water velocities ranged from nil to 0.66 m/s (Figure 24). There were no eddies or countercurrents present. Water depths gradually increased away from shore with a uniform slope throughout. The bottom substrate in the area was similar to the river bank, being predominantly gravels with some sand. Physical parameters along each transect are listed in Appendix 8.1 (Table 22).

5.3 EDDIES DOWNSTREAM OF ISLANDS

5.3.1 Athabasca River at Unnamed Island (km 10.6)

An eddy with vortices and countercurrents was observed immediately downstream of an unnamed island at km 10.6 in the Athabasca River (Figure 25). This eddy was the result of the sweep of the Athabasca River current along both sides of the island. Water depths in the sheltered area were generally shallow (<2 m) with a steep drop-off at one location. The bottom substrates varied from sands and silts near the island to sands, gravels, and rubble in deeper areas. Physical parameters along each transect are listed in Appendix 8.1 (Table 23).

5.3.2 Athabasca River at Stony Island (km 22.9)

Downstream of Stony Island (km 22.9) in the Athabasca River, there was a large wedge-shaped eddy with complex currents and slack waters (Figure 26). The eddy was noticeable downstream for 100 m and had a maximum width of 40 m. A shallow compact sand bar extended for 5 m downstream of the island. Water depths then increased quickly. The bottom substrates progressed from sands and silts near the island to sands, gravels, and rubble in deeper areas. Physical parameters along each transect are listed in Appendix 8.1 (Table 24).

5.3.3 Athabasca River at Alexander Island (km 57.9)

Immediately downstream of Alexander Island, a large exposed sand bar was associated with a backwater eddy and slack waters (Figure 27). The vortex was approximately 15 m long and 10 m wide, beneath which was a deep hole. Water depths upstream of the exposed sand bar were shallow compared to areas adjacent to it. Substrates were uncompacted sands. Physical parameters along each transect are listed in Appendix 8.1 (Table 25).

CURRENT VELOCITY (m/s) AND DIRECTION (↑)

DEPTH (m)

Figure 23. Athabasca River at km 96.4 (continued).

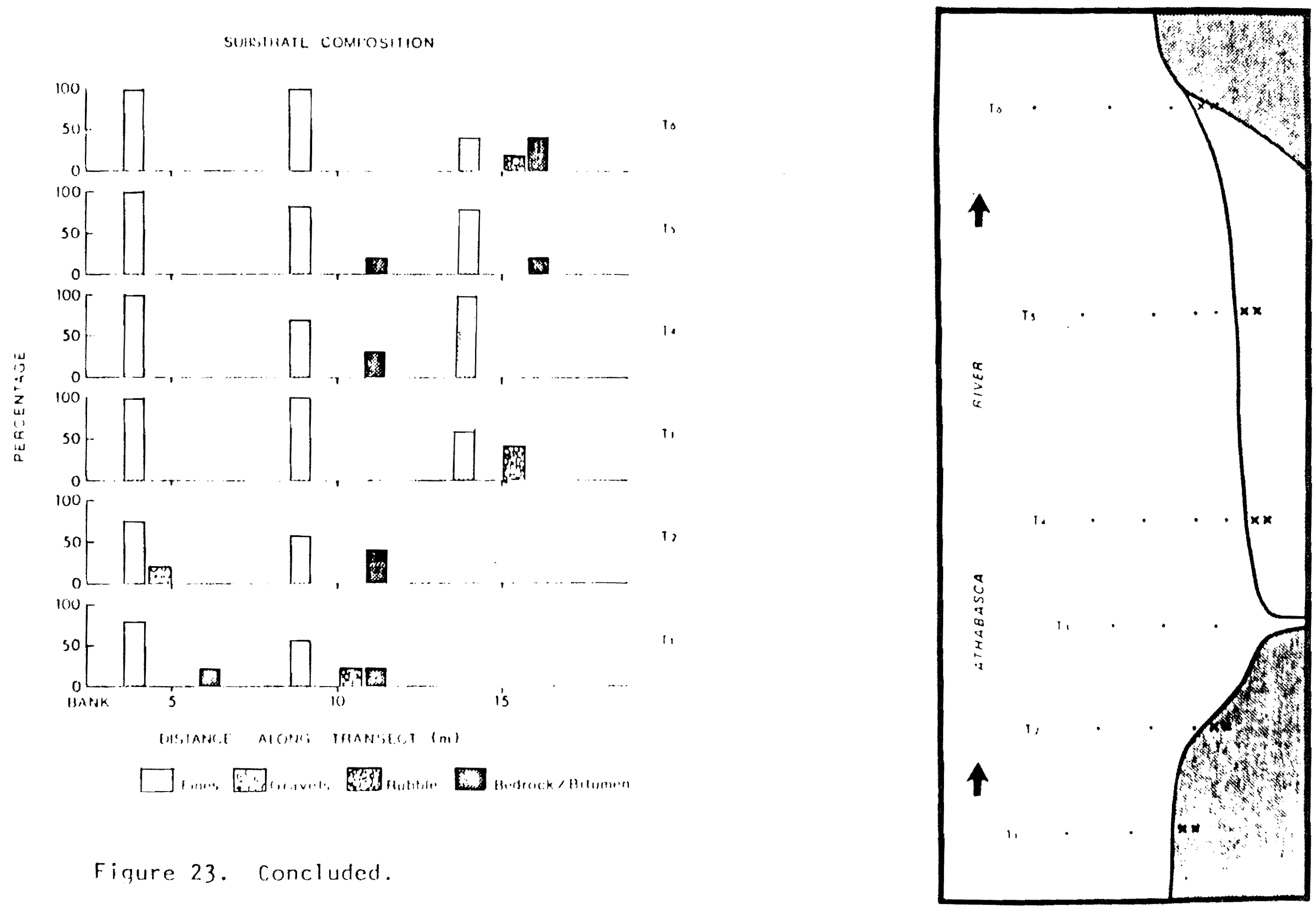


Figure 23. Concluded.

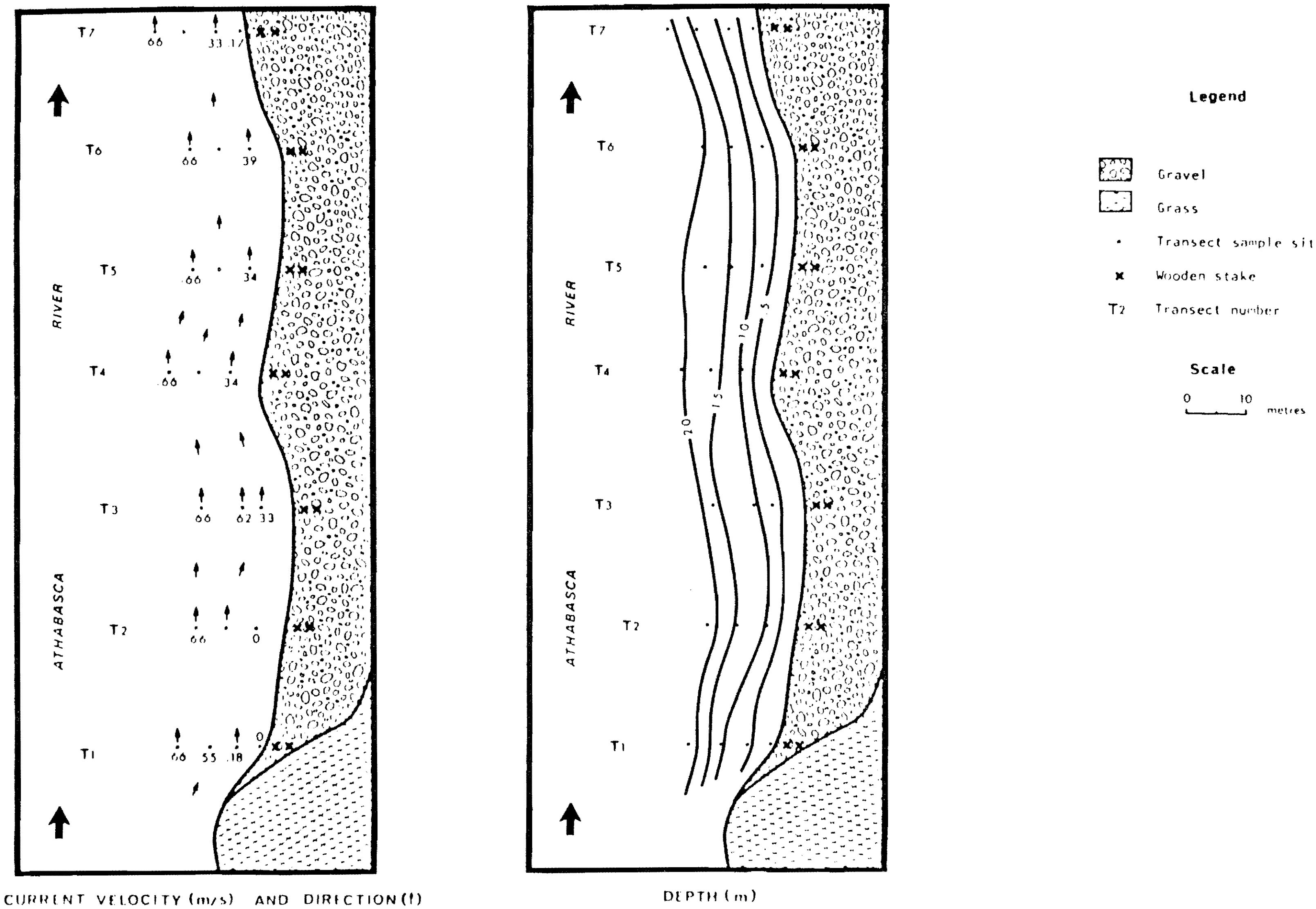
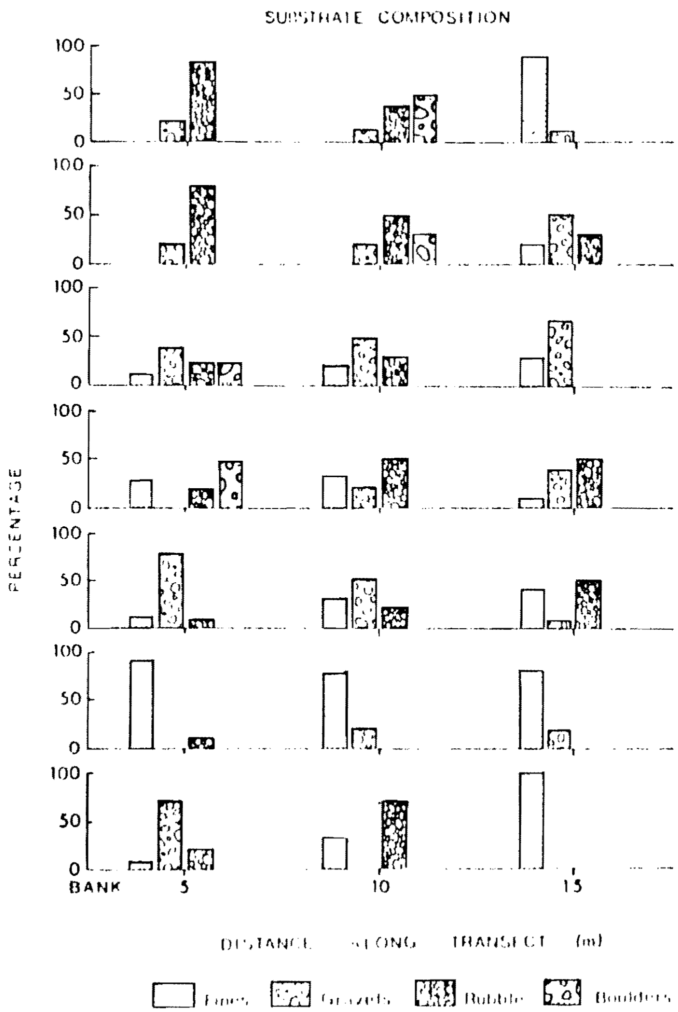


Figure 24. Athabasca River at km 124.4 (continued).



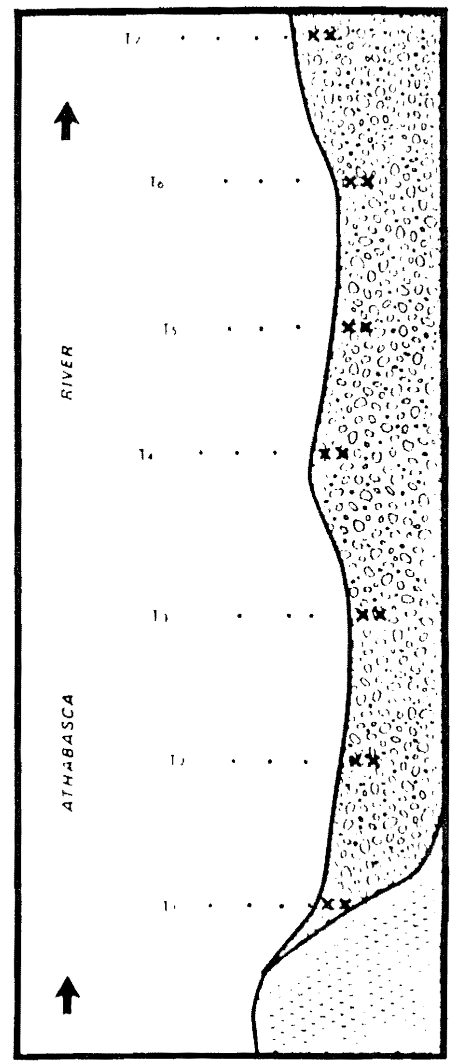


Figure 24. Concluded.

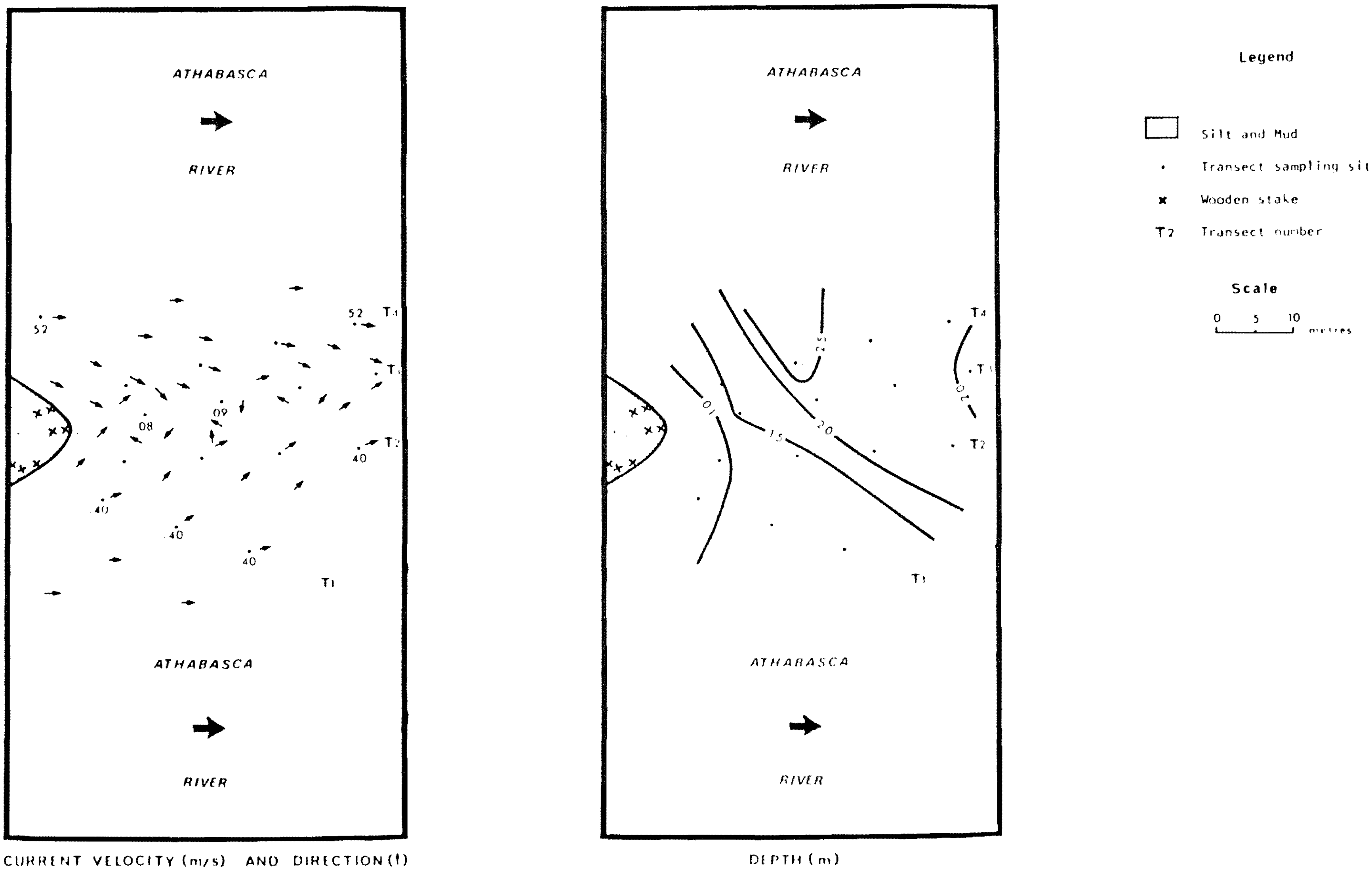
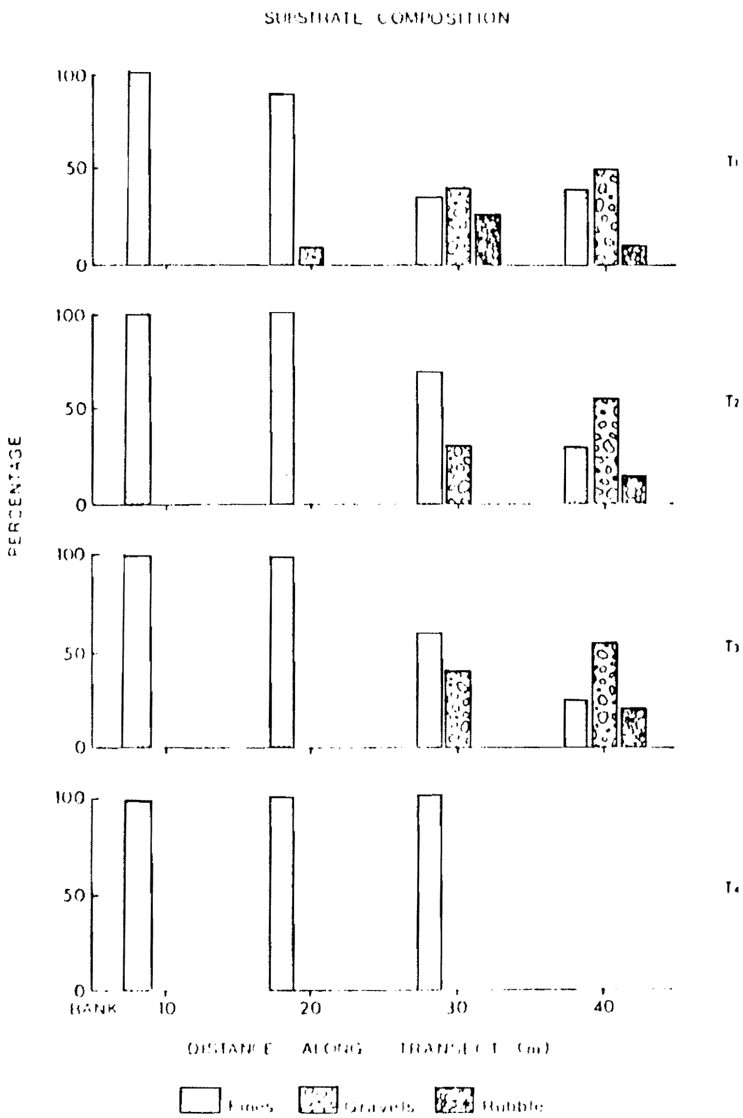


Figure 25. Athabasca River at unnamed island (km 10.6) (continued).



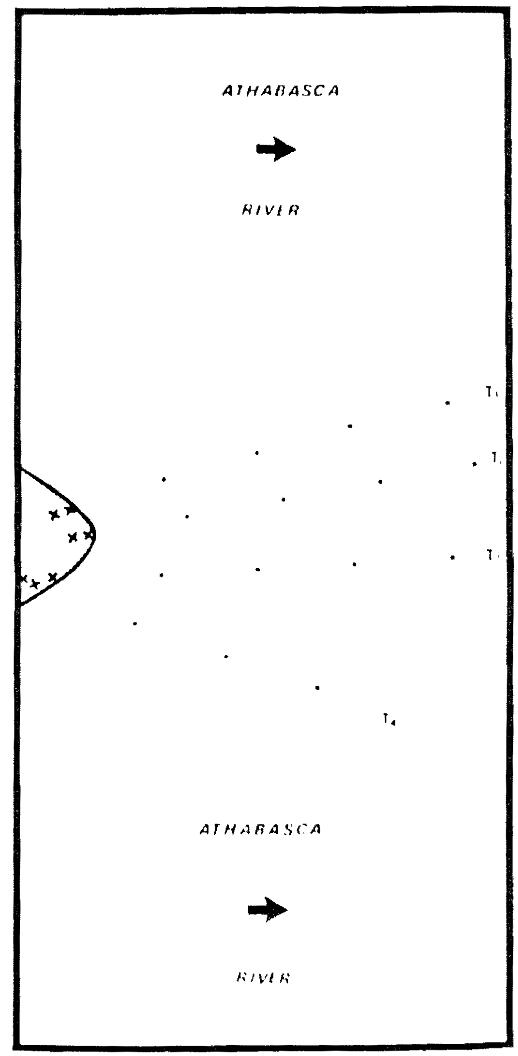


Figure 25. Concluded.

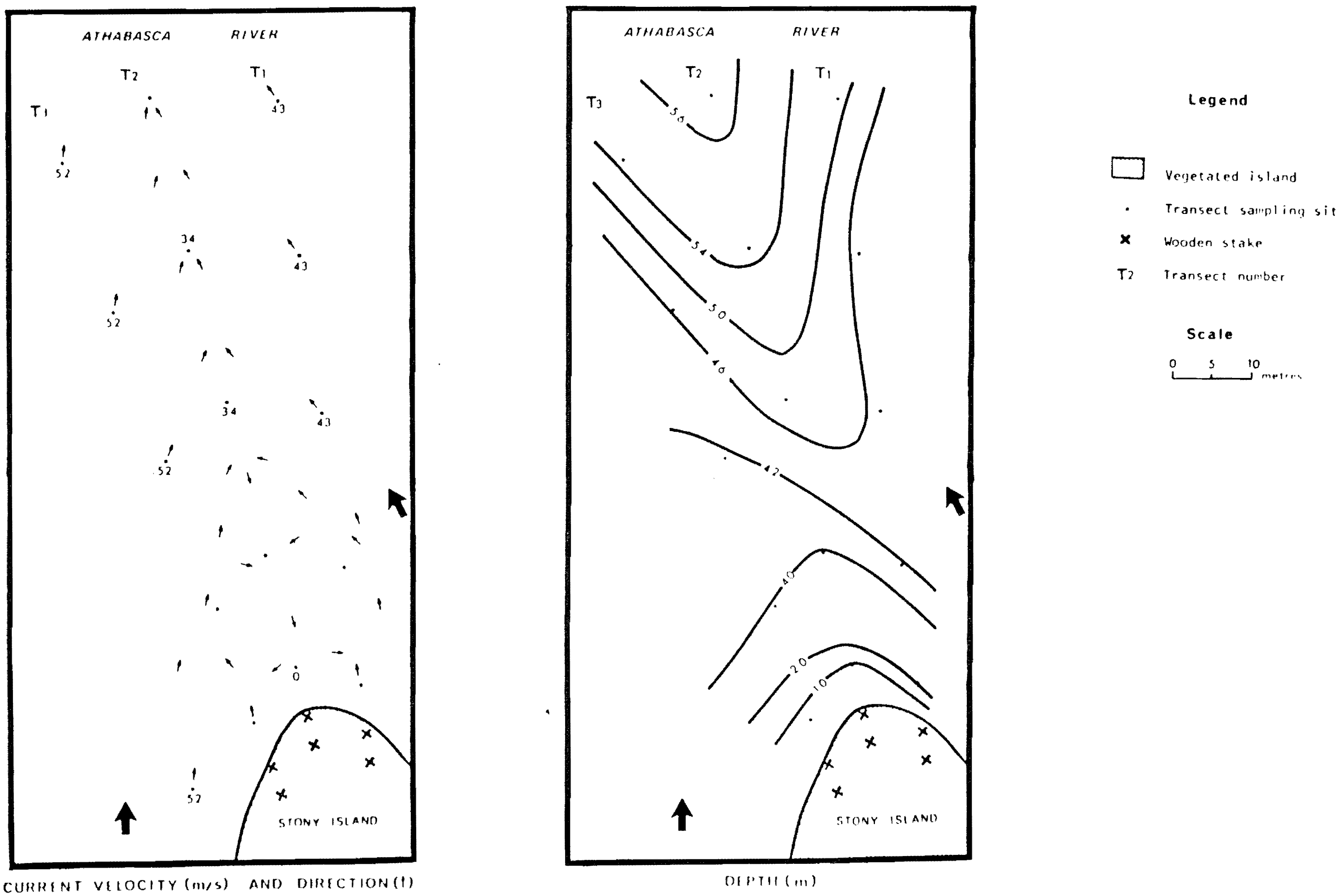
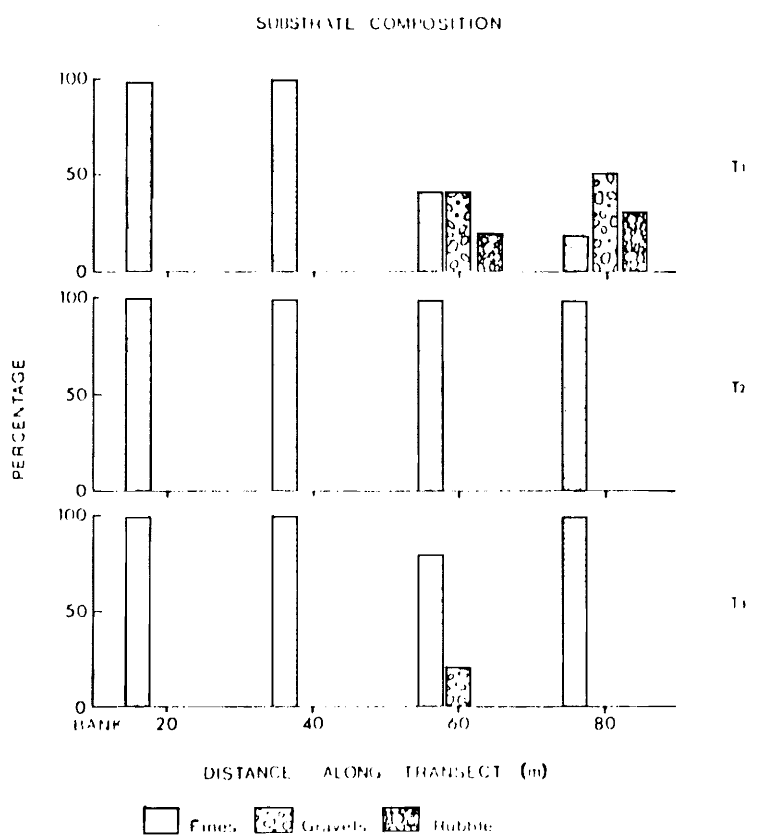


Figure 26. Athabasca River at Stony Island (km 22.9) (continued).



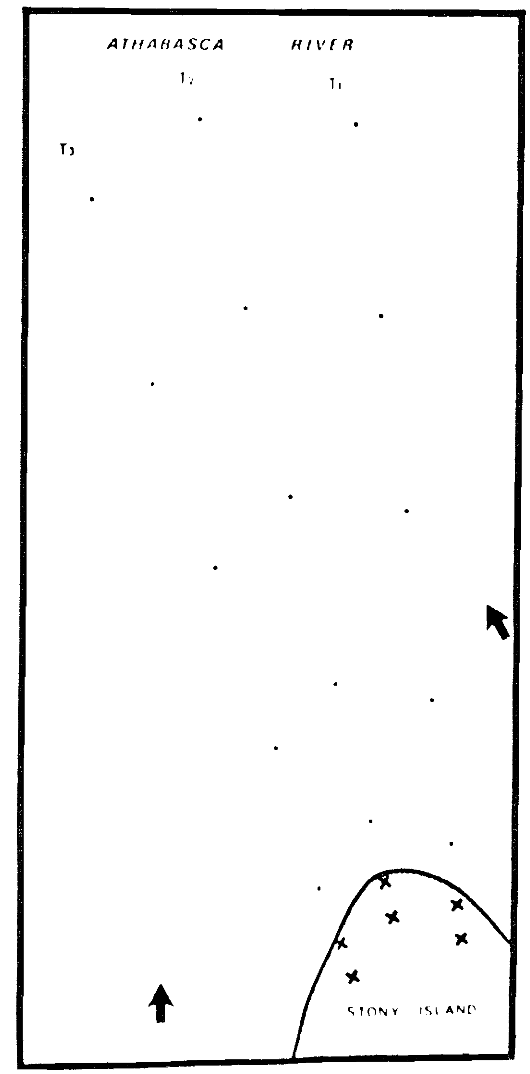


Figure 26. Concluded.

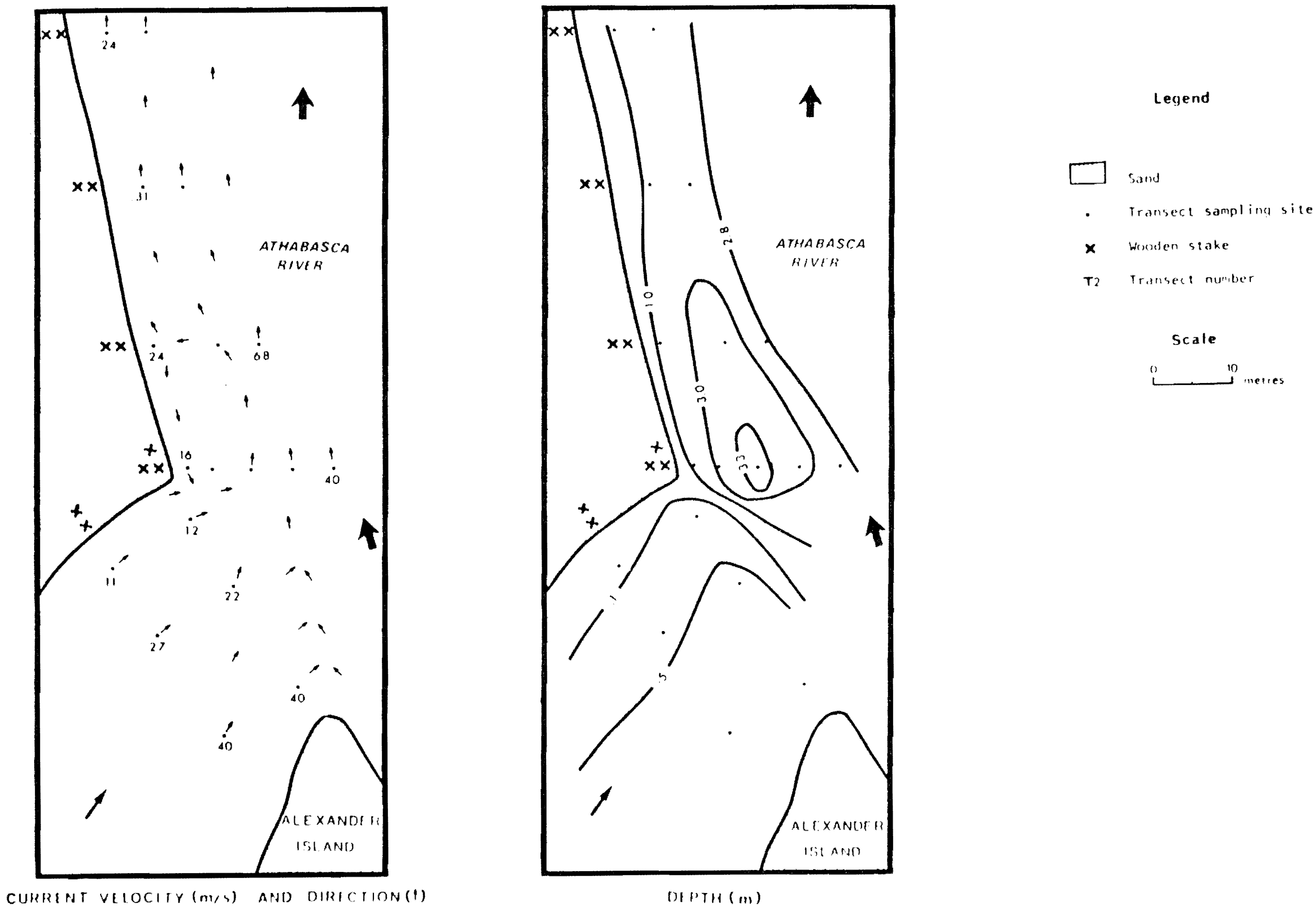


Figure 27. Athabasca River at Alexander Island (km 57.9) (continued).

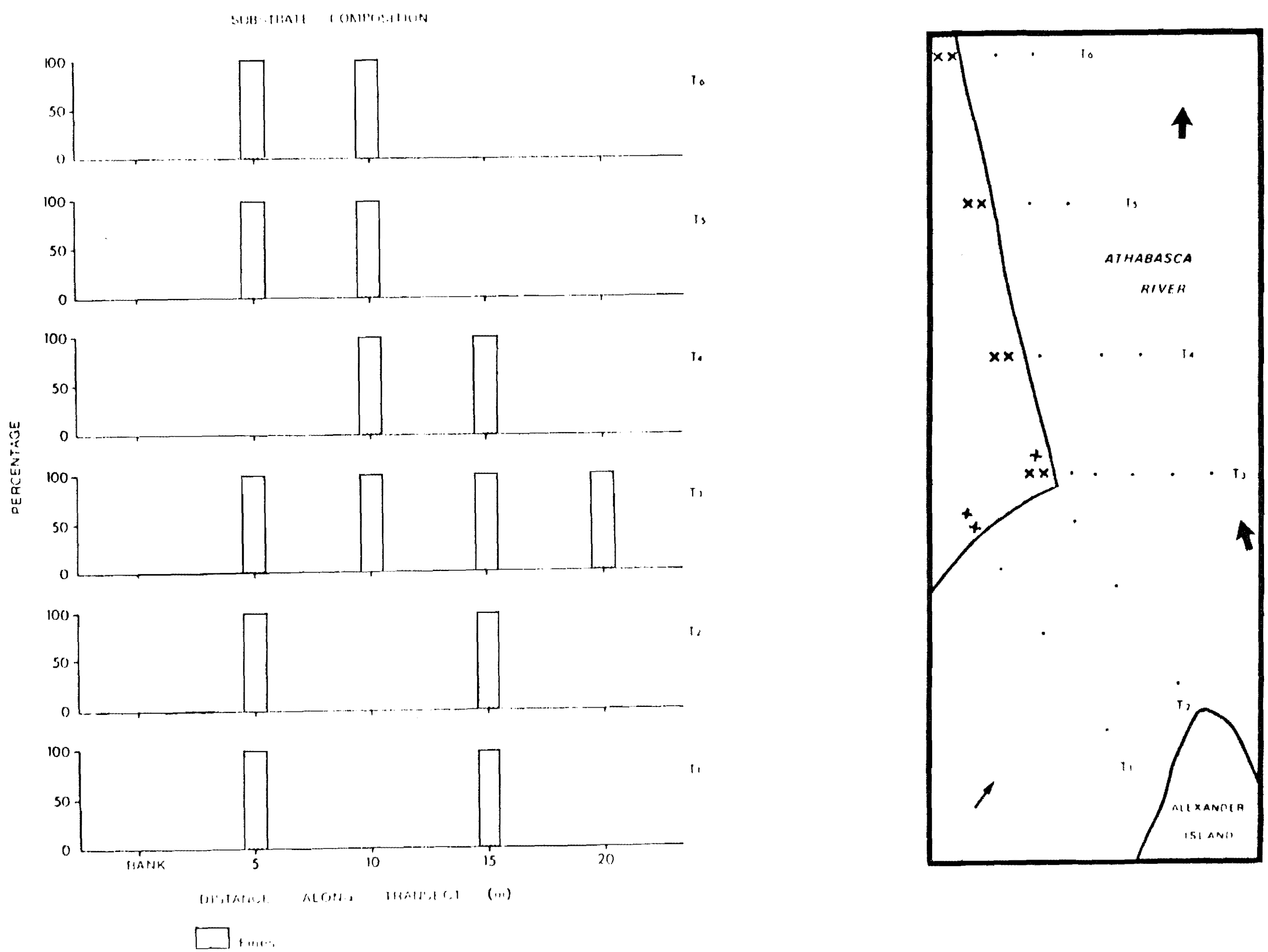


Figure 27. Concluded.

6. DISCUSSION

The entrances of tributaries into the Athabasca and Clearwater rivers influenced, often markedly, the physical characteristics of the confluence areas. Most apparent were the turbidity differences as the clear, brown water tributaries (Secchi visibility of about 1.8 m) mixed with the turbid Athabasca River (Secchi visibility of about 0.1 m). The extent of the zone of influence of the tributaries was primarily a function of the flow volume of the tributary. Hence, the mixing of tributary waters was in some cases almost immediate (e.g., Poplar Creek), and in others was not complete for several kilometres downstream (e.g., Clearwater and Firebag rivers). At its mouth, the upstream bank of a tributary is similar to a point of land. The slight deflection of the receiving water (e.g., Athabasca River), together with inflowing tributary waters, usually generated eddies with countercurrents and upwellings. Substrates in the sheltered tributary mouths were soft sands and silts while rubble or bitumen substrates prevailed in the Athabasca River proper.

Sites downstream of points of land or in the lee of islands were characterized by substantial changes in current velocity and direction. Typically, there was an eddy or series of eddies with countercurrents, upwellings, or areas of complete stagnation for a short distance (maximum 100 m) downstream. Even in the absence of eddies, current velocities were reduced considerably. The bottom substrates in these sheltered backwaters were usually deposits of soft sands, silts, or muds, occasionally overlying bitumen or limestone. Gravel, bitumen, limestone, or boulder substrates were apparent in adjacent areas of higher water velocity.

In the various habitats of flowing waters, it is the combination of such abiotic factors as current velocity, depth, turbidity, temperature, and bottom substrate that determine the extent to which fish can utilize the biota. For example, tributary confluence areas offer several biological advantages over mainstem Athabasca River waters. The clarity of tributary waters permits easier predation of small fish, drift material, and benthic macro-invertebrates. The slower water velocities in the tributary mouth and the immediate mixing zone allow fish to rest and feed. Substrate sizes at confluences are varied, perhaps encouraging a more diverse benthic fauna. Similarly, eddies downstream of points of land or downstream of islands provide shelter from the Athabasca River current. At some of these sheltered areas examined in the present study, unknown species of fish were observed feeding on insects (mostly Ephemeropteran adults) floating in the eddies.

The variation of the flow regime and fluctuating water levels (e.g., spring and summer freshets), in both the Athabasca River mainstem and its tributaries, changes the physical characteristics and suitability for utilization by fish of many habitats throughout the year. During the spring freshet and after heavy rainfalls in the region, there is an increase in the flow volumes and sediment loading of Athabasca River tributaries. Hence, the low velocity currents and visibility advantage (for predation) at the confluences would be lost at these times. Also, increases or decreases in flows in the mainstem Athabasca River can eliminate or diminish the sheltered eddies downstream from points of land or islands. Consequently, the low velocity waters and floating fish food (invertebrates) at these locations are lost under some circumstances.

This study presents descriptions of the habitat conditions at particular sites in the Athabasca and Clearwater rivers where fish collections have been made in previous studies. Many qualitative relationships between the biological and physical requirements of fish are recognized (Hynes 1970), but the interactions amongst factors that make up the stream environment are so numerous as to preclude the expression of these relationships in quantitative terms. A comprehensive evaluation of the relationships between fish species utilization and physical characteristics of particular habitat types in the Athabasca River would require repeated and simultaneous collections of both fish and physical data from a variety of areas, followed by detailed analysis.

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8. APPENDIX

8.1 PHYSICAL PARAMETERS MEASURED AT THE STUDY SITES

Tables 1 to 25 list the physical parameters (depth, velocity, water temperature, Secchi visibility, and substrate composition) that were measured at each of the 25 locations on the Athabasca and Clearwater rivers. (Blanks in the tables indicate that a parameter was not measured at the given distance along the transect.)

Table 1. Physical parameters measured at the confluence of the Clearwater and Christina rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
10 m	1.50	0.68	15.5	0.75	10	90	0	0	0	0
20 m	0.90	0.00	16	0.80	97	2	0	0	0	1
30 m	0.25	0.68	16	0.25	30	70	0	0	0	0
40 m	0.50	0.68	16	0.50	0	100	0	0	0	0
Transect 2										
0 m	2.80	0.42	15	0.60	100	0	0	0	0	0
10 m	1.80	0.42	15.5	0.65	99	0	0	0	0	1
20 m	2.60		16	0.85	30	60	10	0	0	0
30 m	2.20		16	0.95	0	50	50	0	0	0
40 m	2.30	0.68	16	0.95	0	40	60	0	0	0
Transect 3										
10 m	1.20	0.42	15	0.55	30	10	60	0	0	0
20 m	3.00	0.42	15.5	0.50	0	60	40	0	0	0
30 m	2.00		16	0.95	0	50	50	0	0	0
40 m	2.00	0.68	16	0.95	0	40	60	0	0	0
Transect 4										
10 m	1.60		16	0.75	99	0	0	0	0	1
20 m	2.50	0.68	16	0.85	0	70	30	0	0	0
30 m	2.90	0.68	16	1.00	0	50	50	0	0	0

Table 2. Physical parameters measured at the confluence of the Clearwater and Hangingstone rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	Bedrock and/or Bitumen	% Organic
Transect 1										
15 m	0.25	0.26	15	0.25	98	1	0	0	0	1
20 m	1.30		15	0.70	60	40	0	0	0	0
45 m	2.70	0.61	15	0.60	20	80	0	0	0	0
Transect 2										
5 m	1.30		15	0.70	95	2	0	0	3	0
10 m	1.80		15	0.70	0	0	100	0	0	0
15 m	2.80	0.61	15	0.70	0	0	100	0	0	0
30 m	2.80	0.61	15	0.70	10	80	0	0	10	0
Transect 3										
10 m	1.70		15	0.80	80	20	0	0	0	0
20 m	2.00	0.61	15	0.70	10	90	0	0	0	0
30 m	2.50	0.61	15	0.80	10	80	10	0	0	0

Table 3. Physical parameters measured at the confluence of the Athabasca and Horse rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
40 m	1.60		16	1.20	99	0	0	0	0	1
50 m	1.50		17	0.20	99	0	0	0	0	1
Transect 2										
13 m	1.00		17	0.20	1	0	0	0	99	0
28 m	0.50		17	0.20	95	0	0	0	0	5
40 m	1.50		17	0.20	99	0	0	0	0	1
50 m	1.30		17	0.20	98	0	0	0	0	2
Transect 3										
10 m	1.00		17	0.25	80[a]	20[a]	0	0	0	0
15 m	1.10		17	0.20	100[a]	0	0	0	0	0
20 m	1.50		17	0.20	100[a]	0	0	0	0	0
30 m	1.50	0.67	18	0.20	100[a]	0	0	0	0	0
40 m	1.00	0.67	18	0.20	100[a]	0	0	0	0	0
Transect 4										
10 m	1.50		16	0.20	0	0	10	20	70	0
20 m	0.70	0.67	18	0.20	0	0	0	0	100	0
30 m	0.80	0.67	18	0.20	0	0	0	0	100	0

[a]Material overlays a base of bedrock or bitumen.

Table 4. Physical parameters measured at the confluence of the Athabasca and Clearwater rivers.

					SUBSTRATE					
	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	% Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
10 m	2.50		17	0.30	100	0	0	0	0	T[a]
25 m	1.50		17	0.50	100	0	0	0	0	T[a]
40 m	2.30	0.61	16.5	0.80	100	0	0	0	0	0
Transect 2										
10 m	3.00		17.5	0.15	100	0	0	0	0	0
25 m	2.00		17	0.30	100	0	0	0	0	0
40 m	1.90		17	0.50	100	0	0	0	0	0
Transect 3										
15 m	2.40	0.61	16.5	0.80	100	0	0	0	0	0
30 m	2.50	0.61	16.5	0.80	0	0	0	0	100	0
45 m	2.60		17	0.50	0	0	0	0	100	0
60 m	2.50		17	0.20	0	0	0	0	[illegible]	0
75 m	3.00		17.5	0.15	0	0	0	0	[illegible]	0
100 m	3.00		17.5	0.15	0	0	[illegible]	10	[illegible]	0
115 m	2.80		18	0.15	35	0	10	5	50	0
130 m	3.20		18	0.15	15	0	10	10	65	0
145 m	3.00	0.60	18.5	0.15	0	0	10	10	80	0
Transect 4										
15 m	2.10	0.61	16.5	0.70	0	0	0	0	100	0
30 m	2.60	0.61	17	0.40	0	5	0	0	95	0
45 m	3.20		17	0.15	0	5	5	0	90	0
60 m	3.00		18	0.15	0	0	5	5	90	0
75 m	3.00	0.60	18.5	0.15	0	0	5	5	90	0
100 m	3.20	0.60	18.5	0.15	0	5	5	5	85	0
Transect 5										
15 m	2.00	0.60	17	0.80	0	10	10	10	70	0
30 m	1.60	0.60	17.5	0.80	0	20	20	20	40	0
45 m	1.50	0.60	18	0.60	0	15	10	5	70	0
60 m	1.60	0.60	18	0.30	0	0	15	15	70	0
75 m	2.90	0.60	18.5	0.30	0	0	15	15	70	0
Transect 6										
15 m	2.90	0.60	17.5	0.50	15	15	0	0	70	0
30 m	2.20	0.60	18	0.20	10	10	0	0	60	0
45 m	1.80	0.60	18.5	0.20	10	15	0	0	75	0
60 m	2.20	0.60	18.5	0.25	0	0	10	10	80	0
Transect 7										
15 m	2.30	0.60	17.5	0.50	15	15	0	0	[illegible]	0
30 m	3.00	0.60	18.5	0.30	15	10	0	0	75	0
45 m	2.70	0.60	18.5	0.30	10	10	0	0	[illegible]	0
60 m	2.80	0.60	18.5	0.30	0	10	10	5	75	0

[a] T = trace.

Table 5. Physical parameters measured at the confluence of the Athabasca River and Poplar Creek.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.40	0.00	17.5	0.40	100	0	0	0	0	0
10 m	0.90		18	0.30	100	0	0	0	0	0
15 m	1.40		18	0.30	100	0	0	0	0	0
Transect 2										
5 m	1.40		18	0.30	100	0	0	0	0	0
10 m	2.10		18	0.20	80	0	5	0	0	15
15 m	2.30	0.45	18.5	0.10	80	10	10	0	0	0
Transect 3										
5 m	1.70	0.45	18	0.10	100	0	0	0	0	T[a]
10 m	2.70	0.45	18.5	0.10	100	0	0	0	0	0
15 m	2.90	0.45	18.5	0.10	100	0	0	0	0	0
Transect 4										
5 m	1.50	0.45	18.5	0.10	100	0	0	0	0	T[a]
10 m	2.50	0.45	18.5	0.10	100	0	0	0	0	0
15 m	3.10	0.45	18.5	0.10	100	0	0	0	0	0

[a]T = trace.

Table 6. Physical parameters measured at the confluence of the Athabasca and Steepbank rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2 mm)	% Gravel (2 mm-7.5 cm)	% Rubble (7.5 cm-30 cm)	% Boulders (>30 cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.60	0.02	20.5	B[b]	100[a]	0	0	0	0	0
10 m	1.20	0.08	20.5	B[b]	100[a]	0	0	0	0	0
15 m	1.40		20.5	1.20	100[a]	0	0	0	0	0
Transect 2										
10 m	1.00	0.22	20.5	B[b]	40[a]	50[a]	10[a]	0	0	0
20 m	1.00	0.22	20.5	0.60	40[a]	0	0	0	60	0
30 m	1.30		18.5	0.15	0	0	0	0	100	0
40 m	1.10		18.5	0.15	0	0	0	0	100	0
Transect 3										
10 m	0.20	0.47	20.5	B[b]	0	0	0	0	100	0
30 m	0.40	0.88	18.5	0.15	0	0	0	0	100	0
40 m	[illegible]	0.34	18.5	0.15	0	0	0	0	100	0
60 m	1.00	0.84	18.5	0.15	0	0	0	0	100	0
80 m	1.60	0.84	18.5	0.15	0	0	0	0	100	0
Transect 4										
10 m	0.20	0.34	20	B[b]	0	30[a]	0	0	70	0
40 m	0.20	0.51	20	B[b]	0	30[a]	0	0	70	0
60 m	0.40	0.60	18.5	0.15	0	0	0	0	100	0
80 m	0.60	1.36	18.5	0.15	0	0	0	0	100	0
100 m	1.00	1.36	18.5	0.15	0	0	0	0	100	0
120 m	2.10	1.38	18.5	0.15	0	0	0	0	100	0
Transect 5										
20 m	0.35	0.15	20	B[b]	0	0	0	0	100	0
40 m	0.10	0.04	20	B[b]	100[a]	0	0	0	0	0
60 m	0.30	0.43	18.5	0.20	0	0	0	0	100	0
80 m	0.40	0.48	18.5	0.15	0	0	0	0	100	0
100 m	0.60	0.75	18.5	0.15	0	0	0	0	100	0
Transect 6										
10 m	0.40		19	B[b]	30[a]	20[a]	0	0	50	0
20 m	0.15	0.09	20	B[b]	30[a]	20[a]	0	0	50	0
30 m	0.50	0.05	20	B[b]	30[a]	20[a]	0	0	50	0
40 m	0.90	[illegible]	20	0.50	30[a]	20[a]	0	0	50	0
50 m	0.20	0.16	20	B[b]	30[a]	20[a]	0	0	50	0
60 m	0.35	0.15	20	B[b]	30[a]	20[a]	0	0	50	0
70 m	0.60	0.18	20	0.20	0	0	0	0	100	0
80 m	0.60	0.27	20	0.30	0	0	0	0	100	0
100 m	1.50		18.5	0.15	0	0	0	0	100	0
Transect 7										
10 m	0.45		18.5	0.16	60[a]	20[a]	0	0	20	0
20 m	0.50	0.07	18.5	0.32	50[a]	20[a]	0	0	30	0
30 m	0.60	0.10	18.5	0.15	40	20[a]	0	0	40	0
40 m	0.50	0.16	18.5	0.15	0	0	0	0	100	0

[a] Material overlays a base of bedrock or bitumen.
[b] B = bottom.

Table 7. Physical parameters measured at the confluence of the Athabasca and Muskeg rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.30	0.14	14.5	B[a]	100	0	0	0	0	0
10 m	0.40	0.07	14.5	B[a]	100	0	0	0	0	0
15 m	0.60	0.04	14.5	0.30	100	0	0	0	0	0
25 m	0.70	0.00	15	0.30	100	0	0	0	0	0
30 m	0.90	0.00	16	0.80	100	0	0	0	0	0
Transect 2										
5 m	0.10	0.34	14.5	B[a]	T[b]	90	10	0	0	0
10 m	0.50	0.59	16	0.30	T[b]	90	10	0	0	0
15 m	0.40	0.66	17.5	0.15	T[b]	100	0	0	0	0
20 m	0.45	0.68	18	0.15	T[b]	95	5	0	0	0
Transect 3										
5 m	0.25	0.34	15.5	B[a]	T[b]	100	0	0	0	0
10 m	0.30	0.52	16	0.20	40	60	0	0	0	0
15 m	0.35	0.59	17	0.15	10	90	0	0	0	0
20 m	0.40	0.66	18	0.15	5	95	0	0	0	0
Transect 4										
5 m	0.10	0.16	15.5	B[a]	T[b]	90	10	0	0	0
10 m	0.15	0.31	16	B[a]	T[b]	100	0	0	0	0
15 m	0.20	0.30	16	B[a]	T[b]	90	10	0	0	0
25 m	0.30	0.39	17.5	0.15	20	80	0	0	0	0
50 m	0.45	0.51	18	0.15	0	100	0	0	0	0
Transect 5										
10 m	0.12	0.13	15.5	B[a]	T[b]	90	10	0	0	0
20 m	0.25	0.10	16	B[a]	T[b]	95	5	0	0	0
30 m	0.50	0.21	17	0.20	10	90	0	0	0	0
50 m	0.55	0.26	18	0.15	10	90	0	0	0	0

[a]B = bottom.
[b]T = trace.

Table 8. Physical parameters measured at the confluence of the Athabasca and MacKay rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
20 m	1.00	0.73	19	0.15	100	0	0	0	0	0
40 m	1.20	0.73	19	0.15	100	0	0	0	0	0
60 m	1.40		19	0.15	100[b]	0	0	0	0	0
80 m	0.85	0.49	19	0.15	0	20[b]	0	0	80	0
Transect 2										
20 m	1.30		19	0.20	100	0	0	0	0	0
40 m	1.70		19	0.20	100[b]	0	0	0	0	T[a]
60 m	0.60	0.47	19	0.15	20	0	0	0	80	0
Transect 3										
20 m	0.90		18	0.40	100	0	0	0	0	0
40 m	1.20		19	0.15	100	0	0	0	0	0
60 m	1.20	0.73	19	0.15	100	0	0	0	0	0
80 m	1.20		19	0.15	100	0	0	0	0	0
100 m	1.10		19	0.15	60	40	0	0	0	0
Transect 4										
10 m	0.35	0.13	19	0.15	80	20	0	0	0	0
20 m	0.60	0.43	19	0.15	10	90	0	0	0	0
30 m	0.60	0.42	19	0.15	50[b]	50[b]	0	0	0	0

[a] T = trace.
[b] Material overlay, a base of bitumen impregnated with gravel.

Table 9. Physical parameters measured at the confluence of the Athabasca and Ells rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE: % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.08	0.43	19	B[a]	100	0	0	0	0	0
10 m	0.11	0.34	19	B[a]	100	0	0	0	0	0
15 m	0.12	0.39	19	B[a]	100	0	0	0	0	0
30 m	1.40		19		100	0	0	0	0	0
35 m	1.30		19		100	0	0	0	0	0
40 m	1.60		19	1.00	100	0	0	0	0	0
44 m	0.80	0.14	17	B[a]	100	0	0	0	0	0
Transect 2										
2 m	0.30	0.16	19	0.10	100	0	0	0	0	0
4 m	1.10	0.07	19	0.10	100	0	0	0	0	0
10 m	1.60	0.44	19	0.10	100	0	0	0	0	0
19 m	0.90	0.14	19	B[a]	100	0	0	0	0	0
Transect 3										
2 m	0.95	0.06	19	0.10	100	0	0	0	0	0
13 m	1.70		19	0.10	100	0	0	0	0	0
21 m	0.90	0.08	19	0.55	100	0	0	0	0	0
Transect 4										
2 m	1.05	0.15	19	0.20	100	0	0	0	0	0
15 m	1.50		19	0.10	100	0	0	0	0	0
24 m	0.70	0.06	19	0.25	100	0	0	0	0	0

[a]B = bottom.

Table 10. Physical parameters measured at the confluence of the Athabasca and Tar rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
1 m	0.70	0.05	18	0.13	100	0	0	0	0	0
5 m	3.50		19	0.13	100	0	0	0	0	0
10 m	3.10	0.42	19	0.13	100	0	0	0	0	0
15 m	2.90	0.42	19	0.13	100	0	0	0	0	0
Transect 2										
5 m	3.20		18	0.13	100	0	0	0	0	0
10 m	3.30		19	0.13	100	0	0	0	0	0
15 m	2.90	0.42	19	0.13	100	0	0	0	0	0
Transect 3										
5 m	2.90		18	0.13	100	0	0	0	0	0
10 m	3.30		19	0.13	100	0	0	0	0	0
15 m	2.90	0.42	19	0.13	100	0	0	0	0	0
Transect 4										
5 m	2.80		19	0.13	100	0	0	0	0	0
10 m	3.10		19	0.13	100	0	0	0	0	0
15 m	3.00	0.42	19	0.13	100	0	0	0	0	0
Transect 5										
5 m	2.50		19	0.13	100	0	0	0	0	0
10 m	2.80		19	0.13	100	0	0	0	0	0
15 m	3.20	0.42	19	0.13	100	0	0	0	0	0
Transect 6										
1 m	0.30	0.18	17	B[a]	100	0	0	0	0	0
3 m	0.30	0.20	15	B[a]	100	0	0	0	0	0

[a]B = bottom.

Table 11. Physical parameters measured at the Confluence of the Athabasca River and Eymundson Creek.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.50		19	0.15	100	0	0	0	0	0
10 m	1.20		19	0.15	100	0	0	0	0	0
20 m	2.50		19	0.15	10	10	0	0	80	0
40 m	3.30		19	0.15	0	0	0	0	100	0
Transect 2										
5 m	0.50		18	0.15	100	0	0	0	0	0
10 m	1.20		16.5	0.15	100	0	0	0	0	0
20 m	2.50	0.42	19	0.10	20	0	0	0	80	0
Transect 3										
2 m	0.15	0.00	19	0.10	100	0	0	0	0	0
3 m	0.60	0.00	19	0.10	100	0	0	0	0	0
10 m	2.20		19	0.10	100	0	0	0	0	0
20 m	3.00		19	0.15	20	0	10	0	70	0
Transect 4										
2 m	0.25	0.18	19	0.10	100	0	0	0	0	0
10 m	2.00		19	0.10	100	0	0	0	0	0
20 m	3.30		19	0.15	0	0	0	0	100	0
Transect 5										
2 m	0.30	0.05	19	0.10	100	0	0	0	0	0
4 m	0.75	0.07	19	0.10	100	0	0	0	0	0
10 m	2.40	0.42	19	0.15	100	0	0	0	0	0
20 m	3.50	0.42	19	0.15	0	10	10	0	80	0

Table 12. Physical parameters measured at the confluence of the Athabasca and Firebag rivers.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
30 m	1.50		20	0.20	100	0	0	0	0	0
60 m	1.50		20	0.20	100	0	0	0	0	0
90 m	1.30		20	0.20	100	0	0	0	0	0
120 m	1.60		20	0.20	100	0	0	0	0	0
150 m	1.70		20	0.20	100	0	0	0	0	0
Transect 2										
20 m	1.60		18	B[a]	100	0	0	0	0	0
40 m	1.00	0.09	18	B[a]	100	0	0	0	0	0
60 m	0.70	0.09	18	B[a]	100	0	0	0	0	0
90 m	1.60		18	1.20	100	0	0	0	0	0
100 m	1.40		20	0.20	100	0	0	0	0	0
120 m	1.10		20	0.20	100	0	0	0	0	0
Transect 3										
5 m	0.75	0.43	18	B[a]	5	70	25	0	0	0
15 m	2.50		20	0.20	0	20	60	20	0	0
30 m	3.30	0.90	20	0.20	0	10	60	30	0	0
Transect 4										
4 m	1.00	0.56	18	0.80	10	30	10	0	0	0
10 m	2.50		19	0.25	20	60	20	0	0	0
20 m	3.70	0.90	20	0.20	25	0	50	25	0	0
Transect 5										
1 m	0.50	0.04	18	B[a]	100	0	0	0	0	0
3 m	1.15	0.13	18	0.50	100	0	0	0	0	0
10 m	3.20		19	0.25	20	80	0	0	0	0
20 m	3.60	0.90	20	0.20	70	0	30	0	0	0
Transect 6										
3 m	0.90	0.34	18	0.50	0	30	0	0	70	0
10 m	2.70		19	0.25	30	60	10	0	0	0
20 m	3.70	0.90	20	0.25	50	20	10	0	20	0

[a] B bottom.

Table 13. Physical parameters measured in the Athabasca River at km 11.3.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
0 m	0.20	0.17	17	0.20	10	50	40	0	0	0
10 m	0.55	0.05	17.5	0.25	30	20	50	0	0	0
20 m	0.50	0.00	17.5	0.25	40	0	60	0	0	0
30 m	0.55	0.00	17.5	0.20	75	5	20	0	0	0
40 m	0.60	0.00	18	0.20	80[a]	0	20[a]	0	0	0
50 m	0.70	0.03	18	0.20	90[a]	5[a]	5[a]	0	0	0
60 m	0.85	0.06	18	0.20	90[a]	0	0	10	0	0
70 m	0.90	0.06	18	0.20	90[a]	0	0	10	0	0
80 m	0.80	0.04	18	0.20	100[a]	0	0	0	0	0
90 m	0.60	0.04	18	0.20	100	0	0	0	0	0
Transect 2										
0 m	0.55	0.69	17.5	0.20	5	35	60	0	0	0
10 m	0.60	0.65	17.5	0.20	0	70	30	0	0	0
20 m	0.60	0.61	17.5	0.20	0	60	40	0	0	0
30 m	0.60	0.62	17.5	0.20	0	50	50	0	0	0
40 m	0.60	0.52	17.5	0.20	25	50	25	0	0	0
50 m	0.70	0.43	17.5	0.20	25	60	15	0	0	0
60 m	0.65	0.34	17.5	0.20	0	75	25	0	0	0
70 m	0.70	0.29	17.5	0.20	5	25	20	0	50	0
80 m	1.50		17.5	0.20	0	30	50	0	20	0
90 m	1.50		17.5	0.20	50[a]	0	0	0	50	0

[a]Material overlays a base of limestone bedrock.

Table 14. Physical parameters measured in the Athabasca River at km 37.2.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.60	0.39	18.5	0.12	0	40	0	60	0	0
10 m	0.95	0.53	18.5	0.12	0	20	20	0	60	0
Transect 2										
5 m	0.50	0.32	18.5	0.12	0	25	75	0	0	0
10 m	1.10	0.47	18.5	0.12	0	80	0	0	20	0
Transect 3										
5 m	0.55	0.27	18.5	0.12	0	25	75	0	0	0
10 m	1.65		18.5	0.12	10	80	10	0	0	0
Transect 4										
5 m	0.50	0.24	18.5	0.12	0	50	50	0	0	0
10 m	1.60		18.5	0.12	0	90	10	0	0	0
Transect 5										
5 m	0.60	0.20	18.5	0.12	50	20	30	0	0	0
10 m	1.30	0.43	18.5	0.12	0	80	20	0	0	0
Transect 6										
5 m	0.60	0.08	18.5	0.12	50	0	0	0	50	0
10 m	1.30	0.40	18.5	0.12	0	40	40	0	20	0
Transect 7										
5 m	0.45	0.09	18.5	0.12	100	0	0	0	0	0
10 m	1.10	0.40	18.5	0.12	0	40	40	0	20	0
Transect 8										
5 m	0.50	0.09	18.5	0.12	100	0	0	0	0	0
10 m	1.60		18.5	0.12	40	60	0	0	0	0
Transect 9										
5 m	0.50	0.09	18.5	0.12	100	0	0	0	0	0
10 m	1.50		18.5	0.12	40	40	0	0	20	0

Table 15. Physical parameters measured in the Athabasca River at km 40.1.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
3 m	0.40	0.61	18	0.10	30	70	0	0	0	0
Transect 2										
3 m	0.40	0.12	18	0.10	30	60	10	0	0	0
6 m	0.80	0.56	18	0.10	10	90	0	0	0	0
Transect 3										
3 m	0.30	0.16	18	0.10	20	80	0	0	0	0
6 m	0.70	0.56	18	0.10	20	80	0	0	0	0
Transect 4										
3 m	0.30	0.45	18	0.10	10	90	0	0	0	0
6 m	1.00	0.59	18	0.10	10	90	0	0	0	0
Transect 5										
3 m	0.50	0.38	18	0.10	5	95	0	0	0	0
6 m	1.00	0.51	18	0.10	5	95	0	0	0	0
Transect 6										
3 m	0.60	0.33	18	0.10	5	95	0	0	0	0

Table 16. Physical parameters measured in the Athabasca River at km 42.3.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.90	0.44	18	0.10	0	25	75	0	0	0
10 m	2.20	0.55	18	0.10	0	20	20	0	60	0
Transect 2										
1 m	0.15	0.00	18	0.10	0	0	100	0	0	0
2.5 m	0.40	0.12	18	0.10	100	0	0	0	0	0
5 m	0.90	0.31	18	0.10	0	25	50	25	0	0
10 m	2.20	0.55	18	0.10	0	60	20	0	20	0
Transect 3										
2 m	0.10	0.12	18	0.10	100	0	0	0	0	0
3 m	0.60	0.17	18	0.10	100	0	0	0	0	0
10 m	1.70	0.55	18	0.10	0	50	0	0	50	0
Transect 4										
2 m	0.30	0.15	18	0.10	100	0	0	0	0	0
10 m	1.60	0.55	18	0.10	0	30	0	0	70	0
Transect 5										
2 m	0.20	0.00	18	0.10	100	0	0	0	0	0
10 m	1.60	0.60	18	0.10	10	40	0	0	50	0
Transect 6										
2 m	0.20	0.05	18	0.10	100	0	0	0	0	0
10 m	1.30	0.68	18	0.10	0	100[a]	0	0	0	0
Transect 7										
2 m	0.20	0.00	18	0.10	100	0	0	0	0	0
10 m	1.70	0.68	18	0.10	0	80[a]	0	0	20	0
Transect 8										
2 m	0.20	0.00	18	0.10	100	0	0	0	0	0
10 m	2.20	0.68	18	0.10	20[a]	70[a]	0	0	10	0

[a] Material overlays a base of bedrock or bitumen.

Table 17. Physical parameters measured in the Athabasca River at km 59.9.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
2 m	0.60	0.25	18	0.15	0	0	0	0	100	0
6 m	1.10	0.39	18	0.15	0	50	0	0	50	0
10 m	1.50		18	0.15	0	10	10	0	80	0
20 m	2.90		18	0.15	0	10	10	0	80	0
Transect 2										
2 m	0.40	0.24	18	0.15	100	0	0	0	0	0
5 m	0.60	0.33	18	0.15	10	60	30	0	0	0
10 m	1.00	0.51	18	0.15	0	80	20	0	0	0
20 m	2.20		18	0.15	0	40	60	0	0	0
Transect 3										
2 m	0.30	0.00	18	0.15	100[a]	0	0	0	0	0
5 m	0.65	0.24	18	0.15	90[a]	0	10[a]	0	0	0
12 m	1.10	0.45	18	0.15	0	20	80	0	0	0
20 m	2.20		18	0.15	10	30	60	0	0	0
Transect 4										
2 m	0.40	0.00	18	0.15	100[a]	0	0	0	0	0
5 m	0.65	0.11	18	0.15	20	20	60	0	0	0
10 m	1.05	0.28	18	0.15	20	60	20	0	0	0
20 m	2.10		18	0.15	0	60	40	0	0	0
Transect 5										
2 m	0.60	0.05	18	0.15	100	0	0	0	0	0
5 m	0.90	0.04	18	0.15	90	0	10	0	0	0
10 m	1.10	0.03	18	0.15	40	50	10	0	0	0
20 m	2.40		18	0.15	0	40	60	0	0	0
Transect 6										
2 m	0.35	0.00	18	0.15	100[a]	0	0	0	0	0
5 m	0.70	0.00	18	0.15	20	40	40	0	0	0
10 m	1.10	0.03	18	0.15	0	20	80	0	0	0
20 m	2.10		18	0.15	20	40	40	0	0	0

[a]Material overlays a base of bedrock or bitumen.

Table 18. Physical parameters measured in the Athabasca River at km 71.0.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
1 m	1.00	0.05	18	0.11	80[a]	0	0	0	20	0
6 m	1.80		18	0.11	30[a]	0	0	0	70	0
12 m	2.10		18	0.11	60[a]	0	0	0	40	0
Transect 2										
3 m	1.10	0.16	18	0.11	70[a]	0	0	0	30	0
6 m	1.40		18	0.11	90[a]	0	10[a]	0	0	0
12 m	2.20		18	0.11	90[a]	0	10[a]	0	0	0
Transect 3										
4 m	1.10	0.24	18	0.11	60[a]	0	0	0	40	0
6 m	1.45		18	0.11	100[a]	0	0	0	0	0
12 m	3.30		18	0.11	100[a]	0	0	0	0	0
Transect 4										
4 m	1.10	0.16	18	0.11	100[a]	0	0	0	0	0
6 m	1.90		18	0.11	100[a]	0	0	0	0	0
12 m	2.10		18	0.11	40[a]	0	20[a]	0	40	0
Transect 5										
1 m	0.60	0.04	18	0.11	100[a]	0	0	0	0	0
6 m	1.80		18	0.11	100[a]	0	0	0	0	0
12 m	2.60		18	0.11	20[a]	0	20[a]	0	60	0
Transect 6										
2 m	0.50	0.09	18	0.11	100[a]	0	0	0	0	0
6 m	2.10		18	0.11	80[a]	0	0	0	20	0
12 m	2.90	0.51	18	0.11	100[a]	0	0	0	0	0

[a]Material overlays a base of bitumen

Table 19. Physical parameters measured in the Athabasca River at km 75.3.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.40	0.30	18.5	0.10	50	0	0	0	50	0
10 m	1.10	0.39	18.5	0.10	100	0	0	0	0	0
20 m	1.70	0.49	18.5	0.10	100	0	0	0	0	0
Transect 2										
5 m	0.55	0.08	18.5	0.10	100	0	0	0	0	0
10 m	1.10	0.42	18.5	0.10	100	0	0	0	0	0
20 m	1.70	0.49	18.5	0.10	100	0	0	0	0	0
Transect 3										
5 m	0.60	0.18	18.5	0.10	100	0	0	0	0	0
8 m	1.10	0.36	18.5	0.10	100	0	0	0	0	0
20 m	1.50	0.49	18.5	0.10	80	20	0	0	0	0
Transect 4										
5 m	0.50	0.25	18.5	0.10	100	0	0	0	0	0
10 m	1.10	0.37	18.5	0.10	100	0	0	0	0	0
20 m	1.60	0.49	18.5	0.10	100	0	0	0	0	0
Transect 5										
5 m	0.80	0.27	18.5	0.10	100	0	0	0	0	0
8 m	1.10	0.35	18.5	0.10	100	0	0	0	0	0
20 m	1.60	0.49	18.5	0.10	100	0	0	0	0	0
Transect 6										
5 m	0.90	0.27	18.5	0.10	100	0	0	0	0	0
10 m	1.40		18.5	0.10	100	0	0	0	0	0
20 m	1.40	0.49	18.5	0.10	100	0	0	0	0	0
Transect 7										
5 m	0.80	0.30	18.5	0.10	100	0	0	0	0	0
10 m	1.70		18.5	0.10	100	0	0	0	0	0
20 m	1.90	0.49	18.5	0.10	100	0	0	0	0	0

Table 20. Physical parameters measured in the Athabasca River at km 82.2.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
2 m	0.30	0.00	21	0.15	10	30	60	0	0	0
5 m	1.00	0.33	21	0.15	40	10	50	0	0	0
10 m	2.10		21	0.15	25	0	25	50	0	0
20 m	3.40		21	0.15	25	0	25	50	0	0
Transect 2										
3 m	1.00	0.09	21	0.15	100	0	0	0	0	0
10 m	1.90		21	0.15	70	0	0	30	0	0
20 m	2.70		21	0.15	50	0	50	0	0	0
Transect 3										
3 m	0.60	0.00	21	0.15	100	0	0	0	0	0
6 m	0.95	0.02	21	0.15	100	0	0	0	0	0
10 m	1.60		21	0.15	50	0	0	50	0	0
25 m	4.00		21	0.15	50	0	0	50	0	0
30 m	4.50		21	0.15	50	0	0	50	0	0
Transect 4										
3 m	0.40	0.14	21	0.15	100	0	0	0	0	0
7 m	1.10	0.17	21	0.15	100	0	0	0	0	0
10 m	1.20		21	0.15	100	0	0	0	0	0
20 m	4.20		21	0.15	100	0	0	0	0	0
Transect 5										
2 m	0.30	0.34	21	0.15	100	0	0	0	0	0
5 m	1.10	0.33	21	0.15	100	0	0	0	0	0
10 m	1.90		21	0.15	100	0	0	0	0	0
20 m	3.40		21	0.15	100	0	0	0	0	0
Transect 6										
2 m	0.60	0.09	21	0.15	100	0	0	0	0	0
10 m	2.10		21	0.15	100	0	0	0	0	0
25 m	3.50		21	0.15	100	0	0	0	0	0

Table 21. Physical parameters measured in the Athabasca River at km 96.4.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
4 m	1.00	0.36	18	0.10	80[b]	0	0	0	20	0
10 m	2.20	0.40	18	0.10	60[b]	0	20[b]	0	20	0
Transect 2										
1 m	0.25	0.18	18	0.10	100	0	0	0	0	T[c]
5 m	1.50	0.40	18	0.10	80	20	0	0	0	0
10 m	2.20	0.40	18	0.10	60[b]	0	0	0	40	0
Transect 3										
5 m	1.60		18	0.10	100	0	0	0	0	0
10 m	2.30		18	0.10	100[b]	0	0	0	0	0
15 m	2.70	0.40	18	0.10	60[b]	0	40[b]	0	0	0
Transect 4										
2 m	0.10	0.16	18	B[a]	100	0	0	0	0	0
5 m	0.55	0.00	18	0.10	100	0	0	0	0	0
10 m	2.30		18	0.10	70[b]	0	0	0	30	0
15 m	2.70	0.40	18	0.10	100[b]	0	0	0	0	0
Transect 5										
2 m	0.30	0.09	18	0.10	100	0	0	0	0	0
4 m	1.20	0.19	18	0.10	100	0	0	0	0	0
8 m	2.60		18	0.10	80[b]	0	0	0	20	0
15 m	3.10	0.40	18	0.10	80	0	0	0	20	0
Transect 6										
2 m	0.60	0.36	18	0.10	100[b]	0	0	0	0	0
8 m	2.60		18	0.10	100[b]	0	0	0	0	0
15 m	3.00	0.40	18	0.10	40[b]	0	20[b]	0	40	0

[a] B = bottom.
[b] Material overlays a base of bitumen.
[c] T = trace.

Table 22. Physical parameters measured in the Athabasca River at km 124.4.

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble 7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
3 m	0.25	0.00	19	0.10	20	20	60	0	0	0
5 m	0.55	0.18	19	0.10	10	70	20	0	0	0
9 m	1.10	0.55	19	0.10	30	0	70	0	0	0
15 m	2.50	0.66	19	0.10	100	0	0	0	0	0
Transect 2										
5 m	1.00	0.00	19	0.10	90	0	10	0	0	0
10 m	1.50		19	0.10	80	20	0	0	0	0
15 m	2.30	0.66	19	0.10	80	20	0	0	0	0
Transect 3										
5 m	0.70	0.33	19	0.10	10	80	10	0	0	0
8 m	1.10	0.62	19	0.10	30	50	20	0	0	0
15 m	1.60	0.66	19	0.10	40	10	50	0	0	0
Transect 4										
5 m	0.40	0.34	19	0.10	30	0	20	50	0	0
10 m	1.90		19	0.10	30	20	50	0	0	0
15 m	2.00	0.66	19	0.10	10	40	50	0	0	0
Transect 5										
5 m	0.85	0.34	19	0.10	10	40	25	25	0	0
10 m	1.50		19	0.10	20	50	30	0	0	0
15 m	1.60	0.66	19	0.10	30	70	0	0	0	0
Transect 6										
5 m	0.70	0.39	19	0.10	0	20	80	0	0	0
10 m	1.50		19	0.10	0	20	50	30	0	0
15 m	2.10	0.66	19	0.10	20	50	30	0	0	0
Transect 7										
1 m	0.15	0.17	19	0.10	50	40	10	0	0	0
5 m	0.80	0.33	19	0.10	0	20	80	0	0	0
10 m	1.40		19	0.10	0	10	40	50	0	0
15 m	2.20	0.66	19	0.10	90	10	0	0	0	0

Table 23. Physical parameters measured in the Athabasca River at unnamed island (km 10.6).

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
10 m	1.50		18	0.15	100	0	0	0	0	0
20 m	2.80		18	0.15	90	10	0	0	0	0
30 m	2.00		18	0.15	35	40	25	0	0	0
40 m	2.20	9.52	18	0.15	40	50	10	0	0	0
Transect 2										
10 m	1.90	0.08	18	0.15	100	0	0	0	0	0
20 m	2.00	0.09	18	0.15	100		0	0	0	0
30 m	2.20		18	0.15	70	30	0	0	0	0
40 m	1.90		18	0.15	30	55	15	0	0	0
Transect 3										
10 m	0.40		18	0.15	100	0	0	0	0	T[a]
20 m	1.15		18	0.15	100	0	0	0	0	T[a]
30 m	2.20		18	0.15	60	40	0	0	0	0
40 m	2.20	0.04	18	0.15	25	55	20	0	0	0
Transect 4										
10 m	0.60	0.04	18	0.15	100	0	0	0	0	0
20 m	1.00	0.04	18	0.15	100	0	0	0	0	0
30 m	1.20	0.04	18	0.15	100	0	0	0	0	0

[a] T = trace.

Table 24. Physical parameters measured in the Athabasca River at Stony Island (km 22.9).

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	2.00		18.5	0.15	100	0	0	0	0	0
20 m	4.20		18.5	0.15	100	0	0	0	0	0
40 m	4.50	0.43	18.5	0.15	100	0	0	0	0	0
60 m	4.50	0.43	18.5	0.15	40	40	20	0	0	0
80 m	5.10	0.43	18.5	0.15	20	50	30	0	0	0
Transect 2										
5 m	1.00	0.00	18.5	0.15	100	0	0	0	0	0
20 m	4.00		18.5	0.15	100	0	0	0	0	0
40 m	4.80	0.34	18.5	0.15	100	0	0	0	0	0
60 m	5.50	0.34	18.5	0.15	100	0	0	0	0	0
80 m	5.80		18.5	0.15	100[a]	0	0	0	0	0
Transect 3										
5 m	1.00		18.5	0.15	100	0	0	0	0	0
20 m	4.00		18.5	0.15	100	0	0	0	0	0
40 m	4.20	0.52	18.5	0.15	100[a]	0	0	0	0	0
60 m	4.60	0.52	18.5	0.15	80[a]	20[a]	0	0	0	0
80 m	5.40	0.52	18.5	0.15	100[a]	0	0	0	0	0

[a]Material overlays a base of bedrock or bitumen.

Table 25. Physical parameters measured in the Athabasca River at Alexander Island (km 57.9).

	Depth (m)	Velocity (m/sec)	Water Temperature (°C)	Secchi Visibility (m)	SUBSTRATE % Fines (<2mm)	% Gravel (2mm-7.5cm)	% Rubble (7.5cm-30cm)	% Boulders (>30cm)	% Bedrock and/or Bitumen	% Organic
Transect 1										
5 m	0.10	0.11	18	B[a]	100	0	0	0	0	0
15 m	0.35	0.27	18	0.15	100	0	0	0	0	0
30 m	0.80	0.40	18	0.15	100	0	0	0	0	0
Transect 2										
5 m	0.30	0.12	18	0.15	100	0	0	0	0	0
15 m	0.60	0.22	18	0.15	100	0	0	0	0	0
30 m	0.90	0.40	18	0.15	100	0	0	0	0	0
Transect 3										
2 m	1.10	0.16	18	0.15	100	0	0	0	0	0
5 m	3.10		18	0.15	100	0	0	0	0	0
10 m	3.30		18	0.15	100	0	0	0	0	0
15 m	3.10		18	0.15	100	0	0	0	0	0
20 m	2.90	0.40	18	0.15	100	0	0	0	0	0
Transect 4										
2 m	1.20	0.24	18	0.15	100	0	0	0	0	0
10 m	3.20		18	0.15	100	0	0	0	0	0
15 m	2.80	0.68	18	0.15	100	0	0	0	0	0
Transect 5										
5 m	1.05	0.31	18	0.15	100	0	0	0	0	0
10 m	2.40		18	0.15	100	0	0	0	0	0
Transect 6										
5 m	1.05	0.24	18	0.15	100	0	0	0	0	0
10 m	2.40		18	0.15	100	0	0	0	0	0

[a]B = bottom.

9. AOSERP RESEARCH REPORTS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
3.	HE 1.1.1	Structure of a Traditional Baseline Data System
4.	VE 2.2	A Preliminary Vegetation Survey of the Alberta Oil Sands Environmental Research Program Study Area
5.	HY 3.1	The Evaluation of Wastewaters from an Oil Sand Extraction Plant
6.		Housing for the North--The Stackwall System
7.	AF 3.1.1	A Synopsis of the Physical and Biological Limnology and Fisheries Programs within the Alberta Oil Sands Area
8.	AF 1.2.1	The Impact of Saline Waters upon Freshwater Biota (A Literature Review and Bibliography)
9.	ME 3.3	Preliminary Investigations into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10.	HE 2.1	Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area
11.	AF 2.2.1	Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12.	ME 1.7	Very High Resolution Meteorological Satellite Study of Oil Sands Weather: "A Feasibility Study"
13.	ME 2.3.1	Plume Dispersion Measurements from an Oil Sands Extraction Plant, March 1976
14.		
15.	ME 3.4	A Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area
16.	ME 1.6	The Feasibility of a Weather Radar near Fort McMurray, Alberta
17.	AF 2.1.1	A Survey of Baseline Levels of Contaminants in Aquatic Biota of the AOSERP Study Area
18.	HY 1.1	Interim Compilation of Stream Gauging Data to December 1976 for the Alberta Oil Sands Environmental Research Program
19.	ME 4.1	Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area
20.	HY 3.1.1	Characterization of Organic Constituents in Waters and Wastewaters of the Athabasca Oil Sands Mining Area
21.		AOSERP Second Annual Report, 1976-77
22.		Alberta Oil Sands Environmental Research Program Interim Report to 1978 covering the period April 1975 to November 1978
23.	AF 1.1.2	Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout
24.	ME 1.5.2	Air System Winter Field Study in the AOSERP Study Area, February 1977.
25.	ME 3.5.1	Review of Pollutant Transformation Processes Relevant to the Alberta Oil Sands Area

26.	AF 4.5.1	Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
27.	ME 1.5.1	Meteorology and Air Quality Winter Field Study in the AOSERP Study Area, March 1976
28.	VE 2.1	Interim Report on a Soils Inventory in the Athabasca Oil Sands Area
29.	ME 2.2	An Inventory System for Atmospheric Emissions in the AOSERP Study Area
30.	ME 2.1	Ambient Air Quality in the AOSERP Study Area, 1977
31.	VE 2.3	Ecological Habitat Mapping of the AOSERP Study Area: Phase I
32.		AOSERP Third Annual Report, 1977-78
33.	TF 1.2	Relationships Between Habitats, Forages, and Carrying Capacity of Moose Range in northern Alberta. Part I: Moose Preferences for Habitat Strata and Forages.
34.	HY 2.4	Heavy Metals in Bottom Sediments of the Mainstem Athabasca River System in the AOSERP Study Area
35.	AF 4.9.1	The Effects of Sedimentation on the Aquatic Biota
36.	AF 4.8.1	Fall Fisheries Investigations in the Athabasca and Clearwater Rivers Upstream of Fort McMurray: Volume I
37.	HE 2.2.2	Community Studies: Fort McMurray, Anzac, Fort MacKay
38.	VE 7.1.1	Techniques for the Control of Small Mammals: A Review
39.	ME 1.0	The Climatology of the Alberta Oil Sands Environmental Research Program Study Area
40.	WS 3.3	Mixing Characteristics of the Athabasca River below Fort McMurray - Winter Conditions
41.	AF 3.5.1	Acute and Chronic Toxicity of Vanadium to Fish
42.	TF 1.1.4	Analysis of Fur Production Records for Registered Traplines in the AOSERP Study Area, 1970-75
43.	TF 6.1	A Socioeconomic Evaluation of the Recreational Fish and Wildlife Resources in Alberta, with Particular Reference to the AOSERP Study Area. Volume I: Summary and Conclusions
44.	VE 3.1	Interim Report on Symptomology and Threshold Levels of Air Pollutant Injury to Vegetation, 1975 to 1978
45.	VE 3.3	Interim Report on Physiology and Mechanisms of Air-Borne Pollutant Injury to Vegetation, 1975 to 1978
46.	VE 3.4	Interim Report on Ecological Benchmarking and Biomonitoring for Detection of Air-Borne Pollutant Effects on Vegetation and Soils, 1975 to 1978.
47.	TF 1.1.1	A Visibility Bias Model for Aerial Surveys for Moose on the AOSERP Study Area
48.	HG 1.1	Interim Report on a Hydrogeological Investigation of the Muskeg River Basin, Alberta
49.	WS 1.3.3	The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta
50.	ME 3.6	Literature Review on Pollution Deposition Processes
51.	HY 1.3	Interim Compilation of 1976 Suspended Sediment Date in the AOSERP Study Area
52.	ME 2.3.2	Plume Dispersion Measurements from an Oil Sands Extraction Plan, June 1977

53.	HY 3.1.2	Baseline States of Organic Constituents in the Athabasca River System Upstream of Fort McMurray
54.	WS 2.3	A Preliminary Study of Chemical and Microbial Characteristics of the Athabasca River in the Athabasca Oil Sands Area of Northeastern Alberta
55.	HY 2.6	Microbial Populations in the Athabasca River
56.	AF 3.2.1	The Acute Toxicity of Saline Groundwater and of Vanadium to Fish and Aquatic Invertebrates
57.	LS 2.3.1	Ecological Habitat Mapping of the AOSERP Study Area (Supplement): Phase I
58.	AF 2.0.2	Interim Report on Ecological Studies on the Lower Trophic Levels of Muskeg Rivers Within the Alberta Oil Sands Environmental Research Program Study Area
59.	TF 3.1	Semi-Aquatic Mammals: Annotated Bibliography
60.	WS 1.1.1	Synthesis of Surface Water Hydrology
61.	AF 4.5.2	An Intensive Study of the Fish Fauna of the Steepbank River Watershed of Northeastern Alberta
62.	TF 5.1	Amphibians and Reptiles in the AOSERP Study Area
63.	ME 3.8.3	Analysis of AOSERP Plume Sigma Data
64.	LS 21.6.1	A Review and Assessment of the Baseline Data Relevant to the Impacts of Oil Sands Development on Large Mammals in the AOSERP Study Area
65.	LS 21.6.2	A Review and Assessment of the Baseline Data Relevant to the Impacts of Oil Sands Development on Black Bears in the AOSERP Study Area
66.	AS 4.3.2	An Assessment of the Models LIRAQ and ADPIC for Application to the Athabasca Oil Sands Area
67.	WS 1.3.2	Aquatic Biological Investigations of the Muskeg River Watershed
68.	AS 1.5.3 AS 3.5.2	Air System Summer Field Study in the AOSERP Study Area, June 1977
69.	HS 40.1	Native Employment Patterns in Alberta's Athabasca Oil Sands Region
70.	LS 28.1.2	An Interim Report on the Insectivorous Animals in the AOSERP Study Area
71.	HY 2.2	Lake Acidification Potential in the Alberta Oil Sands Environmental Research Program Study Area
72.	LS 7.1.2	The Ecology of Five Major Species of Small Mammals in the AOSERP Study Area: A Review
73.	LS 23.2	Distribution, Abundance and Habitat Associations of Beavers, Muskrats, Mink and River Otters in the AOSERP Study Area, Northeastern Alberta
74.	AS 4.5	Air Quality Modelling and User Needs
75.	WS 1.3.4	Interim Report on a Comparative Study of Benthic Algal Primary Productivity in the AOSERP Study Area
76.	AF 4.5.1	An Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
77.	HS 20.1	Overview of Local Economic Development in the Athabasca Oil Sands Region Since 1961.
78.	LS 22.1.1	Habitat Relationships and Management of Terrestrial Birds in Northeastern Alberta

79. AF 3.6.1 The Multiple Toxicity of Vanadium, Nickel, and Phenol to Fish.
80. HS 10.2 & HS 10.1 History of the Athabasca Oil Sands Region, 1980 to 1960's. Volumes I and II.
81. LS 22.1.2 Species Distribution and Habitat Relationships of Waterfowl in Northeastern Alberta.
82. LS 22.2 Breeding Distribution and Behaviour of the White Pelican in the Athabasca Oil Sands Area.
83. LS 22.2 The Distribution, Foraging Behaviour, and Allied Activities of the White Pelican in the Athabasca Oil Sands Area.
84. WS 1.6.1 Investigations of the Spring Spawning Fish Populations in the Athabasca and Clearwater Rivers Upstream from Fort McMurray; Volume I.
85. HY 2.5 An intensive Surface Water Quality Study of the Muskeg River Watershed. Volume I: Water Chemistry.
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88. AF 2.0.1 Ecological Studies of the Aquatic Invertebrates of the Alberta Oil Sands Environmental Research Program Study Area of Northeastern Alberta
89. AF 4.3.2 Fishery Resources of the Athabasca River Downstream of Fort McMurray, Alberta. Volume 1
90. AS 3.2 A Wintertime Investigation of the Deposition of Pollutants around an Isolated Power Plant in Northern Alberta
91. LS 5.2 Characterization of Stored Peat in the Alberta Oil Sands Area

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